Online ISSN : 2249-4596
Print ISSN : 0975-5861
DOI : 10.17406/GJRE

Global Journal

of Researches in Engineering: G

Industrial Engineering

Modelling Hospital Triage

Linearization of Power Amplifier

Highlights

SMV Distribution of Double

Theoretical Study of the Influence

Discovering Thoughts, Inventing Future

VOLUME 17 ISSUE 1 VERSION1.0

Global Journal of Researches in Engineering: G
Industrial Engineering

Global Journal of Researches in Engineering: G
Industrial Engineering
Volume 17 Issue 1 (Ver. 1.0)

Open Association of Research Society

Incorporation No.: 0423089
License No.: 42125/022010/1186
Registration No.: 430374
Import-Export Code: 1109007027
Employer Identification Number (EIN):
USA Tax ID: 98-0673427

Global Journals Inc.

*(A Delaware USA Incorporation with "Good Standing"; **Reg. Number: 0423089**)*

Sponsors: Open Association of Research Society
Open Scientific Standards

Publisher's Headquarters office

Global Journals® Headquarters
945th Concord Streets,
Framingham Massachusetts Pin: 01701,
United States of America
USA Toll Free: +001-888-839-7392
USA Toll Free Fax: +001-888-839-7392

Offset Typesetting

Global Journals Incorporated
2nd, Lansdowne, Lansdowne Rd., Croydon-Surrey,
Pin: CR9 2ER, United Kingdom

Packaging & Continental Dispatching

Global Journals
E-3130 Sudama Nagar, Near Gopur Square,
Indore, M.P., Pin:452009, India

Find a correspondence nodal officer near you

To find nodal officer of your country, please email us at *local@globaljournals.org*

eContacts

Press Inquiries: *press@globaljournals.org*
Investor Inquiries: *investors@globaljournals.org*
Technical Support: *technology@globaljournals.org*
Media & Releases: *media@globaljournals.org*

Pricing (Including by Air Parcel Charges):

For Authors:
22 USD (B/W) & 50 USD (Color)
Yearly Subscription (Personal & Institutional):
200 USD (B/W) & 250 USD (Color)

Editorial Board

Global Journal of Research in Engineering

Contents of the Issue

Global Journal of Researches in Engineering: G
Industrial Engineering
Volume 17 Issue 1 Version1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

SMV Distribution of Double Layer Men's Shorts on the basis of Time Study: An Authentic Mode of Operation Breakdown for Industrial Bulk Production

By Mahmudul Hasan, Habibur Rahman, Md. Ishrak Ahmed & Md. Najmul Haque

University of Business and Technology

Abstract- The production system of apparel manufacturing industry depends on different factors. Among these operation break down and SMV (standard minute value) distribution play vital role on the productivity depending on lead time to dispatch the product. To cope up with this situation shorten production cycle time in the garment industry is being an emergence. Sometimes labors are forced physically and mentally to perform their task within undefined time. In this study an approach to experimental knowledge based roadmap is presented for men's shorts sewing line production. A details description of workstations sequence, machine and man allocation based on SMV are described.

GJRE-G Classification: FOR Code: 290502

SMVDISTRIBUTIONOFDOUBLELAYERMENSSHORTSONTHEBASISOFTIMESTUDYANAUTHENTICMODEOFOPERATIONBREAKDOWNFORINDUSTRIALBULKPRODUCTION

Strictly as per the compliance and regulations of:

SMV Distribution of Double Layer Men's Shorts on the basis of Time Study: An Authentic Mode of Operation Breakdown for Industrial Bulk Production

Mahmudul Hasan [α], Habibur Rahman [σ], Md. Ishrak Ahmed [ρ] & Md. Najmul Haque [Ѡ]

Abstract- The production system of apparel manufacturing industry depends on different factors. Among these operation break down and SMV (standard minute value) distribution play vital role on the productivity depending on lead time to dispatch the product. To cope up with this situation shorten production cycle time in the garment industry is being an emergence. Sometimes labors are forced physically and mentally to perform their task within undefined time. In this study an approach to experimental knowledge based roadmap is presented for men's shorts sewing line production. A details description of workstations sequence, machine and man allocation based on SMV are described. Reasonable SMVs is calculated by time study for producing shorts. Hourly target is also defined with normal efficiency as well as set up a well-balanced sewing line in manufacturing process. A standard may be maintained in the apparel industry to obtain maximum productivity by using the operation break down properly. The outcome of this observation is to synchronize workstations and to minimize SMV as the sense of productivity improvement.

I. Introduction

The ready-made garment (RMG) sector is the life-blood of Bangladesh economy achieving higher export growth every year. The sector is now the largest contributor not only to overseas trade but also to the national economy. Bangladesh textiles and RMG industry comprises 1,55,557units – 1,48,000 handlooms units, 3,284 mechanized primary textile units, 5150 export-oriented readymade garments manufacturing units and 273 garments washing-dyeing units. The sector is a major foreign exchange earner for Bangladesh contributing 77 percent to the country's net exports. At the end of the fiscal year 2011, total export of Bangladesh garments was worth US$ 23 billion, a 43

Author α: Assistant Work Study officer, Industrial Engineering & planning Department, Ehsan Garments Ltd. Gazipur, Dhaka, Bangladesh. e-mail: hasanbangladesh@yahoo.com
Author σ: Assistant Professor, Department of Textile Engineering, Bangladesh University of Business and Technology(BUBT) Mirpur-2, Dhaka-1216. e-mail: mhr_ratu@yahoo.com
Author ρ: Department of Textile Engineering, Pabna Textile Engineering College, Pabna. e-mail: ishrakptec@gmail.com
Author Ѡ: Junior Executive, Industrial Engineering Department, LZ Fashion Wear Ltd., DEPZ, Dhaka.
e-mail: haque.bangladesh45@gmail.com

exports. At the end of the fiscal year 2011, total export of Bangladesh garments was worth US$ 23 billion, a 43 percent increase over the previous year, accounting for almost 25 percent of the GDP(gross domestic product) [1]. Now a day, fashion & styles are changing rapidly. The rapid rate at which the whole process takes place, the interaction between workers, and the different transition times between workers make it increasingly more difficult for a human being to make correct decisions regarding how fast each operator should work in order to continue the process, while at the same time keeping productivity high and throughput at an acceptable level [2]. Different type bottom, top and underwear are manufactured in Bangladesh. Shorts are a garment worn by both men and women over their pelvic area, circling the waist and splitting to cover the upper part of the legs, sometimes extending down to the knees but not covering the entire length of the leg. Shorts are typically worn in warm weather or in an environment where comfort and air flow are more important than the protection of the legs [3]. Shorts owe much of their contemporary origins to the military. Possibly the earliest example (1880's) of modern-day shorts, is the uniform of the heavily respected Gurkha soldiers of the Nepalese army. During World War I, British Rear Admiral Mason Berridge, who stayed North American Headquarters in Bermuda and adopted a style for his fellow officers and named them "Bermuda Shorts". From then on this style is adopted as school uniform in Britain.In 1932, when Britain's top ranked tennis player, Bunny Austin appeared in the U.S. National Championships in Forrest Hills, Long Island, he wore flannel shorts instead of the standard white trousers. By the 1950's, in suburban America, Bermuda shorts were seen as essential. Today Hollywood and athletics greatly influences style, Michigan basketball's 1991's "best recruiting class ever" that created a cultural shift, from short shorts to a new, longer, baggy short, that asserted ego, personality and a new style of player [4]. In modern fashion trend, shorts belong as unisex formal and informal outwear all over the globe. Although, they are a shortened version of trousers, many derivatives and designed shorts are available in Market.

Baggies, Bermuda shorts, Boardshorts, Boxer shorts, Cargo shorts, Jorts, Cut-offs short etc. are used by men. Women use Boyshorts, Bun huggers, Culottes, Daisy Dukes, Dolphin shorts, Hotpants, Short shorts, Skorts etc. most [5].

To make shorts industrially about 44 operations are needed. Some of these are performed by helper manually and rest of operations is completed by the operator with help of machine.

Assembly Lines are used in high production situations where the work to be performed can be divided into small tasks and tasks assigned to the workstations on the line. Key advantage of using manual assembly line is specialization of labor. By giving each worker a limited set of tasks to do repeatedly [6].

A standard method is needed to get the maximum productivity by using the assigned time properly. The job is broken down into parts and the parts are timed. The parts are known as Element. Contents of each element should be homogeneous as possible. If the element is shorter, two or more should be combined into one [7]. In assembly line balancing, allocation of jobs to machines is based on the objective of minimizing the workflow among the operators, reducing the throughput time as well as the work in progress and thus increasing the productivity. Sharing a job of work between several people is called division of labor. Division of labor should be balanced equally by ensuring the time spent at each station approximately the same. Each individual step in the assembly of product has to be analyzed carefully, and allocated to stations in a balanced way over the available workstations. Each operator then carries out operations properly and the work flow is synchronized. In a detailed work flow, synchronized line includes short distances between stations, low volume of work in process, precise of planning of production times, and predictable production quantity [8].

Standard minute value is the standard time, to complete any given task by using best possible methods at standard level of performance. To estimate SMV we have to analyze the garment carefully and check different factors that affect the SMV. SMV of a product varies according to the work content or simply according to number of operations, length of seams, fabric types, stitching accuracy needed, sewing technology to be used etc.

Standard minutes (SMV) of few basic products have been listed down with its SMV range according to work content variation [9].

Breakdown is a listing of the content of a job by elements. A garment consists of some parts& some group of operations. Breakdown means to writing down all parts & all process/operation after one another lying with the complete garment according to process sequence. It is a must to write down the estimated SMV & type of machine beside each &every process [10].

Work study is a generic term for method study and work measurement which are used in the Examination of human work in all its contexts and which lead systematically to the Investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement [11].

Therefore, garment production needs properly rationalized manufacturing technology, management and planning [12].

Performance rating is the process during which the time study engineer compares the performance of the operator under observation with his own concept of normal performance. The concept of normal performance must be such that the time standards set from it and must be within the capacity of the majority of workers in the enterprise [13].

Line balancing is the allocation of sewing machine according to style and design of garment. It depends of that what type of garment we have to produce [14].

An experimental investigation for the distribution of SMV for each and every operation require for making a men's and provides a clear and details concepts for determining line balancing, machine requirements, man power allocation for setting a definite target within a reasonable efficiency.

II. Objectives of the Study

The main objective of this study is to form a sequential list of all the elements (operation breakdown) in sewing line involving with producing double layer shorts as well as distributing Standard minute value for every element (tasks) of this job. Besides, following issues are concerned: To draw a clear job flow chart of making shorts, to determine the manpower and machine allocation, to define a way to minimize SMV and maximize productivity and to set up a balanced sewing line practically.

III. Methodology

A study was carried out in the garments Industry named Ehsan Garments Ltd. Located at Tongi, Gazipur, Dhaka, Bangladesh and Moonlight Garments Ltd. Located at Tongi, Gazipur, Dhaka, Bangladesh. We attempted this study for proper utilization of man and machine.

a) Analysis of particular Garment (designed double layer shorts)

Generally, two different types of fabric are used for double layer shorts. For our study we took 100% polyester single jersey fabric (width-58-60", weight-120gsm, technique-knitted) as lining fabric and ricehole mesh fabric (width58-60", 140gsm, warp knitted) as shell (outer) portion. As such type of shorts is used as nightwear, ready for the gym, walking fit wear, athletic fit and loose fitting appearance; Elastic waistband (2" synthetic) with hidden drawstring (0.5" synthetic flat draw cord) and two side pockets are existed.

The investigation occurred for M size garments consisting with 32-34" waist and 8" inseam.

Figure.1: Basic figure of men's shorts

b) *Making process of shorts*

Preparatory section

Care label attach to back
↓
Side pocket bag close
↓
Pocket bag join to body
↓
Pocket opening 1/4 top
↓
Side Pocket fixed tack
↓
Pocket w/belt positions tack

Lining part section

Back rise join lining part
↓
Front rise join lining
↓
Side seam join lining

Shell part section

Front rise join Shell part
↓
Back rise join shell part
↓
Side seam join shell part
↓
Side seam join position over

Assembly section

Lining part joins to shell part w/belt
↓
Elastic mouth tack & mark
↓
Elastic join to w/belt
↓
Elastic join position over lock
↓
Size label attaching
↓
W/belt hole making
↓
W/belt false tack
↓
W/belt rolling
↓
Inseam joins shell part
↓
Inseam joins Lining part
↓
Bar tack at pocket corner & inseam
↓
Bottom hem over lock
↓
Bottom hemming

c) *Operation breakdown*

- ❖ After analyzing the provided shorts construction in section by section (i.e. preparatory, lining section, shale section, assembly), had to list down operations. Once we had listed all operations cross-check with sample shorts again and visualize that if all operations are done as per our list we would get exactly complete shorts as per sample.
- ❖ Based on seam type used we selected one machine and enter into the sheet against each operation with name and description of attachments or folder or guides if needed for an operations.
- ❖ At this stage we had to find SMVs by conducting Time study (time study sheet) .SMV is shown at 100% efficiency and also converted SMVs into Target efficiency (i.e. 65%). Refer to the formula. SMV at Target Efficiency = SMV @ 100% efficiency / Target efficiency%
- ❖ By using following formulas we fixed up Production per hour at target efficiency% and Number of machines.
  Calculated Production/Hour @ target efficiency = 60/Operation SMV @ target Efficiency
  Calculated Machine number = (SMV @ target efficiency * Hourly production target/60)
- ❖ Last of all a table form summary of required number of machine was drawn to achieve hourly production target.

d) Time study

In order to balance the sewing line as well as to increase the efficiency of the line, at first a detailed work and time study was carried out to find the task durations.

However, the time required to complete a task depends on a lot of factors such as the task, the operator, the properties of fabric and sub materials, working environment, quality level of the product, the hour of the day, psychology of the operator etc.[16]

e) Line balancing

Standard Minute Value (SMV) is used as the most usable tool for the line balancing, production control and the estimation of efficiency. After time study following steps are required to balance the line.

- Target setting
- Identification of bottleneck areas
- Eliminate bottlenecks from the line

IV. Result and Discussion

a) Operation breakdown sheet and time study sheet

The following table denotes the operations breakdown (elements) sheet and number of required machines.

Table 1: Operations breakdown (elements) sheet

NO	OPERATION	M/C	M/C OPN		MNL OPN		REQ	
		TYPE	SMV	TGT	SMV	TGT	OP	HEL
1	Back rise join lining part	4 OL	0.3	200			1.27	
2	Care label attach to back part	SNL	0.23	261			0.97	
3	Front rise join lining part	4 OL	0.27	222			1.14	
4	Back + front part matching lining part	H			0.28	214		1.18
5	Side seam join lining part	4 OL	0.5	120			2.11	
6	Side pocket bag close	5 OL	0.3	200			1.27	
7	Pocket pair matching & thread cut	H			0.28	214		1.18
8	Front rise join Shell part	4 OL	0.29	207			1.23	
9	Pocket join position mark	H			0.28	214		1.18
10	Pocket bag join to body	SNL	0.9	67			3.80	
11	Pocket join position corner cut	H			0.28	214		1.18
12	Pocket opening 1/4 top stitch	SNL	0.65	92			2.75	
13	Side Pocket fixed tack	SNL	0.5	120			2.11	
14	Pocket w/belt position tack	SNL	0.28	214			1.18	
15	Sticker remove	H			0.25	240		1.06
16	Back rise join shell part	4 OL	0.25	240			1.06	
17	Back + front part matching shell part	H			0.26	231		1.10
18	Side seam join shell part	SNL	0.75	80			3.17	
19	Side seam join position over lock	4 OL	0.55	109			2.32	
20	Side seam join position iron	IRN			0.28	214		1.18
21	Shell part mark &fitting	H			0.28	214		1.18
22	Lining part & shell part matching	H			0.22	273		0.93
23	Lining part join to shell part w/belt position	SNL	0.75	80			3.17	
24	Body turning	H			0.30	200		1.27

25	Elastic mouth tack & mark	SNL	0.3	200			1.27	
26	Elastic join to w/belt	SNL	0.5	120			2.11	
27	Elastic Join position over lock	4 OL	0.25	240			1.06	
28	Hole mark	H			0.24	250		1.01
29	Size label attach	SNL	0.25	240			1.06	
30	W/belt hole	BH	0.27	222			1.14	
31	Elastic cut, mark & wash	IRN			0.28	214		1.18
32	W/belt false tack	SNL	0.5	120			2.11	
33	Side pocket up & down check	H			0.24	250		1.01
34	W/belt rolling make	KNS	0.58	103			2.45	
35	W/belt thread cut	H			0.25	240		1.06
36	W/belt tack remove	H			0.90	67		3.80
37	Body turning	H			0.28	214		1.18
38	Inseam join shell part	4 OL	0.3	200			1.27	
39	Inseam join Lining part	4 OL	0.3	200			1.27	
40	Bartack at pocket corner & inseam point	BTK	0.4	150			1.69	
41	Inseam body arrange & turn	H			0.28	214		1.18
42	Bottom hem over lock	4 OL	0.8	75			3.38	
43	Bottom hemming	FLAT LOCK	0.85	71			3.59	
44	Final thread trimming	H			0.75	80		3.17
	TOTAL		**11.82**		**5.93**			**21.89**
			17.75					
	SUPPORTING MC							
	GRAND TOTAL		**11.82**		**5.93**		**0.00**	**21.89**
			17.75					

	M/C Operator	78	TARGET **100%**		**264**pcs/hour				
	Helper	22	TARGET **65%**		**171**pcs /hour				
	Ironman	06							
	M/C Name	SNL	5 OL	4 OL	K-S	BH	BTK	FLAT LOCK	**Total**
	Number	**27**	**1**	**14**	**2**	**1**	**2**	**3**	**50**

Table 2: Time study sheet

Sl No	M/c	OP id no.	Process name	TIME(Second)					Avg. time	B.T. with allowance	S.M.V
				T-1	T-2	T-3	T-4	T-5			
1	OL	100	Back rise join lining part	15	16	15	14	15	15	18	0.30
2	SNL	348	Care label attach to back part	12	12	12	12	11	12	14	0.23
3	OL	321	Front rise join lining part	12	14	15	13	14	14	16	0.27
4	H	323	Back + front part matching lining part	13	14	15	13	14	14	16	0.28
5	OL	370	Side seam join lining part	26	27	25	24	25	25	30	0.50
6	OL	A-52	Side pocket bag close	15	14	15	14	16	15	18	0.30
7	H	B-81	Pocket pair matching & thread cut	12	16	14	12	13	13	16	0.28
8	OL	174	Front rise join Shell part	15	14	16	16	15	15	18	0.29
9	H	277	Pocket join position mark	14	15	12	15	13	14	16	0.28
10	SNL	24	Pocket bag join to body	46	44	48	43	47	46	54	0.90
11	H	339	Pocket join position corner cut	14	14	15	13	12	14	16	0.28
12	SNL	152	Pocket opening 1/4 top stitch	33	34	35	32	33	33	39	0.65
13	SNL	358	Side Pocket fixed tack	29	26	23	25	24	25	30	0.50
14	SNL	352	Pocket w/belt position tack	12	13	15	11	14	13	16	0.28
15	H	367	Sticker remove	12	10	13	12	14	12	15	0.25
16	OL	138	Back rise join shell part	15	11	10	12	13	12	15	0.25
17	H	361	Back + front part matching shell part	15	12	12	15	13	13	16	0.26
18	SNL	142	Side seam join shell part	39	37	35	39	40	38	45	0.75
19	OL	173	Side seam join position over lock	31	27	28	26	25	27	33	0.55
20	IRN	317	Side seam join position iron	13	10	16	12	14	13	16	0.28
21	H	373	Shell part mark & fitting	12	14	13	13	14	13	16	0.28
22	H	316	Lining part & shell part matching	13	9	12	9	11	11	13	0.22
23	SNL	327	Lining part join to shell part w/belt	41	39	37	37	38	38	45	0.75

			position								
24	H	77	Body turning	14	13	14	18	15	15	18	0.30
25	SNL	322	Elastic mouth tack & mark	15	13	16	14	16	15	18	0.30
26	SNL	37	Elastic join to w/belt	29	27	26	22	24	26	30	0.50
27	OL	226	Elastic Join position over lock	13	12	14	13	12	13	15	0.25
28	H	128	Hole mark	13	11	13	11	12	12	14	0.24
29	SNL	397	Size label attach	13	13	12	13	12	13	15	0.25
30	BH	179	W/belt hole	14	14	15	12	13	14	16	0.27
31	SNL	37	Elastic cut, mark & wash	12	15	14	13	14	14	16	0.28
32	SNL	232	W/belt false tack	31	23	23	22	26	25	30	0.50
33	H	368	Side pocket up & down check	14	10	11	11	12	12	14	0.24
34	KS	315	W/belt rolling make	28	29	31	27	32	29	35	0.58
35	H	334	W/belt thread cut	12	11	13	12	14	12	15	0.25
36	H	389	W/belt tack remove	44	46	48	45	47	46	54	0.90
37	IRN	317	Body turning	14	15	11	14	13	13	16	0.28
38	OL	172	Inseam join shell part	13	16	15	14	16	15	18	0.30
39	OL	11	Inseam join Lining part	15	14	11	16	17	15	18	0.30
40	BTK	223	Bar tack at pocket corner & inseam point	19	24	21	20	19	21	24	0.40
41	H	374	Inseam body arrange & turn	15	13	14	12	13	13	16	0.28
42	OL	233	Bottom hem over lock	40	38	43	39	41	40	48	0.80
43	FL	222	Bottom hemming	46	42	47	42	40	43	51	0.85
44	H	380	Final thread trimming	36	38	39	37	39	38	45	0.75

Calculation of SMV
Example for the first operation 'Back rise join lining part'
SAMV = Basic minute + Bundle allowances + machine and personal allowances
[Add bundle allowances (10%) and machine and personal allowances (10%) to basic time]
Now, we get Standard Minute value (SMV) = (0.25+0.05+0.05) = 0.3 minutes.

A. Line balancing Chart

Line balancing is the allocation of sewing machine according to style and design of garment. Line balancing Chart is such type of tool that indicates how a sewing line balanced. It describes every workstation and required time for completing individual task in sequence with the cooperation of Basic pitch Time (BPT).

The line balanced according to our calculated SMV for the double layer men's shorts we found the following Line Balancing Chart:

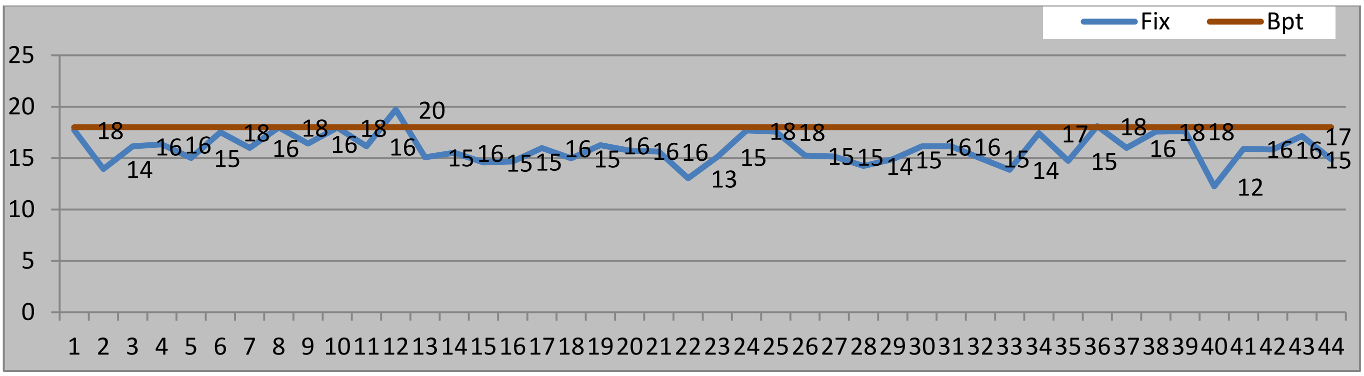


Fig.2. Line balancing Chart

The time consumption of every workstation is nearly about to BPT and that means the chances of bottleneck are reduced.

