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DISCOVERING THOUGHTS AND INVENTING FUTURE

Highlights

Optimized Implementation Approach

Packed Bed Solar Air Heater

Premixed Combustion Model

Tensile Behavior of Cryorolled

Assembly Line

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An Empirical Investigation of Assembly Line Balancing Techniques and Optimized Implementation Approach for Efficiency Improvements

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Abstract - The concept of mass production essentially involves the assembly of identical or interchangeable parts of components into the final product at different stages and workstations. The relative advantages and disadvantages of mass or flow production are a matter of concern for any mass production industry. How to design an assembly line starting from the work breakdown structure to the final grouping of tasks at work stations has been discussed in this paper using two commonly used procedures namely the Kilbridge-Wester Heuristic approach and the Helgeson-Birnie Approach. Line Balancing (LB) is a classic, well-researched Operations Research (OR) optimization problem of significant industrial importance. The specific objectives of this paper is to optimize crew size, system utilization, the probability of jobs being completed within a certain time frame and system design costs. These objectives are addressed simultaneously, and the results obtained are compared with those of single-objective approaches.

Keywords : Line Balancing, Kilbridge-Wester Heuristic Approach, Helgeson-Birnie Approach, Optimization.

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AN EMPIRICAL INVESTIGATION OF ASSEMBLY LINE BALANCING TECHNIQUES AND OPTIMIZED IMPLEMENTATION APPROACH FOREFFICIENCY IMPROVEMENTS

Strictly as per the compliance and regulations of:

An Empirical Investigation of Assembly Line Balancing Techniques and Optimized Implementation Approach for Efficiency Improvements

Dalgobind Mahto [α], Anjani Kumar [σ]

Abstract - The concept of mass production essentially involves the assembly of identical or interchangeable parts of components into the final product at different stages and workstations. The relative advantages and disadvantages of mass or flow production are a matter of concern for any mass production industry. How to design an assembly line starting from the work breakdown structure to the final grouping of tasks at work stations has been discussed in this paper using two commonly used procedures namely the Kilbridge-Wester Heuristic approach and the Helgeson-Birnie Approach. Line Balancing (LB) is a classic, well-researched Operations Research (OR) optimization problem of significant industrial importance. The specific objectives of this paper is to optimize crew size, system utilization, the probability of jobs being completed within a certain time frame and system design costs. These objectives are addressed simultaneously, and the results obtained are compared with those of single-objective approaches.

Keywords : Line Balancing, Kilbridge-Wester Heuristic Approach, Helgeson-Birnie Approach, Optimization.

I. Introduction

Recently some of the most successful business corporations seem to have hit upon an incredible solution: Line Balancing. Line Balancing is a classic Operations Research optimization technique which has significant industrial importance in lean system. The concept of mass production essentially involves the Line Balancing in assembly of identical or interchangeable parts or components into the final product in various stages at different workstations. With the improvement in knowledge, the refinement in the application of line balancing procedure is also a must.

This reproof gives the methodology of application of line balancing in an ABC company, where four areas were selected as a sampling to study and implement line balancing. The four areas are Feeder frame assembly, Base frame assembly, Revolving vibratory feeder, and Gear housing. The characteristics of the relevant departments of ABC Company are studied and with the purpose of reducing assembly time and hence cost, this assignment has been undertaken. The assembly machines are selected and then the layout of the selected facilities has been performed. Task allocation of each worker was achieved by assembly line balancing to increase an assembly efficiency and productivity.

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II. Formulation of Assembly Line-Balancing Problem

The Assembly line balancing is generally a problem of minimizing the total amount of idle time or equivalently minimizing the no of operators to do given amount of work at a given assembly line speed. This is also known as minimizing balance delay. Balance delay is defined as the amount of idle time for the entire assembly line as a fraction of total working time resulting from unequal task time assigned to the various stations. Mathematically, this objective can be stated as follows:

$$\min \sum_{J=1}^{R} w_j \text{ Subject to } t_j \leq C \; wj \text{ for } j = 1.....R \quad (1)$$

Where,

- R is the number of work centers,
- W is the (integer-adjusted) number of required workers in work centre j,
- t_j is the estimated time required to complete the tasks in work centre j, and
- C is the pre specified cycle time.

In short, with the traditional assembly line-balancing problem, it is desirable to place minimum number of workers, as far as possible, to each work centers, at the same time one should also adhere to the policy that no worker is 'overloaded'.

III. Or Characterization of Line Balancing

The OR definition of the line balancing problem was christened by Becker and Scholl [2,3] as SALBP, which stands for Simple Assembly Line Balancing

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Problem. SALBP is defined as follows, "Given a set of tasks of various durations, a set of precedence constraints among the tasks, and a set of workstations, assigns each task to exactly one workstation in such a way that no precedence constraint is violated and the assignment is optimal". The optimality criterion gives rise to two variants of the problem: either a cycle time is given that cannot be exceeded by the sum of durations of all tasks assigned to any workstation and the number of workstations is to be minimized, or the number of workstations is fixed and the line cycle time, equal to the largest sum of durations of task assigned to a workstation, is to be minimized. Becker and Scholl [2, 3] define many extensions to SALBP. One of the extensions is GALBP, which stands for Generalized Assembly Line Balancing Problem. Each of the extensions reported in their authoritative survey aims to handle an additional difficulty present in real-world line balancing. The real-world line balancing, as faced in particular by the automotive industry, requires tackling many of those generalizations, simultaneously.

IV. Aims and Objectives of the Present Study

The aims and objectives of the present study are as follows

- To minimize the total amount of idle time and equivalently minimizing the number of operators to do a given amount of work at a given assembly line speed
- To optimize the production functions through construction of mix form of automation assembly and manual assembly.
- To classify the whole assembly process into each unit and decide the automation possibility of each process, and if, automation assembly is not possible, decide criteria for manual assembly.
- To determine machinery and equipment according to assembly mechanism.

V. Literature Review

According to Becker and Scholl [1,2] and Scholl and Becker [3] the earliest forms of the presented problem, along with the more modern research efforts, have typically concentrated on the minimization of workers needed to staff a line while adhering to task precedence and cycle time restrictions. In short, with the traditional assembly line-balancing problem, it is desirable to place workers in work centres in such a way that as few workers as possible as used, while simultaneously adhering to the policy that no single worker can be 'overloaded'. Askin and Zhou [4] have explained that with line balancing the objectives of system utilization could be met. Gocken and Erel [5,6] expressed the similar views. Vilarinho and Simaria[7]gave the mathematical solution about the probability of jobs being completed within a desired time frame. Merengo et al [8], have addressed the issue of system design cost. Askin and Zhou [4], Rekiek et al. [9], Bukchin and Rubinovitz [10] and Ponnambalam et al. [11], have proposed and concluded that evenness of workload assignments is pre requisite for line balancing. Either a cycle time is given that cannot be exceeded by the sum of durations of all tasks assigned to any workstation and the number of workstations is to be minimized or the number of workstations is fixed. The line cycle time, equal to the largest sum of durations of task assigned to a workstation, is to be minimized. Falkenauer and Delchambre [12], Salveson [13] provided the first mathematical attempt by solving the problem as a linear program.

It has been seen from the literatures [14] that assembly line balancing problem is generally minimizing the total amount of idle time or equivalently minimizing the number of operators to do a given amount of work at a given assembly line speed. This is known as minimizing the balance delay. One very compelling reason why few researchers have addressed the multiple objectives of the assembly line-balancing problem simultaneously is because the job is very difficult. Past research by McMullen and Frazier[14] has indicated that many of these important objectives are in conflict with each other. According to them, these objectives are directly opposed to each other. They further emphasized that when a solution is obtained requiring a relatively large number of workers, there is a high probability that these jobs will be assembled within a certain period. The Line balancing problem can be gauged with the help of data like line efficiency, Balance delay and smoothness index.

Kirkpatrick et al.[15], Glover[16], Goldberg [17], Dorigo and Gambardella [18] have mentioned that construction of the efficient frontier for a problem cannot be obtained by direct application of a simple rule . Even though the assembly line balancing problem has received significant attention over its lifetime, many companies still do not utilize the methods proposed in the literature. This fact can be seen in a survey conducted by Chase [19]. His survey showed that roughly only 5% of companies with production lines utilize traditional line balancing techniques to balance their assembly lines. A more recent article by Milas[20] showed that this trend is still valid in today's manufacturing environment. Milas further stated that most companies perform their line balancing based on historical precedent or the 'gut feel' of their engineers. Tsujimura, et al [21] presented solutions for assembly-line balancing problem with genetic algorithms. Similarly, Gen et al 22have presented their work in assembly line balancing using genetic algorithm.

The important conclusions witnessed from the literature reviews [1 – 22] on Line balancing are to minimize time of worker's movement and assembly. It has been recommended that it ensure balanced allocation of assembly work to each worker by realizing assembly line balancing after deciding the number of workers who can produce the target yield.

VI. Optimization Criteria in Line Balancing

The following terms are very much associated with Kilbridge-Wester Heuristic approach and the Helgeson-Birnie Approach.

a) Line efficiency (LE)

This is the ratio of total station time to the product of the cycle time and the no of workstations. We can express this as

$$LE = [\{ \sum_{I=1}^{K} STi \ / (K) \times (CT)\} \times 100\ \%] \qquad (2)$$

Where,

ST_i= Station time of station I, K= Total No of work stations and CT = Cycle time

b) Balance delay (BD)

This is the measure of line inefficiency and the total idle time of all stations as a percentage of total available working time of all stations

Thus,

$$BD= [\{(K) \times (CT) - (\sum_{I=1}^{K} STi)\} / \{(K) \times (CT)\} \times 100\ \%] \qquad (3)$$

Where,

ST_i = Station time of station i , K = Total No of work stations and CT = Cycle time

c) Smoothness index (SI)

This is an index to indicate the relative smoothness of a given assembly line balance. A smoothness index of 0 indicates a perfect balance. This can be expressed as:

$$SI = \sqrt{\sum_{i=1}^{K} (ST\max - STi)^2} \qquad (4)$$

Where,

ST_{max} =Maximum Station time, ST_i = Station time of station I, K = Total No of work stations

d) Limitations

It may be noted that in designing an assembly line the no of work stations, K cannot exceed the total no of work elements, N (in fact K is an integer such that 1≤ K ≤ N. Also the cycle time is greater than or equal to the maximum time of any work element and less than the total of all work element times, that is

$$T_{max} \leq CT \leq \sum_{I=1}^{N} Ti \qquad (5)$$

Where,

T max = Maximum work element time

Ti = the time for work element i

N = Total No of work elements

CT = Cycle time

e) Line Balancing Methodologies

Many scholars argue that while doing line balancing one must consider the complex social problems with the fear that this will create social problem. This is being discussed with this tool because it aims to minimize manpower. The frequently used line balancing problems are two types namely, Assembly line balancing and Fabrication line balancing: The Assembly line balancing refers to the type of operation taking place on the line to be balanced on the other hand Fabrication line balancing refers a production line made up of operations that form or change the physical or sometimes, chemical characteristics of the product involved. The term assembly line indicates a production line made of purely assembly operations. Machining or heat treatment would fall into operations of Fabrication line balancing. In this research the two line Balancing methods are studied

- Kilbridge-WesterHeuristic approach, and
- Helgeson-Birnie Approach

i. *Kilbridge-Wester heuristic approach*

The procedures proposed by Kilbridge and Wester numbers are assigned to each operation describing how many predecessors it has. Operations with the lowest predecessors are assigned first to the workstations. The procedure consists of the following steps

- Construct the precedence diagram for the work elements
- Select a feasible cycle time
- Assign work elements to the station so that the sum of elemental time does no exceed the cycle time (Step 3)
- Delete the assigned elements from the total no of work elements and repeat the step 3
- If the station time exceeds the cycle time due to the inclusion of a certain work elements this work element should be assigned to the next station
- Repeat step 3 to 5 untill all elements are assigned to workstations

ii. *Helgeson-Birnie approach*

The procedure proposed by Helgeson and Birnie is based on the ranked positional weight technique having the following steps

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- Construct the precedence diagram for the work elements
- Determine the positional weight for each work elements
- Rank the work elements based on the positional weight in step 2. The work element with highest positional weight is ranked first
- Proceed to assign work elements to the workstations where elements of the highest positional weight and rank are assigned first.
- If at any work station additional time remains after assignment of an operation, assign the succeeding ranked operation to the work station, as long as the operation does not violate the precedence relationship diagram and the station time does not exceeds the cycle time
- Repeat step 4 and 5 untill all elements are assigned to workstations

VII. Combination of Process for Line Optimization and its Constraints

a) Re-balancing constraints

Many of the OR approaches implicitly assume that the problem to be solved involves a new, yet-to-be-built assembly line, possibly housed in a new, yet-to-be-built factory. The vast majority of real-world line balancing tasks involve existing lines, housed in existing factories – in fact, the target line typically needs to be rebalanced rather than balanced, the need arising from changes in the product or the mix of models being assembled in the line, the assembly technology, the available workforce, or the production targets.

b) Workstations identities

As pointed out above, the vast majority of real-world lines balancing tasks involve existing lines housed in existing factories. In practice, this seemingly "uninteresting" observation has one far-reaching consequence, namely that each workstation in the line does have its own identity.

c) Unmovable operations and zoning constraints

The need to identify workstations by their position along the line (rather than solely by the set of operations that would be carried out there) is illustrated by the typical need of line managers to define unmovable operations and zoning constraints.

d) Elimination of workstations

Since workstations do have their identity (as observed above), it becomes obvious that a real-world LB tool cannot aim at eliminating workstations. Indeed, unless the eliminated workstations were all in the front of the line or its tail, their elimination would create gaping holes in the line, by virtue of the other workstations' retaining of their identities, including their geographical positions in the workshop.

e) Need to match loads and time

Since eliminating workstations cannot be the aim of the optimization of the line, as pointed out above, it is the equalization or smoothing (indeed "balancing") of the workload and time among workstations that should be the practical aim of LB. It is worth noting that the classic objective of minimization of the cycle time, i.e. minimization of the maximum lead-time over all workstations, is not necessarily the same objective as load equalization. The important practical point to be made here is that the line's cycle time is almost always given by the company's marketing that sets production targets. The maximum cycle time set by marketing cannot of course be exceeded by the line, but it is typically useless to reduce the line's cycle time below that value.

f) Many operators

In many industries, in particular automotive, the product being assembled is sufficiently voluminous to allow several operators to work on the product at the same time. Since that possibility does exist, not exploiting it would lead to unnecessarily long assembly lead times, implying a reduced productivity. Once a workstation features more than one operator, the workstation's lead time ceases to be a simple sum of durations of all operations assigned to it. First of all, the workstation as a whole will need the time equal to the lead-time of its "slowest" operator.

g) Multi-operator operations

Assembly of large products such as cars sometimes requires the collaboration of several operators to carry out an operation. It is therefore desirable to make that operator carry out other operations as well. That, however, significantly complicates the scheduling of operations within the workstation: all the operators in the workstation must be kept as busy as possible, must execute the operations in compliance with the precedence constraints, and must be made available at the same time to carry out multi-operator operations.

h) Ergonomic constraints (operator position)

A major difficulty in assembly of large products is that they are too bulky to be moved (elevated, rotated) easily. In other situations, the working position is imposed from the outset. These considerations give rise to Workstation-Level Ergonomic Constraints.

VIII. Case Studies: Analysis of Assembly Object and Processes

There are 9 subassemblies in ABC Industry according to category of main parts. They are buckets, housings, feeder frames, revolving frames, couplings, arms, booms and gears. Feeder frame is an important prime complicated part and its subassembly is composed of base frame, tension holder, magnetic load cell, drive pulley, tail pulley, struts, guide chutes, guide covers, idlers, bearings, motors, gear drive, couplings, bolts and belt. Hence, the case study was selected to balance the assembly process as the misbalancing of production of this item effects the other activities.

a) Optimization methodology

To justify the improvement of productivity the ant optimization methodology has been created. The following parameters and variables have been considered, which are presented with their notations as under.

