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Weight Reduction of Crank Shaft by using Composite Material Kevlar 49

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Abstract: For an IC Engine, Crankshaft is one of the most important component. It basically converts the reciprocating motion of the piston into rotating motion with the aid of connecting rod which connect piston to crankshaft. Crankshaft is mounted on number of main bearings and a flywheel at one end, which is further connected to clutch and transmission. Current automotive IC engine crankshafts are made of carbon steel alloys, contains of iron and small percentage of carbon (0.25%-0.45%) along with combination of several alloying elements. In this project, a composite material called Kevlar epoxy is suggested for crankshaft. Crankshaft is designed using standard design procedure and modeling is done using SOLIDWORKS. Analysis is performed on the crankshaft made of carbon steel and composite material using analysis software called ANSYS WORKBENCH. Comparison of deformation, stresses and strains is done between crankshaft made of carbon steel and composite material, Kevlar epoxy. Considering the optimum results, crankshaft is fabricated.The aspect of this project is to optimize the weight of the crankshaft. The objective of improving engine performance, reducing initial loads and fuel economy can be achieved by reducing the weight of the crankshaft by using composite material, Kevlar epoxy. It is logical that during its large volume production, reduction of weight of crankshaft will result in large savings.

Keywords : Composite material (Kevlar epoxy), Design (Solidworks), Analysis workbench.

I. INTRODUCTION

A crankshaft is the mechanical part of an engine which converts reciprocating motion of piston into rotational motion. Crank shaft is commonly used in internal combustion engine. It consists of cranks and crank pins which are connected to the connecting rod which converts linear motion of piston to rotary motion of crank. It contains additional bearing surface to which the big ends of connecting rod of each cylinder are attached.To reduce pulses in the Internal Combustion Engine, it is connected to a flywheel and a vibration damper is connected to reduce the torsional vibration, which is caused along the length of the crankshaft.

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Crankshaft Mechanism

The crankshaft is a rotating part of an internal combustion engine. It's main function is to transform the reciprocating motion of the piston into rotating motion. The crankshaft is mounted within the engine block.

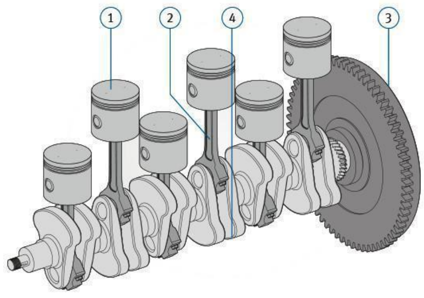


Fig. 1: View of Crank Shaft

The crankshaft is mounted on the engine block through main journals. On the journals of the crankshaft, the connecting rods are mounted. On opposite sides of the journals, the crankshaft has counterweights which compensates outer moments, minimizes internal moments and thus bearing stresses and vibration amplitudes are reduced. The number of main journals and the journals on which connecting rods are mounted depends on the type of engine and the number of cylinders. On both main journal and connecting rod journals, the crankshaft has lubrication orifices (oil bore) through which oil flows when the engine is running.The engine torque is not continuous because it is produced only when each piston is on expansion stroke of the cycle. Due to this, a flywheel is mounted onto the crankshaft in order to reduce vibrations and avoid the discontinuity in the engine torque.

On V-type engine, two connecting rods are mounted. on the same journals. Because of this arrangement, a V-engine, for the same number of cylinders is more compact when compared with a straight engine. The length of a V6 engine is less than the length of a straight 6 cylinders engine.

Between the crankshaft and the engine block, crankshaft bearings are fitted on the main journals. The role of these bearings is to reduce friction through a layer of antifriction material.

1.1 Major Forces Applied On Crank Shaft

1.1.1 Torsional load

Combustion exerts large force on Crankshaft. This force is initially exerted on the top surface of piston which is transmitted to crank shaft with the help of connecting rod which inter connects the piston and the crank shaft.

