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# Static and Harmonic Analysis of Winch Shaft using FEM

**Sambaturu Gopi, Yedukondalu Talakonda, Eswar Balachandar G**

***Abstract*: It is not easy to lift the heavy loads with bare ropes or other components. Winches are very useful for various mechanical applications. In this present work, winch shaft is designed and analysed using Finite Element Method (FEM). Catia and Nastran programs are used for the modelling and analysis. Static and Harmonic analysis are carried out on the winch shaft. In static analysis the maximum displacement induced is .009817 mm, hence based on Rigidity, and stresses in Z-direction are observed to be 0.122E -0.7 mm and 158.731 N/mm$^2$ respectively. The maximum stress and fundamental frequencies found are 119.009 MPa and 143.98 Hz. The deflection value from theoretical calculations is 0.013 mm. The mathematical relations are used for the validation of the analysis and found good agreement.***

***Keywords*** **: CATIA, FEM , Harmonic, NASTRAN, Static, Winch Shaft.**

## I. INTRODUCTION

Winch is a crank with a handle giving motor to a machine. Winch gears are used to convert the high speed, low force input of the handle in to low speed, high torque output at the drum. These are quite highly developed and use tooth forms. That are significantly different from those found in other gear applications.

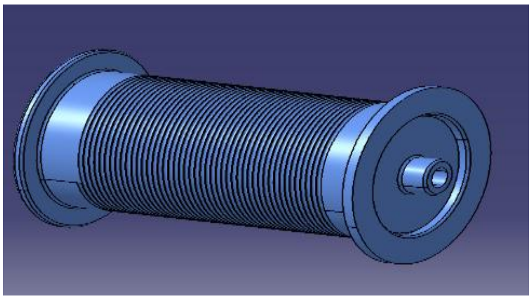

**Fig. 1. Winch Shaft**

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## II. LITERATURE SURVEY

Chun et. al [1] studied on winch and worked on static balance of winch. Scara et al [2] redesigned a naval winch and found good decrement in the total investment cost. Avinash et al. [3], Aditya et al. [4] and Nigam et al. [5] investigated on designing and analysis of winch with FEM. In recent times some of the researchers also used different commercial softwares for the fem analysis among which most used one is Ansys. Theoretical support is taken from the standard textbooks [6-8] and literature [9].

## III. MATERIALS AND METHODOLOGY

### A. Design Parameters

The following dimensions are used for the winch design from the literature and standard handbooks.

**Table- I: Materials for STHE**

| S. No | Description | Unit | Value |
|---|---|---|---|
| 1 | Outer diameter of the shaft | mm | 63.5 |
| 2 | Inner diameter of the shaft | mm | 50.32 |
| 3 | Thickness of the shaft | mm | 5 |
| 4 | Length of the shaft | mm | 275 |
| 5 | Diameter of the sleeves | mm | 150 |
| 6 | Thickness of the sleeves | mm | 5 |
| 7 | Distance of sleeves from shaft end | mm | 15 |
| 8 | Distance between the sleeves | mm | 230 |
| 9 | Outer diameter of the gear | mm | 50.32 |
| 10 | Inner diameter of the gear | mm | 46 |
| 11 | Gear tooth dimensions | mm | 2 & 4 |
| 12 | Length of the Gear tooth | mm | 10 |
| 13 | Number of teeth on gear | mm | 20 |
| 14 | Centerhole diameter | mm | 8 |
| 15 | Distance between center hole | mm | 5 |
| 16 | Downhub Thickness | mm | 14 |
| 17 | Down hub length | mm | 48 |
| 18 | Distance from Gear tooth to hub | mm | 34 |
| 19 | Down hub width | mm | 28 |
| 20 | Load on the shaft | kg | 1000 |

### B. Materials

The material used for making the winch shaft is Cast iron.

The properties of the Cast iron are

| | |
|---|---|
| Density | - 7.4E-09 Ton/mm3 |
| Young's modulus | - 2.4E+05 N/mm2 |
| Poisons ratio | -0.3 |
| Overall force applied | - 10000 N (load to be pulled) |
| Yield Strength | - 250 GPa |

## IV. MODELLING

The winch shaft is modeled by considering the shaft as welded part which is joined by welding front shaft part, cable holder shaft and sleeves as individual part and are assembled in assembly work bench by constraining according by given dimensions using CATIA V5.

