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Design and Fabrication of a Semi-Automatic Wheel Changer for a LMV

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Abstract:- In this paper we discuss about the development of a wheel changer mechanism, which can assist any individual in the process of tyre replacement of an LMV in case of a tyre puncture or any process in which tyre removal is associated. The idea to develop this mechanism popped up during our internship days in an automobile service centre, where we observed technicians experiencing back pain due to fatigue as a result of tyre replacement for a number of vehicles on a day to day basis. Our mechanism is inspired by a Forklift which is driven by a chain drive to lift or drop the tyre, accompanied by a motorised scissor jack and an electric wrench, powered by the 12Volt car battery. The mechanism offers better ergonomics, which reduces physical risk factor and can assist in reducing back pain.

Keywords:- *Tyre Replacement, Forklift, Chain Drive, 12 Volts Car Battery, Ergonomics, Motorised Scissor Jack.*

I. INTRODUCTION

The wheel changer is a device that can be used to replace a flat tyre or just for the removal or installation of a tyre. The device is inspired by a forklift which is driven by a chain drive for the upward and downward movement of the tyre. The development of forklifts originates from the early 20th century by various companies including Clark, which made transmissions and Yale & Towne Manufacturing, which made hoists. The process begins with a motorised scissor jack which is placed under the chassis of a vehicle which gives ground clearance for further removal of tyre. The wheel changer device holds the tire with its claws and then the bolts are loosened using an electric wrench, then the claws moves in the downward direction and the tyre to be replaced is rolled on to the claws which move in the upward direction, bolts are tightened using the same electric wrench and the motorised screw jack is deactivated. This whole process can be powered by a 12V DC power supply which is available in our vehicles.

This system is designed to make the tyre replacement process easier and less tedious for the operator. Further the system also offers better ergonomics while conducting the operation thereby reducing physical risk factor and enhancing safety of the operator. The system has been developed mainly for small scale workshops and garages. In most of the service stations pneumatic ramps and pneumatic guns are used for lifting the vehicle and removal/installation of tyres respectively.

II. SYSTEM DESIGN

A. Material Selection

Selection of a proper material for the system component is one of the most important step in the process of machine design. The best material is the one which will serve the desired purpose at minimum cost. It is not always easy to select such a material and the process may involve the trial and error method. We considered the following factors while selecting the material:-

➢ *Availability*

When speaking about availability, the material should be readily available in the market in large enough quantities to meet the requirement. We considered two materials for our frame i.e. MS Steel and Aluminium.

➢ *Cost*

When it comes to cost as a designer you need to adhere to a certain limit. We considered two factors for cost analysis, cost of material and cost/availability of processes to convert the material into finished products. Aluminium is much cheaper than MS Steel but due to the lack of availability of aluminium welding sites we had to go with MS Steel, which is heavier as compared to aluminium material.

➢ *Mechanical Properties*

Mechanical properties are significant which governs the selection of materials. They include strength under static and fluctuating loads, elasticity, plasticity, stiffness, resilience, toughness, ductility, malleability and hardness. We used steel tubes for our system whose specifications are as follows:

- *Yield strength: 345Mpa*
- *Ultimate tensile strength: 440Mpa*
- *Elongation: 25%*
- *Poisson's ratio: 0.28*
- *Density: 7850 kg/m^3*
- *Hardness: 240 HBr*

Fig 1 Steel Tube Dimensioning

These properties make the tube strong, ductile and corrosion resistant making it a good choice for a variety of applications.

B. Design of Motorised Screw Jack

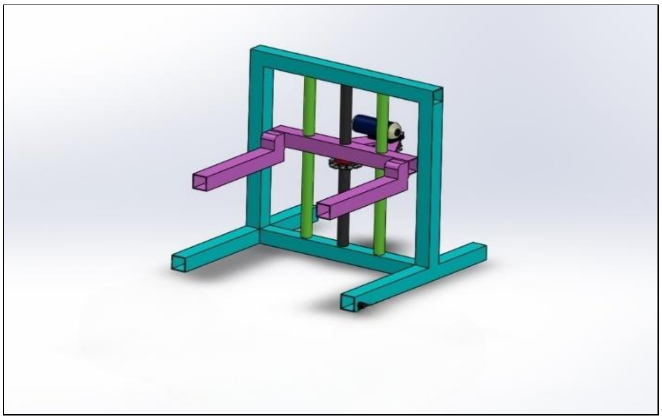

Fig 2 CAD Model of Motorised Screw Jack

- *12V Motor*

Motor Specifications:

$$Nrpm = 45\ RPM, V = 12V, I = 1.5A$$

$$(Electrical\ power)$$

$$Power\ P = I \times V = 18W$$

$$To\ find\ the\ torque\ of\ the\ motor, H.P = \frac{P}{745.7} = 0.0241\ h.p.$$

$$T = 9550 \times H.P/Nrpm = 5.1227\ N - m$$

- *MS Threaded Rod (MS M20)*

A threaded shaft is fixed on the mainframe, paired with a nut which causes the upward and downward movement of the claws, the nut is welded to a sprocket which is powered by the Wiper motor hubbed to the frame.

$$Pitch\ diameter, P = D - 0.6495 \times p$$

$$= 20 - (0.6495 \times 2.5)$$

$$= 18.376mm$$

$$(Fundamental\ Triangle)$$

$$H = P \times \frac{\sqrt{3}}{2}$$

$$= 2.5 \times 0.86$$

$$= 2.165mm$$

$$(Basic\ minor\ diameter\ female\ thread)$$

$$D1 = D - (2 \times 5 \div 8) \times H$$

$$= 20 - (2 \times 5 \div 8) \times 2.165$$

$$= 17.29mm$$

$$(Basic\ minor\ diameter\ male\ thread)$$

$$D2 = D - (2 \times 0.6134 \times P)$$

$$= 20 - (2 \times 0.6134 \times 2.5)$$

$$= 16.933mm$$

(For every complete rotation of threaded rod, the nut will move 2.5mm along the rod's length, e.g.3 rotations=7.5mm)

- *Calculation of Torque Required to Lift the Tyre*

(Here the torque required to lift the tyre is equal to the torque required to rotate the sprocket)

$$Weight\ of\ tyre\ holder + wheel = 27.4\ kg \sim 30\ kg$$

$$\therefore Force = 294\ N$$

For Steel-to-steel contact, K-factor ranges from: 0.15-0.2

Assuming torque reduction due to lubrication=20%

$$Torque\ required\ to\ rotate\ the\ nut\ with\ combined\ load$$

$$= FxDxKx0.8$$

$$= 1.176 \sim 1.2N - m$$

- *Chain and Sprocket*

This mechanism is used to transmit power from motor to the nut for lifting the claws.

Distance Between two Sprocket Centres

$$P = 12.7mm, Links\ of\ Chain, L = 28, N = n = 16$$

$$H = \frac{P \times \left(2L - N - n + \sqrt{(2L - N - n)2 - 0.810(N - n)2}\right)}{8} = 76.2mm$$

$$Pitch\ Angle, \alpha = \frac{360}{n} = 22.5°$$

$$Pitch\ Circle\ Diameter, DP = \frac{P}{\sin\left(\frac{\alpha}{2}\right)} = 65.12mm$$

$$Average\ Velocity\ of\ chain, V = \pi \times D \times \frac{Nrpm}{60 \times 10^3} = 0.1022m/s$$

$$Length\ of\ Chain, LC = L \times p = 355.6mm$$

- *Axial Thrust Ball Bearing (M20 5107)*

It is a type of bearing that is designed to handle axial loads; this bearing is placed between base of claws and the sprocket to ensure frictionless movement while converting the rotational motion into linear motion.

- *Specifications:*

$$M20\ 5107\ Thrust\ Ball\ Bearing$$

$$Do = 35mm, Di = 20mm$$

$$Basic\ Dynamic\ Load\ Rating, Cd = 14300\ N$$

$$Equivalent\ Dynamic\ Bearing\ Load, Pd = 400N$$

$$Rated\ Bearing\ Life, L10 = \left(\frac{Cd}{Pd}\right)^p$$

$$= 2.92 \times 10^6 (revolutions)$$

➢ *Linear Ball Bearing (M20 LM20UU)*

Two linear ball bearing are fitted in the claws, where reducing friction and guiding linear motion is needed. The bearing allow for smooth and low-friction linear movement along the two rods. The housing and carriage are usually made of steel or other durable materials, and the balls are typically made of steel or ceramic.

