STRESS ANALYSIS OF COMPOSITE PROPELLER BY USING FINITE ELEMENT ANALYSIS

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Abstract:

Present work proposes a methodology to design a propeller with a metal and composite material to analyze its strength and deformation using Ansys software. In order to evaluate the effectiveness of composite over metals, stress analysis is performed on both composite and metal propeller using Ansys. Proposed methodology showed substantial improvements in metal propellers. The mean deflection, normal stress and shear stress were found for both metallic and composite propeller by using Ansys. From the results, stress analysis composite propeller is safe resonance phenomenon. In this work effort is made to reduce stress levels so that advantage of weight reduction along with stresses can be obtained. The comparison analysis of metallic and composite propeller was made for the maximum deformation and normal stresses.

Keyword*s: Composite Propeller, FEA, Stress Analysis*

1. Introduction:

Ships use propeller as propulsion device for converting shaft power of the engine to thrust force for the ship to move it through water. Presently conventional marine propellers remain the standard propulsion mechanism for surface ships and under water vehicles. The propeller blade geometry and its design are complex involving many controlling parameters. The strength analysis of such complex 3D blades with conventional formula will give less accurate values. In such cases finite element method gives comparable results with experimental values.

The propeller is a vital component for the safe operation of ship at sea. It is therefore important to ensure that ship propeller have adequate strength to with stand the forces that act upon them. Fiber reinforced plastic composite have high strength to weight and these materials have better corrosion resistance, lower maintenance, non magnetic property and it also have stealth property for naval vessels. The forces that act on a propeller blade arise from thrust and torque of the propeller and the centrifugal force on each blade caused by its revolution around the axis. Owing to some what complex shape of propeller blades, the accurate calculations of the stresses resulting from these forces is extremely difficult. The stress analysis of propeller blade with aluminium and composite material is carried out in the present work.

The application of composite technology to marine applications has with particular benefits of its light weight, less noise, pressure fluctuations and fuel consumption [1]. The finite element method is so popular and has been used many researchers [2]. The research and development of propellers using composites are advancing. The back drop to this advancement is the fact that composites can provide a wide variety of special characteristics that metals can not. In terms of cost, as well as diffusion rates of composites is rapid, technology advances yearly and the costs of composites are becoming cheaper [3]. More over composites can offer the potential benefits corrosion resistance and fatigue performance, improved material damping properties and reduced life time maintenance cost [4]. Taylor [5] considered a propeller blade as a cantilever rigid at the boss. J.E Conolly [6] combined theory and with experimental work for wide blades. Chang suplee [7] investigated the main sources of propeller blade failure and resolved the problems related to blades symmetrically. G.H.M Beet [8] examined the interference between the stress conditions in the propeller blade and the hub. W.J.Colcough [9] studied the advantages of a composite propeller blde with fibre reinforced plastic over that of the propeller blade made from over materials. Gau FengLin [10] carried out a stress calculations for fibre reinforced composite thrust blade.

2. Analytical methods to find out stresses in a blade section:

The calculation of the stresses in a propeller is extremely complicated owing to a number of reasons: the loading fluctuates, its distribution over the propeller blade surface is difficult to calculate, and the geometry of the propeller is rather complex. It is therefore usual to use simplified methods to calculate the stresses in the propeller blades and to adopt a large factor of safety based on experience.

The simple method described here is based on the following principal assumptions:

i) The propeller blade is assumed to be a cantilever fixed to the boss at the root. The critical radius is just outside the root fillets.

ii) The propeller thrust and torque, which arise from the hydrodynamic pressure distribution over the propeller blade surface, are replaced by single forces each acting at a point on the propeller blade.

iii) The centrifugal force on the propeller blade is assumed to act through the centroid of the blade, and the moment of the centrifugal force on the critical section can be obtained by multiplying the centrifugal force by the distance of the centroid of the critical section from the line of action of the centrifugal force.

iv) The geometrical properties of the radial section (expanded) at the critical radius may be used instead of a plane section of the propeller blade at that radius, and the neutral axes may be taken parallel and perpendicular to the base line of the expended section.

Let the propeller have Z blades, and be turning at a revolution rate n when developing a thrust T with a torque Q. J.P.Ghose [11] suggested the following formulas.