Parameters:

n = Total number of tasks

t_i^* = Expected duration of tasks i

σ_i^* = Estimated standard deviation of tasks i

C = Pre-specified cycle time

αh = Multipliers of objective function (h = 1, …, 4)

α = Work center creation factor $(0 < \alpha < 1)$

Variables:

L = List of tasks for assignment into work centers

n_j = number of tasks in work center j

R = total number of work canters from the solution

t_j = expected duration of all tasks in work center j

σ_j = estimated standard deviation of work center j

ω_j = workers required in work center j

W_j = integer-adjusted workers required in work center j

p_j = probability of on-time completion in work center j

u_j = utilization of work center j

$metric_i$ =evaluation metric associated with task i

ph_i = pheromone associated with task i

$M(i, g_i)$ = n by n linkage matrix to used to detail the number of times task i is preceded by task g_i.

b) Selection of Tasks for Work Centers

All relevant entities in the above list are initialized to their appropriate values. Before actually selecting a task for membership in the current (non-empty) work center, a decision must be made whether or not to create a new work center. This is done via the following relationship:

$$P\text{ (New work center)} = \frac{\alpha}{n_j} \quad (6)$$

Where, j is the current work center. The above relationship guards against a very large number or a very small number of work centers, thereby guarding against high fixed costs (several machines) and high variable costs (several workers). When a new work center is opened, tj and σ_j for new work center j are initialized to zero.

c) Task selection

In the event of an empty work center, all relevant statistics are initialized to zero. For each task eligible for membership in L, the utilization and probability of on-time completion are calculated to reflect work center utilization (u_j) and probability (p_j) if task i were to be added to the current work center j:

$$u_j = \frac{\omega_j}{W_j} \quad (7)$$

Where, $\omega_j = \frac{(t + ti^*)}{C}$,

for $i \in L$ and $W_j = 1 + \text{int}(\omega_j)$

$$p_i = 1\sqrt{2\pi\int_{\propto}^{y}\exp(-0.5z^2)dz} \quad (8)$$

Where, $Y = \{C(W_j - \omega_j)\} / \sigma_j,$ (9)

and $\sigma_j = \sqrt{(\sigma_i^2 + \sigma_i^{*2})}$ (10)

Utilization (uj) is a representation of how 'busy' is work centre j, while probability (pj) is the work centre's ability to finish its tasks within the cycle time. A busy system typically reflects a low probability of on-time completion, and vice versa. After determination of uj and pj, the following multiple-objective function value is determined:

$$metric_i = a_1u_j + a_2p_j + a_3(u_jp_j) + a_4u_j(1-p_j) \quad (11)$$

This value, metrici, is intended to show the relative desirability of adding task I to work centre j. It is desired to maximize this value. The first component of this measure provides the utilization contribution. The second component shows the probability of on-time completion contribution. The third component shows the contribution of a composite measure of uj and pj. The fourth component is included as a surrogate for system design cost — a combination of personnel requirements and equipment requirements. McMullen and Frazier (1998) showed that high probabilities of on-time completion are directly related to large equipment needs, which is the reason for the $(1-p_j)$ term.

d) Determining line balance statistics and construct efficient frontier

The following is a list of definitions for entities associated with final assembly line-balancing solution:

W = number of workers required for the solution,

U = utilization of assembly line layout,

P = probability of all work centres completing work on time,

Cost design cost of assembly line layout,

S [W] composite objective function value associated with W workers.

The number of workers required for the recently completed assembly line-balancing solution is as follows:

$$W=\sum_{J=1}^{R} wj \qquad (12)$$

The utilization associated with this solution is as follows:

$$U = \left(\sum_{i=1}^{n} t_i^*\right) / cw \qquad (13)$$

The probability of completing all tasks within cycle time is as follows:

$$P = \prod_{j=1}^{R} Pj \qquad (14)$$

The design cost associated with the assembly line-balancing solution is as follows:

$$Cost = 60000+2510 \sum_{i=1}^{R} n_j w_i \qquad (15)$$

The design cost expressed above considers the total cost associated with both personnel and equipment needed to process jobs passing through the assembly line. The major assumptions of this model are that the annual labour cost for an employee is Rs 60000 /year, and the annual cost for a piece of equipment is Rs2510/year. The labour cost can be modified to reflect the actual average cost of employees on the assembly line. In addition, equipment costs might vary according to the tasks performed, the age of the equipment, and which tasks are assigned to a particular workstation.

With the individual assembly line-balancing statistics calculated, the objective measure of performance associated with W workers is as follows:

$$S [W]=a_1U + a_2P + a_3UP + a_4 \{Cost – Cost\} / (Cost) \qquad (16)$$

The above function contains the 'ah' values as shown in equation (11), and these ah values are contained in the [0, 1] interval. Cost is the highest possible system design cost for the problem at hand. The above calculations represented by equations (12) - (15) are performed each time an assembly line-balancing solution is completed. For each solution, the largest value of S [W] is noted for each value of W. The steps above are repeated number of times — a user-specified number of solutions. The S [W] values and the corresponding values of W then comprise the multiple-objective efficient frontier.

IX. Numerical Examples: Analysis of Assembly Processes

Assembly processes of ABC Industry are made up of a number of 27-unit processes like buckets, housings, feeder frames, revolving frames, couplings, arms, booms and gears etc. They can be combined into of 15 processes like frame assembly, magnetic load cell assembly, pulley assembly, grease application, bolting of frames, magnetization of magnet and airtight test, etc. An assembly process of ABC Industry is given in Table 1.

Table 1 : Assembly process of ABC industry

Sl No	Assembly Process	Time (Min)	No of Manpower / Shift
1	Base Frame and Strut	20	2
2	Load Cell and Feeder Frame	12	3
3	Tension Holder and Feeder Frame	27	2
4	Plummer Block, Pulley and Bearing with O ring	35	2
5	Idlers and Bearings	25	1
6	Motor, Gear Box and Pulley coupling	55	3
7	Belt Vulcanizing with Feeder Frame	30	2
8	Fixing of Guide Chutes and Covers	20	2

9	Checking Alignment	15	1
10	Magnetization of Load cell	8	1
11	Aging (Load test)	12	2
12	Air tight test	8	1
13	Painting	15	1
14	Sticker sticking	5	1
15	Packing	20	2
	$\sum$	307	26

a) Layout of assembly machinery equipment

The basic objective of machinery equipment and facility layout in assembly system is to improve assembly productivity. Its detail objectives shall be smooth inner transporting, efficient place utilization, safe location for the machinery and equipment, and creation of safe and ease inner circumstances for workers, etc.The information and data that are needed to plan and determine the placement of equipment are production capacity, forms of production and processes, inner systems, amount of transporting, amount of work at each positions; and size and form of plants. There are several equipment layouts namely product layout (line layout), process layout, fixed position layout. In this research, the existing old product layout has been studied for the selected item of ABC Industry. The existing process layout is presented in Fig 1.

Work allocation to each worker in a shift has been studied, which was done on the basis of above existing product layout and data has been collected.Then worker allocation has been changed from a shift into groups. The group-work allocation analysis has been tabulated in Table 2.

b) Determination of Automation possibility of assembly process automation

According to geometrical characteristics of products and degree of complexity of assembly process, it can be determined whether the assembly processes has to be automated or not. Sometimes, manual assembly may be performed easily. There are some more factors or parameters, i.e. production volume, cycle time, investment cost, etc., may also influence upon the decision of automatic or manual assembly as to its economic consideration. Secondly, Manual assembly is performed, if part characteristics are weak in transporting, arrangement, feeding, joining areas. In the present work, it was analyzed that whether assembly process can be automated or not. The processes that are determined by manual assembly are decided upon the method of transporting, arrangement, feeding and joining.

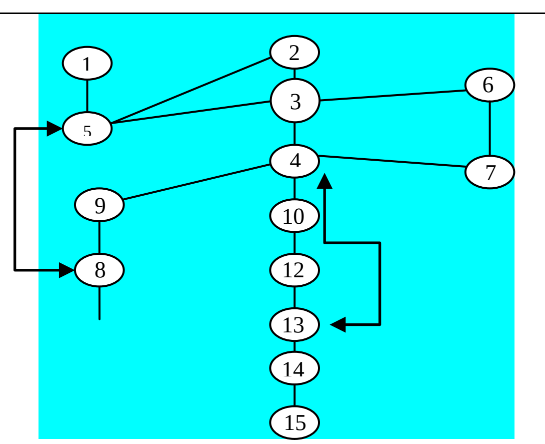

Fig. 1 : Product layout of processes before line balancing

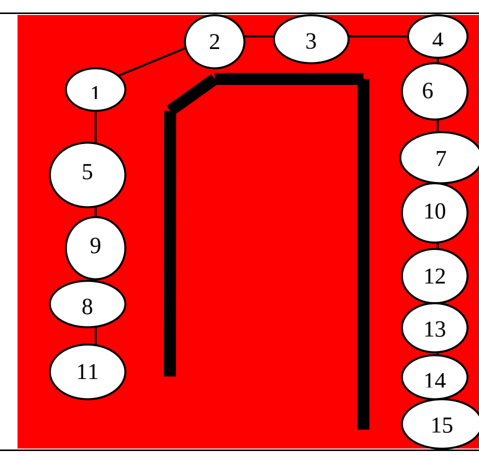

Fig. 2 : Product layout of processes after line balancing

Table 2 : Work allocation of each group

Production Volume: 100 / Month, Item: Feeder Frame									
Work er	Seque nce	Proce ss	Time	Distanc e	Worke r	Sequenc e	Proces s	Tim e	Dista nce
Group A = 7	1	2	12	2.3	Group C = 5	1	6	55	0.9
	2	3	27	1.5		2	7	20	1.2
	3	4	35	1.2		3			
	Sum		74	5.0		Sum		75	2.1
Group B = 5	1	1	20	1.0	Group D = 9	1	8	20	3.7
	2	5	25	0.7		2	11	12	0.7
	3	9	16	0.7		3	12	8	0.6
	4	10	10	1.0		4	13	15	1.2
	Sum		71	0.8		5	14	5	0.5
				4.2		1	15	20	2.5
						Sum		80	9.5
Unit	Time (Minutes) = 307		Distance (Meter) = 20.8		∑ **Worker = 26**				

Table 3 : Automation possibility of grease application

Determination of automation possibility of each area functional factor					
Transporting	Criteria	Degree	Arrangement	Criteria	Degree
	T1	-2		A1	0
	T2	-1		A2	-1
	T3	-2		A3	-2
	T4	-1		A4	-1
	Sum	-6		Sum	-4
Feeding	Criteria	Degree	Joining	Criteria	Degree
	F1	0		J1	+1
	F2	-1		J2	-1
	F3	-2		J3	+1
	F4	-1		J4	-1
	Sum	-4		Sum	0
Total Point = -14					
Legend: -2 = Very difficult, -1 = Difficult, 0 = Same, +1 = Easy, +2 = Very easy					

c) Determination of assembly equipment

After determination of automation possibility of each assembly process; the method and machine of transporting, arrangement and feeding were determined. Assembly machines and equipments are determined on only process that is performed by automation assembly. Assembly machines equipment is determined by characteristics of process. Therefore, this research is consisted of two numbers assembly; Bearing Placing Machine, Motor Pulley Coupling Tester Machine.

X. Work Allocation According to New Process Layout and Selection of Equipment

Actually, as observed there are coexistence forms of different layout in ABC industry. The required space to assembly lines of ABC Industry is 5700mm x 40000mm. In this space, it is impossible and inefficient that equipment like a straight line is determined. So, it has been chosen U-line like Fig.2 in order to efficient rationing and flexible production. The advantages of U-line are to improve line balancing and work efficiency with minimum space size with a free movement of worker in a coexistence of manual and automation line. A U- like shape platform was created for assembly, and an automatic hanging type Monorail system was erected for smooth advancing of the job with a provision of rotation of 3600. The monorail enabled the workers of Group B and C to assemble the components simultaneously after completion of the work of Group A. This reduces the idle time between B and C and ultimately the cost of adjoining group activities. The new process layout and selection of equipment were done in order to improve and optimize the line efficiency. The Table 4 represents the situations after line balancing study.

Table 4 : Work allocation of each worker after re-layout of process

Production Volume: 150 / Month, Item: feeder Frame									
Worker	Sequence	Process	Time	Distance	Worker	Sequence	Process	Time	Distance
Group A = 6	1	2	10	1.5	Group C = 5	1	6	30	
	2	3	21	1.0		2	7	12	
	3	4	30	1.2		3	10	20	2
	Sum		61	3.7		Sum		62	
Group B = 5	1	1	17		Group D = 5	1	7	15	
	2	5	17			2	11	12	
	3	9	12			3	12	8	
	4	8	10			4	13	10	
	5	11	8			5	14	5	
	Sum		64	2		1	15	15	2
						Sum		65	
Summary	Time (Minutes) = 252		Distance (Meter) = 9.7		**∑ Worker = 21**				

a) Comparison of status before and after Line Balancing

From the Table 2 and 4 it is evident that there are improvements in the assembly process. The cost is considered for 600 assemblies per annum. The cost has been calculated using Eqn. (15) and it has been tabulated in Table 5.

Table 5 : Comparison of before and after line balancing results

Sl No	Influencing factors	Before Line Balancing	After Line Balancing	Saving in Cost	% Saving
1	Time (min)	307	252	55	17.92
2	Distance (meter)	20.8	9.7	11.1	53.36
3	Worker	26	21	5	

b) Case study 2: Improvement in line efficiency

To study the line efficiency of link aggregate, the following points were taken into consideration.

- First, the item is regular and used in various models of Apron
- The quantities required are huge and
- The Contribution to the revenue generation of this product is 21.2% of the monthly sales.

The product has to go through the primary operations in the sequence as Cutting, Grinding, Rolling, Bending, Drilling, Sub Assembly and Welding and Boring. The sequence of final operation is Assembly, Welding, Cleaning, and Painting. Based on the available data (Table 6) the numbers of predecessors for each work element has been determined. Assignment of work elements to different stations is given in Table 7 following the Kilbridge – Wester Method.

Table 6 : Determination of number of predecessors for each work element in a feeder

Work element I	Number of predecessors	Time duration of the element Ti (Hrs)	Remark
1	0	5	
2	1	3	
3	2	4	
4	1	3	
5	2	6	
6	5	5	
7	6	2	
8	7	6	
9	6	1	
10	6	4	
11	7	4	
12	11	7	

Table 7 : Assignment of work elements to stations (Kilbridge – Wester Method), Cycle Time = 10 hrs

Station	Element I	Ti (Hrs)	Station sum (Hrs)	Idle time (Hrs)
I	1 2	5 3	8	2
II	4 5	3 6	9	1
III	3 6	4 5	9	1
IV	7 9 10	2 1 4	7	3
V	8 11	6 4	10	0
VI	12	7	7	3
Σ	**12**	**50**	**50**	**10**

Calculations:

The Line Efficiency (LE) = [{50 / (6 x 10)} x 100 %] = 83.3 %

Balance Delay = (100% - 83.3%) = 16.7 %

Smoothness Index = $\sqrt{4+1+1+9+9}$ = 4.89

Improvement in Line Balancing

In the light of study the Table 7 shows the methodology of reassignments of work elements in order to reduce idle time and balance the production line

Table 8 : Reassignment of work elements to stations (Kilbridge – Wester Method) for the improvement, cycle time = 9 Hrs

Station	Element I	Ti (Hrs)	Station sum (Hrs)	Idle time (Hrs)
I	1 2	5 3	8	1
II	4 5	3 6	9	0
III	3 6	4 5	9	0
IV	7 8	2 6	8	1
V	8 11	4 4	8	1
VI	9 12	1 7	8	1
Σ	**12**	**50**	**50**	**4**

Using Eqn. 2 to 4, The Line Efficiency (LE) = [{50 / (6 x 9)} x 100 %] = 92.6 %

Balance Delay = (100% - 92.6%) = 7.4 %

Smoothness Index = $\sqrt{1+1+1+1}$ = 2

XI. Results and Discussion

The results on empirical investigation of assembly line balancing are presented in Table 9. It shows that there is considerable improvement in LB. All the assembly items were regrouped into different stations and the above analysis were repeated. Then on the basis of the analysis it was decided as to how to put these items into different stations to have minimum optimal idle time, better line efficiency and minimum delay. The summary of improvements have been presented in Table 10.

Table 9 : Results on empirical investigation of assembly line balancing

Table Nos.	Line Efficiency %	Balance Delay %	Smoothness Index	Average Cycle time Reduction (Min)
Table 7	83.3	16.7	4.89	
Table 8	92.6	7.4	2	4.8
Difference %	9.3	9.3	2.89	

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Table 10 : Summary of improvements in line balancing, average smoothness and average

Sl No	Category of Assembly Items	Average Line Efficiency %		Average Smoothness Index		Average Cycle Time (Hrs)	
		Before LB	After LB	Before LB	After LB	Before LB	After LB
1	Buckets	81.2	89.6	4.77	3.11	8	6.25
2	Housings	78.5	91.8	5.95	2.23	4	3.15
3	Feeder frames	83.7	92.4	4.52	3.1	6.3	5.4
4	Revolving Frames	84.4	91.3	5.36	3.7	12	9.5
5	Couplings	87.7	95.5	3.8	2.9	9	6.25
6	Arm	78.5	89.6	4.88	3.25	18	16
7	Boom	80.65	89.95	5.01	3.55	23.5	21
8	Gears	82.5	92.7	4.87	2.10	4	3.1
9	Bodies	76.8	91.45	5.37	2.12	14	11

XII. Test of Statistical Significance

Let the data, presented in Table 10, before Line balancing be x and after line balancing be y. Now, the t-test has been conducted because related data, before and after lines balancing, are independent in nature.

