Structural Analysis of Contra Rotating Propeller by Using FEA

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ABSTRACT

Contra Rotating Propellers (CRP) is a type of propulsion system which consists of two propellers on the same line of shaft, spaced at short axial distance apart and rotating in opposite directions. In this project the Structural Analysis of Contra Rotating Propeller is carried out by Finite Element Analysis (FEA). The softwares used are CATIA V5R19, HYPERMESH-10 and ANSYS-14.5. This type of propeller has a hydrodynamic advantage of recovering part of the rotational energy which would otherwise be lost in a conventional single screw system. In this structural analysis, the static and the dynamic response are observed and evaluated.

Keywords: Contra rotating propeller, Static and Harmonic analysis, Finite Element Analysis

1. INTRODUCTION

The component of a ship which converts the engine power into the driving force of the ship is called as *Propeller*. Contra-rotating propellers (CRP) is a type of propulsion system which consists of two propellers on the same line of shaft, spaced at short axial distance apart and rotating in opposite directions. The pitch and loading of the propellers are designed such that the resulting rotational energy in the wake is zero. To reduce shaft vibrations the number of blades of both propellers is different, so that not all blades pass each other simultaneously. The diameter of the front propeller is often slightly larger than that of the rear propeller, to account for the contraction of the propeller wake and to avoid the rear propeller to hit the tip of vortex of the front propeller.

2. DESCRIPTION

In this work static and dynamic analysis of the contra rotating propeller is carried out.

In this design, we need to design the contra rotating propeller in such a way that it should withstand the thrust force acting on its blades. Material considered for this is Carbon Fiber Reinforced Plastic (CFRP).

Material properties of CFRP

Young's modulus	= 1.5×10^5 MPa
Poisson's Ratio	= 0.28
Density	= 1.5×10^{-12} Kg/mm^3
Thermal expansion	= 12×10^{-6}/°C

3. MODELLING AND MESHING

The CRP is considered as 3-D solid model. The structure is modeled using CATIA V5R19 modeling software as shown in Fig. 1. The model is meshed using hypermesh 10 with tetra mesh.

The model consists of 26,816 elements and 45,790 nodes. Fig. 2 shows the solid 92 element considered for meshing. FE model of the contra rotating propeller is shown in Fig. 3. Appropriate boundary conditions are incorporated in the analysis. The solid 92 is defined by ten nodes having three degrees of freedom (UX, UY and UZ) at each node - translations in the nodal x, y and z directions. The element has Plasticity, Creep, Swelling, Elasticity, Stress stiffening, Large deflection, Large strain, Adaptive descent, Initial stress import capabilities.

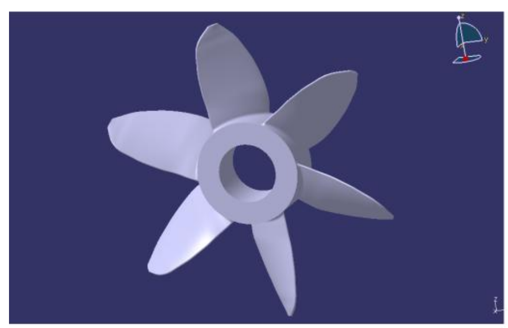

Fig . 1: Solid model of CRP

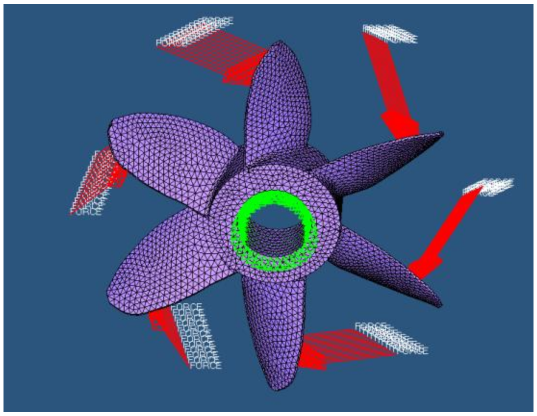

Fig.2 : Finite element model of CRP with boundary conditions

Table 1 : Quality parameters of mesh

Aspect Ratio	5
Tet collapse	0.1
Length	10
Min. angle of trias	20
Max. angle of trias	120