1.1.2 Bending load

For better efficiency of the internal combustion engine, crankshaft must be strong enough to bear the forces caused due to power stroke without undergoing bending.

Tensile strength	N/mm^2	50-60
Compressive strength	N/mm^2	110-120
Flexural strength	N/mm^2	130-150
Impact strength	KJ/m^2	17-20
Modulus of elasticity	N/mm^2	4400 -4600
Coefficient of linear	-	-
Thermal expansion	$10^{-6}/{}^0C$	64-68
Martens value	^0C	75-80
Thermal conductivity	$kcal/mh^0C$	0.211
Water absorption(20^0C/10days)	%w/w	0.5-0.6
(100^0C/1hr)	%w/w	0.8-1.0
Relative dielectric 25^0C	-	4.1
Dielectric loss factor (tand)	$50Hz/25^0C$	0.003
Volume resistivity(25^0C)	10^{15} cm	12
Tracking resistance		KA3c
Arc resistance		L1
Minimum dielectric strength	($50Hz/25^0C$)	200

The crank pin bears distributed load throughout its length which changes with respect to crank positions. Each web is subjected to bending and twisting as that of a cantilever beam.

1. Bending causes tensile and compressive stresses.
2. Twisting moment causes shear stress.

One of the most common failure in crankshaft is due to the bending load caused by combustion. A large bending moment on the crankshaft is caused due to the moment of combustion load. Stress concentration exists at the root of the fillet due to cyclic loads which leads to fracture in crank.

II. MATERIALS:

2.1 Carbon Steel:

Carbon steel contains with carbon up to 2.1% by weight. The desired alloying effect is obtained with the specified minimum amount for copper as 0.40% or the maximum content specified for other elements are manganese 1.65% and silicon 0.60%.

2.2 Kevlar 49:

Epoxide equivalent	gm/eq	182-192
Viscosity at 25^0C	mPa.s	9000-12000
Epoxy value	eq/kg	5.2-5.5

Kevlar is light and very strong fiber. The tensile strength of the steel wire is eight times weaker than that of Kevlar fibre. It also handles heat very well and can withstand temperatures well above 455°C armour. Because of its high tensile strength-to-weight ratio, Kevlar is being used for many applications, ranging from bicycle tyres to body and to make modern drumheads that withstand high impact. Several grades of Kevlar are available such as K29, K119, K129, K49, K100, Kevlar AP, Kevlar X,. K29 is being used in industrial applications, such as cables, asbestos replacement, brake linings, and body/vehicle armor. Lapox – L12 is one of the type of kevlar -49

2.2.1 Materials

In the present study, epoxy resin, AIRSTONE 780E is used as a matrix material. The hardener is AIRSTONE 782H. The reinforcing material used is Kevlar 49 (woven type) which is bi-directional fibre. All the testing procedures are as per ASTM standards.

2.2.2 LAPOX L12

Lapox L12 is used as fibre reinforced composite. Hardener K6 is a curing liquid hardener with low viscosity at room temperature. It is usually utilized for hand layup applications. It gives rapid cure at normal ambient temperatures rather being more reactive.

Table.2: Specification of resins and hardeners

Visual appearance	Pale Yellow liquid
Refractive index at 25^0C	1.4940-1.5000
Water content	1% max
Shear strength on A1 Alloy Joint	1.4 $Kgmm^2$
Processing parameters:	
Lapox L-12	100 pbw
Hardener K-6	10-12 pbw
Viscosity at 20^0C	5,000-8,000 m Pa.s
Pot life at 20^0C	½ -1 hrs
Curing:	
25^0C	14-24 hrs
80^0C	1-2 hrs
100^0C	15-30 mins
14^0C	5-10 mins
180^0C	------

Table. 3:Properties of Cured Resin with Reinforcement

Flexural strength	kg/mm^2	40-50
Impact strength	KJ/mm^2	100 -150
Modulus of elasticity	kg/mm^2	2500-3500
Water absorption (4 days/20^0C)	% w/w	0.02-0.20
Martens value	^0C	100-130

