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Effect of Fiber Angle Orientation on Stress, Deformation and Buckling Torque of the Composite Drive Shaft

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Sinhgadh College of Engg., India

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EFFECTOFFIBERANGLEORIENTATIONONSTRESS,DEFORMATIONANDBUCKLINGTORQUEOFTHECOMPOSITEDRIVESHAFT

Strictly as per the compliance and regulations of :

Effect of Fiber Angle Orientation on Stress, Deformation and Buckling Torque of the Composite Drive Shaft

Miss. Priya Dongare [α] & Dr. Suhas Deshmukh [σ]

Abstract - The objective of this paper is to analyze a composite drive shaft for power transmission applications. Composite materials have many applications ranging from automotive to most of the industrial application and numerous advantages due to its high specific strength (strength / density) and high specific modulus (modulus / density), lighter weight and longer life. Analysis of composite drive shaft is carried out to understand the effect of fiber orientation on load carrying capacity (axial loadings, torque and buckling torque) of drive shaft. MODAL analysis is carried out to observe the effect of fiber angle on modal frequencies. Static and Modal analysis is carried out using FEM, results of FEM analysis is further used to develop a regression equation. These developed regression equation can be used for tuning of properties of shaft and understand the behavior with fiber orientation.

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I. Introduction

A composite is commonly defined as a combination of two or more distinct materials, each of which retains its own distinctive properties, to create a new material with properties that cannot be achieved by any of the components acting alone. Generally, a composite material is composed of reinforcement (fibres, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix.

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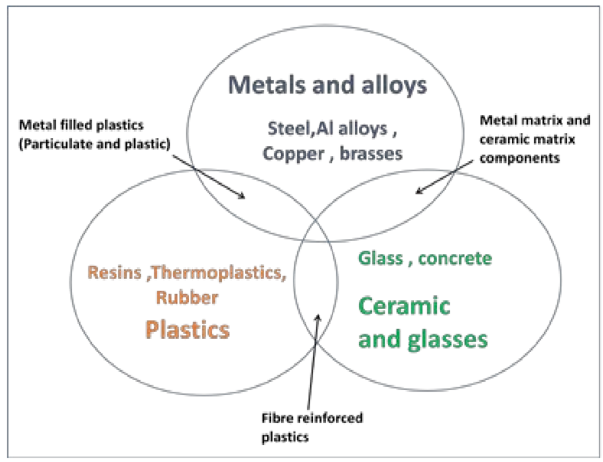

Figure 1 : Relationships between classes of engineering materials, showing evolution of composites

Composite materials have increased its utilization and its structural applications grown considerably in recent years. The major advantage is its higher strength to weight ratio. One of the major applications is to composite drive shafts, where strength to weight ratio is very important. To understand the effect of its fibre orientation various numerical techniques are evolved. Finite element method is one of the best methods adopted for analysing these composite structures (drive shaft). These numerical techniques evaluate, analyse the performance of drive shaft numerically. In present work FEM package ANSYS is used for analysing the composite drive shaft. Further results of FEM analysis is used for regression analysis so that we can easily design the drive shaft.

Section 2 explains detailed design specifi cations of composite drive shaft and its requirements along with suitable application. Section 3 of this paper explains static analysis of composite drive shaft. Here stacking sequence is varied to observe the behaviour of stress. Section 4 explains modal analysis, section 5 explains buckling analysis, section 6 explains about regression models established using FEA results and finally concluding remarks of work carried out.

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II. Composite Drive Shaft

Technologically the most important composite are those in which the dispersed phase is in the form of fibre. The design of fibre-reinforced composite is based on the high strength and stiffness on a weight basis, the principal basis. The principle fibres in commercial use are various types of glass, carbon, graphite and Kevlar. Here E-glass epoxy and carbon epoxy fibres are selected as potential material for the design of shaft.

The fibre orientation changes from layer to layer in a regular manner through the thickness of the laminate, e.g. a 0/90/0 stacking sequence results in a cross-ply composite. Hybrids are composites with mixed fibres and are becoming common place. The fibres may be mixed within a ply or layer by layer, and these composites are designed to benefit from the different properties of the fibres employed. For example, a mixture of glass and carbon fibres incorporated into a polymer matrix gives a relatively inexpensive composite, owing to the low cost of glass fibres, but with mechanical properties enhanced by the excellent stiffness of carbon [4].

In the present work the shaft is considered as simply supported beam with torque applied at the center.

Geometric and Material properties of composite drive shaft under analysis is listed in table below:

Table 1: Geometric Properties

Length	1 m
Inner Diameter	48.2 X 10^{-3}m
Outer Diameter	50 X 10^{-3}m
Thickness	0.2 X 10^{-3}m
Boundary Condition	Simply Supported

Table 2 : Orthotropic Material Properties of Composite Material

	E-Glass Epoxy	Carbon Epoxy
E_x	40.3 X 10^9 N/m^2	126.9 X 10^9 N/m^2
E_y	6.21 X 10^9 N/m^2	11 X 10^9 N/m^2
E_z	40.3 X 10^9 N/m^2	126.9 X 10^9 N/m^2
μ_{xy}	0.2	0.2
μ_{xz}	0.2	0.2
μ_{yz}	0.2	0.2
G_{xy}	3.07 X 10^9 N/m^2	6.6 X 10^9 N/m^2
G_{xz}	2.39 X 10^9 N/m^2	4.23 X 10^9 N/m^2
G_{yz}	1.55 X 10^9 N/m^2	4.88 X 10^9 N/m^2
Density	1910 Kg/m^3	1610 Kg/m^3

Table 1 shows the dimension of the shaft used for the static analysis. Table 2 is the geometric properties of the shaft. these properties are same at all points along the length of the shaft.

Next section explains the static structural analysis of shaft using FEM solver.

III. Static Structural Analysis (FEA)

Static analysis deals with the conditions of equilibrium of the bodies acted upon by forces. A static analysis can be either linear or non-linear. All types of non-linearity are allowed such as large deformations, plasticity, creep, stress stiffening, contact elements etc. A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those carried by time varying loads. A static analysis can however include steady inertia loads such as gravity, spinning and time varying loads. In static analysis loading and response conditions are assumed, that is the loads and the structure responses are assumed to vary slowly with respect to time. The kinds of loading that can be applied in static analysis includes, Externally applied forces, moments and pressures, Steady state inertial forces such as gravity and spinning, imposed non-zero displacements [4].

A static analysis result of structural displacements, stresses and strains and forces in structures for components caused by loads will give a clear idea about whether the structure or components will withstand for the applied maximum forces. If the stress values obtained in this analysis crosses the allowable values it will result in the failure of the structure in the static condition itself. To avoid such a failure, this analysis is necessary.

The composite shaft is considered as the simply supported beam with torque applied at the centre of the shaft as shown in the Figure 2.

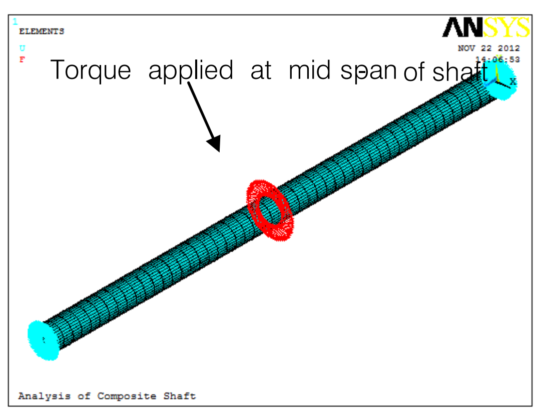

Figure 2 : Composite Shaft FEM Model with Boundary Conditions

The static analysis is done with help of FEM solver like ANSYS. Finite element models of the drive shaft were generated and analyzed. 3D model of hollow composite shaft is generated using APDL language available in ANSYS Multiphysics. Hollow shaft is meshed using layered element SHELL281. Thickness, material properties and fibre orientations of each layer is provided for element viacommandKEYOPT,1,8,1 SECTYPE,1,SHELL, secdata,T1,1,-90, secdata,T2,1,0, secdata,T3,2,0, secdata,T4,1,0. Four numbers of layers are taken into account for analysis. Appropriate simply supported boundary conditions are applied at both ends and torque is applied at mid-span of drive shaft. Application of torque is critical issue in FEA analysis, this is simplified by providing tangential force at exterior nodes of shaft and local co-ordinate system is rotated to provide a tangential directional force. This is possible by command csys, 1nrotat, all in ANSYS APDL. Static analysis is carried out to estimate maximum deformation and stress occurred in shaft.

The variation of the maximum stress along the length of the shaft is shown in figure3.static analysis is done for four layers of composite drive shaft. The comparison of stress variation for four layers is done in figure 4. It shows that the maximum stress is developed at fiber3.

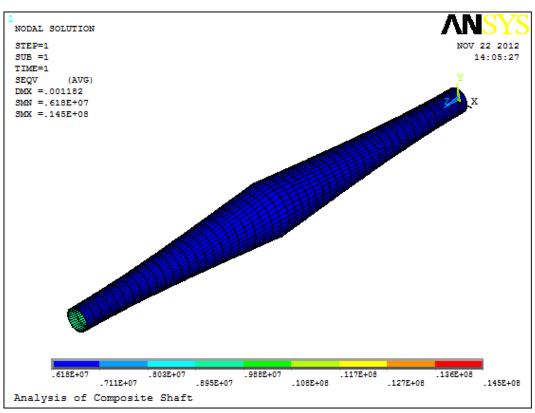

Figure 3 : Change in stress along the length of composite shaft

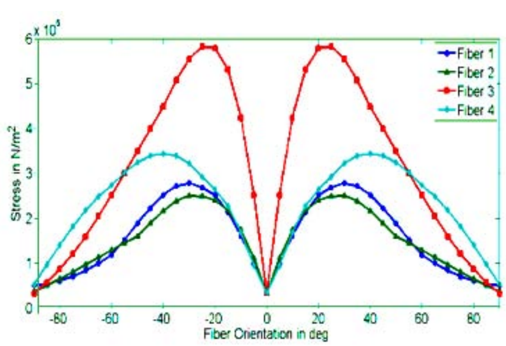

Figure 4 : Variation of the stress in layers composite shaft

Similar to stress analysis, the variation of deformation is also calculated at four layers of the shaft. (Shown in figure 5).

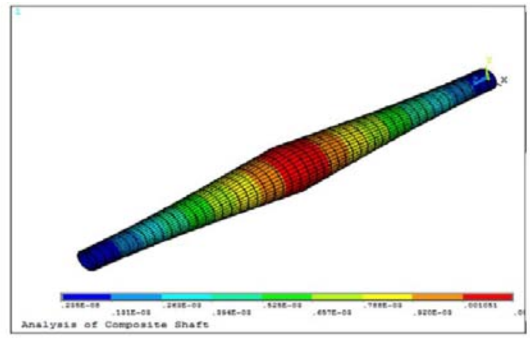

Figure 5 : Change in the deformation along the length of the composite shaft

Same as stress analysis the comparison for deformation variation along four layers of shaft is shown in figure 6.The deformation at third layer is low and shows maximum variation change in the fibre angle orientation.

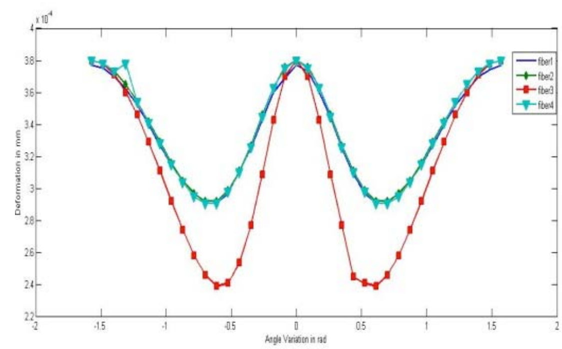

Figure 6 : Comparison of deformation in all layers of composite shaft

Below table summarize the statistical data for the static analysis.

Table 4 : Maximum and minimum stress values for four layers of shaft

	Angle (deg)	Maximum (N/mm^2)	Angle (deg)	Minimum (N/mm^2)
Layer 1	±30	278455	0	33058.5
Layer 2	±30	249726	0	33058.5
Layer 3	±25	582029	0	33058.5
Layer 4	±40	344292	0	33058.5

Table 5 : Maximum and minimum values for deformation for four layers of shaft

	Angle (deg)	Maximu m (mm)	Angle (deg)	Minimum (mm)
Layer 1	±90/0	0.376	±40	0.291
Layer 2	±90/0	0.380	±40	0.292
Layer 3	±90/0	0.380	±35	0.239
Layer 4	±90/0	0.380	±35	0.291

Next section explains modal analysis for the shaft.

IV. Modal Analysis (FEA)

Modal analysis is used to determine the vibration characteristics such as natural frequencies and mode shapes of a structure or a machine component while it is being designed. It can be also a starting point for another more detailed analysis such as transient dynamic analysis, harmonic response analysis or spectrum analysis.

The main parameters considered in free vibration of shaft are natural frequency and vibration. The natural frequency and mode shape are important parameters in design of structure for dynamic loading condition.

In the research, the natural frequencies for each layer are obtained using ANSYS 13 by varying the orientation of fibre in layer 2 by 5^0 and keeping the orientation of other layers constant i.e.0^0.The variations for layers are as shown in figure 7

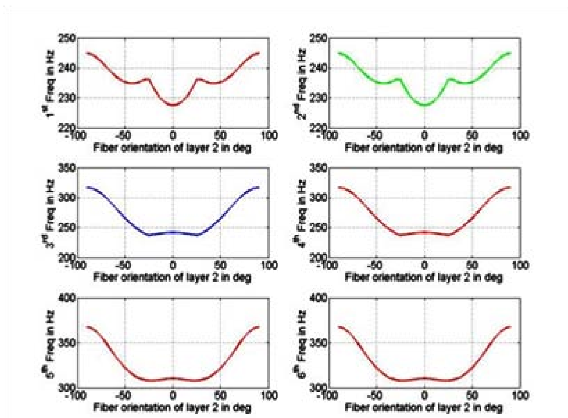

Figure 7 : Effect of the change in fibre orientation angle on natural frequency in second layer

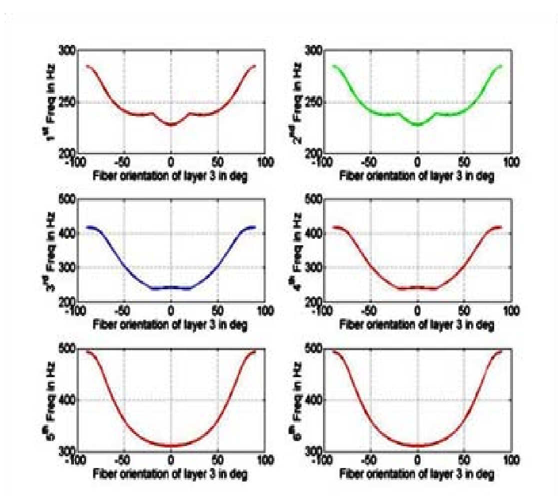

Figure 8 : Effect of the change in fibre orientation angle on natural frequency in third laer

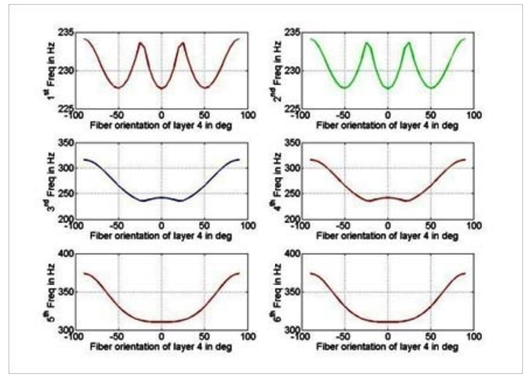

Figure 9 : Effect of the change in fibre orientation angle on natural frequency in forth layer

Figure 7, 8and 9 shows that the variation for the natural frequencies from fibre orientation of -90° to +90°.It gives the behaviour of mode shapes with respect to angle variation for six natural frequencies.

Next section explains about the buckling analysis for composite drive shaft.

V. Buckling Analysis (FEA)

Membranous filter with 37 mm in diameter and 0.8 micron powders.

Figure 10 shows the comparison of the buckling torque of four layers. It shows the variation in the second layer of the shaft.

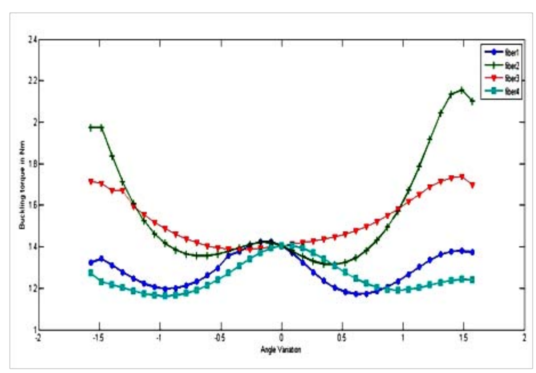

Figure 10 : Comparison for buckling torque of all layers of composite shaft

Table 6 : Result of buckling of each layer for composite shaft

	Angle (deg)	Maximum (Nm)	Angle (deg)	Minimum (Nm)
Layer 1	-10	1.4249	35	1.1719
Layer 2	85	2.1545	25	1.3134
Layer 3	85	1.7370	-20	1.3873
Layer 4	5	1.4046	-55	1.1623

Table.6 is the values obtained at the maximum and minimum values of the buckling torque

VI. Regression Modelling

Regression analysis is a statistical tool for the investigation of relationships between variables In general, there are two types of regression analyses:

Linear regression analysis-A linear regression analysis assumes that the regression model is a linear function with respect to the parameters of the regression model, i.e., the regression parameters are the coefficients of the regression terms.

Nonlinear regression analysis-For a nonlinear regression analysis, the regression model is a nonlinear function with respect to the parameters of the regression model. [7].

Multiple regressions are a statistical technique that allows us to predict someone's score on one variable on the basis of their scores on several other variables. E.g. the composite shaft has four layers.

The regression analysis is done to get the variation of the orientation of the fibre with respect to the stress and deformation. It will have one equation for each layer which will give the stress and deformation in terms of fibre angle orientation.

The regression equation for first layer is as below:

Deformation for θ1,

$$\Delta_{\theta 1} = 0.9911 + 0.0002 \times \sin\theta_1 + 1.0281 \times \cos\theta_1 + 0.0856 \times \sin(\theta_1^2) - 0.0001 \times \sin(\theta_1^3) + 0.3953 \times (\theta_1^2) - 0.0001 \times (\theta_1)$$

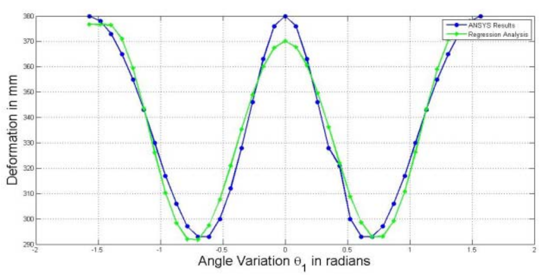

Figure 11 : Comparison of ANSYS result and regression result of first layer of composite shaft

Same as above the second layer fibre angle is varied keeping layer 1, 3, 4 constant (0^0) .the equation of the second layer is as below-

Deformation for θ2,

$$\Delta_{\theta 2} = -1.0032 + 1.0402 \times \cos\theta_2 + 1.0281 \times \cos\theta_1 + 0.0866 \times \sin(\theta_2^2) + 0.3999 \times (\theta_2^2)$$

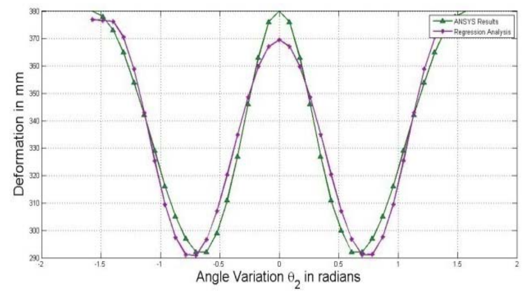

Figure 12: Comparison of ANSYS result for deformation and regression result of second layer of composite shaft

Similarly the equations are obtained for the third and forth layer as below.

Deformation for θ3

$$\Delta_{\theta 3} = -1.5493 + 1.5842 \times \cos\theta_3 + 0.1346 \times \sin(\theta_3^2) + 0.6089 \times (\theta_3^2)$$

Deformation for θ4,

$$\Delta_{\theta 4} = 1.5842 \times \sin\theta_4 + 0.1346 \times \cos\theta_4 + 0.6089 \times \sin\theta_4^3$$

II. Static and regression analysis for the stress in the composite shaft-

Same as deformation we can plot the results of variation in the stress values of the each layer.

Stress for θ1,

$$\sigma_{\theta_1} = 2.1927 - 2.1783 \times \cos\theta_1 - 0.1927 \times \sin\theta_1^2 - 0.8369 \times \theta_1^2$$

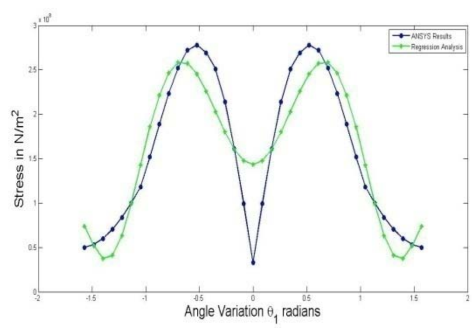

Figure 13 : The effect of fibre orientation angle on stress of First layer of composite shaft

Stress for θ2,

$$\sigma_{\theta_2} = 1.4391 - 1.4235 \times \cos\theta_2 - 0.1244 \times \sin\theta_2^2 - 0.5496 \times \theta_2^2$$

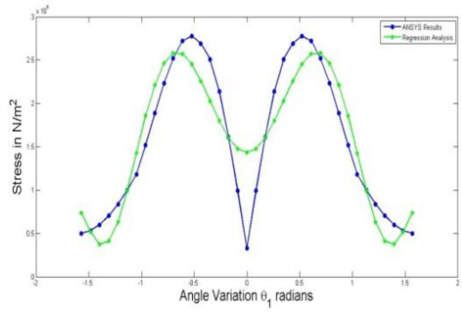

Figure 11 : The effect of fibre orientation angle on deformation of second layer of composite shaft

Stress for θ 3,

$$\sigma_{\theta_3} = 3.1961 - 3.1590 \times \cos\theta_3 - 0.2810 \times \sin(\theta_3^2) - 1.2214 \times (\theta_3^2)$$

Stressfor θ4,

$$\sigma_{\theta_4} = 3.1961 - 3.1590 \times \cos\theta_4 - 0.2810 \times \sin(\theta_4^2) - 1.2214 \times (\theta_4^2)$$

Regression analysis for buckling-

Below figures show the comparison of ANSYS result and regression result for respective layers.

