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Design and Analysis of Gear Box used in Mining Rigs

N. Ranjith Kumar[1], Badayi Nagaraju[2], Lakkoju Ravi[3]

[1,2,3]Department of Mechanical Engineering, Sri Indu College of Engineering and Technology, Hyderabad

Abstract: **Rotary head gearbox is Heavy duty hydraulic driven top head rotation head unit with single speed or dual speed arrangement having infinitely variable speed (0 to 500 rpm) and is designed for required user torque and speed. This unit travels on the mast and is of sturdy construction to absorb sudden & varying shock loads generally encountered during drilling operations. Based on requirement the type of Drive is selected whether it is a direct drive or Gear transmission. If we select Direct Drive then the torque and speed to be achieved by the rotary head will depend upon the torque and speed hydraulic motor. Only one motor can be used when user selects the Direct Drive. In Direct Drive the Main spindle of Rotary Head is directly connected to the motor shaft by providing the key slot on Main Spindle. Based on application we will be selecting the speeds of gearbox 1 speed or 2 speeds or 4 Speed Gear box. Only for Core Drilling we use 2 speeds or 4 speed gear box. In all other drilling applications single speed gear box has to be used. The analysis is done with maximum loads faced in core drilling. In the present work the geometric model is created in Catia Software and imported to hyper mesh for convergent Finite element mesh and analysis. Stress and displacement on gearbox are calculated by using Ansys software.**

Keywords: **Gearbox, Speed, Catia, Hypermesh, FEM, Ansys etc.,**

I. INTRODUCTION

Mining rigs are the machines which are used to drill rock or other hard material. These machines need all high strength parts to withstand heavy loads during drilling operation. The gearbox is one of the eminent parts which face heavy loads. In mining rigs the gearbox undergoes high frequency vibrations during the operation. Hence, a careful study of gearbox making is needed for successful running rig. A gearbox is a mechanical method of transferring energy from one device to another and is used to increase torque while reducing speed. Torque is the power generated through the bending or twisting of a solid material. This term is often used interchangeably with transmission. Located at the junction point of a power shaft, the gearbox is often used to create a right angle change in direction, as is seen in a rotary mower or a helicopter. Each unit is made with a specific purpose in mind, and the gear ratio used is designed to provide the level of force required. This ratio is fixed and cannot be changed once the box is constructed. The only possible modification after the fact is an adjustment that allows the shaft speed to increase, along with a corresponding reduction in torque. In a situation where multiple speeds are needed, a transmission with multiple gears can be used to increase torque while slowing down the output speed. This design is commonly found in automobile transmissions. The same principle can be used to create an overdrive gear that increases output speed while decreasing torque. A wind turbine is an example of a very large gearbox. The turbine moves at a slow rate of rotation with a great deal of torque. The transmission translates this power into the faster but lower torque rotational speed of the electricity generator. Due to the sheer size and the amount of power they can generate, wind turbines have multiple gears and stages. This feature is required to ensure that the electricity generator can provide a consistent output even as the turbine rate of rotation fluctuates. In an automobile, there are three types of transmission: automatic, manual, or continuously variable. A manual transmission vehicle provides the best example of a simple gearbox. In both the automatic and continuously variable transmissions, the gearboxes are closed systems, requiring very little human interaction.

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II. EFFECT OF GEARBOX IN INCREASING TORQUE

Most modern gearboxes are used to increase torque while reducing the speed of a prime mover output shaft (e.g. a motor crankshaft). This means that the output shaft of a gearbox rotates at a slower rate than the input shaft, and this reduction in speed produces a mechanical advantage, increasing torque. A gearbox can be set up to do the opposite and provide an increase in shaft speed with a reduction of torque. Some of the simplest gearboxes merely change the physical rotational direction of power transmission. Many typical automobile transmissions include the ability to select one of several gear ratios. In this case, most of the gear ratios (often simply called "gears") are used to slow down the output speed of the engine and increase torque. However, the highest gears may be "overdrive" types that increase the output speed. Many applications require the availability of multiple gear ratios. Often, this is to ease the starting and stopping of a mechanical system, though another important need is that of maintaining good fuel efficiency. The need for a transmission in an automobile is a consequence of the characteristics of the internal combustion engine. Engines typically operate over a range of 600 to about 7000 revolutions per minute (though this varies, and is typically less for diesel engines), while the car's wheels rotate between 0 rpm and around 1800 rpm. Furthermore, the engine provides its highest torque and power outputs unevenly across the rev range resulting in a torque band and a power band. Often the greatest torque is required when the vehicle is moving from rest or travelling slowly, while maximum power is needed at high speed. Therefore, a system is required that transforms the engine's output so that it can supply high torque at low speeds, but also operate at highway speeds with the motor still operating within its limits. Transmissions perform this transformation.