Thrust force per blade, $$F_T = \frac{1}{Z}T \quad \text{\_\_\_\_\_\_\_(1)}$$

Torque force per blade, $$F_Q = \frac{1}{Z}\frac{Q}{R} \quad \text{\_\_\_\_\_\_\_\_(2)}$$

Centrifugal force, $$F_c = \frac{W}{g}.\bar{r}(2\pi n)^2$$

$$= 4\pi^2 \frac{W}{g} n^2 \bar{r} \quad \text{\_(3)}$$

3. Finite element analysis of metallic and composite propeller:

In the present problem, element type solid 46 is used for composite propeller and solid 45 is used for Aluminum propeller.

3.1 Finite element modeling of the Propeller:

Modeling of the propeller is done using CATIA V5 R 17. In order to model the blade, it is necessary to have sections of the propeller at various radii. These sections are drawn and rotated through their respective pitch angles. Then all rotated sections are projected onto right circular cylinders of respective radii as shown in figure below. Now by using multi section surface option, the blade is modeled.

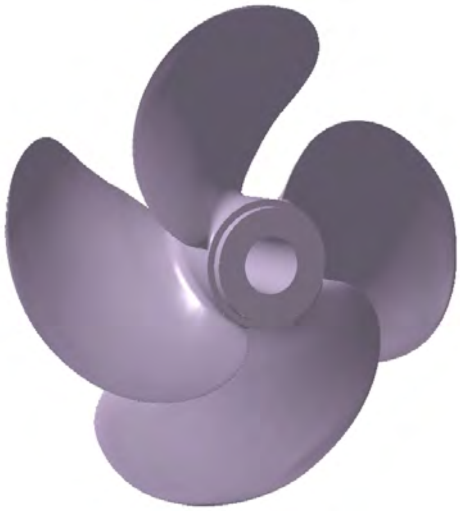

Fig:1 Final solid model of propeller

3.2 MESH GENARATION USING HYPERMESH

The solid model is imported to HYPERMESH 10.0 and hexahedral mesh is generated for the same. The meshed model is shown in figure 5.2. The meshing was done by splitting it into different areas and the 2D mapped mesh was done and then it was converted into 3D mesh using the tool linear solid. The number of elements created is 27,388 and number of nodes created is 52,412. Quality checks are verified for the meshed model. Jacobian, warpage and aspect ratio are within permissible limits. Now the pressures are applied on the propeller which is obtained in FLUENT 6.3. Then the meshed model is imported into the ANSYS.

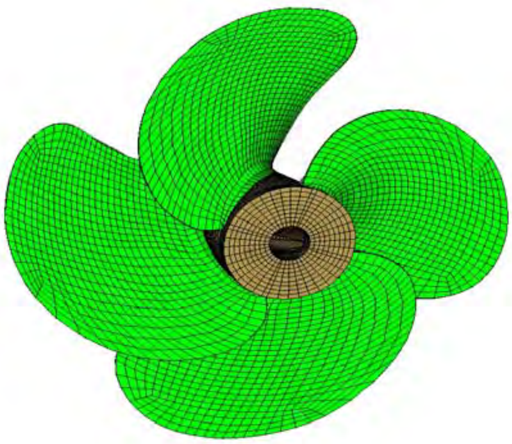

Fig:2 Aluminium propeller meshed model

For meshing the composite propeller the solid model is imported in to hyper mesh and the elements are selected for various layup sequence as given by their thickness. Assure that proper connectivity exists between the layers. Now again the pressures are applied on the propeller which is obtained in FLUENT 6.3. Then the meshed model is imported into the ANSYS.

