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Discovering Thoughts, Inventing Future

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Mathematical Model of Fluid Flow in Rocket Fuel System

By N.I. Klyuev
Samara State Technical University

Abstract- The article reviews mathematical model of liquid flow in metering system of fuel tank of rocket. The control system contains one horizontal and two vertical channels. Vertical channel has sensors for fixing free surface level of fluid in the channel. When the level of fuel reaches the sensor, it is activated, and the signal comes to the control system. As a result, fuel consumption is changing. Fuel level in the tank is determined on the basis of the fuel level in the channel. It is known that in the course of fuel consumption, surface free levels in the channel and in the tank do not match. The task is described by unsteady-state equation of motion. Viscous incompressible liquid model is used. The solution of the differential equation was performed numerically. Measurement error of liquid level in the fuel tank has been determined. The study proposes engineering solution to avoid the measurement error.

Keywords: *liquid, flow, level, channel, oscillations, error.*

GJRE-D Classification: *FOR Code: 090199*

MATHEMATICALMODELOFFLUIDFLOWINROCKETFUELSYSTEM

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Keywords: liquid, flow, level, channel, oscillations, error.

I. Introduction

The problem of mathematical simulation of fluid flow in the fuel consumption control system is reviewed. In the course of the rocket travel the fuel from the oxidizer tank and fuel tank enters to the rocket combustion chamber. Synchronous fuel entry provides efficient operation. In real conditions this requirement is violated due to various reasons [1], resulting in inefficient fuel consumption. Residual fuel should have a minimum volume. Accomplishment of this objective depends on accurate measurement of fuel level in the tank. The problem is non-stationary, and is described by parabolic equation of motion. Solution of unsteady-state equation of motion for one-dimensional problem was found by a number of researchers.

Solutions reviewed in [2, 3] may be considered as classical. Paper [2] investigates laminar flow development from the rest state, work [3] reviews the pulsating flow. In [4] calculation results are compared with experimental records. Operational calculus methods are used to resolve parabolic equations in [2-4]. Research paper [5] presents oscillatory flow mathematical model. The solution is obtained using numerical method, obtained results are compared with experimental data. The authors [6] review non-Newtonian fluid throbbing stream in cylindrical channel with immediate valve closing. Method of Runge-Kutta was used to resolve the motion equation. Paper [7] contains the results of incompressible liquid flow in micro-tube at pressure jump research. The problem solution was obtained analytically, using Laplace transformation, and numerically, using Boltzmann method. Stationary flows and pulsating streams in slightly bent tube for a wide range of Reynolds numbers are reviewed in [8]. Numeric methods were used to resolve the problem.

Work [9] presents pulsed incompressible flow through the pipeline. The flow is generated by periodical pressure gradient. The results show good compliance between analytical and numerical solutions. The study [10] represents method of characteristics for fluctuating streams simulation in the pipeline. It provides convergence estimate and method accuracy. Article [11] contains analysis of dynamical interference between the pipe and non-stationary flow on the basis of experiments and numerical models. Method of characteristics for determination of one-dimensional model of fluctuating fluid stream in the pipeline is used in [12]. Paper [13] provides experimental study of characteristics of non-stationary oscillatory flow in cylindrical channel. Obtained results comparison with known experimental results confirms good compliance. Work [14] reviews incompressible liquid non-steady laminar flow in expanding (convergent) channel with porous walls. Analytical solutions are compared with numerical solutions. In [15] the authors study non-stationary fluctuation problems related to non-viscous and low viscosity fluid in extensive network.

II. Physical Statement of The Problem

Liquid level metering system is provided in the tank to control propellant consumption. For this purpose, vertical cylindrical channel, with fuel surface level indicators, is installed in the tank. Due to tank design features, the vertical channel may not match the tank centre line. Besides, short-period oscillations may occur at liquid free surface. In order that liquid level in the vertical channel reflects the liquid level in the tank, the metering system is supplemented by two horizontal channels located at the tank bottom. Horizontal channels outlets are located at one tank diameter. Horizontal channels overall length may exceed the tank diameter (Fig.1).

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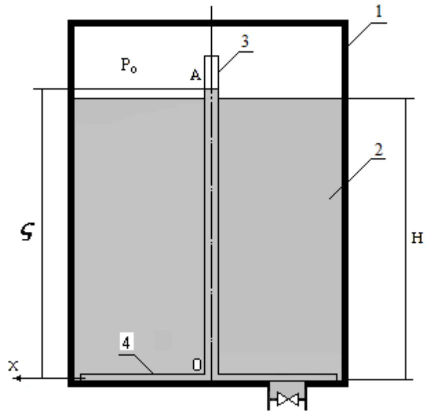

Figure 1: Second diagram of a fuel tank. 1- tank, 2- fuel, 3- measurement vertical channel, 4- horizontal channels, p_0 - gas pressure, ξ - liquid level in the channel, H - liquid level in the tank, x - coordinate axis

In case of fuel level reduction in the tank, the fuel level in the vertical channel is also reduced. When the propellant level in the channel reaches the indicator, the indicator is activated. The signal comes to the fuel consumption control system. As a result, fuel consumption may by changing. Thus, fuel level in the tank is determined on the basis of the fuel level in the channel. The channel and the propellant tank are communicating vessels. The problem is that in case of fuel consumption free surface levels in the channel and in the tank do not match. The error in the fuel level measurement results to inefficient fuel consumption. As a result, rocket motor is operated not with the optimum performance, and "excessive" fuel volume is left in the tanks.

At the initial moment the tank and the channel are filled with the fuel with level H_0. Free upper end of the cylindrical channel is above the fuel level in the tank, therefore the fuel overflow from the tank to the channel at this point is excluded. Fuel is free communicating between the tank and the channel. Constant pressure p_0 is maintained above free fuel surface in the tank and in the channel. From the time point $t > 0$ fuel is taken from the tank, so that the liquid level in it is reduced in linear fashion $H(t) = H_0 - V_0 t$, where V_0 – fuel level depression rate in the tank. Therefore, liquid level in the channel is changing.

III. Mathematical Model Of Liquid Flow

The equation of viscous incompressible liquid non-steady motion in horizontal cylindrical channel is used as the flow model

$$\frac{\partial u}{\partial t} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{\nu}{r}\frac{d}{dr}\left(r\frac{du}{dr}\right), \qquad (1)$$

where $u = (r, t)$ - liquid velocity in the horizontal channel, p - pressure, ρ - density, t - time, ν - kinematic viscosity.

Find approximate solution of equation (1). Enter average channel section longitudinal flow velocity - $< u >= \frac{2}{R^2}\int_0^R rudr$. Multiply left and right sections of equation (1) by r and integrate each additive component from 0 to R, where R - horizontal channel radius. Taking into account, that in the process motion the acceleration of rocket increases in linear fashion $(g = 9{,}8 + 0{,}07t)$, we obtain equation (the oblique brackets are omitted in the following).

$$\frac{du}{dt} = -\frac{\rho(9{,}8 + 0{,}07t)(H_0 - V_0 t - \xi(t))}{\ell} - \frac{\lambda u^2}{4R}, \qquad t = 0, u = 0, \xi = H_0, \qquad (2)$$

where λ - friction coefficient, ℓ - horizontal channel length, $\xi(t)$ – liquid level in a vertical channel.

Using volumetric flow rate conservation law, we write down: $u_1(t) = \frac{2u(t)R^2}{R_1^2}$, where R_1 - vertical channel radius. Then

$$\xi(t) = H_0 - \frac{2R^2}{R_1^2}\int_0^t u(t)dt, \qquad (3)$$

and the problem will be determined by system of equations (2) and (3).

As a result, we obtain Cauchy problem. For numerical solution of set problem, formulate system of equations (2), (3) as standard form. For that purpose take derivative with time from equation (3)

$$\frac{d\xi}{dt} = -\frac{2R^2 u}{R_1^2} \quad . \qquad (4)$$

Now the problem will be determined by the system (2) and (4).

IV. Numerical Solution And Results

Problem solution is obtained numerically for $R_1 = 0{,}039\ m$, $R = 0{,}02\,m$, $H_0 = 8{,}2\ m$, $\lambda = 5 \cdot 10^{-2}$, $V_0 = 0{,}039\ m/s$, $\ell = 2m$. Using Mathcad application software package, solution results are given at diagrams (Fig.2-Fig.5). Fig. 2 illustrates liquid levels in the tank and in the vertical channel, Fig.3 illustrate under damping oscillations of liquid average velocity in vertical channels.

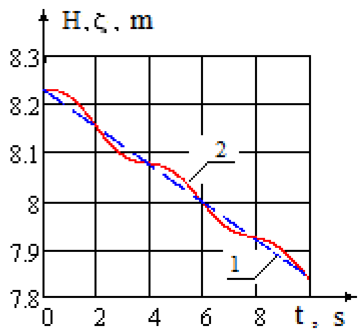

Figure 2: Level of liquid: 1- in the tank, 2- in the vertical channel

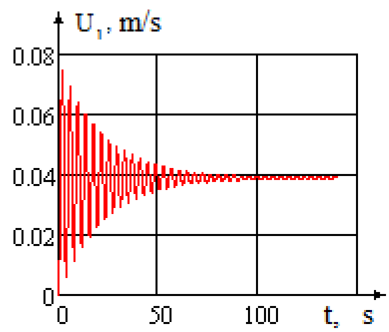

Figure 3: The average velocity of the fluid in the vertical channel

The oscillations are damping with constant period - $T = 3{,}9\ s$, maximum amplitude - $a = 0{,}024\ m$.

Fig. 4 and Fig.5 illustrate the error $\Delta(t) = H(t) - \varsigma(t)$ of liquid level measurement in the tank for friction coefficient $\lambda = 5 \cdot 10^{-2}$ and $\lambda = 10^{-1}$

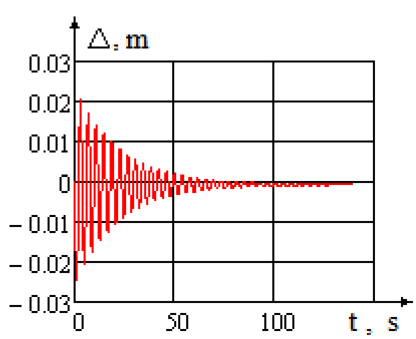

Figure 4: Error in the measurement the liquid level, $\lambda = 5 \cdot 10^{-2}$

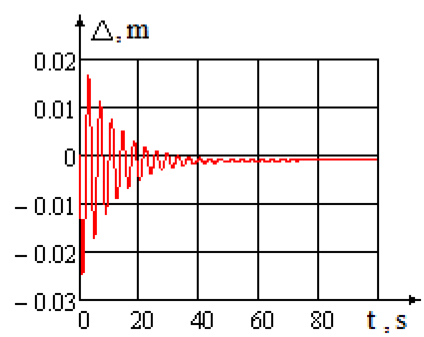

Figure 5: Error in the measurement the liquid level, $\lambda = 10^{-1}$

For the friction coefficient $\lambda = 5 \cdot 10^{-2}$ oscillations period - $T = 3\,s$, maximum error $\Delta = 0{,}024\ m$ is observed at the beginning of the process; approximately in $130\ s$ from the beginning of motion the error is becoming small to negligible. For the friction coefficient $\lambda = 10^{-1}$, oscillations damp in 73 seconds, at that, oscillations period $T = 4\,s$, maximum error do not changed $\Delta = 0{,}024\ m$.

V. Discussion

Can be seen (Fig.3), that the average velocity of the fluid in the vertical channel has synchronous damped oscillations. Fluctuations in a vertical channel are attenuated through 100 seconds. We can see (Fig.4), that the magnitude of the error is a periodic function, in which the amplitude of oscillations decreases with time. The maximum error in determining the level of fuel in the tank is observed in the beginning of the flight of a rocket $\Delta = 0{,}015\ m$, after about 130 seconds error becomes negligible. Mathematical experiment demonstrates, that increasing of the horizontal channel length from $\ell = 2m$ to $\ell = 4m$ results in the increase of oscillation period $T = 5{,}4\,s$ and maximum measurement error $\Delta = 0{,}034\ m$.

VI. Conclusion

Executed study proves that it is impossible to completely exclude liquid oscillations. Measurement error reduction may be expected in case of changing fuel consumption measurement system design features (introduction of holes on the vertical channel or dampers installation in the horizontal channels). To ensure zero error the indicators should be located at the points, corresponding to functions intersection nodes $H(t)$ and $\xi(t)$.

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Experimental and Simulation Performance for Fan Extraction System

By Dr. Klaudio Bari & Dr. Syed Hasan
University of Wolverhampton

Abstract- Computational Fluid Dynamics (CFD) is commonly implemented in industry to perform fluid-flow and heat-transfer analysis, however, rarely used in computational material engineering. The project aim is to select a biodegradable composite for impeller used in conventional domestic extraction fan. The analysis starts with a validation of the experimental values of thrust obtained from different materials used to manufacture impellers tested in a wind tunnel. An identical model was used in the CFD simulation using STAR-CCM+ software. The study compares thrust values of different impellers made from thermoplastic polymer such as Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA) and composite materials such as Bronze-fill, fibre glass and wood fill composites. The results revealed that composite impellers like Bronze-fill and Glass fibre fill composites perform better in term of thrust than traditional ABS impeller. Also, biodegradable wood fill composite shows competitive alternative to replace the conventional AB Simpeller used in fan extraction units. A cost comparison shows that wood-fill composite impeller would be cheaper to manufacture using Polymer Injection Moulding (PIM). A crack growth can be monitor using Acoustic Emission (AE) during solidification of molten plastic.

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EXPERIMENTALANDSIMULATIONPERFORMANCEFORFANEXTRACTIONSYSTEM

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Dr. Klaudio Bari [α] & Dr. Syed Hasan [σ]

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I. Introduction

Traditionally, Computational Fluid Dynamics (CFD) is commonly used in industry to perform fluid-flow and heat-transfer analysis of turbo machinery equipment. The use of CFD plays an important role in fluid mechanics. Due to the progress of numerical methods and computer capability, the impeller design nowadays has been analysed by using numerical analysis and CFD software to predicttimpeller performance (Shah 2013). However, both manufacture and design cannot be done easily with out sufficient details about experimental outcomes. If there is discrepancy between result obtained from the CFD and experimental set up, the impeller cannot be manufactured in a real production line (Kaminsky, 2012).

The project used STAR-CCM+ as a simulation software tool of an identical model of domestic fan extraction placed in a wind tunnel, which was manufactured in the University of Derby workshop. Validation of the results in such case is necessary because the designs and implementers of publically used components could make errors in operation of the component. These errors will result in term of undetected faults in the impeller blades, numerous errors such as loss of system integrity, electric fire hazard in the motor, and worst of all loss of human lives. The mission of validating and verifying is therefore to find out and correct these errors that causes misinterpretation, as early as possible thus preventing exposure of the faulty components or systems to customers. In order to validate the experimental results, an identical design of3D parts was assembled to duplicate a real physical model of fan extraction system and test it in the wind tunnel. The challenge in this project that the simulation software does not possess a tool to select appropriate material of the impeller during simulation, thus a comparison between the simulation/experimental results will be limited to one scenario. Wood-fill/PLA composite impeller was proposed as an option for domestic fan extraction system.

a) Aim

The goal of this study is to analyse the thrust of different types impellers in a wind tunnel and examine the performance and in particular wood-fill composite impeller. The reuse and recyclability of impellers were considered in the selection of the best bio degradable material, thus have gaining a positive environment impact due to recycling and reuse.

b) Star CCM+ Simulation

The use of STAR-CCM+ is becoming more and more important, as it is one of the most powerful CFD software. Ideally when choosing a CFD software, a compromise had to be made between accessibility and powerful functionality. However, STAR-CCM+ integrates a set of tools that perform design, mesh and analyse simulations without having to compromise the accuracy of the boundary conditions. It was chosen in this study because of its ability to solve complex boundary conditions involving several laws of physics with minimum user effort. The software usage in this study is based solely on its rapid expansion through the ranks of CFD and other mechanical engineering fields.

(Kaewnai, 2009) has an objective of using the CFD technique in analysing and predicting the performance of a radial flow-type impeller of centrifugal pump. Although currently there is limited information available of the physics models used axial flow type

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impeller, there is comprehensive research detail for simulation centrifugal impellers in water flow in pumps.

This information can be used at some point in term of comparison criteria and source of error which may encountered during both experimental and simulation process. In the present study, the main concern is the noise and vibration impact on the multi pressure sensors deployed in our wind tunnel. Most research on impellers using STAR-CCM+ was performed ontide, wave and wind energy generation turbines using open air media (Kumawat, H. (2014).However, the validation of low speed air stream (< 10 m/s) a wind tunnel has never been investigated due to lack of interest.

II. Methodology

This research investigates the thrust of an axial impeller rotated at low rotation speed (RPM=10,000). Most of other sresearches were performed mainly on predicting flow pattern of air in axial impellers at above 350 m/s (Kumawat, 2014)

Impeller: The impeller parts have been manufactured using an Ultimaker2 3D printer via a process of fused filament fabrication (FFF), also known as fuse deposition modelling (FDM) as shown in Figure 1. This process deposits a polymer filament into a heated extrusion nozzle. The nozzle moves to a build plate and constructs the 2D cross section of the 3D model; the cross section moves down and allows the nozzle to print another 2D cross-section of the model on the initial 2D cross-section, using heat as an adhesive. The layers are stapled till the 3D model is completed.

Figure 1: 3D Printer Ultimaker allocated to manufacture five different impellers

Before printing the CAD model of the impellers, it had to be prepared using software called CURA; it is associated with Ultmaker2 (the 3D printer model). The Ultmaker2 does not support files from other software, hence a change of file extension to STL was done in order to open the file in CURA. CURA was used in changing the printing conditions such as; size and shape of components, and Layer height (the movement of the control plate between each layer). Note that the higher the layer height the lower the printing quality, just as pixels in 2D picture printing. There are two other parameters that determine the finishing of the components being printed; fill density and wall thickness. Fill density, is the internal cavity, a fill density of 100% would create a solid part while a fill density of 0% would create a component with hollow cavities. Then the impellers were aligned to find the accurate centroid of the rotation in order to prevent vibration at all rotation speeds as shown in Figure 2.