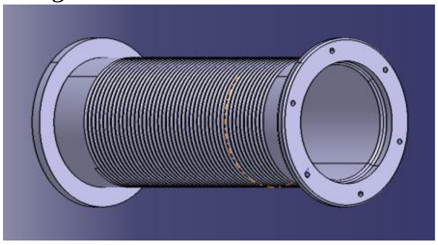

**Fig. 2. Isometric View of Winch Shaft as a welded Component**

## V. MESHING AND ANALYSIS

### A. Meshing

NASTRON PATRON is used for the analysis of winch shaft.

**Fig. 3. Finite Element Model of Winch Shaft**

### B. Boundary Conditions

The winch shaft is constraining at the sleeves on the both sides of the shaft and the shaft is constrained by bushing pin at one side and gear tooth shaft on the other side.So the nodes on the plate are selected and are constrained in all the three directions(i.e. along x,y,z). The load to be pulled will be acting along the dimensional direction nodes on the top surface of the shaft. The load is so divided that the total load is distributed to each load equally.

- Angular speed of 90 rpm has been applied on the wench shaft
- Aluminum material properties has been used with E (Young's Modulus) = 70000 MPa, density = 2.7E-06 kg/mm3

Entire inner surface has been constrained in all the three translations.(Ux, Uy, Uz) as shown in figure with blue colour

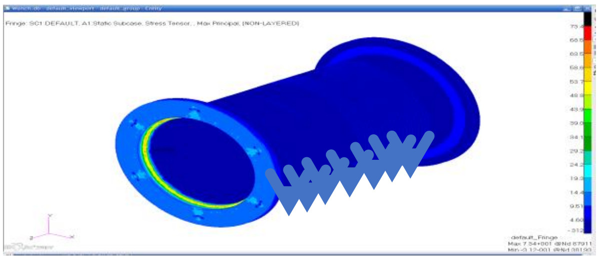

**Fig. 4. Finite Element Model of Winch Shaft**

### C. Static Analysis

The static analysis is performed from the input conditions, by using NASTRON PATRON program. The results and contours obtained are provided here. The figures shows, the variation of Maximum principle stress deflection in the winch shaft under static load condition. The static load tangentially on the shaft along the top surface of the shaft.