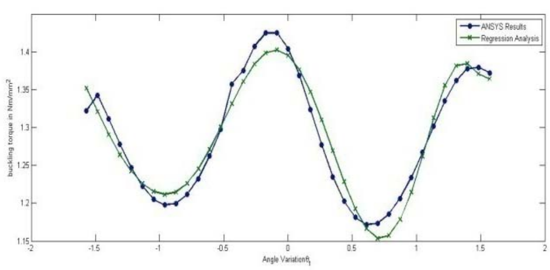

Figure 12 : The effect of fibre orientation angle on buckling torque of first layer of composite shaft

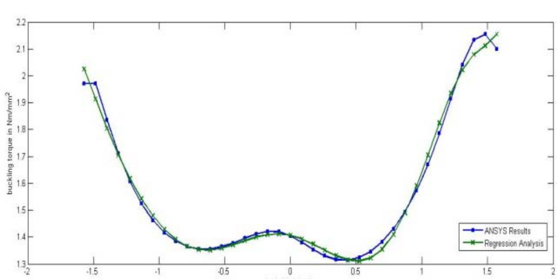

Figure 13 : The effect of fibre orientation angle on buckling torque of second layer of compositeshaft

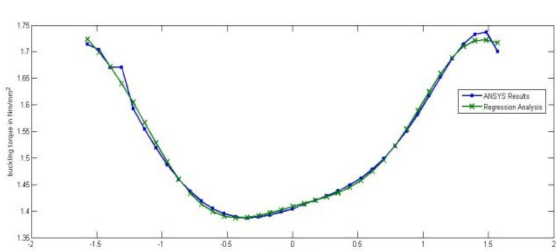

Figure 14 : The effect of fibre orientation angle

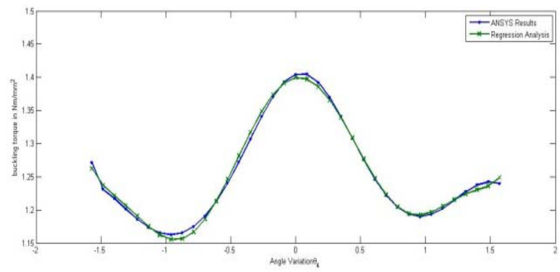

Figure 15 : The effect of fibre orientation angle on buckling torque of forth layer of composite shaft

Regression equation of each layer for buckling torque is as follows-

Layer1-

$$\tau_{\theta_1} = -2.0039 - 0.0153 \times \cos\theta_1 + 2.1434 \times \sin\theta_1^2 + 0.1717 \times \sin\theta_1^3 + 0.0098 \times \theta_1^2 + 0.0058 \times \theta_1^3$$

Layer2-

$$\tau_{\theta_2} = -2.2311 - 0.0108 \times \sin\ \theta_2 + 2.3717 \times \cos\theta_2 + 0.1961 \times \sin\theta_2^2 + 0.0140 \times \sin\theta_2^3 + 0.9393 \times \theta_2^2 + 0.0068 \times \theta_2^3$$

Layer3-

$$\tau_{\theta_3} = -4.8184 - 0.0695 \times \sin\theta_3 + 6.2265 \times \cos\theta_3 + 0.6136 \times \sin\theta_3^2 + 0.0085 \times \sin\theta_3^3 + 2.4946 \times \theta_3^2 - 0.0173 \times \theta_3^3$$

Layer4-

$$\tau_{\theta_4} = -1.3941 + 0.0034 \times \sin\theta_4 + 1.5340 \times \cos\theta_4 + 0.1137 \times \sin\theta_4^2 + 0.5871 \times \theta_4^2 - 0.0011 \times \theta_4^3$$

VII. Conclusion

If fibre angle orientation of any one layer is changed and it is kept constant in other layers-

Shear stress in that layer increases up to 45 degree orientation, then decreases till 90 degree and then again starts increasing; it shows sine nature of graph.

While shear stress in other layers decreases till 45 degree, then increases till 90 degree and again starts decreasing; it shows cosine nature of graph.

Deflection in each layer remains same for any angle of orientation; it decreases till 45 degree then increases for 90 degree and 0 degree.

2nd, 3rd, 4th and 5th natural frequencies increases with angle of orientation and then remains constant.

While 6th natural frequencies decreases with angle of orientation and then remains constant.

By doing regression analysis we have obtained relations between stress and fibre angle orientation, deflection and fibre angle orientation.

From fig.18, the buckling torque of second layer is maximum.

From fig.18, the buckling torque of second layer is maximum.

From buckling analysis it can be concluded that the fibre orientation angle has effect on the buckling torque.

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Synthesis and Characterisation of Al-Si Alloy

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Abstract - Within the last few years there has been a rapid increase in the utilization of aluminium-silicon alloys, particularly in the automobile industries, due to their high strength to weight ratio, high wear resistance, low density and low coefficient of thermal expansion. The advancements in the field of application make the study of their wear and tensile behaviour of utmost importance. In this present investigation, Aluminium based alloys containing 12% weight of Silicon were synthesized using Centrifugal casting method. In case of this centrifugal process the molten metal is poured in to the mould rotating at different rotational speeds. The centrifugal force helps in feeding and positioning metal in the mould. The product produced by centrifugal casting has a good quality, dimensional accuracy as Centrifugal casting results in denser and cleaner metal as heavier metal is thrown to parts of the mould away from the centrifugal action removes unwanted inclusions, dross, cleaner casting, and material that contains shrinkage, which can be machined away. Study of microstructure has showed the presence of primary silicon. Hardness is compared with the different casting speeds. Tensile tests were carried out with universal testing machine. Yield strength and ultimate tensile strength are studied for different rotational speeds. Wear behavior was studied and resistance to wear is analyzed. The worn surfaces were analyzed.

Keywords : Al-Si alloys, centrifugal casting, wear, hardness, microstructure.

GJRE-A Classification : FOR Code: 091207

SYNTHESIS AND CHARACTERISATION OF AL-SI ALLOY

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Synthesis and Characterisation of Al-Si Alloy

Prashantha Kumar H.G [α], Asst. Prof. Mohan Kumar.S [σ] & Prof. Keerthiprasad K.S [ρ]

Abstract - Within the last few years there has been a rapid increase in the utilization of aluminium-silicon alloys, particularly in the automobile industries, due to their high strength to weight ratio, high wear resistance, low density and low coefficient of thermal expansion. The advancements in the field of application make the study of their wear and tensile behaviour of utmost importance. In this present investigation, Aluminium based alloys containing 12% weight of Silicon were synthesized using Centrifugal casting method. In case of this centrifugal process the molten metal is poured in to the mould rotating at different rotational speeds. The centrifugal force helps in feeding and positioning metal in the mould. The product produced by centrifugal casting has a good quality, dimensional accuracy as Centrifugal casting results in denser and cleaner metal as heavier metal is thrown to parts of the mould away from the centrifugal action removes unwanted inclusions, dross, cleaner casting, and material that contains shrinkage, which can be machined away. Study of microstructure has showed the presence of primary silicon. Hardness is compared with the different casting speeds. Tensile tests were carried out with universal testing machine. Yield strength and ultimate tensile strength are studied for different rotational speeds. Wear behavior was studied and resistance to wear is analyzed. The worn surfaces were analyzed.

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I. Introduction

Centrifugal casting is a casting technique that is typically used to cast thin walled cylinders. It is noted for the high quality of the results attainable, particularly for precise control of their metallurgy and crystal structure. Unlike most other casting techniques, centrifugal casting is chiefly used to manufacture stock materials in standard sizes for further machining, rather than shaped parts tailored to a particular end-use.

Centrifugal casting consists of producing castings by causing molten metal to solidify in rotating moulds. The speed of the rotation and metal pouring rate vary with the alloy and size and shape being cast. The following operations include in centrifugal casting - rotation of mold at a known speed, pouring the molten metal, proper solidification rate, and extraction of the casting from the mold. Centrifugal are relatively free from gas and shrinkage porosity. In centrifugal casting, a permanent mold is rotated continuously about its axis at high speeds (200 to 2000 rpm) as the molten metal is poured. The molten metal is centrifugally thrown towards the inside mold wall, where it solidifies after cooling. The casting is usually a fine-grained casting with a very fine-grained outer diameter, owing to chilling against the mould surface. Impurities and inclusions are thrown to the surface of the inside diameter, which can be machined away. Centrifugal casting results in denser and cleaner metal as heavier metal is thrown to parts of the mould away from the centre of rotation and the lighter impurities like slag, oxides and inclusion are squeezed out to the centre. The castings produced have a close grain structure, good detail, high density and superior mechanical properties.

In recent years aluminium alloys are widely used in automotive industries. This is particularly due to the real need to weight saving for more reduction of fuel consumption. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc. Surfaces of aluminium alloys have a brilliant lustre in dry environment due to the formation of a shielding layer of aluminium oxide. Aluminium alloy of 4xxx series, containing major elemental additives of Si, are now being used to replace steel panels if various automobile industries. Due to such reasons, these alloys were subject of several scientific studies in the past few years.

Silicon also has a low density (2.34 g cm^{-3}), which may be an advantage in reducing the total weight of the cast component. Silicon has a very low solubility in aluminium; it therefore precipitates as virtually pure silicon, which is hard and hence improves the abrasion resistance. Aluminium-silicon alloys form a eutectic at 12.6 wt% silicon, the eutectic temperature being 577°C. This denotes a typical composition for a casting alloy because it has the lowest possible melting temperature [6]. Al-Si alloys containing more than about 12% Si exhibit a hypereutectic microstructure normally containing primary silicon phase in a eutectic matrix [10].Wislei R. Osório et. al [13] studied the effect of microstructure on mechanical properties for Al–9wt% Si.

Mechanical properties of Al–Si casting alloys depend not only on their chemical composition but are also significantly dependent rotational speed of the mould. The effects of silicon on the mechanical properties of Al-Si alloys are well studied.

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II. Experimental Set Up

Actual centrifugal casting set up as shown in fig.1 Here a mild steel mould of dimensions 81mm in inner diameter and 88mm in length with wall thickness on 10mm is connected to a motor of 2HP through a shaft. The mould is rotated precisely 20 to 2000 without vibrations. The material was prepared to study the influence of rotational speed on cast. Aluminium is melted in a pit furnace heated to a 720 degree Celsius temperature with 200 degree Celsius super heat. After skimming dross, it was poured into the rotating mould quickly. After a few seconds the motor is turned off and casting pulled out, casting thickness of the cast was controlled by taking calculated amount of metal .these casting were made for different speeds.

III. Experiments

Charging calculated amount of Al &Si into Graphite crucible pit furnace and temperature of about 720˚C is maintained for few seconds till it turns to molten boiling temperature 200̊C maintained for few seconds. This process is to remove absorbed gasses. Hexachloroethane (C2Cl6) in tablets form are used a mild steel mould is used. It is Connected to a 2HP motor can rotate at 0 to 2000 rpm till it get steady then setting the RPM of the mould ie 400, 600, 800, 1000, 1400,1600,1800. Then pouring the Al-Si 12% molten into mould, It will get solidify within 8 to 10 sec. Solidified cast is taken out from the mould and used for further analysis.

Figure 1 : Centrifugal casting set up

Figure 2 : Castings of 8 mm-thick cylinders

IV. Results and Discussion

Experiments are carried out to study the influence of rotational speed on formation of full hollow cylinder and their effects on mechanical properties. Al-Si alloys (12%) are used as study materials. These melts are centrifugally cast at different rotational speeds to get 8 mm thick hollow cylinders. During casting of 8 mm thick hollow cylinder at lower speeds ie, at 200 RPM and 400 RPM the speed not enough to lift the melt. Very poor cylinder with non uniform distribution of molten metal and irregular shape is formed. At 600 RPM uniform hollow cylinder is formed it has poor inner surface with non uniform thickness. At 800 RPM a cylinder formed with poor inner surface. At 1000 RPM a good cast is formed with good inner surface and mechanical properties compare to than at 800 RPM. At 1200 RPM & 1400 RPM higher centrifugal force tends to lift the melt poured and also impression of raining are observed due to high fluidity.

a) Microstructure of Al-12%Si alloy

Metallographic preparation, sequential steps have to be performed to prepare Al- 12%Si for micro structural investigation are involved careful selection of sectioning, mounting, grinding, polishing, and etching procedures is required, and each step must be optimized for each.

Figure 3 : Machined specimen for microstructure

The microstructures shown in the figure.3 at across the section of the casting, under various rotational speeds, it may be seen that more-or-less rounded particles of aluminium (light areas, α-solid solution) are crystallized, which are surrounded by fine eutectic silicon (dark areas). Here, silicon has networked structure. The silicon has long rod like structure. Here the primary silicon appears as coarse polyhedral particles. In addition, presence of primary silicon is also observed in the Al-12% Si, although the size and volume fraction of the primary silicon is more at the outer diameter, as compared to inner diameter of the different speed alloys. It was observed that the rotational speed of the mould has profound influence on the microstructure of Al-12%Si alloys.

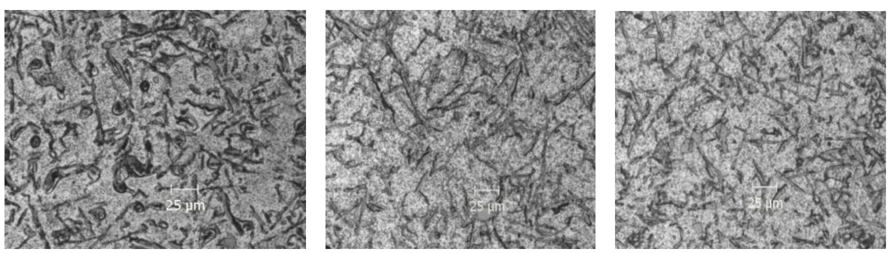
b) Wear Test

i. The tests were carried out by varying one of the following three parameters and keeping other two constants: Applied load (is 0.5,1.0, 1.5, 2.0 N is varied).
ii. Sliding speed (is 600 rpm, when constant).
iii. Sliding distance (is 2266 m, when constant).

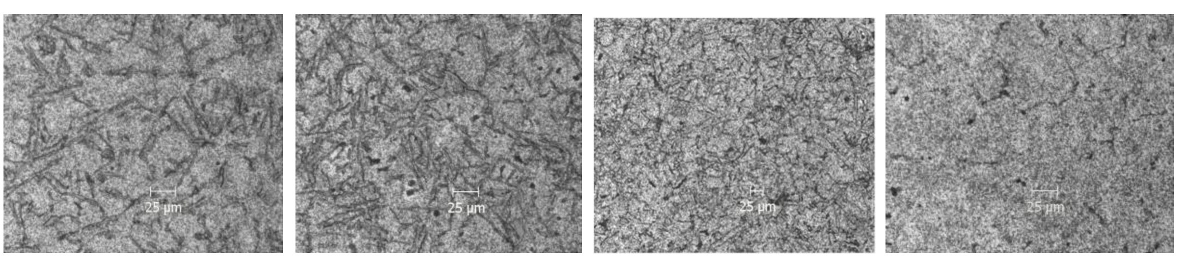
The wear tests of Al-Si alloys were carried out with varying applied load, constant sliding speed and constant sliding distance. The results are obtained from the series of tests which is done by keeping two parameters out of the constant against wear. The effects of these parameters have been studied. Relationship between Cumulative Mass Loss (CML) with time, wear rate dependence of sliding distance etc. have been co-related. The results from the above tests are noted and corresponding curves are drawn.

Table 1 : Wear test parameters

PARAMETER	UNITS	USED
Wear disc		
Diameter	mm	100
Thickness	mm	8
Counterpart Material	Carbon steel	
Square pin	mm*mm	4*4
Length	mm	10
Wear track dia	mm	30
Disc speed	RPM	600
Normal load	N	0.5,1.0,1.5,2.0
Test duration	s	1200
Track distance	Km	2.262
Samples duration	s	60



a. Al Si 400RP b. Al Si 600 RPM c. Al Si 800 RPM



d. Al-Si1000 RPM e. Al-Si 1400 RPM f. Al-Si 1600 RPM g. Al-Si 1800 RPM

White background – Aluminium (Al), Light black portion- Silicon (Si),

Figure 3 : Effect of Rotational speed on microstructure of Aluminium Silicon alloy

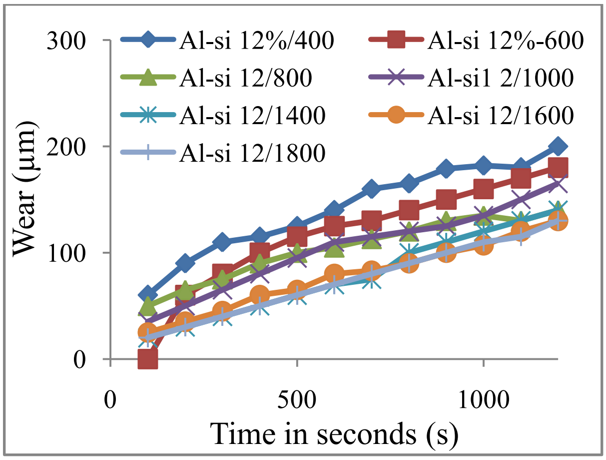


Figure 4 a : Wear rate for 0.5N load

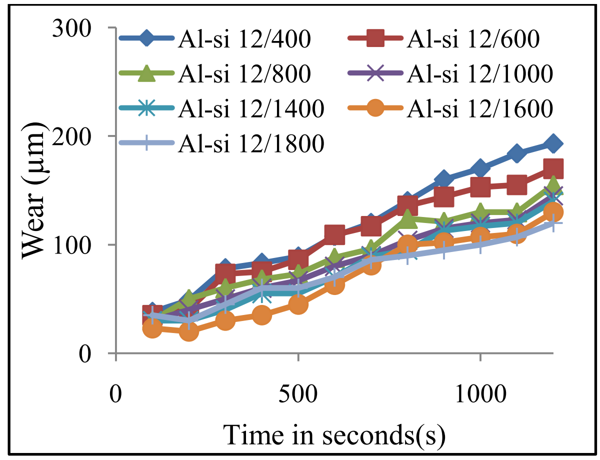


Figure 4 b : Wear rate for 1.5N load

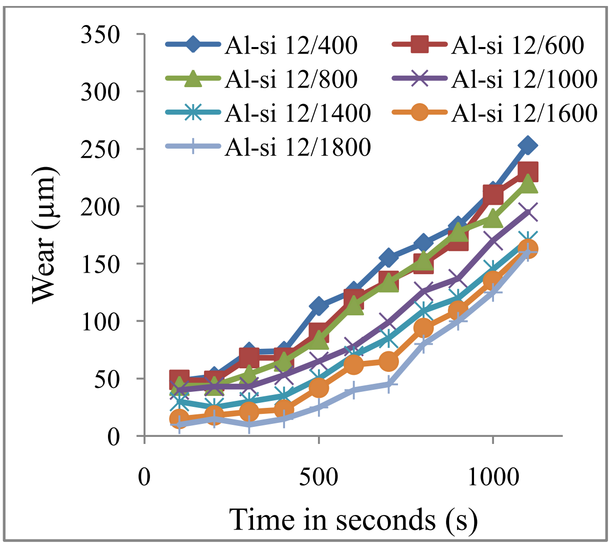


Figure 4 c : Wear rate for 1.0N load

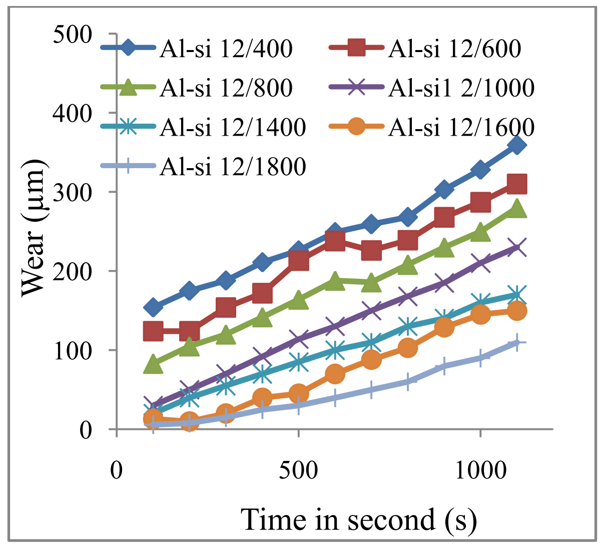


Figure 4 d : Wear rate for 2.0N load

For Al-12% Si alloy, the maximum height loss is for lower casting speeds specimen for all loads,

i. *Load v/s coefficient of friction*

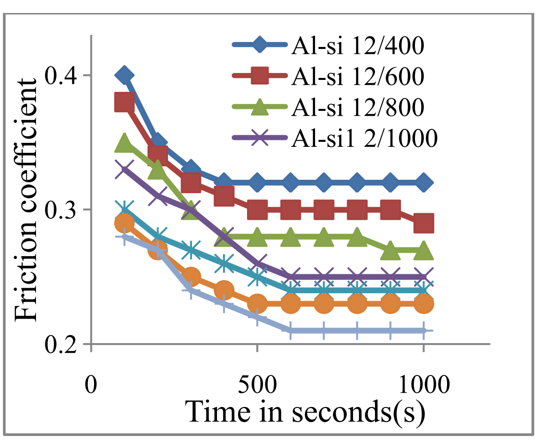


Figure 5 a : Friction behaviour for 0.5N load

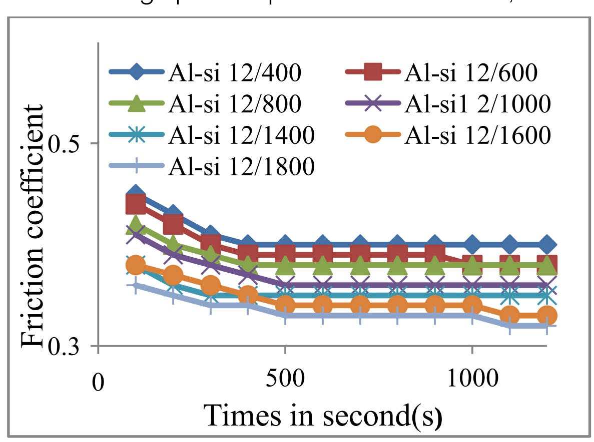


Figure 5 a : Friction behaviour for 1.5N load

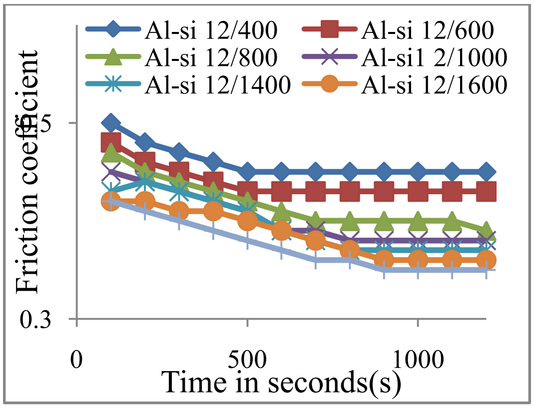


Figure 5 a : Friction behaviour for 1.0N load

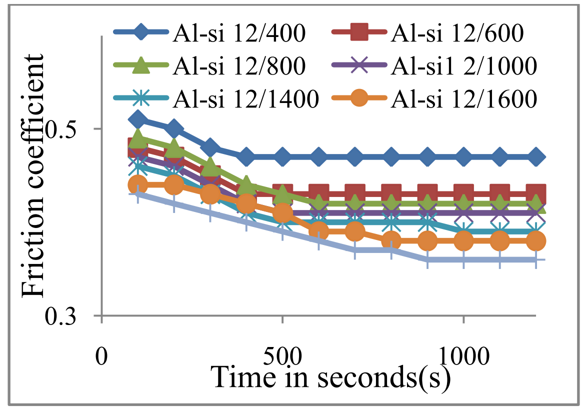


Figure 5 a : Friction behaviour for 2.0N load

ii. *Mass loss comparison*

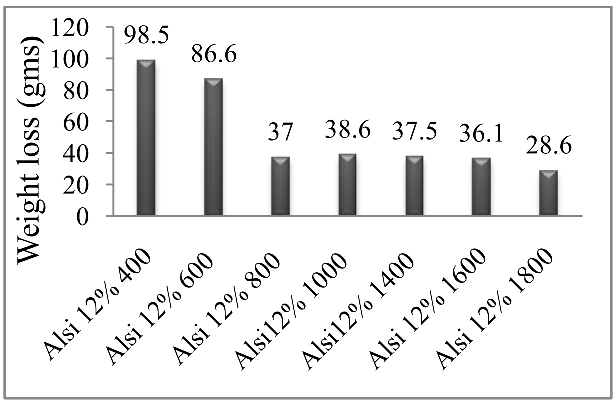


Figure 6 : Mass loss comparison

The results of wear tests on all samples with varying loads (0.5, 1.0, 1.5, 2.0 N) behaviour is illustrated in Fig 4.a to Fig 4.d. It is noticed that the height loss (wear loss) due to wear decreases when the casting speed increases.