Null Hypothesis H_0:

$\mu_x = \mu_y$ i.e. there is no significant difference between the mean increase in line efficiency.

Alternate Hypothesis H0:

$\mu_x \neq \mu_y$ (Two Tailed)

Table 11 : Generation of data to compare Line efficiency statistically

Sl No	x	$x - \bar{x}$	$(x - \bar{x})^2$	y	$y - \bar{y}$	$(y - \bar{y})^2$
1	81.2	-0.35	0.1225	89.6	-1.99	3.9601
2	78.5	-3.05	9.3025	91.8	0.21	0.0441
3	83.7	2.15	4.6225	92.4	0.81	0.6561
4	84.4	2.85	8.1225	91.3	-0.29	0.0841
5	87.7	6.15	37.8225	95.5	3.91	15.2881
6	78.5	-3.05	9.3025	89.6	-1.99	3.9601
7	80.65	-0.9	0.81	89.95	-1.64	2.6896
8	82.5	0.95	0.9025	92.7	1.11	1.2321
9	76.8	-4.75	22.5625	91.45	-0.14	0.0196
Mean	81.55	0.00	93.57	91.59	-0.01	27.9339

From the Table 11,

Mean value of x, $\bar{x} = 81.55$.

Mean value of y, $\bar{y} = 91.59$,

No. of data of mean values of x, $n_1 = 9$,

No. of data of mean values of y, $n_2 = 9$,

$$S^2 = \frac{1}{n_1 + n_2 - 2}[\sum(x-\bar{x})^2 + \sum(y-\bar{y})^2] = 7.594$$

Where, S = An unbiased estimate of the common population Variance σ^2

Under Null Hypothesis, H_0:

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$$t = [(\bar{x} - \bar{y}) / \{\sqrt{S^2}(\frac{1}{n1} + \frac{1}{n2})\}] \sim t\, n_1 + n_2 - 2 = -10.04$$

Where, t denotes the value of t-test.

Tabulated t at 5% level of significance is 2.12. Since, calculated t is less than tabulated t at 5% level of significance. Hence it may be concluded that Line efficiency x and y differ significantly. Further, $\bar{y} > \bar{x}$. Hence, Line efficiency y is superior to x.

XIII. Conclusions

The field of assembly line balancing has been vigorously researched in recent decades. Some of these innovations include parallel treatment of workers, tasks with stochastic durations, multiple objectives (minimum crew, maximum probability of on-time completion and minimum design cost), and mixed-models for JIT systems. Complexity and suitability of automated assembly is also a deciding parameter in this regard. Plant layout is one of the vital aspects in improving the utility of plant spaces. It facilitates smooth functioning of various activities in a limited space. In Small Scale Industries, particularly when there is a constraint of space U-line layout should be preferred.

On the basis of the reported case studies, it can be concluded that Line balancing improves the product quality and productivity along with an improvement in line efficiency. Proper Line Balancing reduces worker's movement and thereby assembly time and minimizes the product cost.

References Références Referencias

1. Becker C. and Scholl, A.(2004), "A Survey on Problems and Methods in Generalized Assembly Line Balancing," European Journal of Operations Research,.
2. Becker, C. and Scholl, A.(2003), "A Survey on Problems and Methods in Generalized Assembly Line Balancing," European Journal of Operations Research,
3. Scholl, A. and Becker, C.(2003) "State-of-the-Art and Heuristic Solution Procedures for Simple Assembly Line Balancing," European Journal of Operation Research,
4. Askin, R.G. and Zhou, M.(1997), "A Parallel Station Heuristic for the Mixed-Model Production Line Balancing Problem," International Journal of Production Research, Vol.35, pp.3095–3106.
5. Gocken, H. and Erel, E. (1998) "Binary Integer Formulation for the Mixed-Model Assembly Line Balancing Problem," Computational. Industrial. Engineering. Vol.23, pp.451–461.
6. Gocken, H. and Erel, E. (1997), "A Goal Programming Approach to the Mixed-Model Assembly Line Balancing Problem,". International Journal of Production Economics, Vol.48, , pp.177–185
7. Vilarinho, P.M. and Simaria, A.S. (2002), "A Two-Stage Method for Balancing Mixed-Model Assembly Lines with Parallel Workstations," International Journal Production Research, Vol.40, Pp.1405–1420.
8. Merengo, C., Nava, F. and Pozzetti, A. (1999), "Balancing and Sequencing Manual Mixed Model Assembly Lines,"International Journal Production Research," Vol.37, pp.2835–2860.
9. Rekiek, B., Delit, P. and Delchambre, A. (2000), "Designing Mixed-Product Assembly Lines," IEEE Transactions. Robot. Automation, Vol.16, pp.268–280.
10. Bukchin, J. and Rubinovitz, J. (2002), "A Weighted Approach for Assembly Line Designs with Station Paralleling and Equipment Selection," IIE Transactions, Vol.35, pp.73–85.
11. Ponnambalam, S.G., Aravindan, P. and Mogileeswar Naidul, G. (2000), "A Multi-Objective Genetic Algorithm for Solving Assembly Line Balancing Problem," International Journal of Advanced. Manufacturing. Technology, Vol.16, pp.341–352
12. Falkenauer, E. and Delchambre, A.(1992), "A Genetic Algorithm for Bin Packing and Line Balancing," IEEE International Conference Proceedings 1992 on Robotics and Automation,May10-15,Nice, France. IEEE Computer Society Press, Los Alamitos, CA. pp. 1186-1192.
13. Salveson, M.E. (1955), "The Assembly Line Balancing Problem," Journal of Industrial Engineering, Vol.6, pp. 62-69.
14. McMullen, P.R. and Frazier, G.V.(1998), "Using Simulated Annealing to Solve A Multi Objective Assembly Line Balancing Problem with Parallel Workstations," International Journal Production Research, Vol.36, pp.2717–2741
15. Kirkpatrick, S., Gelatt, C.D. and Veechi, M.P. (1983), "Optimization by Simulated Annealing," Science, Vol. 220(4598), pp.671–679.
16. Glover, F. (1990), "Tabu Search: A Tutorial," Interfaces, Vol.20, pp.74–94.
17. Goldberg, D.E.(1989), "Genetic Algorithms in Search, Optimization and Machine Learning," Reading, MA, Addison-Wesley,
18. Dorigo, M. and Gambardella, L.M. (1997) "Ant Colonies for the Traveling Salesman Problem,". Biosystems, Vol.43, ,pp. 73–81
19. Chase, R.B. (1974), "Survey of Paced Assembly Systems," Industrial Engineering, Vol.6, pp. 82-90.
20. Milas, G., (1990), "Assembly Line Balancing: Let's Remove the Mystery," Industrial Engineering, Vol. 22, pp. 12-18
21. Tsujimura, Y., Gen, M., and Kubota, E. (1995), "Solving Fuzzy Assembly-line Balancing Problem

with Genetic Algorithms," Computers and Industrial Engineering, Vol.29, pp. 62-69.

22. Gen, M., Tsujimura, Y., and Li, Y. (1996), "Fuzzy Assembly Line Balancing Using Genetic Algorithms," Computers and Industrial Engineering, Vol.31, pp. 49 -52.

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Robust Optimization of Fins by Taguchi Technique

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Abstract - "The sole aim of any design optimization technique is price and performance. In case of fins the optimization of price is concerned with minimum material requirement with improved temperature drop in terms of performance". In analytical or conventional optimization techniques, involved design parameters are related to each other in mathematical model, in form of ordinary/partial differential equation. If the design variables are such that they cannot be related mathematically then a mathematical model cannot be prepared and none of the classical design optimization techniques can be applied for solving the problem but Taguchi technique can account for such case. The application of mathematical optimization technique in case of fins involving parameters such as surface finish, effect of duct, bending, etc will be difficult to relate with the fins performance in a mathematical model. Over coming to this major limitation of classical techniques Taguchi method does not only account such variables but also provide robust optimization. Advantageously the method provides percent contribution of each variable/parameter for optimization of objective function.

Keywords : Robust Design, Taguchi philosophy, Fractional Factorial experiment, Orthogonal array, Optimization of fin.

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ROBUST OPTIMIZATION OF FINS BY TAGUCHI TECHNIQUE

Strictly as per the compliance and regulations of:

Robust Optimization of Fins by Taguchi Technique

Yash Mehta [α], Vimlesh Patel [α], Ms Priyanka Pathak [σ] & Dr. S.K. Dhagat [ρ]

Abstract - "The sole aim of any design optimization technique is price and performance. In case of fins the optimization of price is concerned with minimum material requirement with improved temperature drop in terms of performance".

In analytical or conventional optimization techniques, involved design parameters are related to each other in mathematical model, in form of ordinary/partial differential equation.

If the design variables are such that they cannot be related mathematically then a mathematical model cannot be prepared and none of the classical design optimization techniques can be applied for solving the problem but Taguchi technique can account for such case.

The application of mathematical optimization technique in case of fins involving parameters such as surface finish, effect of duct, bending, etc will be difficult to relate with the fins performance in a mathematical model. Over coming to this major limitation of classical techniques Taguchi method does not only account such variables but also provide robust optimization. Advantageously the method provides percent contribution of each variable/parameter for optimization of objective function.

Taguchi techniques are Fractional Factorial experimental design techniques and use standard 'Orthogonal Arrays' of Fisher[1] for forming a matrix of experiments in such a way as to extract maximum important information with minimum number of experiments.

Economic performance of *fins* is not proportional to surface area but is proportional to effective surface area.

Keywords : Robust Design, Taguchi philosophy, Fractional Factorial experiment, Orthogonal array, Optimization of fin.

I. Introduction

Taguchi built upon W. E. DEMING's[2],[3] observation that 85% of poor quality is attributed to the manufacturing process and only 15% to the worker. Quality and hence performance improvement start at very beginning. He proposed "Offline" strategies.

During 1940s Genichi Taguchi[4] has developed new statistical concepts of optimization tool which has been widely used in management and quality related optimization problem. In recent years it has been successfully implemented for the optimization of technical problems. Some of them are reported here:-

1. Optimization of preload on bolts [5]
2. Engine valve train noise study [2]
3. Study of crankshaft surface finish process[2]
4. Case study of Electrostatic powder coating process optimization[6]

Although the thermal optimization has been carried out conventionally (Hyung Suk Kang)[7] an attempt has been made here in implementation of Taguchi technique on optimization of fins.

Analysis of heat flow in the finned surface in conventional optimization is made on following assumptions[8],[9] :-

- Temperature gradient over the cross sections is neglected and the heat transfer is treated as one- dimensional.
- Uniform heat transfer coefficient over the entire fin surface.
- Spacing between fins has no significant effect on heat dissipation rate.
- Negligible radiation exchange with the surrounding and other fins.
- Temperature gradient along the width remains constant.
- Perfect steady state heat dissipation.
- Material properties remain constant with the variation of temperature.

Since in Taguchi technique experiments are performed in ground situation hence 'Robust Optimization[10],[11]' is achieved eliminating the list of assumptions involve.

In analytical optimization it is assumed that rate of heat dissipation is double by doubling the number of fins but during practical observation such was not the case.

The expected cause is strong interaction[*] between different physical variables that has not been accounted in formulation of differential equation. But Taguchi technique provides percentage contribution of this interaction which may be some time more important than physical variables itself.

II. Problem Statement

a) Robust optimization of fins by Taguchi technique

Step1: conceptualization of the problem and formulation of measurable target quantity

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Author ρ : Professor Mechanical Engg. SSTC Bhilai.

Conceptualization: - Following observations are made during formulation of problem statement.

1. The conventional fin (fig 1) has certain zone which shows insignificant temperature drop along with length that's appear in (fig 3) as center duct after removal of that zone.
2. Experimentally parabolic fins (fig2) are comparatively better than other shape for ratio of heat transfer to mass required. But the major limitation of such type of fins is that its performance is less than conventional fin for same length.
3. Contrary to theoretical parabolic it is not curved out exactly from the base (fig2) but away from the base to certain length (c) (fig4), experimentally better results were obtained.
4. Combination of above observations and redefining the parabola yields fins of (fig 4) which has been further optimized by Taguchi technique for close tolerance.

Here the temperature drop (ΔT) is measurable target quantity which is difference between temperatures at base and tip of fin.

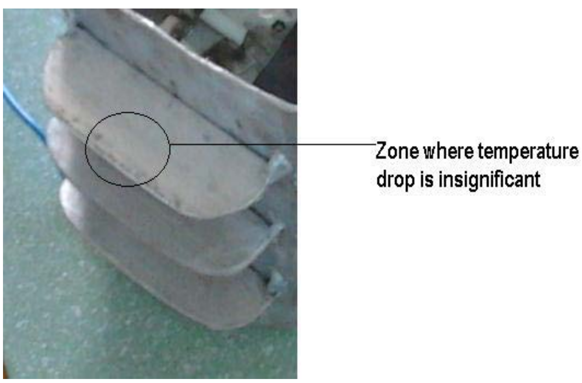

fig1

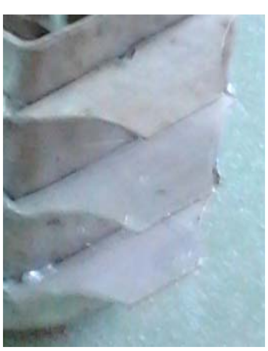

fig2

fig3

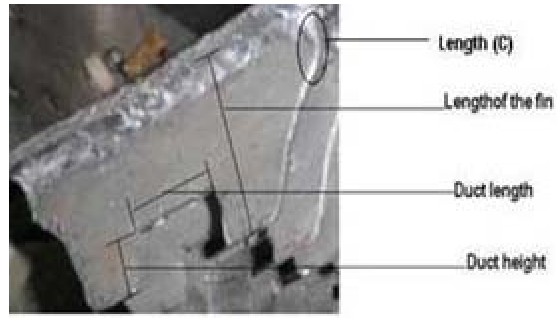

fig 4

Step2: Selection of parameters

Table 1.1 : Planning and Carrying Out Experiments:-

Factor No.	Factor Specification	Factor Level1	Factor Level2
1	B : BEND	B1 : SIMPLE	B2 : BEND
2	L : LENGTH	L1 : 36mm	L2 : 30 mm
3	L × B	-------	------
4	H:DUCT HEIGHT	H1 : 10mm	H2 : 15 mm
5	N : No. of FINS	N1 : 7	N2 : 4
6	L × H	-------	------
7	l : DUCT LENGTH	l1 : 26 mm	l2: 34

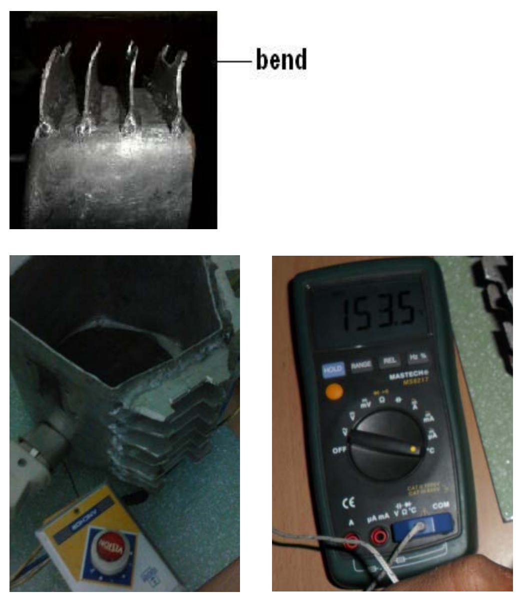

Fig 5

Step 3: In full factorial experimentation with 7 parameters and 2 levels of each would require $2^7 = 128$ number of experiments. But applying Dr. Taguchi's L_8 series only 8 set of experiments are required. And hence maximum information is extracted from minimum number of experiments.

∗Interaction –The mutual action between physical variables that may give entirely different resultant then expected one, if both are not fully independent.

