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Design & Analysis of Electronically Controlled Self-locking Differential Gear Box

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Abstract- The engine, clutch, gearbox, propeller shaft, and simple differential are being used from the last 130 years have some limitations as today's lifestyle is 130 years ahead of that system. Generally, some limitations regarding differential can be observed such as one or both wheels of drive system lifted, on a slippery track, stuck into mud or stuck to obstacle then, vehicle struggles to move further. In said situations rate of failure to overcome the problem is very high in conventional as well as some of the modern differentials. Hence there comes a need for a differential that can counter the above-mentioned issues along with providing different speeds at the rear axles and providing proper traction control. The 3D CAD model of our project will be drawn with the help of CATIA software, for analysis, we will be using Ansys v18.0. All the components which are required for our project will be manufactured. After the manufacturing of the components assembly will be done. The experimental testing will be carried out and then the result and conclusion will be drawn.

Index Terms- differential gearbox, stuck into the mud, slippage problem, CATIA V5, ANSYS v18.0, conventional, traction.

1. INTRODUCTION

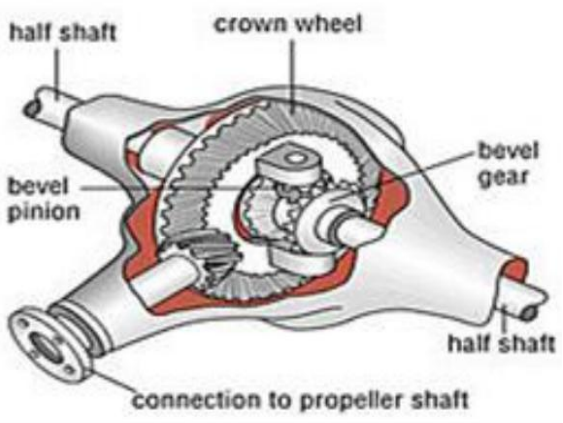
In 1887 the first car was invented by Karl Benz. Rather than using animals to pull cart, he was thinking for the successful self-propelled car by the use of steam-engine. The first car was having a rear-wheel drive with a chain system. When a vehicle is traveling along a path and a single shaft is used to drive both wheels at the same speed, then the system fails to turn. The vehicle will move in a straight line as both driving wheels are moving with the same velocity. To overcome such condition differential was invented. In differential of the vehicle, both wheels can receive different torque, also it can turn in any direction without stopping power transmission. A differential is a particular type of gear set which is widely used in automotive applications. Due to the differential, the two driving wheels of a car can rotate at different speeds as they follow different ways around a corner. These axle differentials usually split the torque symmetrically to both driving wheels. Differential used today has some limitations. When one of the wheels is on a slippery track, the power will be transmitted more to the slipping wheel and the vehicle gets stuck in the stationary position used in automotive applications.

This slippage problem will be eliminated in our electronically controlled self-locking differential gearbox. We aim to develop a differential locker whose initial cost is less and will provide complete locking of the differential to overcome slippage issues faced by a conventional differential gearbox.

This e-locker will be sturdy, cheap, and more efficient as compared to most of the differential lockers available in the market. This will not only help the vehicle to get out of a stuck condition but also provide proper traction control on slippery surfaces.The tractors, tillers, trucks, power weeder, and most of the agricultural machines are subjected to the same problem. Some manufacturers used locking differential, some used turning purpose clutches on single shaft drive, But using all of the above systems increases cost andcomplexity; hence it is needed to define a technique which will overcome the above-mentioned problem. Before going to know what is the solution, we have to understand the problem deeply and a possible alternative for it.

1.1 DIFFERENTIAL GEARBOX

Simply put, a differential is a system that transmits an engine's torque to the wheels. The differential takes the power from the engine and splits it, allowing the wheels to spin at different speeds.



