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Modeling and analysis of Differential gear box using Ansys

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Abstract
The differential is a component of the rear axles, along with the wheels, bearings, and the inner axle housing assembly. Transmission gears in the differential link the rear wheels to the engine, which in turn powers the propeller. When turning, a car's differential gear arrangement creates a speed difference between the left and right driving axles. Outside wheels have further to travel in a turn than inside wheels. To provide this torque variation, a differential gear system constructed from a variety of materials using a refined 3-D model of the gear system is an option. Additionally, it transmits the power from the propeller shaft to each wheel hub. It takes a differential gear system at each wheel hub for an all-wheel drive system, whereas a rear-wheel drive system only needs one at the back.

INTRODUCTION

Gears are an integral part of nearly every mechanical device. Gears are a fundamental component of machinery, just as springs, nuts, and bolts. Gears have come a long way from their first uses, both in terms of materials and design. Aristotle, writing in the fourth century B.C., discovered the reversible rotation of gears and the transmission of motion from one wheel to another. Then, gears found their way into water wheels, clocks, and other devices. After that point, nothing changed for quite some time, until the 17th century, when the need for conjugate profiles began to increase. The significance of involute profiles emerged as a result. The modern form of these curves as used in gear toothing was developed, however, by Professor Robert Willis of Cambridge University. Hobbing equipment, including hob cutters, made its debut. Numerous advancements followed, and we're now in the present day.

Simply put, a gear is any component with teeth whose purpose is to transmit or receive motion via a mesh of successively engaged teeth. Because of its positive nature, the gear drive is superior to friction drives such as friction drums and belts. Gears can be found in a wide variety of vehicles and machines including cars, tractors, rolling mills, naval engines, forklifts, and metal-cutting machine tools. They're simple to operate, take up little space, consistently deliver on their promises, and are incredibly efficient. However, specialised equipment and materials are required to make them. Tooth milling flaws might also create operational vibration and noise. Gears on parallel shafts and gears on shafts with axes crossing at right angles should be favoured wherever possible. When a cylindrical gear called a spur gear is used as a reference, the traces of its teeth will produce straight lines.

Advantages of Gears:

Gear drives are used in a wide range of machines, such as rolling mills, cars, material handling equipment, marine power plants, and metal cutting machine tools-

(a) “Compact layout
(b) High efficiency
(c) Reliability in operation and
(d) Constant velocity ratio”.

Design practice in gears:

The concept of designing gears is not new. Ancient engineers effectively used it by establishing the gear design, using the appropriate gear performance, and being mindful of the operating situations. Gear drives were manufactured using available resources, technology, and methods.

There are specific requirements for the tooth profiles used in gearing to provide a steady gear ratio at all times. Regardless of how the point of contact shifts as the action progresses, the tooth curves must be built so that the common normal to the tooth profiles at the point of contact always passes through the pitch point. To be successful, the tooth curves must be finished.

The fundamental rack, which is the progenitor of the mating gears, must have a tooth profile that is symmetrical with respect to the pitch point. In this case, symmetry between the pitch point and the line of action is required. shapes similar to those of cycloid and involute gears.

LITERATURE REVIEW

Congfang Hu et. al. (2021) The effects of mistake randomization and dynamic load sharing were studied. Our first step is to build a model of stochastic multi-body dynamics utilising closed differential planetary transmission. We then assess the sampling and stochastic distributions for the load-sharing behaviour in light of the Taguchi technique. After that, we look at how the production and assembly processes within the tolerance zone affect load-effectiveness sharing. Finally, the experimental results for a MW wind turbine's main gearbox verify the results obtained using stochastic errors. The load-sharing coefficients in the differential stage are overestimated by the method with the most errors by 92%, and in the closed stage by 100%. Load-sharing faults are caused by the combined eccentricities of the sun gear, planetary/star gear, and ring gear. The solar gear's free-floating displacement is also impacted by the eccentric error. In order to ensure an even distribution of force, it is crucial that the manufacturing error of the planetary/star gear and the sun gear be maintained to a minimum.

