Review on Failure Analysis of a Differential Crown Gear in Rear Axle of an Automobile

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ABSTRACT: In this project work, bevel pinion and crown gear present in the differential assembly is redesigned. The selected crown gear is the existing part of the SAFARI, the passenger car. In this project, the crown and pinion material is replaced by upgraded material with more strength and durability of the gear set. Bevel pinion and crown gear are High efficiency gears (98 and higher) which can transfer power across non-intersecting shafts. Spiral bevel gears transmit loads evenly and are easy going than straight bevel.
This project, gives the detail summary of the material selection, its load transmission, design of crown gear of differential, selection of different loads to clarify certain design factors and comparison between considered material which offers better results. For the material change approach, steel grade SAE 9310 is analysed and compared with other material in terms of strength, mechanical properties, torque increment, processing, cost, etc. Strengths and strain are calculated theoretically and also with (ANSYS 16.0) analytical tool by tolerating loads on materials. Here, Crown Gear is designed and analyzed for different speeds at 1200 rpm, 2000 rpm and 4000 rpm. Analysis is also conducted by varying the materials for gears, SAE 9310, AISI 4310 and Aluminium Alloy. Further, the analysis is conducted to verify the best material for the crown gear in the gear box at higher speeds by analyzing stress, displacement and also by considering weight reduction. Analysis is done on the differential by applying tangential and static loads.

KEYWORDS: Design of Crown Gear, Analysis of Crown Gear.

INTRODUCTION

The power from an engine is transmitted equally between the driving wheels through clutch system, a propeller shaft to transmit the torque output from the gear box to the rear axle using differential gear [1]. In automobiles and other wheeled vehicles, the differential allows the outer drive wheel to rotate faster than the inner drive wheel during a turn. This is necessary when the vehicle turns, making the wheel that is travelling around the outside of the turning curve roll past and faster than the other. The average of the rotational speed of the two driving wheels equals the input rotational speed of the drive shaft. It should be noted that in the interest of sound engineering and good gear design practice, the total number of teeth in a gear pair should, wherever possible, be an odd number which is not divisible by any other number, so that when the gear ratio pair is calculated an unequal number of teeth is called for on the gears [2]. An increase in the speed of one wheel is balanced by a decrease in the speed of the other. When used in this way, a differential (hereafter, diff) couples the input shaft (or prop shaft) to the Pinion, which in turn runs on the Crown wheel of the diff. This also works as reduction gearing to give the ratio.

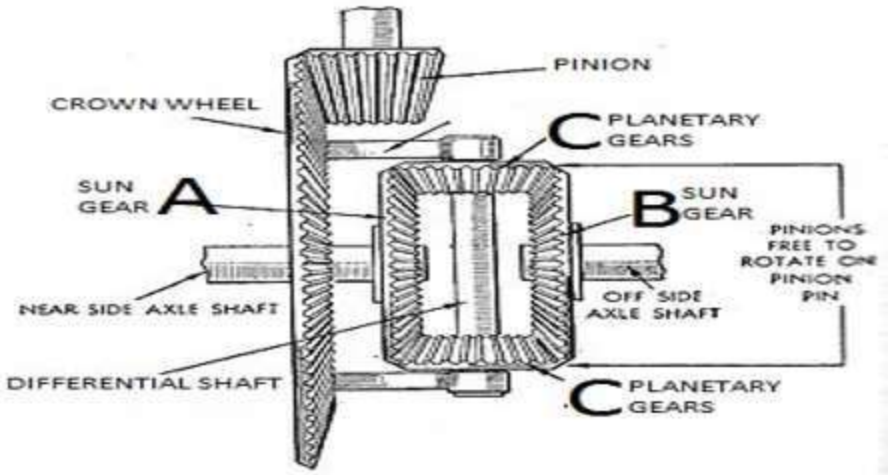

Fig.1 Crown and Pinion in Differential view [3]

A typical crown wheel and pinion used in heavy vehicles, are the most stress liable parts of a vehicle and demands high wear resistance, high contact fatigue strength.