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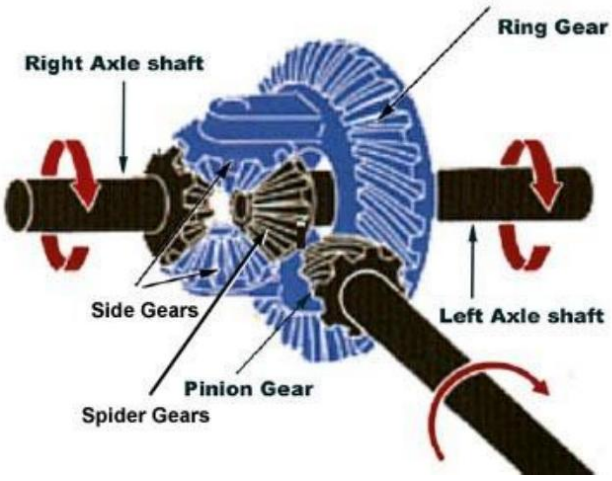
1.2NEED

Car wheels spin at different speeds, especially when turning. Each wheel travels a different distance through the turn, and that the inside wheels travel a shorter distance than the outside wheels. Since speed is equal to the distance traveled divided by the time it takes to go that distance, the wheels that travel shorter distance travel at a slower speed. Also, note that the front wheels travel a different distance than the rear wheels.The biggest backlash faced by the differential gearbox is that it loses traction over slippery track and this causes the vehicle to skid on the road and due to which the driver loses control of the vehicle. There have been many advancements in this field and many differential locks have been manufactured which can overcome those issues but those methods are bulky and occupy more space. So there's a need for an electronically controlled lightweight and a precisely controlled differential gearbox that can counter all of the mentioned issues. Also, there are a few differential lockers available in the market but they are bulky, heavy, expensive, occupies more space but do not provide sufficient tractioncontrol.

1.3WORKING

On a straight road the wheels and the side gears rotate at the same speed, there is no relative motion between the differential side gears and pinions, and they all rotate as a unit with the case and ring gear. If the vehicle turns to the left, the right-hand wheel will be forced to rotate faster than the left-hand wheel, and the side gears and the pinions will rotate relative to one another. The ring gear rotates at a speed that is equal to the mean speed of the left and right wheels. Consequently, if one wheel slips, as in ice or mud, the torque to the other wheel is reduced. This disadvantage can be overcome somewhat by the use of a limited-slip differential. In one version a clutch connects one of the axles and the ring gear. When one wheel encounters low traction, its tendency to spin is resisted by the clutch, thus providing greater torque for the other wheel.

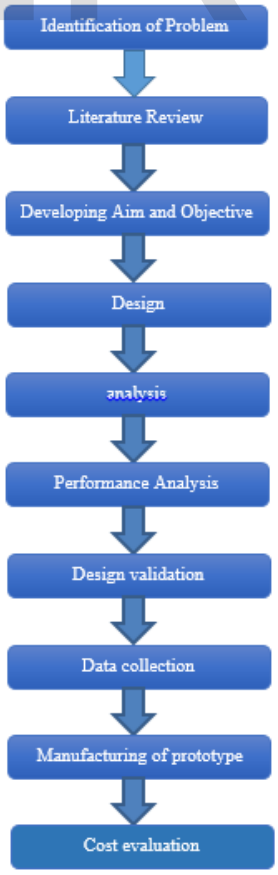


1.4 SOME OF THE ADVANCEMENTS DONE IN DIFFERENTIAL GEARBOX

1. Torsional differential gearbox.
2. Samurai arb differential locker.
3. Mahindra Thar differential locker.

2. METHODOLOGY

1. **Identification of the problem-** The biggest backlash faced by the differential gearbox is that it loses traction over slipperytrack and this causes the vehicle to skid on the road and due to which driver loses control of the vehicle.
2. **Literature review-** the potential of the project was acknowledged after referring several research papers, which also helped in the proper design and analysis process.
3. **Design-** designing software CATIA was used for the designing of all the components.
4. Analysis- complete analysis of the components was done using ANSYS software.
5. **Performance analysis**- using iteration method large number of iterations were performed and performance analysis was carried out.
6. **Design validation**- data collected using the iterative method was used to finalize the design and respective changes were made in the model for better performance.
7. **Manufacturing of the prototype**- modern techniques such as 3d printing, CNC milling will be used for the making of prototype.