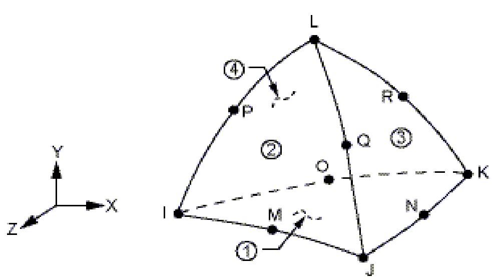

Fig. 3: Solid 92 element

4. Analysis of contra rotating propeller

Static Analysis

Static analysis is carried out to know the strength of the propeller blade by applying thrust force.

Harmonic Analysis

Harmonic analysis is carried out to know the frequency response of the contra rotating propeller.

5. RESULTS & DISCUSSION

5.1 Static Analysis

Static analysis of contra rotating propeller made with carbon fiber reinforced plastic is performed. Displacements in X, Y and Z directions are shown in Fig. 4, Fig. 5 and Fig. 6 respectively. Fig. 7 shows stress in X direction. Stress in Y direction is shown in Fig. 8. Fig. 9 shows stress in Z direction. The Vonmises stress of the CRP is shown in Fig.10

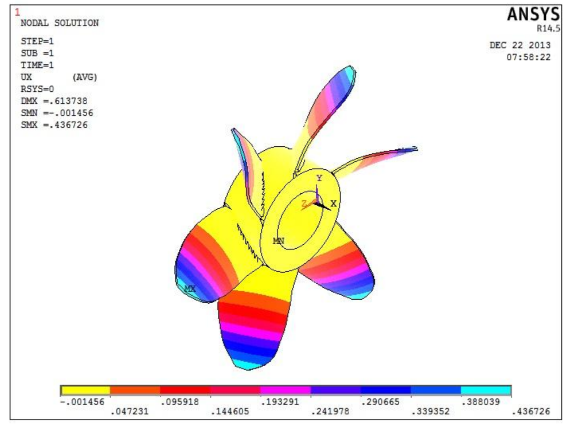

Fig.4: Displacement in X-direction

Table 2: Static analysis of CRP

Name	Results as per Analysis	Allowable stresses and deflection	Reference figure
Displacement in X-direction, mm	0.436	6.0	4
Displacement in Y-direction, mm	0.432325	6.0	5
Displacement in Z-direction, mm	0.388783	6.0	6
Stress in X-direction, MPa	52.0294	550	7
Stress in Y-direction, MPa	132.679	550	8
Stress in Z-direction, MPa	137.885	550	9
Vonmises stress, MPa	122.25	550	10

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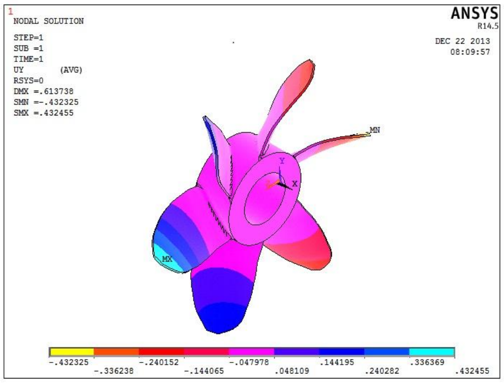