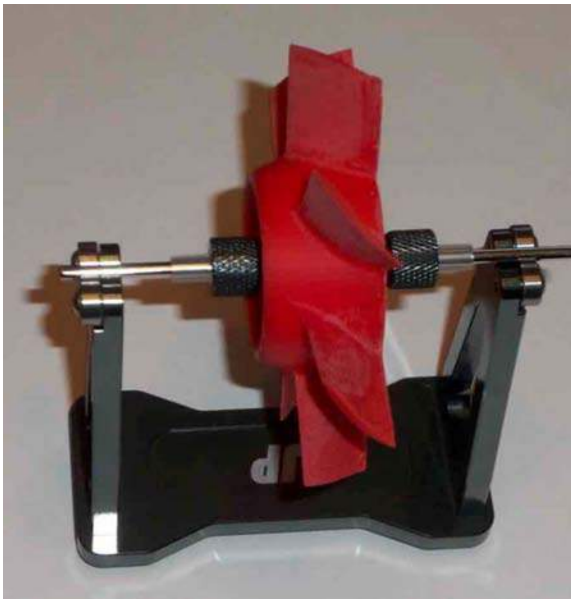


Figure 2: ABS impeller produced by 3 D printing device fixed by alignment shaft

After successfully printing the impeller in ABS and PLA, three other composites were used. Wood-fill (70% PLA, 30% recycled Wood-fibre), Bronze-fill (a composite of PLA and fine bronze particles) and Glass fibre (70% PLA, 30% E-Glass fibre). The same layer height and infill parameters were used for Bronze-fill (0.1mm layer height, 25% infill), however Wood-fill required a layer height of 0.25mm due to its lower printing temperature. All five impellers and the backward stator are shown in Figure 3. The material properties of the impellers are listed in Table 1.

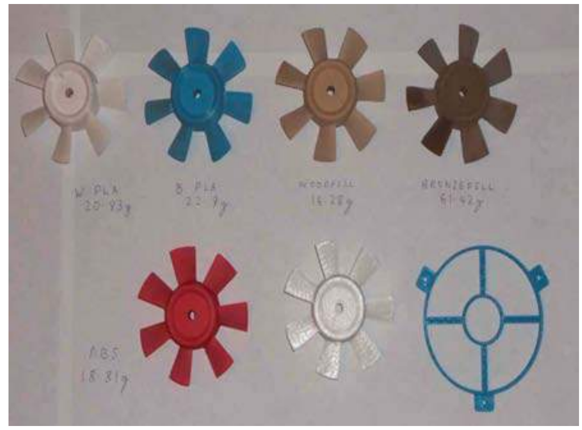


Figure 3: Image shows five Impellers and stator

Table 1: The material properties of different impellers tested in the wind tunnel

Material	Fan Size	Tolerance	Density g/cm^3	Melting Point(°C)	Tg(°C)	Impact Strength KJ/m^2
ABS	90 mm	±0.10mm	1.03	-	105	36
PLA	90 mm	±0.10mm	1.24	150-160	60-65	7.5
Wood-fill/PLA	90 mm	±0.05mm	1.29	*220*	60-65	17.4
Glass fibre fill/PLA	90 mm	±0.05mm	3.1	*n/a*	*n/a*	21.1
Bronze-fill/PLA	90 mm	±0.05mm	3.9	*n/a*	*n/a*	22.5

a) *Wind Tunnel*

The wind tunnel was manufactured in our workshop using laser cut machine and assembled using expert technicians to fit all components inside. It is a cylindrical geometry tunnel of synthetic smooth PVC plastic in order to reduce intrinsic drag from air streams and supported by ply wood frames to reduce vibration. It was mainly designed to minimise the turbulence created by the rotating impeller. The outlet air streams measured by 0.5 mm^{2}highly sensitive pressure sensor that measures the velocity and mass flow rate. The impeller, fan case and the other components used in the experiment shown in Figure 4.

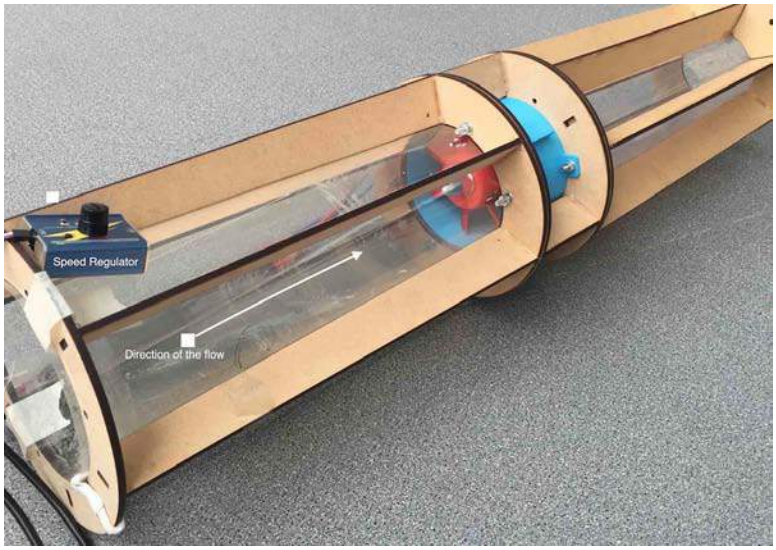


Figure 4: Image shows a Wind tunnel includes impeller and fan case

Speed Regulator:

The device shown in Figure 4 is an electric servo regulator adjusting the impeller speed during the experiment. The fan was power up by 12 DC battery able to run the impeller up to 40 hours, the regulator would switch off the fan in case of motor overheat in the wind tunnel using servo consistency master. The motor rotating the fan is connected to a car battery, to provide stable DC power for long period of time and constant rotation of 10000RPM. that Controlled by a digital Tachomter shown in Figure 5

Figure 5: Image shows the digital Tachometer

Guided Vanes:

This is a non-rotating fan stationed in the tunnel to laminate the level of turbulence in exited at the outlet. This stator acts like a frame fastened to the walls of the container, to make sure all air streams are aligned to horizontal axis in order to prevent turbulence at the outlet end. Figure 6 shows the horizontal view of outlet end of the wind tunnel.

Figure 6: Image shows the Outlet view of the wind tunnel

III. Results

a) Experimentation Case

A mass rate and velocity meter is fixed on the outlet of the tunnel to measure the outlet mass rate and air velocity. By replacing the impeller for each batch process, the thrust can be measured for different impellers using the equation1.

$$Thrust = Velocity\ x\ mass\ flow\ rate \qquad (1)$$

The velocity meter is connected to PC. The probe has very high sensitivity and an accuracy of ± 0.3%. With that kind of sensitivity and accuracy, the application of the device on the tunnel would require a level of precision; any sudden vibrations could affect the accuracy of the readings and cause a variation in results as shown in Figure 7.

Figure 7: Image shows Manometer is connected without fixing the ends, which cause vibrations

The averaged outlet velocity, mass flow and thrust measured using the manometer are listed in Table 2.

Table 2: The list of outlet velocity, mass flow and thrust of different impellers tested in the wind tunnel.

Material	Outlet velocity m/s	Outlet mass flow rate Kg/s	Thrust (N)
ABS	12.50	0.041	0.51
PLA	10.30	0.032	0.33
Wood-fill/PLA	11.91	0.039	0.465
Glass fibre fill/PLA	12.94	0.044	0.57
Bronze-fill/PLA	13.96	0.049	0.68

b) Simulation Case

The first step is use of a CAD based software (Solid Works) to draw the structure and topology of complete wind tunnel includes the internal parts. As the impellers were already designed in a CAD based software, a simple transfer of the drawing would merely suffice to Solid Works. The second step is to import the identical model geometry from solid work file (STL format) to star CCM+. The wind tunnel, fan case, motor, cables and impeller were identically represented and were applied to the same boundary conditions used in the experiment case. After that, appropriate physics models (RANS with K-epsilon correction) were applied to specify the behaviour of the turbulence produced as shown in Figure 8.

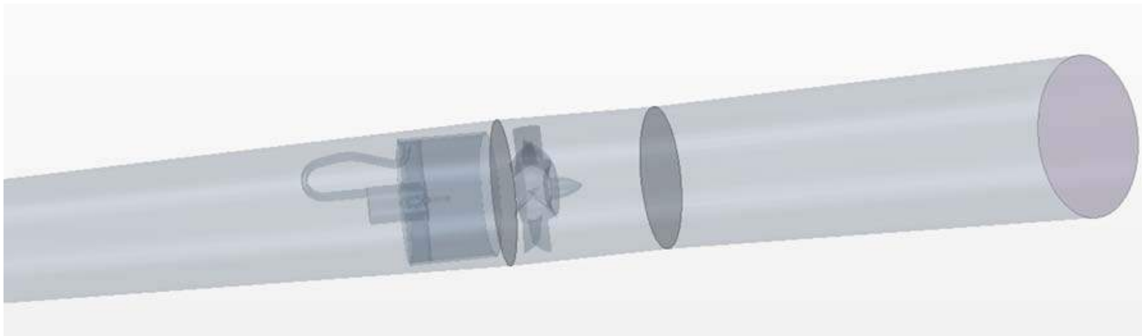


Figure 8: The model configuration shows the exact real case, motor, guide vain, wires, fan and wind tunnel case.

c) Simulation Results

The model meshed using different size of Polyhedral size for the fluid region (1-10 mm) and fixed Prism layer size of 1 mm for surface structure region.

The velocity value-location from the outlet wind tunnel pipe of from different mesh size are shown in Figure 9a, b, c, d, e.

It was found that mesh size between 1-3 mm was appropriate and it would produce repeatable results. The similar outlet velocity profile is evident when comparing the outlet velocity profile in Figure 10 and Figure 12.

The quality of the model mesh was over 99.9%. This was achieved using automated mesh which uses surface and geometry mesh control.

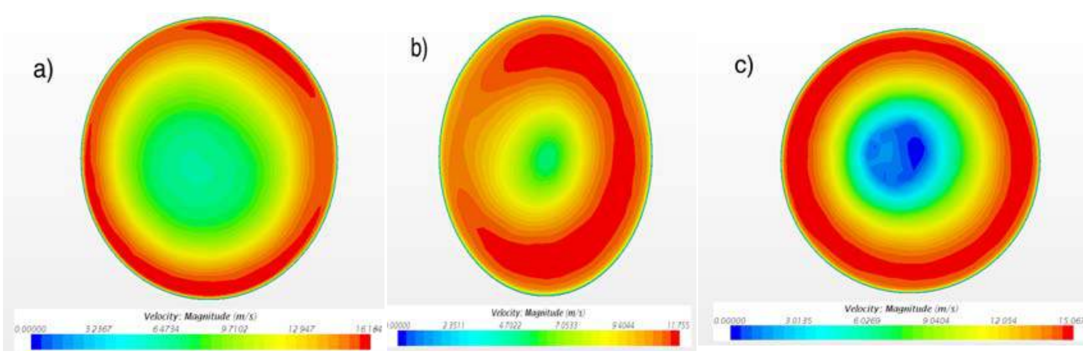
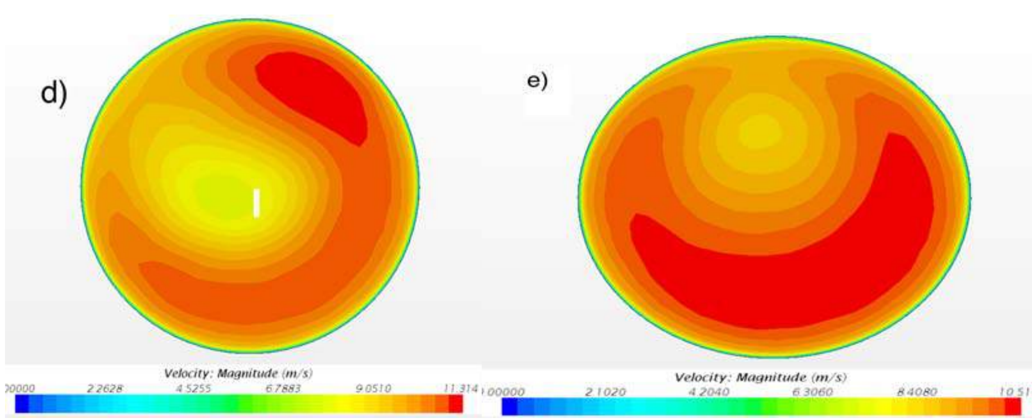


Figure 9: 10 mm mesh 8 mm mesh 6 mm mesh



3 mm mesh 1 mm mesh

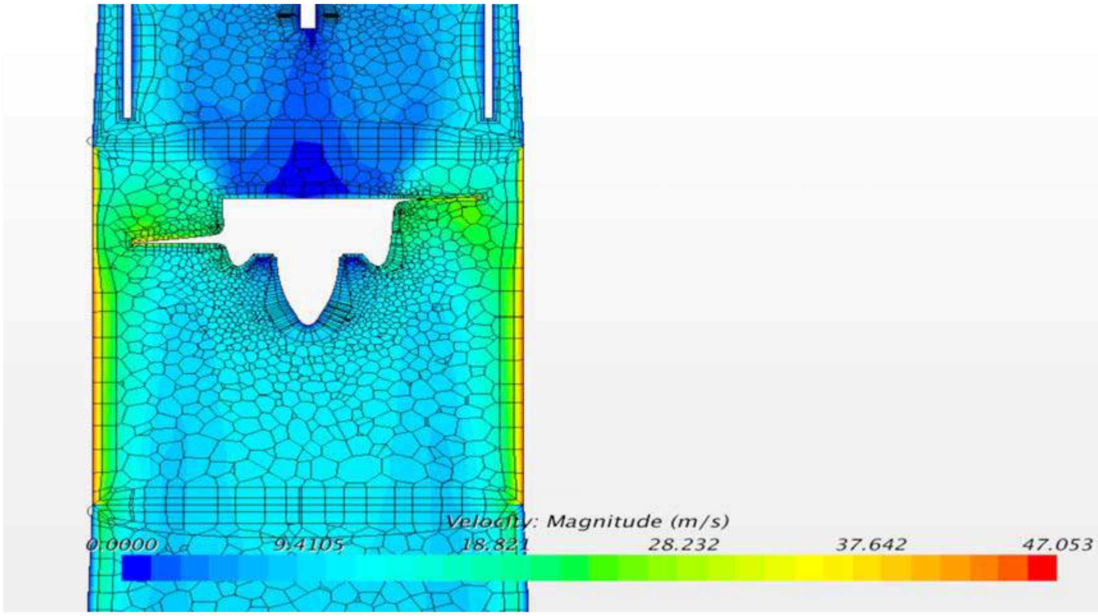


Figure 10

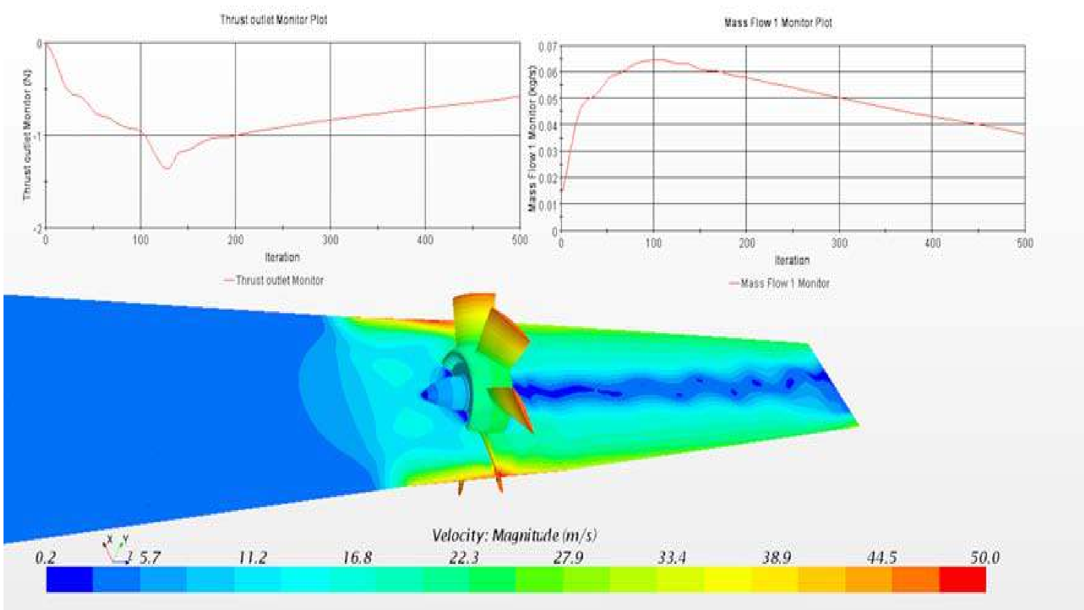


Figure 11: Image shows the final results from the simulation

IV. Experimental Results

Similarly, the outlet mass rate and velocity of different impellers, from the wind tunnel were measured using the bespoke manometer. The averaged of 10 readings were obtained and the final results are summarized in Figure 12.

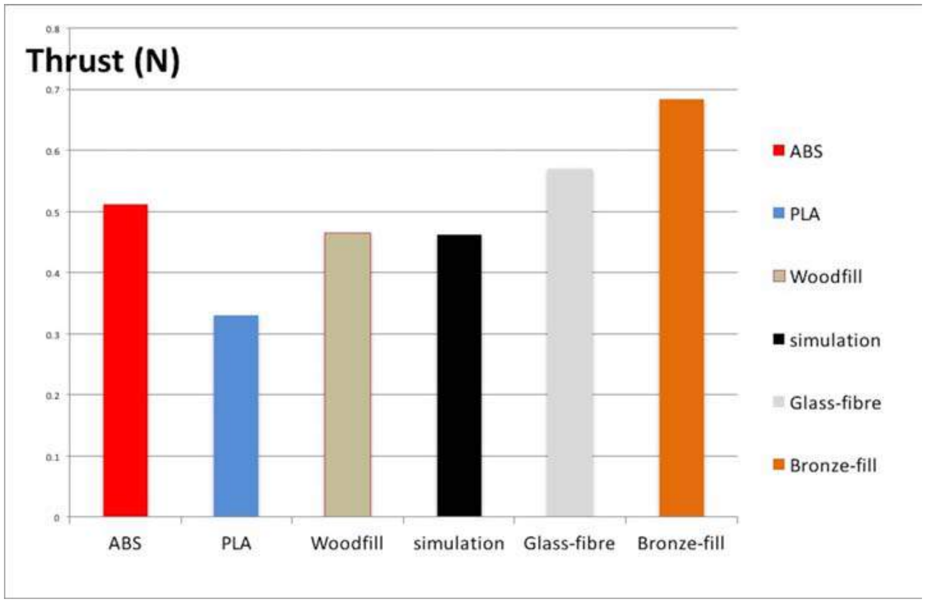


Figure 12: Chart shows a comparison between the experimental and simulation thrust results

V. Discussion

The discussion of the results can be summarised as below:

- Composite impellers like Bronze-fill/PLA and glass Fibre fill/PLA composites showed better performance in term of thrust compared to traditional ABS impeller used in domestic extraction fan system.
- Wood fill/PLA composite as a biodegradable material to shows similar thrust values to simulation results. This makes it attractive to be used in as base line in simulation using Star CCM+.
- A modification was proposed to CD-Adapco to add-on a Rigidity Factor (RF) in the rotation section in the software. This will enable the user to choose an appropriate material factor in the simulation using rotation reference frame.