III. DESIGN OF CRANKSHAFT

3.1 Modelling:

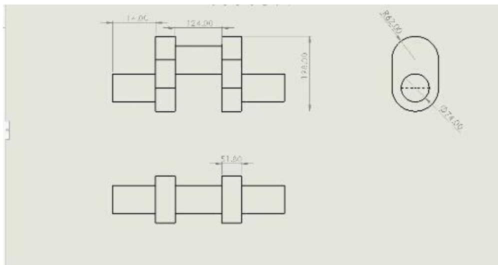
Computer-Aided Design (CAD) Software, Solid Works is used to create the design of proposed connecting rod.

Table.4: Properties of Materials

Type	Density in kg/m^3	Modulus of Elasticity in Gpa	Possion's ratio
Kevlar 49	1440	124	0.3

Objective: To design a crankshaft to transmit 10kW of Power at 75rpm.

Sol: Given data:
P=10KW=10×10³W
N=75rpm



T_1/T_2=1.25
W_b = 450N
W_a = 1350N
D_b = 375mm (or) R_b = 187.5mm
D_a = 625mm (or) R_a = 312.5mm
T=P×60/2Πn
=636.619×10³N-mm.
T_1 & T_2 are Tensions in the tight side & slack side of the belt on pulley A.
Torque on pulley=636.619×10³N-mm
$(T_1-T_2)R_a$=636.619×10³
T_2=2037N
T_1=10185.0N
Therefore,
Total vertical load acting downwards on the shaft at
A=$T_1+T_2+W_a$=19683.0N
$F_t=T/R_b$=636.619×10³/187.5=3395N
W_b=450N (acts vertically downwards)
Total vertical loads acting upwards on the shaft at B.
F_t-W_b=3395-450=2945.0N
Taking moments about D
R_c=25634.5N
For equilibrium of the shaft,
R_d+19683=R_c+2945=28579.5N
R=28579.5-19683=8896.5N
The bending moment at A & B is 0.
Bending moment at C=19683×125=2460375.0N-mm
Bending moment at D=2495×175=436625.0N-mm
The bending moments maximum at C.
Therefore
Maximum Bending Moment, M=M_c=2460×10³N-mm
The equivalent twisting moment,
$T_e = \sqrt{(k_m \times M)^2 + (k_t \times T)^2}$
But T_e=2505907=π/16× ζ ×d³
d=74.01mm.

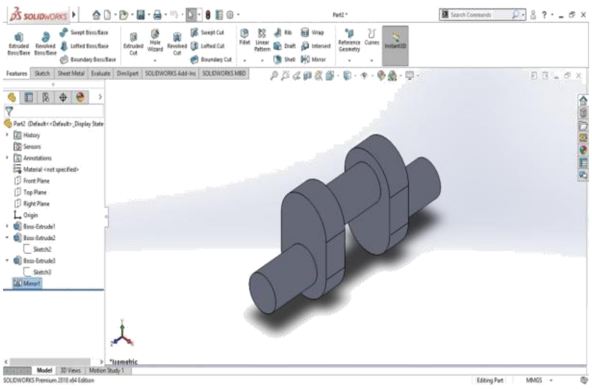


Fig 3.1 3D view of crank shaft

IV. ANALYSIS

4.1 Ansys Work Bench:

Ansys Work Bench is a CAD software which is used by engineers to perform Structural and Thermal Analysis on 3D Models. It helps to work with different analysis tools. In the present paper, 3D model of designed crankshaft is imported in Ansys Work Bench from Solidworks. The material is selected as carbon steel in the engineering data cell.

