Design & Analysis of Housing Foot of a Planetary Gearbox using Finite Element Analysis.

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***Abstract*— Planetary gears are particularly useful for transmitting significant power with large speed reductions or multiplications. These kinds of gears are used in many fields of application like automotive passenger car and truck transmissions, aerospace engine drives, off-road vehicles and other industrial applications such as mining equipment and wind turbines.**

The analysis is carried out on housing foot of the planetary gearbox assembly. It provides support to the shaft, bearings and the gear loadings. The strength of the housing foot is an important parameter to be taken into account while designing. In order to evaluate the strength, of the housing foot, a step by step approach is adopted. To solve this problem it is essential to carry out the analysis of housing foot and redesign the existing housing foot in order to improve strength as well as save material. These models are made using part and assembly design module in CATIA V5R20 software. while static analysis is done in ANSYS V14 software. Optimization is based on ANSYS results, which can be used to enhance the efficiency of the design process.

Keywords*— *Planetary Gear Box Winch, Planet Carrier, body frame, Housing foot

INTRODUCTION

Planetary gearbox is used in machineries and machine tools to obtain speed reduction, which in turn increases the torque. These gearboxes are used in many applications such as automatic automobile transmissions and hybrid transmission systems.

Foot housing is a part of gearbox, it provides support to the shaft bearings and hence the gear loadings. Foot housing is typically a metallic material and made by casting process. Foot housing not only provides shield to the gear box but also support to the gearbox assembly. Foot type arrangement made in foot housing at the bottom for better support to the assembly. Thus, the strength of the foot housing should be more essential parameter.

METHODOLOGY

Planetary gearbox is commonly used to obtain speed reduction and increasing torque in winch mechanism. Winch is a mechanical device powered by planetary gear reduction system for hauling or pulling. Housing foot is basic but most important part of mechanical winch. It provides support to the shaft, bearings and the gear loadings. The strength of the housing foot is an important parameter to be taken into account while designing. In order to evaluate the strength, of the housing foot, a step by step approach is adopted. To solve this problem it is essential to carry out the analysis of housing foot and redesign the existing housing foot in order to improve strength as well as save material. These models are made using part and assembly design module in CATIA V5R20 software. while static analysis is done in ANSYS V14 software. Optimization is based on ANSYS results, which can be used to enhance the efficiency of the design process.

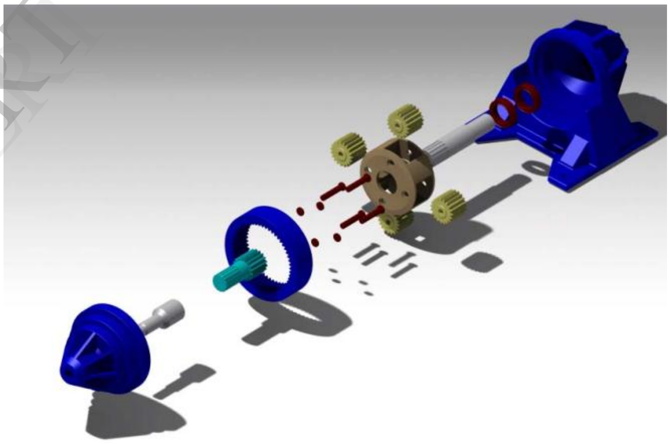

Figure no-1. 3-D Exploded view of planetary gearbox winch assembly

Following are the objectives of the work:

- To carry out static analysis using ANSYS for analyzing load effect on gearbox casing.
- In future for optimization and design modification of gearbox casing for better output performance.
- The most important advantages are decreased prototype development and assessment time.

Finite element model

The finite element method is a technique for mathematically modeling complicated shapes (feature) as an assembly of a simpler shape (elements) that is more easily defined. Linear and non-linear problem in engineering field are of the great importance to be studied in this work. Therefore, the Finite Element package called Ansys V14 has been chosen to solve this problem. The meshed carrier and planet gears are examples of 3-D finite elements models (FEM).

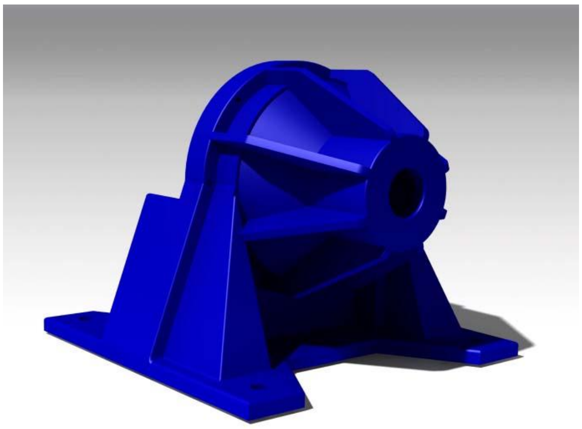

Figure no-2.