Plastic Impellers are manufactured using one of our Pre-Tooled Plastic Impeller molds. This method saves molds development time and money by using our existing tooling inventory. Also, the time from placement of order to delivery of actual parts is significantly reduced. The cost unit of wood fill/PLA composite impellers will be reduced to half using the advance air plastic injection molding.

Advanced Air produces plastic injection molded impellers for a wide variety of OEM, commercial and industrial applications. The early results show that the design and manufacture high quality impellers have meet our exact specifications. The use innovative manufacturing facilities to produce plastic impellers and impeller products that give us 100% recyclability and zero impact on the environment, maximum durability and high performance.

In order to detect and monitor crack growth during solidification of the impeller, Acoustic Emission (AE) could be a micro-scale detection tool to monitor crack and porosity of the final product. AE technique also uses relatively simple but effective means of monitoring the time progress development of different failure mechanisms during air injection molding. The data of the emission can be analysed and differentiated to provide instantly alarm for shrinkage rate during solidification of the impeller in the mold (Spasova, 2008).

VI. Conclusion

Biodegradable impellers are promising material to replace the current ABS used in domestic fan extraction system. This will have a significant positive environmental impact by recycling the used impellers. An early result shows that wood-fill/PLA impeller was viable to be manufactured using traditional extrusion process to reduce cost of production. Plastic Mold Injection (PIM) was selected as a cost effective manufacture process in the mass production of wood-fill/ PLA composite impeller.

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Path Loss Prediction for Some GSM Networks for Akwa Ibom State, Nigeria

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Abstract- Path loss prediction for some Global System of Mobile Communication (GSM) networks for Akwa Ibom State in the Federal Republic of Nigeria was undertaken in this study in order to obtain a suitable path loss model for path loss prediction for the State. Received Signal Strength (RSS) and path loss were obtained from MTN and GLO base stations (networks) located in Uyo, Eket, Ikot-Ekpene, Onna, Etinan and Oruk-Anam which are some major towns in Akwa Ibom State. Path loss plots from theoretical models and experimental data against Basic Transceiver System (BTS), mobile device distance, gave positive linear relationships resulting in the proposed path loss model for Akwa Ibom State. Comparative analysis of Mean Square Error (MSE) obtained showed Hata model to be the most reliable and suitable path loss prediction model for Akwa Ibom State. The MSE value for each town was 5.9dB, 4.09dB, 5.93dB and 4.03dB for Uyo, Eket, Onna and Etinan, respectively. It was found that Egli model with MSE value of 5.97dB is suitable for path loss prediction in Ikot-Ekpene due to its irregular terrain.

Keywords: path loss, global system of mobile communication (GSM), base transceiver station (BTS), received signal strength (RSS), networks and akwa ibom state.

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Strictly as per the compliance and regulations of:

Path Loss Prediction for Some GSM Networks for Akwa Ibom State, Nigeria

Michael U. Onuu [α] & Emem M. Usanga [σ]

Abstract- Path loss prediction for some Global System of Mobile Communication (GSM) networks for Akwa Ibom State in the Federal Republic of Nigeria was undertaken in this study in order to obtain a suitable path loss model for path loss prediction for the State. Received Signal Strength (RSS) and path loss were obtained from MTN and GLO base stations (networks) located in Uyo, Eket, Ikot-Ekpene, Onna, Etinan and Oruk-Anam which are some major towns in Akwa Ibom State. Path loss plots from theoretical models and experimental data against Basic Transceiver System (BTS), mobile device distance, gave positive linear relationships resulting in the proposed path loss model for Akwa Ibom State. Comparative analysis of Mean Square Error (MSE) obtained showed Hata model to be the most reliable and suitable path loss prediction model for Akwa Ibom State. The MSE value for each town was 5.9dB, 4.09dB, 5.93dB and 4.03dB for Uyo, Eket, Onna and Etinan, respectively. It was found that Egli model with MSE value of 5.97dB is suitable for path loss prediction in Ikot-Ekpene due to its irregular terrain. Results also showed that none of the models being considered gave acceptable MSE value for Oruk-Anam. In this case, the proposed path loss prediction model for Akwa Ibom State should be used for Oruk-Anam. The results of this investigation therefore lend credence to the fact that terrain and infrastructural development affect not only path loss, but also the suitability of a given path loss model for a particular environment.

Keywords: path loss, global system of mobile communication (GSM), base transceiver station (BTS), received signal strength (RSS), networks and akwa ibom state.

I. Introduction

a) Overview

Since the advent of telecommunication, there have been researches on how to improve and enhance communication between people at various locations. This resulted in Global System for Mobile Communication (GSM) which is a wireless form of communication that propagates information (voice and data) in the form of an electromagnetic (EM) wave.

It is a fact that cellular phones have revolutionized personal communications for millions of people around the globe. Like any mobile radio, a cellular phone transmits and receives electromagnetic waves [19]. The use of GSM has bridged the communication gap between urban and rural dwellers. Since the inception of commercial operation of GSM globally in 1991 and in Nigeria in 2001, the demand for good delivery of voice and data services by subscribers is high.

It has been observed that even with the operation of four telecommunication giants and other communication industries in Nigeria, there is still an outcry by subscribers on poor quality network. This is due to the fact that GSM faces the problem of reduction in power density (path loss) in electromagnetic wave as it propagates between the BTS and mobile device.

A particular BTS has a limit to which it can cover for effective communication; thus locating a communication mast and BTS must be done such that the number is minimized through proper link design and path loss prediction. Poor network coverage brings about frequent drop calls, poor quality of service, poor inter -connectivity, echoes and general congestion [12].

This is due to the fact that signal value and signal level for voice and data service for a network depend on the power density of an electromagnetic wave as it propagates through the space from the source to the mobile device.

The gradual loss in power density of an electromagnetic wave as it propagates from the source to the receiver is a problem to network providers. For cellular network to effectively cover a terrain or environment, accurate prediction of the coverage of the radio frequency signal is highly needed. Wave propagation models are essential and very important tools in determining the propagation characteristics for a particular environment [12].

Path loss prediction is a necessary tool for GSM network design, location of BTS and coverage area for such a network. Path loss is due to several effects such as free space path loss, refraction, diffraction, reflection, absorption, coupling and cable loss. Path loss depends on several factors which are; type of propagation, environment, distance between the transmitter and receiver, height and location of antennas [1]. From the foregoing, it means that the area to which a particular BTS can cover is not fixed but depends on the nature of the environment, terrain and the level of infrastructural development of such a location. In urban areas with dense population, high rise buildings and structures,

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reflection and absorption of radio energy by buildings is high, thus loss in power density will be high.

According to Mawjoud [6], networking planning is vital in the prediction of path loss and hence the coverage area, frequency assignment and interference which are the main concerns in mobile network planning. The available empirical formulae cannot be generalized to different environments (urban, sub-urban, rural). In general, suitability of these models differ for different environment.

Several propagation models have been formulated for prediction of path loss, but due to difference in terrain and level of development of a particular environment, appropriate model for a particular environment differs. This study is aimed at obtaining a propagation model that is suitable, reliable and most accurate for path loss prediction in an environment and terrain like Akwa Ibom State in the Federal Republic of Nigeria.

II. Review Of Previous Works

Path loss is the gradual reduction in power density of an electromagnetic wave as it propagates through the space from a source. Electromagnetic wave propagates through space from one region to another even when there is no matter in the intervening region. Electromagnetic wave, when traveling through an unguided medium, undergoes different kinds of propagation effects such as reflection, diffraction, free space loss, absorption, aperture medium, coupling loss and scattering. These propagation effects are the causes of reduction in power density (path loss). Path loss is as a result of received signal becoming weaker due to increasing distance between the base station and the transceiver system. This occurs even when there are no obstacles between the transmitting antenna and the receiving antenna. Radio wave propagation through a city is greatly affected depending on whether there is line- of- sight (LOS) between transmitting and receiving antennae or not. This is because propagation characteristics of the radio wave, such as path loss, fading and attenuation do not only depend on the distance and frequency, but also on the scatter angle that depends on what is causing the obstruction to the propagated wave [13].

A number of researchers have worked on path loss prediction which is of vital importance in GSM network design, planning, location of BTS, coverage area, frequency assignment and interference for effective cellular networks aimed at achieving effective signal values and levels between a transceiver and a mobile device.

Mawjoud [6] in his work on path loss propagation model prediction for GSM network planning studied the outdoor path loss behavior in Mosul city in Iraq to predict a suitable propagation model at the frequencies of 900MHz and 1800MHz in urban and sub-urban environments. After comparing the empirical models such as Hata, costs-231 Hata, International Telecommunication Union - Radio (ITU-R), Ericson and Stanford University Interim (SUI) with the experimental measured path loss for urban areas in Mosul city, the result showed that at 900MHz frequency, the best fit model for urban and sub-urban is Hata and Ericson models and for 1800MHz frequency, the best fit model for industrial and sub-urban areas is the Costa-Hata model. This shows that every environment has its distinctive characteristic factors and features that affect the propagation of wave differently. This, thus, precludes the generalization of a particular model for different environment. Various works [10,11] also showed that a path loss model cannot be generalized for different environment.

Also Isabona and Konyeha [5] in their study on urban area path loss propagation prediction and optimization using Hata model at 800MHz showed how Okumura Hata model is chosen and optimized for urban outdoor coverage in the Code Division Multiple Access (CDMA) system operating in 800MHz UHF frequency band in South South Nigeria. They compared measured path loss with theoretical path loss obtained from Hata, SUI, Lee and Egli models. In their result, Hata model was the nearest in agreement with the measured values. Based on these, they developed an optimized Hata model for the prediction of path loss experienced by CDMA 2000 signal in 800MHz band.

a) *Reasons and causes of path loss*

The reduction in power density (path loss) of a signal as it propagates from a source is caused by various factors which includes free space loss, diffraction, multipath fading, buildings and vegetation, terrain and atmosphere.

b) *Theoretical path loss models*

Theoretical models were derived based on the physical laws of wave propagation [10]. The theoretical path loss prediction models are divided into two basic types, namely; free space path loss model and plane earth propagation model.

i. *Free space propagation model*

In free space, the wave is not reflected or absorbed. Ideal propagation implies equal radiation in all direction from the radiating source and propagates to an infinite distance with no degradation. The free space path loss model is used to predict received signal strength when the transmitter and receiver have a clear unobstructed line-of- sight, LOS, path between them [10]. In satellite communication, microwave in LOS radio links typically undergo free propagation. According to [2,8,10], the power flux is given by

$$P_d = \frac{P_t}{4\pi d^2} \qquad 2.1$$

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where P_t is known as transmitted power (W/m^2) and P_d is the power at a distance d from the antenna. The effective power of an isotropic antenna is given by

$$A_e = \frac{\lambda^2}{4\pi} \quad 2.2$$

and the received power by

$$P_r = P_d \times A_e = P_t \times \frac{\lambda^2}{(4\pi d)^2} \quad 2.3$$

The actual power received by the antenna depends on the aperture of the receiving antenna A_0, the wave length of the received signal λ and the power flux density at the receiving antenna P_d. Path loss is given by the equation

$$L_P = Power\ transmitted\ (P_t) - power\ \ received\ (P_r) \quad 2.4$$

Substituting equation 2.3 into 2.4 gives

$$L_P = 20\log_{10}(4\pi) + 20\log_{10}(d) - 20\log_{10}(\lambda) \quad 2.5$$

Also substituting $\lambda\,(in\,km) = \frac{0.3}{f}(in\,MHz)$ and rationalizing the equation produces the generic free space path loss formula as given below:

$$L_P\ (dB) = 32.5 + 20\log_{10}(d) + 20\log_{10}(f) \quad 2.6$$

where *f* is the carrier frequency in MHz, *d* is the T-R distance in km.

ii. *The plane earth model*

According to [14,18], path loss experience is worse in terrestrial environment than in free space. The most significant difference between terrestrial environment and free space is the presence of ground (and ground reflection) in a terrestrial environment. The plane earth loss increases far more rapidly than the free space loss and it is independent of carrier frequency. In plane earth model [14,18],

$$L_p = \frac{h_t^2\ h_r^2}{d^4} \quad 2.7$$

where d is the distance (in metres) between the transmitter and receiver, h_t is the height (in metres) of the transmitter antenna and h_r is the height (in metres) of the receiver antenna.

In practice, a correction factor a is added to equation 2.7 to yield

$$L_p = \frac{a h_t^2\ h_r^2}{d^4} \quad 2.8$$

The correction factor a depends on the frequency of the carrier. Converting equation 2.8 to decibel gives.

$$L_p = 10\log(a) + 20\log(h_t) + 20\log(h_r) - 40\log(d) \quad 2.9$$

The plane earth loss is rarely an accurate model of real-world propagation when taken in isolation. It only holds for long distance and for cases where the amplitude and phase of the reflected wave is very close to the idealized in case a equals 1.

c) *Empirical Models*

Empirical models, also known as stochastic models, are models obtained from experimental observation. There are of various types and their suitability differs with respect to terrain. In this work, Okumura model, Hata model, Cost-231 model and Egli model will be discuss.

i. *Okumura Model*

According to [10], the Okumura's model is an empirical model based on extensive drive test measurements made in Japan at several frequencies within the range of 150 to 1920 MHz, but is extrapolated to 3000 MHz. For Okumura model, the prediction area is divided into terrain categories; open areas, suburban area and urban area [15]. Nadir and Ahmad showed that the signal strength decreases at much greater rate with distance than that predicted by free space model [7].

Okumura developed a set of curves giving the median attenuation relation to free space (A_{mu}), in an urban area over a quasi-smooth terrain with a base station effective antenna height (h_b) of 200m and a mobile antenna height (h_m) of 3m. The curves are plotted as a function of frequency in the range of 100MHz to 1920MHz and as a function of distance from the base station in the range 1km to 100km.

The empirical path loss formula of Okumura is expressed as [10,15]

$$L_{50}\,(dB) = L_F + A_{mu}\,(f,d) - G(h_b) - G(h_m) - G_{AREA} \quad 2.10$$

where $L_{50}\,(dB)$ is the medium value of the path, L_F is the free space path loss as given in equation (2.6), A_{mu} is the median attenuation relation to free space, $G(h_b)$ is the base station antenna height gain factor, $G(h_m)$ is the mobile antenna height gain factor, G_{AREA} is the gain or correction factor due to the type of environment.

The value of $A_{mu}(f,d)$ and G_{AREA} are obtained from Okumura's empirical plots shown in figure 1. Okumura derived empirical formula for $G(h_b)$ and $G(h_m)$ as follows:

$$G(h_b)=20\log_{10}(h_b/200) \quad : \; 30m < h_b < 1000m \qquad 2.11a$$

$$G(h_m)=10\log_{10}(h_m/3) \quad : \; h_m < 3m \qquad 2.11b$$

$$G(h_m)=20\log_{10}(h_m/3) \quad : \; 3m \le h_m \le 10m \qquad 2.11c$$

Table 2.1: Range of validity for Okumura model

Parameter	Symbol	Range
Carrier frequency	F	150 to 1920 MHz
Base station antenna height	h_b	30 to 1000m
Mobile antenna height	h_m	1 to 10m
Distance	D	1km to 100km

ii. *Hata Model*

The Hata model is an empirical formulation of the graphical path loss data provided by Okumura model (Hata, 1980). It is valid over roughly the same range of frequencies 150MHz to 1500MHz. This empirical formula simplifies the calculation of path loss because it is closed form formula and it is not based on empirical curves for different parameters. Two forms of the Okumura-Hata model are available [20]. In the first form, the path loss (in dB) is written as

$$PL = PL_{free\,space} + A_{exc} - H_{cb} - H_{cm} \qquad 2.12$$

where $PL_{free\,space}$ is the free space path loss, A_{exc} is the excess path loss (as a function of distance and frequency) for a base station height, h_b , 200m and mobile station height, h_m , 3m.

The more common form is a curve fitting of Okumura's original result. In that implementation, the path loss is written as [17]

$$PL = A + B\log(d) - C \qquad 2.13$$

where A, B and C are factors that depend on frequency and antenna height according to the following equations:

$$A = 69.55 + 26.16\log(f_c) - 13.82\log(h_b) - a(h_m) \qquad 2.14a$$

$$B = 44.9 - 6.55\log(h_b) \qquad 2.14b$$

where f_c is given in MHz and d in km, $a(h_m)$ is a correction factor for mobile antenna height.

The function $a(h_m)$ and C depend on the environment for small and medium-size cities.

$$\left.\begin{array}{l} a(h_m) = (1.1\log(f_c) - 0.7)h_m - (1.56\log(f_c) - 0.8) \\ C = 0 \end{array}\right\} \qquad 2.14c$$

For metropolitan areas or large cities

$$\left.\begin{array}{l} a(h_m) = \begin{cases} 8.29(\log(1.54h_m))^2 - 1.1 & for\ f_c \le 200MHz \\ 3.2(\log(11.75h_m))^2 - 4.97 & for\ f_c \ge 400MHz \end{cases} \\ C = 0 \end{array}\right\} \qquad 2.14d$$

For suburban environment

$$C = 2[\log(f_c/28)]^2 - 5.4 \qquad 2.14e$$

For rural area

$$C = 4.78\log(f_c)^2 - 18.33\log(f_c) - 40.98 \qquad 2.14f$$

The function $a(h_m)$ in suburban and rural area is the same as urban (small and medium-size cities) areas.

The Hata model will approximate the Okumura model for distance $d > 1$ km. Hence, it is a good model for first generation cellular system, but it does not model propagation well in current cellular system with smaller cell size and higher frequencies. The table below shows the validity range for Okumura-Hata model.

Table 2.2: Range of validity for the Okumura-Hata model

Parameters	Symbol	Range
Carrier frequency	f_c	150 … 1500 MHz
Effective base station antenna height	h_b	30 … 2000m
Effective mobile station antenna height	h_m	1 … 10m
Distance	*D*	1…20km

where

$$A = 46.3 + 33.9\log_{10}(f) - 13.82\log_{10}(h_b) - a(h_m) \qquad 2.16a$$

$$B = 44.9 - 6.55\log_{10}(h_b) \qquad 2.16b$$

$$C = \begin{cases} 0, \text{for medium city and suburban areas with moderate tree density} \\ 3, \text{for metropolitan centres} \end{cases} \qquad 2.16c$$

$$a(h_m) = 1.1\log(f) - 13.82\log_{10}(h_b) - a(h_m) + [44.9 - 6.55\log]_0(h_b)\ \log_{10}(d) + C \qquad 2.16d$$

Thus

$$L_p = 46.3 + 33.9\log(f) - 13.82\log_{10}(h_b) - a(h_m) + [44.9 - 6.55\log_{10}(h_b)\log_{10}(d) + C] \qquad 2.17$$

iii. *COST-231 Model*

The COST-231 model sometimes called the Hata model PCS extension is an enhanced version of the Hata model that includes 1800-1900MHz [15]. COST-231 model is for propagation in the PCS band.