Table 1.2 : L_8 (2^7) Series with allocated interaction(*)

	Factor								
Experiment	**Bend (B)**	**Length(L)**	**B x L** interaction	**Height(H)**	**No. Of Fins(N)**	**L x H** interaction	**Duct Length**	**Result (Temperature drop °C)**	**Target (Y_i)**
Trial 1	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3.05**	**305**
Trial 2	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**3.3**	**330**
Trial 3	**1**	**2**	**2**	**1**	**1**	**2**	**2**	**2.5**	**250**
Trial 4	**1**	**2**	**2**	**2**	**2**	**1**	**1**	**3.10**	**310**
Trial 5	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**3.63**	**363**
Trial 6	**2**	**1**	**2**	**2**	**1**	**2**	**1**	**2.94**	**294**
Trial 7	**2**	**2**	**1**	**1**	**2**	**2**	**1**	**2.9**	**290**
Trial 8	**2**	**2**	**1**	**2**	**1**	**1**	**2**	**2.21**	**221**
								Total(∑Y)	**=2363**

Step4: Calculation of average effect of parameters:-

$$\sum B1 = \frac{305+330+250+310}{4} = 298.75$$

$$\sum (B\times L)_1 = \frac{305+330+290+221}{4} = 286.5$$

Similarly, effect of other parameters are tabulated in table 1.2

$\sum B2 = 292$ $\sum L1 = 323$ $\sum L2 = 267.75$

$\sum N1 = 267.5$ $\sum N2 = =323.25$ $\sum (L\times H)_1 = 299.75$

$\sum (L\times H)_2 = 291$, $\sum l1 = 299.75$, $\sum l2 = 291$, $\sum (B \text{ X } L)_2 = 304.25$

Table 1.2 : Main Effect Table

Serial No.	Main Effect	Level 1(Le_1)	Level 2(Le_2)	Le_2-Le_1
1	B	298.75	292	-6.75
2	L	323	267.75	-55.25
3	B × L	286.5	304.25	17.75
4	H	302	288.75	-13.25
5	N	267.5	323.25	55.75
6	L × H	299.75	291	-8.75
7	L	299.75	291	-8.75

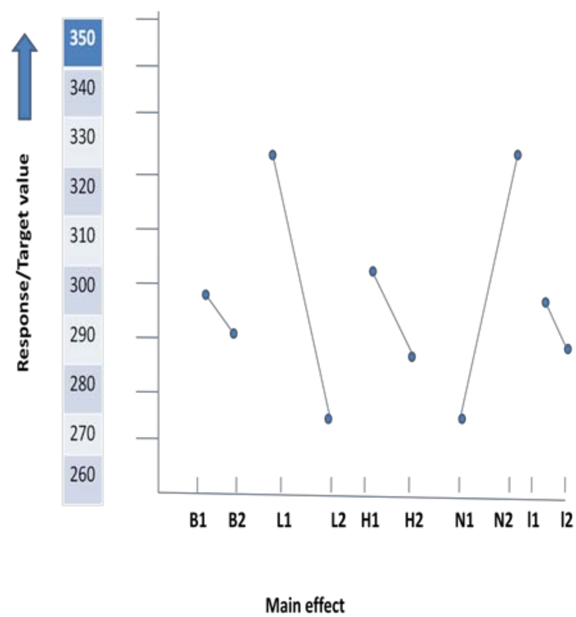

Fig 6

Average effect of Interaction:-

$$B_1 L_1 = (305+330)/2 = 317.5$$

(*) Allocation of interaction:-Dr. Taguchi has already defined the rules forfff for positioning the interactions and common variable (here L)

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Similarly,

$H_1 L_1 = 334$

$B_1 L_2 = 280$ $H_2 L_1 = 312$

$B_2 L_1 = 328.5$ $H_1 L_2 = 270$

$B_2 L_2 = 255.5$ $H_2 L_2 = 265.5$

The interaction diagram below indicates there exist strong interaction between bend (B) and length (L).Whereas the interaction between duct height (H) and length (L) is limited or weak.

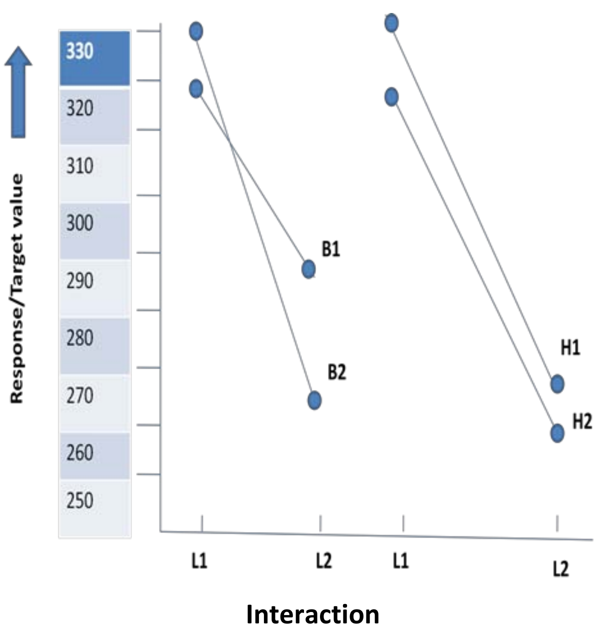

fig7

Step 5 : ANOVA (Analysis of variance)

Step 5.1 : Total of all result:-

$$\sum Y = T = 2363$$

Step 5.2 : Procedure of ANOVA

$\mathbf{CF} = \frac{T^2}{n}$ where n is the number of experiments

$$CF = \frac{2363^2}{8} = 637971.125$$

*Step 5.3 :*Total sum of Square

$$S_T = \sum_{i=1}^{8} Y_i^2 - CF$$

$$S_T = (305^2+330^2+250^2+310^2+363^2+294^2+290^2+221^2)-(697971.125)$$

$$S_T = 13699.875$$

Step 5. 4 : Factor sum of square

$$S_B = \frac{(\sum B_1)^2}{n_{A1}} + \frac{(\sum B_2)^2}{n_{A2}} - CF$$

$$S_B = \frac{(1195)^2}{4} + \frac{(1168)^2}{4} - 697971.125 = 91.125$$

$$S_{B\,X\,L} = \frac{(1146)^2}{4} + \frac{(1217)^2}{4} - 697971.125 = 630.125$$

Similarly,

$S_L = 6105.125$ $S_H = 351.125$ $S_N = 6216.125$

$S_{H\,X\,L} = 153.125$ $S_I = 153.125$

Step 5.5 : Total and Factor degree of Freedom

DOF total = No. of Experiment – 1

$$f_T = n\text{-}1 = 8\text{-}1 = 7$$

$$f_B = \text{No. of Level -1} = 2\text{-}1 = 1$$

Similarly,

$$f_L = f_H = f_N = f_I = 2\text{-}1 = 1$$

$$f_{H\,X\,L} = 1 \,X\, 1 \qquad f_{B\,x\,L} = 1 \text{ X } 1$$

Degree of error term up till $f_e = f_T$-(f_B +f_L+ f_H + f_N+ $f_{H\,X\,L}$+ $f_{B\,x\,L}$+ f_I) = 7-7 = 0

With the error degree of freedom equal to zero,

$$f_e = 0.$$

Information regarding the error sum of square cannot be determined. In addition F ratios for factor cannot be calculated since the calculations involve f_e ,(pooled) to form a new nonzero estimate of the error term.

Step 5.6 : Mean square (variance)

$$V_B = \frac{S_B}{f_B} = \frac{91.125}{1} = 91.125 \qquad V_{B\,X\,L} = \frac{S_{B\,X\,L}}{f_{B\,X\,L}} = 630.125$$

Similarly,

$V_L = 6105.125$ $V_H = 351.125$ $V_N = 6216.125$

$V_{H\,X\,L} = 153.125$ $V_I = 153.125$

$V_e = \frac{S_e}{f_e} = \frac{0}{0}$ = indeterminate form.

As the variance of error term V_e is zero. The Variance ratio and pure Sum of Square S' cannot be calculated. Following method is adapted to recalculated percentage contribution.

Step 5.7 : Intial percentage contribution :-

$$P_B = \frac{S_B}{S_T} = \frac{91.125}{697971.125} = 0.66\%$$

$$P_{B\,X\,L} = \frac{S_{B\,X\,L}}{S_T} = \frac{630.125}{697971.125}\ 4.6\%$$

$P_L = 44.56\%$ $P_H = 2.56\%$

$P_{H\,X\,L}1.11\%$ $P_N = 45.37\%$ $P_I = 1.11\%$

P_e cannot be calculated since V_e is zero.

ANOVA Table 1.4

Column	Factor	*f*	S	v	P
1	Factor B	1	91.125	91.125	0.66%
2	Factor L	1	6105.125	6105.125	44.56%
3	Interaction BXL	1	630.125	630.125	4.6%
4	Factor H	1	351.125	351.125	2.56%
5	Factor N	1	6216.125	6216.125	45.37%
6	Interaction BXH	1	153.125	153.125	1.11%
7	Factor I	1	153.125	153.125	1.11%
All other error	0	0	0	0	100%
Total			13699.875		

Step 6 : Pooling (*) :-

The effect of factor B is less than unity(0.66% only), Hence this factor is pooled to obtained non zero Estimates of S_e and f_e.

Step 7 Sum of Square of Error :

Let , $S_e = S_T - (S_L + S_{B\,X\,L} + S_H + S_N + S_{H\,X\,L} + S_I)$

$= 13699.875 -$

$(6105.125+630.125+351.125+6216.125+153.125+153.125)$

$S_e = 91.125$

Degree of freedom of error term

$f_e = f_T - (f_L + f_{B\,X\,L} + f_H + f_N + f_{H\,X\,L} + f_I)$

$= 7-(1+1+1+1+1+1)$, $f_e = 1$

Variance of error term

$$V_e^{(\Delta)} = = \frac{S_e}{f_e} = \frac{91.125}{1} = 91.125$$

Step 8 : F ratio of significant factors

$$F_L = \frac{V_L}{V_e} = \frac{6105.125}{91.125} = 66.99$$

$$F_{B\,x\,L} = \frac{V_{B\,x\,L}}{V_e} = \frac{630.125}{91.125} = 6.914$$

$F_H = 3.85$ $F_N = 68.21$ $F_{Hx\,L} = 1.68$

$$F_I = \frac{V_I}{V_e} = \frac{153.125}{91.125} = 1.68$$

Pure Sum of Square S', for significant figure

$$S'_L = S_L - (V_e\ X\ f_L)$$

$=6105.125-(91.125 \times 1) = 6014$

(*)Pooling – pooling means elimination of factors having insignificant % contribution.

(Δ) Compare the new variance and new percentage contribution of error term with the results of without pooling

Similarly,

$S'_{B\,x\,L} = 539$ $S'_{H} = 260$ $S'_{N} = 6125$ $S'_{H\,x\,L} = 62$ $S'_{l} = 62$

Step 9 : New Percent contribution

$$P_L = \frac{S'_L}{S_T} = \frac{6014}{13699.875} = 43.9\%$$

$$P_{B\,x\,L} = \frac{S'_{B\,x\,L}}{S_T} = \frac{539}{13699.875} = 3.93\%$$

$P_H = 1.9\%$ $P_N = 44.7\%$ $P_{H\,x\,L} = 0.45\%$ $P_l = 0.45\%$

$$P_e^{\Delta} = 100\% - (43.9+3.93+1.9+44.7+0.45+0.45)$$

$= 4.67\%$

From F Table .find the F valve at

n_1 = DOF of factor L = 1

n_2 = DOF of Error term=1

At a confidence level of 90% (confidence level)

F_L = 39.864 (from F table)

As F_L from experiment (66.99) is larger than F Table

Value (39.864) the factor L is not needed to be pooled.

Pooled ANOVA Table 1.5

Step10 : Estimated Result at Optimum condition

Pooled factor are not included in the estimate.

Grand average performance: $T = \frac{2363}{8} = 295.375$

As the Factor L, BXL, H, HXL, N, l are significant

$$= \bar{T} + (\bar{L}1 - \bar{T}) + (\overline{B\,X\,L})_2 - \bar{T} + (\bar{H}1 - \bar{T}) + (\bar{N}2 - \bar{T}) + (\overline{B\,X\,L})_1 - \bar{T}) + (\bar{l}1 - \bar{T})$$

=295.375+(323-295.375)+(304.5-295.375)+(302-295.375)+(323.25-295.375)+(299.75-295.375)+(299.75-295.375)

=375.125

III. Conclusion

- Note the optimum condition for the “higher the better”
  Configuration i.e. higher is the temperature drop better is the performance.
  Following are the opted specifications: -

  B_2 bend
  L_1 36 mm
  H_1 10mm
  N_2 4
  l_1 26mm

- From the calculation the percentage contribution of duct length (l) is less than unity hence this particular parameter can be adjusted according to economic consideration without affecting the performance to larger extent, hence opt l_2.
- In theoretical problems the performance of single fin (in terms of rate of heat dissipation) is multiplied with number N (where N is number of fins involved), to get the cumulative performance of N number of fins. But the experiment suggest so is not the case, because N as a parameter has only 78% contribution in the cumulative result. (Shown in fig).
- The duct and the shape have peculiar effect (cornering effect) in the governing of heat dissipation, in which even after reducing the surface area in (certain zone) comparable performance has been achieved. In this particular experiment the one fact reveled is percentage contribution of interaction is more than individual parameter (for bending) and but it is difficult to point out this effect in conventional method.
- (a) If 4 conventional fins are compared with 4 optimized fins by this experiment then 22 % cost saving can be achieved with improved performance.
  (b) if performance of 7 conventional fins is compared with 4 optimized fins them primary calculation indicate that at the expense of 32% of the performance up to 55% cost can be saved.

The pie chart shown below represents the percentage contribution of each parameter including interactions on temperature drop.

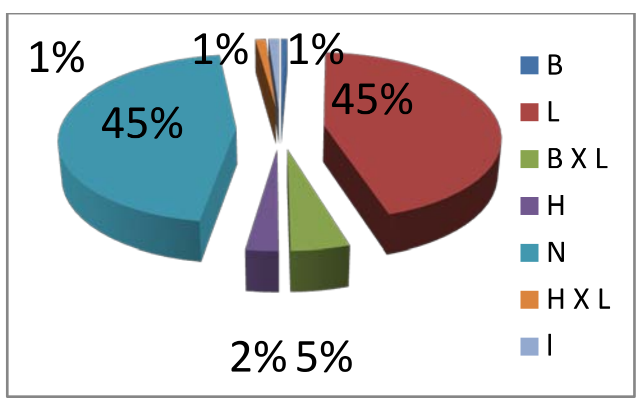

Fig 8

IV. Scope

With more number of parameters, (including more number of possible interactions) and higher series of orthogonal arrays such as L_{16} (4^5),L_{18} (2^1 x 3^7), L_{27} (3^{13}), L_{32} (2^1 x 4^9) series, further refinement can be carried out.

Advantages of the Taguchi techniques

1) The Taguchi techniques are applicable for both type problems for which mathematical modeling is possible and for which formation of ordinary/partial differential equation is not possible.
2) Advantageously over full factorial experimental optimization techniques maximum information is extracted with minimum number of experiments.
3) Mathematical modeling is not required.
4) Being a fractional factorial method and use of orthogonal arrays ensures minimum time and minimum cost of experimentation.

Disadvantages of the Taguchi techniques

1) All the possible interactions amongst the parameters cannot be studied as this technique is not based on full factorial method.
2) Number of levels for the design variables and parameters are required to be assumed to capture the true nature of variation of the variables and parameters.
3) Positioning hinders the repetition of experiment involving interaction.

V. Abbreviation & Symbols

- B, L, H - variable used in design of an experiments
- C.F.- Correction factor
- e- experimental error
- f, n- Degree of freedom(DOF)
- F- variance ratio
- N- The number of experiments
- P-The percent contribution of variable
- S- The sum of squares
- S'- The net/pure sum of squares
- T- The sum of observations
- V- the variance (mean square ,s/f)
- Y- Result measured in terms of quality characteristics example Height, duct length, length, etc.
- V_e- Variance of error terms

References Références Referencias

1. Ronald Aylmer Fisher 'The Design of Experiments '(1935) ISBN 0-02-844690-9
2. Ranjit Roy, 'A primer on the Taguchi method' , Van Nostrand Reinhold International company Limited, London EC4P 4EE, England,1990
3. 'M Mahajan' ,'Statistical quality control' Dhanpat Rai Publication ,Delhi, , Reprint 2011 p. 65
4. Genichi Taguchi, Subir Chowdhury, Shin Taguchi, 'Robust engineering' Tata Mac-Graw Hill, New Delhi , 2004
5. Mr. Kelkar Satej Sudhakar, 'A review on Taguchi Technique' Assistant Professor, Dept of Mechanical Engg, Jaywantrao Sawant College of Engg. Hadapsar, Pune28, Satej_kelkar@yahoo.com
6. 'Case study of Electrostatic powder coating process optimization'- Nutek Inc. 3829 Quarton Road Bloomfield Hills, Michigan 48302, USA.
7. Hyung Suk Kang 'Optimization of a Triangular Fin with Variable Fin Base Thickness' International Journal of Computational and Mathematical Sciences 1;3 © www.waset.org Summer 2007
8. Frank P. Incropera, David P. Dewitt, 'Fundamentals of heat and mass transfer' John Wiley & Sons, 5th edition 2002,p.128-129.
9. Dr. D S Kumar 'Heat & Mass Transfer', S. K. Kataria & Sons, Reprint 2004-2005,p.5.2-5.3
10. M. S. Phadke ,'Fundamental introductions to Taguchi method', Inc. © 2010 by PhadkeAssociates, please visit www.PhadkeAssociates.com
11. C. Zang a, M.I. Friswell a, J.E. Mottershead ba 'A review of robust optimal design and its application in dynamics', Department of Aerospace Engineering, University of Bristol, Queen's Building, Bristol BS8 1TR, United Kingdom Department of Engineering, University of Liverpool, Brownlow Hill, L United Kingdom Received &accepted 13 November, 2003 -04.