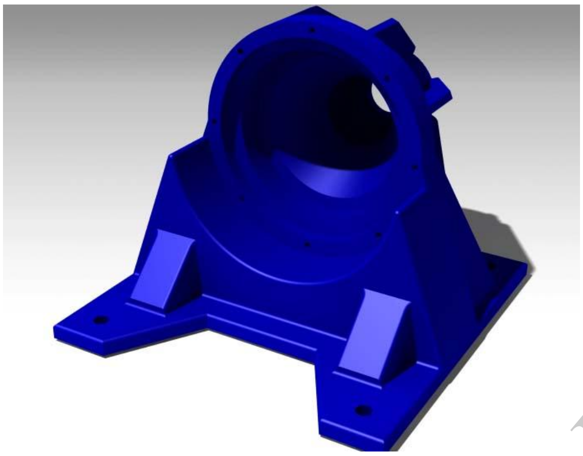

Figure no-3. 3-D structural modal of Housing foot prepared in CATIA V5R20

FEM here is used to characterize the dynamics of the carrier and planet gears efficiently and then these characteristics are split into elements. These elements are connected with each other through points called nodes. The complete collection of the elements is called mesh. Restraints and loads are added after this to the meshed part and whole thing then is called model. One advantages of FEM is thus, many different design concepts can be tested via computer, and shape can often be finalized before any prototype design. The finite element technique has been used in this paper to study the modal analysis of planet gears carries. The modal analysis has been used to determine the natural frequencies and associated mode shapes of the carrier system.

Mathematical Modeling

The considered planetary stage, consists of a Housing, planet carrier with four planets, a sun and a planet-ring wheel. The planet-ring is non-rotating and can be considered as rigid multi-body with discrete flexibilities of full gearbox with free boundaries. Technical parameters for the planetary gearbox are tabulated in Table 1.

Table 1. Technical Specification of Gearbox

Parameters	Sun Gear	Planet Gear	Ring Gear
Number of Teeth (N)	17	19	55
Pitch circle Diameter(DPC)	153	171	495
Root Diameter (DR)	135	153	517.5
Modular (m)	9	9	9
Pressure angle	20	20	20

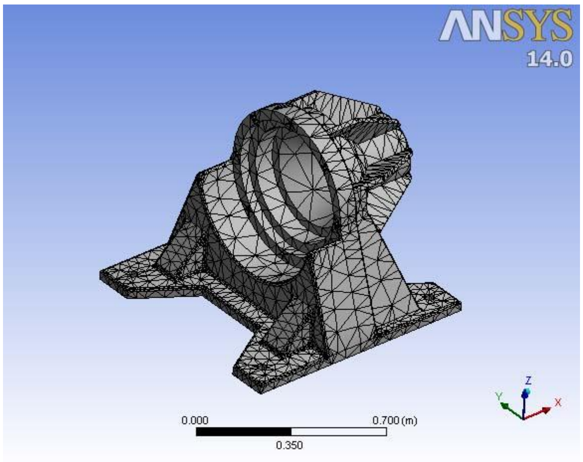

Figure no-4. Meshed structural modal of Housing foot

From the data obtained from the technical specification of gear box as shown in the Table 1, the rpm of the sun gear can be found out by finding the gear ratio for the particular or present stage (Pr) as given in equation 1.

Ratio (Pr) = Nr/Ns + 1 …………………………...……… (1)

Where, Nr = Number of teeth in ring gear

Ns = Number of teeth in sun gear

From equation 1, the gear ratio of present stage was calculated to be 4.23.

The difference in the gear ratio (Rd) is given by

Ratio Difference (Rd) = Fr/Pr……………………….……… (2)

Where, Fr = Final gear ratio

Pr = Present gear ratio

From equation 2, the ratio difference was found to be 106.85.

Also, the rpm of sun gear can be found by the equation

Sun Gear RPM= I rpm……………………………...…… (3)

Where, I rpm = Input rpm

Rd = Ratio difference

The sun gear rpm was calculated to be 9.24 rpm from equation 3.

The torque generated by the sun gear is given by

Torque in sun gear= P / ω…………………………… (4)

Where, P = Output power

ω= Angular velocity

Calculate torque generated by the sun gear was 22736.42 Nm

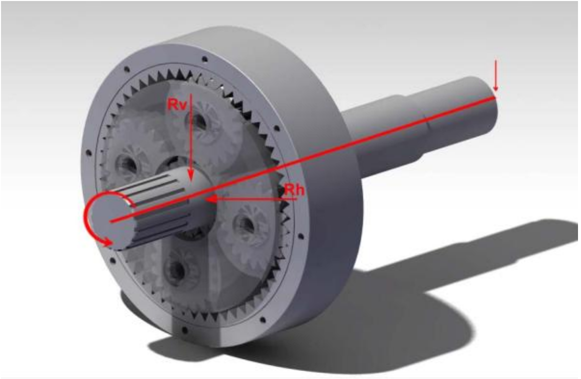

Figure no-5.

Here are descriptions of load conditions over the foot housing. There is two types of loads are applicable over the foot casing. Those are static load and dead weight of output shaft and bearing. So, overall load is the combination of static load and dead weight. Static load of transmission gear and drive shaft act on bearing. As shown in figure no.-5, loading conditions are occurs and we have to find out bearing load Rv & Rh situated at location B. Force F is acting perpendicularly to the shaft from planet-gear carrier.

