Design and Manufacturing of Automatic Differential Self Locking System

Aparna Joshi1, Rutuja Kamthe2, Sanskruti Babar3, Pratiksha Shelke4*, Nitish Gandhi5
1Professor, Department of Mechanical Engineering, RMD Sinhgad School of Engineering, Pune, India
2,3,4,5Student, Department of Mechanical Engineering, RMD Sinhgad School of Engineering, Pune, India
*Corresponding author: pratikshashelke97@gmail.com

Abstract: Differential system is a device that distributes the engine torque in two ways, allowing each wheel to spin at different speeds. It is found on all types of automobiles. Differential locking system provides more traction compared to open differential systems. Locking differential system distributes the speed equally among both the wheels. Differential system is an important part of an automobile which provides traction between the wheel and the road. This traction movement is necessary for the wheel to move while it's on slippery surface. In this project, dog ring and spike shaft mechanism is used in order to provide equal power to both the wheels.

Keywords: Differential locking system, Spike shaft, Dog ring, DLS, Sensor, DC motor.

1. Introduction

The differential system is a device that splits the torque among the two wheels allowing each wheel to rotate at different speed. The differential is found in all automobiles now-a-days. When an automobiles drive on straight path wheels on both side of an automobile drive at same speeds. When a car makes a turn, both the wheels are needed to rotate at different speeds in order to cover the required distance and the curve without any damages. When a vehicle is driven on a slippery road or mud, problems of wheel getting stuck into the mud may occur. In order to overcome this situation, it is necessary to transmit equal amount of torque to both the wheels on either sides of the vehicle. For this purpose, differential locking system is used.

Various types of differential systems are used now-a-days. Open differential system has been most commonly used previously. Limited slip differentials are designed in a way to overcome the disadvantage faced by open differential system. In open differential system even if a wheel is stuck in mud i.e. when it loses traction, power was transmitted to the wheel which resulted in loss of power as well as the amount of power transmitted to the other wheel was not enough in that condition. Due to limited slip differential in such cases, the power supplied to the wheel with no traction is reduced supplying the same to the other wheel. This resulted in movement of the vehicle even with loss of traction.

Locking differential systems were designed to overcome the limitation of these two differential systems. Locking differential systems uses mechanical, electronic, hydraulic, or pneumatic mechanism to lock both the wheels on a common shaft. A locking differential based on gear locking mechanisms are normally used. But use of pneumatic or electrically controlled mechanical system will be more effective.

2. Literature Survey

Karande Mahesh proposed a differential system based on the concept of the constant mesh gear box shifter mechanism which consisted of a dog ring, dog clutch, dog teeth and the gear on which it is to be engaged. The planet gears are mounted on the spike shaft. The spike shaft is stationary and allows the planet gears to rotate freely. The differential gear box was installed on the frame equipped with dynamometer arrangement. Motor was connected to the input shaft of the differential system to provide power to be transmitted. Readings were carried out by locking the mechanism at various speeds. The results obtained concluded that differential locking is a convenient and effective option over conventional differential locking system.

Vinod Sakhare in his paper proposed manual engagement of differential locking system instead of using sensors. The manual engagement of wheels stops the wheel from rotating and locks the differential to distribute the speed equally among wheels at both sides.

R. Saravanakumar has proposed in his paper pneumatic method to lock the differential system. The main purpose of the project was to engage or disengage the differential system when it is needed to be. A pneumatic cylinder, solenoid valve, lever mechanism, push button, circular plates were used for this purpose. The circular plates were connected on either sides of both the shafts. Whenever the pneumatic valve was actuated one of the plates get pushed to the other side so the plates come together and the shafts get connected. To restore the first position a spring was used to push the plates apart.

Kanwar Bharat Singh proposed a brake assisted differential locking system. He used an electronic and pneumatic circuit to control the traction of the vehicle. The electronic circuit was built in a way to sense the speed difference among the wheels. If the speed difference goes beyond a specified limit, the electric signal was generated which actuated the pneumatic circuit. This resulted in braking of the faster wheel to reduce the speed and gain the required traction so that the wheels never...
lose traction.

A. Ravi in his presented an efficient and robust control scheme of electronic differential system for an electric vehicle. The system consisted of two brushless DC Motors that ensures the working of the two rear driving wheels of an electric vehicle. EDC ensured the maximum torque and controlled both the driving wheels independently to turn at different speeds and also distributed power according to the required angle.