B. Discussion

During our investigation, we found few hours that failed to achieve our estimated target and bottleneck has risen up. The reason of this problem was listed out in bellow:

- Lack of skilled operator
- Improper supervising of sewing line
- Machine break down
- Lack proper training & improvement programs
- More allowance time
- Lack of high performance machines
- Lack of compliance issues
- Operators' absenteeism
- Lack of motivational activities

Following points are suggested to minimize Non-productive time (NPT).

- Ensure continuous feeding to the sewing line
- Feed fault free and precise cutting to line
- Reduce line setting time
- Use work aids, attachments, guides, correct pressure foots and folders
- Hourly operator capacity check
- Continuous training to sewing operators and line supervisors
- Setting individual operator target
- Using auto trimmer sewing machine (UBT)
- Installing better equipment
- Conduct R&D for the garment
- Filling up compliance issues
- Operator motivation
- Plan for operator's Incentive scheme

V. Conclusion

This study on operation break down and SMV distribution of men's shorts is on the basis of time study for bulk production in industry. It is very important and critical task in an apparel production industry. In practice we may use more or less machines, man power, raw materials and other resources for want of proper balance of tasks and as well as the prior precise apparel industry. Thus it would reduce the all kinds of wastes and consume least resources i.e. man, machine, materials, money, etc. It will definitely help us to come the main goal of an industry that is making maximum profit.

By this study, we have described the whole job of making double layer short broken down into elements. This study was going on with experienced and non- experienced machine operators and helpers. The environment kept in standard for Bangladesh. It is suggested that to get better productivity all the people involved with production should be experienced and standard environment of workstations should maintain properly. According to our elements (operation) bulletin we also designed a line layout concerned with the SMVs sheet that taken by direct time study. Line balancing chart indicates succeed of the established line.

To conclude, this research has demonstrated the better synchronization among man machine and materials which full fill our main study objective to increase the efficiency and productivity.

References Références Referencias

1. M. Rahman, (Thursday, 06 December 2012). RMG sector: Secret of success and causes of unrest, senior vice president (IBBL).
2. G. Mücella, Güner & Can Ünal, Line Balancing in the Apparel industry Using Simulation Techniques, Fibres & textiles in Eastern Europe April / June 2008, Vol. 16, No. 2 (67), p- 75.
3. Wikipedia https://en.wikipedia.org/wiki/Shorts.
4. Short history of shorts https://www.oldbull-shorts.com/en/articles/History-Of-Shorts1/.
5. Wikipedia https://en.wikipedia.org/wiki/Shorts.
6. L.C. PIGAGE & J.L. TUCKER, Motion and time study, p-26.
7. R. Biswas, Productivity improvement in garments industry through cellular manufacturing approach, p-66.
8. Niebel & S. K. Bahadir (2011), Assembly Line Balancing in Garment Production by Simulation, Assembly Line- Theory and Practice, Prof. Waldemar Grzechca (Ed.), ISBN: 978-953-307-995-0, InTech.
9. M. M. Khatun(2014), Effect of time and motion study on productivity in garment sector International Journal of Scientific & Engineering Research, Vol. 5, Issue 5, pp827-828.
10. Guidelines for Industrial Engineering, KSA Technopak.
11. http://wiki.answers.com/Q/Industrial_engineering_work_study_in_garments.
12. R. E. Glock, & G. I. Kunz (1995), Apparel Manufacturing-Sewn Product Analysis, Prentice Hall, New Jersey, p:4.
13. M. M. Khatun(2013), Application of industrial engineering technique for better productivity in garments production, International Journal of Science, Environment and Technology, Vol. 2, No. 6, pp1367 – 1368.
14. M. Syduzzaman, & A. SundarGolder, Apparel Analysis for Layout Planning in Sewing Section, International Journal of Current Engineering and Technology, vol.5, No. 3, p 1736
15. G. Fozzard, J. Spragg, & D. Tyler, (1996). Simulation of flow lines in clothing manufacture: Part1 : mode construction, International Journal of Clothing Science and Technology, Vol. 8, pp. 17-27.

This page is intentionally left blank

Global Journal of Researches in Engineering: G
Industrial Engineering
Volume 17 Issue 1 Version1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Modeling Hospital Triage Queuing System

By Ibrahim Bedane
Maddawalabu University

Abstract- Proper Triage queuing system's modeling and performance analysis is important components of Customers waiting time reduction and Hospital quality improvement. This paper develop A Cumulative Approach Modeling Technique and shows how to apply and model queuing system on Hospital Triage queuing network composed of one stations with two servers. Using Modeling Technique developed, this paper shows how to Model and analyze queuing systems and track the Analytical result of phenomenon of waiting in lines using representative measures of performance, such as average queue length, and average waiting time in queue. Beside other necessary data taken from hospital records, sample service time data of 300 patients selected randomly from both shifts and data on number of patients enter the system within one-hour time Interval for consecutive four weeks were collected to determine the service and arrival pattern of Hospital Triage.

Keywords: *queuing theory, waiting time, healthcare, triage, analytical technique.*

GJRE-G Classification: *FOR Code: 290502p*

MODELINGHOSPITALTRIAGEQUEUINGSYSTEM

Strictly as per the compliance and regulations of:

Modeling Hospital Triage Queuing System

Ibrahim Bedane

Abstract: Proper Triage queuing system's modeling and performance analysis is important components of Customers waiting time reduction and Hospital quality improvement. This paper develop A Cumulative Approach Modeling Technique and shows how to apply and model queuing system on Hospital Triage queuing network composed of one stations with two servers. Using Modeling Technique developed, this paper shows how to Model and analyze queuing systems and track the Analytical result of phenomenon of waiting in lines using representative measures of performance, such as average queue length, and average waiting time in queue. Beside other necessary data taken from hospital records, sample service time data of 300 patients selected randomly from both shifts and data on number of patients enter the system within one-hour time Interval for consecutive four weeks were collected to determine the service and arrival pattern of Hospital Triage. Using cumulative data collected up to time x, functions approximately fit arrival and service trend lines values were formulated and required queue values along a continuum within these discrete values were estimated. Furthermore, this paper shows how this model can be used to manage Waiting time and crowd in queue and integrate the movement of the Service into the actual operation of the resource performing the work. Finally, the author concludes that, the application of this model is feasible to drive equations and analyze phenomenon of waiting in lines; and also, this model offer better queuing systems analysis result which can be used to simulate a queuing system's performance and allows the determination of patient appointments and effective arrival pattern management, and hence, hospital service quality improvement.

Keywords: queuing theory, waiting time, healthcare, triage, analytical technique.

I. Introduction

Queuing Theory tries to answer questions like e.g. the mean waiting time in the queue, the mean system response time (waiting time in the queue plus service times), mean utilization of the service facility, distribution of the number of customers in the queue, distribution of the number of customers in the system and so forth. Even though, queuing systems in healthcare operations are complex since patient flows through various units of a particular hospital (Gupta 2013), this paper aims to model Queuing systems which attempts to provide answers to the following questions. Why do queues form? How long customers wait to be served? How many customers wait in crowd to be served at any time t? What trade-offs must be considered by a service system architect when choosing system parameters?

Auhtor: Maddawalabu University Mechanical and Industrial Engineering Department. e-mail: ibrahimbedhane@gmail.com

Customers go into a hospital to get service increasingly equate service quality with rapid service. However, Long waiting list or waiting time in public organization is a notorious problem in most of the countries all over the world. Particularly in healthcare delivery systems waiting in queue crowd lines are ubiquitous (Lade, et al. 2015). Waiting in a crowd queue is not usually interesting; especially waiting for non-value adding activity is undesirable. Because, delay in receiving needed services can cause prolonged discomfort and economic loss when patients are unable to work and possible worsening of their medical conditions that can increase subsequent treatment costs and poor health outcomes. In extreme cases, long queues can delay diagnosis and/or treatment to the extent that death occurs while a patient waits (S.Olorunsola, R.Adeleke and T. 47-53). By awaking this, more and more scholars and companies are focusing on queuing analysis. More recently, Health policy investigators have also sought to apply queuing analysis techniques more widely across entire healthcare systems even though models lack real-world validation (S.Olorunsola, R.Adeleke and T. 47-53). This paper aims to model phenomenon of waiting in lines using average queue length, and average waiting time in queue and analyze their implications on queue crowd management. Moreover,

All patients arriving Hospital with all case like referral, personally, emergency or scheduled appointments by OPD are received by Hospital triage. At triage patients will be welcomed (received), registered, pay registration fee, receive approval of free of charge (credit), screened receive personal cards and will be sent to the outpatient case team. Any emergency cases found here are directly sent to emergency case team without delay. Also, serves to identify priorities for patient care in emergency departments and most surge situations in which resources are rarely limited. Even though, registering and opening patient document/card and assigning them to the right physicians and keeping their documents in appropriate way and place is necessary activities in hospital, it is non-value adding activity. Hence, eliminating or at least reducing waiting time in Triage is important components of quality improvement. Furthermore, the accuracy of resulting expressions of the performance metrics at point of hospital entry or Hospital Triage is mandatory for hospital clinics queuing systems analysis. Thus, By awaking this, this paper intended to make it possible to write equations that describe how the number of customers in case hospital Triage queue system changes over time; using mathematical modeling Approach.

Queueing theory is the mathematical study of waiting line models. A mathematical model usually describes a system by a set of variables and a set of equations that establish relationships between the variables. Usually, the inputs of a queueing model are the distribution of an arrival process and characteristics of the system under study. The characteristics of the system include the number of servers, the service order and discipline, and the distribution of service times. The output of a queueing model is a description of the performance attributes of the system under a specific policy. The solution of a queueing model determines, for example, the fraction of time that each server is idle, the expected waiting time of customers, the expected number of customers waiting in the queue, and the number of servers necessary to ensure some level of performance for the system (Gross and Harris, 1985). In this section mathematical model modeling Technique of the queuing system will be discussed.

A mathematical model is an abstract model that uses mathematical language to describe the behavior of a system. Mathematical models are tractable when closed-form or recursive formulae can be obtained, and in such cases the resulting expressions for the performance metrics are referred to as analytical results (Gupta 2013). The purpose of mathematical models of queues is to obtain closed-form or recursive formulae that allow system designers to analyze performance metrics such as average queue length, average waiting time, and the proportion of customers turned away. Thus, this paper model patient arrival and service distribution, write equations that describe queue pattern change over time and attempts to provide substantial answers to the following questions. How long customers wait to be served? How many customers wait in queue crowd to be served at any time t? Why do queues form?

II. Development of the Model

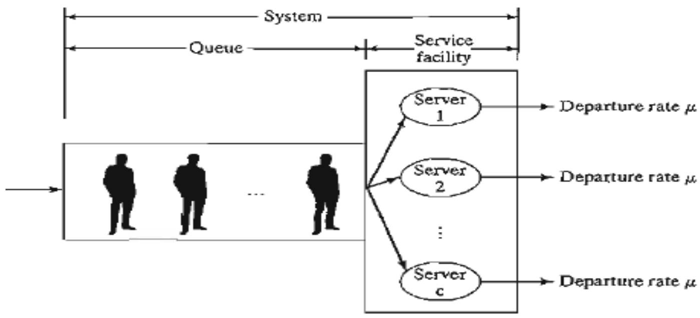
To develop a mathematical model of a hospital in the form that describes the queuing systems requires some background study on Arrival pattern and distribution, service nature and distribution, service mix, arrival and service volume. The entry of a patient into the system (patient arrival) and the release of a patient upon completion (patient departure/exit) are considered as two main events that cause an instantaneous change in the state of the system.

In reality, number of patients arrives vary from shift to shift and time to time. Even, the entire system is not a black box; customers arrive before service start. Consequently, an arrival to a queuing system starts before service start while a departure from a queuing system starts empty. Moreover, time-decisive arrival and service parameters that have been in operation, such that time t, affects the distributions of number in system after that time and the performance of a system. To model observed arrival and service pattern, this paper uses Cumulative number of arrival and exit model and drive equations of the phenomenon of waiting in lines using representative measures of performance, such as average queue length and average waiting time in queue at working time x of a system. Total number of customers arrived and served up to any time can be used to determine all the basic measures of performance. Using Cumulative arrival and service the performance of a system with time-decisive parameters that has been in operation for a sufficiently long time such that time t no longer affects the distributions of number in system, number in different queues, waiting times, and total delay. Thus, to make analytical technique possible and write equations that describe queue crowd changes over time, this paper present Cumulative Approach Modeling Technique.

Let Na(x) denote total number of customers arrived up to time x and Ns(x) denote total number of customers served up to time x where time x is server working time. Using these basic setup basic measures of performance can be determined in the following order.

i. The expected number of customers waiting in the queue at any time x is equal to the expected total number of customers arrived up to time x minus the expected total number of customers served up to time x. $Lq(x) = Na(x) - Ns(x)$
ii. Expected waiting time in the queue of the customer arrived at any time t is equal to the Expected time at service, x, minus arrival time, t. assuming first-in-first-out (FIFO) service protocol Expected time at service, x, of the customer arrived at any time t can be derived from $NA(t) = NS(x)$. thus, $Wq(t) = x - t$
iii. Expected number of customers in the system at any time x is equal to the expected number of customers in queue plus in service at time x. Where, the value of expected number of customers in service is equal to server utilization at time x. $Ls(x) = Lq(x) +$ Expected number of customers in service where, Expected number of customers in service at time x, $\rho(x)$ is: $\rho(x) = Na(x)/Ns(x)$
iv. Expected waiting time in the system of the customer arrived at any time t is equal to the expected waiting time in queue plus the expected service time.
v. In most case, arrival rate of customer, μ, and/or the service rate of server, λ, is uneven or varies from time to time. Using discrete Data along a continuum on Total number of customers arrived and/or served up to any time x, The rate of change in these values with respect to time x can be denoted by fitting a curve along the discrete data points. In case, when arrival rate of customers, μ, and/or the service rate

of server, λ, is uniform or constant, total number of customers arrived up to time x is arrival rate of customers times time and total number of customers served up to time x is effective service rate times time, where effective service rate is number of servers, c, times service rate. Thus, Na(x) = μ*x and Ns(x) =λ*c*x



Using Discrete Data collected for values along a continuum and curve fitting Technique, trend lines equations for total number of customers arrived and total number of customers served up to time x can be easily derived and analytical result of the performance of a system of interest can be easily computed. The basic idea is to fit a curve or a series of curves that pass directly through each of the points. Using this Technique, this paper make it possible to estimate required points between these discrete values and model a function that approximately fit parameters of system of interest. This basic model, identifies the arrival and service pattern of the hospital and the variables used to determine the characteristics of queuing system. To shows how to apply this modeling technique, This paper model case Hospital Triage queuing network composed of two servers and approximate equations describing the queue system of service mechanism.

III. Case Hospital

The Case hospital, Hawassa University Referral Hospital (HURH) in Ethiopia which established in 1994 E.C, is providing Teaching and training service to health science students and medical service to 12,000,000 estimated populations with 350Beds capacity. As might be expected of any hospital, HURH have Triage worker designated to only patients with emergency cases to directly send them to emergency case team without delay, beside regular workers. Thus, this paper studied all patients entered and registered in the regular Hospital Triage.

When patient enter hospital, Hospital Triage front-desk clerk ask them to provide name and reason for visit. The clerk also clarifies if patient was pre-registered for this service or not. If the answer is yes, the clerk gets patient's documentation ready for the registration representative. Then the patient receives an assigned number and is asked to wait in waiting or triage area for registration representative to call the name and number. Registration representative determines if the patient ever receives the service at the hospital and if so, pull up patient's data and verifies patient's personal information. If the patient is visiting the hospital for the first time, CT clerk creates patient's profile in the Hospital Database card. An attendant nurses in this room identifies and determines patient's Triage (OPD) Clinics and creates new account and then orders the carter to transport the card once a patient has paid a registration fee.

In collaboration with HURH Hospital Triage workers Statistical Data were collected on number of patients enter the system within one hour time Interval (T) for consecutive four weeks. It shows that on average 286 Patients visits hospital daily with varying arrival rate. On average 164 and 122 number of patients arrive in Morning and Evening Shift respectively as shown in table below.

Table 1: Number of Patients Enter The System Within One Hour Time Interval

Patients at Morning Time AM		Patients at Evening Time PM	
Intervals	N. Arrived	Intervals	N. Arrived
Before 8:00	19	Before1:00	3
8:00-9:00	62	1:00-2:00	58
9:00-10:00	48	2:00-3:00	37
10:00-11:00	23	3:00-4:00	16
11:00-12:00	12	4:00-5:00	8

Global Journal of Researches in Engineering (G) Volume XVII Issue I Version I Year 2017

Similarly, Statistical Data on patients service time were collected for consecutive two weeks (10 working days) using 300 Sample patients selected randomly shows that CT patient service time varies from 2 to 3.8 minute per patient with 2.55 minute/patient mean server service time. This means 23 patients per hour per server service rate. Thus, HURH have effective mean service rate or service capacity of 46 patients per hour and 368 patients per day, assuming 8 working hour per day, which is much more than average number of Patients visits hospital daily (286). Moreover, Data from hospital Documentation Unit reveals insignificant correlation between days, Monday to Friday, which varies randomly. In general, The Hospital Triage system consist of one stations with two number and configuration of servers and Triage clinics with no customer classes, FIFO service protocols, and unlimited sizes of waiting room are modeled.

IV. Application of the Model

This paper model the phenomenon of waiting in lines using representative measures of performance, such as average queue length, and average waiting time in queue based on Arrival and service distribution trend lines curve fitting equations of Cumulative Approach Analytical Technique (CAAT). Based on Discrete Data collected for values along a continuum, of cumulative number of patients arrived and served up to time x are determined. Using these data representing all values along a continuum, equations of interest changes over time were derived. Estimating required points between these discrete values, equations were derived for every single curve that represents the general trend of the service data, Morning and Evening Arrival data trend lines where $0 \le x \le 4$ with 0.997 R -squared (R^2) value or Square of the correlation coefficient. Thus, functions representing Total number of patients arrived and served up to morning and evening time x are denoted by:

$$NAm(x) = 0.2198x3 - 10.196x2 + 73.425x + 19 \text{ at } R^2 = 0.9978$$

NAe(x) = 1.0676x3 - 15.022x2 + 72.708x + 3 when $R^2 = 0.9989$

NS(x) = 46x with the r-squared value of 1.

Table and figure below shows data and trend lines equations representing Arrival and Service data.

Table 2: Morning and Evening Arrival data

Morning shift					Evening shift				
$NA_m(x) = 0.2198x^3 - 10.196x^2 + 73.425x + 19$				Total Served NS(x)= 46x	$NA_a(x) = 1.0676x^3 - 15.022x^2 + 72.708x + 3$				
X	NA_m	equation (Y1)	e		x	NAa	equation	e	NS(x)
0	19	18.642	0.358	0	0	3	2.8103	0.1897	0
1	81	82.426	-1.426	46	1	61	61.7344	-0.7344	46
2	129	126.852	2.148	92	2	98	96.8721	1.1279	92
3	152	153.42	-1.42	138	3	114	114.7232	-0.723	138
4	164	163.63	0.37	184	4	122	121.7875	0.2125	184

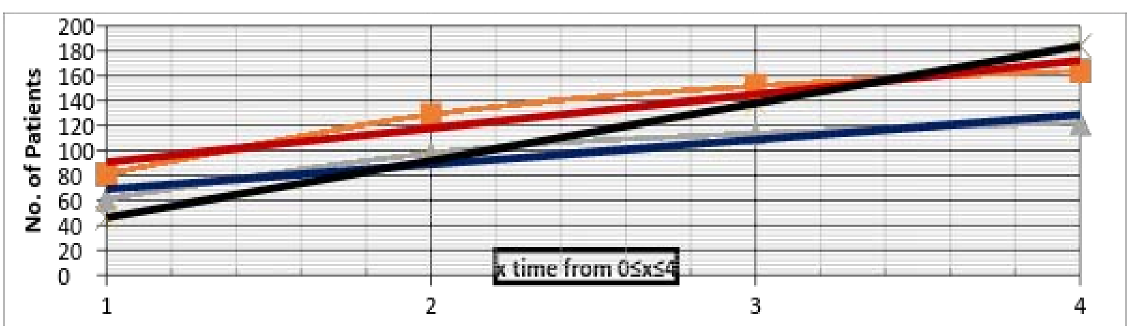


Figure 1: Arrival and Service data trend lines equations

Using this basic setup, Expected number of patients in the queue at time x Lq(x) are denoted by:

Morning Lqm(x) = NAm(x)-Ns(x)

Which is Lqm(x) = 0.2198x3 - 10.196x2 + 27.425x + 19 and

Evening Lqe(x) = NAe(x)-Ns(x)

Which is *Lqe(x) = 1.0676x3 - 15.022x2 + 26.708x + 3* Therefore, Time where an expected number of patients in the queue is zero is where Lq(x)=0 and Time t at which an expected patient in the queue is maximum is where slope of Lq(x) curve is zero which means dLqdx=0 and maximum Expected number of patients in the queue is Lq at time t (Lq(t)). Thus, Expected number of patients in the queue Lqm is zero at 11:29: 10 AM when x = 3.4863 and Lqe is zero at 04:13:02 PM when x=2.21744 morning and evening shift respectively. As a result, Maximum Expected number of patients in the queue is 38 patients at 09:24:32 AM and 16 patients at 01:59:38 PM when x= 1.409100125 and x= 0.9939966 in morning and evening shift respectively as shown in figure below.

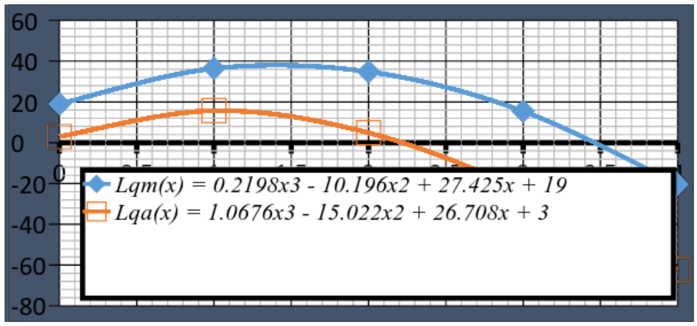


Figure 2: Average numbers of patients in the queue

Similarly, expected patient waiting time in the queue is denoted by Expected time to Service x minus customer arrival time t, which is Wq(x) = x-t. Since it has FIFO service protocol, arrival time t of patient to Service at time x where 0≤t≤x≤4 can be mode led using NA (t) =NS(x). Therefore, Expected time to Service x of patient arrival at time t is:

Morning 46x = 0.2198t3 - 10.196t2 + 73.425t + 19 and
Xm=0.004778t3 - 0.22165t2 + 1.5962t + 0.413
Evening $x= 1.0676x^3 - 15.022x^2 + 72.708x + 3$ *and*
$Xe= 0.0232t^3 - 0.3266t^2 + 1.5806t + 0.0652$

Hence, expected waiting time in the queue of the customer arrives at morning and Evening time t, Wqm (t) and Wqe (t) respectively, are denoted by:

Wqm (t) = 0.004778t3 - 0.22165t2 + 0.5962t + 0.413
Wqe (t) = 0.0232t3 - 0.3266t2 + 0.5806t + 0.0652.

Thus, Figure below shows, expected time in the queue of the customer arrives at Morning and evening time t graphs.

