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Research Article

Test Rig design for semi-automatic Differential locking system

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Abstract

A conventional differential mechanism (unlocked) always supplies close to equal torque to each side. With an automotive differential if one wheel is held stationary the counterpart wheel turns at twice its normal speed. A Semi-automatic differential lock system introduced here can be engaged or disengaged manually as per conditions by stalling of one wheel to lock the differential by sliding a dog ring to get engaged in planetary gear spike shaft so that both the wheels have the same traction. If the difference in the speed of driven and rolling wheels is encountered then the differential is controlled to lock.

Keywords: *A semi-automatic differential lock system, dog ring, spike shaft, same traction.*

1. Introduction

[1]The inner and outer vehicle wheels rotate at different speeds during turning. The differential mechanism is designed to transmit the drive to a pair of wheels and allow them to rotate at different speeds. In vehicles like karts with no differential, both the driving wheels forcibly rotate at the same speed, usually on a common axle driven by a simple chain-drive mechanism. While taking a turn, the inner wheel travels a shorter distance than the outer wheel, so with no differential, the dragging of the outer wheel occurs resulting in unpredictable handling, damage to tires and roads, and possible failure of the entire drive train.

Torque from the engine is transmitted to the drive shaft (propeller shaft), which runs to the final drive unit that contains the differential. The propeller shaft drives a spiral bevel pinion gear and is encased within the housing of the final drive unit. The bevel pinion meshes with the large spiral bevel ring gear, known as the crown wheel. The crown wheel gear is attached to the differential cage. The cage contains the sun and the planet gears, which are a cluster of four opposed bevel gears in perpendicular plane. Each bevel gear meshes with two neighbors. The two sun wheel gears are coaxial with the crown wheel gear and drive the axle shafts connected to the vehicle's driven wheels. The other two planet gears are aligned on a perpendicular axis which changes orientation with the ring gear's rotation. In the two figures shown below, only one planet gear (green) is illustrated, however, most automobile applications contain two opposing planet gears. As the differential carrier rotates, the changing axis orientation of the planet gears imparts the motion of the ring gear to the motion of the sun gears by pushing on them rather than turning against them, but because the planet gears are not restricted from turning against each other, within that motion, the sun gears can counter-rotate relative to the ring gear and to each other under the same force.

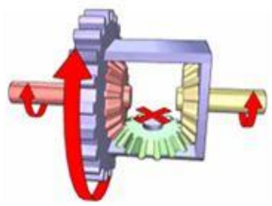

Fig.1.1 differential action when both wheels have same traction

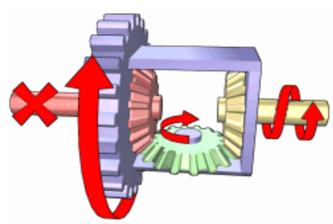

Fig.1.2 differential action when loss of traction at one wheel

Differential gears in an automobile's drive-train allow the driving wheels to transmit torque, or twisting force, at different turning rates. Thus one wheel can follow the longer arc around the outside of a turn while the other wheel tracks the shorter inside arc without skidding on the road surface.

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Fig.2 Basic differential

In a front-engine, rear-drive car, engine torque flows through the transmission and drive shaft to turn the ring-and-pinion gears inside the rear-axle assembly, powering the rear driving wheels. In a front-engine, front-drive car, the differential and final drive gears are in the same housing with the transmission, mounted directly on the engine. In both design, the drive gears work through differential gears to turn the axle and the driving wheels.

The drive shaft ends in a pinion gear inside the differential. When the drive shaft turns, the pinion drives a ring gear that is part of the differential housing, so that both housing and ring gear rotate together. Inside the housing are two pinion gears and two side gears; each side gear is connected, via an axle, to a drive wheel. When the car drives straight ahead and the axle shafts turn at the same speed, the differential housing rotates, but no differential action occurs. When the car negotiates a turn, however, the differential must compensate for the difference in distance traveled by the drive wheels. The opinions roll around the side gears, allowing the inside wheel to turn more slowly and the outside wheel to turn more slowly and the outside wheel to turn faster.

Free-turning gears divide torque equally between the driven wheels. If one drive wheel is on dry pavement and the other on ice, the gears roll around inside the housing to spin the slipping wheel at twice the ring gear's speed. Each drive wheel gets the same slight amount of torque required to spin the slipping wheel; the car does not move at all. Some cars have locking, or limited-slip, differentials to reduce wheel spin by transferring some torque to the wheel with better traction.

1.1 Literature survey

Prof. A. S. Todkar, R. S. Kapare have done stress analysis using ANSYS™ software to obtain Von-Mises stresses and deformation of dog ring and spike shaft. Suyash Kamal Soni, Vidhilekh R. Gautam, Rahul Jain, Rajendra Kumar Vishwakarma concluded that with decrease in speed of output wheel shaft torque is increasing. Torque and speed are inversely proportional. Hence the moment proximity sensor sense the reduction in the speed, the locking differential will try to provide same torque on both wheel shaft.