Fig. 5 : Displacement in Y direction

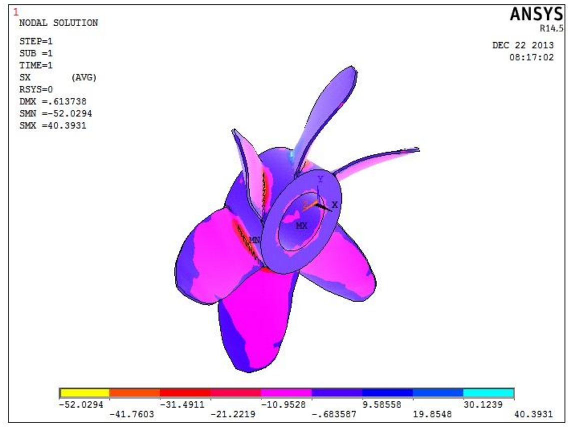

Fig. 7 : Stress in X direction

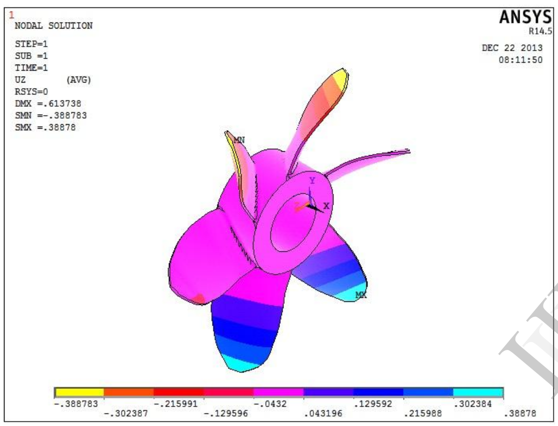

Fig. 6 : Displacement in Z direction

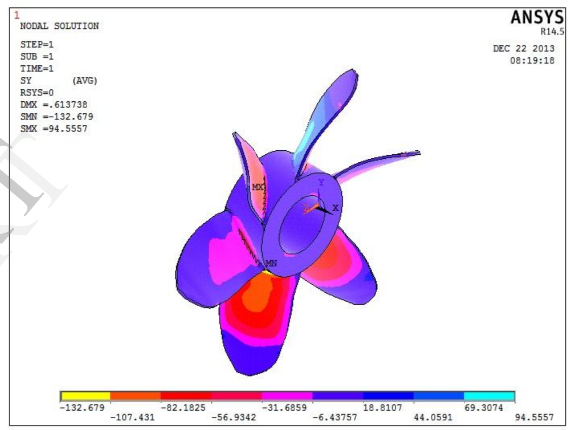

Fig. 8 : Stress in Y direction

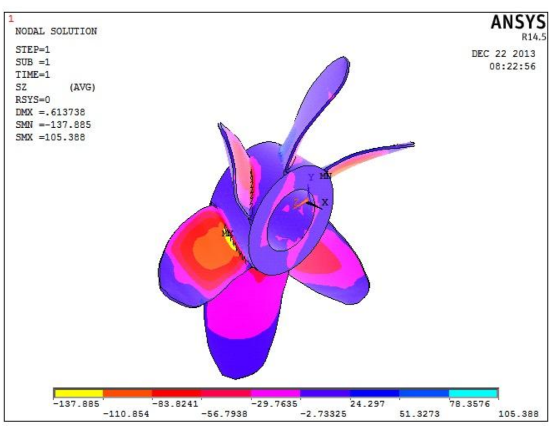

Fig. 9 : Stress in Z direction

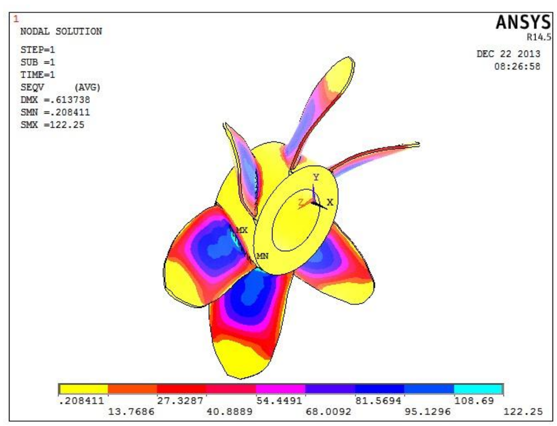

Fig. 10 : Vonmises Stress

5.2 Dynamic analysis

5.2.1 **Modal analysis** of contra rotating propeller made up with CFRP is done to find the natural frequency and the first set result is shown in Fig. 11

