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A Review Design & Analysis For Better Directional Stability Of Centrally Suspended Cage-Less Slip Differential And Performance Of Steering Geometry

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Abstract

Differential is a device that transmits power from the transmission axle to the wheels of the vehicle thereby automatically controlling the speed difference of both wheel and accordingly transmitting adequate torque to the wheels while taking sharp turn. As a result of traction limited behaviour of an open differential there has been a need to develop a differential device that will overcome the shortcomings of the open differential. This paper is aimed at explaining the basis of differential mechanism and its types. The paper also focuses on the various types of Limited slip differential and their working mechanisms

INTRODUCTION

When a Car takes a turn the inner and the outer wheels of the vehicle tries to rotate at differential speeds as the path traced by the inner wheel is smaller than that of the outer wheel. A normal spool drive does not allow such a speed difference and as a result the inner tyre faces excessive wear due to skidding. This often causes the vehicle to lose traction. To overcome this problem a differential was designed to allow the wheels to rotate at variable speeds and controls the torque output to the wheels but only until the vehicle is being driven on a normal road with even friction. Such a differential is named as open differential. If a case arises that one of the driving wheel of the vehicle happens to loos traction with the ground due to ice or muddy patch. The wheel would continuously skid as all the torque will be transmitted to it leaving the other wheel stationary. To solve such a problem the Limited slip differential (LSD) was designed to limit the torque difference between the wheels at the same time it should mimic the working of open differential and only act when the situation arises. Any LSD is unique with a simple idea of mechanism. It has basically two paths of torque transfer. The first one is through the ring bevel gear to the differential pin then to the differential pinions and finally to the side gears as in the open differential. The second path is from the ring bevel gear to the clutch plates directly transferring torque to the wheels. The second path is actuated under the conditions of excessive slip forcing the wheels to rotate at same speeds thereby transferring equal torque to both the wheels. This mechanism helps the vehicle to limit its excessive slip condition hence the name Limited Slip Differential.

Literature Review

Prof. A. S. Todkar, R. S. Kapare [1] designed a differential locking system that can be engaged or disengaged either manually or automatically.They concluded that automatic engagement of the differential when the loss of traction condition is encountered thereby validating the function of the automatic mode of the differential locking system and manual override using push button system for semi-automatic mode of differential locking. Prof. A V Hari babu , Dr B Durga Prasad [2] identified the true design and the extended service life, long term stability can be assured on a CATIA generated geometric model of pinion of rear axle differential and they concluded that above calculated Von-mises stresses, deformation of pinion, stress values are less than ultimate standard value of steel and deformations are very less under the maximum torsional moment. Therefore, the design is safe in condition..

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Prof .Amir Khan, Sankalp Verma [3] obtained the performance parameters of modified automobile central differential and to compare with Transfer gear box and they concluded that by Using the FEA output a design was created that met all the stipulated functional requirements and possessed a reasonable factor of safety while still saving significant mass and rotational inertia as compared to the old differential or transfer gearbox.

Prof .Daniel et al.[4] carried out mechanically design and analysis on assembly of gears in a differential gearbox when they transmit power at different speeds and obvserved the structural analysis results, using Aluminum alloy the stress values are within the permissible stress value. So using Aluminum Alloy is safe with decreased vibrations and increased mechanical efficiency.

Prof .Shashank et al.[5] analyzed the differential gears assembly and its housing for the vibrational effect on a system in which the life of the gears is determined within different frequency range and they designed 3-D deformable-body model of differential gearbox and its housing was developedthrough SOLIDWORKS. The results obtained were then compared with the AGMA theoretical stress values.

Problem Statement

In the field of automotive engineering, ensuring optimal vehicle stability and maneuverability is crucial, especially in high-performance and off-road applications. One of the key components contributing to this stability is the differential, which plays a vital role in distributing torque between the wheels while allowing them to rotate at different speeds during differential, have limitations in terms of traction and directional stability, particularly under challenging driving conditions. To address these limitations, the concept of a centrally suspended cage-less slip differential has emerged as a promising solution. This type of differential is designed to enhance vehicle stability by improving the distribution of torque between the wheels, thereby maintaining better control and traction. The innovative design eliminates the need for a conventional cage, reducing weight and complexity while potentially offering improved performance. The steering geometry of a vehicle also plays a significant role in its overall handling and stability. Analyzing and optimizing the interaction between the differential and the steering system is essential to achieving better directional stability, especially in vehicles equipped with advanced differential systems.