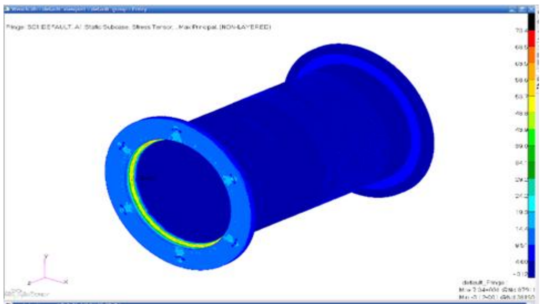

**Fig. 5. Maximum Principle stress deflection is 73.4 MPa**

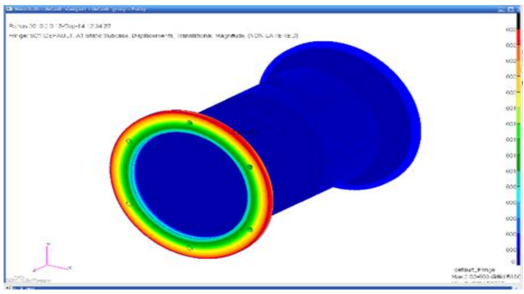

**Fig. 6. Displacement Representation of Winch Shaft**

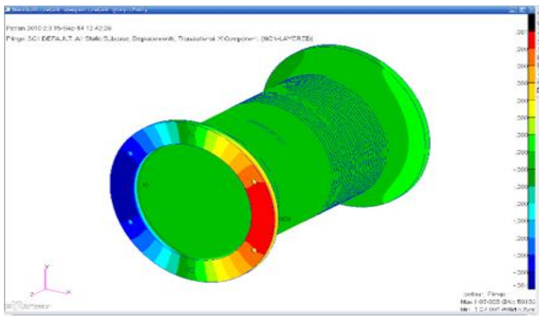

**Fig. 7. Representation of Winch Shaft Displacement in X-Direction**

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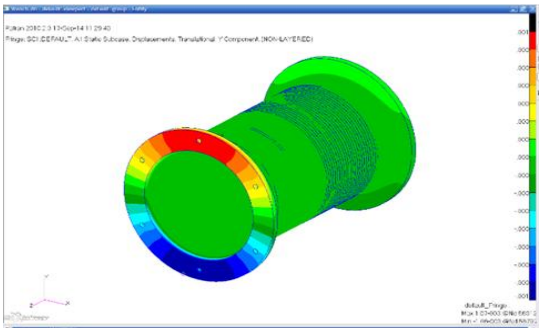