LITERATURE REVIEW

A Bensely Albert et al. (2006) [4] - investigates failure of crown wheel and pinion. A fractured gear was subjected to detailed analysis using standard metallurgical techniques to identify the cause for failure. The study concludes that the failure is due to the negotiation made in raw material composition by the manufacturer, which is evident by the presence of high manganese content and non-existence of nickel and molybdenum. Author pointed out that, Crown and pinion are most stress prone parts of a vehicle and demands high wear resistance, high contact fatigue strength. Further, an ideal crown wheel and pinion should have uniform and optimum metallurgical quality, excellent heat distortion control, maximum impact strength, stiff wear resistance, optimal transmission efficiency, less noise, vibration free qualities. Author mention here that, above qualities may achieve with Gas carburizing process. He suggested that the manufacturer should make the critical component durable and efficient through accurate and consistent manufacturing standards by selecting appropriate materials and correct heat treatment parameters.

S H Gawande et al. (2013) [5] described the design of crown wheel and pinion in differential gear box of Main front wheel design(MFWD) of Front wheel assist(FWA) in Axle of TAFE MF455). His study gives the detailed knowledge about the modelling, assembly and analysis of tooth of crown gear and pinion, performed in Pro-E. as shown in Fig. 2. Author suggested material 18_NiCrMo5 for Crown Gear. He analysed crown gear tooth of gear set for different working load with Finite element analysis.

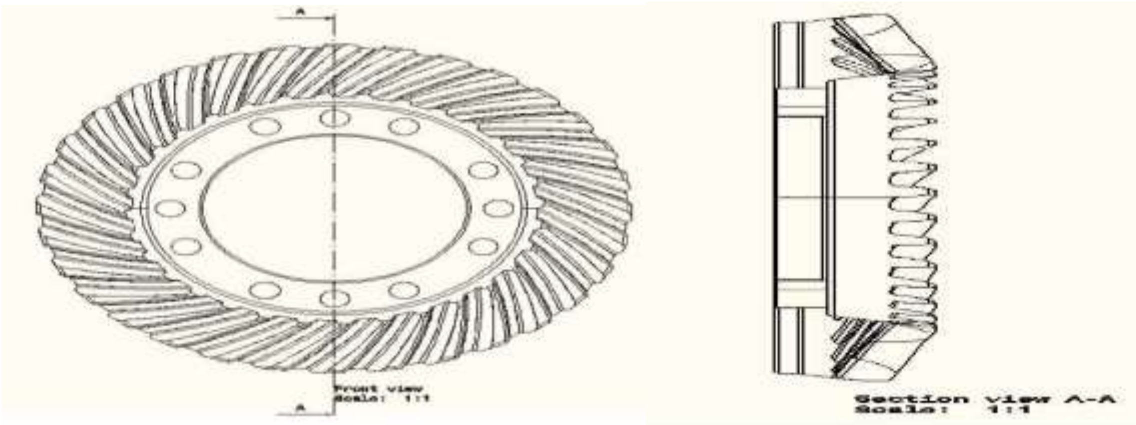

Fig.2 Front view of crown gear(a) and its section(b)[4]

Author conclude that with analyse the results plotting different parameters like stress, strain with tangential load, Pt(working)= 0.5 x Pt. So design is safe at peak load. He results,
σb actual $<\sigma b$ all
Induced equivalent stress is less than allowable stress. From this, it is concluded that design is safe.
Matthew D Brown et.al (2009) [6] investigates a detailed approach to spiral bevel gear design and analysis. Key design parameters are investigated in accord with industry standards and recommended practices for use in a medium class helicopter. Potential gear materials are described leading to the selection of SAE 9310 steel as the proper material for this application, finished with carburization and case hardening processes. A final gear design is proposed and analyzed to show that proper margins of safety have been included in the design. Fatigue analysis is conducted at the two most critical sections of the gear shaft resulting in margins of safety equal to 0.48 and 3.35.Further analysis is conducted on the gear teeth to ensure proper gear tooth geometry and proper loading techniques. Hertz stresses are investigated and calculated to be 180.6 ksi which allows for proper resistance to pitting. Bending stresses are calculated equal to 31.5 ksi which shows proper bending strength in the gear teeth to mitigate the risk of failure to a gear tooth.