Objective

1. Improve traction and grip by efficiently distributing torque between the drive wheels, especially during cornering or uneven road conditions.
2. Enhance vehicle handling characteristics, such as cornering ability, steering response, and stability under acceleration and deceleration.
3. Provide the ability to customize the torque bias ratio (TBR) to suit specific vehicle configurations, driving preferences, and performance requirements.
4. Develop a cost-effective design that balances performance requirements with manufacturing feasibility and scalability.
5. As a part of FEA, 3D modelling of gears was done in Solidworks and analysis was carried on ANSYS.
6. From the analysis, it is found that the forces and stresses obtained are below the allowable stress of the material considered in designing gears of the differential.
7. Maximum von-Misses stress is for Ring gear and Minimum for Side gears.

Static Structural Analysis Of Differential Gears

A simple structural analysis is performed as the first step to see if components were structurally strong. If component fails due to loadings, then there is no need to continue any further analysis since the component isn’t strong enough to be used.

The analysis of the various components of the differential was done in ANSYS 14.5 WORKBENCH for meshing as well as solving. Meshing of all the parts was done in ANSYS. The mesh is generated by using tetrahedron elements of 1 mm size. Mesh quality is further improved by using proximity and curvature function. This improves mesh density where curvature is small or edges are closed in proximity.

Crown gear when designing a pair of bevel gears there are 3 forces which come into action. These are radial force (Pr), tangential force (Pt) and axial force (Pa). To analyse the bevel gears these three forces have been applied on gear's teeth. It is considered that there are 2 teeth in mesh with the bevel pinion. Side gear .Design of Side gears is similar to that of Crown gears. After analysis in ANSYS it is found out that the maximum stress zone is at the root of the gear near the small filleted areas and is 125.46MPa. The displacement of the gear is near the tops of the loaded teeth and is 0.012499mm. From the values of stress and displacement it is shown that the given component is safe. Ring gear teeth are subjected to both bending and wear. The section where it experiences the maximum stress is the root of the tooth. It is considered that, there are 3 teeth in contact with the mating gear.

Tangential force (Pt) because of the torque which the gear is transmitting is applied on these three teeth. Another force acting on the gear is Radial forces (Pr) which is generated due to separating force between the two meshing gears. This force acts towards the centre of the gear. Magnitude of force (Pt) and (Pr) acting on gear are taken from above designed values.

The constraints which were given are only physical constraints. The inner surface of the gear is fixed, where shaft is mounted and also the diagonally opposite surfaces of the slots which are made for fixing the pin. Final drive gear designing of Side gears is similar to that of Crown gears and is found out that the maximum stress zone is at the root of the gear near the small filleted areas.

CONCLUSIONS

The study on the design and analysis of a centrally suspended cage-less slip differential aimed to enhance directional stability and evaluate the performance of steering geometry has yielded significant insights. The design allowed for better control of torque distribution between the wheels, especially during cornering and slippery conditions. This enhancement reduced the tendency for understeer or oversteer, leading to a more stable and predictable driving experience. The evaluation of steering geometry revealed that the optimized differential design contributed positively to the vehicle's handling characteristics. The improved torque distribution minimized the differential slip during turns, thereby reducing the steering effort required and improving the overall responsiveness of the vehicle. The reduction in mechanical complexity, due to the absence of a cage, contributed to a more efficient and lightweight design, further enhancing vehicle dynamics..

References

Prof. A. S. Todkar, R. S. Kapare, 2013, Design Development & Testing Of Automatic Differential Locking System-International Journal Of Advanced Technology

V Hari Babu, Dr B Durga Prasad, 2017, Failure Analysis Of Rear Axle Differential Pinion Shaft- International Journal Of Pure And Applied Mathematics, Volume 117, Paper No.10

Amir Khan, Sankalp Verma, 2015, Design And Analysis Of Automobile Central Differential Having Two Different Side Gear, International Journal For Scientific Research & Development(IJSRD), Vol. 3

Daniel Das.A, Seenivasan.S, Karthick.S, 2016, Structural Analysis of Differential Gearbox, International Journal of Innovations in Engineeraing and Technology (IJIET), Vol 2

Shashank Pandey, Nikhilesh N. Singh, Dr. Prabhat Kumar Sinha, 2017, Modeling, Design & Analysis Of Differential Gear Box And Its housing Through FEM, Solidwork & Ansys Benchwork 14.0, International Journal Of Engineering Sciences & Research technology

N.Vijayababu, Ch.Sekhar, 2015, Design And Analysis Of Differential Gear
Box Used In Heavy Vehicle, Proceedings Of International Conference On Recent Trends In Mechanical Engineering, NECICRTME-2K15, Vol.2, No.1

Mayank Bansal, Nidhi Sindhu, Santosh Anand, 2016, Structural And Model Analysis Of A Composite Material differential Gearbox Assembly, International Journal Of Engineering Sciences & Research Technology