Whereas for Al-12% Si alloy, the height loss was increasing when the load increasing, and also height loss is decreasing with the increasing the casting speeds. Similar trends in height loss for all other loads are observed.

The values of co-efficient of friction obtained from the experiment and friction behaviour is illustrated in Fig 5.a to Fig 5.d. From the graphs it is observed that as the load increases friction also increases and increasing in the coefficient of friction, for lower speeds castings the friction is low and it is range from 0.1 to 0.3 and for higher speeds castings it is range from 0.3 to 0.5.

The Optical micrographs for the worn surfaces in un lubricated conditions are obtained at equal magnify -cations. The micrographs of the samples are shown in Fig 4.2.4.a to Fig 4.2.4.g. The worn surface after dry sliding of Al- 12% above all micrographs shows deep well separated grooves. Cracks are also observed which are spread perpendicular to the sliding direction.

It is found that the grooves are along the sliding direction, but not many cracks are seen. However, crack propagation is seen along the same direction as sliding. With presence of Si content hardness of the material has increased. Deeper grooves in dry sliding condition may be assigned to the abrasion of Si particles that have forced the Silicon in platelet form, for which deeper grooves are produced.

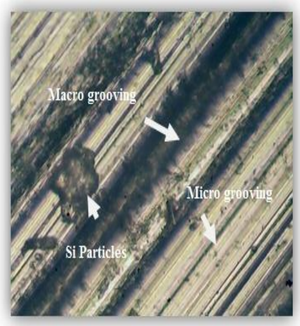


Figure 7 a : 400RPM

Figure 7 b : 600RPM

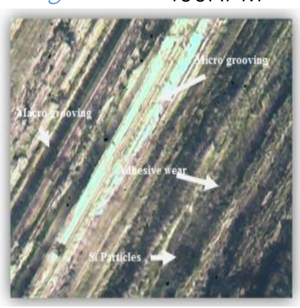


Figure 7 c : 800 RPM

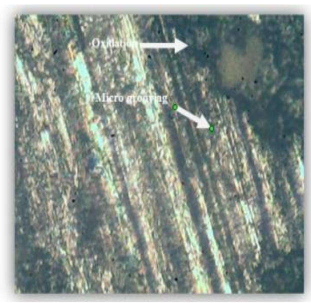


Figure 7 d : 1200 RPM

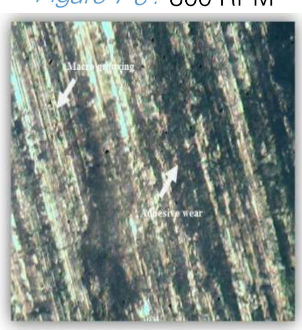


Figure 7 e : 1400RPM

Figure 7 f : 1600RPM

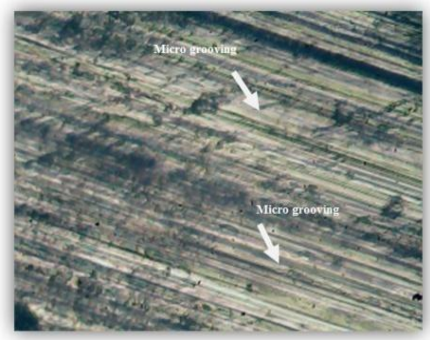


Figure 7 g : 1800RPM

c) Hardness Test

The micro hardness tests of all the samples were conducted using a Vicker's hardness testing machine with a dwell time of 10 s and applied load of 0.1kgf (P) during the tests. For each specimen indentations were taken at inner and outer and value is reported. The following table shows the calculated Vickers hardness number (VHN).The Vickers hardness numbers (VHN) for Al-12% Si for different speeds are found to be range from 55to75. Fig 8.a shows the hardness at outer and inner surface, and it is found that hardness at outer is slightly more compare to that of inner surface at the cast, this is due to concentration of Si particles is more at outer surface.

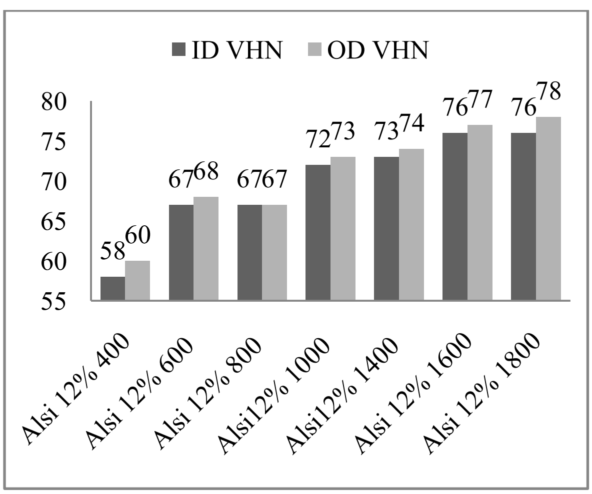


Figure 8 a : Comparison of ID and OD VHN

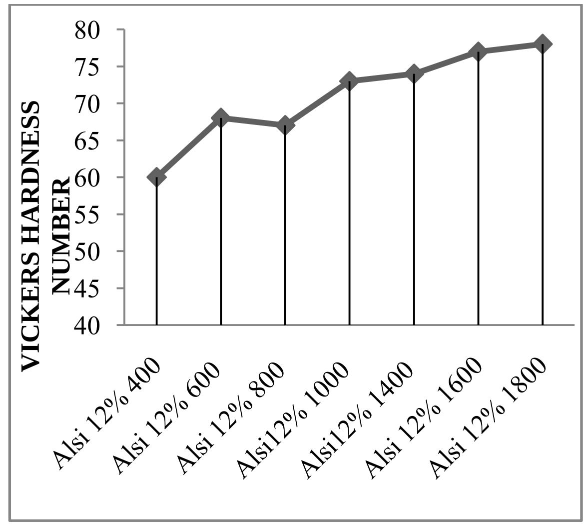


Figure 8 b : Variation of VHN at ID

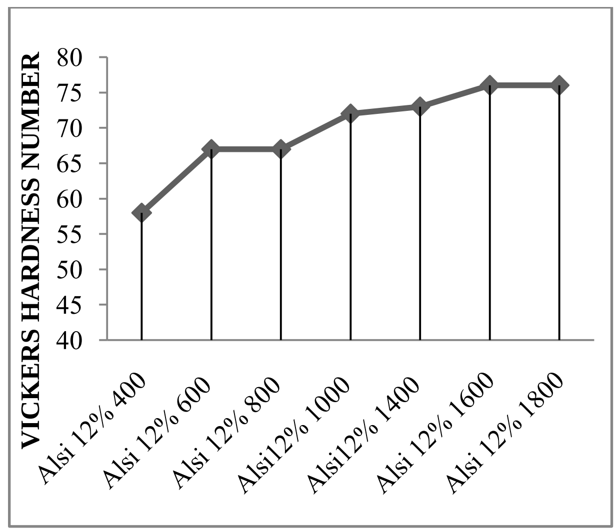


Figure 8 c : Variation of VHN at OD

Fig 8.b&Fig 8.c shows that Variation of VHN with respect to increase in the casting speed, It is such that the hardness increases with increase in rotational speed.

d) Tensile Test Results

From the load and elongation values, obtained from the universal testing machine, corresponding engineering stress and engineering strain were calculated and plotted to get stress vs. strain curves for different samples of Al-12%Si alloys.

i. *Comparison of total elongation*

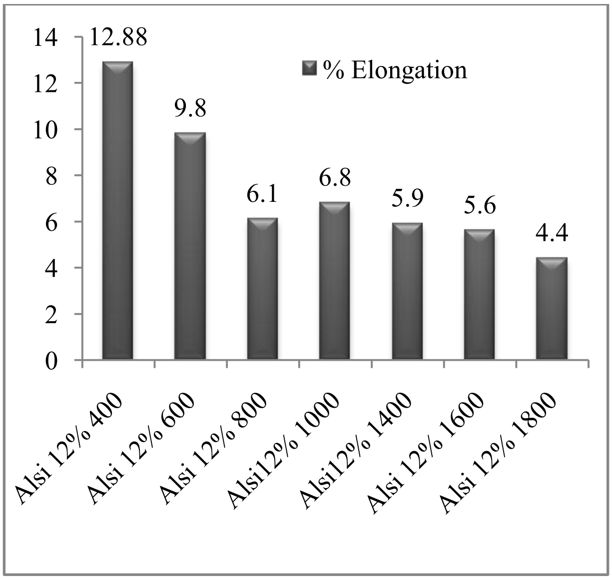


Figure 9 a : Comparison of total elongation

ii. *Comparison of Yield Stress*

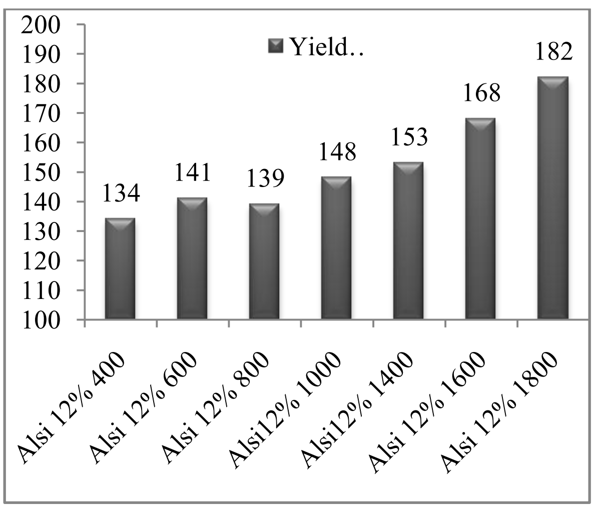


Figure 9 b : Comparison of yield stress

iii. *Comparison of ultimate tensile strength*

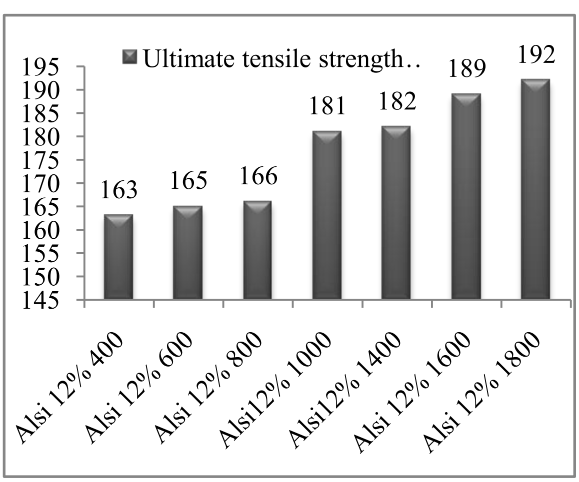


Figure 9 c : Comparison of ultimate tensile strength

From Fig. 4.4.2 and Fig. 4.4.3, it can be observed that, there is continuous increase in the rotational speed of the casting, yield strength and the tensile strength increases with transition from elastic to plastic region takes place. Therefore, the yield strengths of the alloys are computed by 0.2% offset method, according to ASTM standard E8M [20]. From Fig. 4.4.1 it is observed that, it is reverse for the total elongation. This may be due to the presence of hard silicon precipitates which increases the hardness with increase in the rotational speed of the casting of Al-Si alloys.

iv. *Comparison of young's modulus*

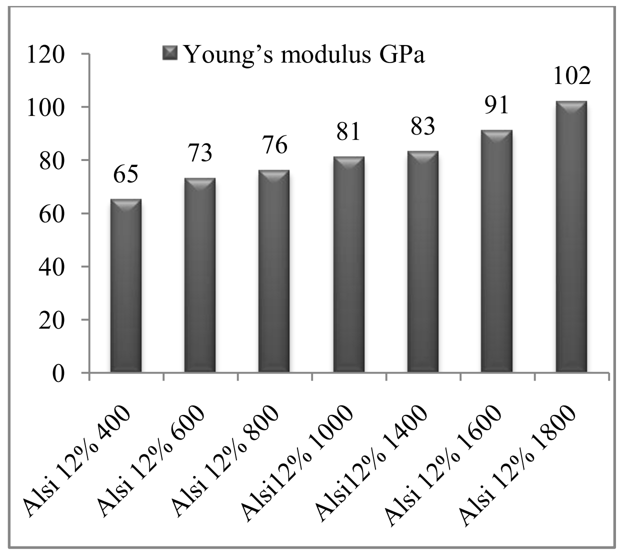


Figure 9.d : Comparison of young's modulus

The modulus of elasticity is calculated from the stress strain curve for all rotational speeds alloy and the values are compared, it shows decreasing with the increasing in the rotational speed of the casting.

V. Conclusions

1. The present study rotational speed is one of the significant parameters in controlling the size and distribution of aluminium and silicon particles.
2. With the increase of rotational speed to the optimum value, there was a remarkable improvement in the microstructure, where a fine equiaxed structure was formed. The microstructure for the specimens rotated at below and above this optimum speed.
3. Wear behaviour is dependent on applied load, sliding speed mainly. However, the wear rate increases with increase in the load.
4. Hardness of the Al-Si alloy increases with the increase in rotational speed of the cast.
5. The height loss due to wear decreases when the increase in rotational speed of the cast.
6. The hardness increase marginally with increase in rotational speed of the cast.

7. Hardness is more at the outer surface compared to the inner surface of the cylinder.
8. Tensile strength also increases marginally with increase in rotational speed.
9. Yield strength and ultimate tensile strength increases with the increase in the rotational speed of the cast.
10. Total elongation decreases with the increase of rotational speed of the cast.

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Condition Monitoring of Wind Turbines: A Review

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Abstract - This paper presents condition monitoring in wind turbines, and related technologies currently applied in practice and under development for aerospace applications, are reviewed. Condition monitoring system estimate the current condition of a machine from sensor measurements, whereas prediction systems give a probabilistic forecast of the future condition of the machine under the projected usage conditions. Current condition monitoring practice in wind turbine rotors involves tracking rotor imbalance, aerodynamic, surface roughness and overall performance and offline and online measurements of stress and strain.

Keywords : wind energy, condition monitoring.

GJRE-A Classification : FOR Code: 660202

CONDITION MONITORING OF WIND TURBINES A REVIEW

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Sachin Sharma [α] & Dalgobind Mahto [σ]

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Keywords : wind energy, condition monitoring.

I. Introduction

Condition based maintenance has been described as a process that require technologies and people skills that integrates all available equipment condition indicators to make timely decisions about maintenance requirement of important equipment. Today most of the maintenance actions are carried out either by preventive maintenance or corrective maintenance approach. The preventive maintenance generally have fixed intervals to prevent the components from failure where as corrective maintenance is performed after a fault or breakdown has occurred. But these approaches proves very costly in many cases due to loss in production, cost of keeping spare parts , quality deficiencies etc. Condition based maintenance involves the measurement or monitoring of specific parameters which directly corresponds to machine. The main difference between preventive maintenance and condition based maintenance is that condition based maintenance uses various methods of monitoring for checking the condition of the machine to determine the actual mean time for failure where as preventive maintenance depends upon industrial average life statistics. Condition based maintenance has three complimentary levels of implementations:

i. Data acquisition step, to obtain data relevant to system health.
ii. Data processing: Data processing analyze the data for interpretation, also known as Diagnosis.
iii. Maintenance decision making step, to implement best optimum maintenance policy (Prognosis).

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iv. This methodology as having existed for many years. Thus methodology is recently developed and has evolved over the past three decades from precursor maintenance methods.

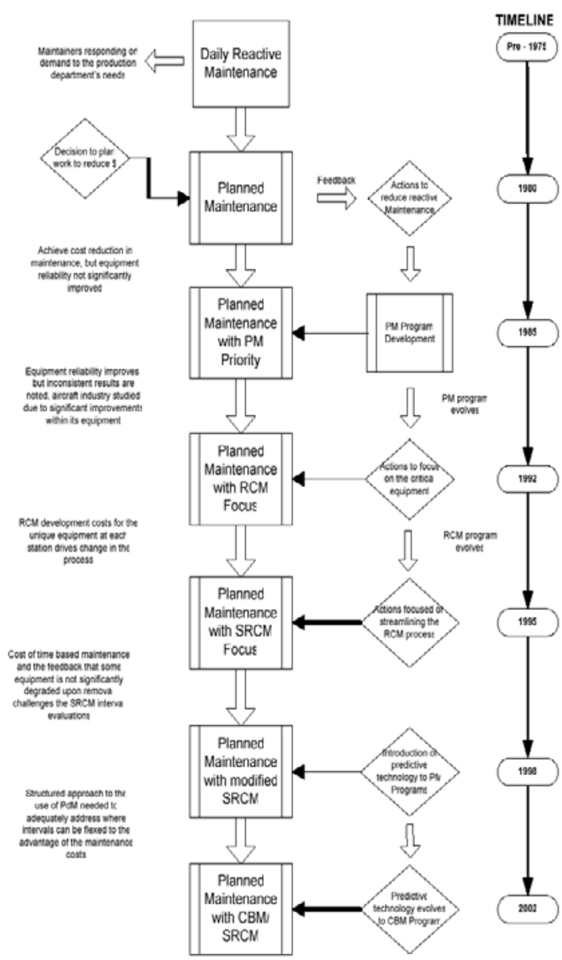

Figure 1.1 : Evolution of condition based maintenance

On the basis of data acquisition and periodicity analyses machine protection system can be of folowing types:

a. OFFLINE system: In this type of system the vibration specialists and maintenance managers determine the system for periodic maintenance of machines , mean data acquisition and analyses based on the time base. The periodicity of data acquisition and analyses is determined by analyzing the current vibration level of machine.

b. ONLINE system:The permanently installed systemfor vibration signals acquisition and analyses must be an online system. In ONLINE system condition monitoring units continuously monitor the vibration as well as other process variables, to trend the condition of the equipment and assist in determining when it should be removed from the service for repair. They run as stand alone davice and periodicaly transfer measured data to storage computer. Then it trigger a alarm automaticaly to plant control system and generate a e- mail message. These systems are capable of automatically communicating through a variety of methods, from earthnet GSM modem and allow monitoring of remote locations anywhere in the world.

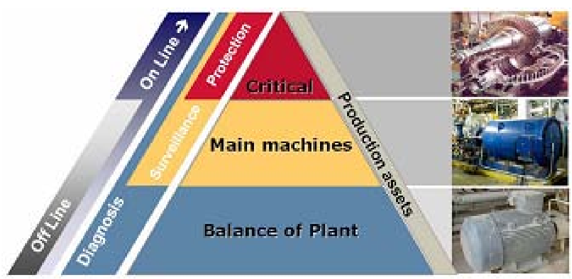

Figure1.2 : Different approaches to condition based maintenance for different equipment in the plan

Figure 1.3 : Online condition monitoring

Figure 1.4 : Handheld data collector system

c. Remote Condition Monitoring System: In REMOTE condition monitoring machines the traditional way of collecting data on site is replaced with web based maintenance equipment and it gathers the data fast and data acquisition and data transfer is cheap. By introducing a high speed computer network into vibration monitoring system, vibration signals can be transferred into a specific database. Using this data maintenance managers and vibration specialists have a real time insight into a machine's condition. Web based condition monitoring can be applied to both OFFLINE and ONLINE monitoring system. However it is generally applied to ONLINE system and in case of OFFLINE system means only remote database and vibrations specialists while the presence of maintenance personnel on site is still required for purpose of vibration data collection.