Mehmet Sarıtaş et. al. (2021) The stress study of the three-stage gearbox is performed using the finite element analysis method and the commercial Ansys tool. Triple reduction helical gearboxes are constructed using AISI 5115 (16MnCr5) and AISI 8620 steels. This research involves both structural statics and stiff dynamic analysis. Firstly, the boundary conditions for helical gears are established, and then the analysis is performed. Gears' rotational velocities are input during static structural analysis. If different types of gearboxes are analysed before they are made, the product can be made with greater care, using the best feasible design parameters and the right safety factors. Following the completion of the static analysis, the dynamic analysis is performed using the modal analysis tool in the Ansys programme. After finishing the mode shape analysis and natural frequency analysis, the operating frequencies of the gearbox are calculated by taking into account the input and output rpm values. These calculated values are then compared to the typical operating state to see if there would be any resonance in the gearbox design.

Prasad Matam et. al. (2021) There were a number of studies examined for this study. Steel should be used for the gear design because of its strength, and aluminium should be blended with other materials to lower the weight of the differential gearbox. A novel framework might be useful in developing a revised differential gearbox. If we modify and add a third inclination gear change on the crown wheel, we may increase the differential's output from one information and two yields to one information and three yields. Research into the use of different materials may also provide ways to improve upon a three-yield differential gearbox. There are many more types of differential gearboxes, but since none of them is sufficient to meet the challenges on their own, we may need to combine them.

Ravi et. al. (2019) We use analytical and finite element analysis to study the bending and contact stresses in the involutes helical gear system. This has led to an increase in research into gear stresses as a means of reducing gear failures and guaranteeing the best possible design. This study makes use of the Lewis stress formula. Analytical approach for evaluating equipment includes certain assumptions and simplifies some equations to obtain maximum stress concentrations. This research examines the surface contact and shear stress of helical apparatus using yet another numerical technique. Furthermore, a parametric study is carried out to assess how changes in face size and helicopter angle influence the helical gear's geometry.

Shubham Palve et. al. (2019) carried out an investigation of the contact stresses and bending strains, as well as the transmission faults brought on by properly meshing gears. One of the most important aspects of mechanical power transfer is wheel work. Contact stress analysis was performed using finite element models. It is common practise to insert a spring into the gap between the two contacting areas in a FEM analysis of contact problems in order to generate a stiffness relationship between the two contacting areas. To do this, a contact component might be placed in between the two existing points of contact. These findings originated from the outcomes of simulations using the ANSYS two-dimensional finite element model. Measuring stresses in theory and comparing them to their theoretical counterparts is what was done here. All of the results are in full agreement with one another. A trustable FEM model is present here.

Xiaohan Tang et. al. (2019) Analyzing stress and strain under typical operating circumstances is how we find out if a structure is stable. With this, a theoretical groundwork and building guidelines for the gearbox may be laid. Results from the study indicate there is room for considerable development in the design of the gearbox. There's a chance that this will improve the signal's stability and transmission accuracy. When analysing a gearbox using finite elements, the first step is to generate a solid model of the gearbox in SOLIDWORKS; then, once the rated working load has been established, the model is simplified geometrically and imported into ABAQUS. The greatest stress that can be placed on the gearbox is far higher than the material's yield strength. With this method, the reasoning behind the gearbox's construction may be displayed. Based on the study's findings, the gearbox can be studied and evaluated to pinpoint its underperforming structural components.

RESULTS AND DISCUSSION

Results and Discussion

The differential gear model under study is partitioned into a tiling of basic framework components whose measurements are strictly constrained. Basic polynomial profile capacity and nodal displacement are assumed to calculate the difference in displacement inside each segment. The strains and stresses are established until the point of indeterminate nodal displacement. The result is a grid format in which the necessary requirements for equilibrium can be simply modified.

Here, we provide the outcomes of a three-part simulation analysis performed in Ansys, with each part corresponding to a different material.

Analysis of Differential gear with Aluminum Alloy material

Here, we present the findings of an Ansys analysis of an aluminum-alloy differential gear, complete with plots of the results and screenshots taken from the programme as it ran. Equivalent stress, deformation, and Shear stress are the output parameters we've chosen to analyse. Differential analysis of Aluminum Alloy is depicted in the figure below.