**Fig. 8. Representation of Winch Shaft Displacement in Y-Direction**

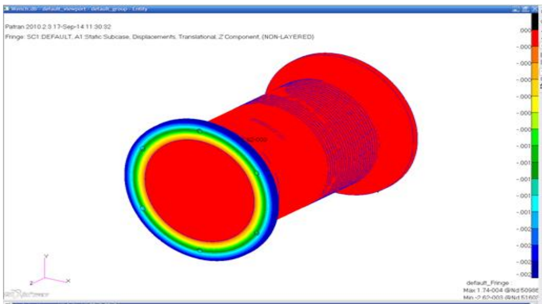

**Fig. 9. Representation of Winch Shaft Displacement in Z-Direction**

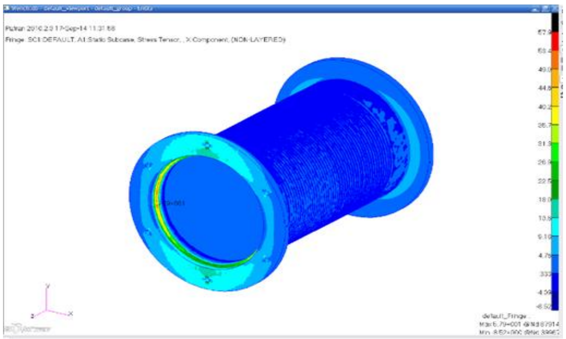

**Fig. 10. Representation of Stress Tenor in X-Direction**

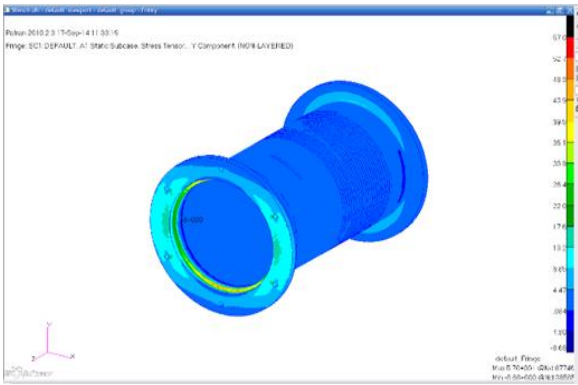

**Fig. 11. Representation of Stress Tenor in Y-Direction**

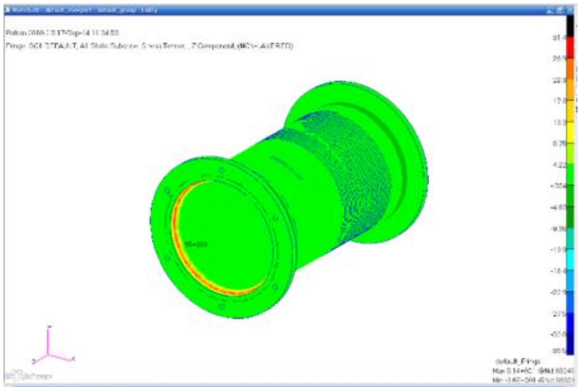

**Fig. 12. Representation of Stress Tenor in Z-Direction**

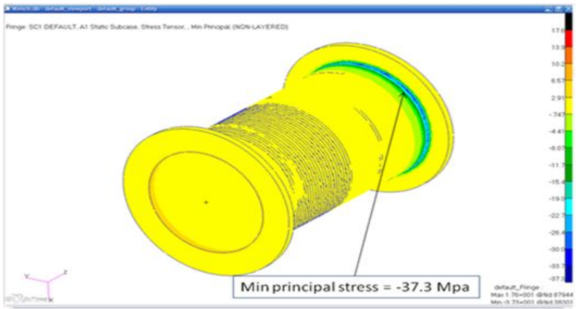


**Fig. 13. Representation of Stress Tenor of Maximum Principle Stress**

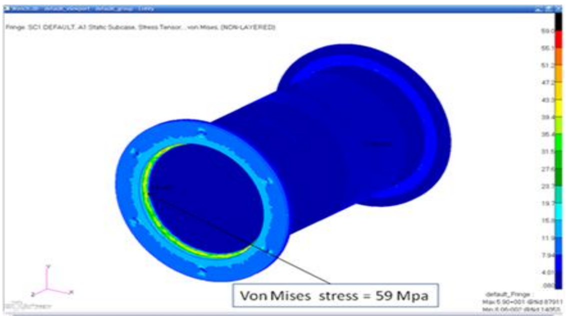


**Fig. 14. Representation of Stress Tenor of Von Mises Stress**

### D. Harmonic Analysis

Harmonic analysis is carried out under the applications of the load as the force on the model with in the frequency range of 0-400 HZ. This particular range is selected since the working range of frequency of the shaft is from 140-380 HZ.

In Harmonic analysis, Displacement is measured in the frequency range of 0-400 HZ, dividing the frequency into 10 sub steps. The response of the system to this excitation frequency is measured at three locations.

A node at the center of the shaft is selected and at that node is displacements are measured along all the directions. In the below displacements along Y-directions are shown as the force is applied in Y-direction

**Table- II: Displacement along Y at center of winch shaft**

| FREQUENCY(HZ) | AMPLITUDE(mm) |
|---|---|
| 40 | 1.00E-02 |
| 80 | 1.50E-02 |
| 120 | 2.25E-02 |
| 160 | 2.10E-02 |
| 200 | 1.01E-02 |
| 240 | 14.55E-02 |
| 280 | 2.00E-02 |
| 320 | 7.50E-02 |
| 360 | 7.30E-02 |
| 400 | 1.00E-02 |

A node at the front end of the shaft is selected and at that node is its displacement are measured along all the directions.

In the below displacements along Y-directions are showed as the force is applied in Y-direction.

**Table- III: Displacement along Y at front end of winch shaft**

| FREQUENCY(HZ) | AMPLITUDE(mm) |
|---|---|
| 40 | 0.10E-02 |
| 80 | 0.20E-02 |
| 120 | 0.21E-02 |
| 160 | 0.18E-02 |
| 200 | 0.19E-02 |
| 240 | 1.70E-02 |
| 280 | 0.19E-02 |
| 320 | 0.03E-02 |
| 360 | 0.05E-02 |
| 400 | 0.01E-02 |

A node at the Rear to end of the shaft is selected and at that node its displacement are measured along all the directions. In the below displacements along Y-directions force is applied in Y-direction.

**Table- IV: Displacement along Y at rear end of winch shaft**

| FREQUENCY(HZ) | AMPLITUDE(mm) |
|---|---|
| 40 | 1.00E-03 |
| 80 | 1.30E-03 |
| 120 | 1.50E-03 |
| 160 | 0.60E-03 |
| 200 | 1.20E-03 |
| 240 | 5.70E-03 |
| 280 | 0.50E-03 |
| 320 | 0.70E-03 |
| 360 | 0.9E-03 |
| 400 | 0.8E-03 |

### E. Theoretical Results

Theoretical results are found out by doing spice men calculations for reflection and stress according to mechanics o math's formula.

The winch shaft is considered to be as simply supported beam with uniform load and applied the boundary conditions.