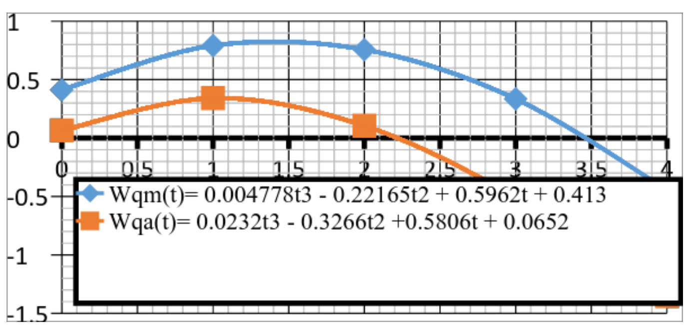


Figure 3: Average times spent in the queue

Time at which an expected patient waiting time in the queue is zero is where Wq(x)=0. Thus, customer arrives after 11:29:10 AM when time t = 3.48629 and after 04:13:02 PM when time t= 2.216859 at morning and evening shift respectively, Expect zero time in queue. The customer arrives at Time t when time in the queue is maximum is where slope of Wq (t) curve is zero which means dWq/dx=zero, Where, 0≤t≤4. Expected Arrival time of patient spend Maximum time in queue are when: is Wq when

Morning time *tm= 1.409100125*
Evening time te= 0.9939966

As a result, Maximum expected patient waiting time in the queue is 0.826hr (49.58 minutes) by patients arrived at 09:24:32 AM and 0.3425 hr (20.55 minutes) by patients arrived at 01:59:38 PM in morning and evening shift, respectively.

Results of the studied triage showed that the queue characteristics of the studied triage during the situation analysis were very undesirable in both morning and evening shifts. There were a big number of patients waiting in the queue and they waited for a long time before being registered. Thus, the average Maximum numbers of patients in the queue were 38 patients at 09:24:32 AM and 16 patients 01:59:38 PM in the morning and evening shift, respectively. The Maximum times spent in the queue by patients arrived at 09:24:32 AM were 49.58 minutes in the morning and 20.55 minutes by patients arrived at 01:59:38 PM in the evening.

As shown in figures, this analytical technique shows how time customers arrive determines the time customers wait in queue lines and analysis the relationship between patient arrival time and average times the customer spent in the queue. customer arrives at 08:30 and 09:30 spent less time in queue waiting line than customer arrives at 09:00. The result has also revealed correlation between patients' waiting times and the number of patients waiting; a positive for patients arrives before number in queue reach its maximum and negative for patients arrives after as shown in figure xx above. Note that queue crowd increase until 09:24:32 AM and 01:59:38 PM when number of arriving patients is greater than server's effective service capacity. In this instance, for each unit of time that the server is available, the average time in queue increases as number of patients in the queues increases and decrease as number of patients in the queues decreases with the same rate.

Briefly, when total number of patients arrived per unit time is greater than total number of patients served per unit time queues continue to grow over time. When total number of patients arrived up to time t is greater than total number of patients served up to time t and total number of patients served per unit time interval t is greater than arrived, queues continue to decelerate over time interval. When Total numbers of patients arrived and served are equal, expected number of customers in queue and time in queue of the customer arrives after time t is zero. In addition, when total number of patients arrived up to time is less than total number of patients served up to time, crowd in queue is zero continuously over time. The customer arrives at time t when number of patients in the queue is Maximum, Expect maximum waiting time in queue and expected waiting time in queue is zero for the customer arrives exactly after time t at which number of patients in the queue is zero.

Furthermore, the analytical results showed that the time patients in queue share 87.157% and 55.421% of system service time while time at which no patients in queue share 12.843% and 44.579% of system service time in the morning and evening shift respectively. Hence servers are capable of serving all arriving patients, queue occurrence not due to server capacity. However, Queues form when customers arrive at a service facility at time they cannot be served immediately upon arrival. Thus, increasing number of server further increase time at which no patients in queue, which means server idleness increased. By specifying reasonable limits on conflicting measures of performance such as average time in the queue and idleness percentage of the servers, anyone can determine an acceptable range of the service level through effective arrival management system. To manage arrival pattern, the arrival rate should be decreased during busy times and increased during "slow" periods. Since, This Analytical techniques show every fluctuation and pattern of queue characteristics of the system changes over time, it can be used to forecast the pattern of waiting time and pre inform customers. Using updated data, healthcare manager can recommend the best moment at which customer arrives and get service without waiting for long time in queue line.

In general, the findings show that, using Cumulative arrival and service parameters up to stationary time that has been in operation, this model limit random variables exist and time-decisive parameters that affects the distributions of number after that time t. Hence, it establish steady-state performance that has been in operation for a sufficiently long time such that time t no longer affects the distributions of number in system, number in different queues, waiting times, and total delay.

V. Conclusion

This paper develop Modeling *Technique* and model the phenomenon of waiting in line, using representative measures of performance, such as average queue length and average waiting time in queue at working time x, of tertiary teaching hospital Triage. This paper showed that, Developed Modeling *Technique, Cumulative Approach Modeling Technique, make it* possible to write equations that describe how the number of customers in each queue in the system of interest changes over time for Hospital Triage and facilities, which are open for a fixed amount of time during the day and experience time-varying customer arrival patterns. Using this model, this paper measures average queue length, and average waiting time in queue which describes the phenomenon of waiting in lines and performance of queuing systems over change of time. Thus, this model suit arrival and service pattern reality, and make it possible to write equations to analyze patients' waiting times and the number of patients waiting at any working time x of both shifts.

The first conclusion was that the Cumulative Approach Analytical Technique (CAAT) model is feasible to limits random variables exist, establish steady state system and drive equations of the phenomenon of waiting in lines using representative measures of performance, such as average queue length and average waiting time in queue at working time x, which can be used to simulate a queuing system's performance. Using this model, analytical result of the performance of a system with time-decisive parameters that has been in operation for a sufficiently long time such that time t no longer affects the distributions of number in system, number in different queues, waiting times, and total delay are possible.

The second conclusion was that the Cumulative Approach Modeling Technique is useful since, it shows how time customers arrive determines the time customers wait in queue lines crowd and analysis the relationship between patient arrival time and average times the customer spent in the queues and queue crowd. On the other hand, it helps us to identify source of queue crowd at any time and easily specify reasonable limits on conflicting measures of performance such as average time in the queue and idleness percentage of the servers. Moreover, this model is useful to indicate how and time at which improvement in system change the queue performance indicators and at what time the queue performance indicators changed very little.

A third conclusion was that the model is flexible. While simple linear models were used in this application, no difficulty is foreseen in adapting the model for nonlinearities in either patient demands or service costs. In addition, the inherent flexibility of the model would permit it to adapt easily to sub models of patient admission rates in the various medical categories.

Finally, the author concludes that, the application of appropriate analytical techniques can offer better queue performance and queue crowd analysis result. Cumulative approach is useful to analyze patients' in queue crowd and waiting times to receive services in both shifts at any working time t belter than transient queues techniques.

VI. Acknowledgements

The author would like to thank Kamil Kadir, Kadir Mamo, Muhammad Kawo, Lenco Samuel and Multezam Mohammed for their helpful comments and suggestions on the draft version of this paper. Responsibility for the contents of the paper, however, rests entirely with the author.

References Références Referencias

1. Adeleke. R. A, Ogunwale O. D, Halid O. Y (2009), Application of Queueing Theory to Waiting Time of Out-patients in Hospitals. *Pacific Journal of Science and Technology* Vol. 10(2) 270-274.
2. Bedane, Ibrahim. "Lean Principle Implementation In Service Organization With Focus on Ethiopian Health Care Facilities." *A Thesis Submitted to School of Graduate Studies of Addis Ababa University in Partial Fulfillment for Degree of Masters of Science in Industrial System*, 09 27, 2013.
3. Costa AX, Ridley SA, Shahani AK, Harper PR, De Senna V, Nielsen MS: Mathematical modelling and simulation for planning critical care capacity. Anaesthesia 2003; 58:320–7.
4. Gupta, Diwakar. "Queueing Models for Healthcare Operations." In *Handbook of Healthcare Operations Management: Methods and Applications, International Series in Operations Research & Management Science*, by B.T. Denton, 19-44. New York: Springer Science+Business Media, 2013.
5. Lade, Ishan P., V. P. Sakhare, M. S. Shelke, and P. B. Sawaitul. "Reduction of Waiting Time by Using Simulation & Queuing Analysi." *International Journal on Recent and Innovation Trends in Computing and Communication*, February 2015: 055– 059.
6. Najmuddin AF, Ibrahim IM, Ismail SR. A simulation approach: improving patient waiting time for multiphase patient flow of obstetrics and gynecology department (O&G Department) in local specialist centre. *WSEAS*. 2010;9(10):778–90.
7. S.Olorunsola, R.Adeleke, and O Ogunlade T. "Queueing Analysis of Patient Flow in Hospital." *IOSR Journal of Mathematics (IOSR-JM)*, 47-53: 2014.
8. Stanford DA, Taylor P, Ziedins I. Waiting time distributions in the accumulating priority queue. Queueing Systems. 2013:1–34.
9. Neuts MF (1981) Explicit steady-state solutions in stochastic models: An algorithmic approach.*the Johns Hopkins University Press,* Baltimore.
10. Worthington D.J (1987) queueing models for hospital waiting list. *the journal of the operational research Soci*ety Vol. 38, No 5, pp 413-422.

.

This page is intentionally left blank

Global Journal of Researches in Engineering: G
Industrial Engineering
Volume 17 Issue 1 Version1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

A Theoretical Study of the Influence of the Injection Velocity on the Heat and Fluid Flow in A Soaking-Pit Furnace when using Flameless Oxyfuel Heating

By Mersedeh Ghadamgahi, Patrik Ound, Nils.A.I Andresson & Par Jonsson
KTH Royal Institute of Technology

Abstract- Flameless oxyfuel combustion is one of the most recently developed combustion systems that has the potential to provide better combustion efficiency combined with a lower pollution production compared to conventional combustion systems. However, a lack of knowledge exists with respect to the influence of different parameters on the combustion results when using the flameless oxyfuel technology. Thus, in the current study a previously validated CFD model is used to investigate the effect of the injection velocity on the temperature distribution, recirculation ratio of the flue gases, flame volume, turbulence intensity, and flame radiation to the ingots. The results show that an increased injection velocity highly affects the temperature uniformity inside the chamber. More specifically, the maximum temperature difference in the flame region drops from 8.59% to 3.78% for burner capacities of 130 kW and 907 kW, respectively.

Keywords: *soaking PIT furnace, CFD, oxy-fuel combustion, flame, heat transfer.*

GJRE-G Classification: *FOR Code: 290502*

A Theoretical Study of the Influence of the Injection Velocity on the Heat and Fluid Flow in A Soaking-Pit Furnace when using Flameless Oxyfuel Heating

Mersedeh Ghadamgahi [α], Patrik Ound [σ], Nils.A.I Andresson [ρ] & Par Jonsson [ω]

Abstract- Flameless oxyfuel combustion is one of the most recently developed combustion systems that has the potential to provide better combustion efficiency combined with a lower pollution production compared to conventional combustion systems. However, a lack of knowledge exists with respect to the influence of different parameters on the combustion results when using the flameless oxyfuel technology. Thus, in the current study a previously validated CFD model is used to investigate the effect of the injection velocity on the temperature distribution, recirculation ratio of the flue gases, flame volume, turbulence intensity, and flame radiation to the ingots. The results show that an increased injection velocity highly affects the temperature uniformity inside the chamber. More specifically, the maximum temperature difference in the flame region drops from 8.59% to 3.78% for burner capacities of 130 kW and 907 kW, respectively. The results also show that as the burner capacity is increased from 130 kW to 906 kW i) the flame volume increases from 0.02 m^3 to 2.6 m^3, ii) the turbulence intensity increases from 1.8% to 16% and iii) the recirculation factor increases from 1.77 to 2.03.

Keywords: soaking PIT furnace, CFD, oxy-fuel combustion, flame, heat transfer.

I. Introduction

In the process of producing steel and billets from scrap iron, the soaking pit furnaces are used to preheat the cast ingots after the casting process to provide for optimum temperature conditions before the rolling process. The latter process provides the desired metallurgical properties in the final products, so the input conditions for the rolling process are important. Therefore, the operational condition of the soaking process such as the efficiency of the combustion, uniformity of temperature and heat transfer, flame shape and flue gas composition largely influences the total energy consumption and pollution generation.

One promising method to control the pollution and to increase the combustion efficiency is to replace the air by a pure oxygen gas as the oxidant. This method was investigated intensely by International Flame Research Foundation (IFRF), where they focused on different aspects such as the measuring equipment, combustion characterization, CFD development and validation (1).

Examples of studies on the subject include the study of Buhre et al. (2) in 2015 and the study by Kim, et al (3) in 2007. More specifically, Buhre et al. (2) studied the effect of employing the oxyfuel systems as a method for CO_2 sequestration (2). Furthermore, Kim, et al (3) investigated the effect of oxyfuel combustion with external flue gas recirculation systems on the NO emission, based on an experimental work. They also investigated the oxyfuel burner flame stability for different external recirculation rates (3).

Wall et al. (4) also studied the effect of the gas recirculation inside the flame region on combustion. They concluded that the gas recirculation controls the flame temperature and flow pattern of the flue gases (4). In another experimental study, Andersson et al. (5) compared the combustion chemistry in conventional air-fuel combustion with the oxyfuel burner combustion. They concluded that the oxyfuel combustion system produces up to 30% less NOx emissions in comparison to the identical air combustion system (5). In 2010, Toftegaard et al. (6) carried out a comprehensive literature study on the subject of oxyfuel combustion and claimed that a big lack of research existed in the area (6). Beside this study, many numerical investigations were also published to study oxyfuel combustion (7) (8) (9). Also, many studies were focused on validating suitable CFD models to use for simulating the complicated case of oxyfuel combustion. In 2010, Johansson et al. (7) studied the effect of different radiation models on combustion when using oxyfuel burners and they compared predicted and measured data. More specifically, they studied special radiative characterization of flue gases in oxyfuel combustion and concluded that the Weighted Sum of the Gray Gases Model (WSGGM) is the most relevant radiation model to use(7). In 2012, Hjärtstam et al. (8) also carried out work to validate radiation models used to simulate oxyfuel combustion. They concluded that the gray-gas model is not sufficiently accurate to be used for this purposes compared to the non-gray gases model (8). In 2013, an

Author α: KTH Royal Institute of Technology. e-mail: mersedeh@kth.se

investigation on a suitable combustion model was also enrolled by Galletti et al. (10). They reported that if it is necessary to consider a fast chemistry this will significantly reduce the accuracy in predicting the temperature when using oxyfuel combustion (10).

In general, many advantages are associated with using oxyfuel combustion compared to air-combustion. These include a higher productivity, a higher flame temperature and thermal efficiency, a better radiative characterization of the flue gases, lower exhaust gases volume, and improved flame stability (11).

As the industry has started to use this combustion system, some practical issues have also observed. Mainly the issues were concerning the high NOx production, in case of air leakage into the combustion chamber. This emphasized that the lack of convective effects and high local temperature leads to the production of thermal NOx in industrial applications. This issue is extensively described in the work by Fredriksson at al. (12). They studied the effect of air leakage on the total NOx formation and reported that the sharp temperature gradient in the flame area produces a large amount of NOx during the combustion. Buhre et al. (2) also investigated some issues associated with the use of oxyfuel combustion with respect to the heat transfer, flame stability and gaseous emissions (2). Since the formation rate of thermal NOx is an exponential function of the flame temperature and a square root function of the oxygen concentration, it can be extremely reduced by controlling the flame temperature or by diluting it (13).

Based on the above described drawbacks with the oxyfuel combustion technology, a modified burner design was introduced by IFRF, namely the flameless oxyfuel technology (14). In this combustion system, a high Internal Flue Gase Recirculation (IFGR) is forced to the system to produce a leaner combusting mixture. The idea is to produce a low concentration of reactant so that the combustion is not initiated before the mixing process is completed (15). After reaching the auto-ignition temperature within the mixture, reactions takes place in a diluted manner. The flame in such combustion systems is very spread as well as it is invisible to the naked eye. This type of combustion, which can be implemented in both air oxidation combustion and oxyfuel combustion, is called flameless combustion (16).

The special aspects in these type of furnaces are two folded; an asymmetric and especial design of the injection nozzles, and very high (near-sonic) injection velocity of fuel and the oxidant. These aspects lead to the formation of a volumetric flame configuration that - in case of correct adjustments- results in a uniform temperature distribution and a lower local temperature within the flame. In this manner the high radiative bulk of flue gases turn into a volumetric flame which is the source of radiation inside the chamber (14).

Even though the flameless combustion technology is very young, it is already widely used in many industrial applications. Examples of applications in the steel industry are: walking beam and catenary furnaces at Outokumpu in Avesta, soaking pit furnaces at Ascometal , Rotary heart furnaces at ArceloMetal in Shelby, and soaking pit furnaces at Ovako Sweden AB, in Hofors (12).

This implies the necessity of filling the gaps of knowledge about this modern combustion technology, since there are very few studies done on the subject. In 2006, Vesterberg et al. (17) studied 10 full scale reheating and annealing furnaces equipped with flameless oxyfuel burners. They concluded that the use of this technology had many advantages such as: a more uniform heat transfer, a shorter heating time and consequently lower energy consumption, an ultra-low NOx formation. In addition, Krishnamurthy at al. (15) compared different combustion systems including flameless oxyfuel and High Temperature Air Combustion (HiTAC) burners with respect to their thermal efficiency, in-flame temperature distribution, heat flux, gas composition and NOx emissions (15). They used a semi-industrial furnace equipped with flameless oxyfuel burners. These results were later used by Ghadamgahi et al. (18) to validate a CFD model for modeling flameless oxyfuel combustion in a soaking pit furnace equipped with flameless oxyfuel burner in Ovako Sweden AB.

In this study, the previously validated CFD model (18) is used to investigate the effect of the burner capacity on the temperature distribution profile, radiation profile and the overall operational conditions of the combustion system.

II. Mathematical Modeling

A 3-dimentional mathematical model was developed to simulate the combustion and turbulence by using Ansys Fluent 16.0. The equations were solved by considering the system to be in a steady state. It was also assumed that the flue gas mixture behaved like a perfect gas mixture. The following governing equations were solved:

Based on these assumptions, the following governing equations were solved:

Continuity equation:

$$\nabla.(\rho\, \mathbf{u}) = 0 \qquad (1)$$

Momentum equation:

$$\nabla\,.(\rho\, \mathbf{u}\, \mathbf{u}) = -\nabla p + \nabla.(\bar{\bar{\tau}}) + \rho \boldsymbol{g} \qquad (2)$$

Energy balance equation:

$$\rho c_p \mathbf{u}.\nabla T = \nabla.(k \nabla T) + S_h \qquad (3)$$

where $\mathbf{u}$ is the velocity vector (m/s), ρ is the density (kg/m3) and $\bar{\bar{\tau}}$ is the stress tensor. Furthermore, ρg and p are the gravitational body forces and the pressure (Pa), respectively. In addition, k represents the thermal conductivity (W/m·K), and c_p defines the heat capacity at a constant pressure (J/kg·K) [26]. Also S_h counts for any volumetric heat sources.

Regarding the incompressible behaviour of the flow, the Navier Stokes equation is solved, which can be written as follows:

$$(\mathbf{u}.\nabla)\mathbf{u} - \nu\nabla^2\mathbf{u} = -\nabla\omega + \boldsymbol{g} \tag{4}$$

where the parameter g represents the gravity and ω is thermodynamic work on the system. Furthermore, the parameter $\nu = \frac{\mu}{\rho}$ is the kinematic viscosity (18).

The flow was assumed to be fully turbulent, incompressible and the diffusion coefficients for all the gaseous products were assumed to be equal. Therefore, turbulence was modeled by using a Realizable k-ε turbulence model to solve the Navier-Stokes equations. This selection of the sub-model is extensively explained in the work by Ghadamgahi et al. (19). However, it can briefly be stated that in this model the kinetic energy (k) and the turbulent dissipation rate (ε) were solved as shown in equation 5 and equation 6:

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho k u_i)}{\partial x_i} = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\varepsilon \tag{5}$$

$$\frac{\partial(\rho\varepsilon)}{\partial t} + \frac{\partial(\rho\varepsilon u_j)}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\epsilon}\right)\frac{\partial\varepsilon}{\partial x_j}\right] + \rho\, C_1 S_\varepsilon - \rho C_2 \frac{\varepsilon^2}{k+\sqrt{\nu\varepsilon}}\,] + C_{1\varepsilon}\frac{\varepsilon}{k}C_{3\varepsilon}G_b \tag{6}$$

Where $C_1 = \max\left[0.43, \frac{\eta}{\eta+5}\right]$, $\eta = S\frac{k}{\varepsilon}$, $S = \sqrt{2S_{ij}S_{ij}}$ And σ_k = 1.0, σ_ε = *1.2*, C_2 = 1.9, $C_{1\varepsilon}$ = 1.44 and $C_{3\epsilon}$ is described by equation (7).

$$\boldsymbol{C_{3\epsilon}} = \mathbf{tanh}\left|\frac{v_\parallel}{u_\perp}\right| \tag{6}$$

The combustion was solved by using a SLFM to solve the PDF. The developed model also treats the combustion chemistry, departed from the chemical equilibrium, which is a necessary consideration in modeling flameless combustion systems **(19)**. In this mathematical solution, the thermochemistry parameters are a function of both the mixture fraction and the dissipation rate ($\boldsymbol{\chi}$), which are described in equations 7 and 8, respectively.

$$f = \frac{Z_i - Z_{i,ox}}{Z_{i,fuel} - Z_{i,ox}} \tag{7}$$

$$\chi = 2D|\nabla f\,|^2 \tag{8}$$

where D is the diffusion coefficient.

It is important to note that in this study the infiltration of air was assumed to be negligible and NO_x products were not considered.

The radiative Transfer Equation (RTE) was solved, using the DO model. In oxyfuel combustion systems the flue gas radiative properties are strongly promoted compared to conventional air-fuel combustions. It is also unsatisfactory for the predictions to consider the non-gray gas model (8). In this regards the WSGGM was also considered to count for the variation of the absorption coefficient of the flue gases. The accuracy of using his model in oxyfuel combustions has been investigated in many former studies (20) (21) (22) (23) (19). Also, the total emissivity over the distance $\vec{s}$ can be presented as follows (24):

$$\varepsilon = \sum_{i=0}^{I} a_{\epsilon,i}\,(T)(1 - e^{-k_i ps}) \tag{9}$$

where $a_{\epsilon,i}$ stands for the emissivity weighting factor for the *i*:th fictitious gray gas and the quantity in the bracket stands for the i^{th} fictitious gray gas emissivity. Furthermore, k_i is the absorption coefficient of the i^{th} gray gas, *p* is the summation of the partial pressure of all absorbing gases, and *s* is the path length (19).

III. Materials and Methods

a) *Soaking pit furnace*

The experimental work that has been done on a soaking pit furnace in Ovako Sweden AB, is extensively described in refernces *(18)* and *(25)*. These furnaces are used to provide preheating on the ingots in order to prepare them for the rolling process. The furnaces are made of four cells which have a rectangular shape with a total volume of 14.11 m^3 . Figure 1 shows the configuration of one cell including the ingots. Each cell accomodates 6 ingots that seat inside the chamber with the aid of automatic hooks. During the heating, the soaking time and soaking temperature are essencial parameters, that are set corresponding to the special type of the steel grade and the desired final steel properties *(18)*.

The soaking pit furnaces in Ovako Sweden AB, are all equipped with REBOX® flameless oxyfuel burners that uses pure oxygen as the oxidant and LPG No.95 as the fuel *(18)*. The injection velocity of the fuel and oxygen may easily be adjusted by the operators. The maximum burner capacity is 900 kW. However, in the soaking pit furnaces in Ovako, a lower amount (560 kW) is used to accomplish a flamelss oxyfuel combustion. This burner is mounted on the frontal wall of the chamber, where both the controlling thermocouple and the exhaust channel are located. The controlling thermocouple is located 400 mm below the center of the burner and it continuously monitors the temperature *(18)*.

The quality of operational conditions of the furnace has a major effect on the soaking cost and quality. Especifically factors such as the temperature and heat transfer uniformity inside the chamber, the level of pollution production, and combustion efficiency determines the overal state of the furnace effectiveness. The refractory walls are made of 230 mm AK60 A, 115 mm Porosil and Skamolex 1100 in 450 and 200 mm at the transverse and longitudinal walls, respectively.