II. Objectives of CBM

CBM is performed to serve the following purposes:

- To identify the fault in the monitored object.
- To identify nature of fault.
- To determine the time up to which machine can serve without interruption before breakdown.
- To determine the degrading components.
- The core objectives of condition based maintenance are:
- To take necessary action before breakdown.
- To reduce the maintenance overhead costs.
- To perform maintenance when required.
- To reduce number of breakdowns and failure frequency rate.

II. How to Start Condition based Maintenance

One of the most attractive as pect of CBM is the fact that it can be implemented in a relatively inexpensive, step by step approach. Because condition based maintenance is based on equipment oriented concepts of predictive maintenance, it can be applied gradually one system a time.

Following steps are involved in condition based maintenance:

a) Phase 1

i. *Data collection and storage procedure*

Maintenance data and its uses creates the main key differences between the classical and modern maintenance methods. In past, a little attention was paid for the comparison and trending and the data was collected from maintenance results from any given interval which had been filed by reviewing. Trending and statistical analyses are the fundamental building blocks of CBM. By comparing data absolute values and data deviations via statistical analyses provide information never before available. Thus a statistically relevant data base is required. There are a lot of maintenance management software available which have same basic purpose and design are similar from one manufacturer to other. Fundamental equipment information is stored in a detailed manner. Information such as size, date of purchase, ratings, cost, maintenance cycle etc. are stored. Many power system operators have kept good paper records over the years. These paper records may be converted into computerized database which is time consuming but simple.

ii. *failure and outage information Equipment*

To access the risk of condition based maintenance program, compilation of this outage data is needed,. This information include items such as type of outage data, cause, length, cost, date etc. The condition based maintenance program implementation sequence can be prioritize by using this outage information. Equipment with high failure rate should be enrolled in the program first.

iii. *Equipment Database*

The equipment database is developed in parallel with other databases. The equipment database may be linked with master maintenance database. But more reliability is realized if they are kept separate.

iv. *Preliminary budget and plan*

The preliminary budget and planning is the final step in phase 1.Table 3.1 shows the steps include in preliminary plan.

Table 3.1 : Steps involved in preliminary plan

Field#	Linked to	Result	Comments
1	4	2	Dimensions of result depend on specific test
2	5	4.5%	
3	6	1	
4	Etc		

b) Phase 2

Information generated in phase 1 will be put to work as a living,, active CBM program.

i. *Develop detailed evaluation criteria and methods*

Based on test result data gathered in phase 1, the development of control chart strategies and other statistical evaluation techniques should begun. The exact nature of which strategies should be used may not be immediately apparent. Two options are available as shown in table 3.2.

Table 3.2 : Evaluation criteria options

1	Contract with CBM consultant for statistical criteria implementation
2	Start simple. Use graphical trending in spreadsheet.

Contracting with qualified CBM consultant, who can assist in selection and implementation of appropriate strategies. Starting simple with a commercially available spreadsheet may not be as rigorous or technically satisfying as more sophisticated statistical analyses, it may well provide a satisfactory compromise between competing technical and economic factors.

ii. *Finalize recommended maintenance procedure and intervals*

Maintenance procedure can be added as needed in future intervals, Using transformer as an example table 3.3 lists typical, predictive results, types of tests that might be used. The opinion and observations of skilled technicians are extremely important in overall evaluation.

iii. *Test reporting forms /or software*

Test forms have been around for as long as electrical equipment, virtually ever test technician has, at one time or another, created his her own form. Two approaches are now available

a. *Printed paper form*

Such forms are available from a number of sources. These preprinted forms have limitation that they need modification and manual transfer of data into various computer databases.

b. *Direct computer entry*

If a user friendly interface for the database has been designed, a mini version may be taken into the field by maintenance technicians. After such test the technician can keyboard the results directly into computer.

IV. Condition Monitoring of Wind Turbines

A Change in process parameter is an indicative of a developing failure [86]. A modern condition monitoring system consist of sensors and a processing unit which continuously check and record the condition of the component. There are various techniques to access the component condition. These techniques include vibration analyses, acoustics, oil analyses, strain measurement, and thermography. In case of wind turbine these techniques are used to monitor the major components such as blades, gear box, tower, bearings etc. A condition monitoring may be ONLINE or OFFLINE. A ONLINE monitoring provide instantaneous feedback of condition while OFFLINE provide data collected at regular intervals. For a fast fault detection while the component is in operation require good data acquisition system and appropriate signal processing. Maintenance tasks may be planned and scheduled with great efficiency which increase the reliability, safety and maintainability of the system and reduce the downtime and operational costs [87]. Therefore CM techniques are widely adopted by the industry [88,89] and its most benefits are used in offshore wind farms [90].

V. Condition Monitoring Techniques

The following techniques, available from different applications, which are possibly applicable for wind turbines, have been identified:

Vibration analysis

1. Oil analysis
2. Thermography
3. Physical condition of materials
4. Strain measurement
5. Acoustic measurements
6. Electrical effects

7. Process parameters
8. Visual inspection
9. Performance monitoring
10. Self diagnostic sensors

a) Vibration Analysis

Vibration analysis is the most known technology applied for condition monitoring, especially for rotating equipment. The type of sensors used depend more or less on the frequency range, relevant for the monitoring:

– Position transducers for the low frequency range
– Velocity sensors in the middle frequency area
– Accelerometers in the high frequency range
– And SEE sensors (Spectral Emitted Energy) for very high frequencies (acoustic vibrations)

Examples can be found for safeguarding of:

1. Shafts
2. Bearings
3. Gearboxes
4. Compressors
5. Motors
6. Turbines (gas and steam)
7. Pumps

For wind turbines this type of monitoring is applicable for monitoring the wheels and bearings of the gearbox, bearings of the generator and the main bearing. Signal analysis requires specialised knowle-dge. Suppliers of the system offer mostly complete systems which includes signal analysis and diagnostics. The monitoring itself is also often executed by specialised suppliers who also perform the maintenance of the components. The costs are compensated by reduction of production losses. Application of vibration monitoring techniques and working methods for wind turbines differ
from other applications with respect to:

– The dynamic load characteristics and low rotational speeds In other applications, loads and speed are often constant during longer periods, which simplifies the signal analysis. For more dynamic applications, like wind turbines, the experience is very limited.
– The high investment costs in relation to costs of production losses. The investments in conditions monitoring equipment is normally covered by reduced production losses. For wind turbines, especially for land applications, the production losses are relatively low. So the investment costs should for a important part be paid back by reduction of maintenance cost and reduced costs of increased damage.

b) Oil Analysis

Oil analysis may have two purposes:

- Safeguarding the oil quality (contamination by parts, moist)

Safeguarding the components involved (characterisation of parts) Oil analysis is mostly executed off line, by taking samples. However for safeguarding the oil quality, application of on-line sensors is increasing. Sensors are nowadays available, at an acceptable price level for part counting and moist. Besides this, safeguarding the state of the oil filter (pressure loss over the filter) is mostly applied nowadays for hydraulic as well as for lubrication oil. Characterisation of parts is often only performed in case of abnormalities. In case of excessive filter pollution, oil contamination or change in component characteristic, characterisation of parts can give an indication of components with excessive wear.

c) Thermography

Thermograhy is often applied for monitoring and failure identification of electronic and electric components. Hot spots, due to degeneration of components or bad contact can be identified in a simple and fast manner. The technique is only applied for of line usage and interpretation of the results is always visual. At this moment the technique is not interesting for on line condition monitoring. However cameras and diagnostic software are entering the market which are suitable for on-line process monitoring. On the longer term, this might be interesting for the generator and power electronics.

d) Physical condition of materials

This type of monitoring is mainly focussed on crack detection and growth. Methods are normally off line and not suitable for on line condition monitoring of wind turbines. Exception might be the usage of optical fuses in the blades and acoustic monitoring of structures.

e) Strain Measurement

Strain measurement by strain gauges is a common technique, however not often applied for condition monitoring. Strain gauges are not robust on a long term. Especially for wind turbines, strain measurement can be very useful for life time prediction and safeguarding of the stress level, especially for the blades. More robust sensors might open an interesting application area. Optical fibre sensors are promising, however still too expensive and not yet state-of-the-art. Availability of cost effective systems, based on fibre optics can be expected within some years. Strain measurement as condition monitoring input will than be of growing importance.

f) Acoustic Monitoring

Acoustic monitoring has a strong relationship with vibration monitoring. However there is also a principle difference. While vibration sensors are rigid mounted on the component involved, and register the local motion, the acoustic sensors "listen" to the component. They are attached to the component by flexible glue with low attenuation. These sensors are successfully applied for monitoring bearing and gearboxes.

There are two types of acoustic monitoring. One method is the passive type, where the excitation is performed by the component itself. In the second type, the excitation is externally applied.

g) Electrical Effects

For monitoring electrical machines MCSA (Machine Current Analysis) is used to detect unusual phenomena. For accumulators the impedance can be measured to establish the condition and capacity. For medium and high voltage grids, a number of techniques are available:

- Discharge measurements
- Velocity measurements for switches
- Contact force measurements for switches
- Oil analysis for transformers

For cabling isolation faults can be detected. These types of inspection measurements do not directly influence the operation of the wind turbines.

h) Process Parameters

For wind turbines, safeguarding based on process parameters is of course common practice. The control systems become more sophisticated and the diagnostic capabilities improve. However safeguarding is still largely based on level detection or comparison of signals, which directly result in an alarm when the signals become beyond predefined limit values. At present, more intelligent usage of the signals based on parameter estimation and trending is not common practice in wind turbines.

i) Performance Monitoring

The performance of the wind turbine is often used implicitly in a primitive form. For safeguarding purposes, the relationship between power, wind velocity, rotor speed and blade angle can be used and in case of large deviations, an alarm is generated. The detection margins are large in order to prevent for false alarms. Similar to estimation of process parameter, more sophisticated methods, including trending, are not often used.

VI. Possible Applications of Condition Monitoring

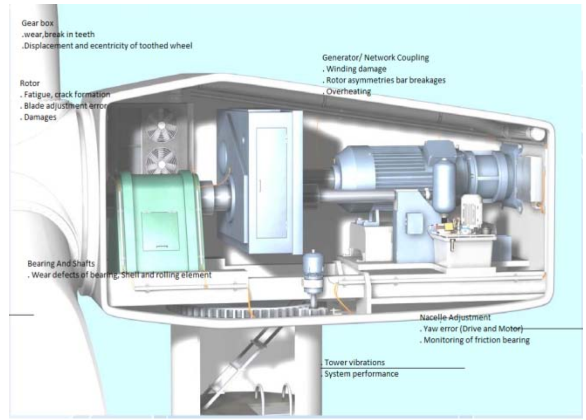

Figure 6.1 : Applications of condition monitoring in wind turbine

a) Gear Box

i. Wear, break in teeth
ii. Displacement and eccentricity of toothed wheels

b) Rotor

i. Fatigue crack formation
ii. Blade adjustment error
iii. Damages (via lightening strike)

c) Generator network coupling

i. Winding damage
ii. Rotor asymmetries, bar breakage
iii. Overheating

d) Bearing and Shafts

i. Wear, defects of bearings shells and rolling elements
ii. Fatigue crack formation in shafts

e) Tower vibration

i. System performance
ii. Environmental influences
iii. Crack formation, fatigue

f) Nacelle adjustment

i. Yaw error (Drive & motor)
ii. Monitoring of friction bearing

VII. Literature Review

Palle Christensen and Gregor Gie bel (2001) [1] introduces a new condition monitoring tool which provide a fully automatic supervision and control of the wind farm on internet and data can be accessed with common interface for all form of data from farm.

T Holroyd (2001) [2] constructed a test rig to seeded the defect of varying sizes on outer races of bearing. A comparison has been done between AE (Acoustic Emission) and vibration analyses. It was concluded that AE not even detect earlier faults but can also provide indication of defect size.

N. Jamludin et al. (2001) [3] present a work in which they apply the stress waves analyses to detect early stages damages of bearing at a very low speed i.e. 1.12r/min.

Shjn Dander (2002) [4] presented a work in which they access the use of time domain model based fault detection and identification (FDI) method for application to a horizontal axis wind turbine (HAWT) that uses pitch to vane control. They use two approaches, the system identification approach and observer based approach using the kalman filter. They construct a horizontal axis wind turbine model and use the simulation to test various approaches. Two algorithms based on kalman filter are presented which provide a reliable estimate of the wind speed by including it in an augmented system state.

T.W. Verbruggen (2003) [5] develop a inventory of available condition monitoring techniques and selecting a set which has added a value for wind turbines. The area for further development of sensors, algorithm for data analyses were investigated.

L. Mihet-Popa et al (2003) [6] proposed a technique based on steady state analyses and applied to induction generators. This technique identify interturn stator fault and rotor asymmetries.

L. W. M.M. Rademakers et al. (2004) [7] they present a condition monitoring system for fiber optic blades. They installed the system on a NORDEX turbine for about one year to get operational experience with it to optimize and extend the algorithm. The data is stored on turbine module with back up at ECN. Based on this historical data algorithm were tested before implementing on any turbine system.

Giurgiutiu, V & Cuc, A. (2005) [8] presented a damage detection method which was based on ultrasonic rely due to propagation and reflection of elastic waves within the material. They identify local damages and flaws via blade field disturbances. They propose the use of piezoelectric transducer in place of conventional non destructive transducer because piezoelectric transducer can act both transmitter and receiver of ultrasonic waves.

Douglas H. (2005) [9] presented a work in which a steady state technique has been applied e.g. Motor Current Signature Analyses (MCSA) and Extended Park's Vector Approach (EPVA) and a new technique which was combination of EPVA and discrete wavelet transform and statics to detect the turn faults in doubly fed induction generators (DFIG). The proposed technique shows that steady state technique is not effective when DFIG's operate under transient condition but stator turn faults can be detected under transient conditions.

Christopher A. Walfard (2006) [10] highlights the relevant issues of reliability for wind turbine power generation projects. They identify the cost elements associated with wind farm operation and maintenance. Causes of uncertainty in reliability estimation of wind turbine was also discussed.

C. Walfard, D. Robert (2006) [11] present a work in which they conduct a cost benefit analyses and estimates that cost liability for failure of wind turbine after four to five years is $75,000 to $ 2,25,000 per event for megawatt scale turbine.

R.W. Hyers et al. (2006) [12] compare the condition monitoring in wind turbine with monitoring and prognosis in helicopter gearboxes. They evaluate the state of art of electronic control and power electronics and compare with state of art in aerospace.

Jesse A. Andrawus et al. (2006) [13] apply the RCM approach to horizontal axis wind turbine to detect various failure modes and their causes and effects on system operation. The failure consequences are estimated in term of financial terms by evaluation. Over the whole life cycle of wind turbine the CBM activities are identified and assessed to maximize the return on investment in wind farms.

David Mc Millan and Grahm W. Ault (2007) [14] measure the benefits of condition monitoring quantitatively. They construct a probabilistic model which uses various methods including discrete-time Markov Chains, Monte Carlo method and time series modeling.

Ayetullah Gunel et al. (2007) [15] present a new technique i.e. fluid condition monitoring system in which temperature of oil filter and cooling subsystems are monitored with various sensors. The other parameters such as absolute pressure drop across the filter, dielectric constant and viscosity are also monitored to analyze oil degradation. The data was recorded for two years for two turbines. Then filter lifetime can be predicted by processing the recorded data with statistical and semantic method. The combination of statistical and semantic method make the technique hybrid.

Michael Wilkinson et al. (2007) [16] develop a electomechanical test rig for assessment that which sensor and fault detection algorithm should be used in a condition monitoring system for operational wind turbines. The test rig has been driven at variable speed to investigate the behavior of wind turbine. A number of fault detection algorithms have been tested on each sensor signal.

Edwin Wiggelinkhuizen et al. (2007) [17] set up a wind farm of five turbines and several condition monitoring systems has been installed. Traditional measurement systems are also used. A algorithm has been developed which can be integrated with a SCADA system.

German Wind energy Association (2007) [18] highlights the objective and condition monitoring

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intervals according to the wind turbine size in megawatt. They highlight the technical experts qualification required for CM plan, inspection requirements, maintenance requirements and technical control system requirements.

Michael R. Wilkinson (2007) [19] constructed 30 kW test rig which have the same feature as wind turbine drive train, for signal processing technique necessary for variable speeds and high torque variation application. The faults are detected by investigating various approaches of condition monitoring on this test rig, and measuring torque, speed and shaft displacement and gearbox vibrations.

R. Andrew Swartz et al. (2008) [20] deployed wireless sensor technology on two wind turbines to construct better models of wind turbine dynamic behavior and response to loading.

Scott J. Johnson et al.(2008) [21] presented a report in which they introduces a number of active techniques which can be used for control of wind turbine blades. They apply active flow control (AFC) to wind turbine performance and loads. A special focus was given on actuators and devices and flow phenomena caused by each device.

Mike Woebbeking (2008) [22] performed various kind of inspections at turbines. The inspection include periodic monitoring, operation and maintenance surveillance, inspection after commissioning of wind turbine etc. The results shows that 26% of defects and damages are due to gearbox, 17% from generator and 13% from drive train.

Asif Saeed (2008) [23] implemented various conventional and latest techniques of condition monitoring including signal processing methods for vibration analyses for early fault detection. As a result of the study, infrared thermography is applied as an online condition monitoring for wind system as a retrofit design to increase performance of early detection system.

William A. Vachon (2008) [24] presented a work which focuses on joint wind project involving IMLD and IpsWich school District (ISD). They install a single MW scale wind turbine generator and the output of the generator is shared in proportion according to funds provided by each party, and value of power delivered to each party reflect the projected time of use of costs. Thus goal of the study was to project the economics of the project.

E Lie-Ahmar et al (2008) [25] presented a work which investigate specific transient techniques suitable for electrical and mechanical failures in an induction generator based wind turbine. An experimental set up of 1.1kW has been constructed and investigations shows that proposed technique can diagnose failure under transient condition.

Cattin Rene et al. (2009) [26] concludes some results from turbines working in ice regions. They revealed that in cloud conditions the air temperature can be used as an indicator for detecting icing conditions. They point out that there is no ice detector in market which can measure icing reliably.

The results of Enrcon E-40 turbine shows that the ice detection via power curve can be a better method except for light icing and in case of low wind speed. They point out that it is not possible to melt ice during one heating cycle specially at leading edge of blades thus heat transfer to leading edge should be optimized.

Yassine Amirat et al. (2009) [27] discussed different types of faults, Their generated signature and their diagnostic scheme by keeping in mind the need for future research.

T. Barszczet et al. (2009) [28] states that there is lack of sufficient data to perform training of method, thus some new states should have created, when there is data different from all known states. Thus they apply Neural Network approach because Neural is a proper tool for classification of operational states in wind turbine and is also capable to recognize new states.

R.F. Mesquita et al. (2010) [29] apply the Neural network to analyze all the wind turbine information to identify possible future failure, based on past data of turbine. They show that neural network is a valid tool to make an early detection of failure in some wind turbine equipments.

Emilio Miguelanez et al. (2010) [30] presents the role of SeeByte's RECOVERY system within the wind industry, specially focus on offshore turbines. Systems of today gives false alarms most of the time which results in incorrect diagnosis and unnecessary intervention and important warnings are ignored. A RECOVERY system has been developed to guide the fault detection process and better automate knowledge discovery to improve diagnostics. The diagnostics concept is represented on the basis of system observation design pattern. This holistic system improve the diagnostic correctness by taking care of events and sensors values for complete turbine system. Thus it reduces the no-fault-found situations.

Bincheng Jiang (2010) [31] analyze the dynamic performance of drive train in wind power station and dynamic behavior of gearbox under normal and transient load conditions has been studied to investigate the reasons of drive train misalignment in future work. A 1-D torsional multibody dynamic model of the drive train taking into account the effect of aerodynamic force and excitation has been developed.

Wenxian Yang et al. (2010) [32] presented a CM technique in which generator output power develop a fault detection signal. A algorithm is used which uses continuous wavelet transform. Adaptive filters are used to track the energy in prescribed time-varying fault-related frequency bands in power signals. The generator control the central frequency and band width is related with speed fluctuations. Using this technique faults can be detected with low calculations time.

Yassine Amirat et al. (2010) [33] proposed a new fault detector which is based on amplitude demodulation of the three phase stator. They proves by simulation that this low complexity method can be well applied for stationary and non stationary behavior.

Milos Milovancevic (2010) [34] states that applied condition monitoring techniques on sub system levels produces useful information about wind turbine. By using advanced methods of signal analyses, significant changes in turbine behavior can detected at an early stages. They develop a approach which is based on general turbine parameters. Due to global nature of information specific diagnostic is difficult to achieve. Thus they develop a system for wind generator transmission gear vibration monitoring. They proposed that wind turbine systems are complex to monitor and there are very small margins for investments and number of systems is high hence adaptation should not only focused on dynamic load behavior but also on streamlining the system and integration.

Joon Young Park et al. (2010) [35] develop a simulator composed of blades, a step up gearbox and a generator. This simulator replaced the conventional simulator which consist of a motor and was not suitable for effective condition monitoring algorithm. They developed the condition monitoring system and also the procedure for designing the simulator.

Eunshin Byon et al. (2010) [36] present a work which shows the effect of dynamic weather conditions on feasibility of maintenance. That state that weather conditions makes the modeling and maintenance strategy season dependent. They formulate a model based on Markov decision process by accounting heterogeneous parameters and solve the model by backward programming method. They highlight the benefits of resulting strategy through a case study by collecting data from wind industry. The case study results shows that a optimal policy can be adapted to operating conditions, choosing the most effective action.

Richard Dupuis (2010) [37] explains that how bearing and gear rolling elements fails by surface fatigue mode and also study the characteristics of debris produced by failure mode. Their work present that how the accumulated debris damage limit can be counted on the basis of gear geometry. They develop an effective PHM technique by presenting actual data obtained from seeded fault bearing and gear test.

Zhi Gang Tian et al. (2010) [38] develop a optimal CBM defined by two failure probability thresholds values at wind turbine level. The CBM decisions can be made by calculating failure probability values on the basis of condition monitoring and prognostic data. The cost of CBM technology is evaluated by simulation.

F.D. Coninck et al. (2010) [39] constructed a back to back gearbox setup which is one of the largest in world. The complexity of dynamics was tackled by the concept of load cases. Each load case represent different turbine behavior. A control architecture was developed to handle the complex interactions between mechanical dynamics and electrical controller of test rig. The test rig is fit for experimental validation of dynamic load situation models.