Table. 5: The engineering data of the carbon steel

Type	Density in kg/m3	Modulus of Elasticity in Gpa	Possion's ratio
Carbon fibre	3539	228	0.3

1. Access the Meshing application functionality. Right-click the Model cell and choose Edit. This step will launch the ANSYS Mechanical application.
2. By accessing the meshing application functionality, the mesh controls are applied on the object by selecting in the tree.

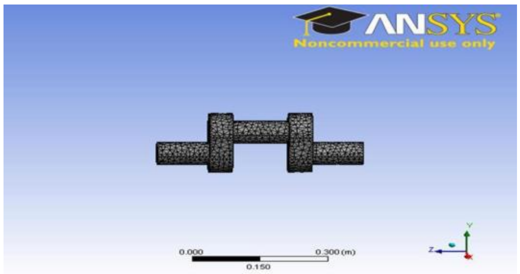


Fig. 2: Meshing of crank shaft made of carbon steel

3. The boundary conditions are defined and the loads are applied. Two sides of the crank shaft is fixed and load applied at the center of the crankshaft is 3395N.

5. Results

5.1. Results obtained for Crankshaft made of Carbon Steel:

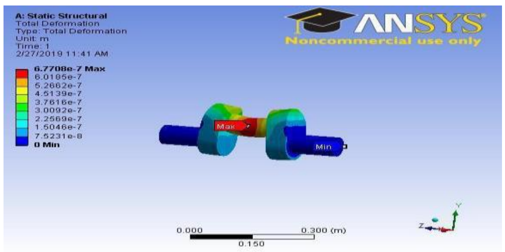


Fig. 3 The Total Deformation of the carbon steel

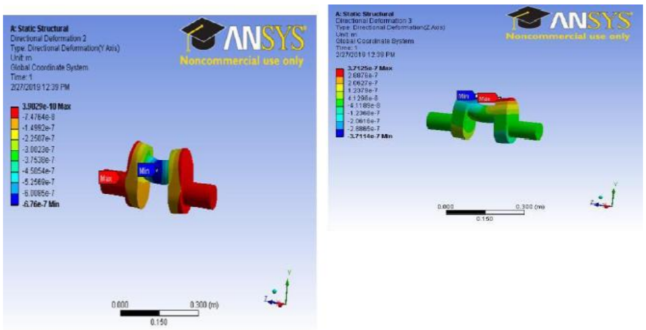


Fig. 4: .Deformation in Y-Axis and Z-axis respectively

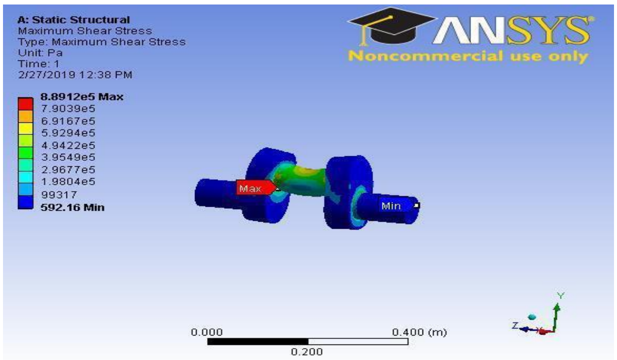


Fig.5: The maximum shear stress of carbon steel

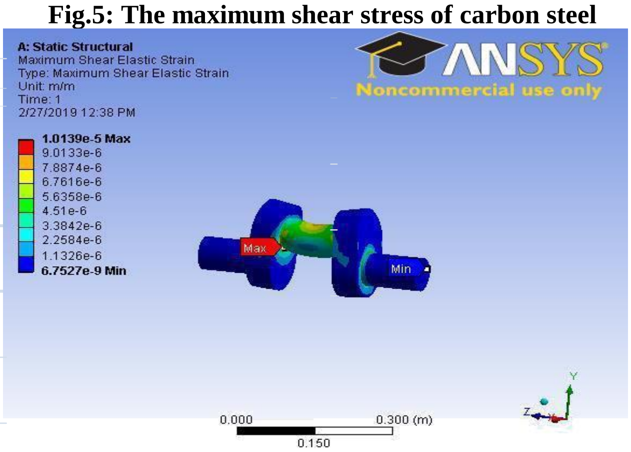


Fig.6: The maximum shear elastic strain

Taable.6: Results obtained for crankshaft made of carbon steel material:

Type	Total Deformation (m)	Equivalent Von-Mises Stress (Pa)	Maximum Shear Stress (Pa)	Maximum shear Elastic Strain (m/m)	Directional Deformation (m)
Minimum	0	1041	592.16	6.7527e-009	-6.76e-007
Maximum	6.7708e-007	1.7557e+006	8.8912e+005	1.0139e-005	3.9029e-010

5.2. Results obtained for Crankshaft made of Kevlar Epoxy:

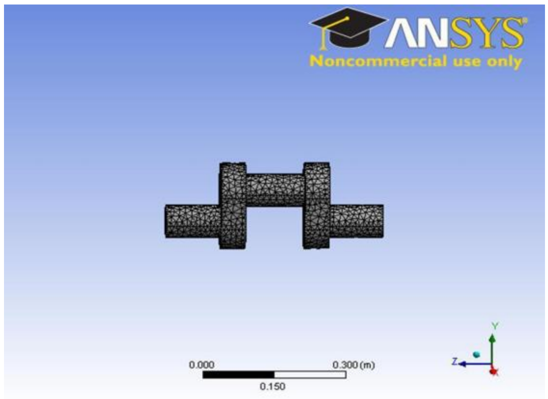


Fig.7: Meshing of Crank Shaft made of Kevlar Epoxy

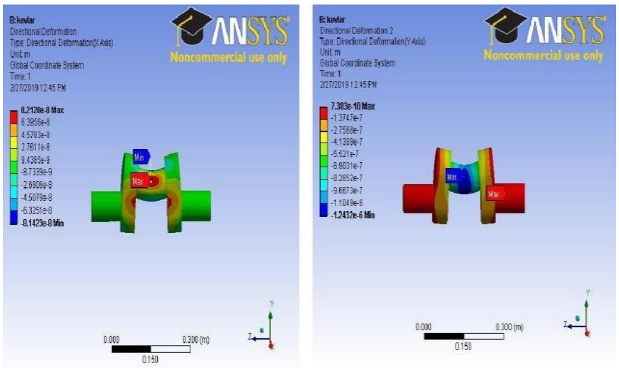


Fig.8: The total deformation of Kevlar 49

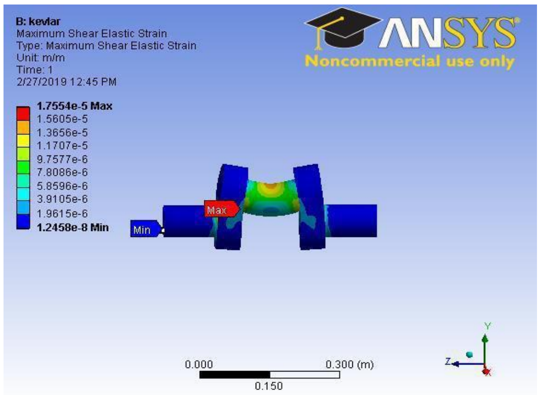


Fig.9: Deformation in X-Axis and Y-Axis respectively

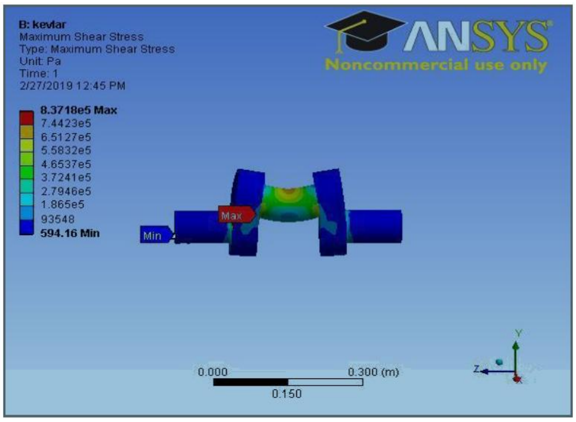


Fig.10: maximum shear stress

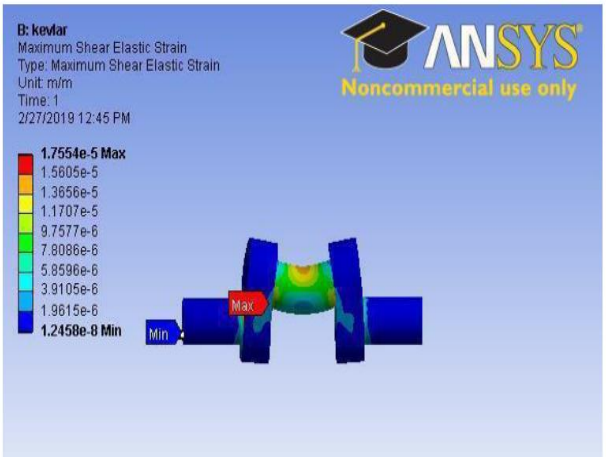


Fig.11: maximum shear strain

Table.7: Results obtained for crankshaft made of Kevlar 49 material:

Type	Total Deformation (m)	Maximum Shear Elastic Strain (m/m)	Maximum Shear Stress (Pa)	Directional Deformation (m)	
Min	0	1.2458e-008	594.16	-8.1423e-008	-1.2432e-006 m
Max	1.2432e-006	1.7554e-005	8.3718e+005	8.2128e-008	7.383e-010

V. FABRICATION

Equipments :

Fibre strands – 4kgs

Fibre ribbons _5 bands

Epoxy resin L12 -5kgs

Hardner K6 – 5 bottles

Mould box - 1box

Plaster of paris – 20kgs

Greece (required)

Pattern

Fig 8.1 Wood Pattern

Fig 8.2 Mould withpop

Fig 8.3 Die of Crankshaft

Fig 8.4Fibre strands in die

Fig 8.5 Strands with Resin

Fig 8.6 Component