Force F will be. Where torque T and distance r are known,

$$T= F/r$$

$$F=T/r= (22736.42/0.09)$$

$$F=2.526\times10^{5}\ N$$

Using those load conditions we can find bearing loads by taking vertical and horizontal reactions. Those loads are as follows,

$$Rv= 217837.85\ N$$

$$Rh= 340087.15\ N$$

Total reaction will be,

$$R'= \sqrt{(Rv^2+Rh^2)}$$

$$R'= 4.0387\times10^{5}\ N$$

Now total load acting on foot casing R is,

R=R'+ dead weight of shaft & bearing

$R= 4.0387e5 + 353.0949$

$R= 4.0422\times10^{5}N$

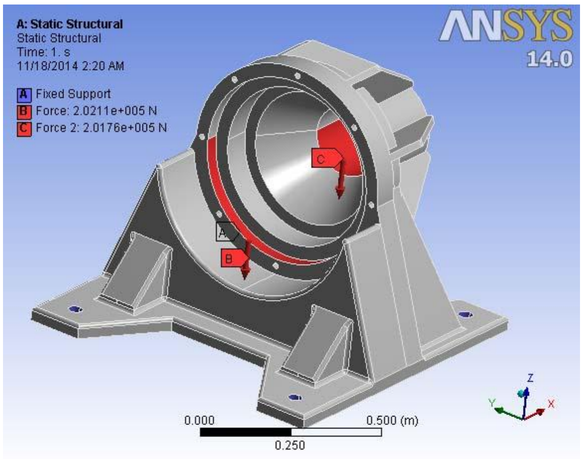

Figure no-6.

RESULT AND DISCUSSION

Study has been carried out to evaluate static analysis of the gearbox Housing foot using commercial software ANSYS V14. Analysis is to find out the total amount of stresses and deformation of any structural component by applied load. Initially, It was carried out for the existing model of the Housing foot of planetary gearbox winch the deflection at the region of bearing fixed was observed to be 0.0004144 mm as shown in (Figure no.- 7) and von-Mises stress plot observed for the existing model as shown in (Figure no.-8). The maximum von-Mises stress was found to be 3.3924e8Mpa

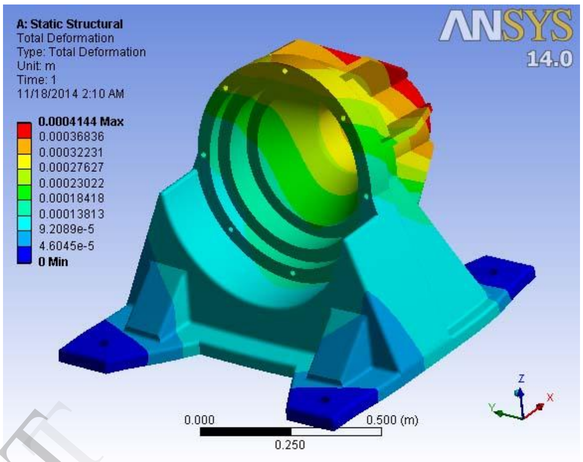

Figure no-7 Deflection act on Housing foot

The size has been varied by keeping loads and boundary conditions constant. The results obtained using these conditions are shown in Figure 7 and Figure 8 respectively.

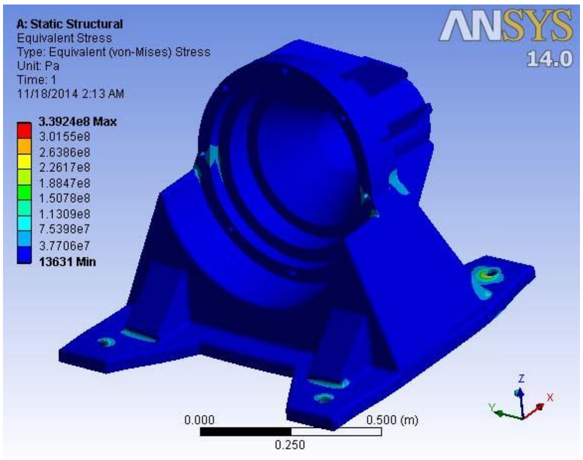

Figure no-8. Von-mises Stress act on Housing foot

CONCLUSION

The results obtained from the finite element analysis, the model showed good results with von-Mises stress of 3.3924e8Mpa., deflection of 0.0004144 mm and with factor of safety is good as compared to other modified models. These results are so far better than existing model. In practice analysis is also important factor for the optimum design and reverse engineering of any mechanical structure and system.

SCOPE FOR FURTHER WORK

This process helps in finding the optimized design for the Housing foot of planetary gear trains in which it has the best performance without any failure and with Optimum Loads acting on the housing foot. The main aim of this research is to optimize the planetary gear train through load analysis, to prevent load failure from happening in the future.

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