Bodil Anjar et al. (2011) [40] conducted a feasibility study and they investigate the possibilities of using thermal condition monitoring of the systems and components in wind turbines. They conclude that thermography is suitable for monitoring electrical systems, transformers and also for fire detection and fire extinguishing. The IR cameras can be mounted on a pan tilt unit for continuous monitoring. They show that as the size of wind power plant increases the cost for downtime and repair also increases.

Shuangwen Sheng (2011) [41] present a study work which focuses on results obtained by various CM techniques from a damaged Gearbox Reliability Collaborative (GRC) test gearbox. The study shows the capabilities and limitations of each technique. The results from a test gear box under healthy condition are compared with damaged gearbox. A fieldtest of one GRC gearbox shows that damaged gearbox experienced two unexpected oil losses which damage its internal components. The damaged gearbox is reset by using different CM techniques which help in evaluating the different CM techniques.

Pratesh Jayaswal et al. (2011) [42] present a work in which they acquired the vibration signals of bearings and analyzed them with the help of vibration analyses techniques. In present work they detect the earlier fault in bearing using vibration monitoring. By study the FFT spectrum of bearing vibration signal they access the condition of bearing.

Peng Guo et al. (2011) [43] proposed a new technique Autoassociative Kernel Regression (AAKR) which is used to construct the normal behavior model of gearbox temperature. The measurement temperature become significant, when residual between AAKR estimates on incipient failure of gearbox. To detect the changes of the residual mean value and standard deviation in timely manner a moving window statistical method is used. As one of these parameters exceeds the predefined value the incipient failure flagged.

Secil Vorbak Nese et al. (2011) [44] constructed a model of three blades horizontal axis turbine and fault due to possible blade deformation was studied. By applying Continuous Wavelet Transform (CWT) approach a comparison is done between generator rotor speed and torque for healthy and damaged blades.

Suratsavadee Koonlaboon Korkua et al. (2011) [45] develop a Zig Bee based wireless sensor network for health monitoring of induction machines. The proposed technique is like a control network which integrates sensors and embedded computer, wireless communication and intelligent processing technology. The proposed technology consumes low power, having low cost and short time delay characteristics. The technique is used with suitably modified algorithm for extracting the information for induction machine diagnostic.

Dariusz BRODA et al. (2011) [46] states that vibration of wind turbine is greatly affected by wind. They discuss the seasonal diurnal vibrations with the help of statics of wind and vibrations. Variability of wind and vibrations are compared with the help of mean/std ratio. The results obtained help in determining operational states of wind turbine.

Joon-Young Park et al. (2011) [47] present a work in which they develop a condition monitoring system for three different kind of SCADA system of three different turbines from different manufacturer. Thus their work include the designing of condition monitoring system and design of its control function.

Douglas Adams (2011) [48] presented a work in which they perform the structural health monitoring of Micon 65/13 horizontal axis wind turbine. It is observed that vertical wind shear and turbulent wind load to different modal contributions in operational response of the turbine and they conclude that sensitivity of operational data to change depends upon the wind loads. A modal criterion was used to analyze corresponding changes in modal deflections.

Ivo Houtzager (2011) [49] addressed two research goals one deal with the data driven modeling methods using system identification and other deal with repetitive controller to reject periodic disturbances. In first method the recursive identification is performed via the subsequent solution of only three linear problems and they are solved by recursive least square. They use Tikhonov regularization to overcome possible numerical problems in practice. The real time implementation and ability to multi input and output systems with closed loop make this approach best suitable for unstable dynamics estimation.

Radoslaw Zimroz et al. (2011) [50] proposed the use of advanced signal processing techniques for measuring instantaneous shaft speed recovery from vibration signals generated.

Peng Gua (2012) [51] used the history data of Supervisory Control and Data Acquisition (SCADA) system and analyzed this data for detecting the failure of turbine generator bearing. A new condition monitoring method based on Nonlinear State Estimate Technique (NSET) is proposed which is used to construct the normal behavior model of generator bearing temperature. When the generator bearing has an incipient failure the residual between NSET model estimates and measured generator bearing temperature will become insignificant and when residual exceeds the thresholds, an incipient failure is flagged.

Wenxian Yang et al. (2012) [52] proposed that reliability centered maintenance is best for offshore wind turbines which include preventive and predictive maintenance techniques enabling wind turbine to achieve high availability and low cost of energy. They present the wind industry with a detailed analyses of the current challenges with existing wind turbine condition monitoring technology.

Simon Gill et al. (2012)[53] used the operational data from wind turbine to estimate bivariate probability distribution functions representing the power curves of existing turbines. Hence deviations from expected behavior can be detected. They proposed application of empirical copulas to reduce the complexity between active power and wind speed which was either impossible to approximate by any parameterized distribution.

Bill Chun et al. (2012) [54] addressed that cost of manufacturing, logistics, installation, grid control and maintenance of offshore wind turbine is high. They apply Prognostics and system Health Management (PHM) to enhance the cost effectiveness of the maintenance strategy.

Wenxian Yang et al.(2012) [55] developed a new online, load independent, condition monitoring technique based on concept of information entropy. An entropy based condition monitoring strategy has been developed and verified by applying it to vibration and electrical signals from a specially designed wind turbine condition monitoring test rig and hence they proposed that this technique is reliable for detecting mechanical and electrical faults in wind turbines.

Y. Wang et al. (2012) [56] uses a Nonlinear State Estimation Technique (NSET) to model a healthy wind turbine gearbox using stored historical data. A model is constructed which have interrelationship between model input and output parameters and covers as much turbine operational range as possible and model is applied to access the operational data. Welch's test together with suitable time series filtering is used in the algorithm so that faults can be detected before they develop into catastrophic failure.

Dr. Wei Qiao (2012) [57] reduces the complexity of sensors which are difficult to access during wind turbine operation. A nonintrusive lower cost and more reliable technology is developed. This technology uses only the phase current signals to measured from generator stator terminals for condition monitoring of wind turbines. The Proposed technology eliminate the use of sensors or data acquisition system.

Zijun Zhang (2012) [58] use three models for detecting abnormalities of wind turbine vibrations reflected in time domain. Supervisory Control and Data Acquisition (SCADA) data collected from various turbines is used to develop models. The vibrations of wind turbine is characterized on the basis of drive train and tower acceleration. An unsupervised data mining algorithm, the k mean clustering algorithm was applied to develop the first monitoring model and other two are developed by using the concept of control chart for detecting abnormal values of drive train and tower acceleration.

Shane Butler et al. (2012) [59] develop a methodology to estimate the Remaining Useful life (RUL) of the main bearing of commercial wind turbine. A residual model was developed to indicate a faulty behavior, Which produce a signal on post processing for extrapolation using particle filters. The RUL is then specified in term of probability distribution which narrows as the failure point is approached.

Deepak Kumar et al. (2012) [60] proposed the wavelet transform technique for the monitoring and fault diagnosis of wind turbine to eliminate the disadvantages of conventional spectral techniques in processing instantaneous turbine signals. The technique is applied to generators which are directly coupled to the turbine. The technique diagnosis the imbalance of rotor and heralding. Eric Bechoefer et al. (2012) [61] installed a condition monitoring system on a utility scale wind turbine and. The system produces a number of unexpected results. The installation allowed testing of a microelectromechanical system based sensor technology and vibration data & RPM data was analyzed. They observed that ability to easy measure changes in main rotor RPM as a result of tower shadow and wind shear phenomenology also facilitate the detection of icing on blade pitch error.

K. Smarsly et al. (2012) [62] Developed an autonomous software based on multi-agent technology to detect any malfunctioning in the system. The software is modularly integrated into the monitoring system to monitor the installed sensor. A e-mail notification were automatically composed and immediately send to the responsible personnel. As a result appropriate actions were undertaken in time.

Anoop Prakash verma (2012) [63] presents the wind turbine performance monitoring using historical wind turbine data. A model was constructed using SCADA operational data and fault logs. Two research directions were proposed first is identification and production of critical turbine fault and second is to monitor overall wind farm. The performance of overall wind farm can be accessed daily, weekly or monthly basis.

Lain Dinwoodie et al. (2012) [64] applies an auto regressive (AR) climate modeling approach to simulate both wind and wave time series coupled with Markov chain Monte Carlo (MCMC) based failure simulation. The AR approach produces rapidly a synthetic time series on the basis of site data available. Failures are simulated on the basis of failure rates and associated time to repair based on simulated weather climate. They investigate that how turbine size influence the breakdown of operational costs. The modeling methodology has been developed to investigate novel asset management techniques and to identify and quantify the sensitivity of overall cost to key operational parameter.

Takeshi Ishihara (2012) [65] proposed a concept of physical model based condition monitoring (PCM) including system identification and dynamic response analyses using advanced wind field model. The model is introduced to cost effective and reliable condition monitoring. Damping effects of movable parts are identified and then evaluated. Various parameters of model are determined and difference of damping in fore and aft and side by side are expressed.

Schlechtingen, Meik et al (2012) [66] in their approach employed Neuro-Fuzy interface system (ANFIS) models in training phase. Then trained models applied to product predict the target signals in application phase eg. Temperature, pressure, currents etc. The normal or abnormal behavior of component can be indicated by prediction error with respect to learned behavior. This method is applied to 18 onshore wind turbines of 2MW and results shows that proposed method is well suited to closely monitor a large variety of signals. The accuracy of developed model is high hence even a small behavior changes can be detected.

Walter Bartelmus (2012) [67] present a new way of diagnostic which is based on object and operation factor oriented analyses. The data is presented in the term of susceptibility characteristics. The system shows two types of susceptibility. With increase in load mean value of generated vibration given by acceleration signal increases, and change in object condition, create a parallel shift of susceptibility characteristics.

Robert B. Randall et al. (2012) [68] presented a work in which a number of ways for compensating for speed and load variations on basis of obtained signals from study of natural occurring faults in wind turbine transmission were discussed. The gearbox was mounted on a test rig and a "pseudo-encoder" signal is extracted from a vibration signal.

Pavle Boskoski and Dani Juricic (2012) [69] propose an approach for gear fault prognosis in non stationary and unknown operating conditions. In this approach the evolution of statistical complexity of the generated vibration envelop are monitored. The wavelet coefficients are calculated from generated vibrations and statistical complexity is then obtained from wavelet coefficients. The approach estimates the remaining useful life of component without any information about operating conditions and its physical characteristics.

Mohamed Elforjani and David Mba (2012) [70] presented a work to detect natural defect initiation and crack propagation in rolling element bearing. They construct a test rig to allow accelerated natural degradation of bearing race and concluded that AE is able to detect sub surface initiation and crack propagation.

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Ridha Ziani et al. (2012) [71] presented a work in which they compare the performance of bearing fault detection by using Artificial Neural Network (ANN) and Genetic algorithm(GA). The time domain signals from normal and defective gear boxes are extracted and used as input to ANN. The system features are selected on the basis of genetic algorithm and linear Discriminant analyses (LDA) is used as evolution function.

Hedi Hamdi et al. (2012) [72] presented a work to determine the influence of the gyroscopic couple on dynamic behavior of blades made of glass fiber reinforced (GRP).

Yassine Driss et al. (2012) [73] present a wind turbine with a helical three stage gear system having twenty eight degree of freedom. The aerodynamic forces are considered constant and excitation of the model is induced by periodic variation of mass stiffness. Then dynamic response is calculated by integration method. Finally variation of aerodynamic force is introduced in model and their effect on gear system behavior is studied.

Jin Zhang et al. (2012) [74] state that impulses in vibration signals and their spectral features are the key indicators for diagnosing gear damages. They proposed a new method time wavelet energy spectrum for extracting characteristic frequency of faulty gears. The experimental results shows that this method can highlight impulses and is very effective for extracting repeating frequency of periodic impulses and it can even extract the weaker fault feature of gear tooth wear.

Mohamed Boufenar et al. (2012) [75] presented a work in which they study, compare and modify the time frequency representation techniques such as Wigner Ville Distribution(WVD), Short Time Fourier Transformation (STFT) and wavelets to analyses non stationary phenomena.

Ilyes Khelf et al. (2012) [76] proposed a diagnostic method of rotating machinery using vibration signature and residual basis function classifier. Wavelet Decomposition method is used to process the recorded signals and indicators are extracted both in temporal and frequency domain. To improve the performance of diagnostic two techniques reduce of indicators space were combined. The method was tested on real signature at various operating condition on a test rig and results shows that choice of indicators closely affect the diagnosis performance.

Michael G. Lipsett (2012) [77] point out that an effective condition monitoring system depends on good observability of effects of a fault. Thus a simple framework has been described for incorporating damage accumulation into lumped parameter system models.

Ryszard Makowski et al. (2012) [78] proposed a adaptive algorithm for vibration signal modeling to enhance local changes of signal statics. The approach is based on the normalized exact least square time variant lattice filter (Adaptive Schur Filter). This filter have a fast parameters tracking capability, fast start up and excellent convergence behavior. Thus this method is well adapted for diagnostics of gear box working in time varying load and speed conditions.

Radoslow Zimzoz et al. (2012) [79] apply statistical feature processing instead of simply comparing value with threshold. It has been observed that data behavior and good-bad separation of data is different for different load conditions. It proves that recognition efficiency is better for decomposed data than for all data taken together.

Michael Wilkinson et al. (2013) [80] proposed that operational costs get greatly reduced by monitoring the condition of major components in the drive train. They conduct the validation study on this method using five wind farms and conclude that a good detection accuracy and high detection rate is possible.

Dr. Shaik Nafeez Umar et al. (2013) [81] apply acoustic emission technique for condition monitoring of wind turbine and they conclude that AE technique can be successfully applied for condition monitoring of low speed rotating components. They observed that technique is able to detect very small energy release rates due to incipient failure at starting stage.

Schlechtingen, Meik (2013) [82] present a system for wind turbine condition monitoring by using adaptive Neuro-Fuzy interference systems (ANFIS). To fulfill the purpose a normal behavior model for common SCADA are developed to detect abnormal signals.

Van Horenbeek, Adriaan et al. (2013) [83] state that it is difficult to implement condition monitoring system due to uncertain parameters. They take into account the performance of the condition monitoring system itself which had been neglected in most of available literature. The modeling is done on the base of P-F curve for for different failure modes and then implemented on turbine gearbox. The case study proves that condition monitoring system is beneficial as compare to other maintenance strategies and benefit depends directly on performance of CBM.

A.Augustin Rajasekar (2013) [84] presented a work to investigates online condition monitoring based on voltages and currents for diagnosis of mechanical wind turbine brake. They conclude that the application of online condition monitoring systems can optimize maintenance scheduling but by evolution of condition based maintenance procedure rather than corrective maintenance and minimizes the rest of catastrophic failures.

Tommi Karkkainen et al. (2013) [85] point out that there is no generally accepted widely deployed condition monitoring method for power converters. Thus in this study they investigate the benefit and desirability of condition monitoring for electronic converter.

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VIII. Summary of Literature Survey

Table 8.1: Summary of developments in condition monitoring techniques based on literature survey

Refno.	Author, Year	Investigated Problem Type
1	Palle Christensen et al.(2001)	Automatic supervision and control of wind turbines
2	T. Holroyd (2001)	Defect of varying size on outer races of bearings.
3	N.Jamludin et al. (2001)	Stress wave analyses to detect early stages damages
4	Shjn Dander (2002)	Time domain model based fault detection
5	T.W. Verbruggen (2003)	Develop inventory of available condition monitoring techniques
6	L. Mihet-Popa et al. (2003)	Steady state technique for detection of interturn stator faults
7	L.W.M.M. Rademakers et al. (2004)	Condition monitoring of fibers blades
8	Giurgiutiu,V (2005)	Fault detection method based on ultrasonic rely
9	Douglas H. (2005)	Fault detection in Doubly Fed induction generator
10	Christopher A. Walfard (2006)	Reliability of wind power generation
11	C. Walfard (2006)	Cost estimation of failure of wind turbine
12	R.W. Hyers et al. (2006)	Comparison of CM techniques of turbine and helicopter gearbox
13	Jesse A. Andrawus et al. (2007)	Detection of wind turbine faults using RCM
14	David Mc Millan et al. (2007)	Measurement of benefits of CM quantitatively
15	Ayetullah Gunel et al. (2007)	Fluid condition monitoring technique
16	Michael Wilkinson et al. (2007)	Selection of sensors and algorithm
17	Edwin Wiggelinkhuizen et al. (2007)	Algorithm based on SCADA
18	German wind energy association (2007)	Requirement of a CM plan
19	Michael R. Wilkinson (2007)	Signal Processing technique
20	R.Andrew Swaetz et al. (2008)	Dynamic behavior and loading of wind turbine
21	Scott. J. Johnson et al. (2008)	Active flow control
22	Mike Woebbeking (2008)	Percentages of various type of damages responsible for failure
23	Asif Saeed (2008)	Fault detection by signal processing techniques
24	William A. Vachon (2008)	Project Economics
25	E Lie-Ahmar et al. (2009)	Transient Techniques
26	Cattin Rene et al. (2009)	CM techniques for wind turbines in icy regions
27	Yassine Amirat et al. (2009)	Faults and their signatures
28	T. Barszczet et al. (2009)	Fault detection by Neural Network approach
29	R.F. Mesquita et al. (2010)	Fault detection by Neural Network approach
30	Emilio Miguelanez et al. (2010)	Role of See Byte's Recovery system in wind industry
31	Bincheng Jiang (2010)	Dynamics behavior of gear boxes in transient conditions for fault detection
32	Wenxian Yang et al. (2010)	Continuous Wavelet Transform
33	Yassine Amirat et al. (2010)	Fault detection based on amplitude demodulation of three phase generator
34	Milos Milovancevic (2010)	Dynamic load behavior and streamlining
35	Joon Young et al. (2010)	Designing of a new simulator
36	Eunshin Byon et al. (2010)	Effect of weather conditions on feasibility of maintenance
37	Richard Dupuis (2010)	Characteristics of debris produced after failure mode
38	Zhigang Tian et al. (2010)	CBM decisions made by calculating failure probabilities
39	F.D. coninck et al. (2010)	Reproduction of dynamic load for wind turbine gearbox
40	Bodil Anjar (et al.2011)	Feasibility of thermal condition monitoring
41	Shuangwen Sheng (2011)	Condition monitoring of wind turbine gearbox

42	Pratesh Jayashwal et al.(2011)	Fault detection in bearings
43	Peng Guo (2011)	Fault detection in gearboxes using AAKR
44	Secil Vorbal Nese et al. (2011)	Faults due to blade deformation
45	Suratsavadee Koonlaboon Korkua et al. (2011)	Monitoring of induction machines
46	Dariusz Broda et al. (2011)	Varying operational conditions in wind turbines
47	Joon-Young Park et al. (2011)	Development of CM system with control functions
48	Douglas Adams (2011)	Structural health monitoring of horizontal axis wind turbine
49	Ivo Houtzager (2011)	Data driven control for wind turbines
50	Radoslaw Zimroz et al. (2011)	Fault detection in gearboxes using signal processing
51	Peng Gua (2012)	Failure detection of turbine generator bearing
52	Wenxian Yang et al. (2012)	Challenges with existing wind turbine condition monitoring techniques
53	Simon Gill et al. (2012)	Fault detection on the basis of power curves
54	Bill Chun et al. (2012)	Failures and fault prognostics methods
55	Wenxian Yang et al. (2012)	Condition monitoring on basis of information entropy
56	Y. Wang et al. (2012)	Gearbox fault detection by NSET technique
57	Dr. Wei. Qiao (2012)	Current based online condition monitoring
58	Zijun Zhang (2012)	Monitoring of wind turbine vibrations using SCADA data
59	Shane Butler et al. (20120	Bearing life failure and life estimation
60	Deepak kumar et al. (2012)	Condition monitoring of utility scale wind turbine
61	Eric Bechoefer et al. (2012)	Testing of microelectromechanical system based on sensor and RPM data
62	K Smarsly et al. (2012)	Monitoring of wind turbine with autonomous software
63	Anoop Prakash Verma(2012)	Wind turbine performance monitoring using SCADA system
64	Lain Dinwoodie et al. (2012)	Sensitivity of wind turbine to operational parameters
65	Takeshi Ishihara (2012)	Fault detection by dynamic response of wind turbine
66	Schlechtengen, Meik et al. (2012)	Fault detection by Neuro-Fuzy interference system (ANFIS)
67	Walter Bartelmus (2012)	Diagnostic based on object and operation factor
68	Robert B. Randall et al. (2012)	Fault detection in wind turbine Gearbox
69	Pavle Boskoski et al. (2012)	Gear fault detection in non stationary and unknown operating conditions
70	Mohamed Elforjani et al. (2012)	Natural fault detection in rolling element bearing
71	Ridha Ziani et al. (2012)	Fault detection in bearing using Artificial Neuro Network
72	Hedi Hamdi et al (2012)	Effect of gyroscopic couple on dynamic behavior of blades
73	Yassine Driss et al. (2012)	Dynamic behavior of aerodynamic turbines
74	Jin Zhang et al. (2012)	Gearbox fault analyses
75	Mohamed Boifenar et al. (2012)	Study, compare and modification of time frequency techniques
76	Ilyes Khelf et al (2012)	Diagnostic of rotating machinery using vibration signature
77	Michael G. Lipsett (2012)	Observability requirement for condition monitoring
78	Ryszard Makowski et al. (2012)	Local damage detection in gearboxes
79	Radoslow Zimzoz et al. (2012)	Turbine generator bearing diagnostics
80	Michael Wilkinson et al. (2013)	Comparison of methods for wind turbine CM with SCADA
81	Dr. Shaik Nafeez Umar et al. (2013)	Acoustic emission condition monitoring
82	Schlechtingen, Meik (2013)	Fault detection by Artificial Neuro-Fuzy Interference System
83	Van Horenbeek et al. (2013)	Fault detection in wind turbine gearbox
84	A.Augustin Rajasekar (2013)	Retrofit the mechanical braking system using CM system
85	Tommy Karkkainen et al (2013)	Necessity of CM in electronic converter

IX. Conclusions

This paper provides an overview of RP Technology in brief and emphasizes on their ability to shorten the product design and development process and detail of few important processes is given. The RP technologies provide the freeform fabrication of the complex geometry directly from their CAD models automatically.