First take a mould box and pattern apply greece on it . Now fix the pattern in the mould box.Now mix the plaster of paris with water and pour in the mould box. Mix the mould like clay and let it dry for 2 days. After drying turn the mould box and remove the pattern. Now the die is prepared apply greece on the die and arrange the strands in it. Mix the resin with the hardner throughly and pour on the strands and leave for 24hrs to dry. Then we get the first half component. Repeat the same procedure to get another half component . after getting both components join the components with the help of ribbons in to one piece let it dry now turn the piece on the lathe machine and bind the ribbon on the shaft to increase the diameter.

VI. CONCLUSION

1. The weight of the crankshaft made of carbon steel material is 128.9kgs and for Kevlar 49 is 52.5kgs. The maximum weight 76.4kgs has been reduced
2. By analysis we have observed that the maximum deformation values for carbon steel is

$6.77*10^{-7}$ mm and for Kevlar 49 the maximum deformation is $6.76*10^{-7}$ mm. The deformation of the crankshaft made of Kevlar 49 is very less as compared to the crank shaft made of carbon steel so the Kevlar 49 is more suggestable for the weight reduction.

3.The crank shaft made of Kevlar 49 can resist heat upto 1500˚C where as the crank shaft made of carbon steel can resist heat upto 760˚C. So the composite material kevlar 49 can be used for crankshafts for working under high temperatures upto 1500˚C.

4.The weight reduction of the crankshafts reduces the initial loads and in large volume production, it will result in large scale savings.