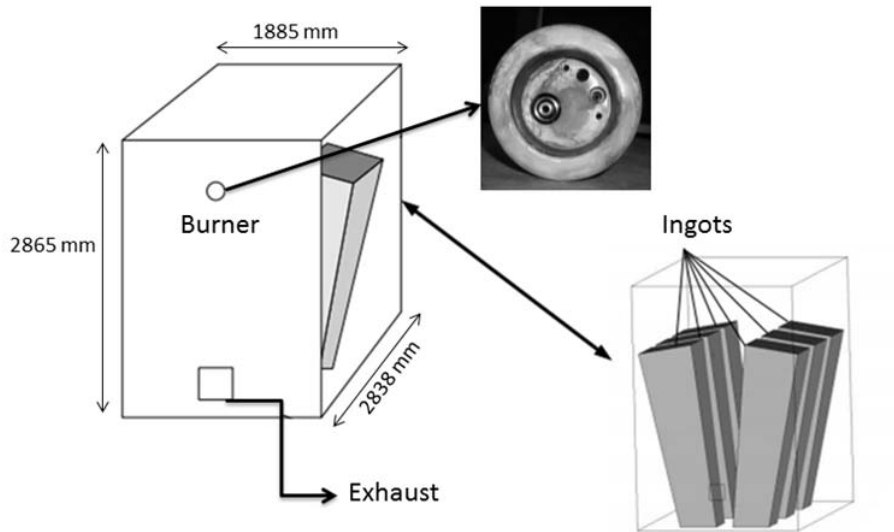


Figure 1: Soaking pit furnace configuration and arrangement of ingots inside the furnace (18)

b) Experimental Work

The experimental work which has been done in Ovako Sweden AB, is explained in detail in the work by Ghadamgahi et al. *(18)*. For the experimental result used in th ecurrent study the local temperature of the flue gases was measured by using shielded S-type thermocouples. In addition, the locations of the sampling was carefully selected to provide a comprehensive view of the temperature profile inside the chamber. Overall, eight thermocouples were inserted to the furnace from the top side. These were divided in two different groups that were located at two different levels inside the chamber. These levels are called the High and Low levels, which are located at the heights of 2016 mm and 1065 mm, respectively. The exact position of the probes are given in Table 2 and the configuration is illustrated in figure 2 *(18)*.

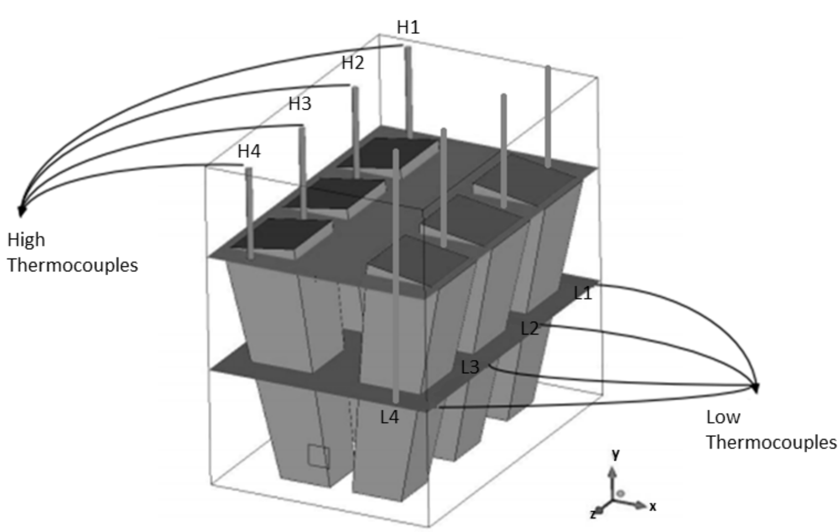


Figure 2: Rrangement of thermocouples in the soaking pit furnace (18)

Table 2: Coordinates of the S-types thermocouples inside the soaking pit furnace (18)

Thermocouple	Ref.	Low1	High1	Low2	High2	Low3	High3	Low4	High4
X (mm)	910	1487	514	1487	514	1487	514	1487	514
Y (mm)	1105	1065	2065	1065	2065	1065	2065	1065	2065
Z(mm)	0	2631	2631	1810	1810	987	987	246	246

c) *Geometry and mesh*

ICEM 13 was used to draw the geometry of the furnace as well as the mesh structure. Note, that the configuration of the ingots inside the chamber is simplified in this scheme compared to the original arrangement. More specifically, the ingots were assumed to be standing up in the chamber and therefore the effect of leaning them towards the walls was neglected. This helps to decrease the number of nodes from 980000 to 850000, which consequently reduces the computational costs *(25)*.

A study on the grid independancy of the mesh was also done *(18)* by observing the results of the simulation from two mesh configurations, namely tetragonal mesh and hexagonal mesh. The unstructured tetrahedron mesh with a combination of the O-rings (Figure 3) for the inlet area was reported to be the best choice, regarding both the time required for a converged solution and an acceptable prediction accuracy *(25)*. Also, the minimum orthogonal quality was 0.84, which is adequate according to the previously presented results *(18) (19)*.

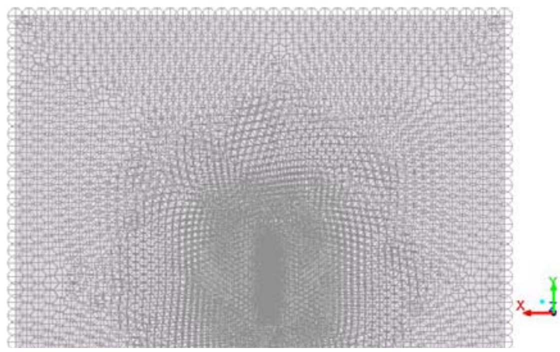


Figure 3: Unstructured mesh and O-rings located at the frontal face

d) *Boundary conditions*

The boundary conditions for the reference case at the inlets are shown in Table 1. These data are taken from the operational conditions of the furnace at the plant. They were used in the simulations made by Ghadamgahi et al. **(18)** in order to validate sub-models for simulating the flameless oxyfuel burner at Ovako Sweden AB.

Table 1: Inlet boundary conditions for the reference model. (18)

Parameter	Propane	Oxygen
Mass Flow (kg/s)	0.013	0.06
Inlet temperature (°C)	22	25
Hydraulic Diameter (mm)	7	5
Turbulent Intensity (%)	5	6

In order to study the role of the burner capacity on the combustion, six cases with different inlet boundary conditions were simulated. The burner capacity in these cases gradually increased from 130 kW in case 1 to 907 kW in case 6. Also, the mass rate for fuel and oxygen was calculated according to the corresponding burner capacity by assuming a constant lambda value for all the cases. These data are shown in Table 2.

Table 2: Inlet boundary condition for the different cases in this study

Case Number	Inlet Fuel Rate (Kg/s)	Inlet Oxygen Rate (Kg/s)	λ	Burner Capacity(KW)
CASE 1	0.002	0.0074	1.02	130
CASE 2	0.005	0.0185	1.02	259
CASE 3	0.008	0.0296	1.02	389
CASE 4	0.011	0.0407	1.02	518

CASE 2	0.005	0.0185	1.02	259
CASE 3	0.008	0.0296	1.02	389
CASE 4	0.011	0.0407	1.02	518
CASE 5	0.016	0.0592	1.02	777
CASE 6	0.019	0.0703	1.02	907

It is important to note that the mentioned inlet boundary conditions are used to demonstrate that the flameless oxyfuel mode, which is applied after the chamber, reaches the self-ignition temperature.

In the simulation, fuel and oxygen are not preheated and therefore they enter the chamber at 22°C and 25°C, respectively. Also, the refractories are defined as heat sinks with constant heat fluxes. These magnitudes are computed regarding the material of the .

Table 3: Heat flux boundary condition parameters for the exterior walls (18)

Layer	Bottom	Longitudinal wall	Transversal wall	Lid
Heat loss (W/m²)	530	450	500	650

The ingots are also considered as heat sinks, with a separate constant heat flux for each ingot. The procedure of calculating these magnitudes is extensively explained in the work by Ghadamgahi et al. (18). In this study, the total heat flux on each ingot was predicted by assuming a fixed temperature for each of the ingots during the entire heating period. The final magnitudes for all the ingots are shown in Table 4 (18). The ingots' marking is illustrated in Figure 4.

Table 4: Wall boundary conditions for the ingots. (18)

Ingot	Heat flux (kW/m²)
Ingot 1 (Front-right)	56.7
Ingot 2 (Middle-right)	43.7
Ingot 3 (Rear-right)	61.0
Ingot 4 (Front-left)	45.2
Ingot 5 (Middle-left)	48.4
Ingot 6 (Rear-left)	65.1

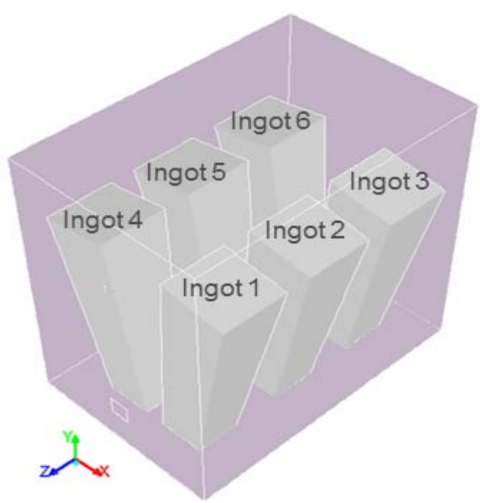


Figure 4: The marking of the ingots located in the soaking-pit furnace cell

IV. Results and Discussions

a) Validation

In this section, the results of simulation and experiments done by Ghadamgahi et al. *(18)* are used to show that the sub-models used in this study have been previously validated. The maximum deviation between the predicted results and experimental results, for all the thermocouples (High and Low) are shown in Table 5. The experimental work was done at the plant in Ovako Sweden AB, using a real-size soaking pit furnace *(18)*.

Table 5: Maximum deviation between the CFD predictions and experimental data (18)

Thermocouple positions	Experimental Temperature (°C)	Predicted Temperature (°C)	% Deviation
High 1	1366	1230	9.95 %
High 2	1264	1220	3.48 %
High 3	1236	1119	3.47 %
High 4	1239	1193	3.71 %
Low 1	1320	1195	9.46%
Low 2	1277	1173	8.14%
Low 3	1225	1155	5.71%
Low 4	1206	1176	2.48

As shown in the table 5, the deviations between the predicted and measured temperatures varied between 3.47% and 9.95 %, which is considered to be fairly small for this type of furnace. Thus, the authors feel comfortable that the model can be used to make reliable predictions of temperatures in soaking pit furnaces.

b) *Temperature Distribution And IFGR*

An increase of the burner capacity when using flameless oxyfuel burner combustion highly affects the temperature distribution, flame shape and the flame temperature. Figure 5 shows the results for predicted temperature at the centerline of the furnace for all the studied cases. The line of representation starts from the burner face on the frontal side and ends at a position of 2000 mm from the back-wall.

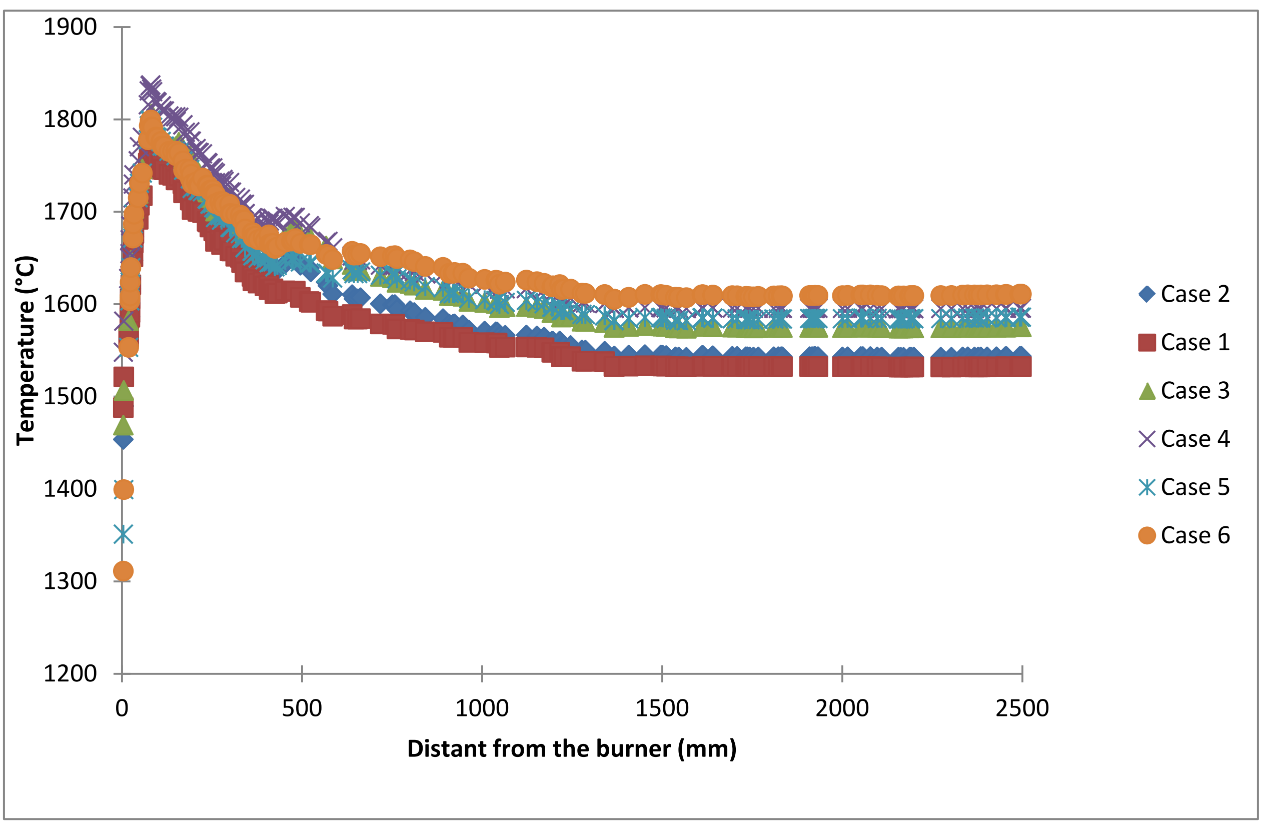


Figure 5: Local temperature in the flame region shown at a distance starting from the burner and ending on the back-wall

A very rapid increment for temperature is seen in regions very close to the burner side, which stands for the formation of the reaction zone for all the cases. This is followed by a rapid decrement for the temperature values at a distance of 500mm from the burner.

The maximum temperature in the flame region is highly dependent on the injection velocity. More specifically, this temperature is increasing while moving from case 1 with 130 kW to case 4 with 518 kW (1785 °C to 1820 °C). Afterwards, this temperature is decreasing from case 4 with 518 kW (1820 °C) to case 5 with 717 kW (1812 °C) and case 6 with 907 kW (1799 °C). Also, the maximum difference (between the peak and chamber temperature) for cases1, 2 and 3 are 255°C, 242 °C and 235°C, respectively. This magnitude for cases 5 and 6 is seen to be 172 °C and 149 °C, which is considerably smaller compared to the other cases. Figure 6 shows the magnitudes of these values with respect to the percentage of the temperature deviation at the centerline.

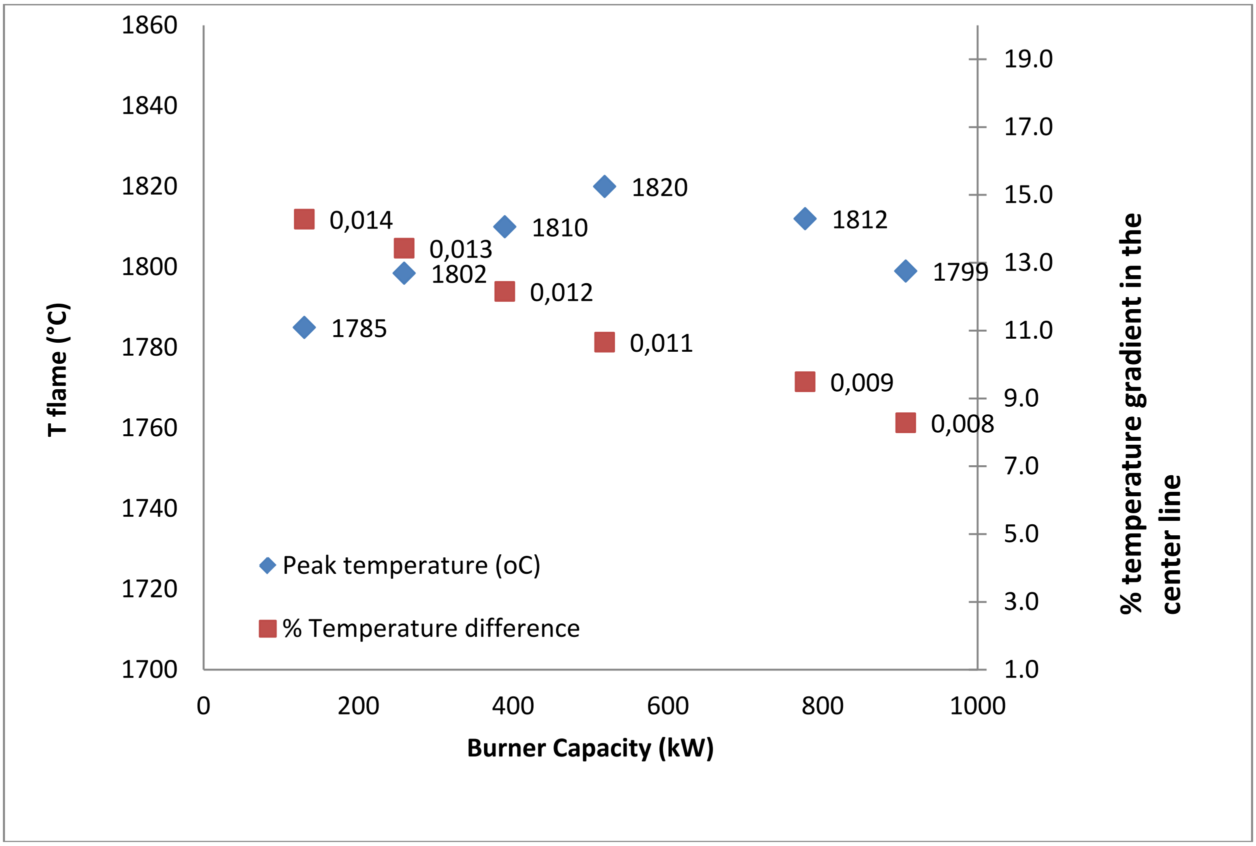


Figure 6: Predicted flame temperature (right axis) and the percentage of predicted temperature difference (left axis) at the centerline of the furnace

This figure indicates that the temperature uniformity is improved by increasing the inlet velocities of oxygen and fuel, as the temperature difference on the centerline decreases from 13% for case 2 to 8 % for case 6. This velocity increase leads to formation of a leaner reacting mixture and lower concentration of O_2 with a colder but more uniform flame. These results also show the effect of higher velocity on reducing the flame temperature in cases 5 and 6, which is in good agreement with the work done by Milani et al (26). Also in 2016, Ghadamgahi et al. (25) reported results on the influence of the lambda value on the operational conditions in form of increasing the inlet oxygen mass rate. More specifically, they looked into the effect of increasing inlet velocities on the temperature distribution and consequently the exhaust losses. They also reported that although an increased oxygen velocity leads to a larger exhaust loss by 9.2%, it improves the temperature uniformity by 28%.

In order to further study the relevance between a total increase of the burner capacity and flame characterization, Figure 7 Shows the temperature distribution profile for the selected cases of 1, 2, 5 and 6 at a middle plane on a z-y axis.

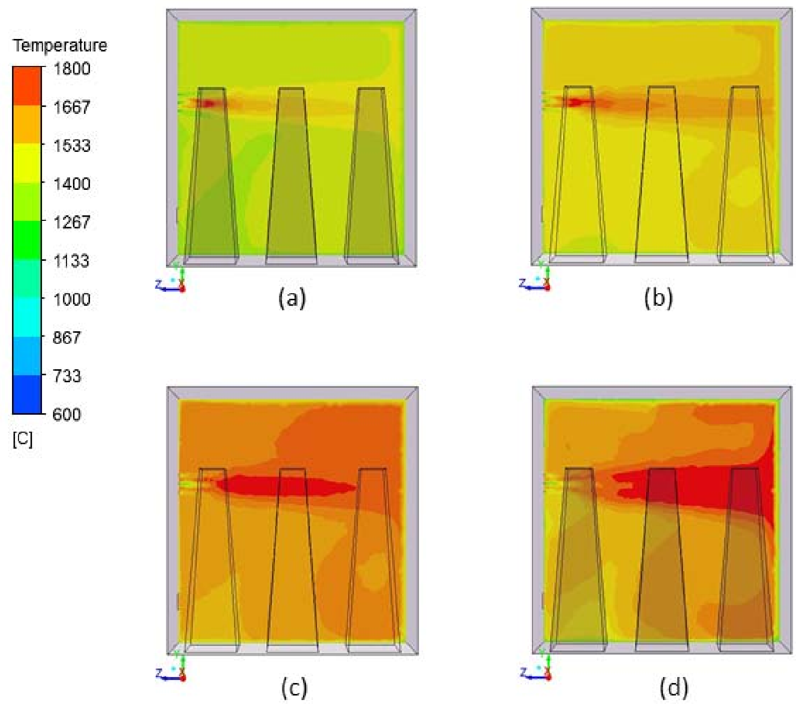


Figure 7: Temperature distribution profile for the following cases: (a) Case 1, (b) Case 3,(c) Case 5 and (d) Case 6 on a plane located in the middle of the z-y axis

As it is shown in Figure 7, an increase of the injection velocities leads to the formation of a more turbulent mixing flow and a better recirculation of gases inside the chamber. In Case 3, especially in areas with fluid impinging effect, a wider range of temperature spectrum (temperature difference of 422°C) on this z-y plane is seen . Although a less temperature difference exists in case 6 (384°C), due to formation of large eddies and turbulence intensity. Figure 8 shows the predicted values of the turbulence intensity (%) for all the cases, in the length of the chamber.

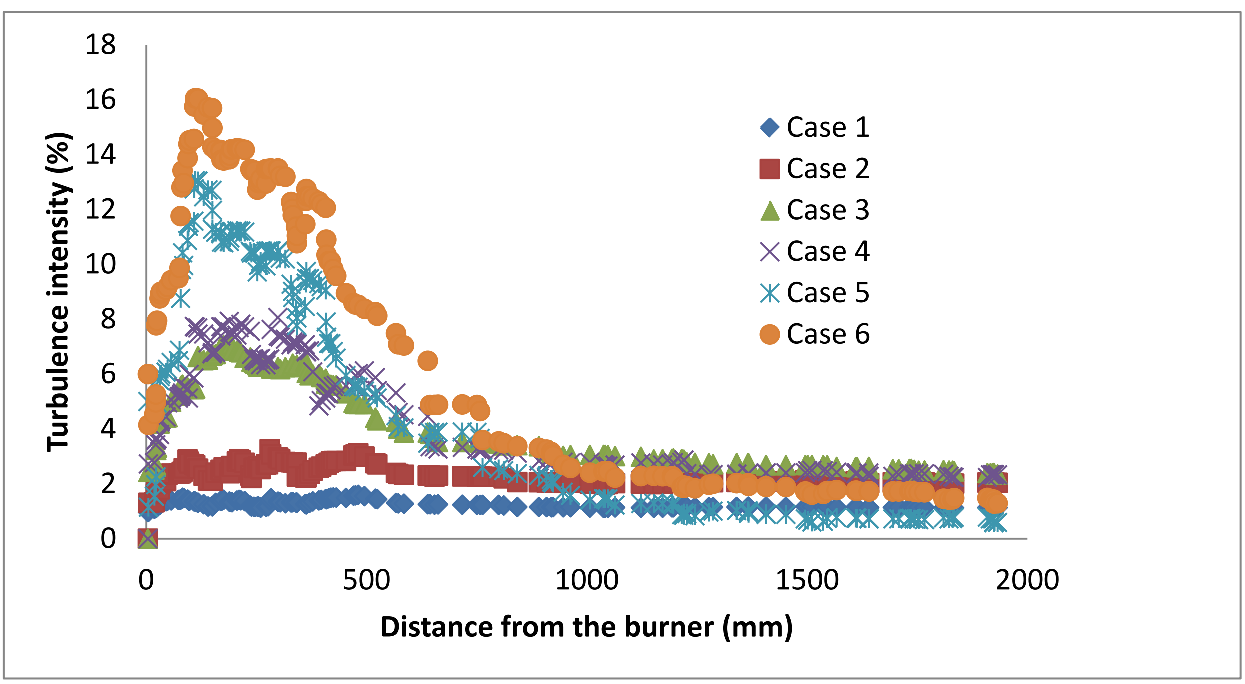


Figure 8: The turbulent intensity of the flow on an axial line for cases 1 to 6

As shown in Figure 8, turbulence intensity dramatically increases with an increased injection velocity, in the flame region (50-400 mm away from the burner). This effect, which is in line with the predicted results for temperature, shows the effect of turbulence in making a more uniform temperature distribution. Additionally, Figure 9 shows the temperature profile on an x-z plane in the middle of the furnace. A higher degree of volumetric flame is expected to form by going from case 1 to 6 (increasing injection velocities), according to the results in this figure. However, the flame impinging effect on the rear wall suppresses this effect due to the chamber configuration. In the previous studies brought in sections 5 and 6 (supplements 2 and 3) the effect of a flame impingement on the temperature distribution was argued. Although this effect is neglected in this study, as Figure 8 reports the turbulence far away from the impinging side.

