Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 3, Issue 2; January-March, 2016 pp. 105-110
© Krishi Sanskriti Publications
http://www.krishisanskriti.org/Publication.html

Design and Analysis of a Propeller Blade for Underwater Vehicle

Pritam Majumder[1], K.M. Pandey[2] and N.V. Deshpande[3]

[1,2,3]Dept. of Mechanical Engineering National Institute of Technology Silchar- 788010, Assam, India
E-mail: [1]majumderpritam08@gmail.com, [2]kmpandey@yahoo.com, [3]email:director@nits.ac.in

Abstract—*In recent times, Fibre Reinforced Composite is being used for the fabrication of propeller blade in order to improve its performance by increasing payload and speed of the underwater vehicle. Due to its light weight and high strength, many researchers replaced the conventional metallic material with composite material for designing the propeller. In the present work, prediction of stress distribution around a propeller blade profile due to hydrostatic pressure difference is presented. A static structural stress analysis has been done for a single composite i.e. carbon fibre reinforced plastic (CFRP) and for a hybrid composite (combination of two composite materials) i.e. CFRP and Glass fibre reinforced plastics (GFRP). Ansys APDL software is used to determine the von Mises stress developed in the propeller blade. It has been observed from the result that using the hybrid composite material is more advantageous than the single composite material. The stress value of the propeller blade is found to be lower for the hybrid composites, suggesting the merit of the present work.*

Keywords*: Propeller blade, Carbon Fibre Reinforced Plastic (CFRP), Glass Fibre Reinforced Plastic (GFRP), hydrostatic pressure difference, hybrid composite*

1. INTRODUCTION AND LITERATURE SURVEY

In this advanced time of science and technology, it has become an important issue to use our non traditional resources as a source of energy. One of such important field is underwater platform of sea for which a lot of research work has been done to develop underwater vehicles and to observe its various effects. Propeller is one of the most important part of underwater vehicle for propulsion system. Strength of the propeller blade is one of the most important aspect for the proper performance of the whole underwater vehicle. Propeller blade are usually made of conventional metallic elements such as aluminium alloy, stainless steel etc. Now a days due to light weight and long durability, composite materials are used instead of metallic element.

In the past literature, Rao and Reddy (2012) concluded that composite propeller blades are safer in case of resonance phenomena in their harmonic analysis. Vibration defect can also be controlled in case of composite as damping effect is more. Khan et al. (2013) observed inter laminar shear stress for composite material considering different number of layers and observed that there is a strong bonding between the layers. Eigen value analysis shows composite material has 80.5% more natural frequency than aluminium propeller. Ganesh et al. (2014) has done static and modal analysis for aluminium propeller and composite (carbon reinforced plastics) propeller. From the analysis, it is observed that the blade deflection in case of composite propeller is very less compared to aluminium. Yeo et al.(2014) suggested a prediction about the stress distribution around a propeller blade through finite element method. Considering a three bladed propeller and stainless steel as the material, hydrodynamic analysis is carried out. With an increasing rotational speed, the developed stress is also increased after 3000 rpm, crossing its critical stress.

2. MODELLING OF PROPELLER BLADE

CATIA V5 software is used for modeling of the propeller blade. The shape design module is used to generate the 3D model of the propeller blade. The model is created by taking into consideration the outer diameter of the propeller blade as 200mm and the inner diameter (i.e. hub diameter) as 30mm. The blade corners are given a round shape with a radius of 40mm. The blade thickness applied for analysis purpose is 1 mm. The 3D model of the propeller blade is shown in Fig. 1.

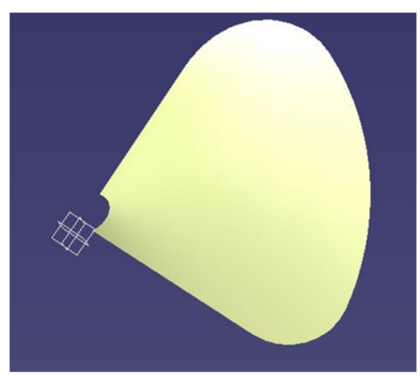

Fig. 1. 3D model of propeller blade.