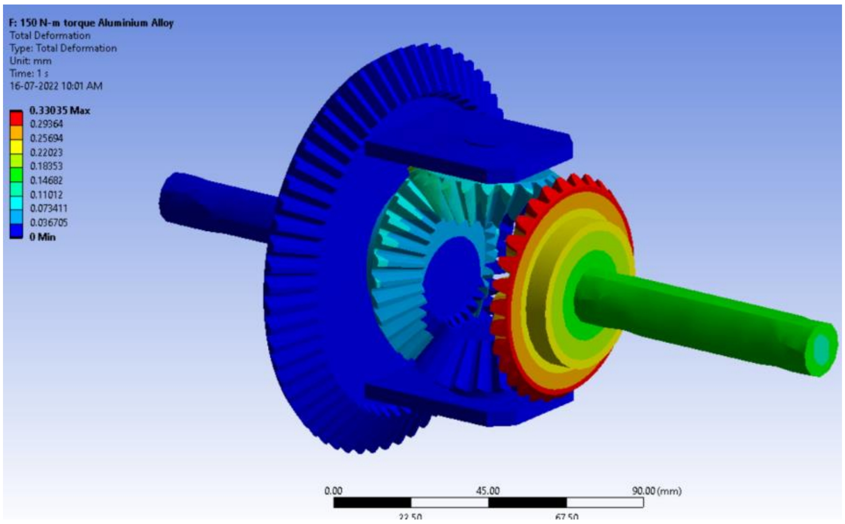

Figure 1: Total deformation of Gear assembly using Aluminum alloy material

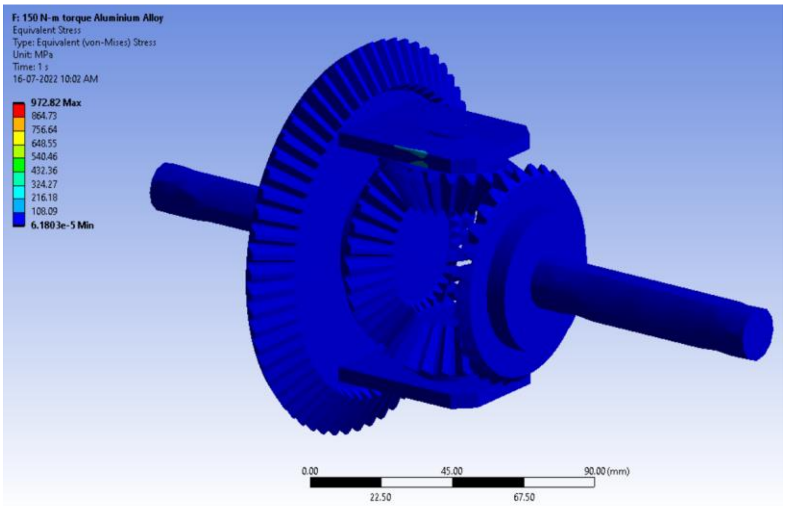

Figure 2: Equivalent Stress of Gear assembly using Aluminum alloy material

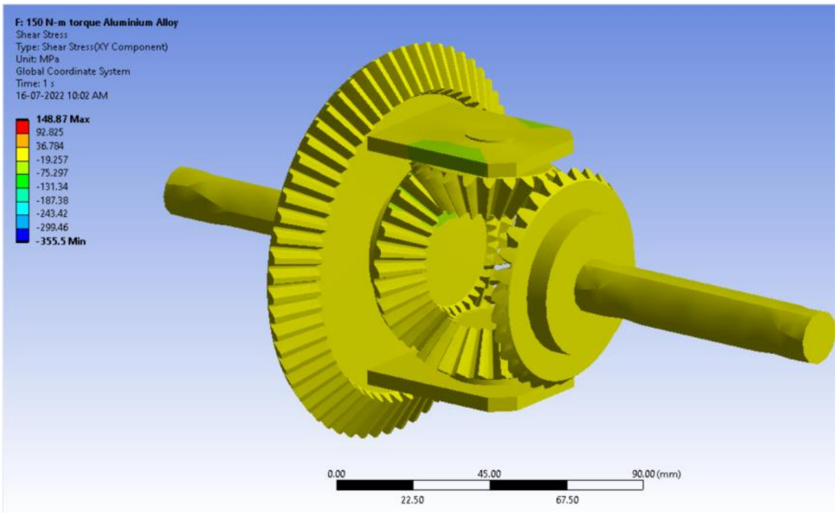

Figure 3: Shear Stress of Gear assembly using Aluminum alloy material

Analysis of Differential gear with Cast iron material

Here, we provide the findings of an Ansys examination of a differential gear made of Cast iron, complete with plots and screenshots of the software in action.