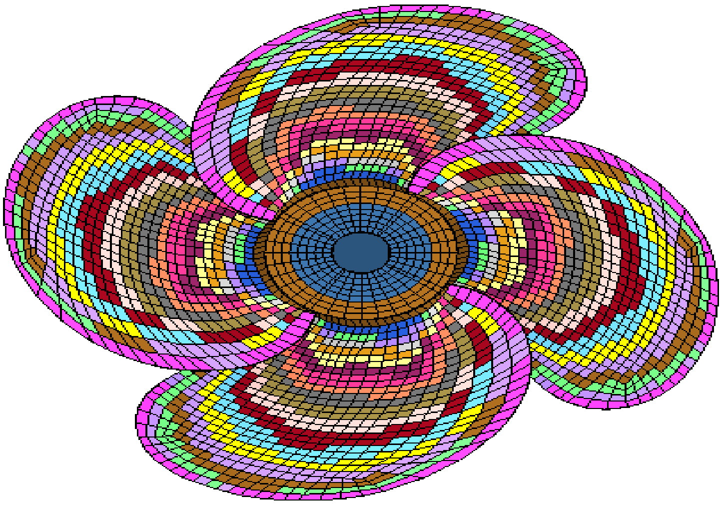

Fig:3 Composite propeller meshed model

3.3 EXPORTING MESH TO THE ANSYS11.0

First delete all the surfaces and 2d elements before exporting to the ANSYS so that only 3D elements are exported. Now select the user profile in the preferences then go to utility menu and mention the ET type as solid45 if it is aluminium or solid 46 for composite material, specify material properties and real constants if necessary. Then go to 3D option and mention the ET type and element types. Update all the components in the component option and at last renumber all the components. Now go to export option to export the FE model to the ANSYS.

3.4 Material properties of propeller:

Aluminum properties

Young's modulus E= 70000 MPa
Poisson's ratio NUXY=0.34
Mass density =2700 kg/m^3
Damping co-efficient =0.03

Material properties for composite Propeller used for present work

Mat no 1: S_2Glass fabric/Epoxy		Mat no 2: Carbon UD/Epoxy	
E_x	=22.925Gpa	E_x	=120Gpa
E_y	=22.925Gpa	E_y	=10Gpa
E_z	=12.4Gpa	E_z	=10Gpa
NUXY	=0.12	NUXY	=0.16
NUYZ	=0.2	NUYZ	=0.2
NUZX	=0.2	NUZX	=0.16
G_{xy}	=4.7Gpa	G_{xy}	=5.2Gpa
G_{yz}=G_{zx}	=4.2Gpa	G_{yz}	=3.8Gpa
ρ	=1.8gm/cc	G_{zx}	=6Gpa
		ρ	=1.6gm/cc

3.5 BOUNDARY CONDITIONS AND LOADS

The propeller is fixed at hub and shaft intersection so all DOF condition is applied to the nodes. Pressure is applied to the total propeller which is obtained from the CFD analysis.

