Modelling and Structural Analysis of Planetary Geared Winch

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Abstract: ***Planetary gear sets are used widely in many diverse product applications. Their compact and co-axial design and gear ratio make them preferable to counter-shaft gear drives. Planetary gear sets are complex, multi-mesh systems formed by multiple stages of planet gears that are in mesh with a sun gear and a ring gear and they are held by a common carrier through needle bearings and planet pins. Their design presents unique challenges stemming from a number of load factors issues, including their planet load sharing behavior, dynamic response, deflections, and support conditions. This study investigates the influence of load factors on gear stresses, and their impact on the resultant bending fatigue lives of the gears in planetary gear sets. These models are made by using part and assembly design module in CATIA V5R20 software, while the 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, Sun gear, Planet gear, Ring gear, Planet carrier.

1. Introduction

Planetary gearbox is widely used in industrial machineries and machine tools to obtain speed reduction, which in turn increases the torque. These gearboxes are used in many applications such as power transmission system and hybrid transmission systems. Planetary gear trains are one of the main subdivisions of the simple planetary gear train arrangement. The Planetary gear train arrangement in general has a central "sun" gear which meshes with and is surrounded by planet gears. The outer most gear, the ring gear, meshes with each of the planet gears. The planet gears are held to a cage or carrier that fixes the planets in orbit relative to each other. Planetary gear is a widely used industrial product in mid-level precision industry, such as printing lathe, automation assembly, semi-conductor equipment and automation system. Planetary gearing could increase torque and reduce load inertia while minimized the speed.

To compare with conventional gearbox, planetary gear box has several advantages. One advantage is its unique combination of both compact arrangement and outstanding power transmission efficiencies. A typical efficiency loss in a planetary gearbox arrangement is only 3% per stage. This type of efficiency ensures that a high proportion of the energy being input is transmitted through the gearbox, rather than being wasted on mechanical losses inside the gearbox. Another advantage of the planetary gearbox arrangement is load distribution. Because the load being transmitted is shared between multiple planet gear, torque capability is greatly increased. Higher load ability, as well as higher torque density is obtained with more planet gear in the system. The planetary gearbox arrangement also creates greater stability due to the even distribution of mass and increased rotational stiffness.

Figure 1: Arrangement of Planetary gear train

2. 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. Planet carrier is basic but most important part of mechanical winch. It provides support to the planet gear, bearings and the gear loadings. The strength of the Planet carrier is an important parameter to be taken into account while designing. In order to evaluate the strength, of the Planet carrier, a step by step approach is adopted.

To solve this problem it is essential to carry out the analysis of Planet carrier and redesign the existing Planet carrier in order to improve strength as well as save material. Gears are present in all kinds of machinery and vehicles because of their advantages over other available methods of transmitting power and matching the speeds and torques of one machine to another. Gear transmissions usually exhibit high power-to-weight ratios, can be made very compact and present the major advantage of high efficiency.

Figure 2: Modeling of Planet carrier

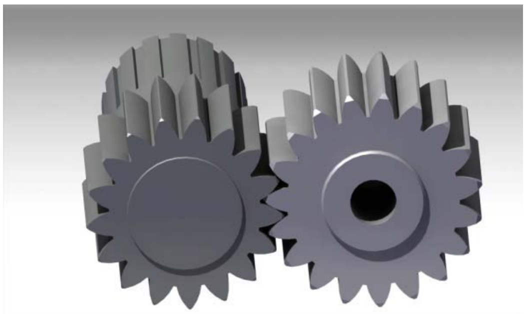

Figure 3: Sun gear and Planet gear teeth meshing

Figure 4: Planet gear and Ring gear

Figure 5: Close view Planet gear and Ring gear teeth meshing

These models are made using part modeling and assembly design module generated in CATIA V5R20 software and 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. Material selection criteria is based factors such as strength, rigidity, cost etc. FG260 is an appropriate element for planet carrier. FG260 is cast iron material which is mainly used for casting.