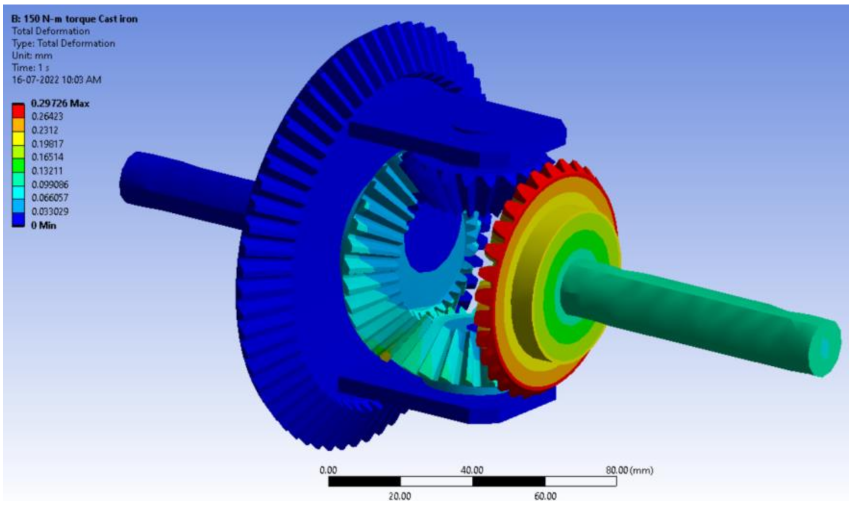

Figure 4: Total deformation of Gear assembly using Cast Iron material

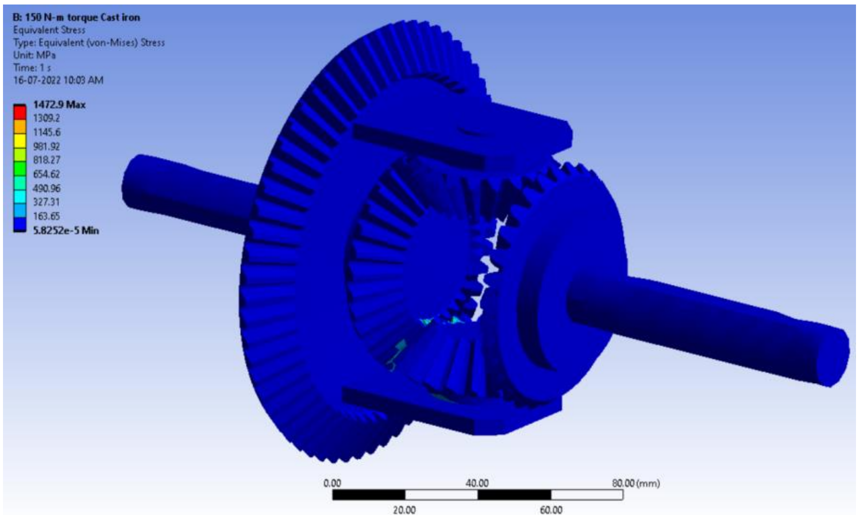

Figure 5: Equivalent Stress of Gear assembly using Cast Iron material

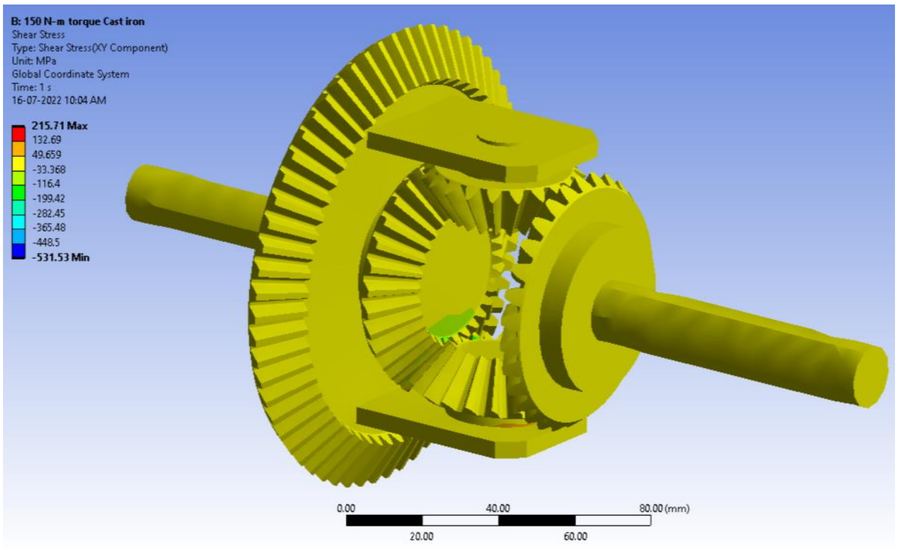

Figure 6: Shear Stress of Gear assembly using Cast Iron material

Analysis of Differential gear with Nickel Chrome steel material

In this part, we provide the findings of an Ansys study of a differential gear made of Nickel Chrome steel, complete with plots and screenshots of the software in action.