2.1 Mesh generation

The meshed propeller blade is shown in Fig. 2. The element used for meshing is 4 noded 141 shell element. Considering element size 2 mm fine meshes are generated in pre-processor meshing module of ANSYS APDL.

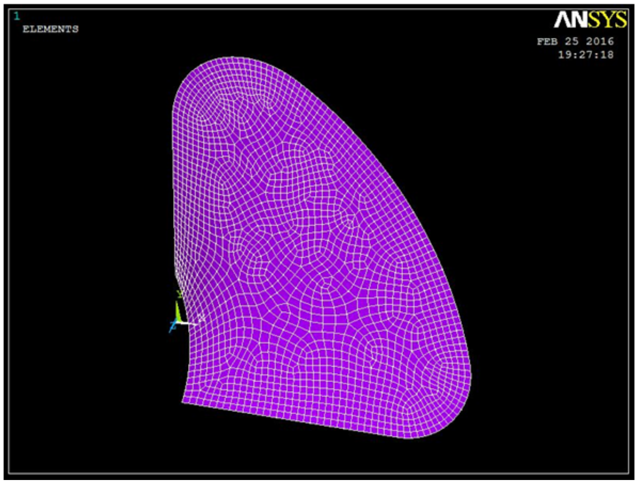

Fig. 2. Meshed propeller blade.

2.2 Boundary condition

The circumferences of the blade which meet with the hub are fixed for all translation degree of freedom. During the analysis propeller blade is consider as cantilever beam. Loads are applied approximately 1/3 distance from the blade tip i.e at 0.7R to 0.75R, where R is the propeller blade radius. The magnitude of load applied is equal to 4000N for static structural analysis and loads are uniformly distributed among the selected nodes and normal to the blade face.

2.3 Material properties of composites

Composite material	CFRP	GFRP
Young's modulus E_X(Gpa)	22.925	120
Young's modulus E_Y (Gpa)	22.925	10
Young's modulus E_Z(Gpa)	12.4	10
Poisson's ratio NUXY	.12	.16
Poisson's ratio NUYZ	.2	.2
Poisson's ratio NUZX	.2	.16
Rigidity modulus G_{XY}(Gpa)	4.7	5.2
Rigidity modulus G_{YZ}(Gpa)	4.2	3.8
Rigidity modulus G_{ZX}(Gpa)	4.2	6
Density(ρ)(gm/cc)	1.8	1.6

3. RESULTS AND DISCUSSIONS

During analysis different number of layers such as 4 layers, 8 layers, 12 layers and 16 layers are considered for the both single composite and hybrid composite material. Thickness of every layer is considered to be uniform. In case of hybrid composite the layer of CFRP and GFRP are changing alternately as shown in the Fig. 4. Orientation of composite fibre are taken as 45˚and -45˚ alternately as shown in the Fig. 3 and Fig. 4.

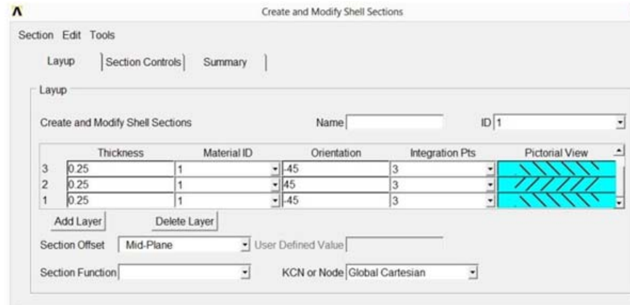

Fig. 3. Various layer and fibre orientation of CFRP (4 layers).

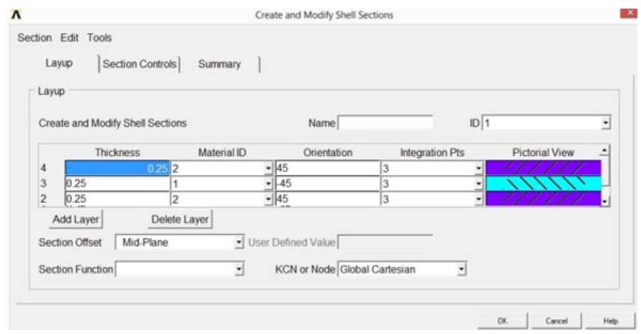

Fig. 4. Various layer and orientation of hybrid composite (4 layers).