3. Material Procurement

General material used for manufacturing process is:
EN24- Alloy Steel
EN9- Plain Carbon Steel
MS- Mild Steel

4. Concept of Design

- When one wheel of the vehicle is stuck in mud due to loss of traction, the shaft of that wheel stops rotating. For example, consider, right hand wheel of the vehicle is stuck into mud.
- Right hand wheel lose traction and therefore all the power is than supplied to the left hand side wheel. This results in left hand side wheel turning twice its normal speed.
- Required amount of traction is needed to be provided in order for a wheel to move.
- The proximity sensor senses the reduction in the speed of the shaft. Once the speed reduces to zero it sends signal to the driver. The driver than operates the switch which further sends signal to the DC Motor through the electronic relay.
- The DC Motor pinion operates the rack shifter mechanism that is connected to the dog ring. The dog pin than engages into the slot of the spike shaft which is connected to the planetary gears.
- This engagement results into connection of shafts of each of the wheels and equal quantity of power is supplied to wheels at each side.
- After receiving the required amount of power the vehicle will simply be driven out of the mud.
- Driver once more operates the switch for the disengagement of dog ring and spike shaft.

5. Design Methodology of System

While designing any machine or the system the design gets separated in two parts likely,
1. System design - System design deals with varied physical parameters like, ergonomics, space requirement, arrangement of different parts of system or their position from ground or space between them etc.
2. Mechanical design – The mechanical design the components are categorized in 2 parts:
   a) Design parts: The parts that aren’t simply available in markets or complicated in size and shape that we have to design by some assumptions, specifications etc.
   b) Components to be purchased: The components which are available in market like electric components, nut and bolts, washers etc.

A. Design and Manufacturing of Spike Shaft

Material selection:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Tensile Strength (N/Mm²)</th>
<th>Yield Strenth (N/Mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 24</td>
<td>850</td>
<td>680</td>
</tr>
</tbody>
</table>

ASME code for design of shaft

Since the masses on most shafts in connected machinery are not constant. It’s necessary to make proper allocation for the consequences of load fluctuations.

According to ASME code permissible values of shear stress could also be calculated from various relations.

\[
\tau_{\text{per}} = 0.18 * S_u \\
\tau_{\text{per}} = 0.18 * 850 \\
\tau_{\text{per}} = 153 \text{ N/mm}^2 \\
\text{OR} \\
\tau_{\text{per}} = 0.3 * S_y \\
\tau_{\text{per}} = 0.3 * 680 \\
\tau_{\text{per}} = 204 \text{ N/mm}^2 \\
\]

Considering minimum value of the above values.
Shaft is given key way; this will reduce its strength. Hence reducing above value of allowable stress by 25%

\[
\tau_{\text{per}} = 114 \text{ N/mm}^2 \\
\]

This is the allowable amount of shear stress that can be produced in the shaft for safety.

Check for Torsional Shear Failure of shaft
Assuming min. section diameter on input shaft = 16mm
d = 16mm

\[
T_d = \frac{\pi}{16} \* \tau_{\text{act}} \* d^3 \\
\tau_{\text{act}} = 16\pi*(d^3) \* T_d \\
\tau_{\text{act}} = 16*20.53*10^2/\pi*16^3 \\
\tau_{\text{act}} = 25.5269, \text{ N/mm}^2 \\
\]

As \( \tau_{\text{act}} < \tau_{\text{per}} \)

Spike shaft is safe under torsional load.

Fig. 1. Catia model of spike shaft
B. Design and manufacturing of dog ring

Pin is located at PCD (D) = 87mm
Area of pin, A= b*h
A= 5*3
A= 15mm²

<table>
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Pin on dog ring is located on PCD=87mm, this pin engages within the cage of the spike shaft and act as transmission component.

It is designed similar to the bush pin in the bush pin type flexible flange coupling. Single pin transmits the entire torque.

Shear stress= shear force/ shear area

\[ \tau_{\text{act}} = \frac{F_t}{A} \]
\[ \tau_{\text{act}} = 471.954 / 15 \]
\[ \tau_{\text{act}} = 31.4636 \text{ N/mm}^2 \]

Where, \( F_t \) = Tangential force on each pin
A = Area of pin under shear
\( \tau_{\text{act}} \) = Actual shear stress
Allowable shear stress,
\[ \tau_{\text{all}} = 0.5 \times \frac{S_{yt}}{FOS} \]
\[ \tau_{\text{all}} = 0.5 \times 680 / 3 \]
\[ \tau_{\text{all}} = 113.33, \text{ N/mm}^2 \]

As, \( \tau_{\text{act}} < \tau_{\text{all}} \),
Design is safe

![Catia model of dog ring](image)

Fig. 2. Catia model of dog ring

6. Conclusion

When one of the wheels is stuck into mud it losses traction. Required amount of traction should be provided in order for a wheel to move further. This can be provided using locking mechanism of dog ring and spike shaft. When the mechanism is operated using sensor and circuit, differential system can be simply operated by the driver. This mechanism can be easily installed in all other vehicles.

References