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Tensile Behavior of Cryorolled Zircaloy-2

By P.Aditya Rama Kamalanath & Apu Sarkar
N.I.T.Warangal, Warangal, India

Abstract - Zircaloy-2 is mainly used in nuclear technology, as cladding of fuel rods in nuclear reactors, especially water reactors (BWRs). Hence high strength of Zircaloy-2 is of prime importance. This investigation deals with the effect of cryorolling on Zircaloy-2 by comparing different tensile properties. For this analysis, four samples with various degrees of cryorolling are taken and tensile tests are conducted on these samples. The obtained results are analyzed and the optimum degree of cryorolling of Zircaloy-2 is obtained. The cryorolling improved the mechanical properties of the material as the dislocations are entangled near the grain boundaries and also due to decrease in the grain size. The microstructure of the sample is analyzed by optical microscope, before and after cryorolling and the grain structure analysis is done.

Keywords : Zircaloy-2, Cryorolling, Entanglement of dislocations, Dynamic recovery, Degree of cryorolling.

GJRE-A Classification : FOR Code: 091308

TENSILE BEHAVIOR OF CRYOROLLED ZIRCALOY-2

Strictly as per the compliance and regulations of:

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I. Introduction

Zirconium has very low absorption cross-section of thermal neutrons, high hardness, ductility and corrosion resistance. Hence its alloys are mainly used in nuclear reactors for the cladding of fuel rods. Zircloy-2 is one such alloy which is mainly used in boiling water reactors(BWR). In the recent past, water reactors of higher capacity are being developed .In the late 1990s GE Hitachi(GEH) and Toshiba has produced advansed boiling water reactor(ABWR). The standard ABWR plant design has a net output of about 1350 MWe (3926 MWth). Various tests are being conducted on zircaloy-2 at such high burn-up[1], and while the zircaloy-2 cladding has had a very good track record of safe use in nuclear reactors, the material becomes susceptible to failure over long times for the above ABWRs at such high burn-up. As a result, fuel rods are often taken out of service even though they may have a substantial amount of fuel remaining to produce energy[2]. So methods which increase the strength of zircaloy-2 without decreasing its ductility and corrosion resistance are being explored.

Cryorolling, deformation at cryogenic temperature is proved to be effective method for increasing the yield strength and tensile strength for various Al alloys[3],[4]. So this technique is implemented on zircaloy-2. Also optimum degree of cryorolling for zircaloy-2 is also found in this investigation.

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II. Experimental Procedure

Process of cryorolling: The samples are dipped in LN2(liquid nitrogen) for 10min before first pass and 2 min for each pass, sample was found to attain nearly -160^{0}C. The process is controlled by microprocessors in order to avoid thermal shocks and also damage to the components.

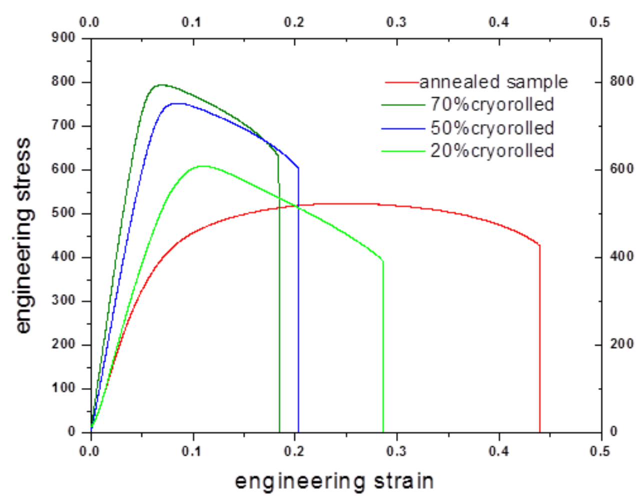
Here in cryorolling as the material cools its molecular structure contracts and hence there is entanglement of dislocations near the grain boundaries.

The samples are cryorolled up to three degrees of rolling (leaving the annealed sample) .One up to 20%; another to 50%: and the last one up to 70% of cryorolling.

Then the material is tested by tensile testing machine and the testing data is supervised by blue-hill software to get the required data of the material.

Then graphs are simulated using the data obtained for both annealed sample and cryorolled sample using ORIGIN PRO software.

III. Results and Discussion

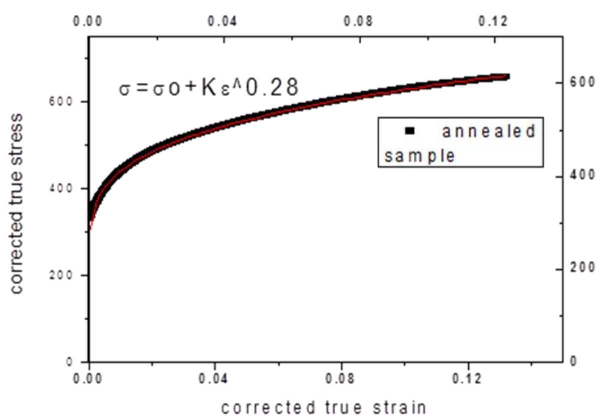


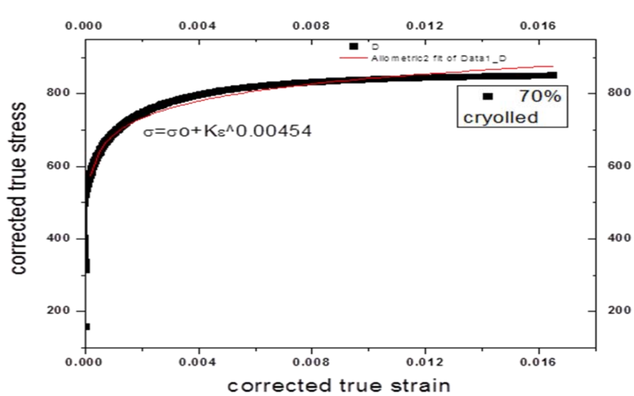
This shows that the Yield stress and the Ultimate tensile stress of the sample increases with the % of cryorolling.

a) The values obtained from the graph are

	Annealed sample	20% cryorolled sample	50% cryorolled sample	70% cryorolled sample
Yield stress	381 MPa	496.5 MPa	668.9 MPa	732.3 MPa
Ultimate Tensile stress	523.26 MPa	609.5 MPa	753.5 MPa	795.9 MPa
e_u	0.23	0.106	0.083	0.07

b) Strain Hardening curve

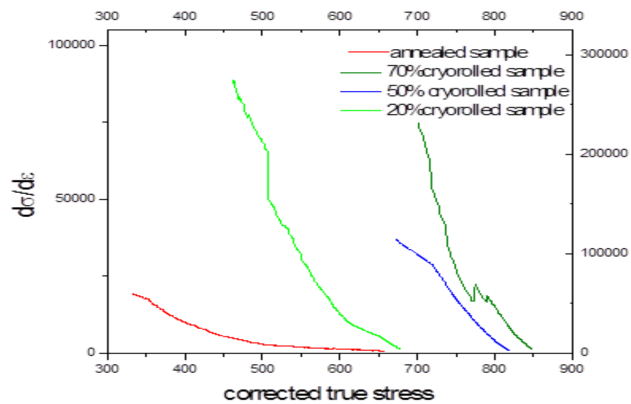




It is found that the value of n is found to decrease from the annealed sample to 70% cryorolled sample indicating that the mean free path of the dislocations has decreased with cryorolling due to their increasing density.

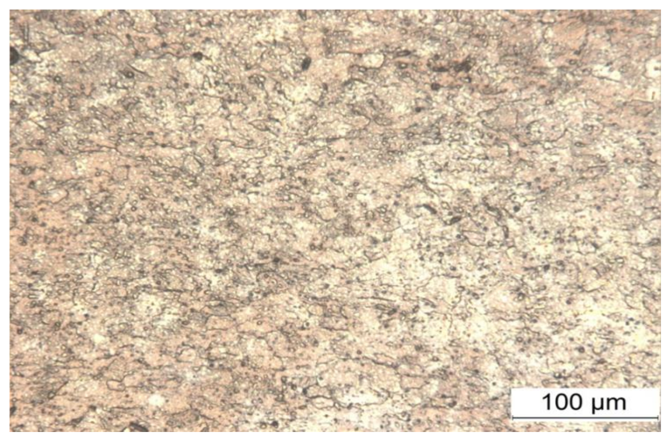
	Annealed Sample	20% cryorolled	50% cryorolled	70% cryorolled
n	0.28	0.04	0.019	0.004

c) Work hardening

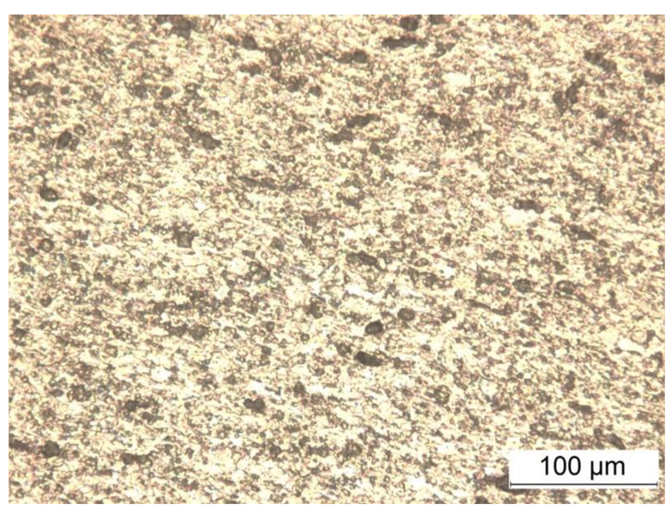


These curves show that there is a decrease in the dynamic recovery pace with the % of cryorolling.

d) Microstructure Analysis



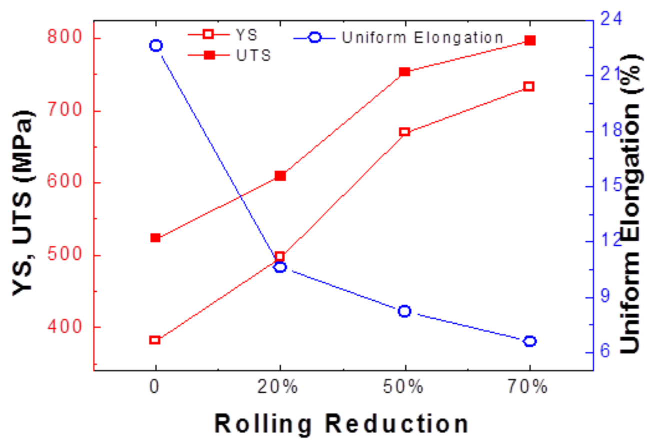
Optical microscope Image of Annealed sample



Optical microscope Image of 70% cryorolled sample

There is a noteworthy decrease in the grain size from annealed sample to 70% cryorolled sample.

IV. Conclusions



We observe that with the increasing amount of cryorolling there is a significant increase in the Y.S and U.T.S at the cost of its ductility. An optimum degree of cryorolling is obtained between 20%-50% of cryorolling.

Due to cryorolling, we get

a. Fine grain size and
b. More dislocation density
c. Suppression of dynamic recovery.

i. *Fine grain size*

Normally for annealed sample the dislocations are present within the grain and the grain boundaries. When some stress is applied, the dislocations move along one grain to another. In this process, when it comes through another grain, it encounters a barrier due to the misorientation of the crystallographic texture from one grain to another. Thus some additional force is required to move the dislocations across the barrier. Now due to cryorolling, since the grain size is reduced, there is an increase in the number of grains and overall grain boundary and therefore the size of the overall barriers for the dislocations increases and more force is required for the dislocations to cross the barrier which in turn increases the strength of the material.

ii. *More dislocation density*

Due to rolling, quite a large number of dislocations are produced. These dislocations get entangled between the grain boundary which impedes their motion and the strength gets increased.

With the increasing extent of cryorolling, more amount of dislocations get piled up within the grain boundaries and the sample starts to fracture after quite some time with increasing stress. Thus the ductility gets decreased with the extent of cryorolling at the cost of its strength.

iii. *Suppression of dynamic recovery*

There is suppression of dynamic recovery as in cryogenic temperature, the total internal energy of the atoms decreases as it is a function of temperature of the material. So the atoms kinetic energy decreases which results in the suppression of dynamic recovery.

References Références Referencias

1. Weblink:http://www.ne.anl.gov/capabilities/ip/highlights/light_water_reactor.html
2. Weblink:http://www.energyblogs.com/coretech/index.cfm/2011/1/31/Interest-Builds-for-New-Nuclear-Fuel-Cladding
3. K. Gopala Krishna, Nidhi Singh, K. Venkateswarlu and K. C. Hari Kumar, Tensile Behavior of Ultrafine-Grained Al-4Zn-2Mg Alloy Produced by Cryorolling, Journal of Materials Engineering and Performance,DOI:10.1007/s11665-011-9843-1,1 february. 2011, springerlink
4. SUSHANTA KUMAR PANIGRAHI,R.JAYAGANTHAN, Effect of Annealing on Thermal Stability, Precipitate Evolution,
5. and Mechanical Properties of Cryorolled Al 7075 Alloy, DOI: 10.1007/s11661-011-0723-y,The Minerals, Metals & Materials Society and ASM International 2011.

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Computational Analysis of Combustion Chamber Using Cavity-based fuel Injector with Non-Premixed Combustion Model

By J.P.Kalita, K.M.Pandey & A.P.Singh
N.I.T Silchar, India

Abstract - This paper presents the supersonic combustion of hydrogen fuel using cavity-based fuel injector with two-dimensional turbulent non-premixed combustion model. The present model is based on the standard k-epsilon (two equations) with standard wall functions which is P1 radiation model and a PDF (Probability Density Function) approach is created. The hydrogen fuel is injected just upstream of the cavity. The Contour of Mass fraction of OH indicates a little amount of OH around 0.001454 after combustion. A cavity flame holder is provided which injects hydrogen fuel in a supersonic hot air stream that facilitates enhanced mixing and combustion efficiency.

Keywords : Mach number, CFD, combustion, hydrogen fuel, non-premixed combustion, scramjet, standard kepsilon turbulence model, standard wall functions, steady state, supersonic combustion, two-dimensional.

GJRE-A Classification : *FOR Code: 090201*

COMPUTATIONAL ANALYSIS OF COMBUSTION CHAMBER USING CAVITY-BASED FUEL INJECTOR WITH NON-PREMIXED COMBUSTION MODEL

Strictly as per the compliance and regulations of:

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Keywords : Mach number, CFD, combustion, hydrogen fuel, non-premixed combustion, scramjet, standard k-epsilon turbulence model, standard wall functions, steady state, supersonic combustion, two-dimensional.

I. Introduction

The future of hypersonic air-breathing vehicles lies in the successful development and design of Supersonic combustion ramjet (SCRAMJET) engines which poses some major challenges that has attracted the attention and imagination of researchers worldwide. The serious issues like fuel-air mixing, flame holding, pressure losses and thermal loading can be resolved with the successful implementation of a fuel injection system that provides rapid mixing between the fuel and oxidizer streams, induces pressure losses to a minimum with reduced or zero adverse effects on flame holding capability or thermal/structural integrity of the device. A very short time for fuel injection, fuel-air mixing and subsequently combustion is available of the order of 1 ms and hence the increasing need to develop a system that effectively integrates fuel injection and flame holding for supersonic combustion exists. Thus cavity flame holders has been proposed in recent years as a new concept for flame holding and stabilization in supersonic combustors [4].

Some recent publications have brought to light the subject of cavity flows and their relevance to flame holding in supersonic combustion engines [1,2,3].Low-speed combustion studies with an axis symmetric cavity [5]found optimum flame holding performance using a cavity with its length-to-depth ratio $L=D$ sized for the minimum aerodynamic drag. Longer cavities produced vortex shedding that resulted in unstable flames, and shorter cavities did not provide enough air entrainment to hold the flame. Experimental and numerical results were show n to agree closely on this point [6]. Cavities with small aspect ratios provide better flame holding capability than longer cavities with aft ramp angles as suggested in a study by Yu et al[7] where fuel was injected upstream of a variable L/D cavity at flow speed of Mach 2.

