ABSTRACT
A conventional differential that is non-locked differential 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 differential locking system introduced here can be engaged or disengaged either manually or automatically, as per the conditions or a sensor based system can be developed that will sense the difference in speed or stalling of one wheel to lock the differential by sliding a dog ring to get engaged in planetary gear spike shaft so that both wheels will have same traction. If the difference in the speed of driven and rolling wheels is encountered then the differential is controlled to lock.

1. INTRODUCTION
One problem with an automotive differential is that if one wheel is held stationary, the counterpart wheel turns at twice its normal speed as can be seen by examining the complete scheme of automobile differential. This can be problematic when one wheel does not have enough traction, such as when it is in snow or mud. The wheel without traction will spin without providing traction and the opposite wheel will stay still so that the car does not move. This is the reason for a device known as a "limited slip differential" or "traction control". The solution to the above problem is to have a differential locking system which can be engaged or disengaged either manually or automatically, as per the conditions or a sensor based system can be developed that will sense the difference in speed or stalling of one wheel to lock the differential so that both wheels will have same traction.

A locking differential, such as ones using differential gears in normal use but using air or electrically controlled mechanical system, which when locked allow no difference in speed between the two wheels on the axle. They employ a mechanism for allowing the axles to be locked relative to each other, causing both wheels to turn at the same speed regardless of which has more traction; this is equivalent to effectively bypassing the differential gears entirely. Other locking systems may not even use differential gears but instead drive one wheel or both depending on torque value and direction. Automatic mechanical lockers do allow for some differentiation under certain load conditions, while a selectable locker typically couples both axles with a solid mechanical connection like a spool when engaged. [1] [2]

2. CURRENT PRACTICES
Katsumi Ito[3] 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 differential locking mechanism, and a gate for sending a control signal to the actuator in response to a signal received from selectors. The gate is adapted to send a differential locking signal to the actuator upon receipt of a parallel steering mode signal from the selectors. In response to the differential locking signal the actuator actuates differential locking mechanism. Since the differential revolutions of wheels are limited at a time of parallel teering, the vehicle is capable of accurate course revision and alterations without slipping.
Alfred Sigl[4] has discussed in his patent work that to improve traction which can be applied by the wheels of the vehicle, and to automatically engages a locking mechanism or locks a differential. Desirably also the guidance or stability of driving and road holding is ensured by also controlling torque being applied to the wheels. Briefly a control unit is provided to control drive torque applied by the engine to the wheels. This wheel control is combined with a locking differential. Engagement of lock of locking differential to lock the wheels of an axle together is commanded by control unit.

Kumihiho Suzuki[5] discussed a theory that a four wheel drive system of a vehicle has center differential between four wheels and rear wheels and a means for restraining or locking the center differential.

The present invention relates to an automotive vehicle having wheels operable about wheel shaft in which locking apparatus is provided so that the wheels on the both side of the vehicle will operate at essentially the same speed. Apparatus are provided to prevent slippage or spinning of the driven wheels. Typically, the vehicle has a locking type differential in which the locking action of the differential can be controlled based the existing vehicle operating condition

3. CONCEPT DESIGN AND DEVELOPMENT

Fig. 1 illustrates a cross-section view of the differential and a propeller shaft in the rear drive housing:
Fig. 2 illustrates a view taken on line II- II of one of the side gears:
The operation of the locking means for the differential will be described in the following paragraphs:
The differential lock on the differential is mechanically operated by the controlling linkage 36. The lever 37 moves the shift rail 39 to a detent position in which the detent 40 engages the recess 60 or 61. In the position as shown in FIG. 1, the differential is locked. The plurality of pins 51 are received within the plurality of peripheral grooves 56 so that the side gear 16 is locked to the housing 13 and the differential rotates as a unit. When the pinion gear 34 drives the ring gear 32, the drive shafts 10 and 12 rotate synchronously.

When the lever 37 is moved in a clockwise direction the detent 40 is received within the recess 60 and the clutch collar 43 moves in the left-hand direction. As the clutch collar 43 moves in the left-hand direction it is positioned by the detent 40. In this position the plurality of pins 51 are completely retracted from the annular recesses 56 in the rear face of the side gear 16. The pins, however, are never retracted from the openings 53 maintain their axial alignment in parallel relationship to the axis of the movement of the clutch collar. The axial movement of the clutch collar 43 is coincidental with the axis 11 of the rear drive axles 10 and 12. When the pins 51 are withdrawn from their engaging position with the peripheral grooves 56 in the side gear 16, the differential is released. In this position, the side gears 16 and 18 can freely rotate relative to each other in driving their respective axle. The ring gear 32 is driven by the pinion 34 which merely drives the housing while the differential action of the gears 10 and 12 is permitted through the differential which is free to rotate in response to the loads on the rear wheels.

4. MECHANICS OF DIFFERENTIAL LOCKING SYSTEM

**RH/LH Wheel Shaft**

The left-hand rear axle which is also called LH output shaft rotates on the common axis with the right-hand rear axle or RH output shaft.