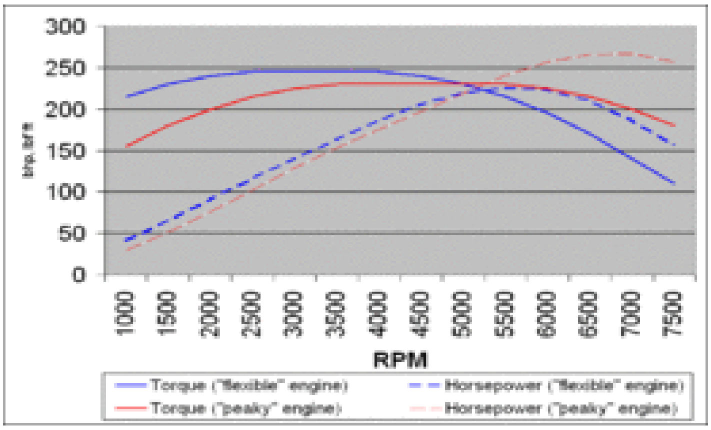

Fig. 1 Torque variation of flexible and peaky engine

A diagram shows comparison for the power and torque bands of a "torque" engine versus a "peaky" one. The dynamics of a car vary with speed: at low speeds, acceleration is limited by the inertia of vehicular gross mass; while at cruising or maximum speeds wind resistance is the dominant barrier.

III. MODELLING OF GEAR BOX

By using various commands in CATIA the following model is designed according to requirements that with high loads bearing capacity. With all required dimensions the solid model is prepared.

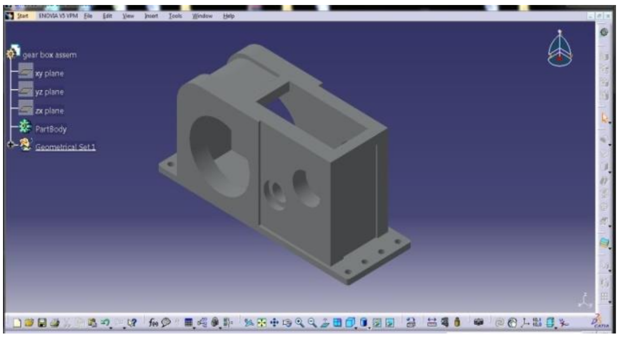

Fig. 2 Gear Box Isometric view

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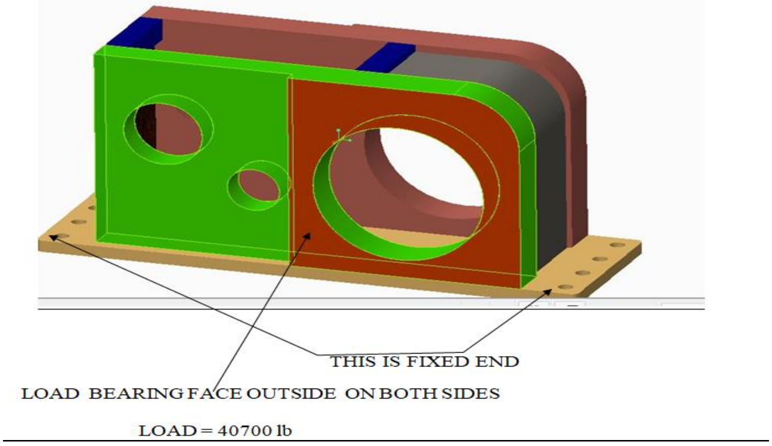

Fig. 3 loads and boundary conditions of a gear box

The above figure shows the application of loads during the operation of mining rig. This helps in analysing the gear box to decide it whether it can successfully withstand the loads or may be failing to withstand the same. This gear box is assembled to the transfer line of mining rig where it can be used to give varying speeds for the operations.