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3. Modeling DESIGN AND NUMERICAL DATA

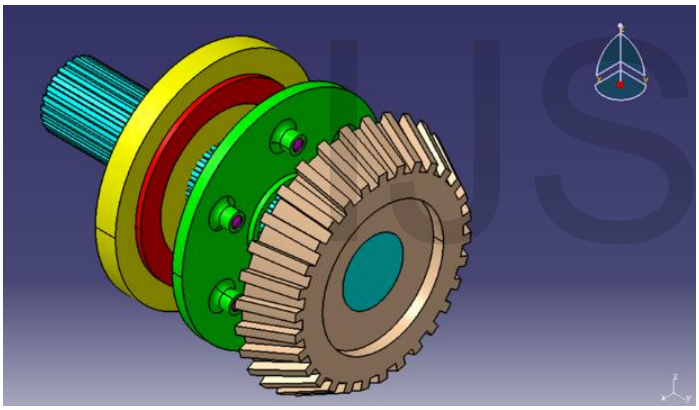
3.1 DESIGN

Computer-aided design (**CAD**) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term **CADD** (for *Computer-Aided Design and Drafting*) is also used.

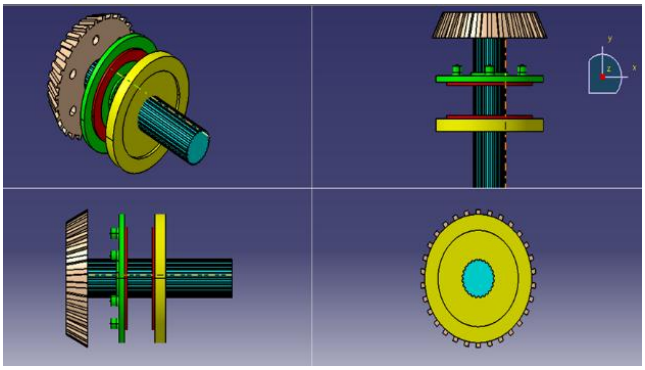
Its use in designing electronic systems is known as electronic design automation (**EDA**). In mechanical design, it is known as mechanical design automation (**MDA**) or **computer-aided drafting** (**CAD**), which includes the process of creating a technical drawing with the use of computer software.