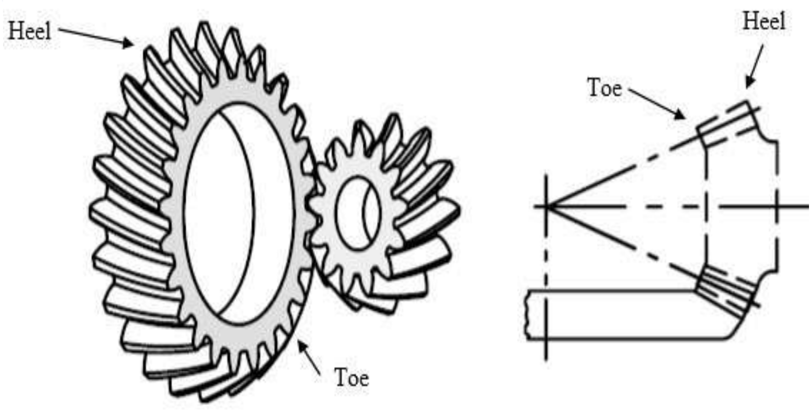

Fig.3 Spiral bevel gear mesh [6]

Results are compared to the recommended allowable stresses as published by the American Gear Manufacturing Association. Finally, fatigue life calculations are performed to show that the gear has been designed with unlimited life for this specific application.
Satya Seetharaman et al. (2010) [7] -proposed to predict power losses for gear pairs operating under wind age conditions. The framework of the model included individual formulations for wind age losses on the periphery and faces of the gears as well as a compressible fluid model for power loss due to pocketing taking place in the meshing zone. The wind age conditions simulate jet lubrication operating conditions or very low oil-level dip lubrication conditions. As an example, the wind age power loss model was applied to two unity-ratio gear sets with varying gear geometry parameters to quantify the contributions of each of the components of the total wind age power loss. For both gear pairs, the wind age pocketing loss was shown to dominate the total gear pair wind age loss. Also, the influence of operating conditions, gear geometry parameters, and lubricant properties on wind age power loss was quantified for the gear pairs in consideration.

B. Venkatesh et al. (2010) [8]- obtained Von-Misses stress theoretically with using ANSYS software. He found that for Aluminium alloy, stress values obtained from ANSYS are less than that of the theoretical calculations. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions, which are safe and less than the other materials like steel. Aluminium alloy reduces the weight up to 55.67% compared to the other materials. Aluminium is having unique property like corrosion resistance, good surface finish. Hence it permits excellent silent operation. Weight reduction is a very important criterion, in order to minimize the unbalanced forces setup in the marine gear system, there by improving the system performance.

Dong Yang et al. (2011) [9]- selected, the appropriate modification size and modification location, tooth deformation would be compensated and the stress distribution would be controlled in the central part of the tooth; the load concentration, agglutination, pitting of the gear could also be avoided effectively. According to the gear geometry theory and the normal meshing motion equation of gear pairs, changes of meshing points and angles were analyzed, and then, the effect of axial modification on gear pairs meshing movement was discussed. The establishment of the relationship between angle changes and modification size provided not only the basis for calculation and the selection of the modification size, but also a reference for the detection of modification effect in the future work.

Anoop Lega et al. (2016) [10] – presented his work with objective of the research to develop the composite material gear box using computer aided Engineering. The modelling of gears is done using parametric methodology; 3D family is generated by set of variables which controls other gear

CONCLUSION

The existing Crown gear is manufactured by AISI4130 steel material. The existing crown gear is redesigned by altering SAE9310 Steel as the Crown material. Further it is found that, decrease in the no. of teeth the crown, leads to the increase in torque at the output. Reduction of teeth also reduce the weight of the crown.

During study work, it is also seen that, the Gear failures, can be avoided if designers and operators recognize that the lubricant is an important component of a gearbox and appreciate that the tribology of gearing requires the attention and control of many related factors.

SAE 9310 Material is used for Crown and are analysed using ANSYS for equivalent(von-Misses) stress, Displacement (total deformation) and maximum shear elastic strain for different revolutions (1200,2000,4000rpm) under static condition. Comparisons of various stress and strain of SAE9310 material with Aluminium alloy and AISI 4310 being performed and found that among all, SAE9310 is suitably better material for Crown. Material SAE9310 also enhances the efficiency of torque. Hence, SAE9310 material is selected as alternative material for crown gear in differential.

In this research study, it is noticed that, with the material SAE9310 crown gear gives better result as compared to other materials. The material AISI 4130 gives smooth machining however, SAE 9310 achieve the good meshing properties and meet the analysis factor.

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