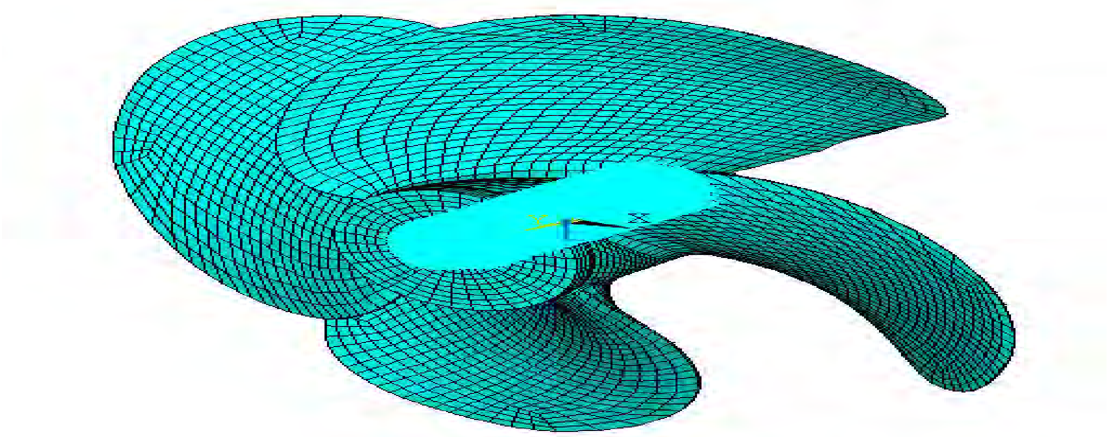

Fig:4 Propeller FE model in ANSYS

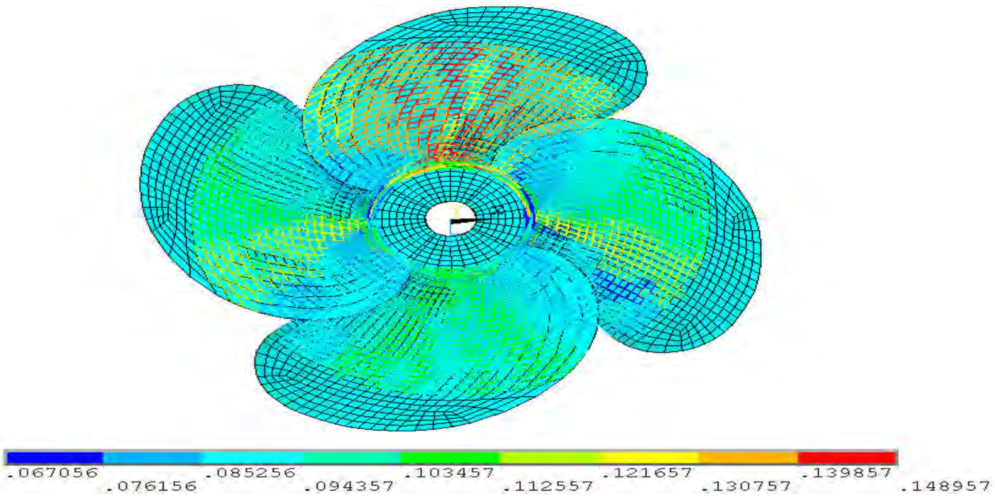

Fig:5Propeller FE model in ANSYS Pressures

4. RESULTS AND DISCUSSIONS:

Propeller made of Aluminum and another one made of composite material is chosen for FE analysis. In present the results of stress analysis are presented in the form of figures and graphs by selecting the effective software like ANSYS.

STRESS ANALYSIS OF ALUMINIUM PROPELLER

The deformation of aluminium propeller is shown in figure 6 and the maximum deflection was found as 0.038611mm. The stresses and displacements in x, y and z directions are shown in table 1.

Table :1 Static analysis results of Aluminium Propeller

Aluminium Propeller	**Results**
Deflection	0.038611mm
Max. Normal stress	9.011 N/mm^2
First principal stress	12.405N/mm^2
Second principal stress	4.849N/mm^2
Third principal stress	2.258N/mm^2