A configuration having a baseline fuel injector/ flame holder with a low angled fuel injection upstream of a wall cavity was used by Tarun Mathur et al [8] where fuel injection and flame piloting was done in a scramjet combustor with all the components contained in the wall. In contrast to in-stream concepts that introduce additional friction drag, wave drag, and cooling requirements to the combustor, this configuration uses no in-stream devices, thereby minimizing these detrimental effects and simplifying the overall combustor and system designs. Similar studies which involves flush-wall injection upstream of similar cavities in non reacting supersonic flow have provided valuable insights into the effects of cavity configuration ($L=D$ ratio, offset ratio, aft ramp angle), fuel injection pressure, and imposed back pressure on drag, residence times, and fuel distribution within the cavity [9, 10]. The combustion experiments as described by Tarun Mathur et al [8] as well as some numerical simulations of cavity-based fuel injector/flame holder [11,12,13] have shown robust flame holding and combustion performance in a scramjet combustor simulating Mach 4-6 conditions at a dynamic pressure of 47.9 k Pa.

Some difficulties associated with hydrocarbon fuels which primarily include the relatively long ignition delay time and the challenge in diffusing stable combustion energy into the main flow without disturbing the flow and creating drag penalties may be tackled by cavity-based flame holders as suggested by Ben Yakar et al [2].A cavity-based flame holder a) creates a sheltered subsonic recirculation area of hot combustion products and increases the effective residence time for the fuel, and b) acts as a pilot light to spread hot combustion products into the main flow. The flow in the vicinity of the cavity can be very stable and can limit the amount of mass entrainment. As can be seen from the fig.1 below which is a result of numerical computations

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by Gruber et al [10] there are trapped vortices within the cavity, including a large primary recirculation zone that interacts with the free stream, and a smaller fuel-rich secondary vortex in the forward corner of the cavity.

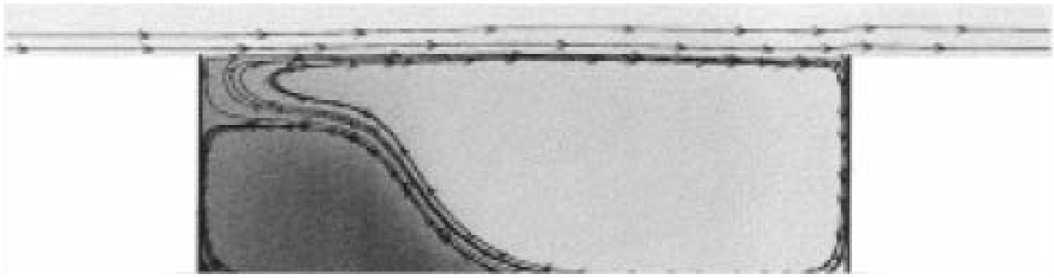

Fig.1 : Fuel distribution in a closed cavity flame holder. Darker shades indicate fuel-rich regions (Gruber et al.,2001).

The Cavity flow regimes has been categorized basically into two types by Ben Yakar et al [14] that depends primarily on length-to-depth ratio, L/D. In all the cases it is seen that a shear layer gets separated from the upstream lip and get reattached downstream. The reattachment takes place in the back face for L/D< 7-10 and hence are termed as open. For L/D< 2-3 transverse oscillation mechanism plays the dominant role but large aspect ratio cavities are controlled by longitudinal oscillations.The high pressure at the rear face as a result of the shear layer impingement increases the drag of the cavity. For $L{=}D$ >10–13 the cavity flow is termed "closed" because the free shear layer reattaches to the lower wall. The pressure increase in the back wall vicinity and the pressure decrease in the front wall results in large drag losses. The critical length-to-depth ratio, at which a transition between different cavity flow regimes occurs, depends also on the boundary-layer thickness at the leading edge of the cavity, the flow Mach number, and the cavity width.

Another way of improving fuel the fuel-air mixture within the cavity can be direct fuel injection into the cavity as investigated by Allen et al [15]. This resulted in decreased size of fuel rich vortex with subsequent improvement in combustion within the cavity which was due to improved fuel air mixture because of additional air injected directly into the cavity. They also observed that the air injection technique did not have merely a undeviating effect on the fuel-rich region, in fact increasing the air injection without bound had diminishing effect, and eventually are verse effect. For lower fuel injection rates, if the air injection was increased to its maximal limit the combustion increases seen at lower air injection rates moderated to levels near the original fuel-only case. It would seem that the direct air injection technique is able to cause the cavity fuel-air mixture to become too lean to gain any enhancements in combustion if the air injection rate is not organized.

II. Materials and Methods

a) Physical Model

A mathematical model consists of equations concerning the dependent and the independent variables and the relevant parameters that describe some physical phenomenon. In general, a mathematical prototype consists of differential equations that govern the performance of the physical system, and the related boundary conditions which is shown in figure 2.

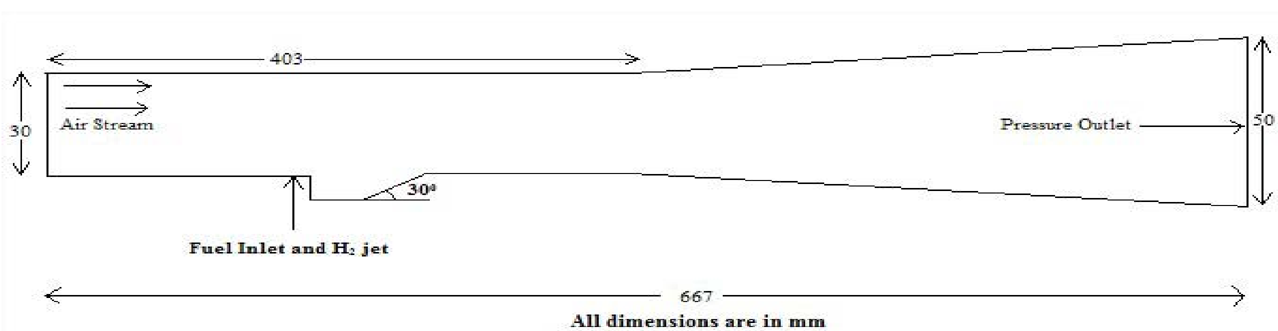

Fig.2 : Physical model of cavity-based non-premixed supersonic combustor

b) Governing Equations

The advantage of employing the complete Navier-Stokes equations extends not only the investigations that can be carried out on a wide range of flight conditions and geometries, but also in the process the location of shock wave, as well as the physical characteristics of the shock layer, can be exactly determined. We begin by describing the three-dimensional forms of the Navier-Stokes equations below. Note that the two-dimensional forms are just simplification of the governing equations in the three dimensions by the omission of the component variables in one of the co-ordinate directions. Neglecting the presence of body forces and volumetric heating, the three-dimensional Navier-Stokes equations are derived as [16]:

Continuity Equation:

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0 \quad (1)$$

X-momentum equation:

$$\frac{\partial(\rho \mathrm{u})}{\partial t}+\frac{\partial(\rho u u)}{\partial x}+\frac{\partial(\rho v u)}{\partial y}+\frac{\partial(\rho w u)}{\partial z}=\frac{\partial \delta_{xx}}{\partial x}+\frac{\partial \tau_{yx}}{\partial y}+\frac{\partial \tau_{zx}}{\partial z} \quad (2)$$

Y-momentum equation:

$$\frac{\partial(\rho v)}{\partial t}+\frac{\partial(\rho u v)}{\partial x}+\frac{\partial(\rho v v)}{\partial y}+\frac{\partial(\rho w v)}{\partial z}=\frac{\partial \tau_{xy}}{\partial x}+\frac{\partial \sigma_{yy}}{\partial y}+\frac{\partial \tau_{zy}}{\partial z} \quad (3)$$

Z-momentum equation:

$$\frac{\partial(\rho w)}{\partial t}+\frac{\partial(\rho u w)}{\partial x}+\frac{\partial(\rho v w)}{\partial y}+\frac{\partial(\rho w w)}{\partial z}=\frac{\partial \tau_{xz}}{\partial x}+\frac{\partial \tau_{yz}}{\partial y}+\frac{\partial \sigma_{zz}}{\partial z} \quad (4)$$

Energy Equation:

$$\frac{\partial(\rho E)}{\partial t}+\frac{\partial(\rho u E)}{\partial x}+\frac{\partial(\rho v E)}{\partial y}+\frac{\partial(\rho w E)}{\partial z}$$
$$=\frac{\partial(u\sigma_{xx}+v\tau_{xy}+w\tau_{xz})}{\partial x}+\frac{\partial(u\tau_{yx}+v\sigma_{yy}+w\tau_{yz})}{\partial y}+\frac{\partial(u\tau_{zx}+v\tau_{zy}+w\sigma_{zz})}{\partial z}$$
$$+\frac{\partial(k\frac{\partial T}{\partial x})}{\partial x}+\frac{\partial(k\frac{\partial T}{\partial y})}{\partial y}+\frac{\partial(k\frac{\partial T}{\partial z})}{\partial z} \quad (5)$$

Assuming a Newtonian fluid, the normal stress σ_{xx}, σ_{yy} and σ_{zz} can be taken as combination of the pressure p and the normal viscous stress components τ_{xx}, τ_{yy}, and τ_{zz} while the remaining components are the tangential viscous stress components whereby $\tau_{xy}= \tau_{yx}$, $\tau_{xz}= \tau_{zx}$, and $\tau_{yz}= \tau_{zy}$. For the energy conservation for supersonic flows, the specific energy, E is solved instead of the usual thermal energy H applied in sub-sonic flow problems. In three dimensions, the specific energy E is repeated below for convenience:

$$E= e+\frac{1}{2}(u^2+v^2+w^2) \quad (6)$$

It is evident from above that the kinetic energy term contributes greatly to the conservation of energy because of the high velocities that can be attained for flows, where Ma>1.Equations (1)-(6) represent the form of governing equations that are adopted for compressible flows. The solution to the above governing equations nonetheless requires additional equations to close the system. First, the equation of state on the assumption of a perfect gas unemployed, that is,

$P = \rho R T$ where R is Gas constant

Second, assuming that the air is calorically perfect, the following relation holds for the internal energy:

$$e = C_v T$$

where C_v is specific heat at constant volume. Third, if the Prandtl number is assumed constant (approximately 0.71) for calorically perfect air), the thermal conductivity can be evaluated by the following:

$$k = \frac{\mu C_p}{pr}$$

The Sutherland's law is typically used to evaluate viscosity μ, which is provided by:

$$\mu = \mu_0 \left(\frac{T}{T_0}\right)^{1.5} \frac{T_0 + 120}{T + 120} \tag{7}$$

Where μ_0 and T_0 are the reference values at standard sea level conditions

Generalized form of Turbulence Equations is as follows:

$$k\frac{\partial k}{\partial t} + \frac{\partial(uk)}{\partial x} + \frac{\partial(vk)}{\partial y} + \frac{\partial(wk)}{\partial z} = \frac{[\frac{V_T}{\sigma_k}\frac{\partial k}{\partial x}]}{\partial x} + \frac{\partial[\frac{V_T}{\sigma_k}\frac{\partial k}{\partial y}]}{\partial y} + \frac{\partial[\frac{V_T}{\sigma_k}\frac{\partial k}{\partial z}]}{\partial z} + (S_k = P - D)$$

$$(\varepsilon)\frac{\partial \varepsilon}{\partial t} + \frac{\partial(u\varepsilon)}{\partial x} + \frac{\partial(v\varepsilon)}{\partial y} + \frac{\partial(w\varepsilon)}{\partial z} = \frac{\partial\left[\frac{V_T}{\sigma_k}\frac{\partial \varepsilon}{\partial x}\right]}{\partial x} + \frac{\partial\left[\frac{V_T}{\sigma_k}\frac{\partial \varepsilon}{\partial y}\right]}{\partial y} + \frac{\partial\left[\frac{V_T}{\sigma_k}\frac{\partial \varepsilon}{\partial z}\right]}{\partial z} + (S_\varepsilon = \frac{\varepsilon}{k}(C_{\varepsilon 1}P - C_{\varepsilon 2}D)$$

Where

$$P = 2v_T\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 + \left(\frac{\partial w}{\partial z}\right)^2\right] + v_T\left[\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\right)^2 + \left(\frac{\partial w}{\partial x} + \frac{\partial u}{\partial z}\right)^2\right]$$

And D=Ɛ

III. Computattional and Model Parameters

a) *Geometry and mesh generation*

Mesh generation was performed in a Fluent pre-processing program called Gambit. The current model is cavity-based fuel injector with non-premixed combustion as shown in figure 3. The boundary conditions are such that, the air inlet and fuel inlet surfaces are both defined as pressure inlets and the outlet is defined as pressure outlet. Recent research has revealed that perhaps the numerical model will improve if the air inlet is defined as pressure inlet and the fuel inlet is defined as a mass flow inlet. In this particular model the walls of the combustor duct do not have thicknesses. The domain is completely contained by the combustor itself; therefore there is actually no heat transfer through the walls of the combustor.

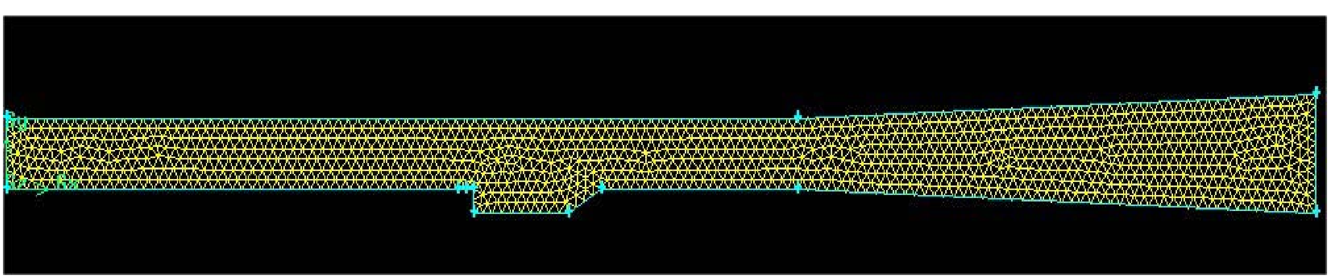

Fig 3 : Gambit profile of Cavity-based fuel injector *b) Boundary Conditions*

During analysis we have taken same pressure for both fuel and air for all the models. Pressure inlet and pressure outlet conditions were taken on the left and right boundaries respectively. Pressure inlet condition was taken for fuel injector. The top and bottom boundaries, which signify the sidewalls of the isolator, had symmetry conditions on them. The walls, obstacles and other materials were set to standard wall conditions. The computations were initially carried out with various levels of refinement of mesh. There exists a definite level of refinement beyond which there is no significant quantitative change in the result. The limit of that refinement is called the Grid Independent Limit (GIL). The input parameters that were for the model is shown in tabulated form.

Input Parameters	Air	Fuel
Mach No	3.12	1.5
Temperature	1000K	300K
Pressure	80325 Pa	80325 Pa
Mass fraction of H_2	0	1
Mass fraction of N_2	0.767	0
Mass fraction of O_2	0.213	0
Mass fraction of H_2O	0.02	0
Turbulent Kinetic Energy(k)	10	2400
Turbulent Dissipation rate(ε)	650	10^8

c) Modeling Details

In the CFD model, the Standard k-**ε**turbulent model is selected which is one of the most common turbulence models. It is a two equation model that means it includes two extra transport equations to represent the turbulent properties of the flow. This two equation model accounts for history effects like convection and diffusion of turbulent energy. Further, because of the intense turbulent combustion, the eddy-dissipation reaction model is adopted. The eddy-dissipation is based on the hypothesis of infinitely fast reactions and the reaction rate is controlled by turbulent mixing. Both the Arrhenius rate and the mixing rate are calculated and the smaller of the two rates is used for the turbulent combustion. While no-slip conditions are applied along the wall, but due to the flow being supersonic, at the outflow all the physical variables are extrapolated from the internal cells. Energy equations were considered and the solution was initialized from the air inlet for simplicity. For hydrogen-air mixing, ideal gas mixing law was followed for determination of thermal conductivity and viscosity, while density was assumed to be for ideal gas. Mass diffusivity was assumed to be following kinetic theory.

IV. Results and Discussions

The various plots of properties such as static temperature, densities etc. along the length of the combustor for the different models are given below. The red colored regions are the regions where the properties attain their maximum values. The blue colored regions indicate the regions where the properties are at their minimum. The properties that were analyzed were:

1. Static Temperature
2. Density
3. Mass Fraction of H_2
4. Mass Fraction of H_2O
5. Mass Fraction of O_2
6. Mass Fraction of OH

The static temperature was taken as an indication of combustion efficiency of the fuel (hydrogen). Higher combustion efficiency means a greater percentage of the injected fuel undergoes combustion resulting in a higher static temperature at the combustor exit. Study of the mass fraction contours of H2, O2 and H2O showed evidence of fuel injection, air fuel mixing and combustion respectively. The presence of H2O indicated the occurrence of combustion. Turbulent kinetic energy was an indication of vortex formation in the cavity which enhances air-fuel mixing. The X-velocity was the velocity at which the combustion products exit the combustor. It represented the thrust available for propulsion of the scramjet. The static pressure and density contours and static pressure and density graphs help in visualizing the shock waves produced by the velocity of hydrogen injection. Moreover, interaction of the reflected shock waves with the air-fuel mixing boundary (visible in the density and static pressure contours) further enhanced the mixing and promoted.

a) Static Temperature

From Fig 4 it is evident that static temperature increases from inlet to the outlet. This is due to combustion of the air and injected H2 fuel. The heat released due to combustion heats up the combustion products (water) and hence, an increase in the static temperature from 398K to 1789 K is observed.