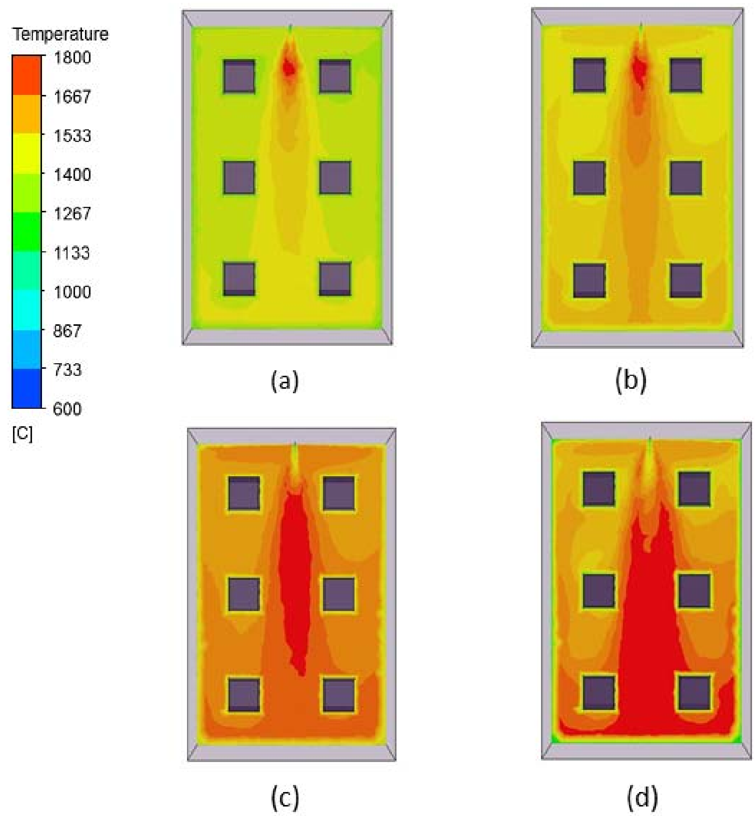


Figure 7: Temperature distribution profile for the following cases: (a).case 1,(b).case 3,(c).Case 5 and (d).Case 6 on a plane located in the middle of the x-z axis

In a flameless oxyfuel combustion, the chemical reactions happens with departure from chemical equilibrium, since the gas mixture of the reactants is leaned with recirculated flue gases. This is due to that the IFGR inside the chamber in the neighborhood of the flame region is increased (26). In this regard one of the most important factors for determining the flameless behavior of the combustion is the value of the recycle ratio of the combusting gases. This value was introduced by Hasegawa et al. (27) as:

$$k_v = \frac{M_e}{M_a + M_f} \quad (10)$$

where $M_e$is the internal exhaust gases flow rate that is recirculated into the mixing reactants before a reaction takes place. Furthermore, $M_a$is the combustion oxygen flow rate, and M_f is the fuel flow rate. Combustion is conventionally stable for $k_v < 0.3$, although for $k_v > 0.3$ temperature of the furnace determines the stability of the flame (3). Higher recirculation of the flue gases threatens the flame stability and can even result in a flame lift-up and a blow-out case of a chamber temperature lower than the self-ignition temperature (29). Therefore, using a stable combustion with a high IFGR value is only beneficial in case of a sufficiently high temperature in the chamber (reactants temperature > ~ 700 °C). This, on the other hand, stresses the necessity of defining a gradual combustion process in order to avoid to operate the burner in the flameless mode in a cold chamber.

c) Flame shape and total radiation on the ingots

Heat transfer inside the industrial furnaces is mainly carried out by two heat transfer methods, namely radiation and convection. Naturally the most effective parameters that influence the heat transfer ratio are the: i) flame temperature, ii) flame shape and emissivity, iii) ingots' initial temperature and emissivity, and iv) the temperature and emissivity of the walls. Oxygen content in the oxidizer plays an essential role in the final radiative fluxes from the flue gases, since it attains the final radiative properties of the flue gases. More specifically, by using oxygen as the oxidant instead of air a significant increment in the total flue gas emissivity is obtained. It also causes a significant decrement in the total flue gas volume, compare to air-fuel combustion systems. Another special aspect of using flameless oxyfuel flames is the formation of a widespread flame shape with a lower peak temperature, as shown in Figure 8. This figure is taken from the work by Blasiak et al. (31) . This ideally turns the flame into a large radiation source that has a uniform temperature, which highly influences the uniformity of the heat transfer.

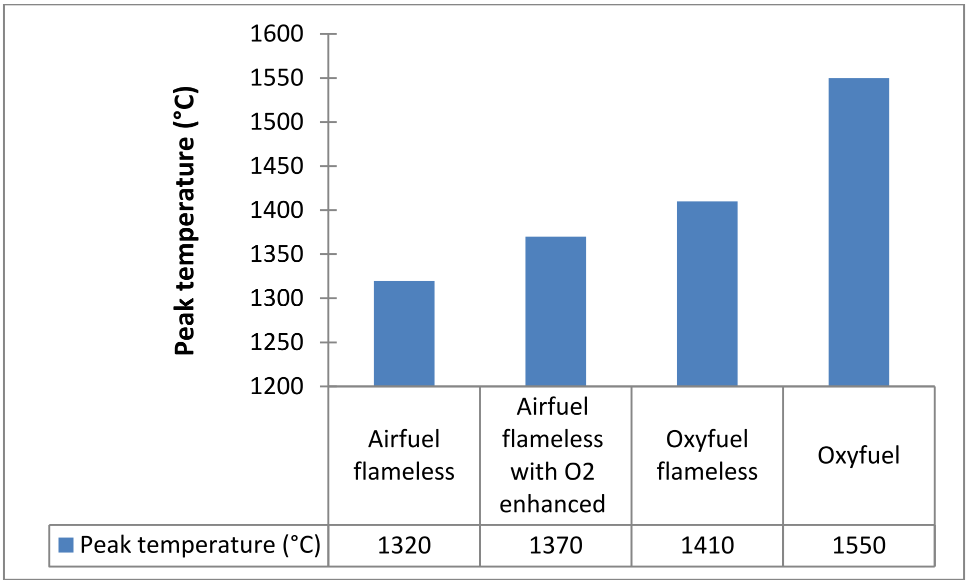


Figure 8: The peak temperature inside the flame region, for different burner configurations (31)

In 2007, Krishnamurthy et al. (13) developed a theoretical model that simply illustrates the radiation inside the industrial furnaces. This model is illustrated in Figure 9 and demonstrates the heat transfer exchange between the flame, the ingots and the furnace walls (15).

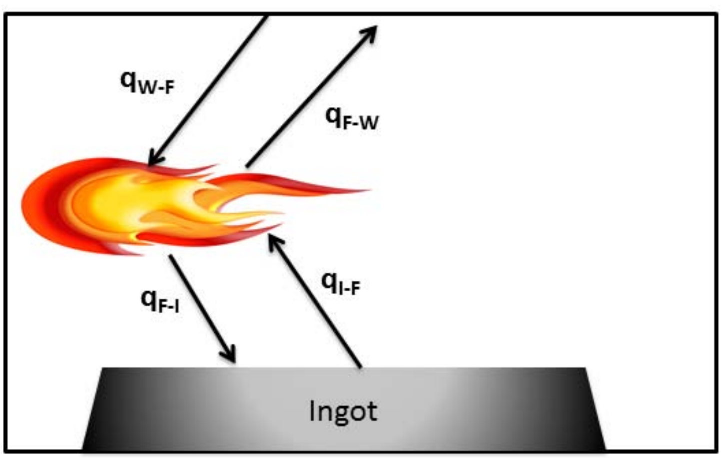


Figure 9: Radiation heat transfer inside a furnace

Overall, in flameless oxyfuel combustion flame has a lower temperature, but a more volumetric shape. These factors change the behavior of heat exchange between the flame and the ingots inside the chamber. Since the flame is the main radiation source, the heat is transferred to the slabs directly from the flame and indirectly from the walls. Thereby a net heat flux from the flame to ingots can be obtained from the following correlation (31):

$$q_{net} = q_{F-I} - q_{I-F} = \frac{A\sigma(T_F^4 - T_I^4) + B\sigma(T_W^4 - T_I^4)}{C} \qquad (16)$$

where

$A = \varepsilon_I \varepsilon_F (2 - \varepsilon_F - \varepsilon_W + \varepsilon_W \varepsilon_F)$
$B = \varepsilon_I \varepsilon_W (1 - \varepsilon_F)$
$C = 1 - (1 - \varepsilon_F)^2 (1 - \varepsilon_W)(1 - \varepsilon_I)$

The subscripts F, I and W correspond to the flame, ingots and refractory wall respectively. Furthermore, T_w is the furnace wall temperature (K), T_F is the flame temperature (K), and T_I is the ingots' temperature (K). Finally, ε_W, ε_I and ε_F are the emissivity values of the walls, ingots and flame respectively. The parameter σ is the Stefan–Boltzmann constant. With the assumption of ε_F, ε_W and ε_I to be 0.25, 0.8 and 0.85, respectively, and assuming the flame having a cylindrical shape, the total heat transferred from the flame to the ingots (kW) can be described as follows (31):

$$Q_{net} = \left[\frac{A\sigma(T_F^4 - T_I^4) + B\sigma(T_W^4 - T_I^4)}{C}\right]\frac{4V_F}{d_F} \qquad (19)$$

where V_F d_F and l_F stand for the flame volume, flame diameter and flame length, respectively. This equation illustrates the importance of the role of the wall temperature and flame temperature on the incident radiation on the ingots' surfaces. As if the combustion happens in a fameless manner, with a low and well-spread volume, the radiation is more uniform on the ingots. On the other hand, a high peak temperature in the flame area has an opposite effect. It can also be understood that having a flame impinging effect on a refractory wall and formation of a thick thermal boundary layer, makes that area a compacted radiative source that jeopardizes the radiation uniformity (32).

In order to investigate this effect, we consider the entire flame as a volumetric source of radiation to the surroundings. Thus, the radiated energy from the flame can be expressed as follows:

$$Q_{rad} \approx \alpha_F V_F \sigma T_F^4 \qquad (20)$$

where α_F is the Planck mean absorption coefficient for an optically thin flame. This simplification leads us to the introduction of a known term *"D"*, based on the study done by Turns in 1996 (32). *D* is defined as the ratio of the radiant heat transfer rate from the flame to the surroundings (Q_{rad}) to the total heat released by the flame (Q_0), and it can be written as follows:

$$D = \frac{Q_{rad}}{Q_0} \approx \frac{\alpha_F V_F \sigma T_F^4}{Q_0} \qquad (21)$$

This can lead us to the following function for the flame volume:

$$V_F \approx \frac{D Q_0}{\alpha_F \sigma T_F^4} \qquad (22)$$

Figure 15 shows the relevance between the flame volume, Q_{rad} and D , for all the studied cases.

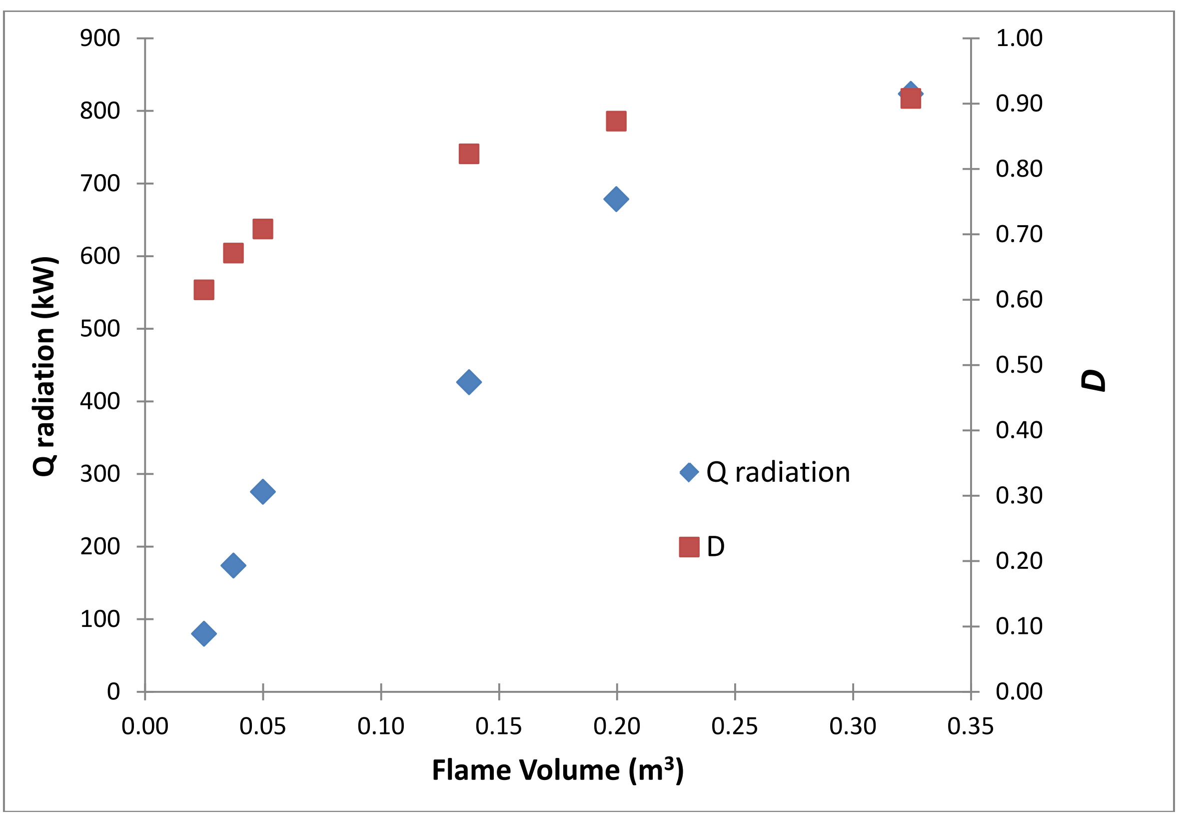


Figure 15: The ratio of the radiant heat transfer rate from the flame to the surroundings and total radiation flux (kW) as a function of the flame volume (m^3)

This figure demonstrates the effect of flame volume on total radiation, meaning an increased flame volume increases the total radiation from the flame. It is also seen that the increase in the ratio between the radiative heat transfer and total released heat from the flame loses its significance after a radiation value of 700 kW. This calculation is done by assuming a 100% combustion efficiency.

In a general view, with the increase of flame volume, temperature drops, but total radiation heat flux increases (31). In 2007, Blasiak et al. (31) carried out the same calculations with the focus on studying the effect of gas emissivity and flame volume on the total heat transfer. They concluded that when the gas temperature distribution inside the furnace chamber (well stirred reactor) is uniform, the effect of the flame emissivity becomes smaller than the effect of the flame volume (31).

V. Conclusions

The aim in the current study was to simulate flameless oxyfuel combustion using a previously validated CFD model. More specifically, the focus was to investigate the effect of the injection velocity on the temperature distribution, flame temperature, flame volume, turbulence intensity, and flame radiation to the ingots. Based on the results of this study, the following main conclusions may be drawn:

- An increase of the injection velocity highly affects the flame temperature and temperature uniformity inside the chamber as the maximum temperature difference in the flame region drops from 14% to 8% for burner capacities of 130 kW and 907 kW, respectively.
- The formation of a more uniform temperature profile when using a higher burner capacity of 907 kW instead of a 130 kW capacity is due to the formation of a more volumetric flame. This, in turn, leads to the formation of a more turbulent flow and increased recirculation ratio of the flue gases in the reacting zone.
- An increased burner capacity from 130 kW to 906 kW leads to an increase of the flame volume from 0.02 m^3 to 2.6 m^3, an increase of the turbulence intensity from 1.8% to 16%.
- With an increase of flame volume from case 1 to case 6, temperature drops, but total radiation heat flux increases.
- The radiation from the flame to the ingots increases from 79.9 kW to 823.5 kW and the Q_{net}/Q_0 ratio increases from 0.36 to 0.85 with an increased burner capacity from 130 kW to 906 kW.

Bibliography

1. *Analysis of theexperimental data collected during the oxyflam-1 andoxyflam-2 experiments* IFRF DocNo. F85/y/4
2. *Oxy-fuel combustion technology for coal-fired power generation* 4Progress in Energy and Combustion Science
3. *NO reduction in 0.03–0.2 MW oxy-fuel combustor using flue gas recirculation technology* Proceedings of the Combustion Institute
4. *Oxy-fuel (O2/CO2, O2/RFG)* the 30th international technical conference on coal tilization &fuel systems2005
5. *NO Emission during Oxy-Fuel Combustion of Lignite* Industrial and Engineering Chemistry research
6. *Oxy-fuel combustion of solid fuels* Progress in Energy and Combustion Science
7. *Models for gaseous radiative heat transfer applied to oxy-fuel conditions in boilers* 1-3International Journal of Heat and Mass Transfer
8. *Computational Fluid Dynamics Modeling of Oxy-Fuel Flames: The Role of Soot and Gas Radiation* 5energy and fuels
9. *Experimental and numerical investigations on a swirl oxy-coal flame* Applied Thermal Engineering
10. *Numerical investigation of oxy-natural-gas combustion in a semi-industrial furnace: Validation of CFD sub-models* Fuel
11. *Oxygen-Enhanced Combustion*CRC Press1998
12. *Application of oxyfuel combustion in reheating at Ovako,Hofors works, Sweden – Background, solutions and results* Linde AGA2006
13. *Flameless oxyfuel combustion: technology* La Revue de Métallurgie-CIT
14. *Flameless oxyfuel combustion for increased production and reduced CO2 and NOx emissions*Stahl und eisen 1282008
15. *Studies on low-intensity oxy-fuel burner* Proceedings of the combustion Institute
16. *Mild Combustion* 4Progress in Energy and Combustion Science
17. *Flameless oxyfuel for highly visible results* Cleveland,AISTech 20062006
18. *Numerical and Experimental study on flameless oxy-fuel combustion in a pilot-scale and a real-size industrial furnace* Submitted to : Appiled thermal engineering
19. *A Comparative CFD Study On Simulating Flameless Oxy-fuel Combustion In A Pilot-scale Furnace* StockholmJournal of Combustion6735971
20. *Numerical Simulation of Properties of a LPG Flame with High-Temperature Air* Thermal Sciences
21. *Chemistry and radiation in oxy-fuel combustion: A computational fluid* fuel
22. *Experimental and numerical investigations on a swirl oxycoal flame* Applied Thermal Engineering

Global Journal of Researches in Engineering (G) Volume XVII Issue I Version I Year 2017

23. *Design Optimization of Flameless-oxyfuel Soaking Pit Furnace Using CFD Technique* Energy Procedia
24. *Radiative Heat Transfer*Academic Press2013ISBN: 978-0-12-386944-9
25. *Numerical study on the effect of lambda value on temperature distribution and efficiency of a flameless oxyfuel combustion system* Submitted to "Energies"
26. *Laseroptical investigation of highly preheated combustion with strong exhaust gas recirculation* Proceedings of combustion institute
27. *Combustion with High Temperature Low Oxygen Air in Regenerative Burner* Osaka, JapanAsia-Pacific Conference on Combustion1997
28. *The Role of Exhaust Gas Recirculation in flameless combustion* Applied mechanics and materials
29. *Mild combustion in a laboratory-scale apparatus* Combustion Science and Technology
30. *Flameless oxidation to reduce thermal NO-formation* Prog. Energy Combust. Sci
31. *Flameless oxyfuel combustion for fuel consumption and nitrogen oxides emissions reductions and productivity increase* Energy institutes
32. *An Introduction to Combustion: Concepts and Applications*New York : McGraw-Hill1996
33. *Nongray-Gas Effects in Modeling of Large-Scale Oxy–Fuel Combustion Processes* 6Enertgy and fuels
34. *Numerical Simulation of Properties of a LPG Flame with High-Temperature Air* 10International Journal of Thermal Sciences
35. *Design Optimization of Flameless-oxyfuel Soaking Pit Furnace Using CFD Technique* Energy Procedia
36. *Analysis of the experimental data collected during the OXYFLAME-3 Staged and Premixed Flames* IFRF DOCD 85/y/5
37. *Emission control of nitrogen oxides in the oxy-fuel process* 5Progress in Energy and Combustion Science
38. *Oxy-fuel combustion of solid fuels* 5Progress in Energy and Combustion Science
39. *New Weighted Sum of Gray Gases Model Applicable to Computational Fluid Dynamics (CFD) Modeling of Oxy−Fuel Combustion: Derivation, Validation, and Implementation* 12energy and fuels
40. *Accuracy evaluation of the gray gas radiation model in CFD simulation* Case Studies in Thermal Engineering
41. *Evaluation of solution methods for radiative heat transfer in gaseous oxy-fuel combustion environments* 14Journal of Quantitative Spectroscopy and Radiative Transfer
42. *Numerical Simulation of Combustion Characteristics in High Temperature Air Combustion Furnace* 2Journal of Iron and Steel Research, International
43. *Application of oxyfuel combustion in reheating at Ovako,Hofors works, Sweden – Background, solutions and results*Linde AGA2006
44. *Flameless oxyfuel combustion: technology,* La Revue de Métallurgie-CIT2006
45. *Oxygen-Enhanced Combustion, Second Edition*2013ISBN 9781439862285 - CAT# K12887
46. *Experimental and Numerical Study of Flameless Combustion in a Model Gas Turbine Combustor* 2Combustion Science and Technology
47. *Flameless oxidation to reduce thermal NO-formation* Prog. Energy Combust. Sci
48. *What is Flameless Combustion?*IFRF Online Combustion Handbook2002ISSN 1607-9116

Global Journal of Researches in Engineering: G
Industrial Engineering
Volume 17 Issue 1 Version1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Linearization of Power Amplifier using the Modified Feed Forward Method

By Mohammad Reza Motavalli & Klaus Solbach
University of Qom

Abstract- A modified circuit for improving linearization of power amplifier based on the model of the Feed Forward circuit amplifier is proposed. With the help of mathematical model for the single power amplifier, the circuit is simulated and a demonstrator is fabricated and measured. complex Taylor series are used for modeling the power amplifier by the approximation of the amplitude transfer function and the leveldependence of the transmission-phase of the power amplifier. This can be understood as a simplified form of Volterra series. In our proof of concept experiment, we verified the concept but also found that the adjustment of the circuit is critically dependent on the drive conditions and linearization is achieved only for a narrow range of drive power. The proposed circuit in compared with the conventional Feed Forward amplifier in addition a significant increase in efficiency, to minimize the power of the distortion signal 3IMDproducts at high drive levels.