3.1 Static structural analysis

Structural analysis is done for four cases for both single CFRP and hybrid composite propeller considering varying number of layers and corresponding deflection and stress are observed.

Case1: analysis result for 4 layers

Maximum deflection for single CFRP propeller blade is 0.802mm in z direction i.e normal to the face of the blade and maximum von mises stress is 22.1 N/mm^2. In case of hybrid composite propeller deflection is 0.9213mm and maximum von Mises stress is 21.1 N/mm^2. Both deflection

and von mises stress are shown below.

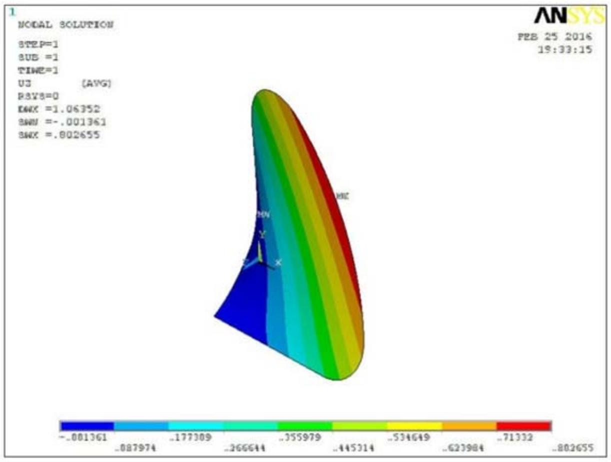

Fig. 5. Deflection of CFRP composite blade (4 layers).

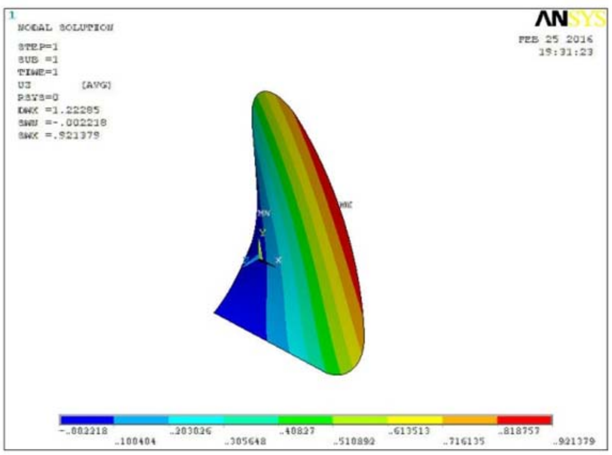

Fig. 6. deflection of hybrid composite blade (4 layers).

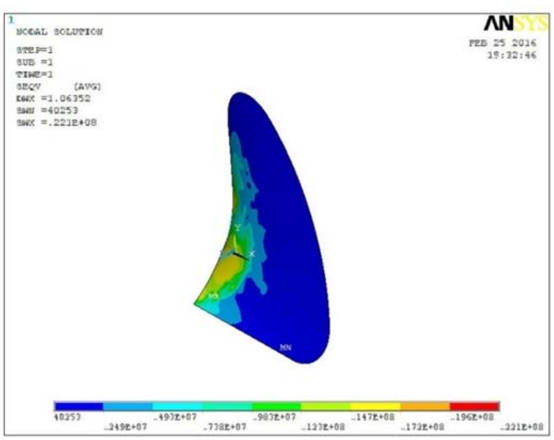

Fig. 7. max von mises stress for CFRP propeller blade(4 layers).

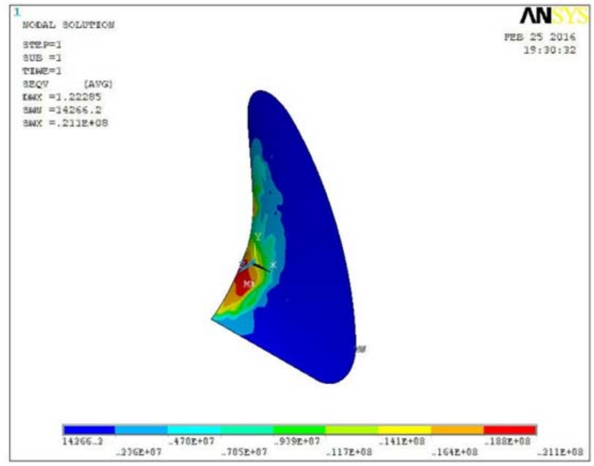

Fig. 8. max von mises stress for hybrid composite propeller blade (4 layers).