REFERENCES

1. J Henry, J. Topolsky and M. Abramczuk, Transactions: Journal of Materials and “Crankshaft Durability Prediction – A New 3-D Manufacturing Approach,” SAETechnicalPaper
2. M. Zoroufi and A. Fatemi, "A Literature Review 920087,Society of Automotive Engineers, 1992 on Durability Evaluation of Crankshafts.

3. M. Guagliano, A. Terranova and L. Vergani,Including Comparison ofCompeting "Theoretical and Experimental Study of the Manufacturing Processes and Cost Analysis", Stress Concentration Factor in Diesel Engine26th Forging Industry Technical Conference, Crankshafts," Journal of Mechanical Design, 115, Chicago, IL, November 2005
4. Fergusen, "Internal Combustion Engines, Applied Thermo Science," John Wiley and Sons, New York, NY, USA, 1986
5. Asi Osman,"Failure analysis of a crankshaft made from ductile cast iron", Department of Mechanical Engineering, Usak Engineering Faculty, Afyon Kocatepe University, 64300 Usak, February 2006,13 (2006) 1260–1267
6. E. Payar, A. Kainz and G. A. Fiedler, "Fatigue Analysis of Crankshafts Using Nonlinear Transient Simulation Techniques," SAE Technical Paper No. 950709, Society of Automotive Engineers , 1995
7. V. Prakash, K. Aprameyan, and U. Shrinivasa, "An FEM Based Approach to Crankshaft Dynamics and Life Estimation," SAE TechnicalPaper No. 980565, Society of AutomotiveEngineers, 1998
8. A. C. C. Borges, L. C. Oliveira and P. S. Neto, "Stress Distribution in a Crankshaft Crank Using a Geometrically Restricted Finite Element Model", SAE Technical Paper No. 2002-01-2183, Society of Automotive Engineers, 2002
9. Steve smith, "Utilizing crankcase deflection analysis to improve crankshaft design and engine performance" vibration Free, Oxford, UK. +44 1869 345535
10. Terry M. Shaw - Cummins Engine Co., Inc. Ira B. Richter – Cummins Engine Co., Inc. Crankshaft Design Using a Generalized Finite Element Model Date Published: 1979-02-01.
11. Pratibha,Dharmavarapu, C.Sravanthi, Pooja Angolkar, "Weight Optimization of Steam Turbine Casing using Optistruct Tool", International Journal of Mechanical and Production Engineering Research and Development, ISSN (P): 2249-6890; ISSN €: 2249-8001, Vol 8, Issue 4, Aug 2018, pp.1155-1168
12. C.Sravanthi ,"Design And Analysis of Fibre Reinforced Composite Ceiling Fan Blade", et.al. Int. Journal of Engineering Research and Application www.ijera.com ISSN : 2248-9622, Vol. 8, Issue 1, (Part -III) January 2018, pp.91-93.
13. Onkar V.PotadaraGanesh S.Kadama. Preparation and Testing of Composites using Waste Groundnut Shells and Coir Fibres. https://doi.org/10.1016/j.promfg.2018.02.013' Ganesh B. Taware, Sham H. Mankar, V. B. Ghagare, G. P. Bharambe, Sandip A. Kale'-Vibration Analysis of a Small Wind Turbine Blade
14. Siva Sankaran P., Kirubanand V B. "Hybrid Cryptography security in public cloud using TwoFish
15. and ECC algorithm", International Journal of Electrical and Computer Engineering (IJECE), 2019
16. Exoneration of Waste Water with Solar Energy", International Journal of Innovative Technology and Exploring Engineering, 2019.
17. Mukhamedieva D.T., Safarova L.U." Main Problems and Tasks of Intellectualisation of Information Processing System. ISSN: 2278-3075, Volume-8 Issue-9S3, July 2019
18. K. Satyanarayana, P. V. J. Mohan Rao, I. N. Niranjan Kumar. "Some studies on mathematical modelling and dynamic stress analysis of a variable compression ratio diesel engine crankshaft", Mathematical Models in Engineering, 2018

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