The future looks very promising for rapid prototyping. The benefits for most applications far outweigh the disadvantages especially when they are used in the correct situation. The price and size are rapidly falling to the point where they will soon be commonplace in any manufacturing company.

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A Comparative Analysis of the Combustion Behavior of Adulterated Kerosene Fuel Samples in a Pressurized Cooking Stove

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Abstract - An experimental study was conducted to establish the influence of cylinder pressure on the combustion behavior of a pressurized kerosene cook stove. The test was carried out under ambient room conditions, by pressurizing and igniting the cook stove containing kerosene fuel at a maximum pressure of 1 bar. The combustion flame temperature, flame height and structure and colour were carefully measured and recorded from a pressure gauge mounted on the fuel tank, athermocouple, vernier height meter and by direct flame photography. The same process was repeated for vessel pressures of 0.8, 0.6, 0.4, 0.2, and 0 bar after an interval period of two minutes, and for B5, B10, B15, and B20 kerosene oil blends and B100 (i.e. 100%) diesel oil fuel samples respectively. The experiment was replicated for each vessel pressure levels, adulterated fuel samples and their mean result values were analyzed. The results show that combustion temperature and flame height of tested fuel samples are strongly influenced by the vessel pressure, and at maximum pressure, the flame temperatures for B2, B10, B15, B20 fuel blends and diesel fuel are lower than the kerosene by 8.82%, 11.76%, 15.58%, 20.59% and 8.82%. While, the flame height for B5, B15, B20 fuel blends and diesel fuel are higher than the benchmark by 0.22%, 1.11%, 18.89% and 37.77%.

Keywords : pressurised kerosene stove, combustion temperature, flame height, statistical validation, kerosene-diesel adulteration, economic benefit.

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Strictly as per the compliance and regulations of :

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Ejilah, I. R. [α], Olorunnishola, A.A.G. [σ] & Enyejo, L.A [ρ]

Abstract - An experimental study was conducted to establish the influence of cylinder pressure on the combustion behavior of a pressurized kerosene cook stove. The test was carried out under ambient room conditions, by pressurizing and igniting the cook stove containing kerosene fuel at a maximum pressure of 1 bar. The combustion flame temperature, flame height and structure and colour were carefully measured and recorded from a pressure gauge mounted on the fuel tank, a thermocouple, vernier height meter and by direct flame photography. The same process was repeated for vessel pressures of 0.8, 0.6, 0.4, 0.2, and 0 bar after an interval period of two minutes, and for B5, B10, B15, and B20 kerosene oil blends and B100 (i.e. 100%) diesel oil fuel samples respectively The experiment was replicated for each vessel pressure levels, adulterated fuel samples and their mean result values were analyzed. The results show that combustion temperature and flame height of tested fuel samples are strongly influenced by the vessel pressure, and at maximum pressure, the flame temperatures for B2, B10, B15, B20 fuel blends and diesel fuel are lower than the kerosene by 8.82%, 11.76%, 15.58%, 20.59% and 8.82%. While, the flame height for B5, B15, B20 fuel blends and diesel fuel are higher than the benchmark by 0.22%, 1.11%, 18.89% and 37.77%. The enhanced combustion quality of the predominating kerosene fuel samples is largely influenced by the calorific values, ignition ability, stoichiometric mixtures, rate of combustion reactions, concentrations of the reactants, fuel mass flow rate, and the specific heat capacity of the fuel samples. The result of the statistical analysis show a strong regression and 76.9% of the variation in vessel pressure could be accounted for by the control variables. Going by the present petroleum products pricing program in Nigeria, the illicit practice of kerosene –diesel fuel adulteration is not capable of generating any economic benefit, and hence would assist to stem the tide of the unlawful trade.

Keywords : pressurised kerosene stove, combustion temperature, flame height, statistical validation, kerosene-diesel adulteration, economic benefit.

I. Introduction

Crude oil is a natural occurring mixture consisting predominantly of hydrocarbons with other elements, such as; sulphur, nitrogen, and oxygen e.t.c, either existing as organic compounds or in some cases as complex of metals [1,2]. In technical terms of one barrel of Nigerian crude oil has a volume yield of 6.6% automotive gas oil, 20.7% gasoline, 9.5% kerosene and jetfuel, 30.6% diesel, and 32.6% fuel oil and residues [3]. The kerosene fraction belongs to the group of hydrocarbon called paraffin, which has lower specific gravity than aromatic hydrocarbon of the same boiling point. The main components of kerosene are paraffin, cycloalkanes (naphtha) and aromatic compounds, where paraffin is the highest composition. Ultimate analysis composition of kerosene is 84.3 % wt Carbon, 14.2 % wt Hydrogen, and remainder is sulfur and nitrogen [4]. The high demand and desirability of kerosene is informed by its lower volatility in comparison to gasoline, good oxidative stability and cleaner burning characteristics [5].

According to Moh [6], kerosene stove consists of wick or the pressurized stove types. The thermal efficiency of kerosene stove is between 20 – 40 % depending on stove and cooking equipment design. Flue Gas emission of pressurized kerosene stove has been reported as follows; 2749 ppm CO2, 73 ppm CO, and 3.8 ppm CH4 , and could be higher if the fuel is adulterated. Existing literature has revealed that if the combustion process is incomplete, CO gas will be produced and a number of fuels will be not combusted, and will result in lower flame temperature, low heating rate and decrease in the thermal efficiency of the stove [7]. The amount of CO gas and other unburnt fuel products usually depends on the configuration of the heating equipment and other factors, such as the flash point of the fuel, air-fuel mixing, ignition, temperature controlling combustion chamber and catalyst respectively. Despite the fact that researchers have for many years tried to improve combustion systems design to enhance complete combustion and lower air pollution, low combustion heat efficiency, unburned fuel and air pollution (such as; CO, NOx, SOx and soot) are still a prevalent problems in combustion systems [8]. The simultaneous evolution of heat and light occasioned by the combustion kerosene is used for household cooking and lighting .The incessant power outages and inadequate distribution and supply of electricity to especially rural Nigeria constitutes a major challenge presently, has increased the patronage of kerosene stoves.

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In Nigeria, official statistics has revealed that an average of about 9 million liters of kerosene is consumed daily, and the bulk of the consumers come from the rural poor, low-income and middle-class economic class [9]. However, the growing demand for this most sought-after cooking and heating fuel has made the illicit practice of kerosene adulteration and its untold consequences commonplace in the country [10, 11, 12, 13, and 14]. Even though some studies has been carried out on the evaporation of kerosene droplets at elevated temperature and pressure, existing data and information on evaporation and combustion of kerosene remain insufficient [15]. To this end, this paper intends to investigate the combustion behavior of adulterated kerosene, with a particular focus on the effect of vessel pressure variations on flame temperature, flame height and flame structure and colour. In addition, the need to establish the economic feasibility of kerosene - diesel fuel adulteration activities through a preliminary cost analysis will also form an essential component of this research.

II. Materials and Methods

a) *Fuel Properties*

The kerosene and diesel fuel samples were collected from an NNPC approved gas station in Bauchi – Nigeria. The comparative specifications and properties of the petroleum fuels used in this study are as presented in table 1. In accordance with standardized ASTM D97-93 test procedures, the densities of the blended fuel samples were also determined [16].

Table 1 : Properties of fuel used

Property	Unit	Diesel	Kerosene
Chemical formula	-	$C_{12}H_{26}$	$C_{10}H_{22}$
Calorific value	kJ/kg	44500	45400
Self- ignition temperature	°C	725	640
Final boiling point	°C	369	249
Ignition delay period	s	0.002	0,0015
Flame propagation rate	cm/s	10.5	11.8
Flame temperature	°C	1715	1782
Kinematic viscosity @ 39°C	mm^2/s	2.7	2.2
Specific gravity @ 15.6/15.6 °C	-	0.893	0.843
Colour	-	Red	Soybolt (20min)
Sulphur content	wt %	0.16	0.04

Source: [17]

b) *Description of pressure stove*

The kerosene pressure stove understudy is fed fuel from a tank under pressure created by gravity and a hand pump. To light the stove, the burner assembly is pre-heated with a small amount of alcohol burned in a circular "spirit cup" or priming pan just below the burner. Once heated, the tank is pressurized by means of a hand pump integrated into the tank, which forces the kerosene from the tank up through the rising tube in the ascending pipe to the pre-heated burner head for heating and vaporization. The kerosene is then forced under pressure through a descending tube to the vapour nozzle. The vapourized kerosene gas is sprayed through a jet in the middle of the burner, where it mixes with air and burns in a sootless, blue cooking flame. The flame continues to heat fuel in the fuel line, either via a loop of the fuel line passing through the flame (or a heat sink) on the stove that maintains the proper temperature, and a steady supply of vaporized fuel is drawn from the tank to the jet [18]. Additional pumping increases the vessel pressure and makes the flame larger. The turning action of a small "air screw" (usually located in the filler cap) releases the vessel pressure and reduces the flame size [19]. The stove (refer to plate 1), which uses pressure and heat to vaporize the fuel before ignition, provides a hotter and more efficient burning without sooty emissions [20].

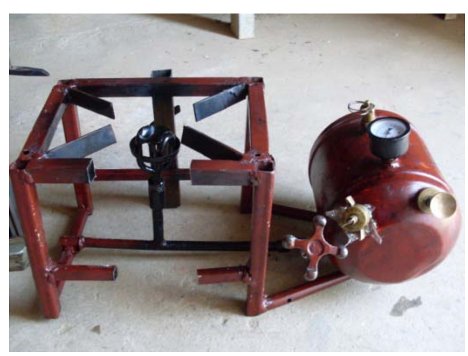

Plate 1 : Pressurized kerosene stove

c) *Experimental Methods*

The oil knob of the pressure stove was unscrewed to allow 1 liters of unadulterated kerosene oil into the tank. The oil knob and air release screw was tightened; the cylinder was pressurized with manual pumping action about three to five times. As soon as the kerosene oil comes out from the burner tip, the air release screw at the top of knob was loosed [21]. The burner is then lit with a match stick and was allowed to warm up for 30 seconds, the air release screw was tightened and the cylinder was further pressurized to a maximum cylinder pressure of 1.0 bar with a manually operated hand pump. The kerosene rises inside the burner and vaporizes. The kerosene vapor is ignited and the combustion process is initiated, the heat from the flame keeps the burner hot enough to continue the vaporization process and the fuel in the tank warms up to keep the stove pressurized and burns [22]. The vessel pressure, flame temperature, height and structure were carefully measured and recorded with a pressure gauge mounted on the fuel tank, a thermocouple, vernier height meter and by visual observation for a period of two minutes. The readings are taken for the different vessel pressure levels of 0.8, 0.6, 0.4, 0.2, and 0 bar, and repeated for B5 fuel oil blend (i.e. 5% diesel and 95% kerosene oil), B10, B15, and B20 kerosene oil blends and 100 B (i.e. 100%) diesel oil respectively. The experiment was replicated and the mean values of results at different vessel pressure levels for fuel samples were computed and presented as figures 1 and 2.

Furthermore, giving a burner orifice diameter and area of 0.0003m and 7.07 x 10^{-8} m^2, and vessel outlet pipe diameter and area of 0.012m and 1.13 x 10^{-4} m^2, the Bernoulli's equation was used to calculate the escape velocity of the fuel at the orifice, and was subsequently used to determine the volumetric and mass flow rate of the fuel samples [23], and their results plotted against the vessel pressure levels. In addition to study the effect of vessel pressure on flame structure, direct flame photography was employed.

d) Statistical validation

The experimental results were also subjected to statistical (i.e. ANOVA and T-test) analysis using the SPSS statistical package; to establish if the multiple linear regression models of the 36 fuel samples comprising of kerosene, B5, B10, B15, B20, and 100B diesel oil combusted at varying vessel pressure levels ranging from 1-0 bar, to ascertain their significance and validity, and also demonstrate if the flame temperature and flame height were truly interacting factors. The vessel pressure was considered as the dependent variable while the flame heights and temperatures of the fuel samples are considered as the independent (i.e. control) variables.

III. RESULTS AND DISCUSSION

From the result presented in figures 1 and 2, the effect of vessel pressure on flame temperature and flame height, fuel combustion, flame structure and color, are discussed accordingly.

a) Effect of vessel pressure on flame temperature

It could be seen from figure 1 below that as the vessel pressure of the test stove increases the flame temperature the flame temperature also increases. However, if the flame temperature of kerosene pressurized at 1 bar (i.e. maximum experimental pressure) is considered as the benchmark, it was observed that the flame temperatures for B2, B10, B15, B20 fuel blends and diesel fuel are lower than the kerosene by 8.82%, 11.76%, 15.58%, 20.59% and 8.82%. Hence, samples of kerosene fuel, B5, B10 and B15 fuel blends exhibited the highest flame temperatures in the group respectively. According to Martin et. al.[24] the higher temperatures recorded is attributed to the increased the rate of combustion reactions, and concentrations of reactants caused by the higher vessel pressure. However, the higher temperature of kerosene in this case could be ascribed to its relatively higher calorific value over diesel fuel (refer to table 1) and its fuel blends. This is because high pressure is equivalent to high escape velocity and longer spray length, providing opportunity for the fuel to fully atomize and granting excess air access to the combustion process.

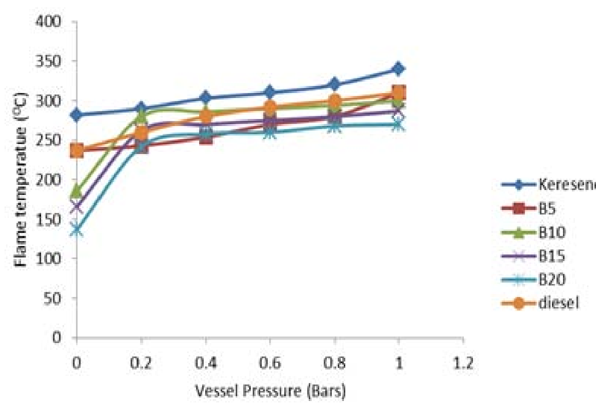

Figure 1 : Plot of flame temperature versus vessel pressure

b) Effect of vessel pressure on flame height

It is obvious that from figure 2 that the performance of the pressurized kerosene stove under test shows that there is a correlation between vessel pressures versus flame height. it could also be seen from figure 2 that the flame height at maximum vessel pressure for B5, B15, B20 fuel blends and diesel fuel are higher than the benchmark by 0.22%, 1.11%, 18.89% and 37.77%. This is with exception of B10 fuel blend that is lower than the benchmark by 8.88%. This exceptional behavior of B10 fuel sample with respect to its flame height could be ascribed to the partial blockage of the spray nozzle by sooty deposits. However, the foregoing has clearly shown that vessel pressure influences the flame height, while the higher flame height of diesel fuel could be attributed to incomplete combustion and over-ventilation -i.e. the volumetric flow rate of air is in excess of the stoichiometric amount required for the volumetric flow rate of fuel to burn completely [25].

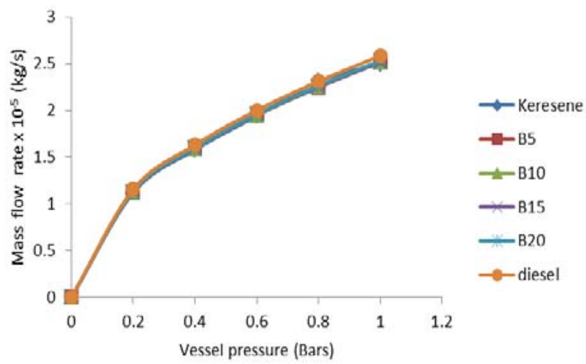

Figure 2 : Plot of flame height versus vessel pressure

By same token, it could be seen from figure 3 that the fuel mass flow rate increases with vessel pressure, and at maximum vessel pressure (i.e. 1 bar) the mass flow rate of fuel samples B5, B15, B20 fuel blends and diesel fuel rose higher than the benchmark by 0.64%, 0.72%, 0.76%,1.20% and 3.28%. The higher densities and relative densities

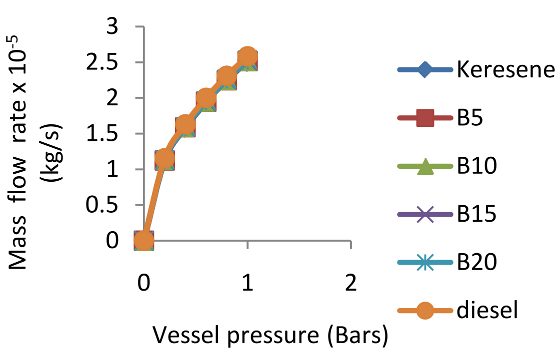

Figure 3 : Relationship of fuel mass flow rate and vessel pressure

(refer to table 2 below) of diesel over kerosene could be responsible for the relatively higher mass flow rate of kerosene –diesel blends and diesel fuel. This is understandable in view of the fact that the implicit variable within the governing functions include mass flow rate, atmospheric pressure, orifice size, flow velocity, flame velocity and the calorific value of the fuel. Furthermore, a further study would be required to optimize the performance of the pressurized kerosene cooker. The guess is that substituting vessel pressure at optimal performance will be close to the pressure at which fluid velocity will equal flame velocity.

Table 2 : Densities of fuel samples

Samples	Kerosene	B5	B10	B15	B20	Diesel
Density (kg/m^3)	843	845	848	850	855	893

c) Effect of vessel pressure on fuel combustion

The combustion quality of the fuels and blends are largely influenced by the calorific values of the fuels, their ignition ability, and stoichiometric mixture, concentrations of the reactant and the specific heat capacity of the fuel. The calorific (heating) value of kerosene is about 1.98% higher than diesel fuel (refer to table 1). The implication of this result is that kerosene and the B5, B10, B15, B20 fuel blends, possess the tendency to combust more efficiently with higher emanation of heat than diesel for reasons that adiabatic combustion (flame) temperature increases for higher heating values, inlet air and fuel temperatures and for stoichiometric air ratios approaching one.

In addition, the self-ignition ability of hydrocarbon fuels – represented by the cetane number, also impacts on the combustion process, as it affects the ignition delay time. It has been reported that the higher the cetane number, the shorter the ignitions delay of hydrocarbon fuels and vice versa [26]. To this end, it is important to mention that the Nigerian diesel fuel has a cetane number in the low 40s, while the Nigerian kerosene has an average cetane number of 49[17]. This implies that the careful blending of kerosene and diesel fuel could result in a blended fuel with cetane numbers in the high end of the range [27]. Hence, this also explains the relatively lower ignition delay period (i.e. 0.0015s) of kerosene in comparison to diesel fuel sample (0.002s).

The combustion efficiency of liquid hydrocarbon fuels could also be better enhanced if the air-fuel ratio is chemically corrected (i.e. stoichiometric). It could be seen from the illustration in figure 3 that the stoichiometric mixture of kerosene (15.6) is higher than that of diesel fuel (14.6). Hence, it implied that more mass of air is required to burn 1kg of kerosene, and partly explains why kerosene and its blended fuel samples under test, burns more richly at higher vessel pressure than diesel fuel. The combustion process is most efficient when the mixture of air and fuel is slightly rich [28]. It is important to add that combustion can be made more efficient, and the amount of energy released maximized if the correct mixture of air is provided to support the combustion process. Excess air however, reduces the ultimate temperature of the product and the amount of energy released. Therefore, an optimum air to fuel ratio can almost and always be determined depending on the rate, extent of combustion and final temperature.

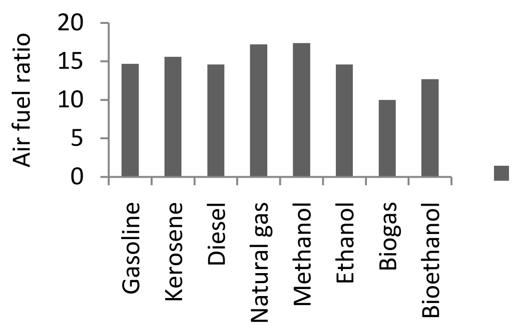

Figure 3 : The stoichiometric ratio of different fuels. Marthur and Sharma [29]

Hence, the air pressurization of the fuel in the cylinder increases the density of air in the cylinder and allows for the fuel/air mixture to escape through a nozzle to ensures better atomization and also enhance fuel droplet vaporization, gasification and combustion. It is important to note that diffusion rates vary with pressure, and the rates of overall combustion reaction vary approximately with the pressure squared. In same vein, it worthy of note that the rate at which the droplets evaporates and burns is generally considered to be determined by the rate of heat transfer from the flame front to the fuel surface [25]. Nonetheless, considering the double film model for the combustion of liquid fuel (i.e. one film separating the droplet surface from the flame front and the other separating the flame from the surrounding oxidizer atmosphere) with the droplet surface assumed to be slightly below the normal boiling temperature of the fuel, it could be seen from the sf region in figure 4, that the fuel evaporates at the droplet surface and diffuses toward the flame front where it is consumed, and the heat is conducted from the flame front to the liquid fuel and vaporizes [30,25]. The fuel and oxidizer meets at stoichiometric proportions, and react at the flame front. Air from the surrounding atmosphere diffuses into the flame front. While, heat and other combustion products are transported to the surrounding atmosphere (along the s∞ region) in compliance with Fick's law of diffussion. According to Martins, et. al. [24], higher pressure could also increase the rate of combustion reactions by increasing the concentrations of the reactants to generate higher combustion temperatures with shorter and more compact flames. Another reason that could be attributed for the higher combustion temperature of kerosene and its blended samples is it specific heat capacity.

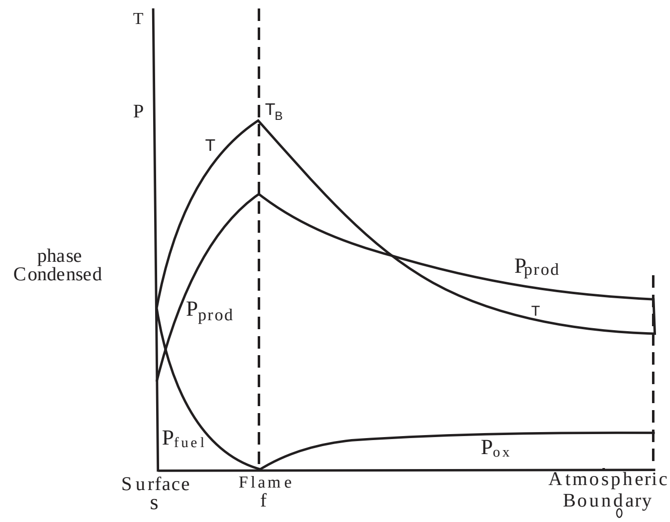

Figure 4 : Parameter variation along a radius of a droplet diffusion flame [25]

It could be seen from table 3 of the specific heat capacities of some fuel that kerosene with 2010 J/kgK demonstrated a higher value than diesel fuel (1750 J/kgK) and implied that more energy is required to warm kerosene by 1 degree K.