According to Nkordeh, COST-231 model is limited to cases where base station antenna is placed higher than the surrounding building. COST-231 model is given by [9,15,16]:

$$L_P = A + B\log_{10}(d) + C \qquad 2.15$$

Table 2.3 Validity Range for COST-231 Model

Parameters	Symbol	Range
Carrier frequency	f_c	1800MHz < f_c < 2000 MHz
Effective base station antenna height	h_b	30m < h_b < 200m
Distance	D	1000m > *d* > 200m

iv. *Egli Model*

Egli model is an irregular terrain model for radio frequency propagation [10,15]. Egli model provides the median path loss due to terrain loss. It predicts the total path loss for point-to-point link (link-of-sight transmission). Typically, it is suitable for cellular communication scenarios where one antenna is fixed and another is mobile. Egli model is expressed as [15]

$$L_{50} = G_b G_m \left[\frac{h_b h_m}{d^2}\right]^2 \beta \qquad 2.18$$

where G_b is the gain of the base antenna and G_m is the gain of the mobile antenna, h_b is the height of the base antenna, h_m is the height of the mobile antenna and d is the propagation distance and

$$\beta = \left(\frac{40}{f}\right)^2 \qquad 2.19$$

where f is the frequency in MHz combing equation 2.18 and 2.19, Egli model is given by

$$L_{50} = G_b G_m \left[\frac{h_b h_m}{d^2}\right]^2 \left(\frac{40}{f}\right)^2$$

The gain for mobile station, G_m and gain for base station, G_b are zero in decimal unit, so the path loss in this case can be simplified by

$$L_{50} = 40\log_{10}(d) - 20\log_{10}(h_b) - 20\log_{10}(h_m) - 10\log_{10}(\beta) \qquad 2.20$$

III. Cell, BTS and Mobile Device

Global system for mobile communication (GSM) is made up of a BTS and a mobile device enclosed within a cell.

In GSM, a cell is the geographical area covered by radio frequency from BTS which a mobile device located within that range can connect reliably is the transceiver (Figure 2.1). The size of a cell is not fixed, it depends on several factors such as line-of-sight, reflection and absorption of radio frequency by obstacles and vegetation, height of the antenna, transmitters rate power, the required uplink/down link data rate of the subscribers device and the terrain.

Sharma and Singh showed that these cells joined together to provide radio coverage over a large geographical area [16]. Path loss determines the cell range. For GSM, there are three cell ranges. Table 2.4. Hamad-ameen from his research showed that the accuracy of cell planning depends on several factors and accuracy of propagation model is one of them [3].

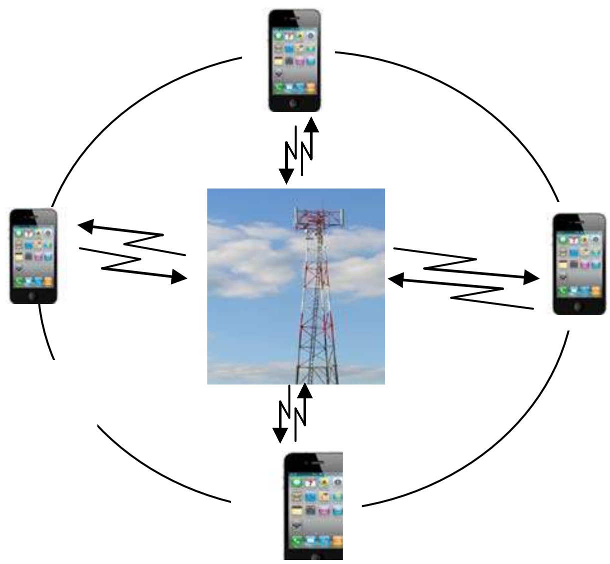

Fig. 2.1: cell

Table 2.4: Cell Range

Cell	Cell Radius
Large cells	1km ≥ r ≥ 30km
Small cells	1km to 30km
Micro cells	200m to 300m

Base Transceiver Station (BTS) in mobile communications holds the radio transceiver that defines a cell and co-ordinate the radio-link protocols with the mobile device. The BTS is the networking component of a mobile communications system from which all signals are sent and received. Thus it facilitates wireless communication between a device and network thereby creating the cell in a cellular network. A BTS consist of the following: antennas that relay radio message, transceivers, duplexers and amplifiers while a mobile device is a portable, wireless computing device that is small enough to be used while held in the hand; a hand-held. These include mobile phones, PDA, computers.

A mobile phone operates on a cellular network which is composed of cells. If a subscriber (user) is located outside the cell belonging to the cellular network provider the user subscribed to, such a user cannot place or receive calls in that location.

a) Experimental Design

The methods employed in this study include physical site survey, collection of data, GPS measurement and analysis (graphs and regression). A detailed field study exercise for collection of data was carried out in selected cities of Akwa Ibom State using a mobile phone.

A NET monitor software installed in a Samsung galaxy phone was used to obtain the received signal strength from a fixed BTS at selected locations while GPS was used to measure the BTS – mobile device distance while a Personal Computer (PC) was used to save the collected data.

This study was conducted in December, 2015 in selected cities of Akwa Ibom State at a temperature of 27°C. The Local Government Areas in which the investigation was carried out were Uyo, Eket, Ikot-Ekpene, Onna, Etinan and Oruk-Anam (Table 3.1).

b) Description of the study area

Akwa Ibom State lies between latitudes 4.32° and 5.33°N and longitudes 7.35° and 8.25°E, the State is in the South-South geopolitical zone of Nigeria, bounded by Rivers State on the West, Cross River State on the East, Abia State on the north and Gulf of Guinea.

The State is in Niger Delta and one of the 36 states in the Federal Republic of Nigeria with a total land mass of 7,249 square kilometers. About 13% of the 960km of Nigeria's Atlantic Ocean runs through Akwa Ibom State.

Akwa Ibom State falls within the tropical zone of Nigeria with a dominant vegetation of green foliage of trees and shrubs. Most parts of the state are coastal areas with Atlantic coastlines that stretch 129km from Oron in the east to Ikot Abasi in the west.

c) Receiver Signal Strength (RSS)

In telecommunications, Received Signal Strength is the power present in a received radio signal and it is express in decibel (dB).

Below is a range of signal strength and its effect on quality of service.

Table 3.1: Signal Strength on GSM

Signal Strength (dB)	Quality of
$-105\ to - 100$	Bad/drop call
$-99\ to - 90$	Getting bad/signal may break up
$-89\ to - 80$	Quality of service should not have problem
$-79\ to - 65$	Quality of service is good
$Overto - 65$	Quality of service is excellent

IV. Results and Discussion

The empirical path loss result was evaluated using four different path loss models, namely, free space model, Hata model, COST -231 model and Egli model. The experimental results were subjected to regression analysis to obtain path loss model for each of the locations and path loss model for the entire study area. The Mean Square Error (MSE) was used to pick an empirical path loss model suitable for Akwa Ibom State.

Table 3.1 Cities and their characteristics

City	Classification	Characteristics
Uyo	Urban (coastal/hinterland)	Level terrain, presence of industries and institutions, heavy road traffic, large number of cluster high – rise building and telecommunication companies.
Etinan	Urban (hinterland)	Moderate road traffic, sparsely distributed buildings, few trees, hill and telecommunication companies
Eket	Urban (hinterland)	Heavy road traffic, oil exploration companies, institutions, large number of cluster high – rise building, level terrain and telecommunication companies.
Onna	Suburban(coastal/hinterland)	Very high road traffic, tall trees, sparsely distributed building and telecommunication companies
Ikot-Ekpene	Urban (hinterland)	Heavy road traffic sparsely distributed high – rise building few trees, hills
Oruk-Anam	Urban (hinterland)	Very high road traffic, thick vegetation with tall trees and telecommunication companies

Ibom State. The minimum MSE Value for good signal propagation is 6dB.

a) *Empirical path loss result*

The result from the four empirical path loss model used are as shown in table 4.1. A frequency (f) of 900MHz, Base Transceiver height of 45m and mobile receiver height (h_m) of 1.5m was used in the evaluation. The result is as shown in table 4.1.

Table 4.1: Empirical result for different path loss models

Distance (km)	Free space (dB)	Hata (dB)	Cost- 231 (dB)	Egli (dB)
1.0	91.58	123.97	123.59	110.46
2.0	97.61	133.95	133.84	122.50
3.0	101.13	139.79	139.84	129.35
4.0	103.63	143.65	144.10	134.54
5.0	105.56	146.86	146.86	138.42

V. Experimental Result

The collected measurement for MTN and GLO bass stations for the selected cities are shown below.

Table 4.2: Measurement for Uyo

Network	Distance (km)	RSS (dB)	Path loss (dB)
MTN	1.0	-71	118
	2.0	-78	125
	3.0	-81	128
	4.0	-89	136
	5.0	-97	144
GLO	1.0	-79	126
	2.0	-85	132
	3.0	-89	136
	4.0	-95	142
	5.0	-101	148

Table 4.3: Measurement for Eket

Network	Distance (km)	RSS (dB)	Path loss (dB)
MTN	1.0	-78	125
	2.0	-81	128
	3.0	-87	134
	4.0	-91	138
	5.0	-97	146
GLO	1.0	-81	128
	2.0	-89	136
	3.0	-95	142
	4.0	-101	148
	5.0	-107	154

Table 4.4: Measurement for Ikot-Ekpene

Network	Distance (km)	RSS (dB)	Path loss (dB)
MTN	1.0	-69	116
	2.0	-74	121
	3.0	-79	126
	4.0	-85	132
	5.0	-95	142
GLO	1.0	-71	118
	2.0	-79	126
	3.0	-83	130
	4.0	-97	144
	5.0	-103	150

Table 4.5: Measurement for Onna

Network	Distance (km)	RSS (dB)	Path loss (dB)
MTN	1.0	-70	117
	2.0	-75	122
	3.0	-83	130
	4.0	-89	136
	5.0	-97	144
GLO	1.0	-79	126
	2.0	-83	130
	3.0	-87	134
	4.0	-93	140
	5.0	-101	148

Table 4.6: Measurement for Etinan

Network	Distance (km)	RSS (dB)	Path loss(dB)
MTN	1.0	-83	130
	2.0	-91	138
	3.0	-97	144
	4.0	-99	146
	5.0	-107	154
GLO	1.0	-79	126
	2.0	-83	130
	3.0	-91	138
	4.0	-95	142
	5.0	-97	144

Table 4.7: Measurement for Oruk Anam

Network	Distance (km)	RSS (dB)	Path loss (dB)
MTN	1.0	-83	131
	2.0	-92	140
	3.0	-98	146
	4.0	-107	155
	5.0	-113	161
GLO	1.0	-75	122
	2.0	-81	128
	3.0	-87	134
	4.0	-91	138
	5.0	-99	144

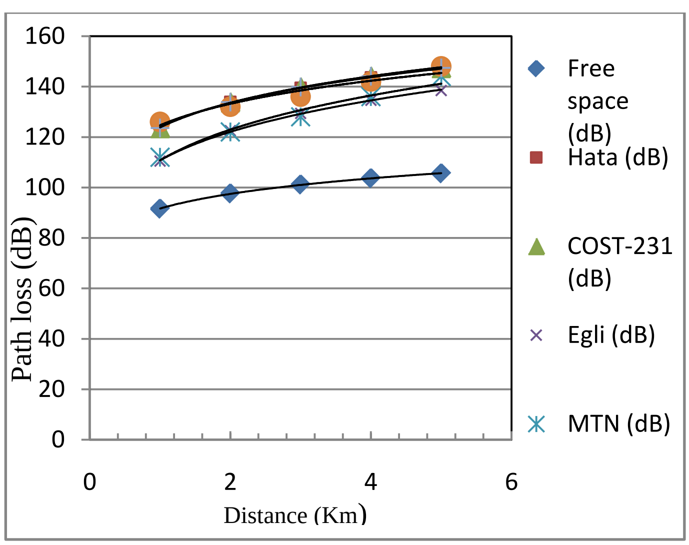

Figure 4.1: Graph of path loss against distance for Uyo L. G. A

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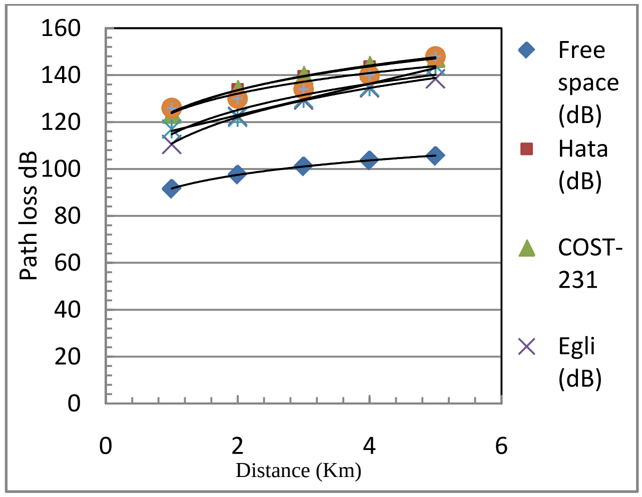

Figure 4.2: Graph of path loss against distance for Ikot Ekpene L. G. A

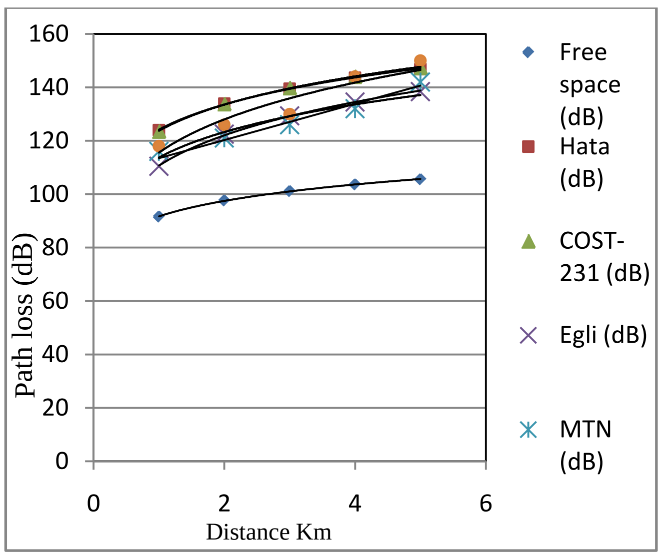

Figure 4.3: Graph of path loss against distance for Eket L. G. A

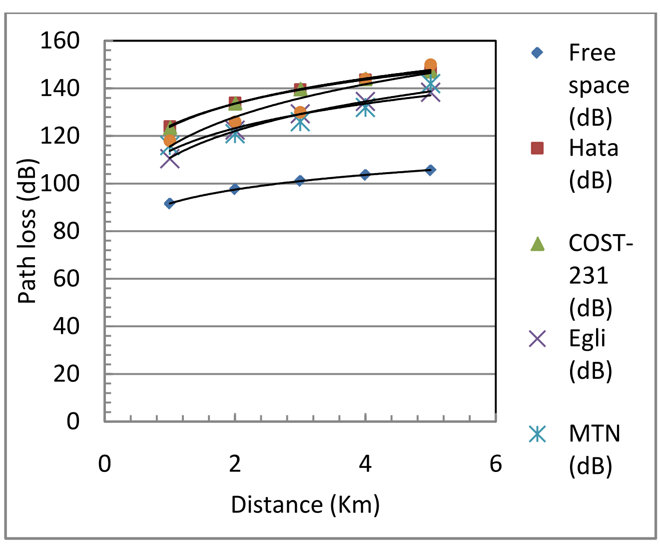

Figure 4.4: Graph of path loss against distance for Onna L. G. A

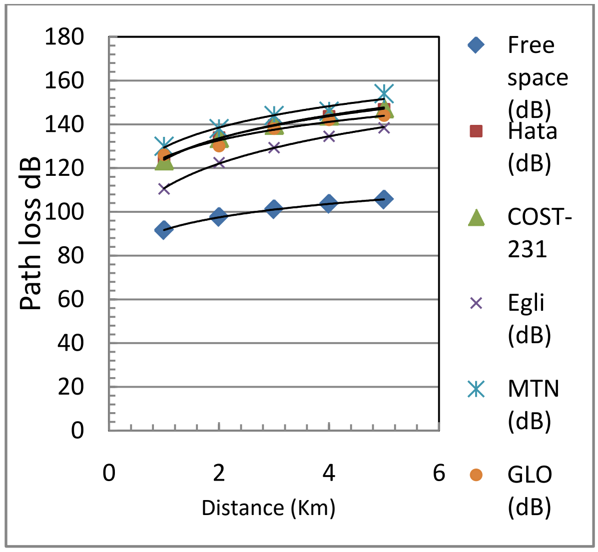

Figure 4.5: Graph of path loss against distance for Etinan L. G. A

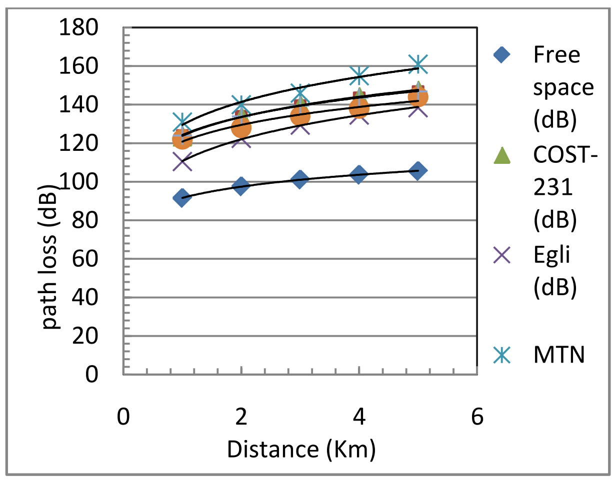

Figure 4.6: Graph of path loss against distance for OrukAnam L. G. A

The equation of the line of regression of Y on X is given as

$$Y = a + a_o X \qquad 3.1$$

where

$$a_{0=} \frac{N\sum XY - \sum XY}{N\sum X^2 - (\sum X)^2} \qquad 3.2$$

$$a_{=} \frac{\sum Y}{N} - a_o \sum \frac{X}{N} \qquad 3.3$$

The proposed path loss model will be given by

$$P_L = a + a_0 X_{BM} + C \qquad 3.4$$

where

P_L is the path loss

X_{BM} is the BTS to mobile receiver distance

C is correction factor for the environment Equations 3.2, 3.3 and 3.4 were used to find equation of line of regression for the study areas.