**Fig 5: Dog Ring**

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

**Fig 6: Planetary Gear spike Shaft**

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.

**WORKING OF PROPOSED DIFFERENTIAL LOCKING SYSTEM**

When one of the wheels (e.g. RH wheel) goes in a pit or slippery condition due to loss in traction (friction between road and wheel) .Wheel shaft stops turning.

- As a result the LH wheel shaft speeds up to twice the transmission speed vehicle tiers cannot generate enough traction to come out of the pit.
- The proximity sensor senses this drop in speed or motion and through the electronic relay operated the DC motor.
- DC motor pinion drives the rack and there by the shifter mechanism to the right.
Shifter mechanism moves the dog ring toward right and the dog teeth engage in the spike shaft slot.

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.

Wheels after receiving the power will pull/push the vehicle out of pit.

Operator moves the reversing switch to bring the dog ring back out of engagement thus conventional differential action is restored.

**DESIGN CONSIDERATION**

In our attempt to design a Differential Locking System we have adopted a very careful approach, the total design work has been divided into two parts mainly;

- System design
- Mechanical design

System design mainly concerns with the various physical constraints and ergonomics, space requirements, arrangement of various components on the main frame of machine no of controls position of these controls ease of maintenance scope of further improvement; height of m/c from ground etc.

In Mechanical design the components are categories in two parts.

- Design parts
- Parts to be purchased.

For design parts detail design is done and dimensions thus obtained are compared to next highest dimension which are readily available in market this simplifies the assembly as well as post production servicing work.

### Table: List of Component

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Component Name</th>
<th>Component Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DC motor</td>
<td>LH OP Shaft</td>
</tr>
<tr>
<td>2</td>
<td>Belt</td>
<td>RH OP Shaft</td>
</tr>
<tr>
<td>3</td>
<td>Reduction Pulley</td>
<td>Guide Bar</td>
</tr>
<tr>
<td>4</td>
<td>differential</td>
<td>Crown</td>
</tr>
<tr>
<td>5</td>
<td>Dog Ring</td>
<td>Crown Casing</td>
</tr>
<tr>
<td>6</td>
<td>Shifter Links</td>
<td>Frame</td>
</tr>
<tr>
<td>7</td>
<td>Shifter</td>
<td>Rack</td>
</tr>
<tr>
<td>8</td>
<td>Spike Shaft</td>
<td>Linear BRG LM-12</td>
</tr>
<tr>
<td>9</td>
<td>Differential Holder</td>
<td>Pinion</td>
</tr>
</tbody>
</table>

**MATERIAL PROCUREMENT**

Material is procured as per raw material specification and part quantity. Part process planning is done to decide the process of manufacture and appropriate machine for the same.

**General Material Used**

- EN24- Alloy Steel
- EN9- Plain Carbon Steel
- MS-Mild Steel
- STD- Standard Parts Selected

From PSG Design Data/ Manufacturer Catalogue

**DEFORMATION AND STRESS CONCENTRATION OF COMPONENTS**

Stress analysis is done by using ANSYS software to obtain Equivalent (Von mises) Stress and deformation.

**Fig8: Meshing, Displacement and Stress concentration of Dog Ring**

**Fig9: Meshing, Displacement and Stress concentration of Spike Shaft**

For testing purpose we take low torque shaft as i/p shaft then by using motor and belt input motion is given. At other end i.e. at high torque shaft various loads are applied and change in rpm is noted accordingly.

The Testing of differential locking system is carried out in order to find the performance characteristics for that the observations which are obtained used to plot the graphs.

**Graphs of Torque, Power, Efficiency v/s Speed**

- **Torque v/s Speed:** From above graphs we can conclude 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.

- **Power v/s Speed:** With increasing speed, power also increases up to certain limits then there will be same output power that power is
known as rated power. Above plotted graphs shows decreasing nature as speed is above the rated speed.

- **Efficiency v/s Speed:** Graph shows increasing efficiency up to limit with speed further increase in speed will not effect as power generated will be constant

**CONCLUSION**

In this dissertation work, testing is done with the view to comment on the utility of the designed drive for given application. The following conclusions are drawn from the previous chapters.

- The set-up developed shows 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.
- The set-up shows the manual override using push button system for semi-automatic mode of differential locking.

**REFERENCES**

2. www.freepatentsonline.com
6. Prof. Dr.-Ing. Berthold Schlecht, TU Dresden Dr.-Ing. Tobias Schulze, Drive Concepts GmbH Dresden “Design and optimization of planetary gears under consideration of all relevant influences”
8. Derek John Smith,David William Secuill,both G.B.;(2002)”Differential lock engaging arrangement”U.S. patent, no. 6,390,226 B1,May 2002
10. Yashwant Gowda (2011),"Automatic differential locking system for automobile" 
12. www.worldautomotive.wordpress.com