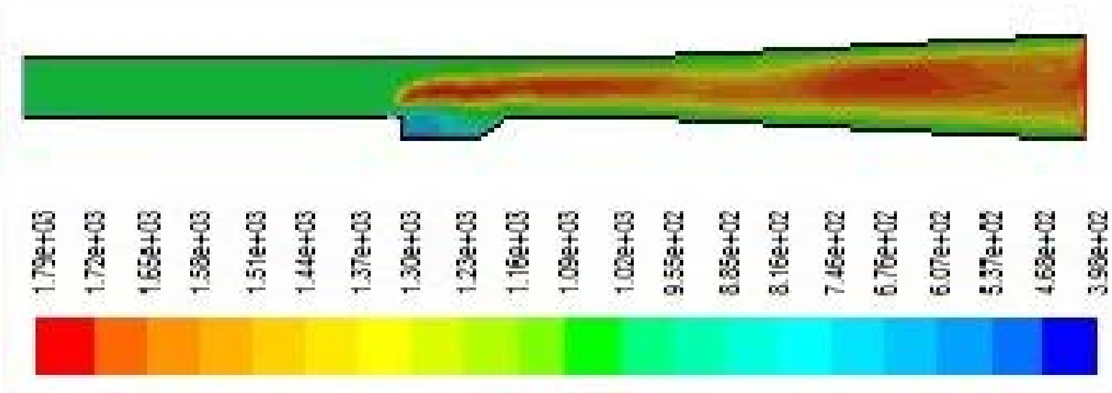

Fig 4 : Contour of Static Temperature

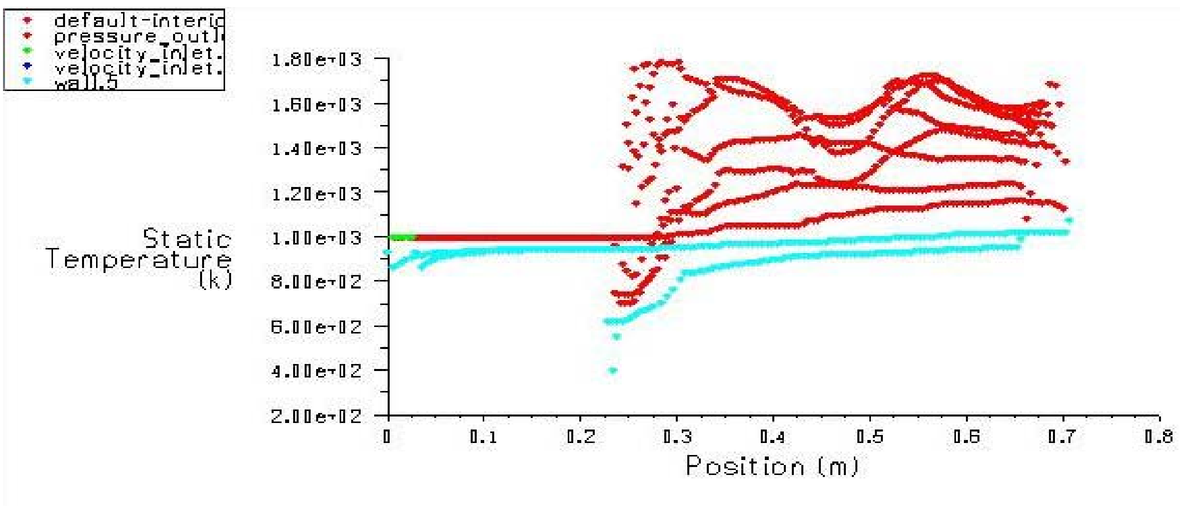

Fig 5 : XY Plot of Static Temperature

b) Density

Plot of density distribution at interior shows that density increases with H2 injection and then, it decreases gradually with mixing and combustion of air and hydrogen fuel mixture and the subsequent expansion of the combustion products. From the contour a maximum density of 0.2758944kg/m^3 is observed at the inlet and injection zones and it decreases to a minimum value of 0.09207605 kg/m^3.

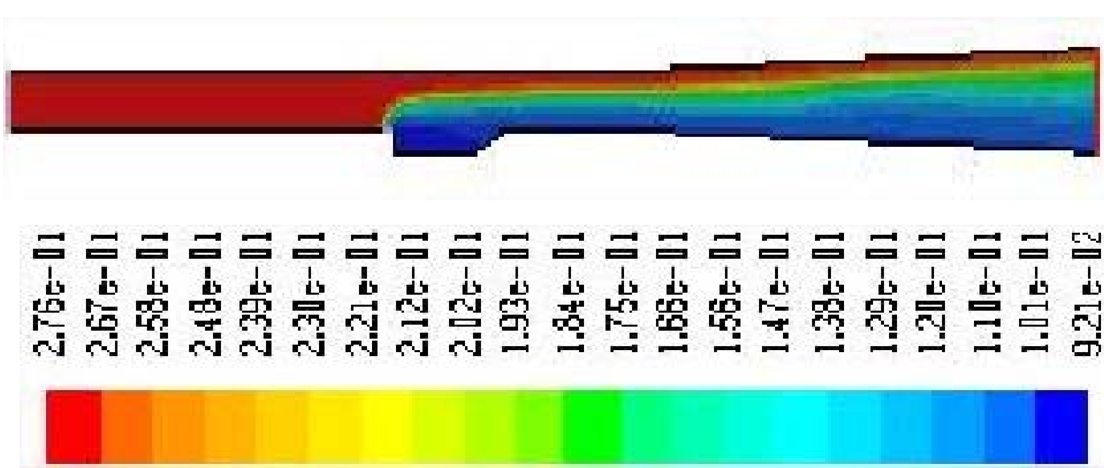

Fig 6 : Contour of Density

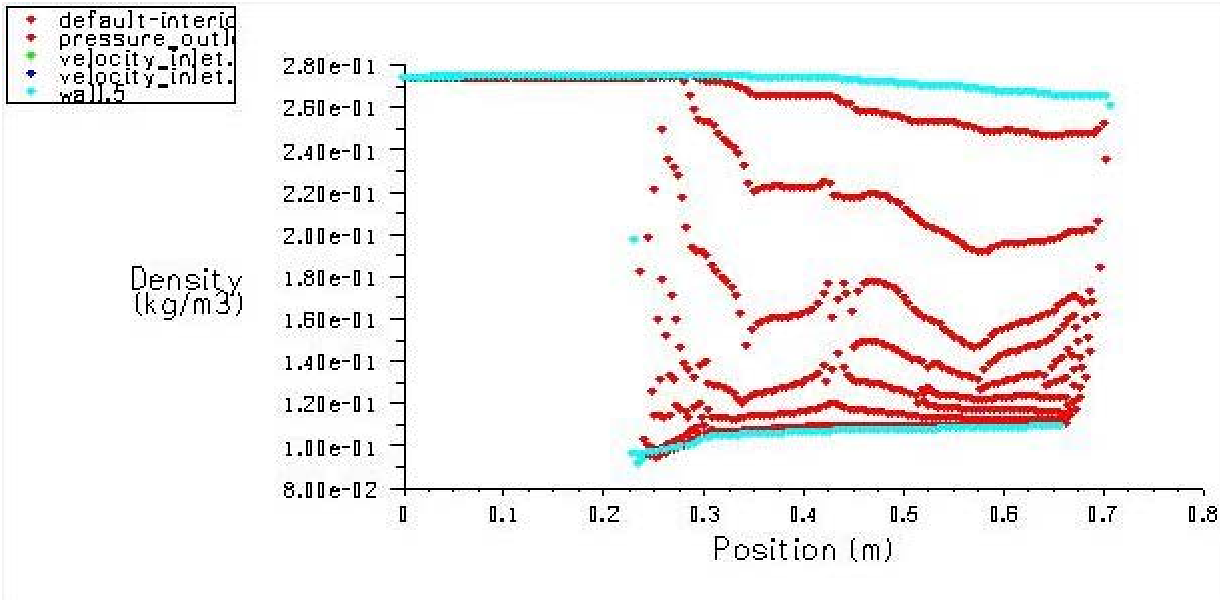

Fig 7 : XY Plot of Density

c) Mass Fraction of H_2

The below graph shows the distribution of H_2 in the interior of the combustor. As can be seen, the mass fraction of hydrogen is maximum at the fuel injection port and continues to decrease along the length of the combustor due to combustion. Thus, the graph provides evidence of combustion.

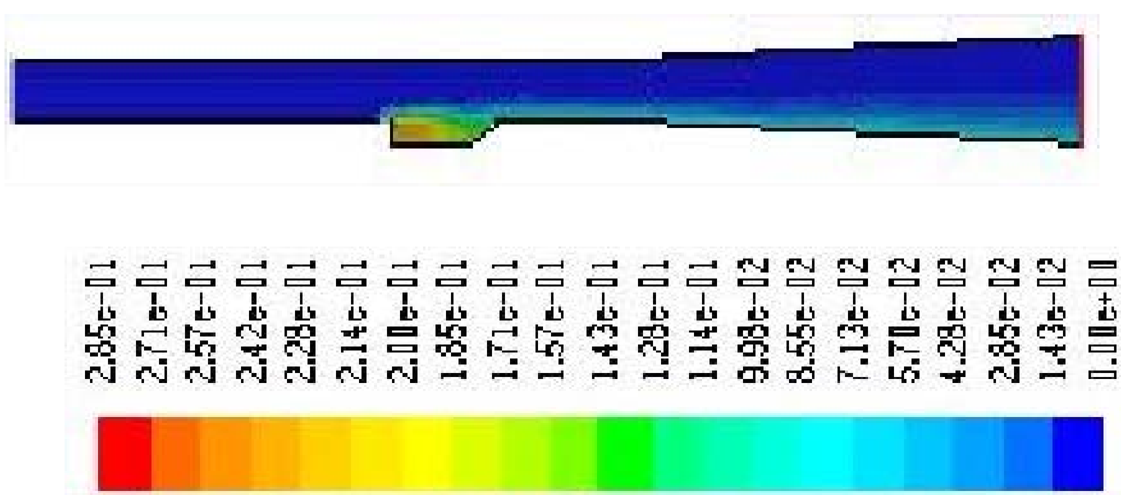

Fig 8 : Contour of Mass Fraction of H_2

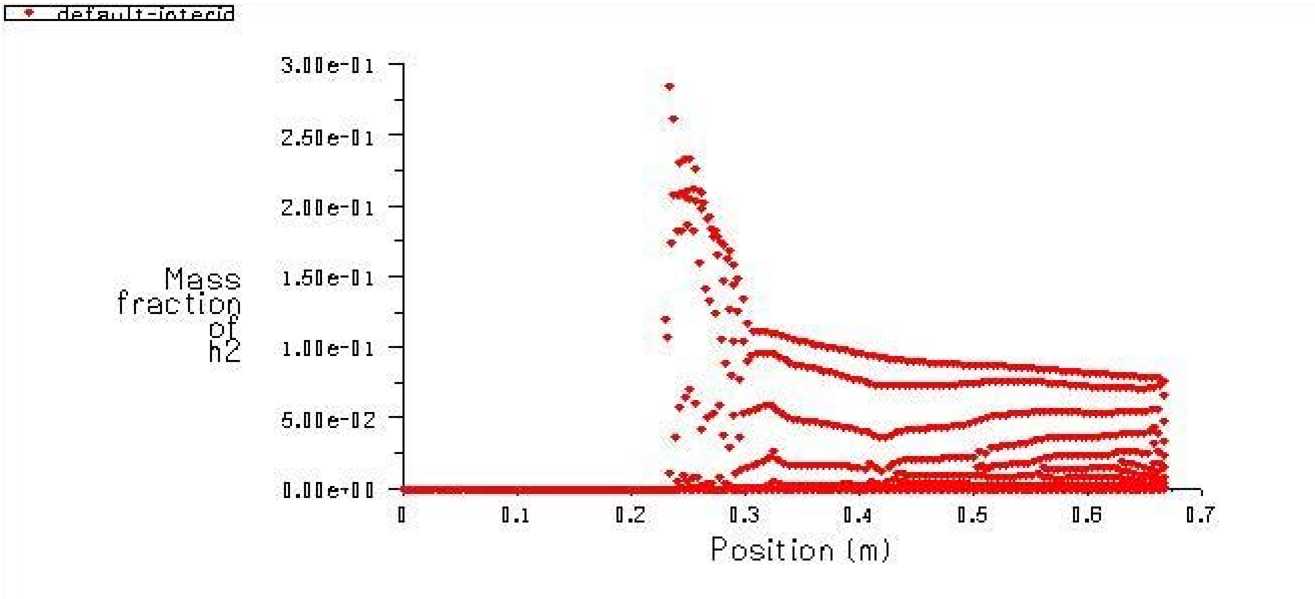

Fig 9 : XY Plot of Mass Fraction of H_2 at interior

d) Mass Fraction of H_2O

The contour and XY Plot of water Mass fraction for the flow field downstream of the injector is shown in the fig 10 and fig 11. From the figure 10and 11 it is observed that, water concentration is found to be maximum value of 0.1259681 in the shear layer formed between the two streams of flow and the low-velocity recirculation regions within the core of the upcoming jet. Typically, when dealing the chemical reaction, it's important to remember that mass is conserved, so the mass of product is same as the mass of reactance. Even though the element exists in different the total mass of each chemical element must be same on the both side of equation.

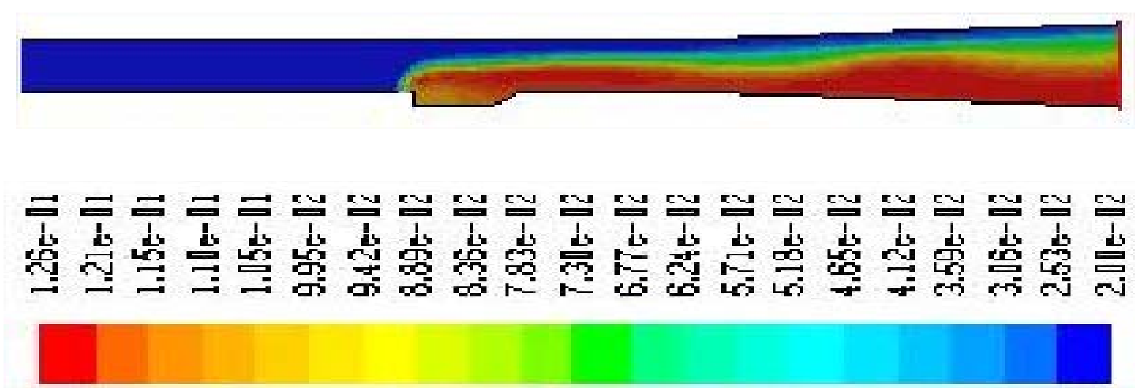

Fig 10 : Mass fraction of H_2O

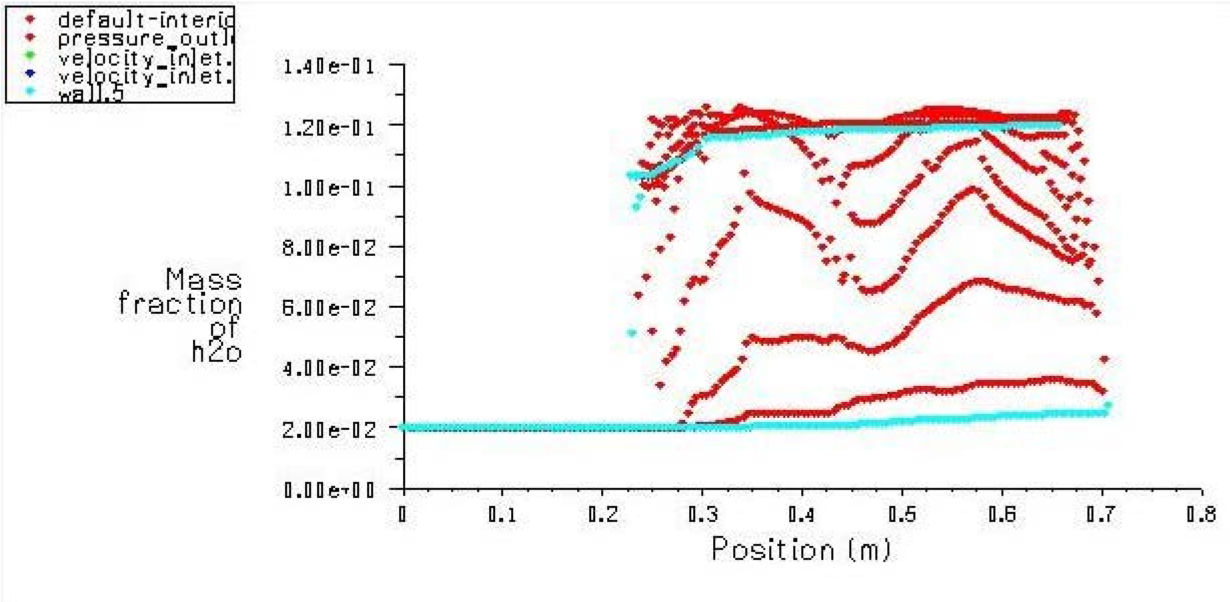

Fig 11 : XY Plot of Mass Fraction of H_2O

e) Mass Fraction of O_2

The contour and XY Plot of O_2 Mass fraction for the flow field downstream of the injector is shown in the figure 12 and figure 13. Oxygen is increased in every combustion reaction in combustion applications and air provides the required oxygen. All components other than air collected together with nitrogen. In air 21% of oxygen and 79% of nitrogen are present on a molar basis. From the figure 12 it is observed that, the maximum mass fraction of O_2 is 0.213 which is seen at the beginning of combustion. Figure 13 shows that the profile between the mass fraction of O_2 and the position of the combustion on all conditions such as air inlet, fuel inlet, pressure outlet, default interior and all walls.

