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DESIGN, DEVELOPMENT AND TESTING OF NOVEL REMOTE CONTROLLED ELECTRICALLY OPERATED HYDRAULIC JACK

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ABSTRACT

Now a days, people have a penchant for luxury, comfort and safety in each and every aspect of their lives provided money and technology available with the mankind. This project aims towards reducing the physical effort by humans to lift an automobile by automating the Hydraulic Jack through coupling it with a wiper motor and a radio frequency (RF) module. It works on the mechanism of conversion of rotatory motion of the wiper motor into the reciprocating motion of the hydraulic jack's plunger. The functioning of the motor being controlled by the RF module and a remote, through simple push of a button one could lift a heavy vehicle thereby reducing the physical effort considerably. A prototype illustrating the aforementioned mechanism was designed and fabricated. Also, it was tested and its functioning can be successfully illustrated.

Keywords: hydraulic jack, design and development, four-bar mechanism.

1. INTRODUCTION

In this project fluid power technology is integrated with electronics to control the hydraulic components and systems of a car jack. An alternate source of energy was provided by taking the power from wiper motor to drive the hydraulic jack automatically that will substantially reduce the physical burden.

The underlying principle is, converting rotatory motion of the wiper motor into the reciprocating motion of the hydraulic jack plunger which was done by using a four bar link designed based on Freudenstein equation. The crank of the four bar link is connected to the motor and the rocker acts as the hydraulic jack plunger. When the crank is being rotated by the motor, the rocker or the jack plunger reciprocates. The plunger is first drawn back, which opens the suction valve ball within the hydraulic jack and draws oil into the pump chamber. As the plunger is pushed forward, the oil moves through an external discharge check valve into the cylinder chamber, and the suction valve closes, which results in pressure building within the cylinder. However, because one cylinder has larger area compared to other, the force produced by the larger cylinder is higher, although the pressure in the two cylinders remains the same allowing the jack to lift hefty loads.

It is mainly focused towards assisting the ones physically weak and to ease the physical effort required to lift a weight using a jack[9]. Briefly, a system was developed which requires negligible physical effort to lift a hefty load in the most comfortable manner.

a) Hydraulic jack

A hydraulic jack[1] uses an incompressible fluid, which is forced into a cylinder by a pump plunger and hence is based on the force generated by pressure. The plunger, when pulled back, draws oil out of the reservoir through a suction check valve into the pump chamber and when moved forward, it pushes the oil through a discharge check valve into the cylinder. In this case, a bottle jack replaces the hydraulic jack as it resembles a bottle in shape, having a cylindrical body and a neck, from which the hydraulic ram emerges. In the bottle jack, a vertical piston directly supports a bearing pad that supports the object being lifted. With a single action of the piston, the lift is slightly less than twice the collapsed height of the jack.

b) Wiper motor

A wiper motor employs the combination of two mechanical technologies which are, a combination of electric motor and worm gear reduction that powers the wipers and a neat linkage that converts the rotational output of the motor into to and fro motion of the wipers. In this project, the linkage is a four bar mechanism that is connected to jack plunger and the rotational output of motor is converted into the reciprocating motion of jack plunger.

It takes a lot of force to accelerate the wipers back and forth across the windshield so quickly and a worm gear is used on the output of a small electric motor to serve this purpose. The worm gear multiplies the torque of the motor by fifty times, while slowing the output of the electric motor by same number as well. The output of the gear reduction operates a linkage that moves the hydraulic jack plunger back and forth.

c) Four bar mechanism

The four bar mechanism was designed using Freudenstein equation[3], that results from an analytical approach towards analysis and design of four-link mechanisms which, along with its variants, are present in a large number of machines used in daily life. An RF module based remote is used to control the wiper motor which in turn controls the jack.

An optimal synthesis of a four-bar linkage by method of controlled deviations was adapted. The advantage of this approximate method is that it allows

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control of motion of the coupler in the four-bar linkage so that the path of the coupler is in the prescribed environment around the given path on the segment observed.