Case 2: Analysis result for 8 layer

Here thickness of each layer is considered 0.125 mm. Maximum deflection for single CFRP propeller blade is 0.75 mm in z direction i.e normal to the face of the blade and maximum von mises stress is 23.7 N/mm^2 . In case of hybrid composite propeller deflection is 0.79 mm and maximum von mises stress is 20.1N/mm^2. Both deflection and von mises stress are shown below

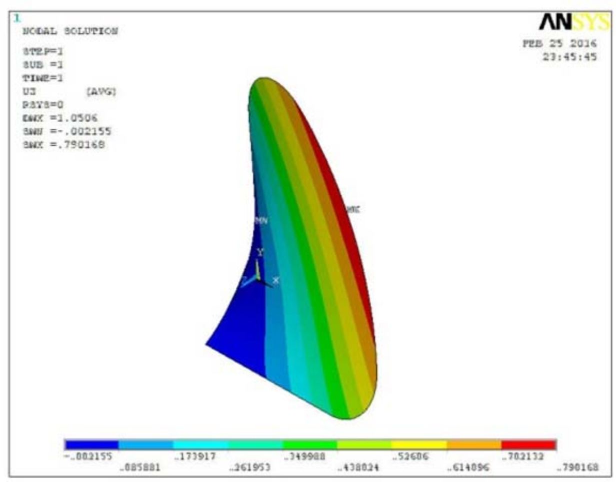

Fig. **9. Deflection of CFRP blade (8 layers).**

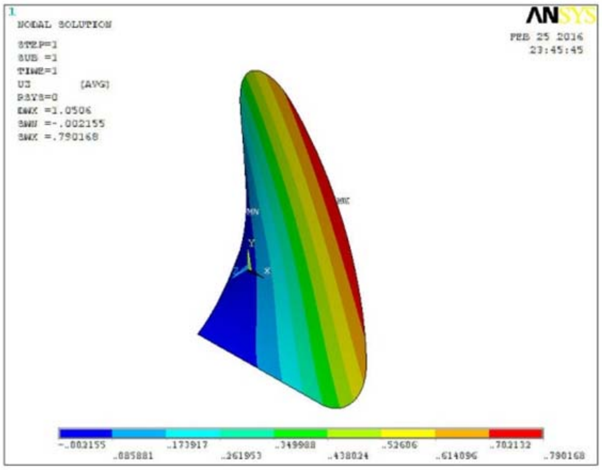

Fig. 10. Deflection of hybrid composite blade (8 layers).

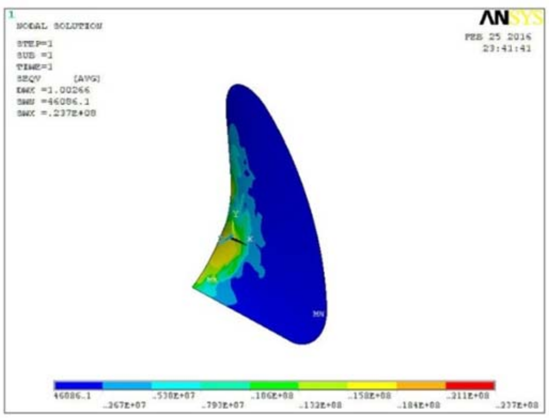

Fig. 11. Max von Mises stress for CFRP propeller blade(8 layers).