Katsumi Ito has proposed that an automatic differential locking vehicle having steerable front and rear wheels, which includes selectors for selecting a steer mode of vehicle, an actuator for operating a has a locking type differential in which the locking action of the differential can be controlled based the existing vehicle operating condition.

1.2 Problem statement

When one wheel is held stationary counterpart wheel Rotates at twice its normal speed. This could prove to be problematic when one wheel has less traction being in slippery condition such as snow or mud. The wheel without traction will continue to spin without generating any traction and the opposite wheel will stand still and as a result the automobile will not move.

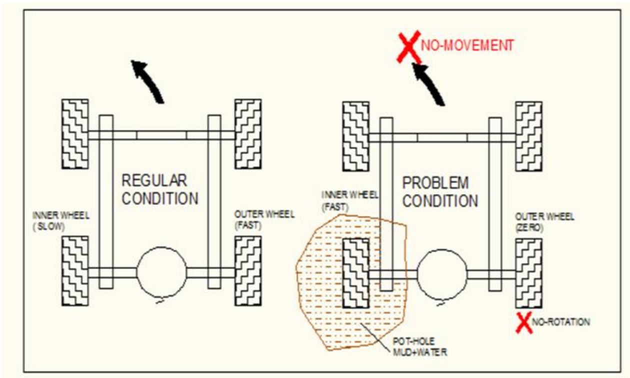

Fig.3 Problematic condition

Solution to the problem

We are going to modify the spike shaft of the differential i.e., shaft that carries the bevel pinions to develop projections on it, which can be locked using a mechanical pin mounted on the dog ring that is made to slide using a rack and pinion arrangement driven by a 12 volt DC motor that runs on car battery. This makes system simple, low cost, maintenance and hence affordable to be used in commercial cars.

1.3 Objectives

1. Design of test rig for semi-automatic differential locking system.
2. Experimental validation of maximum and minimum speeds available from the device under different load condition.

2. Experimental setup

We are designing test rig for differential locking system. For testing purpose we used the Differential of FIAT automobile. After dismantling, the essential measurements were taken to decide diameter of spike shaft, dog ring diameter, length of spike shaft, length of input and output shaft. size of the base frame.

We selected single phase AC motor 50 watt with variable speed of 0-6000 rpm. Motor is foot mounted on the base plate welded to the base frame. Motion is transferred to pulley which in turn is connected to input shaft with the help of belt drive. A spiral bevel pinion takes its drive from the end of the input shaft, and is encased within the housing of the final drive unit.

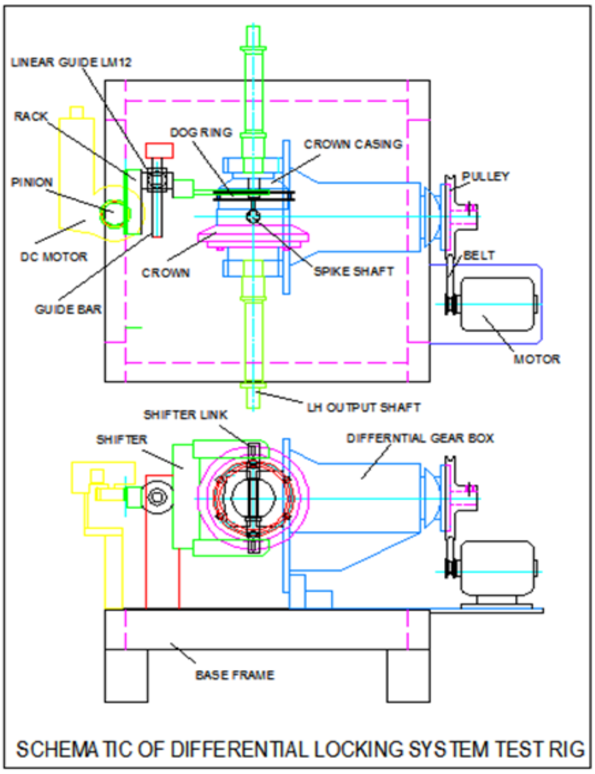

Fig.4 Schematic diagram of test rig

For getting different speeds on both the shafts we are applying load on RH output shaft. Now to encounter this difference in speed we use the differential locking system. Now newly designed spike shaft can be locked using a mechanical pin mounted on ring which is slides with the help of rack and pinion arrangement driven by 12 volt DC motor. Shifter mechanism is used for sliding the dog ring. Shifter mechanism consists of shifter link, guide bar, DC motor, Rack and pinion arrangement.