Keywords: volterra series, complex taylor series, 3IMD-products, pre-distortion, feed forward amplifier, power combiner.

GJRE-G Classification: FOR Code: 290501

LINEARIZATIONOFPOWERAMPLIFIERUSINGTHEMODIFIEDFEEDFORWARDMETHOD

Linearization of Power Amplifier using the Modified Feed Forward Method

Mohammad Reza Motavalli [α] & Klaus Solbach [σ]

Abstract- A modified circuit for improving linearization of power amplifier based on the model of the Feed Forward circuit amplifier is proposed. With the help of mathematical model for the single power amplifier, the circuit is simulated and a demonstrator is fabricated and measured. complex Taylor series are used for modeling the power amplifier by the approximation of the amplitude transfer function and the level-dependence of the transmission-phase of the power amplifier. This can be understood as a simplified form of Volterra series. In our proof of concept experiment, we verified the concept but also found that the adjustment of the circuit is critically dependent on the drive conditions and linearization is achieved only for a narrow range of drive power. The proposed circuit in compared with the conventional Feed Forward amplifier in addition a significant increase in efficiency, to minimize the power of the distortion signal 3IMD-products at high drive levels.

Keywords: volterra series, complex taylor series, 3IMD-products, pre-distortion, feed forward amplifier, power combiner.

I. Introduction

The use of high power amplifiers with high linearity for mobile and satellite communications systems is essential. For example, in second and third generation mobile systems, GSM (Global System Mobile), 3GPP (third Generation Partnership Project), a large number of signals with different frequencies are transmitted from BS (Base Station) by high power amplifiers at the same time [1]. To avoid interference of these amplified signals, the amplifier must operate linear and that linearization is not possible by classical methods. Since the amplitude of intermodulation signals at the output of the amplifiers depends on the size of the input signals, input signals with large amplitude limit the performance of the amplifier. If the connection between an amplifier input and output signals display as transformation function that is extended in the form of a series (for example Taylor's series), we see that for the larger signal, the role of higher degrees of expression is more and more important, that is, the behavior of amplifiers is no longer linear and amplifier operates in saturation (non-linear) region. The saturation region, due to high output power and resulting high efficiency in mobile communications and satellite systems play an important role. Intermodulation signals with large amplitudes produce in this region of amplifier which leads to large distortion in output. Generally, nonlinearity in an amplifier can appear in two different forms: first production of new frequency components in the output of the amplifier and second dependence of gain amplitude and phase of the amplifiers to amplitude of input signals. If amplifiers have been multiple input signals frequency a type of distortion signals, that is, 3IMD-products (third order Intermodulation Distortion) should be considered more than other produced signals in output of amplifier, because they are near to frequency of original signals (input signals). They are in the range of useful bandwidth amplifiers and due to limitations in fabrication are not removable in practice [2].

The distortion signal of type 3IMD-products in base stations are propagated by high power amplifier in total send bandwidth and cause distortion and interference in band of inside channel as well as the neighboring channels. This problem occurs even on TV channels (by 3IMD-products and even 2IMD-products), where a large number of channels have placed at a close frequency near each other. The aim of this paper is to design a concept for a power amplifier with high linearity and high efficiency.

This paper presented the proposed circuit for improving linearization of the power amplifier based on the model of the Feed Forward circuit amplifier. In section 2, the principle of operation of the amplifier concept is discussed. A mathematical model of new amplifier concept is proposed in section 3. In section 4, a simulation model is used to investigate in detail the signals within the circuit and the performance and limitations of the amplifier. Finally in section 5, experimental proof of new amplifier concept is presented. Simulation and measurement results are compared and show good agreement.

II. New Amplifier Design

The classical parallel power combiner amplifier using two equal linear amplifiers have been used for many years in order to efficiently produce higher output power levels (doubles the available output power of one single amplifier) and also in order to improve the reliability and availability of the amplifier system component. However, linearity of amplification of each

Auhtor α: Department of Communication Technique, Faculty of Engineering, University of Qom, Qom, Iran.
e-mail: motavalliReza@gmail.com
Auhtor σ: Department of Microwave And Rf-Technology, Faculty of Engineering, University of Duisburg-Essen, 47057 Duisburg, Germany.
e-mail: hft@uni-due.de

individual amplifier is not improved over the individual amplifiers. Power-added efficiency of the combiner amplifier circuit can be high when the amplifiers are driven close to the saturation level and consequently at high intermodulation level. Another successful concept in linearization of power amplifiers is pre-distortion, which can yield higher power efficiency, yet at lower cancellation ratios of unwanted products [3-6]. On the other hand, amplifiers for very high linearity requirements in mobile communications successfully employ the feed forward (FF) – amplifier scheme, Fig.1, which cancels the nonlinear intermodulation-products (IM) of a high power primary amplifier by superposition of signals from an auxiliary amplifier [7-11]. However, this concept suffers from a degradation of the efficiency of the amplifier which is mainly due to the linearity requirements on the auxiliary amplifier. The FF-amplifier entails a first loop to extract the intermodulation distortion components from the power amplifier output while the second loop inverts phase and amplifies this signal in an auxiliary amplifier such that it destructively superimposes and cancels the original intermodulation signal at the output coupler. Distortions from the auxiliary amplifier have to be kept very low so that this amplifier needs to be operated far off saturation which means high dc power requirement. Since the auxiliary amplifier cannot contribute to the fundamental signal output power, its supply power degrades the power-added efficiency of the FF-amplifier [12-13] and also since the auxiliary amplifier is driven at low input power (low amplitude), a good ratio of cancelling of the 3IMD-products signals for small amplitude obtained, in other words, cancelling of the 3IMD-products signals for high output power is extremely low.

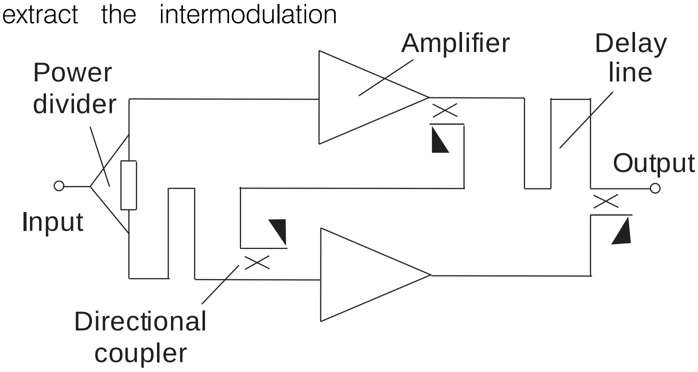


Fig. 1: Conventional feed forward amplifier

While the FF-amplifier has found wide application in communication systems due to its superior intermodulation suppression, its efficiency problem has inspired a modified concept which allows the auxiliary amplifier to contribute fundamental signal power in addition to cancelling the intermodulation products. The new circuit, Fig.2, exhibits a two-loop topology of a conventional feed forward amplifier, however, both loops are modified and the two amplifiers are assumed to be identical power amplifiers. In the first loop, the input power divider splits the input signal in a 1:3 ratio while at the output, the combiner is 1:1. The first loop acts as a pre-distortion stage while the second is a distortion cancelling and power combining loop.

For the presentation of the circuit's operation principle, we assume that the fundamental input voltage signal of the circuit is $s_{in}(t)$. When the first power splitter divides this signal at a ratio of 1 to 3, the input signal to the upper power amplifier A is $s(t) = \frac{1}{\sqrt{10}} \cdot s_{in}(t)$ while the signal incident to the lower power amplifier B is $3 \cdot s(t)$. The two amplifiers are assumed to be identical with equal amplification υ and distortion products $s'(\mathrm{t})$ and $s''(t)$ for power amplifier A and B, respectively, under identical drive conditions.

The output voltage of power amplifier A is a superposition of the fundamental signal amplified by voltage gain υ and a distortion product: $\upsilon \cdot \mathrm{s(t)} + \mathrm{s'(t)}$. The upper coupler samples this combined signal and feeds it to the lower coupler in front of amplifier B. Assuming both coupling coefficients as jk (note: complex notation used to indicate a phase shift of 90°), the sampled signal offered to the input of amplifier B is $k^2 \cdot \upsilon \cdot s(\mathrm{t}) - k^2 \cdot s'(\mathrm{t})$, which is combined with the input signal $3 \cdot s(t)$ after its travel through the lower delay line to give the total voltage signal, $(3 - k^2 \cdot \upsilon) \cdot s(t) - k^2 \cdot s'(t)$.

(Note, the coupler and delay line insertion loss have been neglected for simplification and time delay of the both power amplifiers is compensated by two delay line in two-loop)

With our aim to drive the lower amplifier at the same fundamental signal level as the upper amplifier, we choose $k^2 = \frac{2}{\upsilon}$ to achieve the total voltage signal $s(t) - \frac{2}{\upsilon} \cdot s'(t)$.

It is seen that this lower amplifier input signal is a pre-distorted version of the input signal of the upper amplifier, with the distortion component as a replica of the upper amplifier distortion, but reversed in phase. Assuming the distortion component to be much smaller than the fundamental component, the lower amplifier will amplify the fundamental signal plus its distortion component by the voltage amplification υ. In addition, in the same way as the upper amplifier, the lower amplifier will produce a distortion component due to its fundamental signal excitation. The resulting output signal of amplifier B is then $\upsilon \cdot s(t) - 2 \cdot s'(t) + s''(t)$. Assuming perfectly equal amplifiers A and B, the distortion signal originating from the lower amplifier is equal to the one generated by the upper amplifier, such that the output signal of the amplifier B is $\upsilon \cdot s(t) - s'(t)$.

In the upper signal path, the output signal of the power amplifier A travels through an upper delay line by neglecting the delay line's attenuation, appears at the combiner as: $\upsilon \cdot s(t) + s'(t)$. By comparing signals in the upper and lower path, we see that the fundamental signals are equal and thus can be combined to give double power while the distortion components incident to the combiner are equal and in anti-phase and thus cancel to give the total output power: $\frac{2}{\sqrt{2}} \cdot \upsilon \cdot s(t)$.

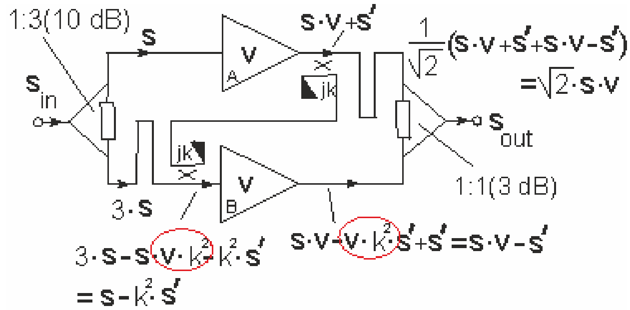


Fig. 2: Concept of the new amplifier circuit with signals indicate

It has to be noted that this analysis is over-simplified with the assumption of perfect identity of the two amplifiers and it neglects the effect of the increased driving level of the lower amplifier due to the added pre-distortion signal. With slightly unequal amplifiers and slightly unequal driving levels, it is still possible to achieve near-perfect cancellation of intermodulation at the price of a loss in the power combining efficiency, as can be shown by simulation, section 4. However, a major performance limitation of the new circuit was found by analysis of an experimental amplifier system in section 5, to originate in the drive power level dependence of the amplifier voltage gain (magnitude and phase) and the insertion loss of the delay lines.

III. Mathematical Model

a) *Characterization of single power amplifiers*

To describe the behavior of the entire circuit mathematically, each power amplifier should be first characterized separately, it means that each power amplifier should be represented as a mathematical model; all other components can be described by simple mathematical models, since their behavior can be assumed to be linear in the region of interest.

For nonlinear behavior of power amplifier, the power transfer function has been measured, in the other words, the behavior of each amplifier is measured regarding 1 dB compression point and intermodulation products of orders 3, 5, 7 and 9 (3IMD-products, 5IMD-products، 7IMD-products and 9IMD-products) separately. To develop the mathematical description of this behavior, Amplifier output voltage to the input voltage is expanded in a series. At first, Taylor series is used, that due to stark non-linearity, model obtained was not fit to actual behavior of amplifiers. Next the volterra series is used that relation other series is more flexible and for describtion nonlinearity systems is more appropriate [14-16]. The measurements of the characteristics of the power transfer function has been done with two tone input signal. In the calculations performed, it has been demonstrated that if both ampltudes input signals are equal (such as common case in GSM), volterra series becomes Taylor series with complex coefficients [17]. Since for creating mathematical model of an amplifier with complex coefficient, complex measurements must be available, therefore, measurements of complex voltage gain in close saturation region is used.

For creating mathematical model, two sinusoidal voltage signal with equal amplitudes $\hat{u}_{in}$ and Frequencies $f_1(\omega_1)$ and $f_2(\omega_2)$ are expended in Taylor series. The generated signals include main input frequencies and all new frequencies in output of amplifier can be summarized in a general form as follows [17]:

$$u_{out}(t) = \sum_{m=0}^{\frac{(N-1)}{2}} \left\{ \sum_{n=m}^{\frac{N-1}{2}} \binom{2n+1}{n} \binom{2n+1}{n-m} \frac{\hat{u}_{in}^{2n+1}}{2^{2n}} c_{2n+1} \cos\left(\left((m+1)\omega_1 - m\omega_2\right)t\right) \right\} + \sum_{m=0}^{\frac{N-1}{2}} \left\{ \sum_{n=m}^{\frac{N-1}{2}} \binom{2n+1}{n} \binom{2n+1}{n-m} \frac{\hat{u}_{in}^{2n+1}}{2^{2n}} c_{2n+1} \cos\left(\left((m+1)\omega_2 - m\omega_1\right)t\right) \right\} \quad (3.1.1)$$

With

- N as maximum Taylor series degree
- n as variable index
- m as degree of the generated intermodulation signals
- c_n as taylor series coefficients

The share of the original signal (or main frequency) and IDM-products various degrees (3 to 9) as follows:

$$\hat{u}_{out,F}=\sum_{n=0}^{\frac{N-1}{2}}\binom{2n+1}{n}\binom{2n+1}{n}\frac{\hat{u}_{in}^{2n+1}}{2^{2n}}c_{2n+1} \qquad (3.1.2)$$

$$\hat{u}_{out,3IMD}=\sum_{n=1}^{\frac{N-1}{2}}\binom{2n+1}{n}\binom{2n+1}{n-1}\frac{\hat{u}_{in}^{2n+1}}{2^{2n}}c_{2n+1} \qquad (3.1.3)$$

$$\hat{u}_{out,5IMD}=\sum_{n=2}^{\frac{N-1}{2}}\binom{2n+1}{n}\binom{2n+1}{n-2}\frac{\hat{u}_{in}^{2n+1}}{2^{2n}}c_{2n+1} \qquad (3.1.4)$$

$$\hat{u}_{out,7IMD}=\sum_{n=3}^{\frac{N-1}{2}}\binom{2n+1}{n}\binom{2n+1}{n-3}\frac{\hat{u}_{in}^{2n+1}}{2^{2n}}c_{2n+1} \qquad (3.1.5)$$

$$\hat{u}_{out\,9IMD}=\sum_{n=4}^{\frac{N-1}{2}}\binom{2n+1}{n}\binom{2n+1}{n-4}\frac{\hat{u}_{in}^{2n+1}}{2^{2n}}c_{2n+1} \qquad (3.1.6)$$

To determine the coefficients series, linear equation system of considered signals using the measured values are written. The equation system for main signals (3.1.2), which is formed of the number M_1 ,the corresponding measured values $\hat{u}_{in}$ and $\hat{u}_{out}$, can be summarized as follows (Since the measured values on the left side (3.1.2) is real, the absolute terms of right side is used):

$$\begin{pmatrix}\hat{u}_{out,F,1}\\ \hat{u}_{out,F,2}\\ \vdots\\ \hat{u}_{out,F,M_1}\end{pmatrix}=\left|\begin{pmatrix}\hat{u}_{in,1} & \frac{9}{4}\hat{u}_{in,1}^{3} & \cdots & \binom{N}{\frac{N-1}{2}}^{2}\frac{\hat{u}_{in,1}^{N}}{2^{N-1}}\\ \hat{u}_{in,2} & \frac{9}{4}\hat{u}_{in,2}^{3} & \cdots & \binom{N}{\frac{N-1}{2}}^{2}\frac{\hat{u}_{in,2}^{N}}{2^{N-1}}\\ \vdots & & \ddots & \vdots\\ \hat{u}_{in,M_1} & \frac{9}{4}\hat{u}_{in,M_1}^{3} & \cdots & \binom{N}{\frac{N-1}{2}}^{2}\frac{\hat{u}_{in,M_1}^{N}}{2^{N-1}}\end{pmatrix}\begin{pmatrix}c_1e^{j\varphi_{c_1}}\\ c_3e^{j\varphi_{c_2}}\\ \vdots\\ c_Ne^{j\varphi_{c_N}}\end{pmatrix}\right| \qquad (3.1.7)$$

The equation system for the 3IMD-products signals is too similar to the manner as the main signals equation and the basis of (3.1.3) for the M_2 measured values can be summarized as follows:

$$\begin{pmatrix}\hat{u}_{out,3IMD,1}\\ \hat{u}_{out,3IMD,2}\\ \vdots\\ \hat{u}_{out,3IMD,M_2}\end{pmatrix}=\left|\begin{pmatrix}\frac{3}{4}\hat{u}_{in,1}^{3} & \frac{50}{16}\hat{u}_{in,1}^{5} & \cdots & \binom{N}{\frac{N-1}{2}}\binom{N}{\frac{N-3}{2}}\frac{\hat{u}_{in,1}^{N}}{2^{N-1}}\\ \frac{3}{4}\hat{u}_{in,2}^{3} & \frac{50}{16}\hat{u}_{in,2}^{5} & \cdots & \binom{N}{\frac{N-1}{2}}\binom{N}{\frac{N-3}{2}}\frac{\hat{u}_{in,2}^{N}}{2^{N-1}}\\ & \vdots & \ddots & \vdots\\ \frac{3}{4}\hat{u}_{in,M_1}^{3} & \frac{50}{16}\hat{u}_{in,M_2}^{5} & \cdots & \binom{N}{\frac{N-1}{2}}\binom{N}{\frac{N-3}{2}}\frac{\hat{u}_{in,M_2}^{N}}{2^{N-1}}\end{pmatrix}\begin{pmatrix}c_1e^{j\varphi_{c_1}}\\ c_3e^{j\varphi_{c_2}}\\ \vdots\\ c_Ne^{j\varphi_{c_N}}\end{pmatrix}\right| \qquad (3.1.8)$$

The equation system of the intermodulation signals higher order are obtained same manner.

To write equations system related to the gain amplifier, the output voltage signal according to the input voltage with amplitude $\hat{u}_{in}$ and Frequency $f_1(\omega_1)$ is expended in Taylor series. In main frequency, output voltage can be summarized as follows:

$$\underline{\hat{u}}_{out,G}=c_1\hat{u}_{in}+\frac{3}{4}c_3\hat{u}_{in}^{3}+\frac{10}{16}c_5\hat{u}_{in}^{5}+\cdots+\binom{N}{\frac{N-1}{2}}\frac{\hat{u}_{in}^{N}}{2^{N-1}}c_N \qquad (3.1.9)$$

The linear equation system of the gain amplfier for the M_3 measured values as follows:

$$\begin{pmatrix}\underline{v}_1\\ \underline{v}_2\\ \vdots\\ \underline{v}_{M_6}\end{pmatrix}=\begin{pmatrix}1 & \frac{3}{4}\hat{u}_{in,1}^{2} & \cdots & \binom{N}{\frac{N-1}{2}}\frac{\hat{u}_{in,1}^{N-1}}{2^{N-1}}\\ 1 & \frac{3}{4}\hat{u}_{in,2}^{2} & \cdots & \binom{N}{\frac{N-1}{2}}\frac{\hat{u}_{in,2}^{N-1}}{2^{N-1}}\\ & \vdots & \ddots & \vdots\\ 1 & \frac{3}{4}\hat{u}_{in,M_8}^{2} & \cdots & \binom{N}{\frac{N-1}{2}}\frac{\hat{u}_{in,M_8}^{N-1}}{2^{N-1}}\end{pmatrix}\begin{pmatrix}\underline{C}_1\\ \underline{C}_3\\ \vdots\\ \underline{C}_N\end{pmatrix} \qquad (3.1.10$$

Now magnitude and phase gain of amplifier ($\varphi_{S_{21}}=\angle\underline{\upsilon}$,$|\underline{\upsilon}|=|\underline{S_{21}}|$) should be regarded as real values separately. Since Taylor coefficients should satisfy all equations system, the individual linear equation system should be solved simultaneously, that is, the following linear equations system for $\mathrm{M_1}$, $\mathrm{M_2}$, $\mathrm{M_3}$, $\mathrm{M_4}$, $\mathrm{M_5}$, $\mathrm{M_6}$ measurd values should be considered together:

$[U_{out,F}]_{M_1\times 1} = \left|[D_{in,F}]_{M_1\times N} \times [\underline{C}_N]_{N\times 1}\right|$
$[U_{out,3IMD}]_{M_2\times 1} = \left|[D_{in,3IMD}]_{M_2\times N} \times [\underline{C}_N]_{N\times 1}\right|$
$[U_{out,5IMD}]_{M_3\times 1} = \left|[D_{in,5IMD}]_{M_3\times N} \times [\underline{C}_N]_{N\times 1}\right|$
$[U_{out,7IMD}]_{M_4\times 1} = \left|[D_{in,7IMD}]_{M_4\times N} \times [\underline{C}_N]_{N\times 1}\right|$
$[U_{out,9IMD}]_{M_5\times 1} = \left|[D_{in,9IMD}]_{M_5\times N} \times [\underline{C}_N]_{N\times 1}\right|$
$\left|[\underline{v}_{out,G}]_{M_6\times 1}\right| = \left|[D_{in,G}]_{M_6\times N} \times [\underline{C}_N]_{N\times 1}\right|$
$[\varphi_{\upsilon_{out,G}}]_{M_6\times 1} = \angle\{[D_{in,G}]_{M_6\times N} \times [\underline{C}_N]_{N\times 1}\}$

With

$U_{out,F}$, $U_{out,3IMD}$, ⋯ as output voltag for main signals, 3IDM-products, ⋯ in (3.1.2), (3.1.3), ⋯

$D_{in,F}$, $D_{in,3IMD}$, ⋯ , as main matrix in (3.1.2), (3.1.3), ⋯

$D_{in,G}$ as main matrix in (3.1.10) and

$$\left|[\underline{v}_{out,G}]_{M_6\times 1}\right| = \begin{pmatrix} |\underline{v}_1| \\ |\underline{v}_2| \\ \vdots \\ |\underline{v}_{M_6}| \end{pmatrix}, \quad [\varphi_{\upsilon_{out,G}}]_{M_6\times 1} = \begin{pmatrix} \varphi_{\underline{v}_1} \\ \varphi_{\underline{v}_2} \\ \vdots \\ \varphi_{\underline{v}_{M_6}} \end{pmatrix}, \quad [\underline{C}_N]_{N\times 1} = \begin{pmatrix} \underline{C}_1 \\ \underline{C}_3 \\ \vdots \\ \underline{C}_N \end{pmatrix} = \begin{pmatrix} c_1 e^{j\varphi_{c_1}} \\ c_3 e^{j\varphi_{c_2}} \\ \vdots \\ c_N e^{j\varphi_{c_N}} \end{pmatrix}$$

The number of measurements M_1, M_2 etc. is not the same but has been selected depending on the available number of measurement points (length of the curve).

b) Optimization

To determine the complex coefficients, the transfer characteristics of the amplifier such as a model in the form of the mathematical approximation are presented; in other words using determine coefficients model, the difference between the model and measurements are minimized. To do this, the numerical optimization techniques are used. For optimization, the complex least square method is an appropriate technique, in which the model coefficients are determined through setting zero of the partial derivatives [18] that is:

$$e = \sum_{i=1}^{n} g_i\left(\left|y_m(\underline{C})\right| - y_i\right)^2 \qquad (3.2.1)$$

And for phase relationship

$$e = \sum_{i=1}^{n} g_i\left(\angle y_m(\underline{C}) - \varphi_i\right)^2 \qquad (3.2.2)$$

With

e as error function,
y_i as measured output value
y_m as model (desired) output value
φ_i as measured output value for phase gain
g_i as weighting function
n as the measured value and
$\underline{C}$ as model parameters that must be found

It is natural that all discussed equations system must be considered in error function. For this reason, cost function (CF) as a function of the total error and the sum of all the dividual functions (functions error) are included andformed. For 6 output signals, we have:

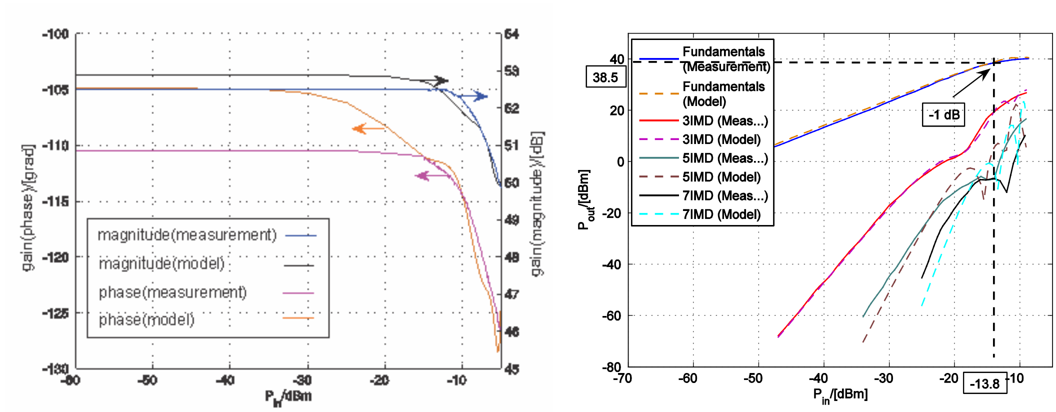
$$e_{Sum} = e_1 + e_2 + e_3 + e_4 + e_5 + e_6 = \sum_{i=1}^{n} g_i\left(\left|y_{1m}(\underline{C})\right| - y_{1i}\right)^2 + \cdots + \sum_{i=1}^{n} g_i\left(\left|y_{6m}(\underline{C})\right| - y_{6i}\right)^2 \qquad (3.2.3)$$

Our research show that it is not possible to determine all the coefficients of the model with the same lowest error, especially the higher order ID-products can always be modeled worse [17]. Because of that, the weighting function (g_1, g_2, ⋯) is added in the cost function, the weighting factors for each output signal also be used so that be able to output signal or output signals with changes of this weights as requires to be optimized. So (3.2.3) is written in a new form as follows:

$$e_{Sum} = G_1 \times e_1 + G_2 \times e_2 + G_3 \times e_3 + G_4 \times e_4 + G_5 \times e_5 + G_6 \times e_6 \qquad (3.2.4)$$

The accuracy of the model depends on the series degree (n). A better accuracy can be achieved in principle by increasing of this value. However, it is difficult to enhance the performance for $n > 13$.