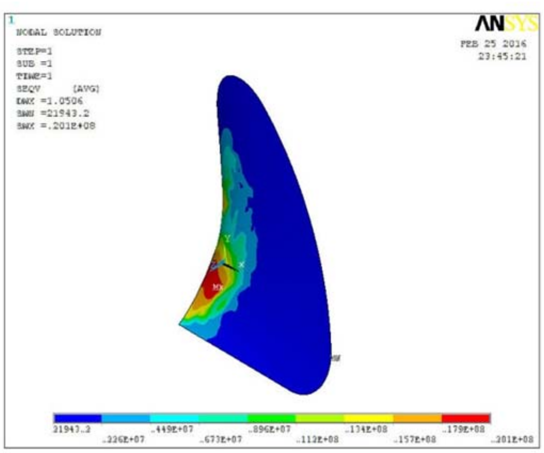

Fig. 12. Max von Mises stress for hybrid composite propeller blade (8 layers).

Case 3: Analysis result for 12 layer

Here thickness of each layer is considered 0.0833 mm. Maximum deflection for single CFRP propeller blade is 0.7534 mm in z direction i.e normal to the face of the blade and maximum von mises stress is 25.7 N/mm^2 . In case of hybrid composite propeller deflection is 0.702 mm and maximum von mises stress is 22.7N/mm^2. Both deflection and von mises stress are shown below

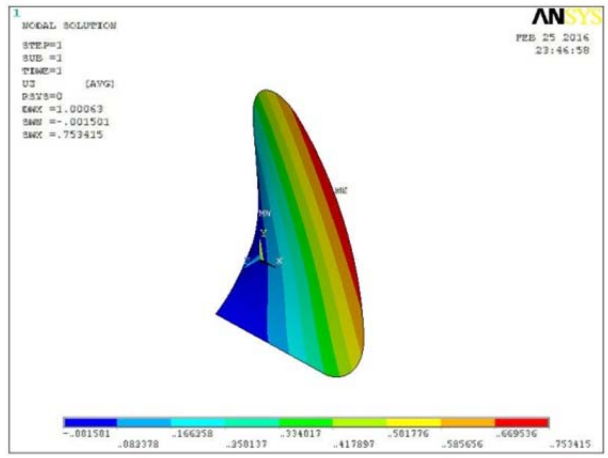

Fig. 13. Deflection of CFRP blade (12 layers).

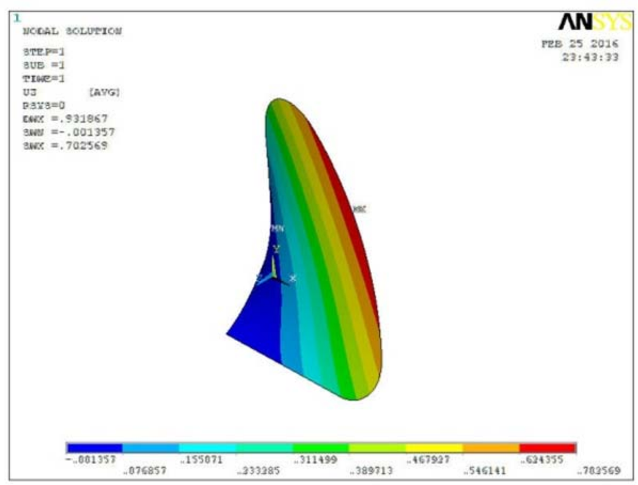

Fig. 14. Deflection of hybrid composite blade (12 layers).

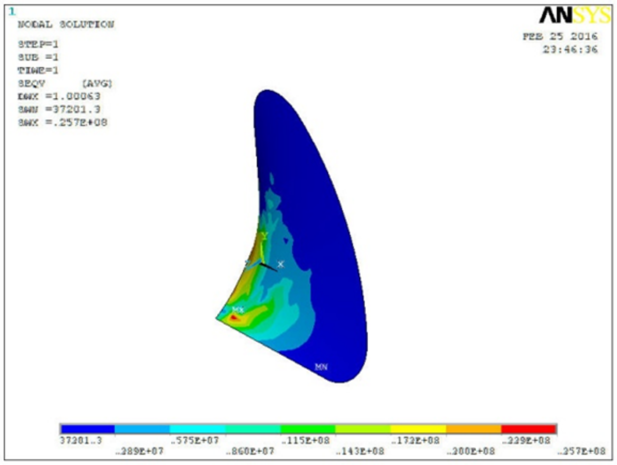

Fig. 15. Max von Mises stress for CFRP propeller blade (12 layers).