For Uyo L.G.A

$$\alpha_o = 10 \frac{(4122)}{10(110)} - 30 \frac{(1325)}{(30)2}$$

$$\alpha_o = 5.85$$

$$\alpha = \frac{1335}{10} - 5.85 \frac{(3o)}{10}$$

$$\alpha = 11\,5.95$$

$$PL = 11\,5.95 + 5.85\, X_{BM}$$

For Eket

$$\alpha_o = 10 \frac{(4253)}{10(110)} - 30 \frac{(1379)}{(30)2}$$

$$\alpha_o = 5.8$$

$$\alpha = \frac{1379}{10} - 5.8 \frac{(3o)}{10}$$

$$\alpha = 12\,0.5$$

$$PL = 120.5 + 5.8\, X_{BM} \qquad 4.2$$

For Ikot-Ekpene

$$\alpha_o = 10\frac{(4060)}{10(110)} - 30\frac{(1305)}{(30)2}$$

$$\alpha_o = 7.25$$

$$\alpha = \frac{1305}{10} - 7.25\frac{(3o)}{10}$$

$$\alpha = 108.75$$

$$PL = 108.75 + 7.25X_{BM} \qquad 4.3$$

For Onna

$$\alpha_o = 10\frac{(4099)}{10(110)} - 30\frac{(1321)}{(30)2}$$

$$\alpha_o = 6.8$$

$$\alpha = \frac{1321}{10} - 6.8\frac{(30)}{10}$$

$$\alpha = 111.7$$

$$PL = 111.7 + 6.8X_{BM} \qquad 4.4$$

For Etinan

$$\alpha_o = 10\frac{10(4280)}{10(110)} - 30\frac{(1392)}{(30)2}$$

$$\alpha_o = 5.2$$

$$\alpha = \frac{1392}{10} - 5.2\frac{(3o)}{10}$$

$$= 123.6$$

$$PL = 123.6 + 5.2X_{BM} \qquad 4.5$$

For Oruk-Anam

$$\alpha_o = \frac{10(4336)}{10(110)} - 30\frac{(1401)}{(30)2}$$

$$\alpha_o = 6.65$$

$$\alpha = \frac{1401}{10} - 6.65\frac{(3o)}{10}$$

$$\alpha = 120.15$$

$$PL = 120.15 + 6.65X_{BM} \qquad 4.6$$

The proposed path loss model for Akwa Ibom State is inducted as follows:

$$\alpha_o = \frac{60(25133)}{60(660)} - 180\frac{(8124)}{(180)2}$$

$$\alpha_o = 6.34$$

$$\alpha = \frac{8124}{60} - 6.34\frac{(180)}{60}$$

$$\alpha = 116.34$$

$$PL = 116.38 + 6.34X_{BM} \qquad 4.7$$

The Mean Square Error (MSE) compares the measured data with the data obtained from each of the empirical models to determine the minimum MSE. The model that gives the least MSE and also not greater than 6dB, the minimum value of Mean Square Error for good signal propagation is suitable for prediction of path loss in the area in consideration. The Mean Square Error is expressed as

$$MSE = \sqrt{\frac{(P_m - P_E)^2}{N}}$$

where P_M is the measured value, P_E is the empirical value and N is the values of data taken.

For Uyo

$$MSE\ (free\ space) = \sqrt{\frac{11552.42}{10}} = 38.99$$

$$MBE\ (Hata) = \sqrt{\frac{347.74}{10}} = 5.9$$

$$MSE\ (cost-231) = \sqrt{\frac{533.59}{10}} = 7.31$$

$$MSE\ (Egli) = \sqrt{\frac{558.61}{10}} = 7.47$$

For Eket

$$MSE\ (free\ space) = \sqrt{\frac{14525.18}{10}} = 38.11$$

$$MBE\ (Hata) = \frac{\sqrt{166.38}}{10} = 4.09$$

$$MSE\ (cost-231) = \sqrt{\frac{196.95}{10}} = 4.44$$

$$MSE\ (Egli) = \sqrt{\frac{1406.38}{10}} = 11.86$$

For Ikot-Ekpene

$$MSE\ (free\ space) = \sqrt{\frac{9698.72}{10}} = 31.14$$

$$MSE\ (Hata) = \sqrt{\frac{772.34}{10}} = 8.79$$

$$MSE\ (cost-231) = \sqrt{\frac{857.11}{10}} = 9.26$$

$$MSE\ (Egli) = \sqrt{\frac{356.54}{10}} = 5.97$$

For Onna

$$MSE\ (free\ space) = \sqrt{\frac{11135.98}{10}} = 33.37$$

$$MSN\ (Hata) = \sqrt{\frac{352.06}{10}} = 5.93$$

$$MSE\ (cost - 231) = \sqrt{\frac{446.66}{10}} = 6.68$$

$$MSE\ (Egli) = \sqrt{\frac{518.74c}{10}} = 7.20$$

For Etinan

$$MSE\ (free\ space) = \sqrt{\frac{15633.09}{10}} = 39.54$$

$$MSE\ (Hata) = \sqrt{\frac{162.32}{10}} = 4.03$$

$$MSE\ (cost - 231) = \sqrt{\frac{174.2}{10}} = 4.17$$

$$MSE\ (Egli) = \sqrt{\frac{1670.1}{10}} = 12.92$$

For Oruk-Anam

$$MSE\ (Free\ space) = \sqrt{\frac{16664.94}{10}} = 40.82$$

$$MSE\ (cost - 231) = \sqrt{\frac{554.11}{10}} = 7.44$$

$$MSE\ (Hata) = \sqrt{\frac{566.64}{10}} = 7.82$$

$$MSE\ (Egli) = \sqrt{\frac{2188.3}{10}} = 14.79$$

VI. Discussion

The results of path loss obtained from four empirical models are shown in table 4.1.The data shows that free space model has least path loss followed by Egli model and then Hata and COST-231 model which has close values.

The experimental results of received signal strength and path loss measured are shown in table 4.2 to 4.7. Regression analysis carried out on the results of each location gives equation 4.1 to 4.6. Figure 4.1 to 4.6 show plots of path loss in decibel against distance in kilometres for the six study area. The graph shows a linear relationship between path loss and distance, increase in distance led to increase in path loss.

The MSE compares the measured data with the data obtained from each of the empirical model to determine the minimum MSE. The model that gives the least MSE and also not greater than 6dB, the minimum value of MSE for good signal propagation is suitable for prediction of path loss in the area in consideration. From the evaluation, MSE value obtained for Hata model (5. 9dB, 4.09dB, 5.93dB, 4.03dB) for Uyo, Eket, Onna and Etinan LGA respectively falls within the acceptable values of MSE for good signal propagation while Egli model (5.97) for Ikot-Ekpene is the acceptable value. From the evaluation, the least MSE value for Oruk-Anam, Hata model (7.44) is above the minimum MSE value of 6db for a good signal propagation.

VII. Conclusion

From the investigation, Hata model has the minimum means square error (MSE) of 5.9dB, 4.09dB, 5.93dB and 4.03dB for Uyo, Eket, Onna and Etinan, respectively. These values fall within the acceptable value of minimum MSE of 6dB for a good signal propagation. Hata model is more reliable and suitable for accurate path loss prediction in these areas while Egli model with MSE value of 5.97db for Ikot-Ekpene is suitable for path loss prediction for Ikot-Ekpene. This investigation also shows that the least MSE value of 7.44db for Oruk-Anam was obtained from Hata model but it is greater than the minimum MSE of 6dB for a good signed propagation. In these cases the proposed model $(PL = 116.38 + 6.3X_{BM})$ obtained from this study can be used Oruk-Anam.

From this study, Hata model gives a fairer result for path loss prediction for Akwa Ibom State. The study also shows that no generic model is suitable for generalized used since each model differs in their applicability over different terrain. For effective path loss prediction in Akwa Ibom State and network coverage performance, the proposed path loss model in equation 4.7 obtained from the experimental results from the state is reliable, suitable and more accurate.

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Ensuring the Guaranteed Level of Flights Safety- the View of the Future

By Volodymyr Kharchenko & Dr. Oleh Alexeiev
National Aviation University

Abstract- Considering statistics for the last decade on accident/incident of a question of providing guaranteed flight safety level is the most relevant as shortcomings and problems of functioning aviation activity are explained by lack of general-theoretical basis and the standard scientifically based approaches to safety management system which development has to be guided upon the demand of ICAO which defines that any region should not have accident/incident frequency level more than twice exceeds universal. These are the following main areas: introduction of an acceptable level of flight safety in the state; mandatory procedures for the development and implementation of safety management system; obligatory procedures for ensuring direct management of the level of the flight safety within acceptable or established level of the enterprise (continuous monitoring and regular assessment of the flight safety, corrective actions required to maintain the agreed flight safety indicators and monitoring, flight information analysis, risk management, etc.) [1,2]

Keywords: flight safety, guaranteed flight safety level, safety management system, rysk analysis.

GJRE-D Classification: FOR Code: *090108p, 090199*

Ensuring the Guaranteed Level of Flights Safety- the View of the Future

Volodymyr Kharchenko [α] & Dr. Oleh Alexeiev [σ]

Abstract- Considering statistics for the last decade on accident/incident of a question of providing guaranteed flight safety level is the most relevant as shortcomings and problems of functioning aviation activity are explained by lack of general-theoretical basis and the standard scientifically based approaches to safety management system which development has to be guided upon the demand of ICAO which defines that any region should not have accident/incident frequency level more than twice exceeds universal. These are the following main areas: introduction of an acceptable level of flight safety in the state; mandatory procedures for the development and implementation of safety management system; obligatory procedures for ensuring direct management of the level of the flight safety within acceptable or established level of the enterprise (continuous monitoring and regular assessment of the flight safety, corrective actions required to maintain the agreed flight safety indicators and monitoring, flight information analysis, risk management, etc.) [1,2]

Purpose of methodology consists in association in the only complex of tasks of assessment, providing and verification of safety aviation activities as complex hierarchical structure with independent critical elements and also hardware, program, network and ergatic komponen which are both means, and subject to safety.

The realization of ensuring the guaranteed result consists in realization of management processes so that not to allow transition of infrastructure or its systems to potentially dangerous state and to provide blocking (exception) of the corresponding technical object in case of threat of transition or upon transition to a dangerous state and minimization of consequences of such transition.

Keywords: flight safety, guaranteed flight safety level, safety management system, rysk analysis.

I. Introduction

The safety management system is the main managerial function which has to be considered at the level, at least adequate behind importance degree to other business functions of any airline which realization has to rely on the balanced allocation of resources on production targets and means of protection which will promote establishment of safety limit.

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The similarity of the nature of the appearance of risks and the increasing relevance of their reduction to an acceptable level for various critical applications determines the relevance of the establishment of a methodology to ensure and maintain a guaranteed level of safety of future flights.

By consideration of aspects of flight safety the accepted postulate that absolute safety does not exist - after acceptance of protective measures the residual risk always remains. It should be noted that this term is used only in that case when there is a possibility of approach of negative consequences. The risk as a measure of probability of infliction of harm to safe functioning of system and the environment and also weight of this harm is considered by us. "Loss" is defined as physical damage or harming, the state of health connected with deterioration or vital signs of the person who reduces his abilities to normal full functioning from the point of view of its physiology. The loss can be caused as directly, and is mediately and qualitatively classified behind levels as catastrophic, critical, limit, insignificant. In separate works assessment of a loss is offered to be stated in monetary units (if it is loss of property) and or the number of the human victims. Generally safety functioning of aviation activity is reached due to reduction to risk to admissible level.

Thus there is a need to have the system of indicators of efficiency of providing flight safety which would consider a ratio of results and process for assessment of a possibility of management of risk factors at the aviation activities.

Measurement of efficiency of providing flight safety has to provide a role of regulator and its influence on efficiency of processes of safety management system in suppliers of production/service, and their influence on results at the aviation activities.

In assessing the effectiveness of the provision of flight safety, account must be taken of the characteristics of the process, which leads to the expected results, and indicators should be developed accordingly. The proposed method of estimating the flight safety, based on three levels of system behavior: the results of high level in the provision of flight safety, the behavior of service providers and the activities of regulatory bodies, is one of the guarantees flight safety level [3,4,5].

II. Theoretical Part

The Integrated Management System allows for the application of static and dynamic information management principles, which makes it possible to identify restrictions and limitations. This concept of the Integrated Management System operation is based upon the separation of static and dynamic information as well as its graded use in the context of implementation of retroactive, proactive and predictive approaches to the management during the services provision.

Retroactive approach is based on the application of corrective measures on the ground of static information received *after* the fact of a non-conformance or an occurrence has already happened. Distinctive items of static component for this approach are the results of relevant audits (inspections) and investigations of occurrences in the course of which the facts of incompliance with the established requirements are recorded. [3,4]

Proactive approach combines application of the static component's information particularly analytic efforts and project evaluation in order to manage or take appropriate corrective measures *before* the fact of non-conformance or an occurrence has already happened. Analytic efforts and project evaluation towards the changes enable the development of preventive measures concerned with the services rendered together with other items of static and dynamic components.

Predictive approach involves application of dynamic information. Such an approach to management processes enables non-conformances identification *under conditions of day-to-day operations* of the ANS system and taking adequate measures for it correction, based on prompt response and predicting the actual state of services if relevant deviations, occurrences, etc. are present [6,7,8].

According to the information received from the results of operation of static and dynamic components of information collection process, routine and periodic analysis, management review, risk assessment and other measures the appropriate corrective measures are being developed. The above measures address the following:

- Development of non-conformances correction strategy;
- Approval of non-conformances correction strategy;
- Allocation of responsibilities on non-conformances correction;
- Execution of non-conformances correction strategy;
- Development of preventive measures which will disable recurrence of non-conformances in the field of services provision[3,4].

Corrective measures are planned in line with the procedure for planning of the Integrated Management System operation.

Turning now to a description of the major trends in the matter of rational choice of strategies aimed at ensuring and maintaining a guaranteed result, it is necessary first of all to emphasize that the activity is no unambiguous relationship between the prediction of the results (outcomes) and the problem of decision-making. It has been said that the chaos of possible outcomes facing the decision maker; At the same time, decision should be made, and it should eventually be uniquely. It is important to draw attention to the fact that even the mathematically and the information problems of forecasting and decision-making is usually not the same.

At present there are the following principles of rational choice.

Isolationism- replacement of the i-th participant only its criteria so as to reduce the number of variables that affect the i-th criterion of efficiency, and ideally to reduce it to the criterion of the type that has to be optimized and no matter what the rest of the participants. This method of action is generally accepted in the presence of random factors as efficiency criterion is replaced by its expectation.

Collectivism- introduction of a single general criterion (general purpose) for the group participants. In this case we speak of coalition and compromise between the parties. The second principle is the formation of rational strategies in the pursuit of good mutual awareness, allows for constant performance criteria form a rational strategy.

The quest for knowledge as the basis of rational choice behavior, of course, is not contrary to the first principle, but rather complements it. For example, the coalition unthinkable substantially without a collective sharing of information, and the extracted individual information reduces the amount of required clotting individual member separate criterion.

The third and very important principle of developing rational behavior consists in the pursuit of *sustainability*, understanding which vary widely. Here, above all it deserves special mention *the principle of guaranteed* ***result*** calling side operates with the lack of information based on the consideration of the worst possible situations, taking into account available information. It is widely understood principle of guaranteed result can be applied in the selection of rational strategies and the results expected. This principle includes, of course, the usual maximum is used in an antagonistic activity and interaction with the environment, but is not limited to it.

It should be emphasized, however, that a reasonable reduction of the number taken into account the values of x1 is reasonable and even an inevitable step. Such a process usually referred to as the method of test, and the 'choice of variables accounted for xx, usually performed by expert procedures.

The most common form of representation of the relationships and interactions of disparate processes and events is a cause-and-effect relationship. [7, 8, 9]

The causal relationship and interaction of processes, events and phenomena in real systems are formed and implemented between objects of different nature. Related technological, informational, administrative, economic, social and other processes are combined in a complex interaction, which is currently not sufficiently precise and easy to use mathematical models. Development of models and methods focused, usually for a specific kind of process and results in a formal apparatus, which is not always convenient to combine disparate processes, objects and phenomena. With the development of common models and methods for solving problems with the use of such models is needed to move from specific and specialized concepts to more general categories of causation. An important and crucial tool models are tangible, imaginable, math.

Isolation in a variety of interactions between objects (processes, events, phenomena) causality is fundamentally difficult.

One option for harmonization of the complex set of developers and users is the availability of the agreement the developer and the user of the universe of objects, processes, events and phenomena used in the synthesis of the complex. Cybernetic sense of purpose related to the behavior of cybernetic systems, presented the process of changing states of the system and the achievement of the desired state of the system. This behavior can be represented by a phase trajectory in the space of states of the system and the set of all possible trajectories of the phase picture [9].

Model is not a second copy of the original. The model contains or may contain:

- Properties that are available and the original,
- Properties only model,
- Properties for which is not yet known that they belong to the original.

The mathematical models of the iconic, not all designs have a direct interpretation in the model application. Broadly speaking, the development of the formalism of causal systems connected, first of all, with the desire for representation of determinism in the interaction of system components and system actions. "In order to use mathematical methods for the analysis of those or other processes necessary for a mathematical description of this process, ie, a description of the language of mathematics. It is what we call a mathematical model." The human mind from the experience tends to perceive reality through the causality. It comes down to a causal relationship.

In assessing the overall meaning of the exchange of information, it should be noted that it should help to reduce the uncertainty in the production process, leaving a narrow variation limits for the selection of operators - in a word, to make the situation more definite.

So, it is advisable to introduce the information sent by one operator to another.

Intuition and experience suggest the reasonableness of collective decisions. One can distinguish three levels of collective action operators $m(m \leq n)$ (we assume that the coalition includes the first m operators):

The exchange of information on activities and process conditions;

The joint selection vector ***xc***= *{**xx**,. . **x***M) on the basis of a joint information;

The pooling of resources and the subsequent selection of a joint course of action, based on the combined resources.

It is clear that each successive stage creates great opportunities coordination. The possibility of combining in the second or third stage is, in fact, collective rules of conduct, collective strategy. Unification, producing such a strategy, according to tradition will be called coalitions.