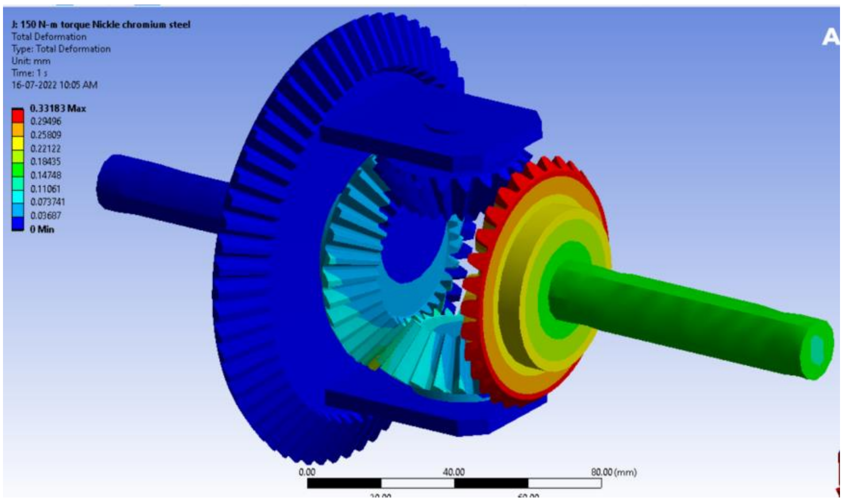

Figure 7**:** Total deformation of Gear assembly using Nickel Chrome material

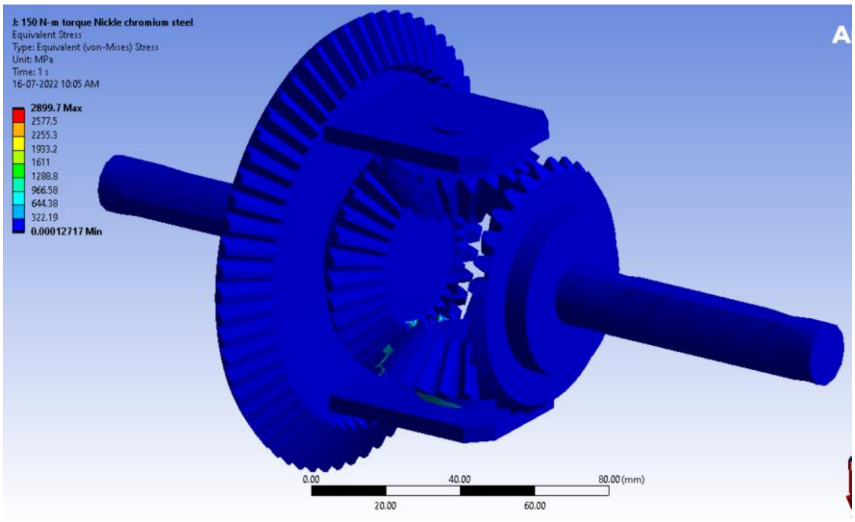

Figure 8: Equivalent stress of Gear assembly using Nickel Chrome material

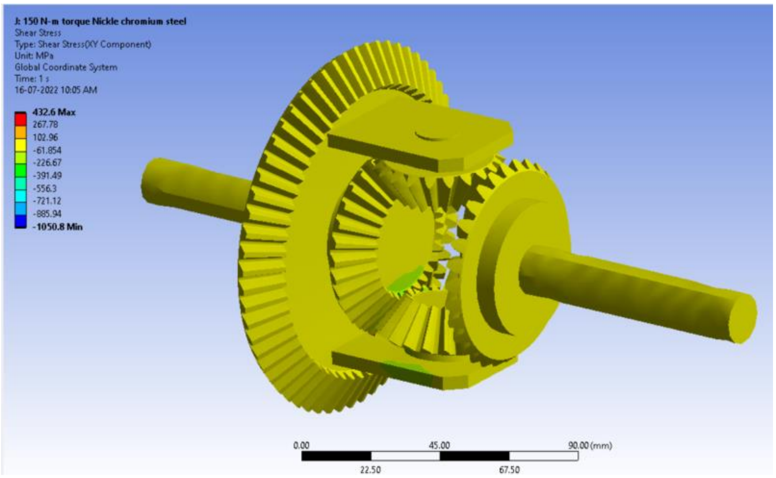

Figure 9: Shear stress of Gear assembly using Nickel Chrome material

Deformation of 0.3318 mm was measured at a torque of 150 Nm, as shown in Figure 7 of the aforementioned study. Figure 8 shows a situation with a high equivalent stress of 2899.7 MPa, whereas Figure 9 shows a high shear stress of 432.6 MPa.

Table 1 shows the comparison of all deformation developed in the Differential gear model at various torque provided with three type of materials variations.

Table 1: Total Deformations of Differential Gear model

Materials	Total Deformations (mm)			
	150 N-m	500 N-m	1000 N-m	2000 N-m
Cast Iron	0.297	0.296	0.295	0.293
Aluminium Alloy	0.33	0.329	0.329	0.328
Nickel Chrome Steel	0.331	0.331	0.296	0.331

Table 1 displays a comparison showing that Aluminum Alloy experiences a maximum deformation of 0.329 mm when subjected to a torque of 1000 Nm. Torque of 2000 Nm results in a minimum deformation of 0.293 mm.

Conclusion

Modeling a differential gear in Ansys reveals Nickel chrome steel gears were found to distort by a maximum of 0.331 mm at 150 N-m and 2000 N-m.

Some conclusion points are described below:

- Differential gearbox static analysis for various material combinations and torque variations.
- Differential gear box design scenarios with results for selected parameters are obtained.