For the numerical solution of the optimization problem, the function "minsearch" to find the minimum of the cost function in MATLAB has been used. Examples of the measured results and of the model results can be seen in Fig. 3(a), where the voltage gain magnitude and phase of amplifier A is plotted as a function of input power level for single-tone excitation, and in Fig. 3(b), where the two-tone fundamental signal level and the intermodulation product levels are plotted versus input power level.



(a) (b)

Fig. 3: Measured and modeled transfer characteristics of amplifier A: (a) Single-and two-tone gain, (b) two-tone fundamental and intermodulation products of orders 3, 5, and 7

Fig.3 shows some deviations between model and measurements in the fundamental signal levels as well as in the intermodulation products; note that in the optimization of the model coefficients the largest weights were used for the fundamental and third-order intermodulation products.

Fig. 3(a) shows a good match for the magnitude and phase of the amplifier. Error obtained for the phase just a few degrees and for the magnitude is less than 0.5 dB. Fig. 3(b) shows the divergence of the model when the two-tone input power goes beyond the highest input power level that was used as measurement data in the calculation of the Taylor series coefficients ($-13.8\ dB$). Less dramatic but notable is the characteristic behavior below the divergence region: Deviations appear as slight oscillations with increasing amplitude closer to the divergence limit.

Using the mathematical model, it was possible to calculate the phase variation of the fundamental output signals for two-tone excitation, Fig.4, which was not accessible when measuring with a spectrum analyzer. Again, a slight oscillatory deviation is included in the calculated variation of the phase versus input power since a smooth parabolic-shaped variation should be expected. The observed oscillatory model errors, though not large on an average over the total extent of the modeled amplifier characteristics, will be found as major sources of error in the simulation of the new circuit, section 4.

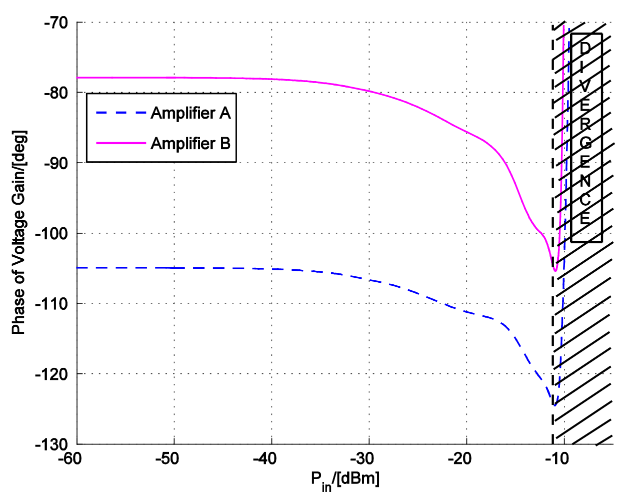


Fig. 4: Simulated phase variation of two-tone fundamental signals at amplifiers A and Bas a function of input power level

IV. Simulation of the New Concept

In order to understand the interdependencies in the intermodulation cancellation of the new circuit, the experimental circuit was simulated using the Taylor-series models for the two individual amplifiers and using scattering matrix models for the other components in the circuit (perfect match for all components assumed. Due to the high volume of the output signals of the amplifier A and B, discrete numerical methods (with help DFT - Discrete Fourier Transform) of the entire circuit in has been simulated in MATLAB which is more flexible than other software. Other simulation programs like ADS[1] have been shown restrictions to model [17].

One obvious deviation of the real circuit from the simplified concept of section 2 is the considerable insertion loss (1.6 dB) of the two delay lines: With reference to the principle of operation and designations of signals and test points given in section II, in the first loop, this insertion loss attenuates the input signal before the sampled signal from amplifier A gets subtracted, which requires a reduction of the amplitude of the sampled signal ($k^2 < \frac{2}{v}$) in order to achieve equal fundamental signal amplitudes at the input of both amplifiers. Also this reduces the amplitude of the sampled distortion signal $s'(t)$ from amplifier A that fed into amplifier B and the resulting distortion signal at the output of amplifier B will been reduced accordingly.

On the upper signal path, the upper delay line attenuates the fundamental and distortion signals in the same way before they appear at the combiner. After the above-described adjustment of the first loop coupling from amplifier A to amplifier B, the signals at the input of amplifier B can be compared to the input signals of amplifier A. Fig. 5 presents the envelope peak voltages of the fundamental tones, of the third-order intermodulation products and of the total signal, normalized to the envelope peak voltage of the fundamental two-tone signal at the input of amplifier A. It is seen that the fundamental tones have been adjusted to be equal in magnitude at both amplifiers for the "null" input power level of +3 dBm. At this input power level, the intermodulation products contribute already more than 10% of envelope voltage to the total input voltage of amplifier B, which presents a serious deviation from the assumption made in section II that the drive conditions of both amplifiers are basically equal.

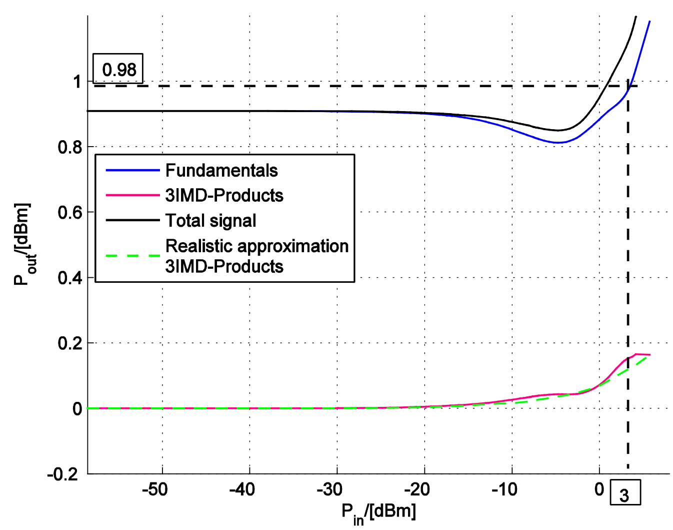


Fig.5: Envelope peak voltage of the fundamental tones, the third-order intermodulation products and the total voltage at the input of amplifier B, all normalized to the input voltage of amplifier A

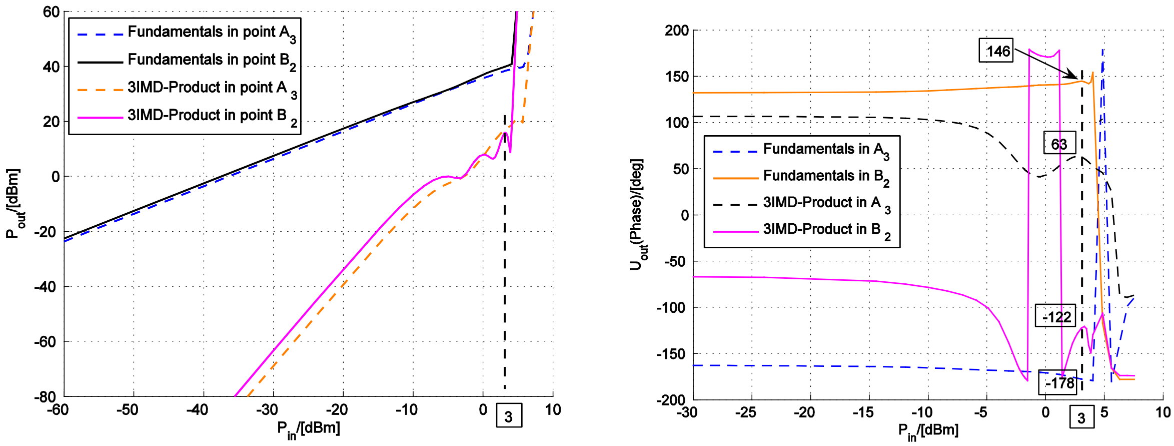
Looking at lower drive levels, we find for the intermodulation products that the variation of voltage with drive power level exhibits an oscillatory error component as described in section 3; a more realistic indication of this variation is also given in the figure. The second notable effect is that the normalized fundamental signal voltage at amplifier B decays with reduced drive level. The reason becomes clear by inspecting Fig.3(a) and Fig.4: With reducing input power level the voltage gain of amplifier A increases and the insertion phase changes;

thus, at the input of amplifier B, an increased signal sample from amplifier A is subtracted from the original input signal and creates a smaller fundamental signal component; the minimum around the drive level of -5 dBm is found to be due to the particular constellation of the amplification amplitude and phase variation with drive level.

Looking at the output side of both amplifiers, Fig. 6 shows the amplitudes and phases of the fundamental and distortion signals at the power combiner: At the +3 dBm"null" drive level; we find the fundamental signal from amplifier B larger than that of amplifier A, which is due to the attenuation of upper delay line. At the same time, the two signals exhibit a considerable phase difference of 36° which in combination with the amplitude imbalance affects a combiner loss of about 0.5 dB; note that the power-added efficiency of the combiner circuit is further

[1]Advance Design System

reduced by about 0.8 dB due to the dissipation loss of 1.6 dB from upper delay line affecting half the generated power of the power combiner.



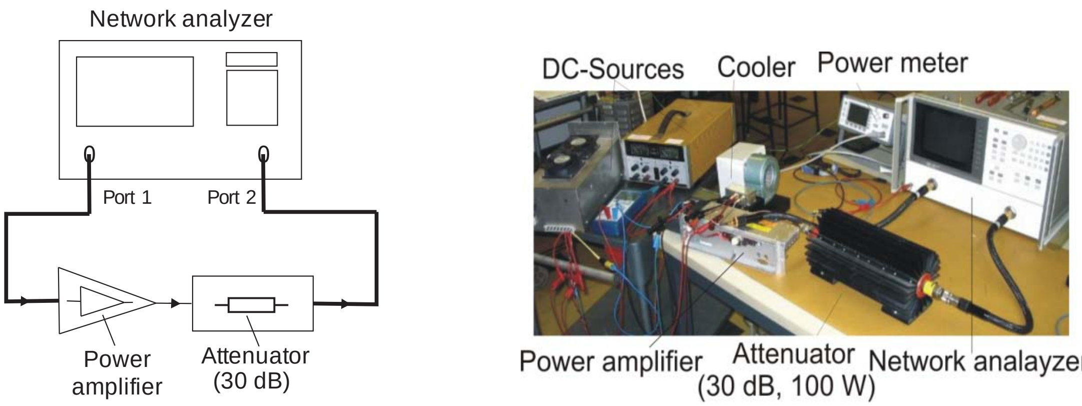
(a) (b)

Fig. 6: Amplitude (a) and phase (b) of the fundamental two-tone signal and the third-order intermodulation product at the power combiner as a function of input power

Instead of for best combining efficiency, the delay line phase and the first loop coupling in this simulation were optimized for intermodulation suppression, seen by approximately equal intermodulation product amplitudes at the "null" drive level and a close to 180° phase difference; note the oscillatory variation in the intermodulation magnitude plot of Fig. 6(a), which again can be attributed to the approximation error in the single amplifiers' Taylor series model. The intermodulation signal amplitudes are found approximately equal because the different effects of the insertion loss of the two delay lines in both loops nearly cancel, as both the intermodulation signals from amplifier A and of amplifier B get reduced in amplitude. Again, turning to lower drive power levels, we observe about equal fundamental signal amplitudes at approx. -5 dBm input power, where Fig. 5 has indicated a dip in the input signal of amplifier B, thus compensating the amplitude imbalance due to the upper delay line attenuation. At even lower drive level, the input signal amplitude of amplifier B recovers from the dip and the fundamental signal from amplifier B becomes larger again than that of amplifier A. At the same time, due to the reduced fundamental signal drive of amplifier B relative to amplifier A, this amplifier produces considerably less intermodulation ($s''(t)$) than amplifier A, approximately a 3 dB reduction for 1 dB reduction in drive power. The combination of the two intermodulation components $-2s'(t)+s''(t)$ at the output of amplifier B thus increases in magnitude as the drive power is reduced and the gain of amplifier A increases. With growing difference in the two intermodulation contributions at the combiner, the circuit loses its cancellation effect as can be observed in Fig. 10.

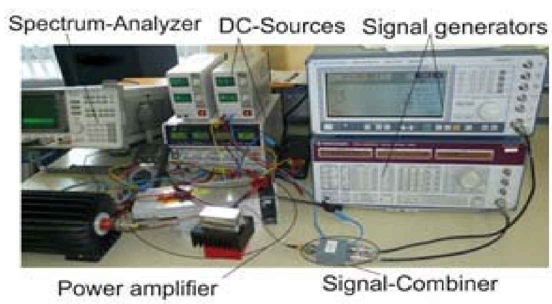
V. Measurmet of the Proposed Amplifier Circuit

Before building an experimental new amplifier circuit, two power amplifiers were assembled and tested: The amplifiers used 900 MHz silicon FET power modules MHW916 in cascade with preamplifiers which gave a saturated output power of about 14 W at a gain of about 53 dB. Measurement of the forward transmission group delay was performed with single-tone at small-signal level using a vector network analyzer HP8722C and the result was used to specify the length of the two delay lines in the new amplifier circuit. Measurements of the complex valued single-tone voltage gain (scattering coefficient s_{21}) as a function of input power level were performed using the vector network analyzer and two tone measurements (910 MHz and 911 MHz) of the fundamental signals and up to the seventh-order intermodulation product were performed using a spectrum analyzer HP8565E (Figs.7 and 8). Both sets of measurements were used for the modeling of the amplifiers transfer characteristics based on a Taylor-series expansion with complex coefficients.



(a) (b)

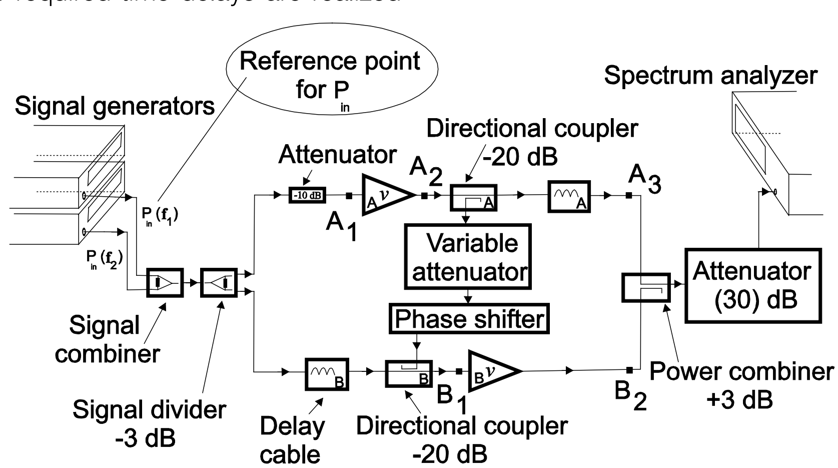
Fig. 7: The experimental single-tone voltage gain, (a) sketch of setup and (b) photograph of bench equipment and amplifier circuit



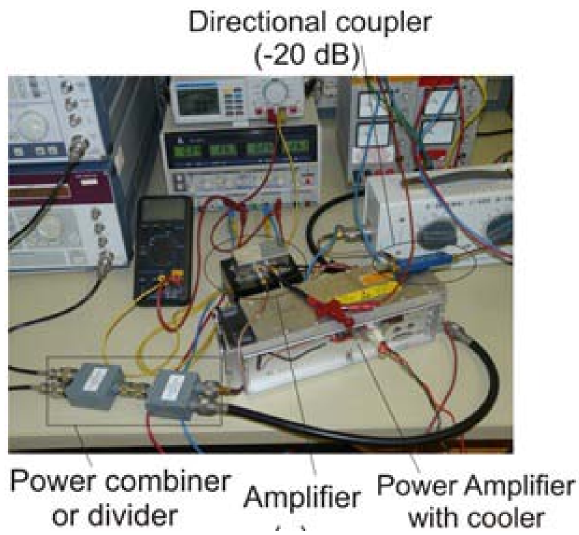
(a) (b)

Fig. 8: The measured fundamental signals and up to the seventh-order intermodulation product, (a) sketch of setup and (b) photograph of bench equipment and amplifier circuit

The setup Sketch of the experimental proposed amplifier circuit (called the feed forward power combiner circuit) is presented in Fig.9. The fundamental two-tone input signal is produced by combining two signal generators and the input signal split of 1:3 voltage ratio is realized by a -3 dB divider with a 10 dB attenuator in the upper signal path to amplifier A. All components of the power combiner circuit are connected by coaxial cables which introduce some insertion loss and phase shift. In particular, the required time delays are realized by about 4 m long coaxial cables RG213 which introduce about 1.6 dB of extra loss. Between the two directional couplers a variable attenuator and a variable phase shifter are inserted in order to allow compensation of amplitude and phase offsets in the first loop. At the output side, a power attenuator is inserted between the power combiner and the spectrum analyzer in order to save the instrument from damage by high incident power.



(a)



(b) (c)

Fig. 9: (a) The measured proposed amplifier circuit and (b) the sketch of setup and (c) photograph of bench equipment and amplifier circuit

Adjustment of the circuit turned out to be difficult: In particular, the variation of the voltage gain in magnitude and phase as a function of input power level, as seen in Figs. 3 and 4, required selecting the drive power level for optimum linearity first of all. In our proof of concept experiment, we set the input power level to +3 dBm which corresponds to the 1 dB-saturation level of the individual power amplifiers.

With the drive signal level fixed, the signal at point $_1$ at the input of amplifier B was observed using a spectrum analyzer and the upper delay line was adjusted and the variable attenuator and phase shifter were set such that the fundamental two-tone signals were approximately equal in level to the signals at point $_1$ at the input to power amplifier A. This setting, at the same time gives approximately the correct pre-distortion level necessary for intermodulation cancellation at the second loop. Final adjustment of the variable attenuator and phase shifter was based on the measurement of the signals at the combiner output; either an optimum cancellation of the third-order intermodulation products could be achieved with the fundamental signals from amplifiers A and B slightly unequal in amplitude and phase or nearly equal fundamental signals could be achieved with considerable difference in phase and amplitude of the intermodulation products. When the amplifier circuit was adjusted for optimum intermodulation cancellation, phase- and amplitude deviations gave rise to a loss in fundamental signal output power of about 0.4 dB.

In Fig. 10, the measurement of the proposed amplifier characteristic is presented and is compared to the expected characteristic of the conventional power combiner circuit using two amplifiers type “A” in parallel if excited at the same input power level as the amplifiers in the proposed amplifier circuit.

It is seen that the proposed amplifier achieves a notable extension of the linear range for the fundamental signals around the 1 dB compression level of the individual power amplifiers while the third-order intermodulation products are reduced by 25 and 45 dB at the +3 dBm input level (the two 3IMD-products are unequal, as explained in [19]). However, the cancellation is confined to a limited range of power levels around the “null”-input level and the intermodulation products level is not improved relative to the level of the conventional parallel power combiner outside this narrow region and is even worse in some parts of the input level range. This is a fundamental limitation of the feed forward power combiner compared to the conventional feed forward amplifier which was investigated by simulation in section 4. For a practical application of the feed forward power combiner concept, this means that in an operation mode with dynamically changing drive conditions, e.g., changing numbers and levels of modulated carriers as in a mobile communications base station amplifier, the loop adjustment has to be adapted dynamically also. Otherwise, under more static drive conditions, as, e.g., in TV-satellite power amplifiers, the feed forward cancellation concept could improve the linearity of present parallel power combining amplifiers with only moderate adaptivity requirements.

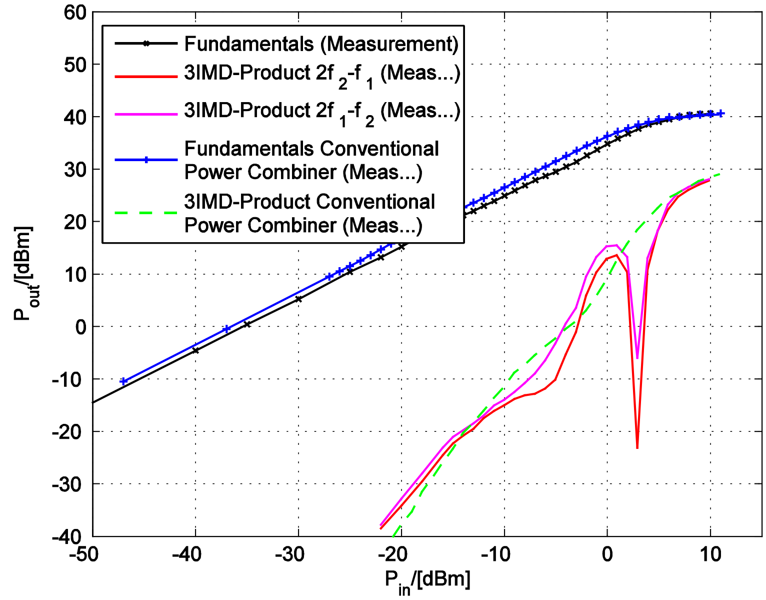


Fig. 10: Measured transfer characteristic of the experimental new amplifier circuit (feed forward-power combiner circuit) compared to the expected characteristic of a conventional parallel power combining amplifier

VI. CONCLUSION

The limitation of the feed forward power combiner circuit was shown to be due to the saturation effect of the upper power amplifier, with its gain variation offsetting the balancing of the circuit loops. However, driving the power amplifiers into the saturation range is a necessary condition for high power efficiency. Power-added efficiency of our experimental amplifier was about 36% which is in contrast to around 10% efficiency of conventional FF-amplifiers. As a price, the critical drive level dependence of the combiner circuit may require higher adaptivity and control of the loop adjustments than a conventional feed forward amplifier, depending on the dynamics of the signals to amplify. By simulation, it can be shown that at lower drive powers the limitations get weaker as the intermodulation cancellation exhibits broader “null” and cancellation is improved even far outside the “null”, similar to the characteristics of the conventional feed forward amplifier, yet losing the advantage in power efficiency.