IV. FINITE ELEMENT ANALYSIS OF GEARBOX

Meshing is generated by using hyper mesh software. Mesh the geometry by using tetra hedral elements. Element type is solid 45. The meshed model is taken into the ANSYS software to complete the static analysis. The following figure shows applying the force in static analysis. It clearly shows that where the high amount of load is applied during the mining operation. For analysis of Gearbox the material is selected as steel as required and the properties are given as shown in the table. The meshed model is imported into the Ansys software and analysis is done for observing it deflection, Shear stresses in various directions as X, Y, Z, XY, YZ and ZX directions.

Material	**Youngs modulus(N/mm2)**	**Poisson's ratio**	**Density (tonn/mm3)**
Steel	**2.1e5**	**0.3**	**7.89e-9**

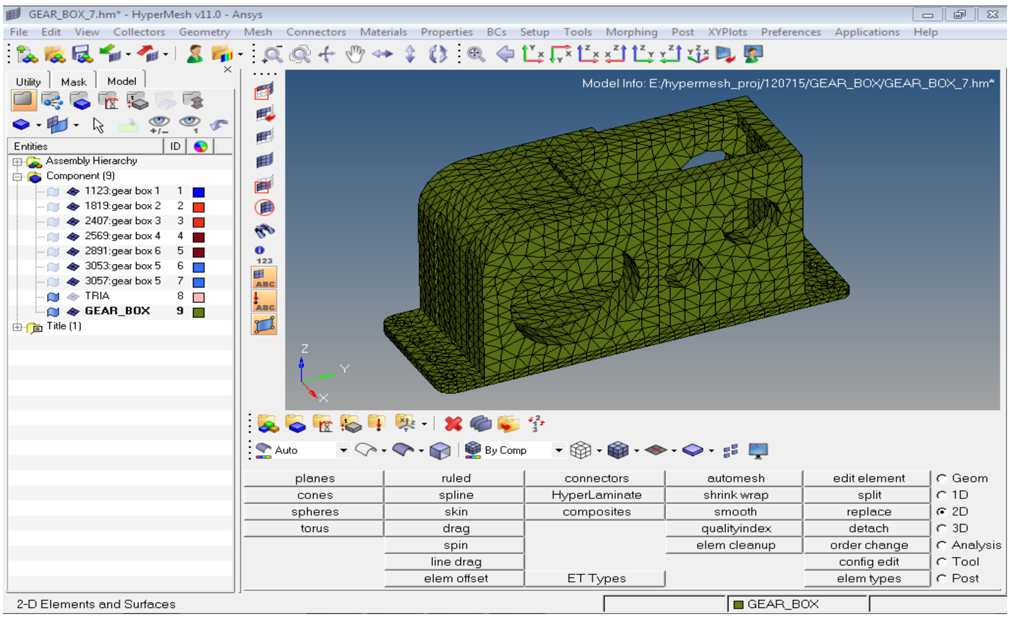

Fig 4 Mesh model of a gear box

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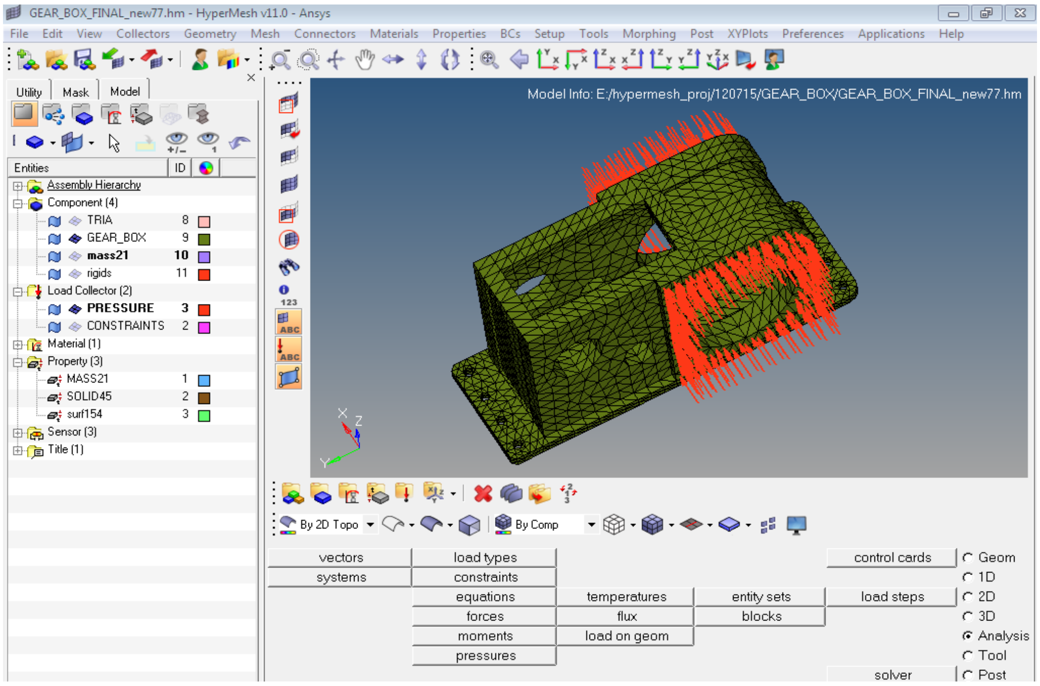

Fig. 5 Loading condition of gear box

The following figures show Ansys models for various results like deformation and stresses in various directions. It also shows the Vonmises stress to confirm the design and strength of the gear box.

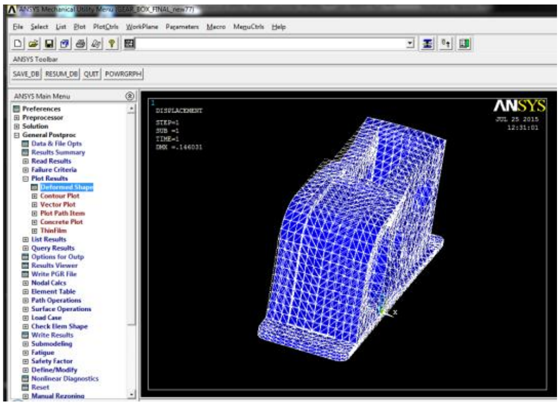

Fig. 6 Deformed-un deformed shape of a gearbox

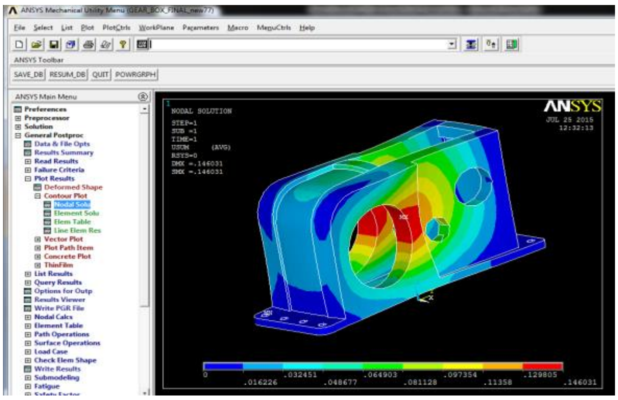

Fig. 7 Displacement vector sum of a gear box is 0.146mm

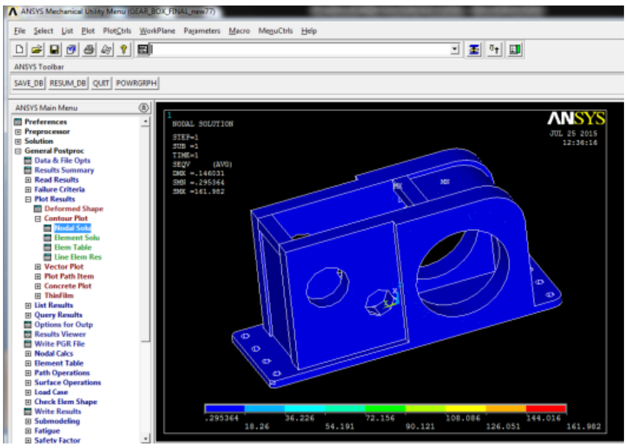

Fig. 8 Vonmises stress of a gear box is 161.98 N/mm^2

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V. RESULTS AND DISCUSSION

Results and Discussion:

Table 1 Various results by ANSYS

S.No.	Parameter	Resulting value
1.	Deformation of the gearbox shape	0.146 mm
2.	XY -shear stress	40.13 N/mm^2
3.	YZ-shear stress	23.139 N/mm^2
4.	XZ-shear stress	41.363 N/mm^2
5.	Vonmises stress	161.98 N/mm^2

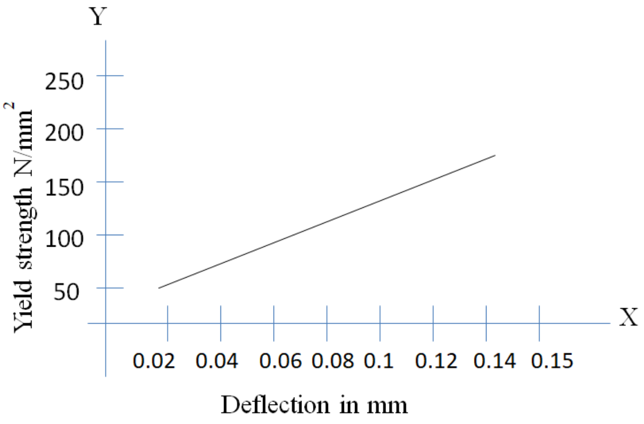

Fig. 9 Graph between Yield strength v/s Deflection

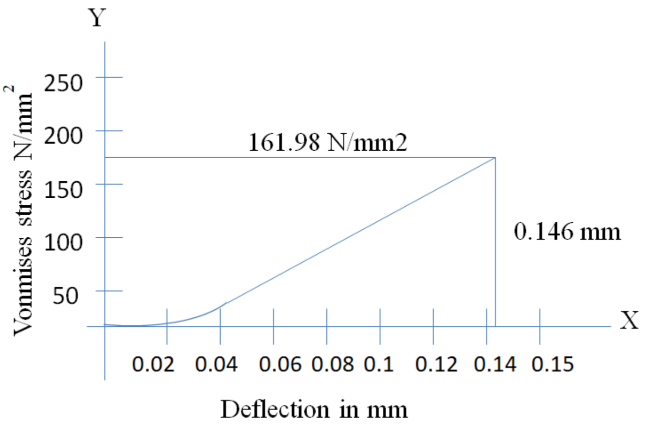

Fig. 10 Graph between Von-misses v/s Deflection

By analyzing the gearbox using Ansys, it is clear that all parameter which undergone through the effect of loads are within the limits. In Ansys, deformation, shear stresses in different directions and vonmises stress are solved. All the values are checked with reference of properties of steel used for making the gearbox. According the assembly of the gearbox on mining drill rig, where the pressure is applied on the gearbox are analyzed and all the calculations are done. The results shown are with the limit. So, the design is safe for manufacturing the Gearbox for mining rigs.

VI. CONCLUSION

The gear box was analyzed by finite element methods. From the above results the Maximum Von-misses stress observed is 161.98 N/mm^2. This value is under safe load condition. The Maximum Displacement for gear box observed is 0.0146 mm, which can be omitted for very small values. The Stress Levels for gear box was checked under max load condition with load of 40,700 lb (i.e. 181042 N) and proved to be safe design and suggested to use for drilling rig operations and

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also for Heavy Engineering Equipments. Our plan is to move a step further in carrying out the assembly analysis which would be compatible by simulation and would provide tangible benefits. And to analyze the data obtained from the data acquisition system to perform dynamic analysis.

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