- Various material combinations and differential gear box designs have been evaluated for total deformation, equivalent (Von-Mises) stress, and shear stress.
- We discovered that the Nickel chrome steel material deformed the most when subjected to 150 N-m and 2000 N-m, respectively.

- Although the deformation results for aluminium alloy are quite close to those for nickel chrome steel, the smallest deformation in gear assembly was observed to occur with a torque of 1000 Nm applied to the gear assembly made of nickel chrome steel.
- According to the research, Cast iron displays the least amount of deformation (0.293 mm) when subjected to a higher torque (2000 N-m). This demonstrates that cast iron provides the differential gear box's gear profile with more stability.
- According to the aforementioned research, the equivalent stress on Chrome nickel is the highest of any material at 2949 Mpa at 2000 N-m of torque, while the equivalent stress on cast iron is the lowest at 996.36 Mpa of deformation at 1000 N-m of torque. contrast between cast iron and nickel chrome steel.
- Based on the results of the shear stress comparison, we know that the nickle chrome material experiences the highest shear stress, at 442.64 Mpa, at a torque value of 2000 Nm, and that cast iron exhibits the lowest shear stress, which prolongs the life of the gears in the differential gear box. The shear stress of aluminium alloy is less than that of chrome nickel steel.
- Cast iron and aluminium alloy exhibit less deformation and strains than chrome nickel steel; maximum failure is observed in the chrome nickel steel material; cast iron is determined to have superior strength in gear assemblies.

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