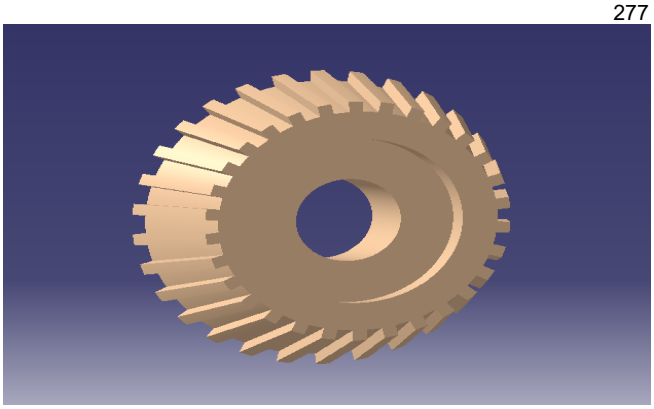
3.1.1 CAD MODEL

1. Isometric view

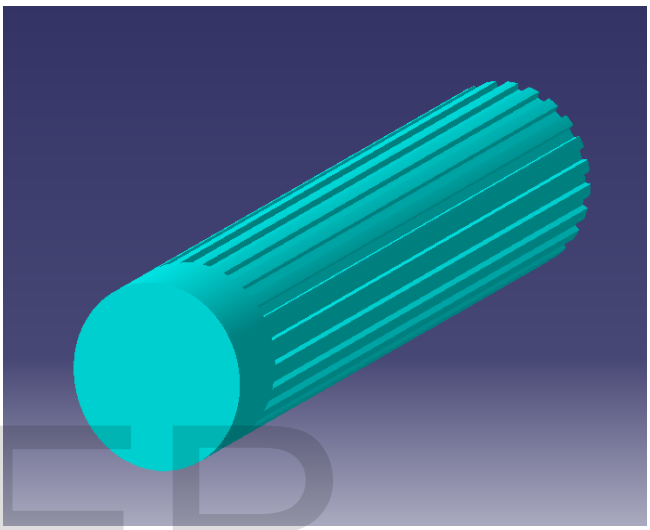


2. Different angle views

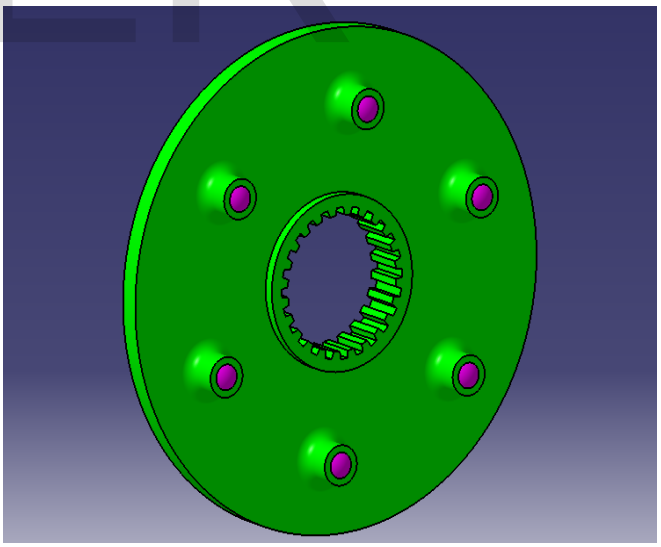




2. Splined shaft



3. Lockplate



4. Electromagnet

3.1.2 COMPONENTS OF DIFFERENTIAL LOCKER

1. Bevel gear with slots on the back of the gear.

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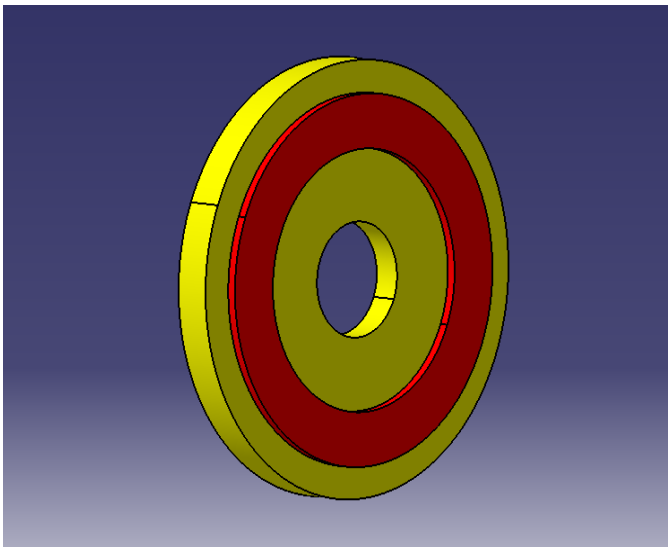
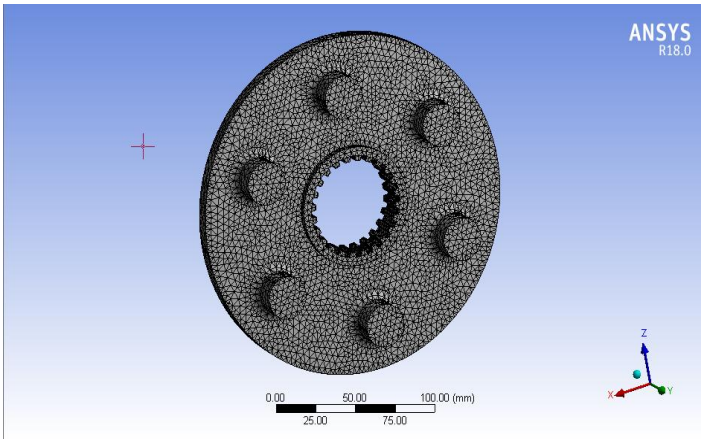


3.2 CAE (COMPUTER-AIDED ENGINEERING)

Computer-aided engineering (CAE) is the broad usage of computer software to aid in engineering analysis tasks. It includes finite element analysis (FEA), computational fluid dynamics (CFD), multi-body (MBD), durability, and optimization. It is included with computer-aided design (CAD) and computer-aided manufacturing (CAM) in the collective abbreviation "CAx".dynamics