Table :2 Maximum stress at the root section

FROM ANSYS	**FROM BURILL METHOD**
9.011 MPa	**8.9 MPa**

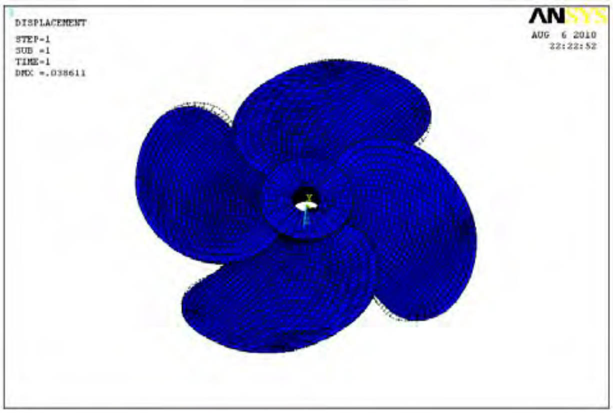

Fig:6 Deformation of Aluminium Propeller

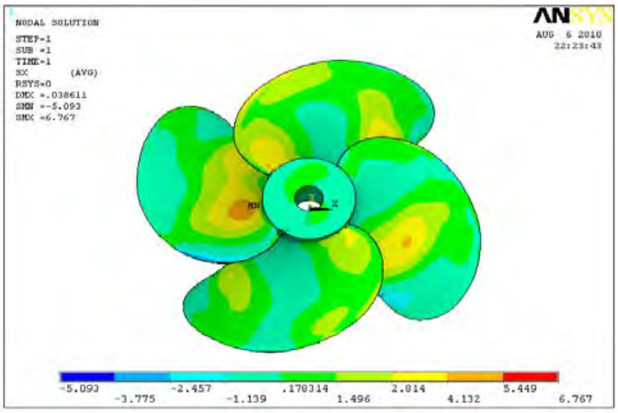

Fig:7 Stress of Aluminium Propeller in X-direction

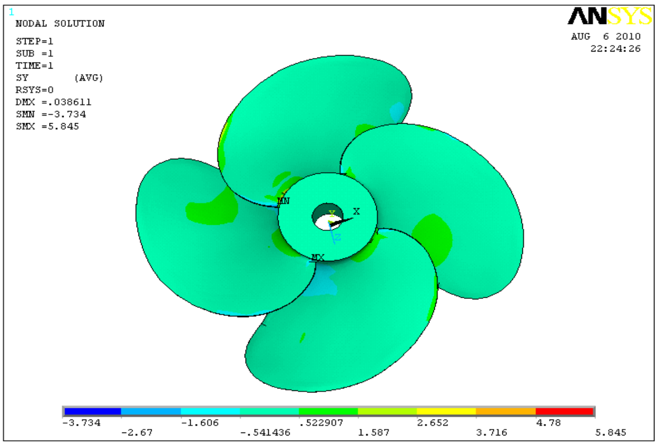

Fig:8 Stress of Aluminium Propeller in Y-direction

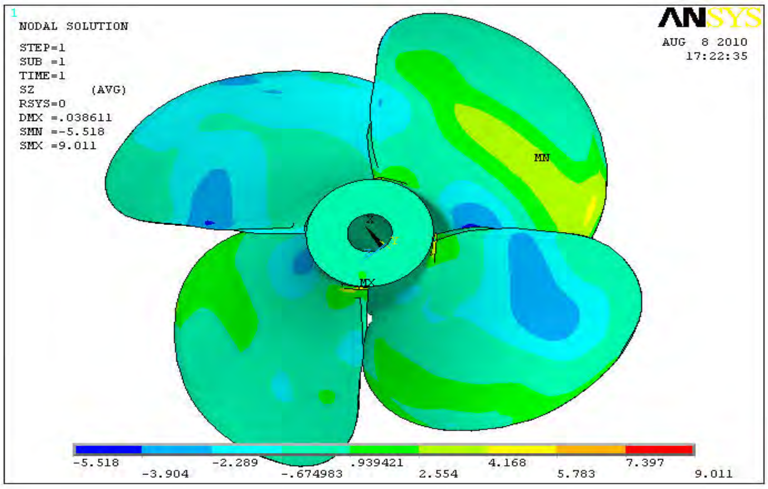

Fig:9 Stress of Aluminium Propeller in Z-direction

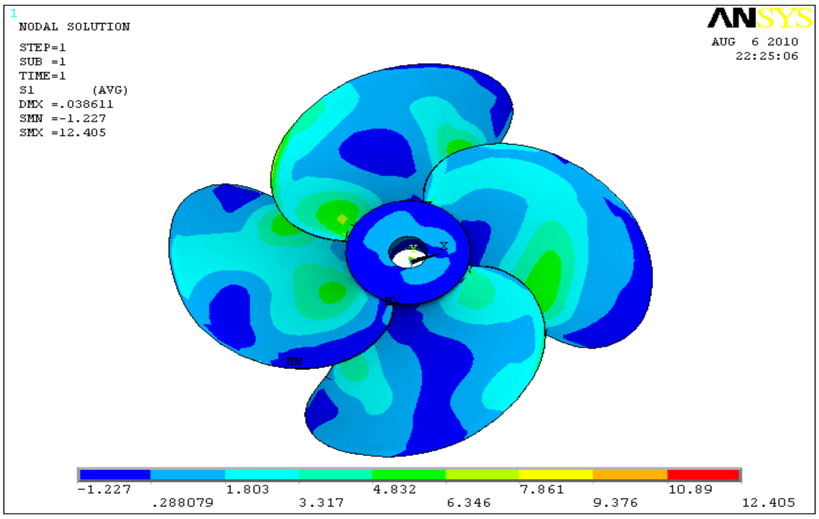

Fig:10 1st Principal Stress of Aluminium Propeller

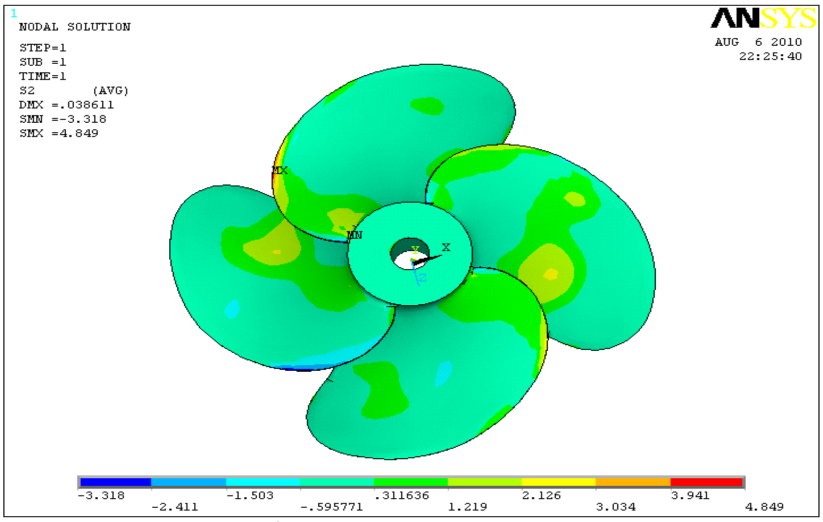

Fig:11 2nd Principal Stress of Aluminium Propeller

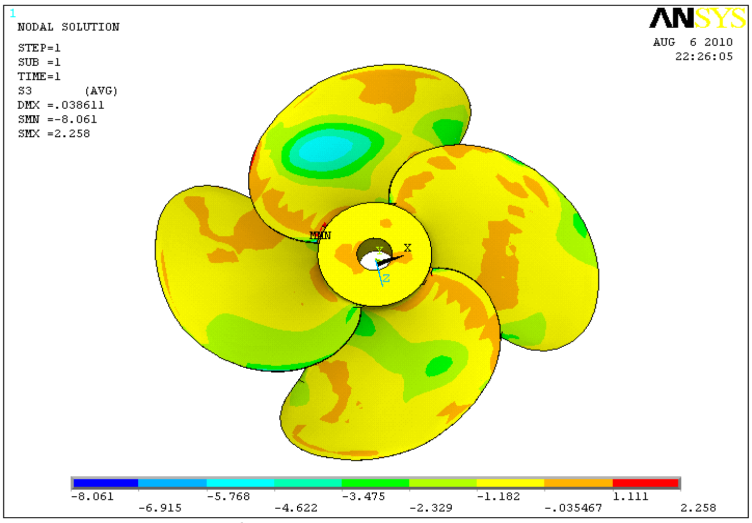

Fig:12 3rd Principal Stress of Aluminium Propeller.

STRESS ANALYSIS OF COMPOSITE PROPELLER

Stress analysis of composite propeller is carried out so as to check the bonding strength between various layers of composite propeller and Inter-laminar shear stresses are calculated.

Maximum deflection for composite propeller with 40 layers was found to be 0.27504 mm as shown in figure 13. The maximum normal stress was found to be 7.995 N/mm^2 in x-direction as shown in figure 14. Table 3 shows induced deformations and stresses in composite propeller.

The deflection for composite propeller was found to be around 0.27504mm mm for all layers which is more than that of Aluminum propeller i.e. 0.038611mm.Interlaminar shear stresses were calculated for composite propeller for 40 layers and the maximum inter-laminar shear stress is found on the layer 40.

Table :3 Stress analysis results of composite propeller

Composite Propeller	**Results**
Max deflection	0.27504mm
Max. normal stress	7.992/mm^2
Maximum Inter-laminar shear stress	1.353N/mm^2