Following are the objectives of the work:

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

3. Finite Element Analysis

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). 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.

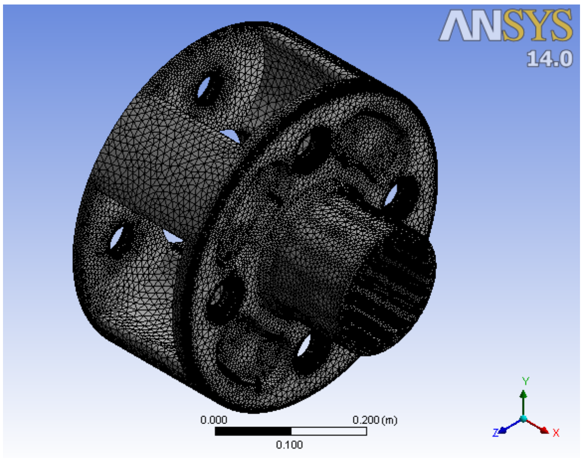

Figure 6: Meshed Wireframe view of planet carrier

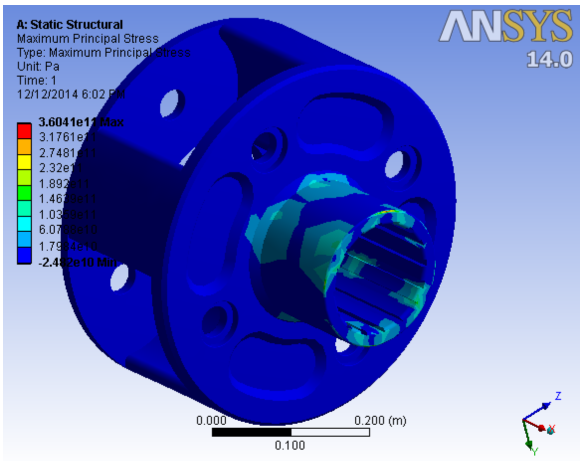

Figure 7: Principal stress act on planet carrier

4. Mathematical Modelling

The Planetary single 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.