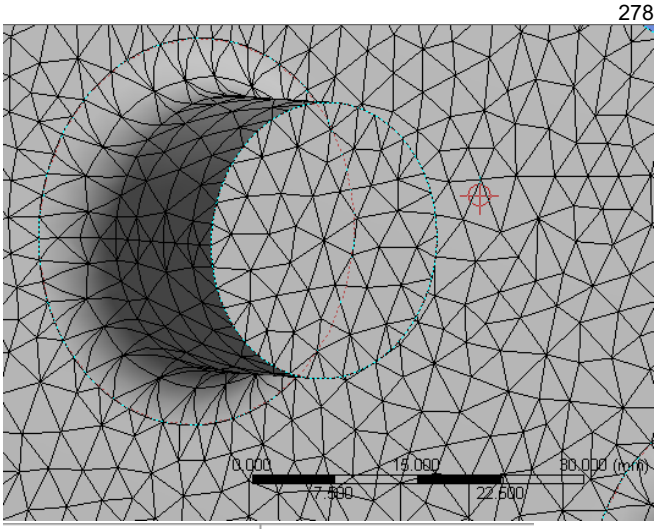
3.2.1 ANALYSIS OF THE LOCK PLATE USING FEA USING ANSYS

1. Mesh and mesh details



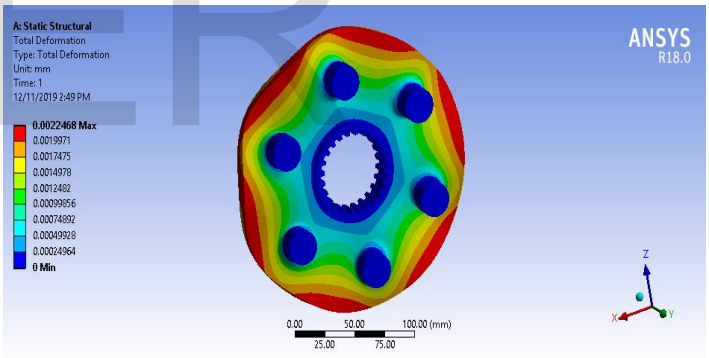
Mesh Details

- Element size- 2mm
- Element type- tetrahedron
- No. of nodes- 81061
- No. of elements- 45833

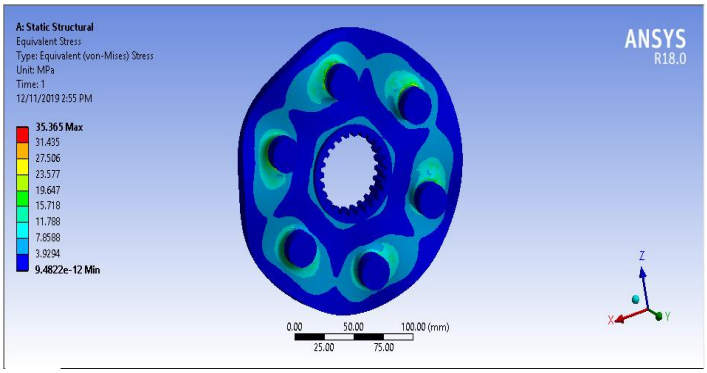


Size Function	Adaptive
Relevance Center	Coarse
Element Size	2.0 mm
Initial Size Seed	Active Assembly
Transition	Fast
Span Angle Center	Coarse
Automatic Mesh Based...	On
Defeature Size	Default
Minimum Edge Length	3.0 mm