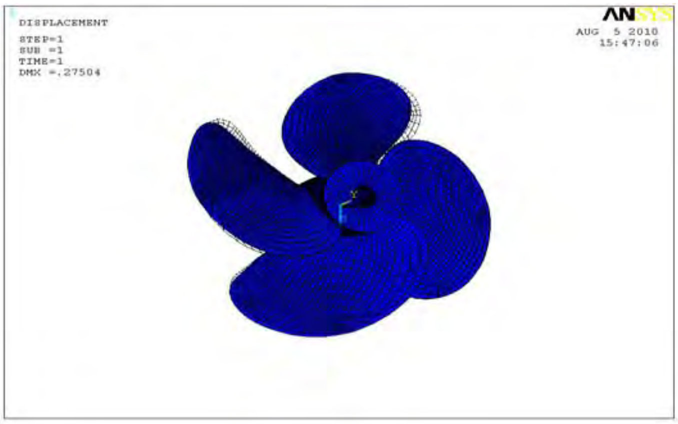

Fig13: Deformation of Composite Propeller

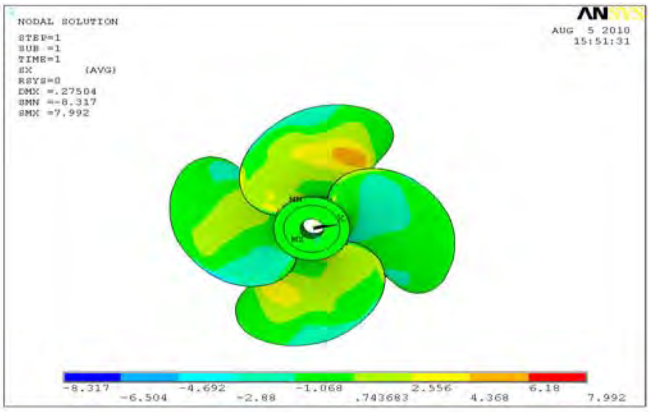

Fig14: Stress of composite propeller in X-direction

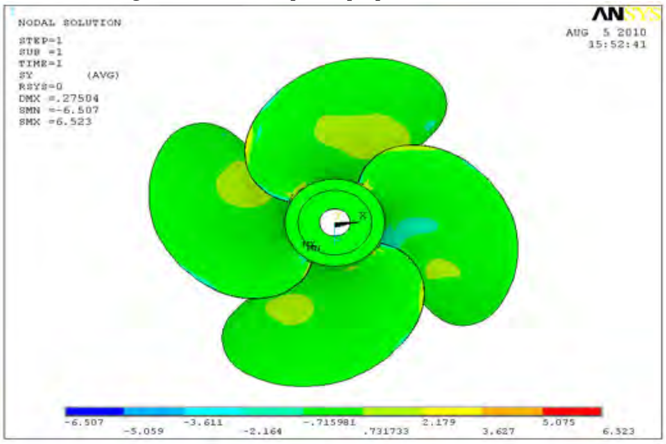

Fig15: Stress of composite propeller in Y-direction

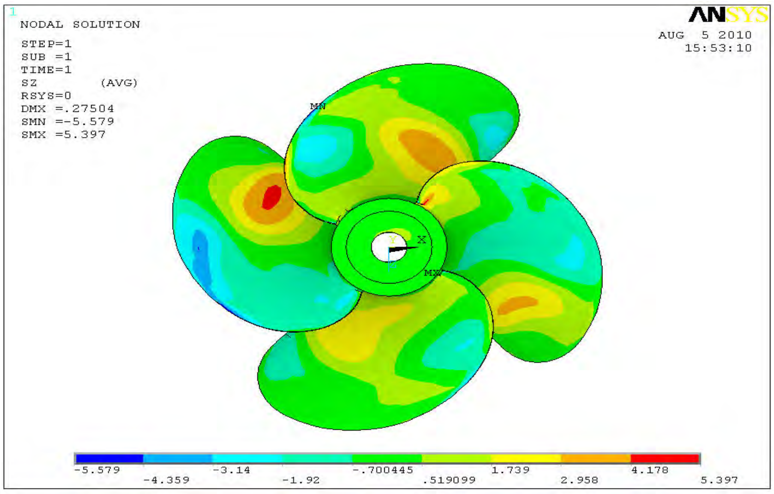

Fig16: Stress of composite propeller in Z-direction

CONCLUSIONS

The following conclusions are drawn from the present work

1. The stresses of composite propeller obtained in static analysis are within the allowable stress limit.

2.The maximum deflection for the aluminium propeller is 0.038611mm and the maximum deflection for the composite propeller is 0.275 mm.

3. The maximum normal stress for the aluminium propeller is 9.011 N/mm^2 and the maximum normal stress for the composite propeller is 7.99N/mm^2 , from analytical method 8.9 MPa.

4. The first, second and third principle stresses for aluminium propeller are 12.405 N/mm^2, 9.849 N/mm^2 and 2.258 N/mm^2.

5. Stress of a composite propeller in X,Y and Z directions are 7.992 N/mm^2 , 6.523 N/mm^2 and 5.397 N/mm^2.

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