Table 3 : Specific heat capacities of some fuels

Fuels	Specific heat capacity (J/kg K)
Gasoline	2220
Kerosene	2010
Diesel	1750

Source: [31]

d) Effect of vessel pressure on flame structure and color

From the images of the flames obtained in plate 2, it could be seen that the flames are bluish at 1bar for kerosene, B5, and B10 blends; at 0.8bars for kerosene, and B5 blends; and at 0.6 bars for kerosene only. Furthermore, light bluish flames were also observed for; B15 blends at 1bar; B10 and B15 at 0.8 bars; kerosene, B5, B10, B15 at 0.6 bars; kerosene, B5, B10, B15, B20,at 0.4 bars; and kerosene, B10, B15, B20 at 0.2 bars . The somewhat fan-shaped bluish flames are suggestive of combustion under-ventilation produced when air supply is reduced below the recommended stoichiometric mixture [24].

In addition, the seemingly elongated orange colored flames manifesting in the combustion of remaining fuel samples in the group, is indicative of over-ventilation, partial (incomplete) combustion, and is also associated with the emission of soot. It was reported that the orange color of diffusion flame in the luminous zone is due to the radiation of carbon particle, formation of soot on the fuel side of the flame, and burnt in the reaction zone to produce the flame temperature

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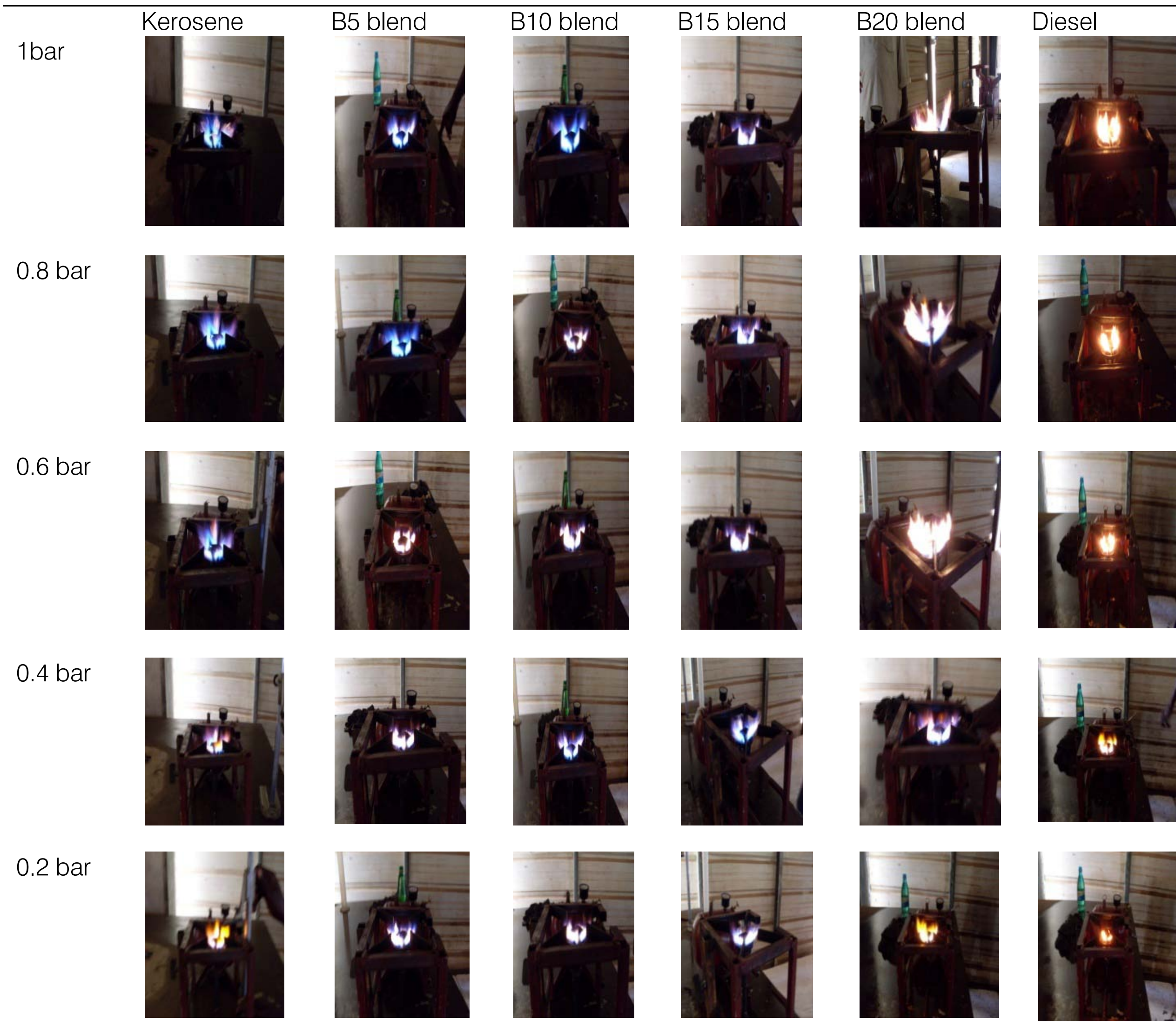
[25]. The flames arising from these fuel samples reflects the predominance of diesel fuel, and the evidence of inefficient combustion in these cases could be attributed to the relatively higher specific gravity (0.893), kinematic viscosity (2.7mm^2/s) and lower calorific value (44500 kJ/kg) of diesel fuel over kerosene (refer to table 1). These prevailing properties could also inhibit effective atomization and consequently leads to undesirable combustion performance. According to Linck ,et al. [32], vessel pressure affects flame structure of combusting liquid fuels, and the flame structure depends to a large extent on the features of the combustion air flow and fuel spray through the nozzle, and the effects of flame structure on the combustion behavior, including the composition of the exhaust gases, have also been reported. In the current investigation, the nozzle formed solid-cone spray, with the fuel droplets occurring throughout the cone.

e) Result of statistical validation

Validated summary of experimental data shown in table 2, gave a computed value for the R^2 as 0.769, thus indicating that the regression was "strong" as about 76.9% of the variation in the vessel pressure could be accounted for by the control variables. The ANOVA analysis in the regression result, shown in table 2, gave a computed value for the F-statistic as 54.794 while the corresponding table value of 3.27 at 0.05 level of significance (q) and (2,35) degrees of freedom showed that the multiple linear regression model was significant and valid. Also large regression sum of squares (3.228) in comparison to the residual sum of squares (0.972) indicated that the model accounts for



0 bar

Plate 2 : Flame photographs of fuel samples

most of variation in the dependent variable. The coefficients b_0, b_1, b_2 shown in table 2 are -1.163, 0.002839, and 0.120, respectively; and the results of the T- test indicated that regression coefficients b_1 and b_2 were statistically significant and not equal to zero (as given by hypothesis ii) at 0.025 level of significance and 35 degrees of freedom (table T-value=$T_{0.025}$, 35 = 2.030). Therefore, the regression equation of vessel pressure (P_v) is expressed in equation 1. It should be noted that the assumptions made were valid for this model with respect to multi co-linearity and residuals' distribution referred to in table 2. The condition indexes values of 9.86 and 17.662 are for flame temperature (FT) and flame height (FH) respectively. From table 1, the residuals average was zero with standard deviation of approximately 1.0 (i.e. 0.971) implying that residuals were actually independent (refer to figure 5). The variance inflation factor (VIF) of 1.447 indicated that

Table 3 : Summary of statistical results

ANOVA				COLLINEARITY DIAGNOSTICS					RESIDUALS		
Parameter	Value	Parameter	Sum of squares	Parameter	Condition index	Coefficients	VIF	T-Statistic	Parameter	Mean (μ)	Standard Deviation (σ)
R^2	0.769	Regression	3.228	Constant (b_0)	1.00	-1.163	-	-5.972	Standard Predicted value	0	1
F-Statistic	54.794	Residual	0.972	FT (b_1)	9.860	0.002839	1.447	3.319	Standard Residual	0	0.971
Significance of F-statistic	0.000	-	-	FH (b_2)	17.662	0.120	1.447	6.410	-	-	-

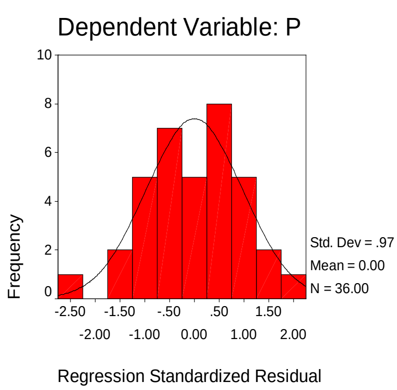


Figure 5 : Plot of regressive experimental result

multi co-linearity was not a problem in this application as VIF < 4 [33], which clearly demonstrate that flame temperature and flame heights were not significantly interacting factors.

f) Comparative cost analysis

Comparative cost analysis has been made for B5 (95% kerosene and 5% diesel fuel), B10, B15, and B20 blended fuel samples and diesel fuel. The cost analysis has been made for the consumption of 1litres of fuel by a household at the current official retail pump prices, namely, ₦155 for diesel fuel and ₦50 kerosene in Nigeria [34, 35]. With the new price regimen, it could be seen from figure 3 below that the present cost of one liter of B5, B10, B15, B20 blended fuel samples are 10.5%, 21.0%, 31.5%, and 42.0% higher than the cost of one liter of kerosene. Hence, the present pricing policy of petroleum products in Nigeria has clearly revealed that kerosene-diesel fuel adulteration is not economical, and will no doubt discourage the illicit practice, unlike in the previous pricing regimen that puts the cost per liter of kerosene higher than that of other petroleum products such as gasoline and diesel, which makes it a prime candidate for adulteration with diesel as it also occurs presently in India [36].

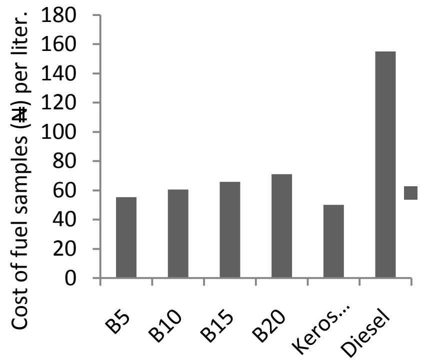


Figure 4 : Cost of fuel samples per liter in Nigeria

IV. Conclusion

From the foregoing, the following could be concluded:

i. Tested samples of kerosene fuel, B5, B10 and B15 fuel blends exhibited thehighest flame temperatures due to higher rate of combustion reactions, and concentrations of reactants occasioned by the higher vessel pressure, and their relatively higher calorific value.
ii. At the maximum vessel pressure, the flame heights for B5, B15, B20 fuel blendsand diesel fuel are higher than the flame height generated from kerosene fuel. The influence of vessel pressure on the flame height was confirmed.
iii. The combustion quality of kerosene and its blends are to a large extent, affectedby the calorific values of the fuels, ignition ability, and stoichiometric mixture, reactant concentrations and their specific heat capacities.
iv. The vessel pressure also affects flame structure of combusting liquid fuels, and the flame structure depends to a large extent on the features of the combustion air flow and fuel spray through the nozzle. A bluish flame was observed at 1bar for kerosene, B5, and B10 blends; at 0.8bars for kerosene, and B5 blends; and at 0.6 bars for kerosene fuel. Finally, the adulteration of kerosene with diesel fuel would not yield any economic benefit in terms of profit.

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Optimization of Productivity by Work Force Management through Ergonomics and Standardization of Process Activities using M.O.S.T Analysis-A Case Study

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Abstract - This paper highlights a methodology developed for standardization in the process activities by using Maynard's Operation Sequence Technique and minimization of fatigue among the workers in manufacturing line by using Ergonomics. Productivity is the primary goal which is to be achieved for any profitable Manufacturing System. Optimization of productivity could be achieved by integration of two techniques; which are M.O.S.T and Ergonomics. Thus, this research will use Ergonomics as the work study and Maynard Operation Sequence Technique (MOST) as the time study method. All this initiated by performing study on the manual operators' activities. This case study was conducted at TATA MOTORS Lko Ltd and at a small sized manufacturing enterprise VINAYAK Industries, Lucknow. From tes study, standard time and optimum utilization of man power could be achieved. The necessary changes were suggested in the workplace and are successfully implemented. This methodology can be used for standardization of time in any manufacturing organization.

Keywords : ergonomics most, standard time, sheets, tmu.

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OPTIMIZATION OF PRODUCTIVITY BY WORK FORCE MANAGEMENT THROUGH ERGONOMICS AND STANDARDIZATION OF PROCESS ACTIVITIES USING M.O.S.T ANALYSIS-A CASE STUDY

Strictly as per the compliance and regulations of :

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I. Introduction

The rate at which a company produces goods or services in relation to the amount of materials and number of employees needed. This is usually expressed in ratios of inputs to outputs. That is (input) cost per (output) good/service. For calculation purpose, expression of productivity is:

Productivity = Output/ Input

ERGONOMICS (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomics is employed to fulfill the goals of health and productivity. Proper ergonomic design is necessary to prevent repetitive strain injuries (RSI), which can develop over time and can lead to long-term disability

MAYNARD OPERATION SEQUENCE TECHNIQUE (M.O.S.T) is a predetermined motion time system that is used primarily in industrial settings to set the standard time in which a worker should perform a task.

The main objective is to achieve OPTIMIZATION of the system with integration of M.O.S.T. and Ergonomics.

II. Literature Review

a) Chronological History of M.O.S.T.

1960-Maynard in the late 1960's, detected striking similarities in the sequence of MTM defined motions whenever an object was handled. The development and release of the MOST happened in the 1960s.

1967–Basic MOST for general industrial applications was developed **Early 1970s**-A variation of MOST known as Admin MOST. Originally developed and released under the name Clerical MOST in the 1970s, it was recently updated to include modern Administrative tasks and renamed. It is on the same level of focus as Basic MOST. It was designed for the clerical activities in office and service environments.

1972-Basic MOST was released in Sweden. It is the most commonly used form of MOST.

1974-Basic MOST was released in United States.

1980-two other variations Mini MOST and Maxi MOST were released.

1991-Lehto, M.R., Sharit, J., Salvendy, G. (16) presented an article on "The application of cognitive simulation techniques to work measurement and methods analysis of production control tasks" in 1991

1996-Koelling, C.P, Ramsey, T.D. presented an article on "Multimedia in Work Measurement and Methods engineering" in 1996.

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2003-A revised Maxi MOST that includes the modification of the Part Handling Sequence Model and a clearer understanding of all of the sequence models and as well Standard method description formats for each sequence model in each MOST System.

Till now no such work is witnessed under this concept.

b) Chronological History of Ergonomics

i. *Foundation*

The foundations of the science of ergonomics appear to have been laid within the context of the culture of Ancient Greece. A good deal of evidence indicates that Greek civilization in the 5th century BC used ergonomic principles in the design of their tools, jobs, and workplaces. One outstanding example of this can be found in the description Hippocrates gave of how a surgeon's workplace should be designed and how the tools he uses should be arranged. The archaeological record also shows that the early Egyptian dynasties made tools and household equipment that illustrated ergonomic principles.

ii. *19th Century*

In the 19th century, Frederick Winslow Taylor pioneered the "scientific management" method, which proposed a way to find the optimum method of carrying out a given task. Taylor found that he could, for example, triple the amount of coal that workers were shoveling by incrementally reducing the size and weight of coal shovels until the fastest shoveling rate was reached. Taylor examined, through time and motion studies, how people carried out their activities, what movement they made and how much time it took. Next he determined how all operations could be executed as effectively as possible to produce as much as possible in the minimum amount of time. That is what is called the 'Taylor system', resulting of course in rushed systems, assembly line production etc.

iii. *Early 1900s*

Frank and Lillian Gilbreth expanded Taylor's methods in the early 1900s to develop the "time and motion study". They aimed to improve efficiency by eliminating unnecessary steps and actions. By applying this approach, the Gilbreths reduced the number of motions in bricklaying from 18 to 4.5, allowing bricklayers to increase their productivity from 120 to 350 bricks per hour.

1935 - Essential progress, during the world war when many pilots were required and airplanes became increasingly complicated, it was discovered that the cockpits were not adequate i.e. logically organized, causing accidents to happen. This was an essential push in the progress of ergonomics. **Edwin Link** developed the first flight simulator. The trend continued and more sophisticated simulators and test equipment were developed. Another significant development was in the civilian sector, where the effects of illumination on worker productivity were examined. This led to the identification of the **Hawthorne Effect,** which suggested that motivational factors could significantly influence human performance.[8]

1949- Origin - The name ergonomics officially proposed at a 1949 meeting of the British Admiralty (July 12), by Prof. Hugh Murrell. The name 'Ergonomics' officially accepted in 1950. The name Ergonomics was derived from the Greek words: Ergon - work; Nomos - natural law. First use of the word actually can be traced to a series of four articles written by Prof. Wojciech Jastrzebowski in Poland in 1857.

1952-The Ergonomic Society was formed in 1952 with people from psychology, biology, physiology, and design in Britain.

1957-The Human Factors Society was formed in 1957. In the US "human factors engineering" was emphasized by the US military with concentration on human engineering and engineering psychology. US efforts also focused on the "role" of an individual within a complex system. **Paul M. Fitts** developed a model of human movement, Fitts's law, based on rapid, aimed movement, which went on to become one of the most highly successful and well studied mathematical models of human motion.

1960- First applied industrial ergonomics group was established by Harry along with Dr. Charles Miller in United States.

1965-The period saw a maturation of the discipline. The field has expanded with the development of the computer and computer applications.

1976-Christensen gave review of ergonomics, expresses the view that the fact that early man specially selected pebbles, made scoops from bone and fashioned tools and utensils in general, is an indication that those early hominids showed 'specific, intelligent reactions to the interactions between man and his environment', something that he considers is the very essence of ergonomics.

1980s- Decade of HCI and software ergonomics.

1982-Office of President of the Society constituted. The Israel Ergonomics Society (IES) founded.

1983- Editorial in Ergonomics concerns the issue of attempts to define ergonomics "The strength of ergonomics is that it does not consider the findings from one discipline to be an irrelevance to the conclusions drawn from another; it is the interaction between the disciplines that makes ergonomics." Brazilian Ergonomics Society (ABERGO) founded on November 30.

1984- An informal group of the Irish Ergonomics Society was formed in October 1984 and in March 1985 was accepted as a Regional Group of the UK Ergonomics Society Second Brazilian Ergonomics Congress.

1985 -The Finnish Ergonomics Society (FES) founded Ergonomics Society of Southern Africa was formally inaugurated at the Council for Scientific and Industrial Research Conference Centre in Pretoria.

1986- Separate Ergonomics Societies for New Zealand and Australia (New Zealand Ergonomics Society and the Ergonomics Society of Australia, ESA) formed.

1987 -DEF STAN 00-25 Human factors for designers of equipment.

1988-The Hellenic Ergonomics Society (HES) founded The Asociación Española de Ergonomía (AEE)/Spanish Ergonomics Association was created MOD adopts MANPRINT philosophy .

1989- Brian Shackel gives a lecture at the Annual Conference entitled "Ergonomics from Past to Future". 89/392/EEC Directive on the safety of machinery.

c) The 1990s

1990-90/269/EEC Directive on the minimum safety and health requirements for the manual handling of loads 90/270/EEC Directive on the minimum safety and health requirements for work with display screenequipment (ISO 9241 supports this).

1993- The Human Factors Society changed its name to The Human Factors and Ergonomics Society. The Ergonomics Society of Taiwan (EST) founded.

1994 -1300 members The Irish Ergonomics Society was formally launched.

1997- 1247 members The Icelandic Ergonomics Society was established under the formal name of Vinnuvistfrae DifélagÍslands or VINNÍS.

1999- The Ergonomics Society celebrates its 50th anniversary with an exhibition at the Science Museum entitled the Human Factor.

d) The new century

2001- Start of investigations into a Royal Charter for the Society.

2002-Macro Ergonomics was defined by Hendricks and Kleiner .The Ergonomics Process model presented takes a "top down" approach to the design of work systems that carry through to the human-machinesoftware interface within the organization. It also takes a "bottom up" approach by engaging employees in the process from the beginning.

2004-Lean manufacturing principles were introduced by Liker which strive to eliminate waste, errors and unnecessary actions and include only those value-added components to enhance the process flow.

2007- The Ergonomics process model was implemented.

JULY 2009- The Japan Ergonomics Society as a general corporate juridical body was founded.

JUNE 2010-The 1st annual general meeting of members was held (during the 51st conference of the JES at Hokkaido University).

Till 2013-55 institutes are been established for research and study in various displines of ergonomics.

III. Proposed Methodolgy

a) The Concept of Ergonomics

Ergonomics is the study of designing equipment and devices that fit the human body, its movements and its cognitive abilities. Ergonomics is concerned with the 'fit' between the user, equipment and their environments. It takes account of the user's capabilities and limitations in seeking to ensure that tasks, functions, information and the environment suit each user.

b) Steps Involved In Ergonomics

- GEMBA Analysis Check Sheet
- Posture Analysis Check Sheet
- Scoring sheet on the basis of posture analysis check sheet
- Summary sheet on the basis of scoring sheet.

Here the ergonomic study of any system is done with the help of 4 sheets which decides the fitness of any Unit on the basis of-

1. Safety of the worker with respect to the working environment, machinery and equipments.
2. Evaluation of manual work done by the worker on the basis of movement in BACK, NECK, SHOULDER/ARM and WRIST/HAND both by observer's assessment and worker's assessment.