The dimensions are

D = 63.5 mm

d = 50.32 mm

For simply supported beam with uniform loading,

Deflection y $= 5wL^4/(384\ El)$ (1)

$Y_{max}$ = 0.01365 mm (2)

From the bending moment equation

$M/I = \sigma/y = E/R$ (3)

Section Modulus = $Z = I/Y_{max} = \pi(D^4\text{-}d^4)/32D$ (4)

Stress = M/Z (5)

= 127.6 $N/mm^2$

From the calculations the deflection is 0.01365 mm and stress is 127.6 $N/mm^2$

## VI. RESULTS AND DISCUSSION

The static results are used for the structural behavior of winch shaft. Various displacement and stress results shown possible failure may be occur at the ends. The following represents the behavior of winch for the harmonic analysis at different places.

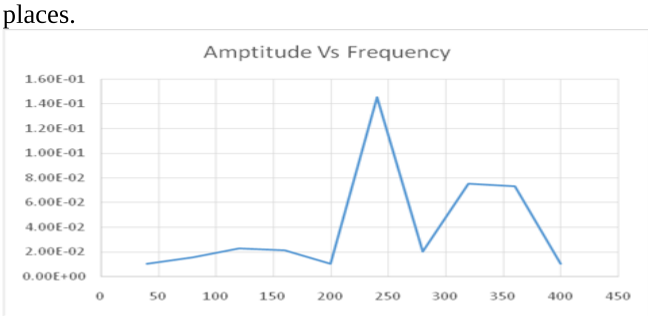


**Fig. 15. Amplitude vs Frequency at center of winch shaft**

The graph shows the amplitude of displacement, is found to be 0.15 mm at its fundamental frequency of 240HZ.

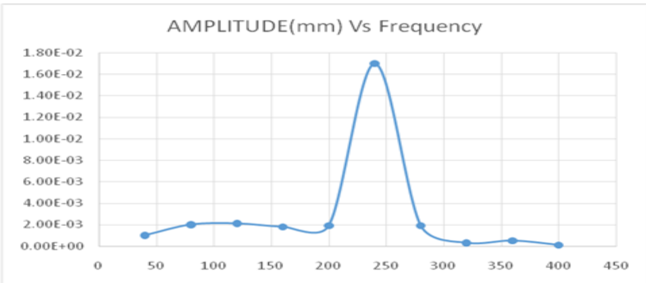


**Fig. 16. Amplitude vs Frequency at front end of winch shaft**

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From the above graph, the displacement is found to be 1.7E-02 mm at its fundamental frequency of 250 HZ.

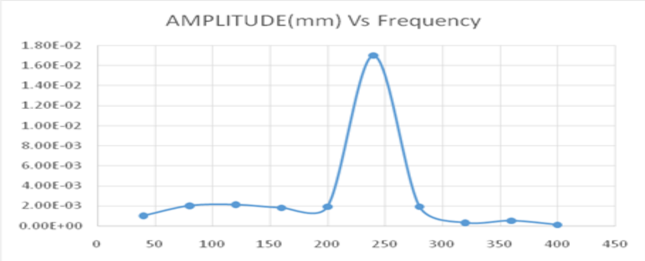


**Fig. 17. Amplitude vs Frequency at front end of winch shaft**

The graph shown the displacement of 5.7E-03 mm at its fundamental frequency at 240 HZ.

## VII. CONCLUSION

In static analysis, the maximum displacement induced is 0.009817 mm, hence based on Rigidity, and stresses in Z-direction are observed to be 0.122E -0.7 mm and 158.731 N/mm$^2$ respectively.

The maximum stress is found to be 119.009 MPa, which is less than the yield strength of the material (250 GPa). Hence, the design is safe based on strength. The von-Mises stresses developed are less than the allowable stresses.

From harmonic analysis, the fundamental frequency obtained is 143.98 Hz. The plots are drawn between amplitude vs frequency at different nodes on winch shaft.

The stresses developed in the casting part are less than stresses developed in welding part at the same load from the given data. The deflection value 0.0098 mm in analysis is approximately equal to the theoretical deflection value i.e. 0.013 mm and the stress obtained from analysis 119.906 N/mm$^2$ is less than the theoretical stress value 127.6 N/mm$^2$. It is concluded that, the analysis values are in good agreement with the theoretical one.

In future the work can be evaluated with different loads at different nodes of the winch shaft.

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