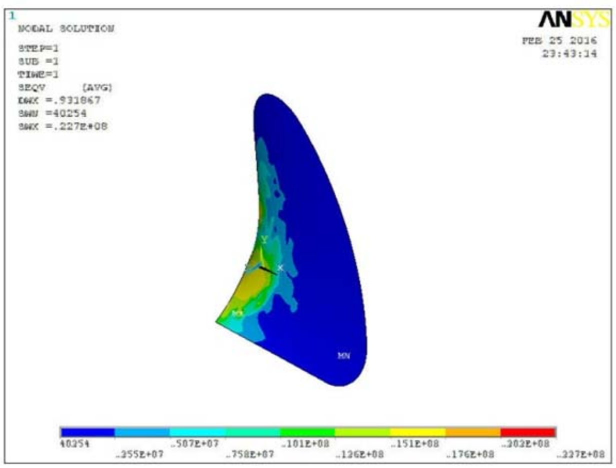

Fig. 16. Max von Mises stress for hybrid composite propeller blade (12 layers).

Case 4: Analysis result for 12 layer

Here thickness of each layer is considered 0.0625 mm. Maximum deflection for single CFRP propeller blade is 0.811 mm in z direction i.e normal to the face of the blade and maximum von mises stress is 26.3 N/mm^2 . In case of hybrid composite propeller deflection is 0.9905 mm and maximum von mises stress is 25.2N/mm^2. Both deflection and von mises stress are shown below

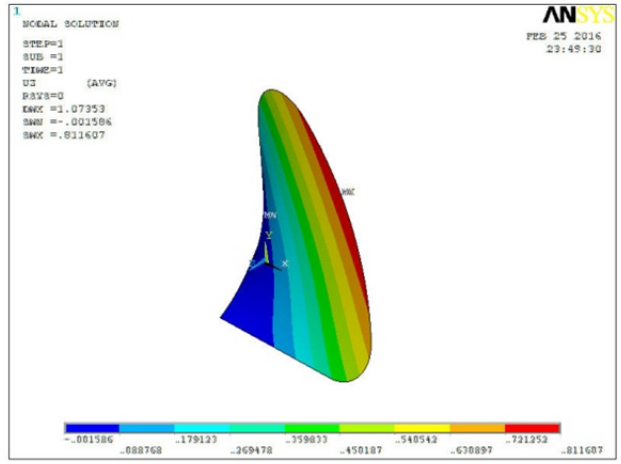

Fig. 17. Deflection of CFRP blade (16 layers).

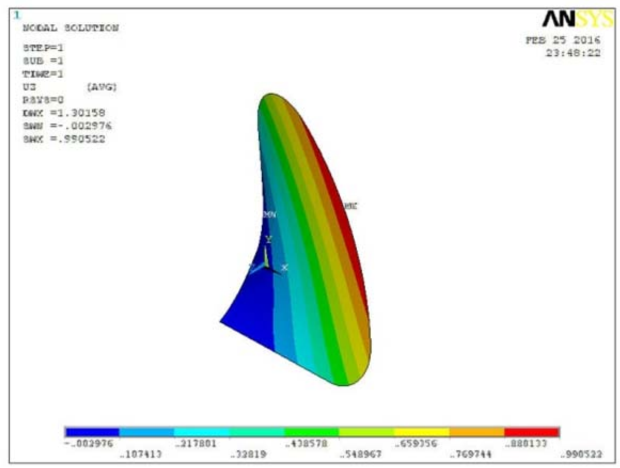

Fig. 18. Deflection of hybrid composite blade (16 layers).

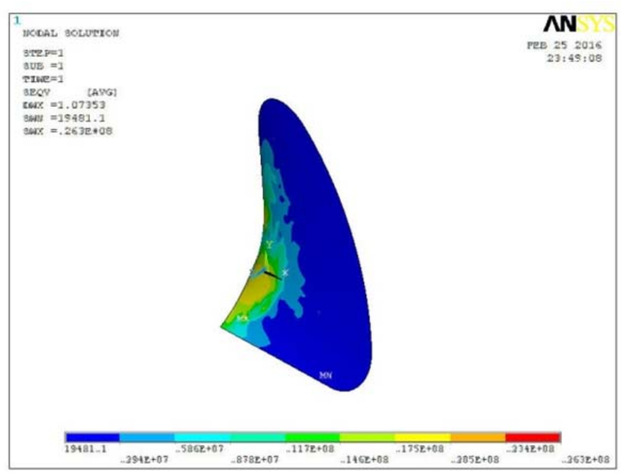

Fig. 19. Max von Mises stress for CFRP propeller blade (16 layers).