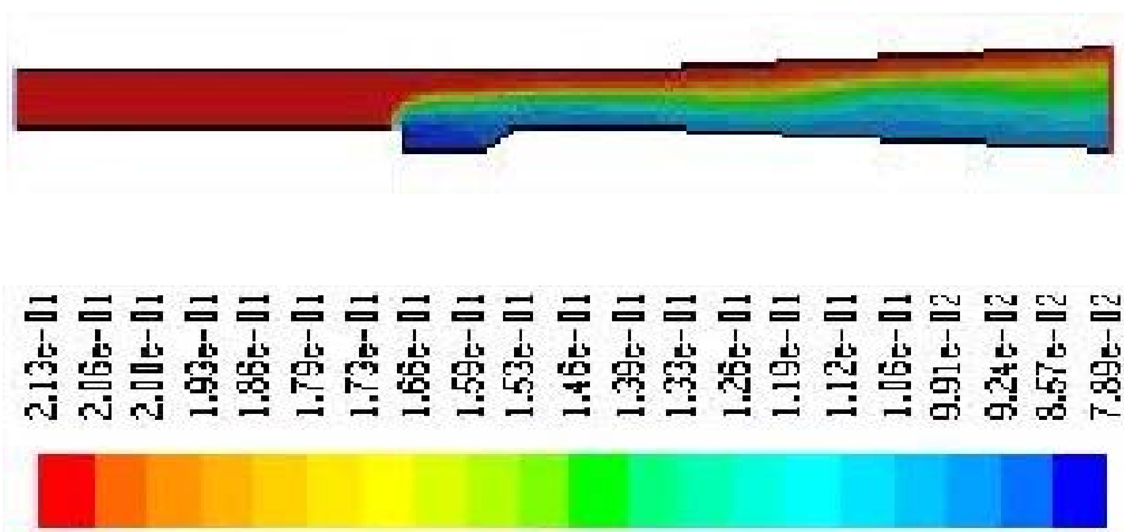

Fig 12 : Contour of Mass Fraction of O_2

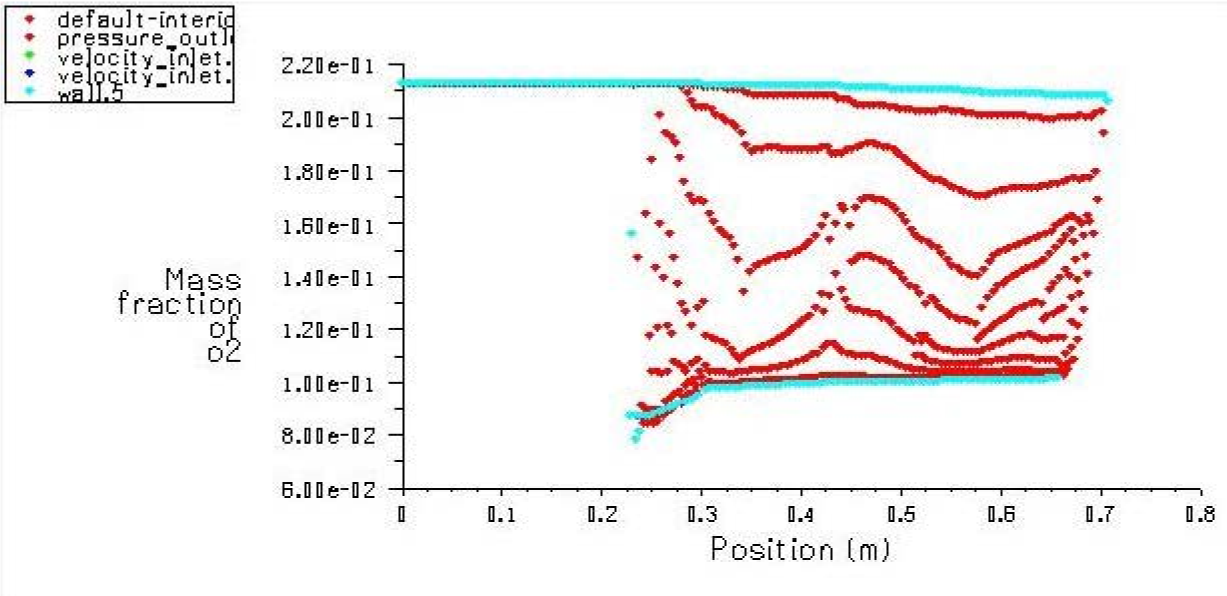

Fig 13 : XY Plot of Mass Fraction of O_2

f) Mass Fraction of OH

The contour of mass fraction of OH is shown in figure 14. From the figure 14 it is observed that, the maximum mass fraction of OH is 0.001454 which is found out after combustion, where the minimum value is 0. Figure 15 shows that the profile between the mass fraction of OH and the position of the combustion on all conditions such as air inlet, fuel inlet, pressure outlet, default interior and all walls.

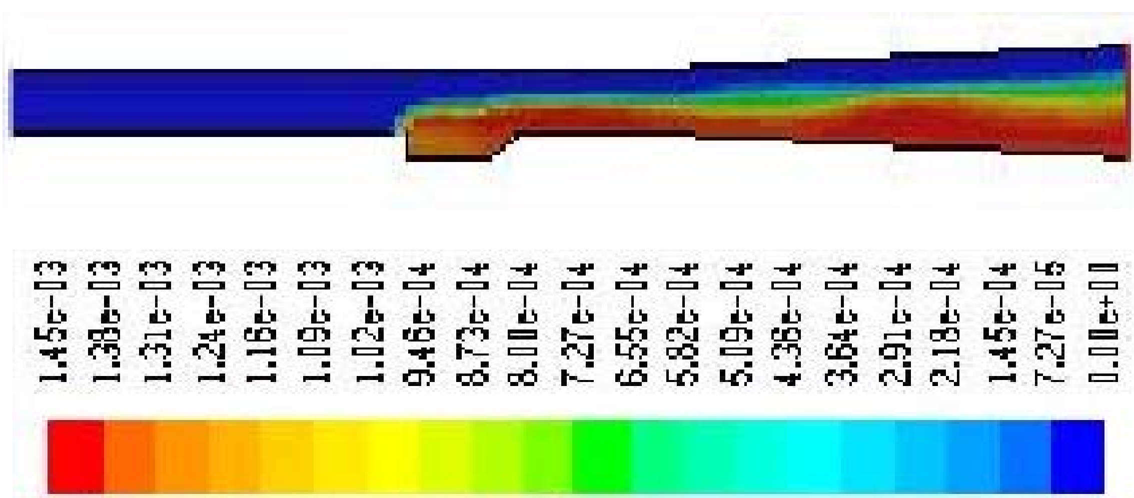

Fig 14 : Contour of Mass Fraction of OH

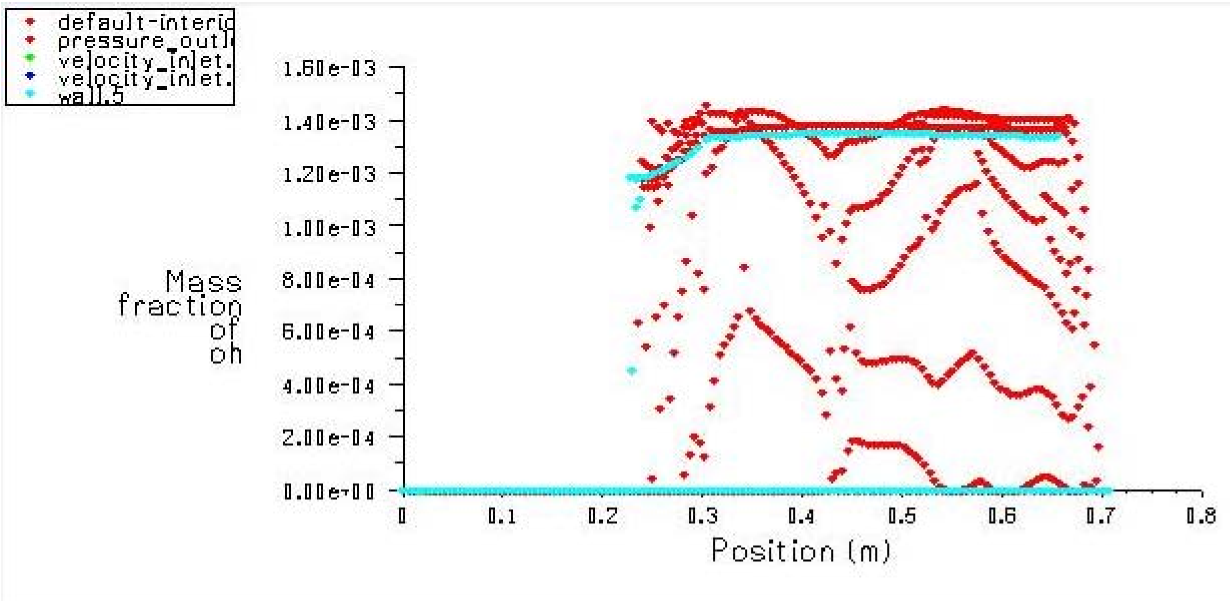

Fig 15 : XY Plot of Mass Fraction of OH

V. Conclusion

The computational analysis of 2D cavity-based fuel injector was carried out with k-Ɛ turbulence model for exposing the flow structure of progress of hydrogen jet through the areas disturbed by the reflections of oblique shock. For that single step reaction kinetics has been used to model the chemistry. The k-ε turbulence model also predicted the fluctuations in those regions where the turbulence is reasonably isotropic. From the maximum mass fraction of OH a very small amount of OH (1.45e-03) was observed after combustion. From the above analysis, it is observed that for a scramjet engine having a wall injector with a cavity of L/D=5, if hydrogen is injected at a speed of Mach 1.5 to an incoming air stream at Mach 3.12 speed, a rich air-fuel mixture can be achieved and efficient combustion of this mixture gives a maximum temperature of 1789K at the outlet of the combustor. Also, there is a weak shock formation. Hence, better flame holding can be achieved if the wall injector is coupled with a cavity having with an L/D ratio of 5. Due to ever increasing human need for greater speed and reduced travel time, hypersonic combustion systems will become more and more important in the future. As the mixing time for fuel in the combustor system is very less (~1ms), newer and better injection systems have to be developed that enhance fuel-air mixing and reduce ignition delay period, thus increasing both combustion efficiency and thrust.

References Références Referencias

1. Baurle, R. A., and Gruber, M. R., "Study of Recessed Cavity Flow fields for Supersonic Combustion Applications," AIAA Paper 98-0938, Jan. 1998
2. Ben-Yakar, A., and Hanson, R., "Cavity Flame holders for Ignition and Flame Stabilization in Scramjets: Review and Experimental Study," AIAA Paper 98-3122, July 1998
3. Davis, D. L., "Numerical Analysis of Two and Three Dimensional Recessed Flame Holders for Scramjet Applications, "Ph.D. Dissertation, Aeronautics and Astronautics Dept., Air Force Inst. of Technology, Wright–Patterson AFB, OH, Sept. 1996.
4. Tishk off, J.M., Drummond, J. P., Edwards, T., and Nejad, A. S., "Future Direction of Supersonic Combustion Research: Air Force/NASA Workshop on Supersonic Combustion," AIAA Paper 97-1017, Jan. 1997.
5. Hsu, K.-Y., Goss, L. P., and Roquemore, W. M., "Characteristics ofa Trapped-Vortex Combustor," *Journal of Propulsion and Power*, Vol. 14,No. 1, 1998, pp. 57-65.
6. Katta, V. R., and Roque more, W. M., "Study on Trapped-Vortex Combustor—Effect of Injection on Flow Dynamics," *Journal of Propulsion and Power*, Vol. 14, No. 3, 1998, pp. 273–281.
7. Yu, K.,Wilson, K. J., Smith, R. A., and Schadow, K. C., "Experimental Investigation on Dual-Purpose Cavity in Supersonic Reacting Flows," AIAA Paper 98-0723, Jan. 1998.
8. Mathur T, Gruber M.R, Jackson K., Donbar J., Donaldson W., Jackson T.,Billig F., "Supersonic Combustion Experiments with a Cavity-based fuel injector", Journal of Propulsion and Power, Vol 17, No.6, N0v-Dec 2001,pp 1305-1312
9. Hsu, K.-Y., Carter, C., Crafton, J., Gruber, M., Donbar, J., Mathur, T., Schommer, D., and Terry,W., "Fuel Distribution about a Cavity Flame holder in Supersonic Flow," AIAA Paper 2000-3583, July 2000.

10. Gruber, M. R., Baurle, R.A., Mathur, T., and Hsu, K.-Y., "Fundamental Studies of Cavity-Based Flameholder Concepts for Supersonic Combustors," *Journal of Propulsion and Power*, Vol. 17, No. 1, 2001, pp. 146–153.
11. Baurle, R. A., Mathur, T., Gruber, M. R., and Jackson, K. R., "Numerical and Experimental Investigation of a Scramjet Combustor for Hypersonic Missile Applications," AIAA Paper 98-3121, July 1998.
12. Eklund, D. R., and Gruber, M. R., "Study of a Supersonic Combustor Employing an Aerodynamic Ramp Pilot Injector," AIAA Paper 99-2249, June 1999.
13. Eklund, D. R., Baurle, R. A., and Gruber, M. R., "Numerical Study ofa Scramjet Combustor Fuelled by an Aerodynamic Ramp Injector in Dual-Mode Combustion," AIAA Paper 2001-0379, Jan. 2001.
14. Ben Yakar A., Hanson R., "Cavity Flame holders for Ignition and Flame Stabilization in Scramjets: An Overview", Journal of Propulsion and Power, Vol. 17, No. 4, July-August 2001, pp 869-876.
15. Allen, W.H., King, P.I., Gruber, "Fuel-Air Injection Effects on Combustion in Cavity-Based Flame holders in a Supersonic Flow,"AIAA-2005-4105, 41st AIAA/ASME/SAE/ASEE Joint Prop. Conf., Tucson, AZ, 10-13 Jul 2005.
16. Jiyuntu, guan Hengyeoh and chaoqunliu. "*Computational Fluid Dynamics*", Elsevier Inc. 2008.
17. Wei Huang, Shi-bin Luo, Mohamed Pourkashanian, Lin Ma, Derek B. Ingham, Jun Liu and Zhen-guo Wang; "Numerical Simulations of a Typical Hydrogen Fuelled Scramjet Combustor with a Cavity Flame holder"; WCE 2010, London, UK, July 2010.
18. Weipeng Li, TakuNonomura, Akira Oyama and Kozo Fujii; "LES Study of Feedback-loop Mechanism of Supersonic Open Cavity Flows"; 40th Fluid Dynamics Conference and Exhibit, AIAA 2010-5112, 28 June - 1 July 2010.
19. K.M. Pandey, A.P.Singh, "Numerical simulation of combustion chamber without cavity at Mach 3.12", International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-1, March 2012.
20. K.M. Pandey, S.K. Reddy K.K., "Numerical Simulation of Wall Injection with Cavity in Supersonic Flows of Scramjet Combustion", International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-1, March 2012.

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4. Manuscript’s Category,

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- 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.

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- Do not give permission to anyone else to "PROOFREAD" your manuscript.

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- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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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

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