A very common type of collective aspirations should be considered joint mixed strategies - distribution laws $\omega_c = x_c$, ,depending, in general, on the elections $x_j$operators that are not included in the coalition, and natural uncertainty β. Thus, you can enter ω_e, the same as previously defined x_1

The use of mixed strategies associated with the introduction and averaged criteria coalition:

$$w_i = \int w_i d\omega_c(x_c), i = 1,...m.$$

Regarding the criteria for operators outside the coalition, they are averaging can only be discussed as one of the possible options. Notice that pure strategies take the form coalition ***xc***(XT+1 , . . ., ***xn*****,** P) = xc. The set of admissible strategies of the coalition will be denoted by ***X***c; these designations may be accompanied by a number l coalitions, such as ***xc****1.*

In discussing the possibilities of coalition cannot forget about the additional interactions between the members of the coalition, and between members of coalition and the rest of the operators, although they can be considered as already included x_c, in the future, given their importance, we usually write them separately. Therefore, together with ***xc***we consider the vector $z_c = \{z_{c1},..., z_{cm}\}$, representing the additional interaction of the coalition as a whole.

$$z_1 = \left\{ \sum_{j=1}^{m} \lambda_{ji} z_{ji} - \sum_{j=1}^{n} z_{if}, and, u_i = \sum_{j=m+1}^{n} \lambda_{ji} z_{ji} \right.$$

But if $i \rangle m$

$$t_i = \left\{ \sum_{j=m+1}^{n} \lambda_{ji} z_{ji} - \sum_{j=1}^{n} z_{if}, and, v_i = \sum_{j=1}^{m} \lambda_{ji} z_{ji} \right.$$

Then the performance criteria can be written as:

$$w_i = f_i(x, \beta) + z_i + u_1, i = 1,..., m,$$

$$w_i = f_i(x, \beta) + t_i + v_I, i = m+1,..., n,$$

where the coalition chooses z_1 u_1 and $v_1 and t_1$ determined by the actions of other operators. If the coalition is exchanged only with additional interactions between its members, the

$$w_i = f_i(x, \beta) + z_i, i = 1,..., m,$$

$$w_i = f_i(x, \beta) + t_i, i = m+1,..., n,$$

where now

$$z_i = \left\{ \sum_{j=1}^{m} \lambda_{ji} z_{ji} - \sum_{j=1}^{m} z_{if}, and, t_i = \sum_{j=m+1}^{n} \lambda_{ji} z_{ji} - \sum_{j=m+1}^{n} z_{ij} \right.$$

As traditional research has not led to a manageable and unambiguous guidelines, we shall proceed from the inability to complete the formalization of the problem of rational choice, including the choice of coalitions is now necessary to study the process rather particular form, but the study of the processes of rational choice in which it should be possible exhaustive. In addition, analysis of the question of the benefit of joining the union of different species, taking into account possible changes in the mutual awareness of the players. This analysis may be, will reduce the amount considered coalitions and thus make the task of rational choice more transparent. For all these purposes, it is desirable to create a sufficiently flexible formalized description of the behavior of the coalition, similar to reality and yet is relatively simple [9].

It seems that one way of formalizing this is the introduction of the common goals of the coalition, reflecting a compromise between the respective characteristics of the operators. Thus, the coalition turns as if to a single operator.

Of course, the efficiency criterion of the coalition can be anything. However, judging from this, it will be difficult to introduce the study of collective action in any foreseeable limits. It is desirable to limit the kind of reasonable compromise criterion on the basis of common sense and the possibilities of mathematical research. Of course, there should be enough space for informal selection criterion performance compromise. [4, 5, 6, 7]

The strategy of ensuring the guaranteed security and reliability of ATC determines a set of approaches, principles and measures that ensure the stable functioning of the blood pressure with the specified safety and reliability indicators. Today, administrative, legal, economic, technical methods and tools, as well as methods and means of risk assessment are advocated. Risk is usually assessed as a combination of the probability of occurrence of a dangerous event and its possible consequences. Recently, risk assessment has become increasingly important in security management. At the same time, the basis of safety management are the following principles:

- Absolute safety does not exist - after acceptance protective
- Actions there is always some residual risk;
- Safety is reached by decrease in risk to established
- Admissible level, at the same time the residual risk is below admissible level;
- The admissible risk level is established and corrected at all stages of life cycle of the object or process connected with safety.

Here first of all deserves a special mention of the principle of the guaranteed result that is called operates the party at insufficient knowledge to be based on consideration of the worst possible situations taking into account the available information So widely clear principle of the guaranteed result can be applied also at the choice of rational strategy, and at assessment of the expected result. This principle contains, of course, usual maximized used at antagonistic activity and interaction with environment, but to it is not built at all.

The risk management system is a tool for supporting management decisions based on the assessment of the risks associated with traffic safety. In order to provide a given level of security, risk management should be effective and of a systemic nature. The risk management process can not be carried out without identifying the strategic, tactical and operational objectives of the MA.

To implement risk management related to security movement, necessary task solution is shown in the fig.1.

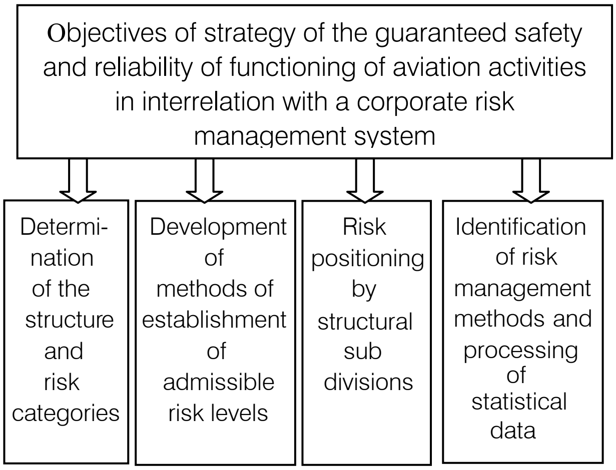

Fig. 1: Objectives strategy of the guaranteed flight safety level.

The purpose of the management of risks related to traffic safety, is to reduce the existing levels of risk to the established level and to maintain the achieved levels of risk at the established maximum allowable level. The main tasks of risk management related to traffic safety: quantitative, semi-quantitative or qualitative assessment of the levels of risks of different types; development of criteria for establishing acceptable levels of risk and effective measures to reduce risks to established admissible levels; analysis of the hazards that arise as a result of security breaches movement and systematic assessment of the conditions of production or activity, are considered potentially dangerous; ensuring the management of risks in accordance with the rules, rules and procedures, the execution of which has been ordered by international and corporate standards.

III. Conclusions

Total actual damage due to accidents and other adverse events is determined by the sum of these components as a consequence of the damage of each individual event, and taking into account the real damage for a certain period. To correctly predict the losses need to evaluate two factors determines their value: the average value of the expected losses in the event of an accident or an event and the probability of an accident or event.

In some cases, implemented in the area of guaranteed safety of air navigation services investment project is aimed at reducing the incidence of accidents and events. In this embodiment, a complex calculation that takes into account all types of losses should be performed. Building a risk management system in the area of guaranteed safety and reliability of air navigation services, it is necessary to provide:

- Full and timely implementation of measures aimed at achieving the strategic security objectives;
- Optimal use of resources allocated to the investment; obtaining additional effect due to optimal matching of mutual investment projects implemented, including their location and the time of implementation;
- More efficient use of technical means used and the optimal use of the results of projects implemented in previous periods.

On the basis of the strategic objectives in the field of safety and reliability of air navigation services need to solve a number of the following tasks:

a) *Objectives of the formation and perfection of normative-methodical safety and reliability management database*

i. The revision and updating of the existing regulatory framework and its harmonization with international standards.
ii. Development of normative-methodical documents aimed at improvement of safety management practices.
iii. Development and implementation of risk management practices related to safety, and the development of a safety management system.
iv. The development of guidelines and training material for the development and assessment of safety culture.

b) *Challenges for the development of technical and technological base*

i. Development and implementation of measures to upgrade the technical technological base associated with safety and reliability of air navigation services.
ii. Conducting periodic analysis of efficiency of the use of technology and the results of the ongoing scientific and technical work.

c) *Challenges for the development of human resource capacity in the management of safety and reliability of the transportation process*

i. Improving personnel management system relating to safety and reliability.
ii. Adaptation of vocational training to the changing technological requirements.
iii. Organization of training processes and risk management practices related to safety.
iv. Organization of training personnel management practices, risk and reliability in the stages of the life cycle of aviation operations.

d) *Challenges for the development of information technology to ensure the safety and reliability of the transportation process*

i. Creation of information decision support systems to ensure the safety and reliability.

ii. Implementation of an automated knowledge testing system in terms of safety requirements.
iii. Development and implementation of automated management systems, risk and reliability in the stages of the life cycle of the air navigation system.
iv. Improving automated systems to ensure safety performance monitoring functions of technological safety processes.
v. Improvement and development of situational monitoring and control safety and reliability of air navigation services, taking into account the existing political situation.
vi. Improve the recording and investigation of accidents and liability allocation rules.
vii. Development of methods for identifying causal relationships safety violations.

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Numerical Studies on Centrifugal Impeller Performance with Different Lean Combinations

By K.V Jagadeeshwar Chary, K. Vijaya Kumar Reddy & T.Ch. Siva Reddy

Abstract- Centrifugal compressors are designed for a given operating pressure and mass flow rate. These machines are often run at off-design conditions depending on the requirement from industrial to Aerospace applications. The need to maintain relatively high efficiency under off-design conditions with adequate stall margin makes the compressor design more challenging. These necessities demand improvement in the flow conditions through the impeller by optimizing the vane shape. Much of the research was carried out on impeller vane shape to minimize the wake regions at impeller exit, and one such effort was to introduce a blade lean at impeller inlet and exit. An investigation from the experimental studies revealed the authors that the introduction of lean at exit suppressed the wake flow regions and henceforth improved the impeller performance either with improved pressure rise or with increased stall margin. Though many of the research studies have proven the influence of lean on the change in the Centrifugal impeller performance, the study was pertained with a combination of positive inlet and exit leans or negative inlet and exit leans that has shown no change in surge margin improvement.

Keywords: lean angle, stall margin, centrifugal impeller.

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NUMERICALSTUDIESONCENTRIFUGALIMPELLERPERFORMANCEWITHDIFFERENTLEANCOMBINATIONS

Strictly as per the compliance and regulations of:

Numerical Studies on Centrifugal Impeller Performance with Different Lean Combinations

K.V Jagadeeshwar Chary [α], K. Vijaya Kumar Reddy [σ] & T.Ch. Siva Reddy [ρ]

Abstract- Centrifugal compressors are designed for a given operating pressure and mass flow rate. These machines are often run at off-design conditions depending on the requirement from industrial to Aerospace applications. The need to maintain relatively high efficiency under off-design conditions with adequate stall margin makes the compressor design more challenging. These necessities demand improvement in the flow conditions through the impeller by optimizing the vane shape. Much of the research was carried out on impeller vane shape to minimize the wake regions at impeller exit, and one such effort was to introduce a blade lean at impeller inlet and exit. An investigation from the experimental studies revealed the authors that the introduction of lean at exit suppressed the wake flow regions and henceforth improved the impeller performance either with improved pressure rise or with increased stall margin. Though many of the research studies have proven the influence of lean on the change in the Centrifugal impeller performance, the study was pertained with a combination of positive inlet and exit leans or negative inlet and exit leans that has shown no change in surge margin improvement. Moreover, the study pertained to a transonic impeller, and the flow investigations are confined to two operating conditions only. Considering the author's knowledge/experience on the usage of lean, our current research is aimed to investigate the effect of combination of positive inlet and negative exit lean on a subsonic impeller without blade lean whose geometry and performance has been described by Eckardt (1980).

In addition, the study is further extended to compare the aerodynamic performance, stability margin and flow behavior throughout the operating range with the other two conventional impeller models. These impeller models are viz., an impeller with negative exit lean and the impeller with zero lean. The performance results revealed a noticeable difference in stall margin among these configurations with no significant sacrifice in head rise. Detailed investigations of these impeller models are herewith published.

Keywords: lea angle, stall margin, centrifugal impeller.

I. Introduction

Centrifugal compressors are widely used in various applications viz., aviation, oil & gas, refrigeration, etc. These type of roto dynamic machines are majorly used in turboprop, turbo-shafts and auxiliary power units for air compression due to their high pressure raising capability in a single stage and their robustness in case of foreign object damage. Centrifugal compressors are capable of producing pressure ratio up to 6:1 in a single stage made of high strength metal alloys. Multistage centrifugal compressors are not preferred in aviation industry because of the huge pressure losses accompanied when compared to multistage axial flow compressors. There have been continuous efforts to improve the performance of centrifugal compressors. To begin with, the impeller design is initially constrained by selection of specific speed that predetermines the impeller characteristics. With the available design concepts viz., blade backswept/radial, impeller shroud &inducer arrangements and the use of splitter blades resulted in the centrifugal impeller advancements to be exhausted. Despite this tremendous design changes identified for the best performance, the flow distribution from the impeller has always become complex and inevitable.

Compressor performance improvements were reported by introducing splitter blades [1, 2], tandem blades [3], three-dimensional impeller design [4, 5]. Elder and Gill [6] showed that the parameters viz., inducer incidence, impeller back-sweep angle, number of impeller and diffuser vanes have the significant effect on the compressor stability limit. Hildebrandt and Genrup [7] investigated the influence of different back sweep angles and exit widths on the impeller outlet flow pattern of a centrifugal compressor with vaneless diffuser through numerical simulations. It was revealed from their studies that the impeller with increased back sweep provides more uniform flow pattern at the outlet that would provide better diffusion process in the downstream.

Further, Moore et al. [8] [9] investigations realized that the impeller with 0° lean (also, defined as Skew in some literature) at outlet realized vast secondary flow losses near shroud region than in any other interior zone. To suppress these wakes, introduced a lean concept that allows redistribution of flow and moving the high loss fluid from shroud region to hub. By incorporating a lean at the exit indirectly affects the blade angle distribution as the tangency and profile smoothness are not to be disturbed as shown in Fig [1]. A patent by Harada and Shin [10] has disclosed the lean blade techniques. He claimed that the compressor performance, including efficiency, can be

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improved by imparting tangential lean to the impeller blades. Based on the above findings, it reveals that the overall performance and stability margin of centrifugal compressors can be improved by introducing negative lean at the impeller blade exit. Arunachalam and Nagpurwala [11] have given better approach in understanding the positive and negative lean affect on centrifugal impeller performance.

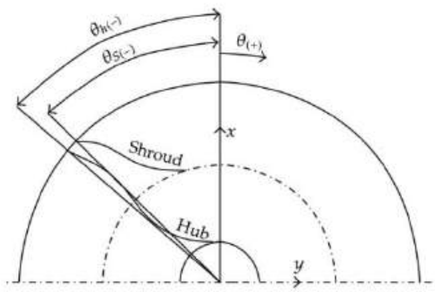

Figure [1]: Blade angle distribution from hub to shroud [14]

Another study from, Howard et al. [12] has also reported a study with the simple lean angle at impeller inlet and outlet as shown in Fig [2]. The numerical results revealed a marginal improvement in impeller efficiency with reduced leakage flow at the shroud, while it lowered the impeller head rise. It was also noticed that lean angle can control the distribution of static pressure along the blade height, especially in the rear part of the cascade which not only reduces the energy losses in the impeller passage but also improves the downstream flow.

Based on the author's observations, impeller with negative lean identified a decent stall margin improvement compared to 0°. Investigations by analysts performed on a transonic impeller with positive inlet lean realized improved operating range with increased stability margin and acceptable pressure ratio while, negative inlet lean at the shroud provided the worst performance.

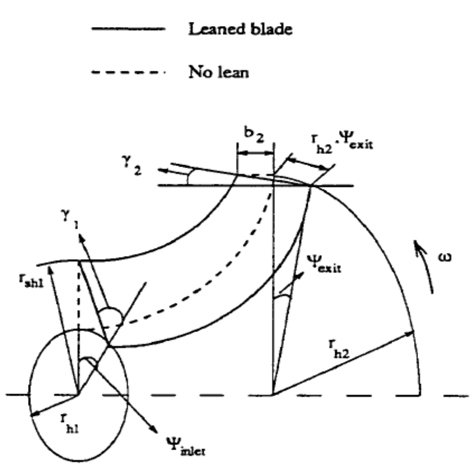

Figure [2]: Inlet and Exit lean angles Howard et al. [11]

Though the published literatures [12] [13] have already provided an understanding on change in the Centrifugal impeller performance, it was for a transonic inlet conditions. Moreover, the investigations so far contributed was on combination of positive lean at inlet and outlet or a negative lean at inlet and outlet with a transonic flow conditions. our current research is herewith intended to design a subsonic impeller that has combination of positive inlet lean and negative exit lean to provide enough surge margin for steady state operation throughout the operating range. Henceforth, it is proposed to develop an impeller model with the combination of 10° inlet positive lean and 45° negative lean at the blade exit. These magnitudes are based on the authors investigations performed in improving stability margin. Impeller performance with detailed flow passage investigation is carried out and compared with the other two models viz., an impeller with No lean and an impeller with exit lean.

II. Impeller Design and Geometric Models

An Eckardt-A type, 1976-80 [15] [16] impeller operating at a design speed 14000 rpm with a mass flow at 4.52 kg/s and total pressure ratio of 1.92 is chosen as BASELINE for our current study. This impeller has 30° backswept with 0° lean. To validate the tested impeller, basic sizing of an impeller is obtained by performing 2D analysis using well-known Jet-wake theory proposed by Japikse. With the basic geometry details obtained and with the available blade geometry information including blade profile and wrap angle distributions [14], impeller model is generated in ANSYS Bladegen for arriving to the optimum blade geometry and validated the impeller performance through ANSYS CFX with the Eckardt impeller experimental data available. This impeller model configuration in this report is hereafter referred as BASELINE MODEL Fig [3a]. After the successful validation of a BASELINE MODEL, Two impeller models are developed for performance comparison, one with an exit lean referred as MODEL A and the other with inlet and exit lean combination named as MODEL B as shown in Fig [3b]and Fig [3c]. As the lean is obtained by moving the shroud section relative to the tangential direction, will not disturb the existing blade profiles and hence minor changes required to be imposed on deriving Models A and B.

III. Grid Generation and Boundary Conditions

Computational model is developed using the Computational fluid dynamics (CFD) code ANSYSCFX - 13.0. It is a Commercial CFD code capable to solve 3D compressible Navier-Stokes equations using a finite volume discretization method. It uses a range of turbulent models with both logarithmic wall function and two-layer approaches to model the boundary layer. A 3D geometric model of the radial compressor stage has been developed using ANSYS Blade-Gen. Model created on Blade-Gen platform is imported into ANSYS Turbo Grid for grid generation. For the current study, a single passage impeller with 5% radial space is simulated with low solidity vaned diffuser (LSVD) configuration at the downstream. A 3Dmesh has been developed using the H-Grid and O-Grid topologies. The O-Grid provides a good mesh around the blades while rest of the passage used H-Grid. Adequate grid is developed with enough number of cells to capture the complex flow phenomena like boundary layers, flow separation, leakage flows and secondary vortices in the blade passage. Grid independence study was carried out to get the optimum grid for numerical solution to be independent of grid. Computational grid with 4, 43,000 elements were generated and the CFD simulations were performed.