2. Displacement



3. Von mises stress



3.2.2 BOUNDARY CONDITIONS

1. Fixed support 1

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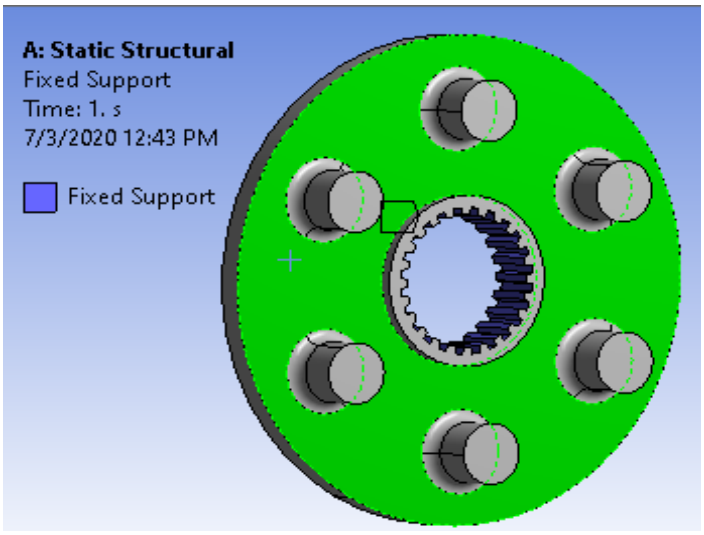
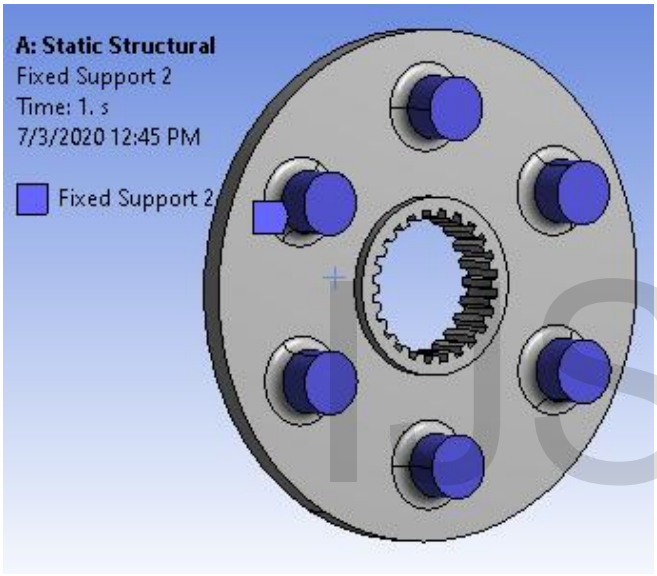
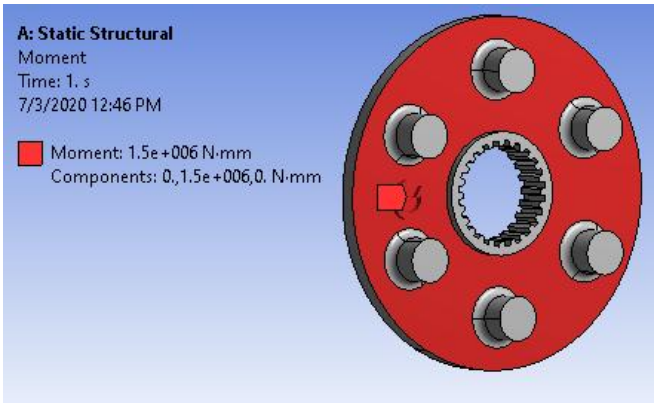


2. Fixed support 2

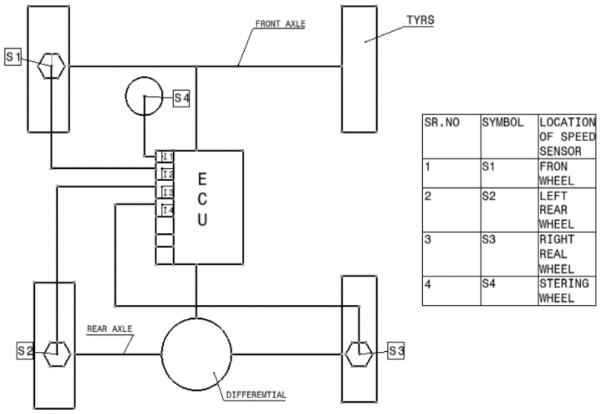


3. Moment



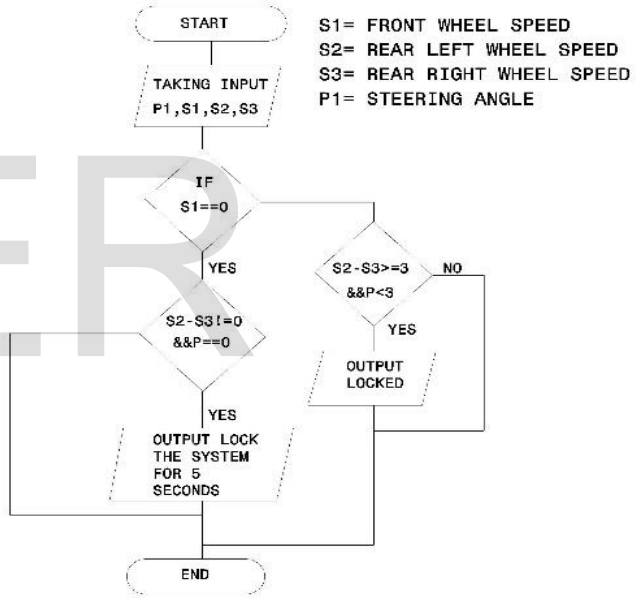
3.3 TECHNICAL DEPTH OF WORK

The layout of the electronically controlled differential unit.