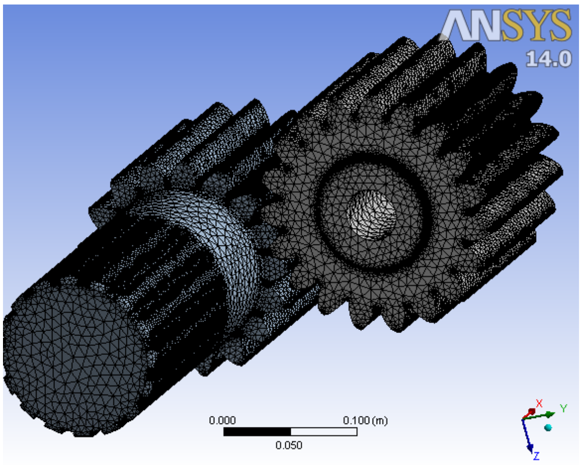

Figure 8: Meshed Wireframe view Sun and Planet gear

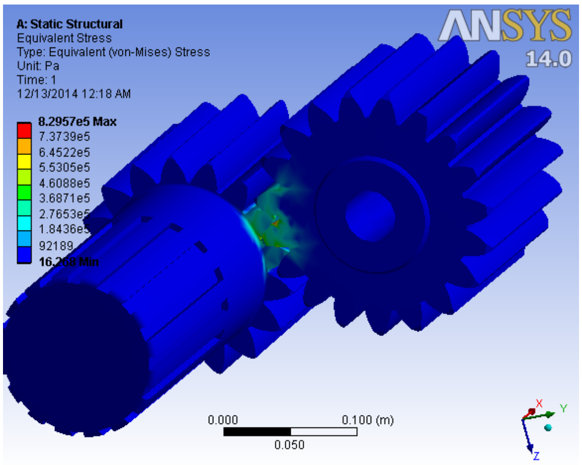

Figure 9: Stress act on sun & planet

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

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

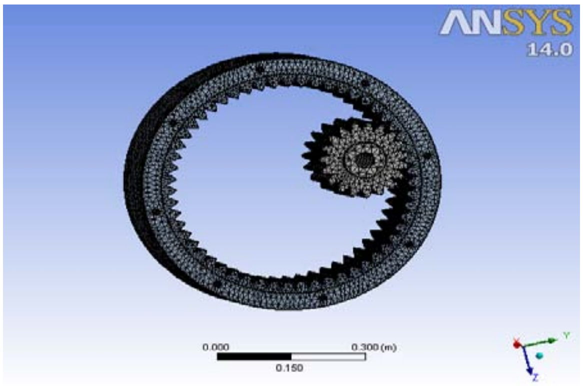

Figure 10: Meshed Wireframe view of Planet & Ring gear

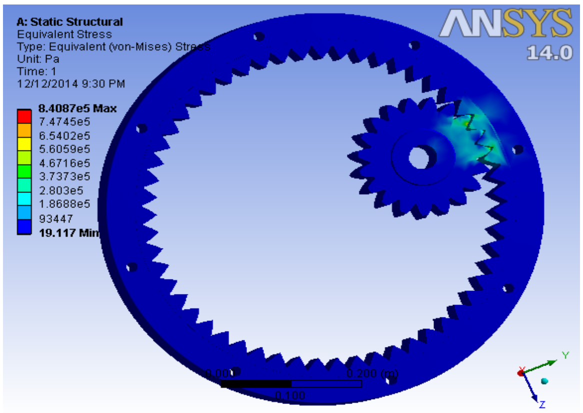

Figure 11: Stress act on Planet & Ring gear

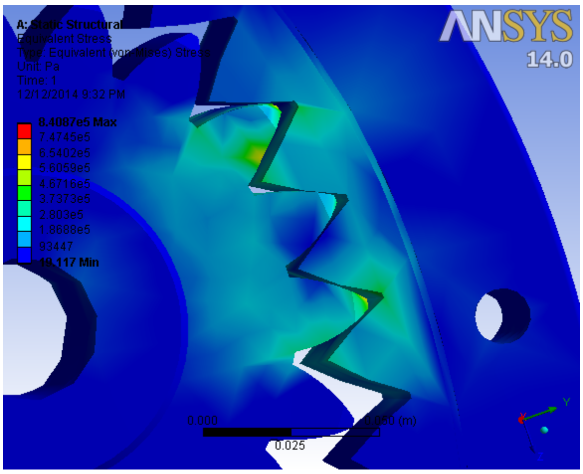

Figure 12: Close view Stress act on Planet & Ring gear

5. Result and Discussion

Study has been carried out to evaluate static analysis of the planetary gear-train using commercial software ANSYS V14. Analysis is to find out the total amount of stresses of any structural component by applied load. Initially, it was carried out for the existing model of the planet carrier, sun & planet teeth meshing, planet & ring gear teeth meshing of planetary gearbox winch. In planet carrier, the maximum principal stress at the region of shaft fixed was observed to be 3.6041e11Mpa as shown in (Figure no.-7). Sun gear teeth and the planet gear teeth mesh together von-Mises Stress acting 8.2957e5Mpa. Shown in (Figure no.-9) and other structural analysis shown in (Figure no.-11and12) Where planet gear and ring gear perform good result under acting von- Mises Stress of 8.4087e5Mpa.The size has been varied by keeping loads and boundary conditions constant. The results obtained using these relative conditions.

6. Conclusion

The results obtained from the finite element analysis, the Planet carrier of gearbox is manufactured by cast iron FG260 material. the model showed good results with maximum principal stress of 3.6041e11Mpa 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.

7. Scope For Further Work

This process helps in finding the optimized design for planetary gear trains in which it has the best performance without any failure and with optimum loads acting on the planet carrier. 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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