REFERENCES RÉFÉRENCES REFERENCIAS

1. ASIF, S. Z. "Wireless Communications Evolution to 3G and Beyond", Artech House, 2007, pp. 18-38.
2. K. Solbach, ”Feed Forward amplifier for GSM“, University Duisburg-Essen, Germany, September 2002.
3. J. Cavers, “Amplifier linearization using a digital predistorter with fast adaptation and low memory requirements”, IEEE Transactions on Vehicular Technology, vol. 39, no. 4, pp. 374-382, November, 1990.
4. T. Ogawa, T. Iwasaki, H. Maruyama, K. Horiguchi, M. Nakayama, Y. Ikeda, H. Kurebayash, “High efficiency feed-forward amplifier using RF predistortion linearizer and the modified Doherty Amplifier”, IEEE MTT-S Digest, SPC Electronics Corporation. Tokyo, Japan, 2004.
5. K. J. Cho, J. H. Kim, S. P. Stapleton, “RF High Power Doherty amplifier for Improving the efficiency of a Feed Forward Linear amplifier”, IEEE MTT-S International Microwave Symposium Digest, Dept. of Radio Sci. & Eng., Kwangwoon University, Vol. 2, South Korea, 2004.
6. USA Patent, US6111462, L. Mucenieks, C. Robertson, B. Irvine, N. Salvador, “RF Power Amplifier Linearization using parallel Power Amplifier having intermod-complementing predisitortion paths”, August, 2000.
7. USA Patent, US2,102,671, H. S. Black, “Wave Translation System”, December 1937.
8. F. J. Tegude, ”Automatic characteristic of the 3G-WCDMA mobile power amplifier“, University Duisburg-Essen, Germany, February, 2006.
9. N. Pothecary, Feedforward linear power amplifiers, Artech House, 1999.
10. P.B. Kenington, High-linearity RF amplifier design, Artech House, 2000.
11. USA Patent, US 6,452,446 B1, J. Eisenberg, L. Altos, S. Avis, “Closed loop active cancellation technique(ACT)-based RF power architecture’’, September 2002.
12. Kyoung-Joon Cho, Jong-Heon Kim, S P. Stapleton, “RF High Power Doherty amplifier for Improving the efficiency of a Feed Forward Linear amplifier”, IEEE MTT-S International Microwave

Symposium Digest, Dept. of Radio Sci. & Eng., Kwangwoon Univ., Vol. 2, South Korea, 2004.
13. T. Ogawa, T. Iwasaki, H. Maruyama, K. Horiguchi, M. Nakayama, Y. Ikeda, H. Kurebayash, “High efficiency feed-forward amplifier using RF predistortion linearizer and the modified Doherty Amplifier”,IEEE MTT-S Digest, SPC Electronics Corporation. Tokyo, Japan, 2004.
14. E. Chong, "The Volterra Series and The Direct. Method of Distortion Analysis", University of Toronto, research work 2001.
15. J. Vuolevi, T. Rahkonen, "Distortion in RF Power Amplifier", Artech House, 2003.
16. J. Aikio, "Frequency Domain Model Fitting and Volterra Analysis Implemented on top of Harmonic Balance Simulation", Faculty of Technology, Department of Electrical and Information Engineering, University of Oulo, research work 2007.
17. Mohammad Reza Motavalli, “Untersuchung einer Leistungs-kombinations-Schaltung mit Feed Forward-Linearisierung”, Dissertation, University Duisburg-Essen, Germany, september , 2010.
18. G. Xiangqian, K. Hongwen, C. Hongxing, “The least-square method in complex number domain”, Beijing, China, March, 2006.
19. N. Carvalho, J. C. Pedro", “A Comprehensive Explantion of Distortion Sideband Asymmetries”, IEEE Transactions on Microwave Theory and Techniques, vol. 50, no. 9, September, 2002.

Global Journals Inc. (US) Guidelines Handbook 2017

www.GlobalJournals.org

Fellows

FELLOW OF ASSOCIATION OF RESEARCH SOCIETY IN ENGINEERING (FARSE)

Global Journals Incorporate (USA) is accredited by Open Association of Research Society (OARS), U.S.A and in turn, awards "FARSE " title to individuals. The 'FARSE' title is accorded to a selected professional after the approval of the Editor-in-Chief /Editorial Board Members/Dean.

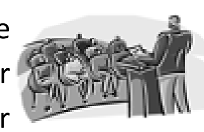
- The "FARSE" is a dignified title which is accorded to a person's name viz. Dr. John E. Hall, Ph.D., FARSE or William Walldroff, M.S., FARSE.

FARSE accrediting is an honor. It authenticates your research activities. After recognition as FARSE, you can add 'FARSE' title with your name as you use this recognition as additional suffix to your status. This will definitely enhance and add more value and repute to your name. You may use it on your professional Counseling Materials such as CV, Resume, and Visiting Card etc.

The following benefits can be availed by you only for next three years from the date of certification:

FARSE designated members are entitled to avail a 40% discount while publishing their research papers (of a single author) with Global Journals Incorporation (USA), if the same is accepted by Editorial Board/Peer Reviewers. If you are a main author or co-author in case of multiple authors, you will be entitled to avail discount of 10%.

Once FARSE title is accorded, the Fellow is authorized to organize a symposium/seminar/conference on behalf of Global Journal Incorporation (USA).The Fellow can also participate in conference/seminar/symposium organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent.

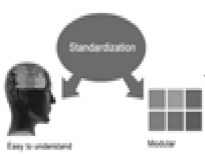


You may join as member of the Editorial Board of Global Journals Incorporation (USA) after successful completion of three years as Fellow and as Peer Reviewer. In addition, it is also desirable that you should organize seminar/symposium/conference at least once.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time.This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The FARSE can go through standards of OARS. You can also play vital role if you have any suggestions so that proper amendment can take place to improve the same for the benefit of entire research community.

As FARSE, you will be given a renowned, secure and free professional email address with 100 GB of space e.g. johnhall@globaljournals.org. This will include Webmail, Spam Assassin, Email Forwarders,Auto-Responders, Email Delivery Route tracing, etc.



The FARSE will be eligible for a free application of standardization of their researches. Standardization of research will be subject to acceptability within stipulated norms as the next step after publishing in a journal. We shall depute a team of specialized research professionals who will render their services for elevating your researches to next higher level, which is worldwide open standardization.

The FARSE member can apply for grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A. Once you are designated as FARSE, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria. After certification of all your credentials by OARS, they will be published on your Fellow Profile link on website https://associationofresearch.org which will be helpful to upgrade the dignity.

The FARSE members can avail the benefits of free research podcasting in Global Research Radio with their research documents. After publishing the work, (including published elsewhere worldwide with proper authorization) you can upload your research paper with your recorded voice or you can utilize chargeable services of our professional RJs to record your paper in their voice on request.

The FARSE member also entitled to get the benefits of free research podcasting of their research documents through video clips. We can also streamline your conference videos and display your slides/ online slides and online research video clips at reasonable charges, on request.

The FARSE is eligible to earn from sales proceeds of his/her researches/reference/review Books or literature, while publishing with Global Journals. The FARSE can decide whether he/she would like to publish his/her research in a closed manner. In this case, whenever readers purchase that individual research paper for reading, maximum 60% of its profit earned as royalty by Global Journals, will be credited to his/her bank account. The entire entitled amount will be credited to his/her bank account exceeding limit of minimum fixed balance. There is no minimum time limit for collection. The FARSE member can decide its price and we can help in making the right decision.

The FARSE member is eligible to join as a paid peer reviewer at Global Journals Incorporation (USA) and can get remuneration of 15% of author fees, taken from the author of a respective paper. After reviewing 5 or more papers you can request to transfer the amount to your bank account.

MEMBER OF ASSOCIATION OF RESEARCH SOCIETY IN ENGINEERING (MARSE)

The ' MARSE ' title is accorded to a selected professional after the approval of the Editor-in-Chief / Editorial Board Members/Dean.

The “MARSE” is a dignified ornament which is accorded to a person’s name viz. Dr. John E. Hall, Ph.D., MARSE or William Walldroff, M.S., MARSE.

MARSE accrediting is an honor. It authenticates your research activities. After becoming MARSE, you can add 'MARSE' title with your name as you use this recognition as additional suffix to your status. This will definitely enhance and add more value and repute to your name. You may use it on your professional Counseling Materials such as CV, Resume, Visiting Card and Name Plate etc.

The following benefitscan be availed by you only for next three years from the date of certification.

MARSE designated members are entitled to avail a 25% discount while publishing their research papers (of a single author) in Global Journals Inc., if the same is accepted by our Editorial Board and Peer Reviewers. If you are a main author or co-author of a group of authors, you will get discount of 10%.

As MARSE, you will be given a renowned, secure and free professional email address with 30 GB of space e.g. johnhall@globaljournals.org. This will include Webmail, Spam Assassin, Email Forwarders,Auto-Responders, Email Delivery Route tracing, etc.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time.This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The MARSE member can apply for approval, grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A.

Once you are designated as MARSE, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria.

It is mandatory to read all terms and conditions carefully.

Auxiliary Memberships

Institutional Fellow of Open Association of Research Society (USA)-OARS (USA)

Global Journals Incorporation (USA) is accredited by Open Association of Research Society, U.S.A (OARS) and in turn, affiliates research institutions as “Institutional Fellow of Open Association of Research Society” (IFOARS).

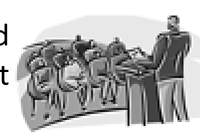
The “FARSC” is a dignified title which is accorded to a person’s name viz. Dr. John E. Hall, Ph.D., FARSC or William Walldroff, M.S., FARSC.

The IFOARS institution is entitled to form a Board comprised of one Chairperson and three to five board members preferably from different streams. The Board will be recognized as “Institutional Board of Open Association of Research Society”-(IBOARS).

The Institute will be entitled to following benefits:

The IBOARS can initially review research papers of their institute and recommend them to publish with respective journal of Global Journals. It can also review the papers of other institutions after obtaining our consent. The second review will be done by peer reviewer of Global Journals Incorporation (USA)
The Board is at liberty to appoint a peer reviewer with the approval of chairperson after consulting us.
The author fees of such paper may be waived off up to 40%.

The Global Journals Incorporation (USA) at its discretion can also refer double blind peer reviewed paper at their end to the board for the verification and to get recommendation for final stage of acceptance of publication.

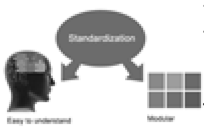


The IBOARS can organize symposium/seminar/conference in their country on behalf of Global Journals Incorporation (USA)-OARS (USA). The terms and conditions can be discussed separately.

The Board can also play vital role by exploring and giving valuable suggestions regarding the Standards of “Open Association of Research Society, U.S.A (OARS)” so that proper amendment can take place for the benefit of entire research community. We shall provide details of particular standard only on receipt of request from the Board.

The board members can also join us as Individual Fellow with 40% discount on total fees applicable to Individual Fellow. They will be entitled to avail all the benefits as declared. Please visit Individual Fellow-sub menu of GlobalJournals.org to have more relevant details.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time. This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.



After nomination of your institution as "Institutional Fellow" and constantly functioning successfully for one year, we can consider giving recognition to your institute to function as Regional/Zonal office on our behalf.
The board can also take up the additional allied activities for betterment after our consultation.

The following entitlements are applicable to individual Fellows:

Open Association of Research Society, U.S.A (OARS) By-laws states that an individual Fellow may use the designations as applicable, or the corresponding initials. The Credentials of individual Fellow and Associate designations signify that the individual has gained knowledge of the fundamental concepts. One is magnanimous and proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice.

Open Association of Research Society (US)/ Global Journals Incorporation (USA), as described in Corporate Statements, are educational, research publishing and professional membership organizations. Achieving our individual Fellow or Associate status is based mainly on meeting stated educational research requirements.

Disbursement of 40% Royalty earned through Global Journals : Researcher = 50%, Peer Reviewer = 37.50%, Institution = 12.50% E.g. Out of 40%, the 20% benefit should be passed on to researcher, 15 % benefit towards remuneration should be given to a reviewer and remaining 5% is to be retained by the institution.

We shall provide print version of 12 issues of any three journals [as per your requirement] out of our 38 journals worth $ 2376 USD.

Other:

The individual Fellow and Associate designations accredited by Open Association of Research Society (US) credentials signify guarantees following achievements:

- The professional accredited with Fellow honor, is entitled to various benefits viz. name, fame, honor, regular flow of income, secured bright future, social status etc.

- In addition to above, if one is single author, then entitled to 40% discount on publishing research paper and can get 10%discount if one is co-author or main author among group of authors.
- The Fellow can organize symposium/seminar/conference on behalf of Global Journals Incorporation (USA) and he/she can also attend the same organized by other institutes on behalf of Global Journals.
- The Fellow can become member of Editorial Board Member after completing 3yrs.
- The Fellow can earn 60% of sales proceeds from the sale of reference/review books/literature/publishing of research paper.
- Fellow can also join as paid peer reviewer and earn 15% remuneration of author charges and can also get an opportunity to join as member of the Editorial Board of Global Journals Incorporation (USA)
- • This individual has learned the basic methods of applying those concepts and techniques to common challenging situations. This individual has further demonstrated an in–depth understanding of the application of suitable techniques to a particular area of research practice.

Note :

"

- In future, if the board feels the necessity to change any board member, the same can be done with the consent of the chairperson along with anyone board member without our approval.
- In case, the chairperson needs to be replaced then consent of 2/3rd board members are required and they are also required to jointly pass the resolution copy of which should be sent to us. In such case, it will be compulsory to obtain our approval before replacement.
- In case of "Difference of Opinion [if any]" among the Board members, our decision will be final and binding to everyone.

"

Process of submission of Research Paper

The Area or field of specialization may or may not be of any category as mentioned in 'Scope of Journal' menu of the GlobalJournals.org website. There are 37 Research Journal categorized with Six parental Journals GJCST, GJMR, GJRE, GJMBR, GJSFR, GJHSS. For Authors should prefer the mentioned categories. There are three widely used systems UDC, DDC and LCC. The details are available as 'Knowledge Abstract' at Home page. The major advantage of this coding is that, the research work will be exposed to and shared with all over the world as we are being abstracted and indexed worldwide.

The paper should be in proper format. The format can be downloaded from first page of 'Author Guideline' Menu. The Author is expected to follow the general rules as mentioned in this menu. The paper should be written in MS-Word Format (*.DOC,*.DOCX).

The Author can submit the paper either online or offline. The authors should prefer online submission.Online Submission: There are three ways to submit your paper:

(A) (I) First, register yourself using top right corner of Home page then Login. If you are already registered, then login using your username and password.

(II) Choose corresponding Journal.

(III) Click 'Submit Manuscript'. Fill required information and Upload the paper.

(B) If you are using Internet Explorer, then Direct Submission through Homepage is also available.

(C) If these two are not conveninet , and then email the paper directly to dean@globaljournals.org.

Offline Submission: Author can send the typed form of paper by Post. However, online submission should be preferred.

MANUSCRIPT STYLE INSTRUCTION **(Must be strictly followed)**

Page Size: 8.27" X 11'"

- Left Margin: 0.65
- Right Margin: 0.65
- Top Margin: 0.75
- Bottom Margin: 0.75
- Font type of all text should be Swis 721 Lt BT.
- Paper Title should be of Font Size 24 with one Column section.
- Author Name in Font Size of 11 with one column as of Title.
- Abstract Font size of 9 Bold, “Abstract” word in Italic Bold.
- Main Text: Font size 10 with justified two columns section
- Two Column with Equal Column with of 3.38 and Gaping of .2
- First Character must be three lines Drop capped.
- Paragraph before Spacing of 1 pt and After of 0 pt.
- Line Spacing of 1 pt
- Large Images must be in One Column
- Numbering of First Main Headings (Heading 1) must be in Roman Letters, Capital Letter, and Font Size of 10.
- Numbering of Second Main Headings (Heading 2) must be in Alphabets, Italic, and Font Size of 10.

You can use your own standard format also.
Author Guidelines:

1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript’s Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

1. GENERAL

Before submitting your research paper, one is advised to go through the details as mentioned in following heads. It will be beneficial, while peer reviewer justify your paper for publication.

Scope

The Global Journals Inc. (US) welcome the submission of original paper, review paper, survey article relevant to the all the streams of Philosophy and knowledge. The Global Journals Inc. (US) is parental platform for Global Journal of Computer Science and Technology, Researches in Engineering, Medical Research, Science Frontier Research, Human Social Science, Management, and Business organization. The choice of specific field can be done otherwise as following in Abstracting and Indexing Page on this Website. As the all Global

Journals Inc. (US) are being abstracted and indexed (in process) by most of the reputed organizations. Topics of only narrow interest will not be accepted unless they have wider potential or consequences.

2. ETHICAL GUIDELINES

Authors should follow the ethical guidelines as mentioned below for publication of research paper and research activities.

Papers are accepted on strict understanding that the material in whole or in part has not been, nor is being, considered for publication elsewhere. If the paper once accepted by Global Journals Inc. (US) and Editorial Board, will become the copyright of the Global Journals Inc. (US).

Authorship: The authors and coauthors should have active contribution to conception design, analysis and interpretation of findings. They should critically review the contents and drafting of the paper. All should approve the final version of the paper before submission

The Global Journals Inc. (US) follows the definition of authorship set up by the Global Academy of Research and Development. According to the Global Academy of R&D authorship, criteria must be based on:

1) Substantial contributions to conception and acquisition of data, analysis and interpretation of the findings.

2) Drafting the paper and revising it critically regarding important academic content.

3) Final approval of the version of the paper to be published.

All authors should have been credited according to their appropriate contribution in research activity and preparing paper. Contributors who do not match the criteria as authors may be mentioned under Acknowledgement.

Acknowledgements: Contributors to the research other than authors credited should be mentioned under acknowledgement. The specifications of the source of funding for the research if appropriate can be included. Suppliers of resources may be mentioned along with address.

Appeal of Decision: The Editorial Board's decision on publication of the paper is final and cannot be appealed elsewhere.

Permissions: It is the author's responsibility to have prior permission if all or parts of earlier published illustrations are used in this paper.

Please mention proper reference and appropriate acknowledgements wherever expected.

If all or parts of previously published illustrations are used, permission must be taken from the copyright holder concerned. It is the author's responsibility to take these in writing.

Approval for reproduction/modification of any information (including figures and tables) published elsewhere must be obtained by the authors/copyright holders before submission of the manuscript. Contributors (Authors) are responsible for any copyright fee involved.

3. SUBMISSION OF MANUSCRIPTS

Manuscripts should be uploaded via this online submission page. The online submission is most efficient method for submission of papers, as it enables rapid distribution of manuscripts and consequently speeds up the review procedure. It also enables authors to know the status of their own manuscripts by emailing us. Complete instructions for submitting a paper is available below.

Manuscript submission is a systematic procedure and little preparation is required beyond having all parts of your manuscript in a given format and a computer with an Internet connection and a Web browser. Full help and instructions are provided on-screen. As an author, you will be prompted for login and manuscript details as Field of Paper and then to upload your manuscript file(s) according to the instructions.

To avoid postal delays, all transaction is preferred by e-mail. A finished manuscript submission is confirmed by e-mail immediately and your paper enters the editorial process with no postal delays. When a conclusion is made about the publication of your paper by our Editorial Board, revisions can be submitted online with the same procedure, with an occasion to view and respond to all comments.

Complete support for both authors and co-author is provided.

4. MANUSCRIPT'S CATEGORY

Based on potential and nature, the manuscript can be categorized under the following heads:

Original research paper: Such papers are reports of high-level significant original research work.

Review papers: These are concise, significant but helpful and decisive topics for young researchers.

Research articles: These are handled with small investigation and applications

Research letters: The letters are small and concise comments on previously published matters.

5.STRUCTURE AND FORMAT OF MANUSCRIPT

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

Papers: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

(a)Title should be relevant and commensurate with the theme of the paper.

(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

(d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.

(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

Authors should very cautiously consider the preparation of papers to ensure that they communicate efficiently. Papers are much more likely to be accepted, if they are cautiously designed and laid out, contain few or no errors, are summarizing, and be conventional to the approach and instructions. They will in addition, be published with much less delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and to make suggestions to improve briefness.

It is vital, that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

Format

Language: The language of publication is UK English. Authors, for whom English is a second language, must have their manuscript efficiently edited by an English-speaking person before submission to make sure that, the English is of high excellence. It is preferable, that manuscripts should be professionally edited.

Standard Usage, Abbreviations, and Units: Spelling and hyphenation should be conventional to The Concise Oxford English Dictionary. Statistics and measurements should at all times be given in figures, e.g. 16 min, except for when the number begins a sentence. When the number does not refer to a unit of measurement it should be spelt in full unless, it is 160 or greater.

Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

Structure

All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

Abstract, used in Original Papers and Reviews:

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.

6. AFTER ACCEPTANCE

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

6.1 Proof Corrections

The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

Proofs must be returned to the dean at dean@globaljournals.org within three days of receipt.

As changes to proofs are costly, we inquire that you only correct typesetting errors. All illustrations are retained by the publisher. Please note that the authors are responsible for all statements made in their work, including changes made by the copy editor.

6.2 Early View of Global Journals Inc. (US) (Publication Prior to Print)

The Global Journals Inc. (US) are enclosed by our publishing's Early View service. Early View articles are complete full-text articles sent in advance of their publication. Early View articles are absolute and final. They have been completely reviewed, revised and edited for publication, and the authors' final corrections have been incorporated. Because they are in final form, no changes can be made after sending them. The nature of Early View articles means that they do not yet have volume, issue or page numbers, so Early View articles cannot be cited in the conventional way.

6.3 Author Services

Online production tracking is available for your article through Author Services. Author Services enables authors to track their article - once it has been accepted - through the production process to publication online and in print. Authors can check the status of their articles online and choose to receive automated e-mails at key stages of production. The authors will receive an e-mail with a unique link that enables them to register and have their article automatically added to the system. Please ensure that a complete e-mail address is provided when submitting the manuscript.

6.4 Author Material Archive Policy

Please note that if not specifically requested, publisher will dispose off hardcopy & electronic information submitted, after the two months of publication. If you require the return of any information submitted, please inform the Editorial Board or dean as soon as possible.

6.5 Offprint and Extra Copies

A PDF offprint of the online-published article will be provided free of charge to the related author, and may be distributed according to the Publisher's terms and conditions. Additional paper offprint may be ordered by emailing us at: editor@globaljournals.org .

You must strictly follow above Author Guidelines before submitting your paper or else we will not at all be responsible for any corrections in future in any of the way.

Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.
- Do not give permission to anyone else to "PROOFREAD" your manuscript.
- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals Inc. (US).

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

Index

A

C

D

I

Q

U

save our planet

Global Journal of Researches in Engineering

Visit us on the Web at www.GlobalJournals.org | www.EngineeringResearch.org
or email us at helpdesk@globaljournals.org

ISSN 9755861