SR.NO	SYMBOL	LOCATION OF SPEED SENSOR
1	S1	FRON WHEEL
2	S2	LEFT REAR WHEEL
3	S3	RIGHT REAL WHEEL
4	S4	STERING WHEEL

Flowchart



Case 1

When the vehicle is stationary (in a mud pit) and slippage occurs as one tire loses traction.

Detection:

S1=0, S2=400 rpm & S3=0 rpm
(Either S2 or S3 is zero)
S1, S2, S3 are the speeds of tires of the car in rpm.
This sensor I/O shows case 1 and gives o/p signal to motor respectively motor will lock both wheels.

Case 2

When the vehicle is moving (on snow). There is a possibility that during motion both rear-wheel have different rpm because of different traction at tires this makes the vehicle unstable on snow.

Detection

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R1= off or under limit, S1= x rpm, S2= 400 rpm & S3= 500 rpm
(S2 and S3 are not zero and vehicle is straight)
This sensor data shows case 2 and according to controls the differential.

Case 3

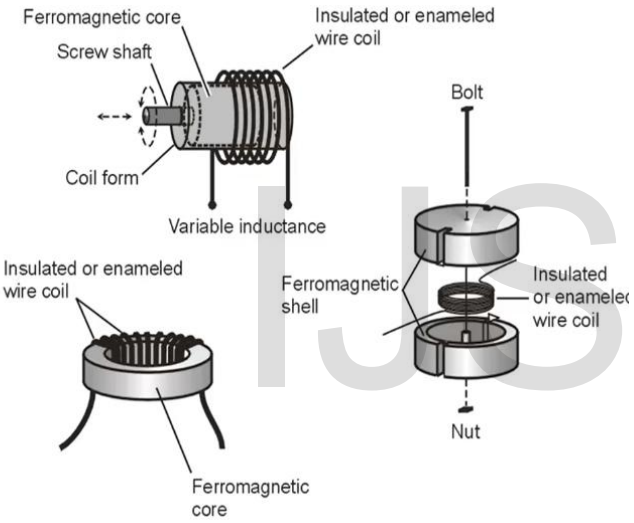
During case 2 while the differential is lock and there is a need to take a turn then the differential is needed to be unlocked.

Detection

R=on, S1=x rpm, S2= y rpm & S3=2 rpm

This condition shows slippage but drivers need to turn so the controller does not lock differential

4. TYPES OF ELECTROMAGNETS



In our differential locker, we are using pot type electromagnet to provide more repulsive force.

5. RESULTS AND DISCUSSION

- No. of iterations was performed by varying material and size of the plate.
- The equivalent stress value is less than the yield strength of the material.
- Max. The deformation is 0.002468 mm.
- Von mises stress is 35.365 Mpa.
- Stress concentration at the highly stressed location is reduced by design modifications.

6. FUTURE SCOPE

- A vast majority of research and development have been made in automobile electronically controlled self-locking differential.
- Promotes the use of mechatronics system in the differential gearbox.
- Provide exposure for change in the current differential lockers.
- An opportunity to make advancements in the conventional differential using the mechatronics system.
- Increase in the stability of the vehicle to another extent.

7. CONCLUSION

An electronically controlled differential locker is developed and provides complete traction control for the vehicle in the stuck condition. This differential locker is compact lightweight and has positive engagement with the slots at the back of the crown gear. Using this differential, the vehicle is easily able to travel in muddy tracks without losing traction. It will give an enhanced off-road performance. Can be activated without any push of the button. This project work has provided us an excellent opportunity and experience, to use our limited knowledge. We gained a lot of practical knowledge regarding, planning, purchasing, assembling, and machining while doing this project work. We feel that the project work is a good solution to bridge the gates between institutions and industries.

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