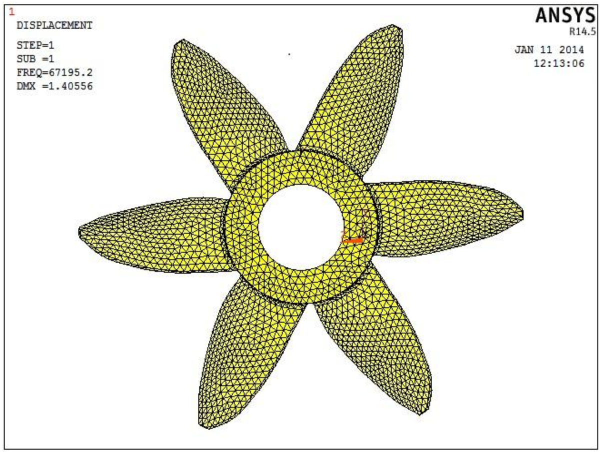

Fig. 11 : First set result is 67195Hz

5.2.2 **Harmonic Analysis** is carried out to find the frequency response of the CRP within the given range 50,000 to 80,000. amplitude vs frequency graphs in X,Y,Z directions are shown in Figs. 12, 13, 14

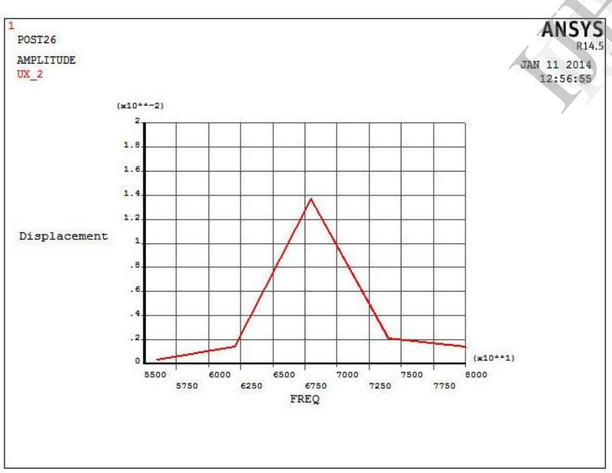

Fig. 12 : Disp. vs Freq. along X direction

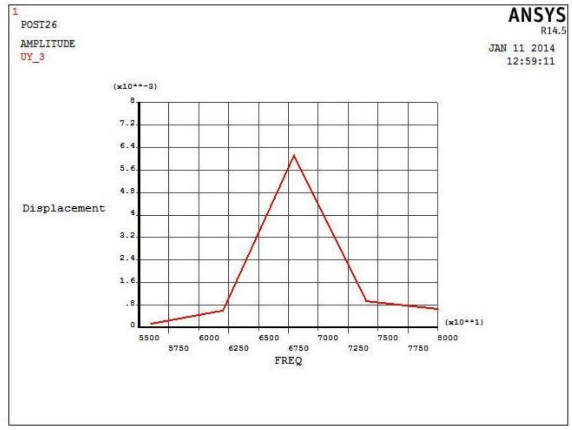

Fig. 13 : Disp. vs Freq. along Y direction

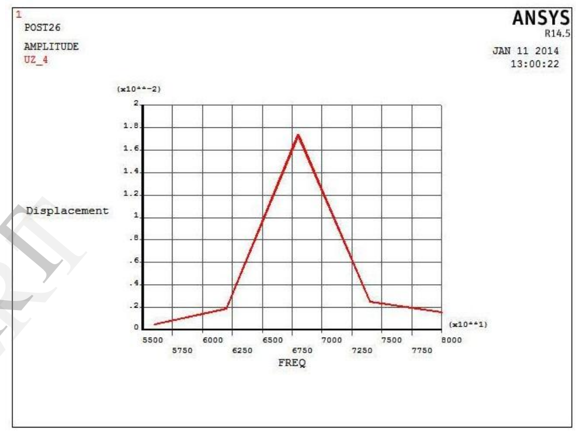

Fig. 14 : Disp. vs Freq. along Z direction

6. CONCLUSIONS

The following conclusions are drawn from the present work.

1. The maximum deflection induced is 0.4323 mm under 87 MPa load which is within the allowable limits i.e. < 6mm.

2. The maximum stress induced is 137.88 MPa which is less than allowable limit of 550 MPa. Hence the factor of safety is 3.98.

3. The natural frequency of the CRP is 67195Hz which is obtained in the first set of modal analysis.

4. The maximum displacement of the nodes is 6.2mm in the frequency range 50000 to 80000 Hz where there is a chance for resonance.

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