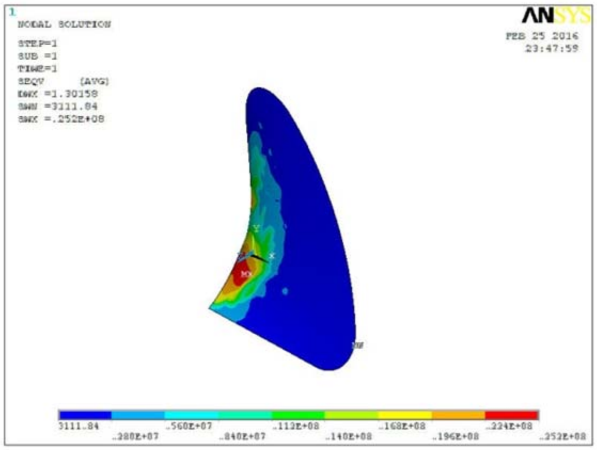

Fig. **20. Max von Mises stress for hybrid composite propeller blade (16 layers).**

4. CONCLUSIONS

From the present work the following conclusions are drawn:

- The average deflection for CFRP propeller blade is around 0.77925mm, where as in case of hybrid composite propeller blade is 0.85107mm. So deflection increase in hybrid propeller is 9.21% less compared to composite propeller.
- The average maximum von mises stress developed in CFRP is 24.45 N/mm^2 but in hybrid propeller 22.275 N/mm^2. So stress decrease in hybrid propeller blade around is about 8.895%.

5. FUTURE SCOPE OF WORK

A comparison study for noise reduction can be carried out in future harmonic analysis and with changing the material..

REFERENCES

[1] Nematollahi, A., Dadvand, A.,and Dawoodain, M., "An axisymmetric underwater vehicle-free surface interaction: A numerical study", ocean engineering, Vol. 96 2015 pp: 205-214

[2] Subudhi, B.,Mukherjee, K.,and Ghosh, S., "A static output feedback control design for path following of autonomous underwater vehicle in vertical plane", Ocean Engineering, Vol.63 2013 pp:72-76

[3] Yeo, K. B., Choong, W. H., and Hau, W. Y., "Prediction of Propeller Blade Stress Distribution Through FEA", Journal of Applied Sciences,Vol.14(2014) pp.3046-3054.

[4] Ganesh,V., Pradeep, K., and Srinvasulu, K., "Modeling and Analysis of Propeller Blade for its Strength" International Journal of Research & Technology(IJERT),Vol.3 February-2014 pp: 291-300

[5] Rao, Y. S., and Reddy, B. S., "Harmonic Analysis of Composite Propeller for Marine Applications", International Journal of Research & Technology(IJERT),Vol.1 Nov-2012 pp: 257-260

[6] Khan, M. A., Uddin, K. S.,and Ahmed, B., "Design and Dynamic Analysis on Composite Propeller of Ship Using FEA",Vol.2 January-2013 pp: 310-315

[7] Young, Y. L., "Fluid-Structural Interaction Analysis of Flexible Composite Marine Propellers", Journal of Fluids and Structure, Vol.24 Aug-2006 pp:799-818

[8] Ghassemi, H., Fadvie, M., and Nematy, D**., "**Hydro-Structure Analysis of Composite Marine Propeller under Pressure Hydrodynamic Loading", American Journal of Mechanical Engineering, Vol.3 2015 pp: 41-46

[9]. Sagar, M. V., Venkaiah, M., and Sunil, D., "Static and Dynamic Analysis Of Composite Propeller Of Ship Using FEA", International Journal of Engineering Research & Technology (IJERT), Vol. July – 2013 pp: 2587-2594