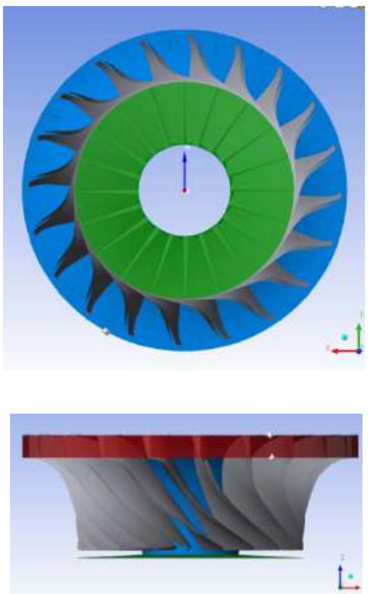

Fig. [3a]: Baseline Impeller

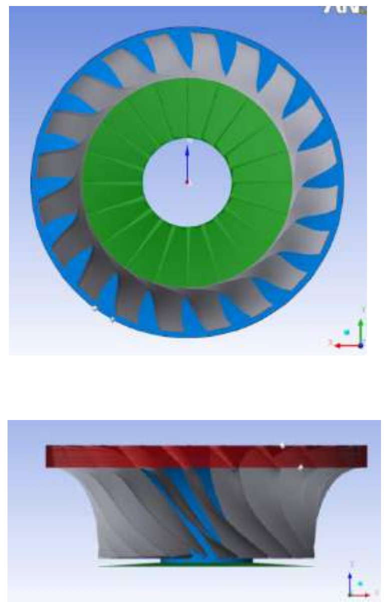

Fig. [3b]: Model A Impeller

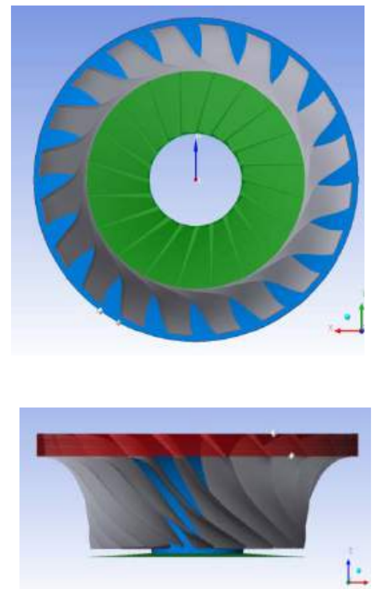

Fig. [3c]: Model B Impeller

IV. Numerical Analysis Setup

After the successful grid complexion completion of every individual model, numerical analysis is planned to setup for all these configurations. The inlet of the computational domain is kept 200mm ahead of the eye of the impeller to ensure that the inlet boundary conditions are not affected by the back pressure of the impeller blade. Ambient states are defined at impeller inlet duct with zero Pascal as relative pressure and total temperature of 288 K. The fluid used for simulation here is air and assumed to be an ideal gas.

K-ε turbulence model is preferred with “Stage” interface for rotor-stator interaction with 5% of turbulence intensity. Considering a single passage configuration, the computational domains are separated into inlet and impeller domains. The side walls of the impeller domain are specified with rotational periodicity. At the impeller solid walls, no-slip boundary condition is applied and all the solid walls are assumed to be adiabatic. The hub wall of the impeller is presumed to be moving with the rotor blade, while the upstream and downstream hub is made stationary. The impeller shroud is defined as counter-rotating that allows the relative motion between the rotating impeller. As mentioned earlier, Inlet boundary conditions with total pressure and static pressure distribution at the outlet are applied. The fluid time step is given as 0.1/ω, where ω is the angular velocity in radian per second. Throughout the calculation the values of maximum residuals, a pressure at the outlet, eventually mass flow imbalances and efficiency were monitored. The convergence criterion is set for the maximum residuals below 10-4. Applying the following boundary conditions, a Numerical analysis is performed by assuming the flow conditions as axisymmetric with periodic conditions imposed. Concrete solution is obtained by analyzing the flow through a single blade impeller passage for all these three models.

V. Numerical Model Validation

A BASELINE MODEL developed with similar geometric dimensions of Eckardt-A type impeller is simulated for a constant speed with Standard inlet Total Temperature and Total Pressure as the boundary conditions with various static pressures at diffuser outlet to check for converged mass flow. A design mass flow of 4.48 kg/s with 92.6% isentropic efficiency and total pressure ratio of 1.92 is realized. The numerical results obtained with LSVD combination may not agree with performance data reported for Eckardt impeller that was tested with VLD configuration. However, the values obtained for the CFD model make sense with Experimental data [15] [17]. Fig [4] [5] shows the performance maps generated for comparison. Following reasons substantiate the discrepancies identified with the numerical model results.

- Numerical model realizes narrow operating range than Eckardt impeller. It is fairly expected as the Test impeller has VLD configuration in the downstream that has no influence on incidence effect in off-design condition, since the fluid follows a logarithmic spiral path.
- Eckardt impeller reported 88.6% gain in isentropic efficiency and total pressure ratio of 1.90 with design mass flow of 4.54 kg/s at design speed. The test data obtained with vaneless diffuser configuration for Eckardt makes sense when compared with the numerical model, as the VLD encounters higher pressure losses over LSVD configuration.

The other factor for the performance deviation can be due to the aerodynamic influence of Impeller-diffuser interaction. Concluding that the performance divergence between numerical model and experimental values are acceptable at the design point, the off-design performance trend was also satisfactory.

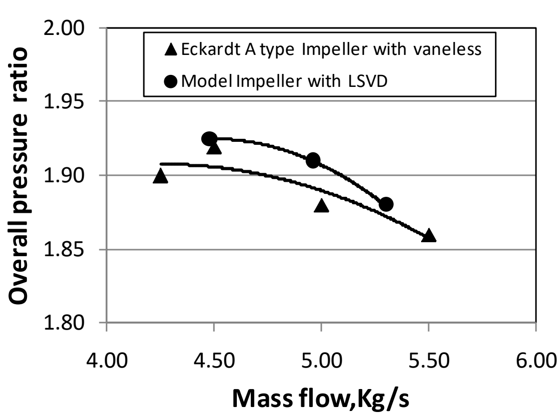

Fig. [4]: Impeller pressure ratio at various mass flows

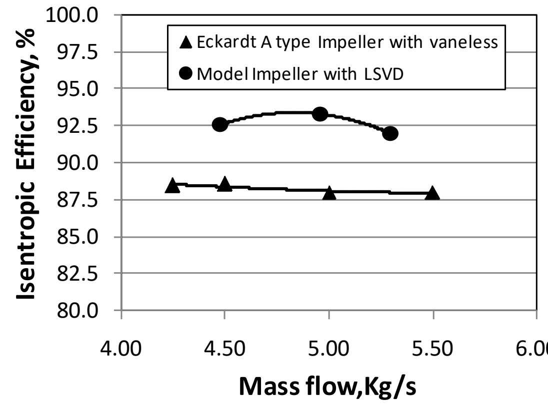

Fig. [5]: Impeller efficiencies at various mass flows

VI. Impeller Performance Results and Discussions

After the successful validation of BASELINE MODEL, the improvement techniques revealed from authors knowledge [11] [12] are applied to investigate the aerodynamic behavior on MODEL A and MODEL B for comparing the performance results. Observations reveal that by imparting lean on the MODEL A, impeller exit has noticed a considerable reduction in total pressure losses with an improved stability, while with added inlet lean to the MODEL B impeller has shown the additional increase in stall margin with no significant loss in total pressure. Performance plots are generated for our discussion herewith. Fig [6] [7] plots show the Normalized mass flow over impeller pressure ratio and Work-input coefficient. It is noticed that higher total pressure ratio is developed with baseline impeller (0° lean) relative to the rest of the impeller models. Introduction of negative lean for MODEL A impeller increases the exit relative flow angle and velocity with consequent reduction in tangential velocity when compared to 0° lean impeller. This change in flow phenomenon resulted to further decrease in work addition causing lower pressure ratio with improved stall margin.

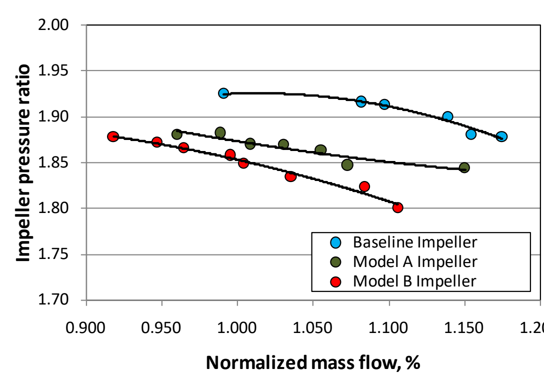

Fig. [6]: Normalized mass flow vs. pressure ratio

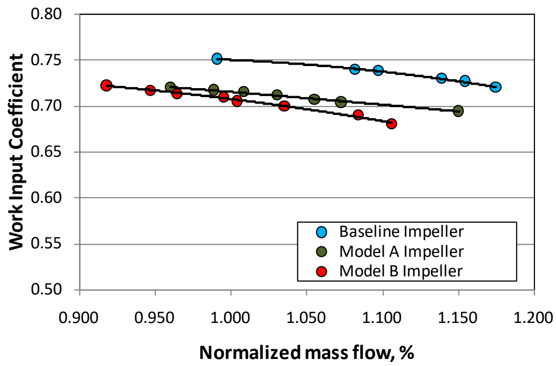

Fig. [7]: Normalized mass flow vs. Work-input coefficient

When inlet lean is provided to MODEL B in addition to the exit lean, the variation of area from Hub to shroud at inducer influence on the inlet blade angle variation and hence on the relative flow diffusion along the blade passage. The consequence of inlet lean feature resulted to further increase in relative velocity (reduction in tangential velocity) at outlet, which is observed on total pressure rise and appreciable increase in stall margin over MODEL A. Fig [12] and [13] substantiate the above discussions. Aerodynamic flow studies at impeller exit on all the three models are relatively compared at design and two off-design conditions. At design point, the highest relative Mach number is observed with MODEL B Impeller over Baseline and MODEL A impellers. This indicates the increase in relative Mach number reduces the tangential velocities (energy transfer) and hence decreases the static pressure rise as evident from the flow studies.

The calculated efficiencies obtained using numerical model shown in Fig [8] is always unpredictable and complex. However, when these magnitudes are compared looks to be acceptable as the pressure losses are function of impeller blade loading. Higher work-input coefficient with baseline impeller obviously envisages lower total pressure losses in relative to other two configurations. Following are the performance parameter observations tabulated below at design and Off-design conditions for three different impeller models. Readers are to be noted herewith, the performance values for Baseline Impeller at $\Phi = 0.95$ is not reported as the impeller underwent the surge occurrence near to design point condition.

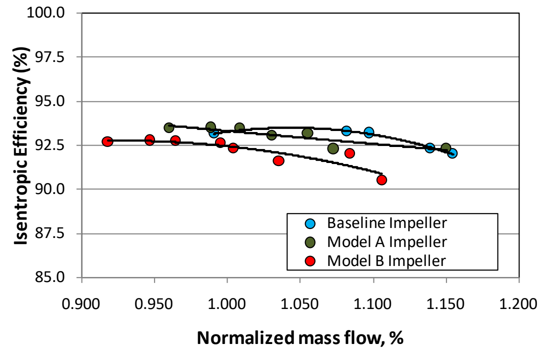

Fig. [8]: Normalized Mass Flow vs. Isentropic Efficiency

Table [1]: Performance Studies of three different impeller configurations

Impeller Type	Parameter	$\Phi = 0.95$	$\Phi = 1.00$	$\Phi = 1.10$
Baseline	Mass flow (kg/s)		4.48	4.89
	Pressure Ratio		1.92	1.91
	Head Coeff.		0.65	0.64
	Impeller Efficiency		93.00	93.15
Model A	Mass flow (kg/s)	4.34	4.56	4.85
	Pressure Ratio	1.88	1.87	1.85
	Head Coeff.	0.63	0.63	0.61
	Impeller Efficiency	93.5	93.5	92.3
Model B	Mass flow (kg/s)	4.15	4.54	4.90
	Pressure Ratio	1.87	1.85	1.82
	Head Coeff.	0.63	0.62	0.59
	Impeller Efficiency	92.70	92.30	92.00

VII. Flow Studies Through Centrifugal Impeller

From the numerical simulations, stall was detected in the diffuser ring as flow break down in between the passage with decrease in stage flow coefficient. Overload conditions are identified by flow break down in the diffuser as the flow coefficient is increased, while the impeller pressure ratio drops to exceedingly low values. No solutions were pursued beyond these limits and the below discussion is within these boundaries to examine the flow behavior.

a) *Flow behavior through Meridional plane*

The flow field of the impeller without inlet lean (MODEL A) and impeller with compounded effect of inlet and outlet lean (MODEL B), are examined through relative Mach number distribution in meridional planes at three different flow coefficients. The purpose is to find possible explanations for the effect of inducer leading edge on the performance of the compressor. It should be understood that the change in relative Mach number along the impeller meridional passage indicates the growth in diffusion process. Higher the diffusion rate, higher will be the pressure rise.

The progressive diffusion along the passage for MODEL B impeller is slow when compared with the Baseline and MODEL A impellers as evident from Fig [9]. This indicates the MODEL B impeller has a lower decay rate of relative Mach number distribution along the meridional passage. Accordingly, this flow phenomenon is visualized with lower pressure rise with MODEL B impeller when compared to rest of the other impeller models as realized from Fig [10]. The static pressure rise at different flow coefficients envisaged the influence of relative Mach number distribution growth. The inlet relative Mach number distribution has no significant change between the three impeller models as evident from Fig [11]. With inlet lean on MODEL B impeller, the inducer inlet has variation of area from Hub to shroud that required the change in inlet blade angle variation. This feature is believed to influence the diffusion control along the impeller passage.

b) Relative Mach number envelops and Static pressure distribution at impeller outlet

The relative Mach number and static pressure distribution at impeller outlet is understood implicitly with the change in static pressure imposed at diffuser outlet. Flow phenomenon observed for the baseline impeller follow a similar trend as noticed by author Krain H. [1984]. Fig [12] confirmed or exhibited similar discharge flow at the exit for the baseline impeller that has low momentum fluid gathering at SS shroud and high momentum flow at PS Hub in relative frame. With the introduction of exit lean (MODEL A), the reduction in Secondary flow patterns is demonstrated by pushing the low momentum flow at the impeller exit shroud suction corner toward the hub resulting a more uniform flow at the impeller exit. Introduction of positive lean at impeller inlet in addition to exit lean (MODEL-B) has further reduced the secondary flow pattern as visualized in Fig [12] at different flow settings. This observation indicates a potential for reducing the low momentum (secondary or wake) zone for designs which have pronounced impeller exit loading.

Further, the provision of inlet lean at impeller inlet (MODEL B), the compound benefit is clearly verified from the flow dynamics showing higher relative Mach number at impeller exit for design and off-design conditions while, the Baseline impeller demonstrate the lowest relative Mach number. This phenomenon reflects on the pressure rise development for the respective impeller models as shown in Fig [13]. Similar interpretation can be made or judged based on realized relative Mach number at impeller exit.

VIII. Conclusions

Numerical investigations have been performed to determine the effect of the inlet and exit lean combinations on the impeller performance and stall margin. The results of the impeller are agreeable when looked onto the performance parameters like Work-input coefficient, Total pressure ratio and stall margin. The outcome of these parameters realized using MODEL B is comparable with BASELINE and MODEL A impeller except the computational values obtained for polytropic efficiencies. Although the commutated efficiencies are overestimated throughout the operating range by various factors, the conclusions drawn are as follows:

- MODEL A impeller reveals an improved stall margin by 3.1% over baseline impeller, while MODEL B envisage further better stall margin by 7.4% compared with Baseline impeller.
- Improvement in surge margin with MODEL B is significant over MODEL A, due to change in impeller inlet incidence angle with inlet lean causing further reduction in mass flow.
- Realized decrease in pressure ratio by 2.6% and 3.65% respectively by MODEL A and B over baseline impeller at design point.
- The change in pressure ratio at design point is insignificant among MODEL A and B impellers as evident from Fig [6]. MODEL B design can be chosen as the best selection, when stall margin is the criteria for aerospace applications.
- The operating range is not much affected with either of any impeller model combination as evident from Fig [6] [7].
- Ease of improving surge margin significantly with lean, when engine diameter is constrained in aero applications.