- *Specifications:-*

$$LM20UU\ M20$$

$$Do = 32mm, Di = 20mm$$

$$Basic\ dynamic\ load\ rating, Cd = 2580\ N$$

$$Basic\ static\ load\ rating, Cs = 1670\ N$$

C. Design of Motorised Scissor Jack

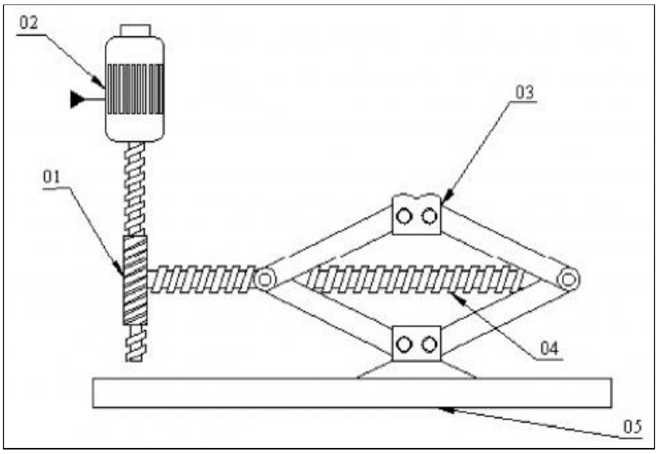

Fig 4 Parts of Motorised Scissor Jack

Table 1 Parts of Motorised Scissor Jack

SR. NO	01	02	03	04	05
PART NAME	Worm gear	DC Motor	Jack	Screw Rod	Base

➢ *Specifications:*

$$12\ V\ DC\ Motor\ with\ 100\ RPM, Torque = 3\ N - m,$$

$$Rating: 1\ tonne\ Scissor\ Jack$$

➢ *Working*

- *It uses an electric motor to rotate a threaded screw that moves a load through a nut attached to a load-bearing platform.*
- *The motor rotates the screw, which in turn moves the nut, either up or down, depending on the direction of rotation.*
- *The rotation of the screw causes linear motion of the nut, which is transferred to the load-bearing platform, causing it to lift the car.*

➢ *Overview*

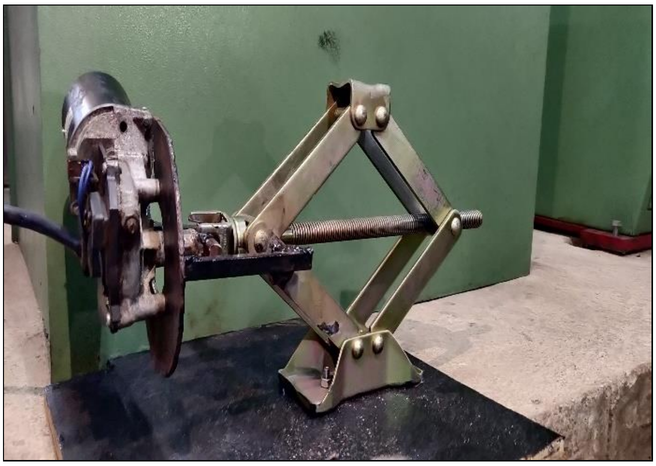

Fig 5 Prototype of Motorised Scissor Jack

The existing car jack was developed by making small adjustments and using an electric motor to rotate power screw. The car battery (12V) is the power source to motor, to make load lifting easier. The advantages of this modified jack is that it will save time, human efforts and easier to operate. Thereby effectively eliminating the problems related to Ergonomics, which is the most fundamental concept of designing process.

III. RESULT

Fig 6 Prototype of Motorised Screw Jack

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In order to enhance the tyre replacement process we designed a semi-automatic tyre changing machine which will allow an individual to replace tyres efficiently. The machine works on the 12V car battery supply, driven by the chain sprocket mechanism for the smooth top-down movement of the mainframe claws. The whole tyre replacement process with the machine takes less human effort as compared to the traditional method and offers better ergonomics. It can be used in small garages and also in some workshops where a lot of tyre replacement is involved.

IV. CONCLUSION

The project titled "Design and fabrication of a semi-automatic wheel changer for a LMV" is aimed to increase efficiency and to reduce human effort. The main advantage of using this model is that it reduces human effort and operates with a 12V power supply which can be found in most vehicles itself. The system is designed and developed successfully. For the demonstration purpose, a prototype model is fabricated. Further, the model can be developed and can be used for heavy duty applications

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