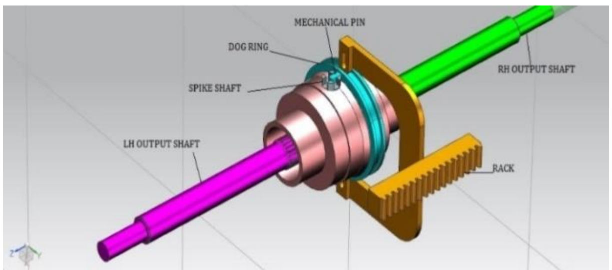

Fig.4 Geometric model of Set-up

Spike shaft is provided with slots on the top of it. Engagement will lock the spike shaft thereby the conventional differential actions stops and both the wheel shafts get engaged in drive and thus equal power is given to either wheels.

3. Design Aspects of Test Rig components

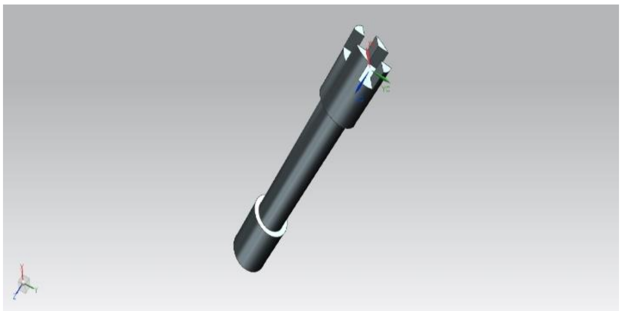

Fig.6 Model of the Spike shaft

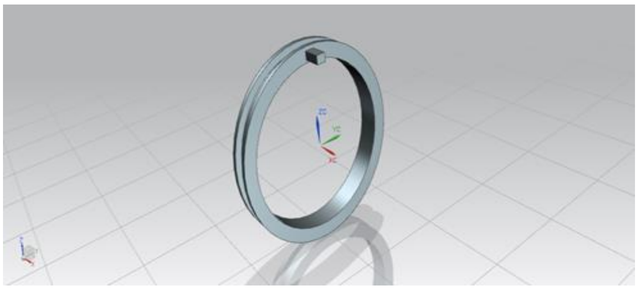

Fig.7 Model of Dog ring

ASME code for design of shaft

Due to continuous load variation encountered by the shaft, it is necessary to make proper allowance for the harmful effects of load fluctuations

According to ASME code permissible values of shear stress may be calculated from various relation, i.e. considering minimum of the values of f_{smax}=144 N/mm^2. Shaft is provided with key way; this will reduce its strength. Hence reducing above value of allowable stress by 25% i.e. f_{smax}=108N/mm^2. This is the allowable value of shear stress that can be induced in the shaft material for safe operation. The material used for Spike shaft and Dog Ring is EN24 (UTS-800 N/mm^2, YS-600 N/mm^2)

The torque for power(P)=50 watt comes out to be 0.5968 Nm, Assuming 100% overload for safety operation we took design torque as twice i.e. 1.19×10^3Nmm

The single spike dog ring is provided for engagement. Shifter mechanism moves the dog ring toward right to engage the dog teeth in the spike shaft slot. Presently the dog ring is provided with a single spike for engagement.

Dog is located on pcd 72 mm. These pins engage in the cage of the spike shaft and act as transmission elements. They can be designed similar to the bush pins in the bush pin type flexible flange coupling. These pins transmit the entire torque. Considering design torque transferred by spike shaft fs_{act} comes out to be 1.68 N/mm^2 which is less than the permissible value. Hence the pins are safe under shear load.

We use shifter link to lock and unlock the differential by sliding the dog ring, so that the mechanical pin mounted on it should lock the spike shaft

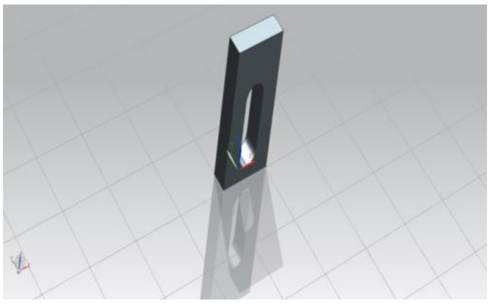

Fig.8 Model of Shifter link

Conclusions

The setup has been developed and the functioning has been checked successfully. It demonstrates the semi-automatic locking of the differential during the loss of traction condition is encountered and thereby validating the function of the semi-automatic mode of the differential locking mechanism by using push button system.

Future scope

The semi-automatic locking system for differential is a low cost solution and has been experimentally proven mechanism.

Further the testing needs to be performed at various loading conditions to generate more data pertaining to the output speeds of LH and RH shaft and the corresponding slip.

Though it is used only in typical situation, it can be developed for all types of vehicles in different geographical locations in the world. It needs to be made more compact, easy to use and more sophisticated for using it commercially

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