IX. Nomenclature

VLD: Vaneless diffuser
LSVD: Low Solidity Vaned diffuser
Φ: Flow Coefficient
PS: Pressure Surface
SS: Suction Surface

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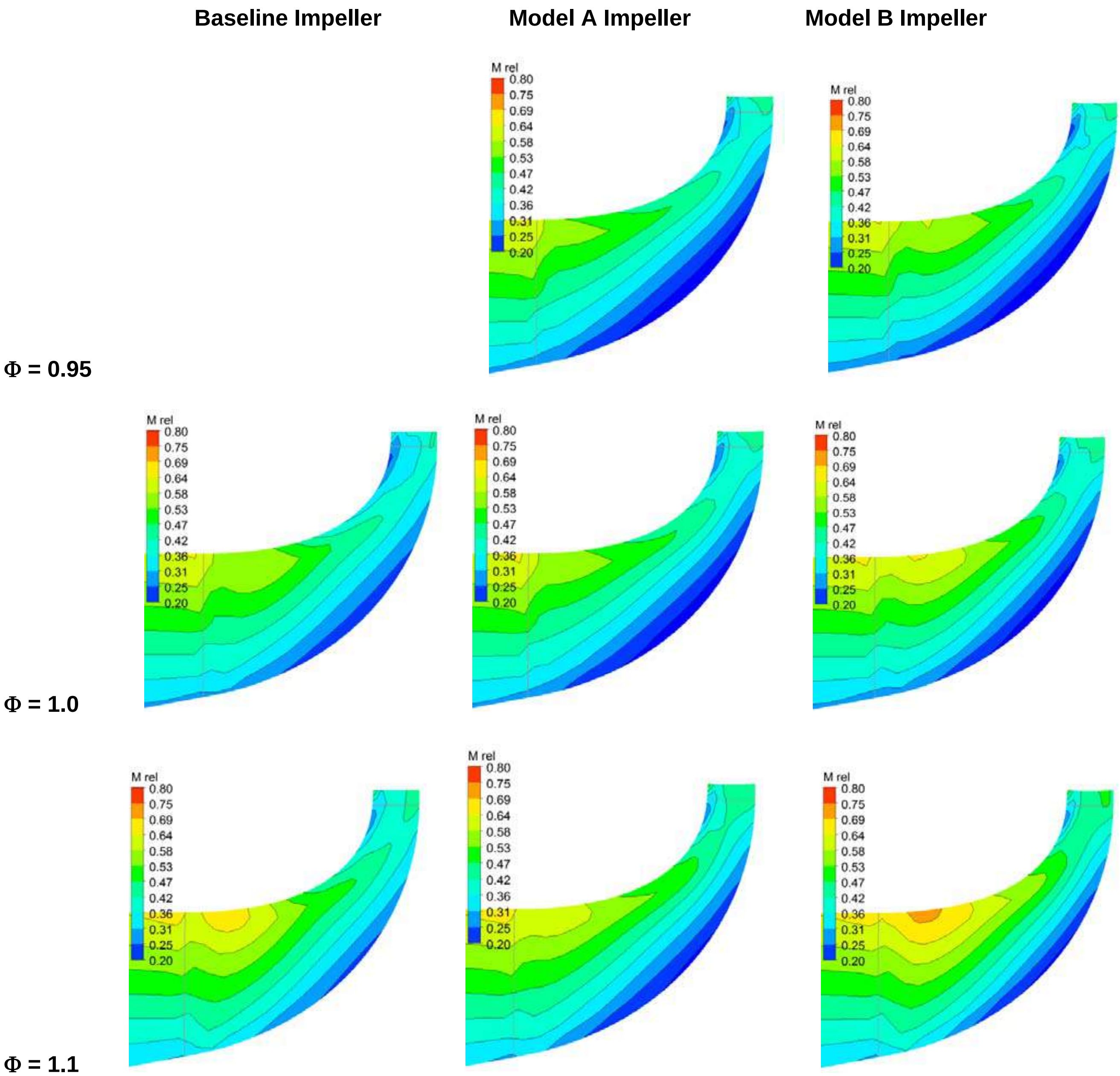

Fig. 9: Relative Mach number distribution along meridional plane

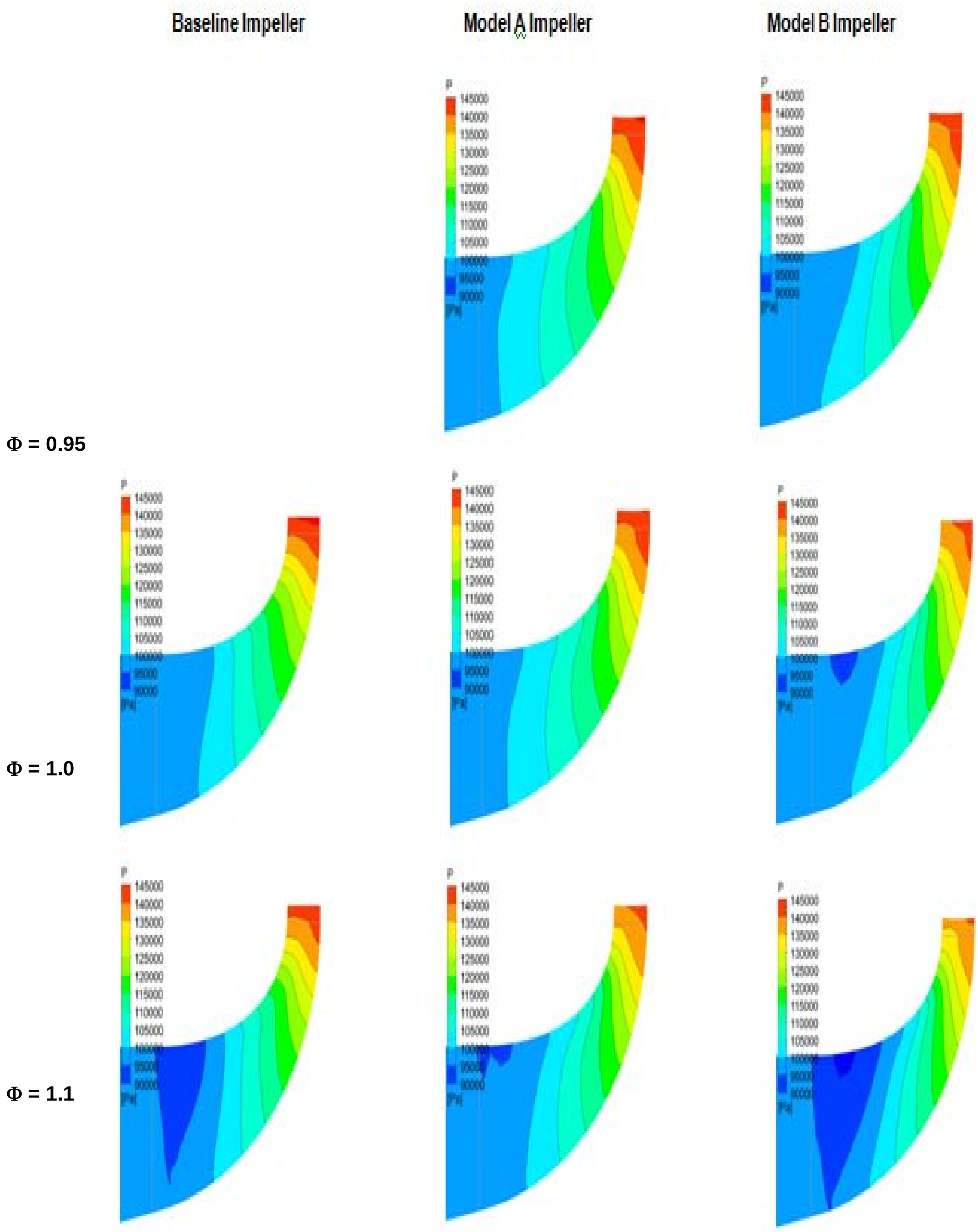

Fig. 10: Static Pressure distribution along meridional plane

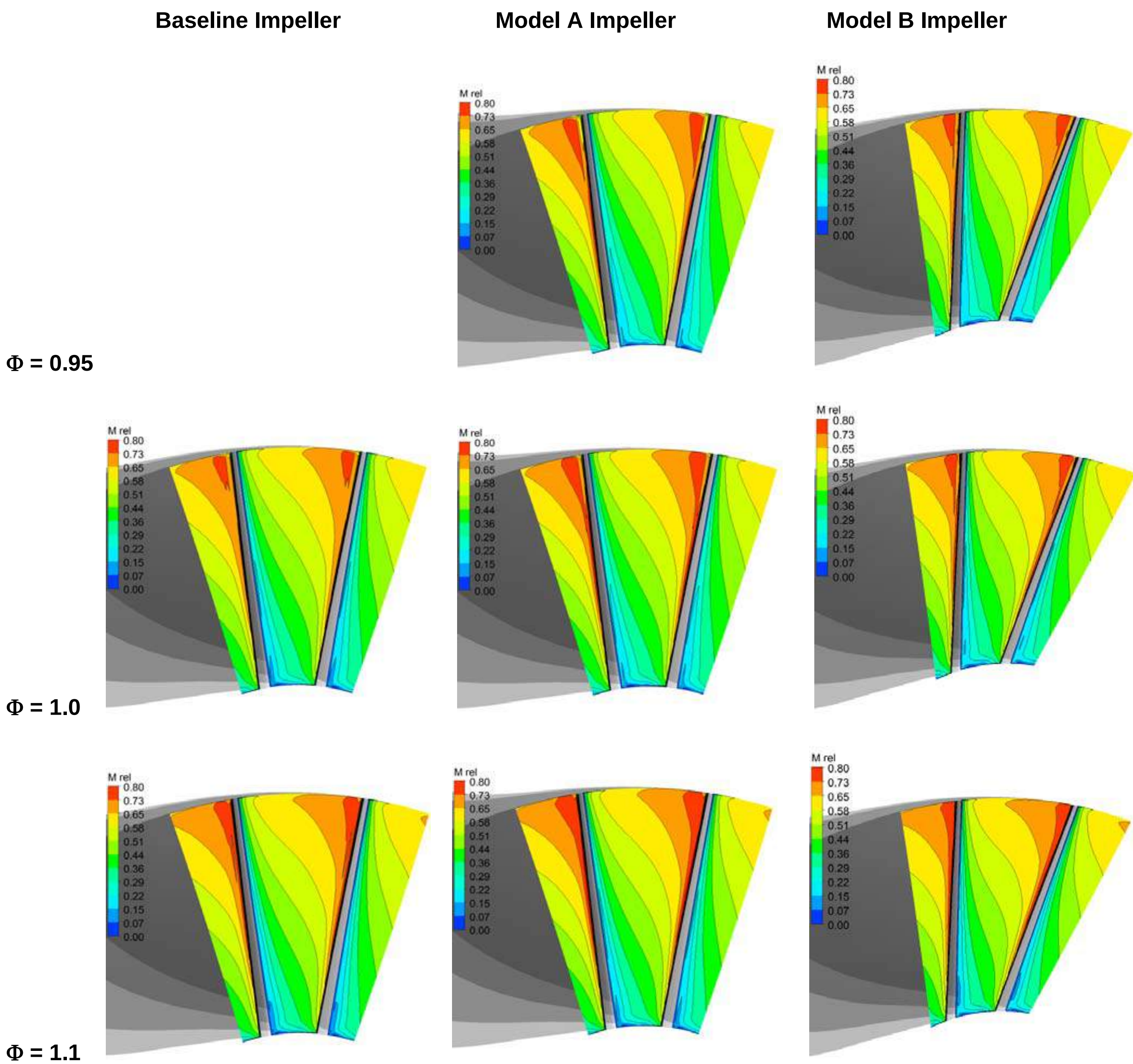

Fig. 11: Relative Mach number distribution at inducer inlet

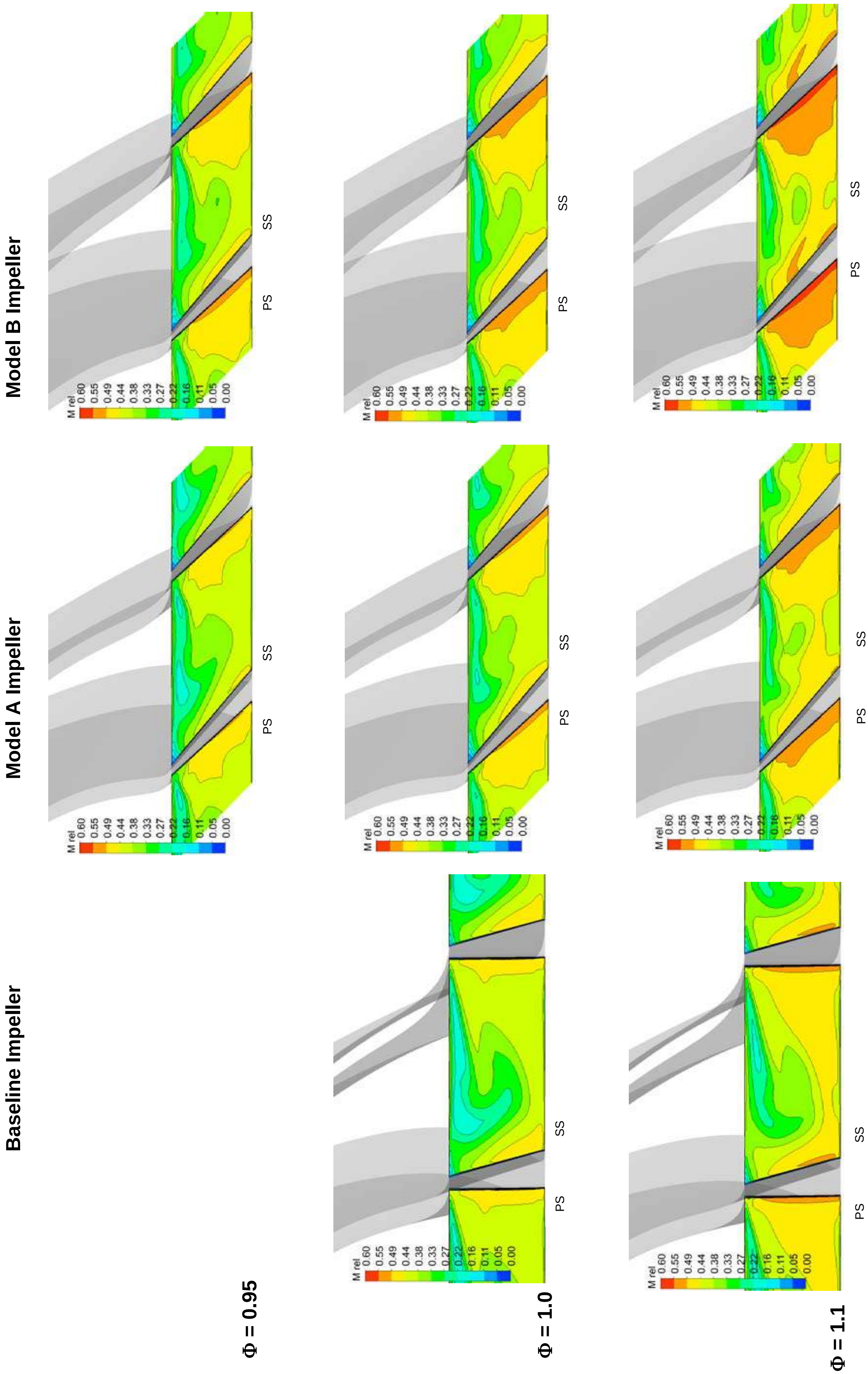

Fig. 12: Relative Mach number distribution at Impeller Outlet

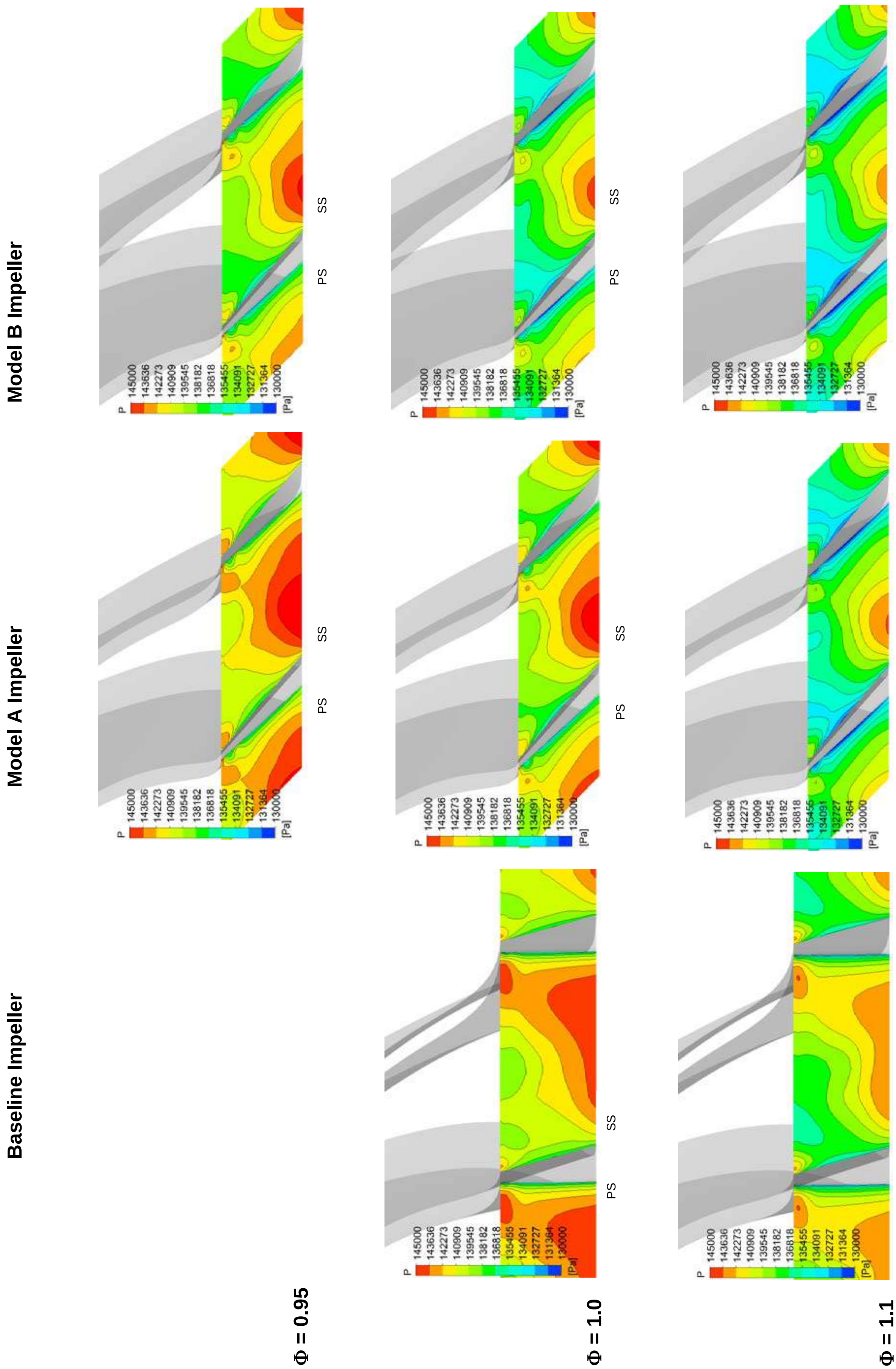

Fig. 13: Static Pressure Distribution at Impeller Outlet

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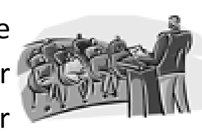

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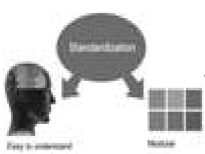

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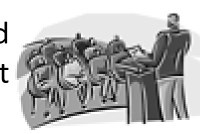

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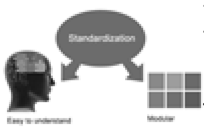

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The paper should be in proper format. The format can be downloaded from first page of 'Author Guideline' Menu. The Author is expected to follow the general rules as mentioned in this menu. The paper should be written in MS-Word Format (*.DOC,*.DOCX).

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

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

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- Author Name in Font Size of 11 with one column as of Title.
- Abstract Font size of 9 Bold, “Abstract” word in Italic Bold.
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- Two Column with Equal Column with of 3.38 and Gaping of .2
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- Paragraph before Spacing of 1 pt and After of 0 pt.
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- Large Images must be in One Column
- Numbering of First Main Headings (Heading 1) must be in Roman Letters, Capital Letter, and Font Size of 10.
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You can use your own standard format also.
Author Guidelines:

1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript’s Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

1. GENERAL

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

Scope

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

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

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

Research articles: These are handled with small investigation and applications

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

5.STRUCTURE AND FORMAT OF MANUSCRIPT

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

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

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

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

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

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

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

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

(h) Brief Acknowledgements.

(i) References in the proper form.

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

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

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

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

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Abstract, used in Original Papers and Reviews:

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

Key Words

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

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

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

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

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- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

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

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

Acknowledgements: Please make these as concise as possible.

References

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

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

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TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Informal Guidelines of Research Paper Writing

Key points to remember:

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

Final Points:

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

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

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

General style:

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

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

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

In every sections of your document

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

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

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

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

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

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

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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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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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