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1. Gemba Analysis Check Sheet

INITIAL EVALUATION SHEET

GEMBA ANALYSIS SHEET

Area: Line:

Operation: Workforce type:

GEMBA ANALYSIS	YES	NO	PPE	REMARKS
Fall by persons				
Falling parts				
Collision against fixed r moving obstacle				
Cuts, Wounds				
Crushing, Shearing				
Dragging by mechanicl elements				
Projection of particles				
Use of chemical producs				
Considerable presenceof smoke, aerosols, dust				
Burns				
Contact with live elemets				
Procrement/Unloading:				
Parts & packaging by frk - lift truck				
Operation carriecout by the section				
Changing of tools				
Maintenance				
Noise				
other				

Page 1

2. Posture Analysis Check Sheet

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

A1 Almost neutral?
A2 Moderately flexed or twisted or side bent?
A3 Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?

B1 No
B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

B3 Infrequent (around 3 times per minute or less)?
B4 Frequent (around 8 times per minute)?
B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

C1 At or below waist height?
C2 At about chest height?
C3 At or above shoulder height?

D Is the shoulder/arm movement

D1 Infrequent (some intermittent movement)?
D2 Frequent (regular movement with some pauses)?
D3 Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)

E1 An almost straight wrist?
E2 A deviated or bent wrist?

F Are similar motion patterns repeated

F1 10 times per minute or less?
F2 11 to 20 times per minute?
F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

G1 No
G2 Yes, occasionally
G3 Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

H1 Light (5 kg or less)
H2 Moderate (6 to 10 kg)
H3 Heavy (11 to 20kg)
H4 Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

J1 Less than 2 hours
J2 2 to 4 hours
J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

K1 Low (e.g. less than 1 kg)
K2 Medium (e.g. 1 to 4 kg)
K3 High (e.g. more than 4 kg)

L Is the visual demand of this task

L1 Low (almost no need to view fine details)?
*L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for

M1 Less than one hour per day or Never?
M2 Between 1 and 4 hours per day?
M3 More than 4 hours per day?

N At work do you use vibrating tools for

N1 Less than one hour per day or Never?
N2 Between 1 and 4 hours per day?
N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?

P1 Never
P2 Sometimes
*P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job

Q1 Not at all stressful?
Q2 Mildly stressful?
*Q3 Moderately stressful?
*Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

* *Additional details for L, P and Q if appropriate*

*** L**

*** P**

*** Q**

3. Marking Sheet

Exposure Scores Worker's name ____________________ Date ________

Back

Back Posture (A) & Weight (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1 ☐

Back Posture (A) & Duration (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3 ☐

Now do **ONLY** 4 if static **OR** 5 and 6 if manual handling

Static Posture (B) & Duration (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

Score 4 ☐

Frequency (B) & Weight (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 5 ☐

Frequency (B) & Duration (J)

	B3	B4	B5
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 6 ☐

Total score for Back
Sum of scores 1 to 4 **OR**
Scores 1 to 3 plus 5 and 6 ________

Shoulder/Arm

Height (C) & Weight (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1 ☐

Height (C) & Duration (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3 ☐

Frequency (D) & Weight (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 4 ☐

Frequency (D) & Duration (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 5 ☐

Total score for Shoulder/Arm
Sum of Scores 1 to 5 ________

Wrist/Hand

Repeated Motion (F) & Force (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 1 ☐

Repeated Motion (F) & Duration (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2 ☐

Duration (J) & Force (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 3 ☐

Wrist Posture (E) & Force (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

Score 4 ☐

Wrist Posture (E) & Duration (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

Score 5 ☐

Total score for Wrist/Hand
Sum of Scores 1 to 5 ________

Neck

Neck Posture (G) & Duration (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 1 ☐

Visual Demand (L) & Duration (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

Score 2 ☐

Total score for Neck
Sum of Scores 1 to 2 ________

Driving

M1	M2	M3
1	4	9

Total for Driving ________

Vibration

N1	N2	N3
1	4	9

Total for Vibration ________

Work pace

P1	P2	P3
1	4	9

Total for Work pace ________

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress ________

4. Scoring Sheet

Microsoft Excel - 1.summary sheet [Compatibility Mode]

ERGONOMICS SUMMARY SHEET

Area:

Line:

Operation:

Workforce : Permanent / flex / temp

PHYSICAL RATING

Exposure scores for body area

Exposure level				
Score	Low	Moderate	High	Very high
Back(static)	8-15	16-22	23-29	29-40
Back(moving)	10-20	21-30	31-40	41-56
Shoulder/arm	10-20	21-30	31-40	41-56
Wrist/hand	10-20	21-30	31-40	41-46
Neck	4-6	8-10	12-14	16-18

Exposure scores for other factors

Exposure level				
Score	Low	Moderate	High	Very High
Driving	1	4	9	.
Vibration	1	4	9	.
Work pace	1	4	9	.
Stress	1	4	9	16

Stage status (✔ in the blank space)

< 40%	GREEN	
41-50%	YELLOW	
>51%	RED	

Page 1

OBSERVATION (IF ANY):

▼ *PHYSICAL*

-
-
-
-
-

▼ *COGNITIVE*

-
-
-
-

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i. *For Static Handling*

Total sum of maximum Index Values (Back+Shoulder/Arm+Wrist/Hand+Neck) =162(value comes from above charts)

% Value = 100/162
= 0.61728

ii. *For Manual Handling*

Total sum of maximum Index Values (Back+Shoulder/Arm+Wrist/Hand+Neck)= 176(value comes from above charts)

% Value = 100/176

= 0.56818

The total index value is calculated for the BACK, SHOULDER/ARM, WRIST/HAND and NECK and the sum of all the values is multiplied by 0.61728 for static or 0.56818.

Example-Summation of index values of BACK + SHOULDER/ARM + WRIST/HAND +NECK=143 (for static handling).

% value = 143* 0.61728

= 88.27% (RED)

The percentage achieved is checked on the basis of Y.G.R Analysis i.e. <40% GREEN, 41-50% YELLOW and >51% RED.

c) The Concept of M.O.S.T.

It was considered that all manual operations were combinations of basic elements. So these were isolated and identified so that methods could be accurately explained and improved. It was reasoned that to reduce the motion of a task was to reduce the effort and time to perform the task. The result is higher production and increased service level.

M.O.S.T. is used primarily in industrial settings to set the standard time in which a worker should perform a task. To calculate this, a task is broken down into individual motion elements, and each is assigned a numerical time value in units known as time

Time Units

1 TMU = 0.00001 hour

1 TMU = 1 Hour /1 lakh times

= 3600 / 100,000 = .036 seconds

1 TMU = 0.036 second or 1 second = 27.8 TMU

The time value in TMU for each sequence model in Basic MOST is calculated by adding the index values and multiplying the sum by 10. A fully indexed General Move Sequence Model might appear whose TMU is calculated as follows:

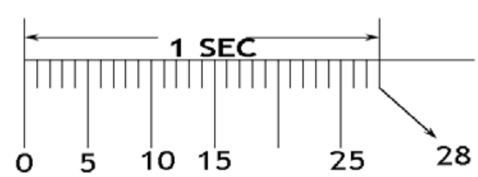
A6 B6 G1 A1 B0 P3 A0

measurement units, or TMUs, where 100,000 TMUs is equivalent to 1 hour. All the motion element times are then added together and any allowances are added, and the result is the standard time. It is much easier to use form of the older and now less common Methods Time Measurement technique, better known as MTM.

Example- walk three steps and pick up a light package from the floor arise and place the package with some adjustments on a scale to be weighed.

- The ***General Move Sequence Model*** is used for the spatial movement of an object freely through the air.
- The ***Controlled Move Sequence Model*** is used for the movement of an object when it remains in contact with a surface or is attached to another object during the movement (e.g., the movement of the object is controlled).
- The ***Tool Use Sequence Model*** is used for the use of common hand tools.

ACTIVITY	SEQUENCE MODEL	PARAMETERS
General Move	A B G A B P A	A-Action Distance B- Body Motion G-Gain Control P- Placement
Controlled Move	A B G M X I A	M-Move Controlled X-Process Time I- Alignment
Tool Use	A B G A B P * A B P A (*represents type of Tool Use)	F-Fasten L- Loosen C- Cut S- Surface Treat M- Measure R- Record T- Think



Where:

A6 = Walk three to four steps to object location

B6 = Bend and arise to gain control of the object

G1 = Gain control of one light object

A1 = Move object a distance within reach

B0 = No body motion

P3 = Place object with adjustments

A0 = No return

General Move Sequence Model : **A6 B6 G1 A1 B0 P3 A0**

Add index values : **6 + 6 + 1+ 1+ 0+ 3+ 0 = 17**

Multiply by = 7 x 10 = **170 TMU**

Or, approximately 6.1 seconds

All time values established using MOST reflect the effort of an average skilled, trained operator working at an *average performance level* or *normal pace* (3 Miles per Hour). This is often referred to as the 100% performance level that in MOST of skill and effort. Therefore when using MOST, it is not necessary to adjust times unless they must conform to particular high task plans used by some companies. This also means that a properly established time standard, using MOST, MTM or stopwatch study, will give nearly identical results in TMU.

IV. Experiment and Result

CASE STUDY 1: Manufacturing of CROWN WHEEL both Machining process and heat-Treatment processes at "TATA MOTORS", Lucknow.

PROCESS : Manufacturing of crown wheel includes-

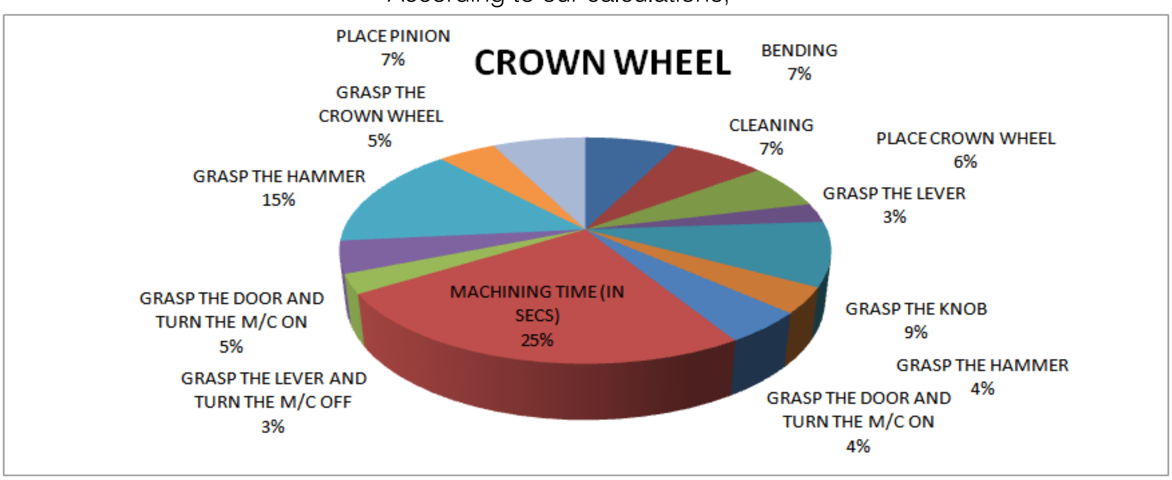
1. Loading of Crown Wheel.
2. Machining process in the Phoenix machine.
3. Unloading of Crown Wheel.
4. Loading of Crown Wheel for Heat Treatment.
5. Heat treatment
6. Unloading of Crown Wheel from the furnace.

Result

S.NO	PROCESS	T.M.U	SECONDS	MINUTES
1.	CROWN WHEEL (PRE HT)	8323.32	299.4	4.99
2.	CROWN WHEEL (HT)	17200	619.2	10.32
	TOTAL	25523.32	918.6	15.31

Total time required for complete manufacturing of 1 piece of crown wheel is 15.31 mins

According to our calculations,

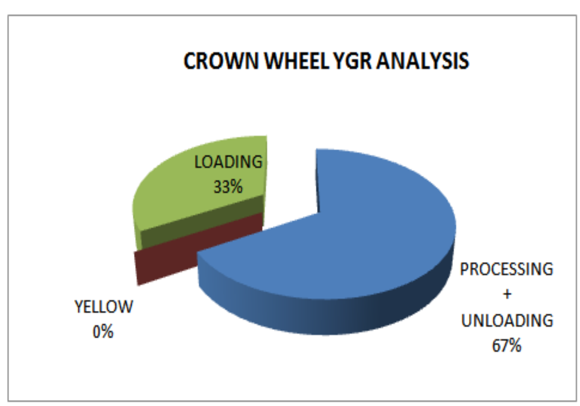


Y.G.R. Analysis

RED-Loading in Heat Treatment (71.27%) and Unloading in pre Heat Treatment (83.09%) of Crown Wheel.

GREEN-Loading (25%) in pre Heat Treatment and Unloading (28%) of Crown Wheel in Heat Treatment process.

YELLOW- Nil



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a) Problems and Implementation

Problem 1 : Excessive Bending while punching no. on crown Wheel.

Implementation : Substation or platform of waist height of an average worker was constructed so that loading of crown wheel can be directly done at the platform (without bending) from the palette.

After loading at the platform punching of numbers must take place and then crown wheels must be forwarded towards the furnace .

Figure : Excessive Bending on crown Wheel

Problem 2 : Excessive push and pull while transportation between stations.

Implementation : Auto - Fork lift must be used for transportation.Stacking of pinions in trolley must be avoided.

.

Figure : Excessive push and pull while transportation between stations

Problem 3 : Excessive stress on back while loading and loading process.

Implementation : Trolleys of waist height of an average men must be used so that their can be no discrepancies. Bins of Standard Height / Make should be use.

Figure : Manufacturing of SHOCK ABSORBER HEAD for cars at Vinayak Lko

CASE STUDY 2 : Manufacturing of SHOCK ABSORBER HEAD for cars at Vinayak Ind Lucknow.

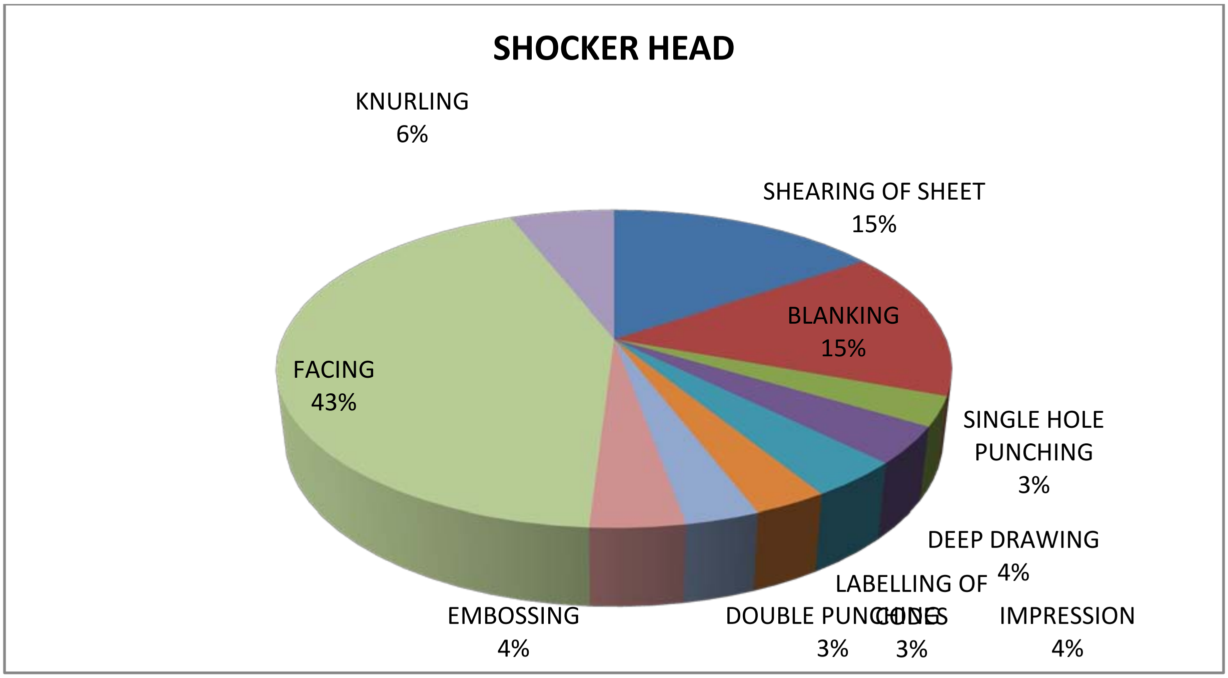
PROCESS : Manufacturing of Shock Absorber Head includes-

1. Shearing of sheets.
2 Blanking.
3. Single punching in the centre of the blanks.
4. Deep drawing.
5. Impression.
6. Labeling codes.
7. Double Hole Punching.
8. Embossing
9. Facing.
10. Knurling of bolts.

Result

S.NO	PROCESS	T.M.U	SECONDS	MINS
1.	SHEARING OF SHEETS	1341.8	48.3	0.80
2.	BLANKING	1303.6	46.93	0.78
3.	SINGLE HOLE PUNCHING	257.8	9.2808	0.15
4.	DEEP DRAWING	257.8	9.2808	0.15
5.	IMPRESSION	325.6	11.72	1.20
6.	LABELLING	325.6	11.72	1.20
7.	DOUBLE HOLE PUNCHING	257.8	9.2808	0.15
8.	EMBOSSING	327.8	11.801	0.20
9.	FACING	3714	133.7	2.23
10.	KNURLING OF BOLTS	515.6	18.562	0.31
	TOTAL	8627.4	310.5754	7.17

Total time required for complete manufacturing of 1 piece of shocker head is 7.17 mins According to our calculations

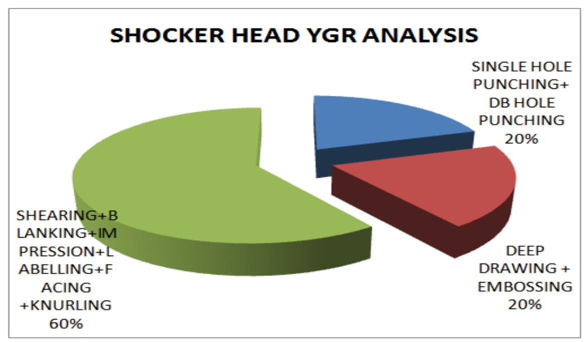


Y.G.R ANALYSIS

RED-Shearing of Sheets (65.48%).Blanking (67%), Impression (50.76%),Labeling of Codes (53%), Facing (57.86%) and Knurling of Bolts (67%).

GREEN-Double Punching (32%) and Single Hole Punching (25.88%).

YELLOW-Deep Drawing (50%) and Embossing (47%)



b) Problems and Implementation

PROBLEM 1 : Absence of Spot Welding Unit due to which fitment is sent out of plant for the purpose which effects the production time per piece. Spot Welding of 1 lot of 1000 parts takes 7 days for completion.

IMPLEMENTATION : Spot Welding Unit must be established with in the plant so that no extra time is wasted in unnecessary part handling.

PROBLEM 2 : Poor material handling and storage facilities which increases the NON- VALUE ADDED Cost with increase in wastage of parts.

Vinayak Ind Lko (Shows Poor material handling and storage facilities)

IMPLEMENTATION : Proper storage of finished parts should be done and material handling should be done carefully to avoid any extra wastage of time or material.

PROBLEM 3: Parts are sent out of plant for zinc plating which take minimum 3 days per 1000 parts.

IMPLEMENTATION: Zinc plating of the parts must be done in the plant to avoid excess wastage of time.

PROBLEM 4: Excessive Bending of back D
uring loading and unloading of parts in Shearing of sheets,Blanking,Impression,Facing, Labeling of Codes and Knurling of Bolts.

IMPLEMENTATION : Trolleys and Bins of average Human Waist height are used so that bending while Loading and Unloading of parts is avoided.

CHALLENGES FACED DURING THE ANALYSIS: Challenges faced during the completion of whole project are-

- Mixed dropping of different models.
- Workers were unaware of ergonomics and M.O.S.T and hence could not understand questions properly.
- Visibility problems of fitment especially in taking videos for the MOST.
- Safety risk involved on the line due to the use of heavy load machines.
- To cope up with the rate of production.
- Work on some stations was not according to the station description card of that station.

V. Conclusion

The purpose of this RESEARCH was to give an idea of the basic functioning of a real industry. This ANALYSIS has not only given an exposure to the various techniques employed in production units but also has added a new dimension to vision of knowledge. It has given the basic idea of the working of an industry and the core of every industry lie its fundamentals MAN MACHINE AND MATERIAL and how the cohesion between them is needed for the smooth running of any industrial organization.

The productivity of any system depends on the INPUT and OUTPUT associated with the work function. **Hence for the overall OPTIMIZATION of any system requires-**

1. INCREASE THE OUTPUT **STANDARIZATION** of the process is needed which is achieved by evaluating STANDARD TIME REQUIRED PER PROCESS.
2. M.O.S.T helps in evaluating the standard time per cycle and it also ignores the unnecessary activities.
3. Hence M.O.S.T helps in complete **STANDARI-ZATION** of the process
4. INCREASE THE INPUT **WORK FORCE MANAGEMENT** is required which is successfully achieved by ERGONOMICS. The plant layout and designing of the machinery is done keeping in mind the fitness of the worker so that it may not lead to any temperamental or chronic hazard as well as VA/NVA of the product is calculated so that least value of NVA is invested per product.
5. Hence Ergonomics helps in complete **WORK FORCE MAANGEMENT** of the system.
6. **So together the integration of M.O.S.T and ERGONOMICS leads to OPTIMIZATION of PRODUCTIVITY.**

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Abstract, used in Original Papers and Reviews:

Optimizing Abstract for Search Engines

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

Key Words

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

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

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

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

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

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

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

Acknowledgements: Please make these as concise as possible.

References

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

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

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

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

Tables, Figures and Figure Legends

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

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

Preparation of Electronic Figures for Publication

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

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

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

6. AFTER ACCEPTANCE

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

6.1 Proof Corrections

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

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

(Free of charge) from the following website:

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

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

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

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

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6.4 Author Material Archive Policy

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

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Informal Guidelines of Research Paper Writing

Key points to remember:

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

Final Points:

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

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

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

General style:

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

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

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

In every sections of your document

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

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

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

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

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

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

Title Page:

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

Abstract:

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

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

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

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

Approach:

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

Introduction:

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

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

Approach:

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

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

Procedures (Methods and Materials):

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

Materials:

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

Methods:

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

Approach:

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

What to keep away from

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

Results:

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

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

Content

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

What to stay away from

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

Approach

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

Figures and tables

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

Discussion:

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

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

Approach:

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

Administration Rules Listed Before Submitting Your Research Paper to Global Journals Inc. (US)

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- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.

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

- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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

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