2. DESIGN APPROACH

A four bar crank rocker Mechanism was employed to convert the rotating motion from the motor to linear motion of the piston and the lengths of rocker (d) and the distance between fixed points (a) was assumed to be 15 and 18 cm respectively. The lengths of the crank (b) and connecting rod (c) are calculated using the Grashoff's Law and Freudenstien equation [5], [7].
Firstly, by Grashoff's Law,

$$d + c > a + b$$
$$15 + c > 18 + b$$
$$c - b > 3$$
$$b + c < a + d$$
$$b + c < 18 + 15$$
$$b + c < 33$$

To satisfy the inequality, assume

$$c = 10$$

Now,

$$c - b > 3$$
$$10 - b > 3$$
$$b < 7$$

Therefore, b was assumed to be 6 cm.
Now, to check the assumptions, Freudenstien equation is used.

$$R_1 \cos(\Phi) - R_2 \cos(\psi) + R_3 = \cos(\Phi - \psi)$$

Where

$$R_1 = \frac{1}{d}$$
$$R_2 = \frac{1}{b}$$
$$R_3 = \frac{(1 + b^2 - c^2 + d^2)}{2bd}$$

Now,

$$R_1 = 0.0667$$
$$R_2 = 0.167$$
$$R_3 = 0.9$$

By Freudenstien equation,

$$\Psi = 34°$$

The transmission Angle came out to be 34° and the lengths of the crank, connecting link, rocker and fixed link are 6, 10, 15 and 18 cm respectively.

3. MODELLING AND ANALYSIS

The whole setup was designed in Solidworks for simulation and later analysis. The solid and wireframe oblique views of the CAD model are drawn as shown in Figures-1 and 2.

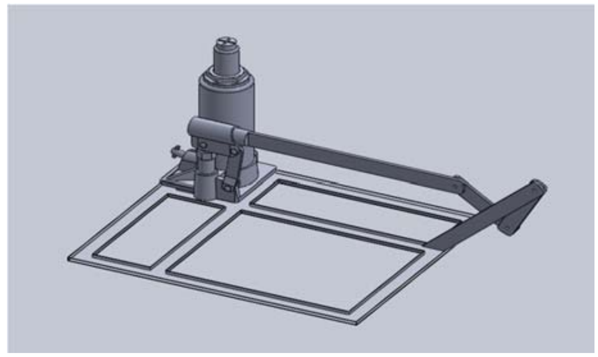

Figure-1. Solid oblique view of the CAD model.

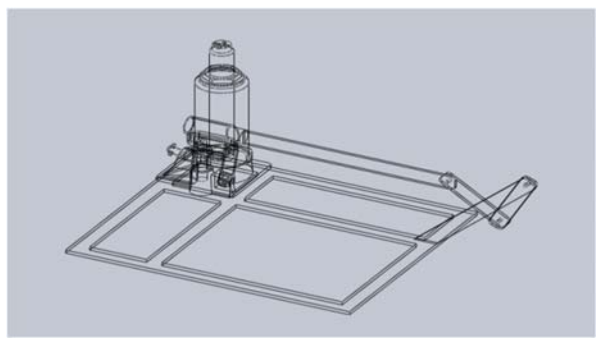

Figure-2. Wireframe oblique view of the CAD model.

The numerical stress analysis of the CAD model was performed[2] using Finite Element based software package ANSYS 14.0 .The equivalent stress developed was determined and is shown below in Figures-3 and 4.

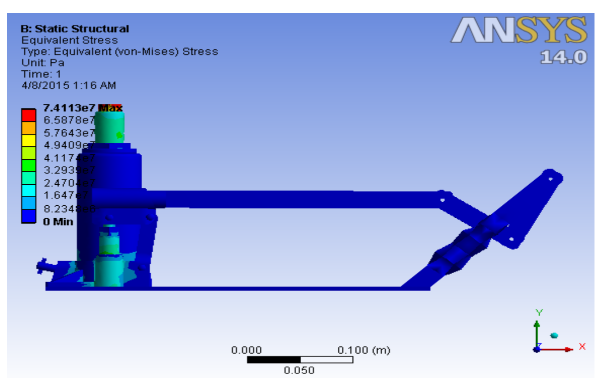

Figure-3. Front view of the model subjected to static stress in ANSYS 14.0 workbench.

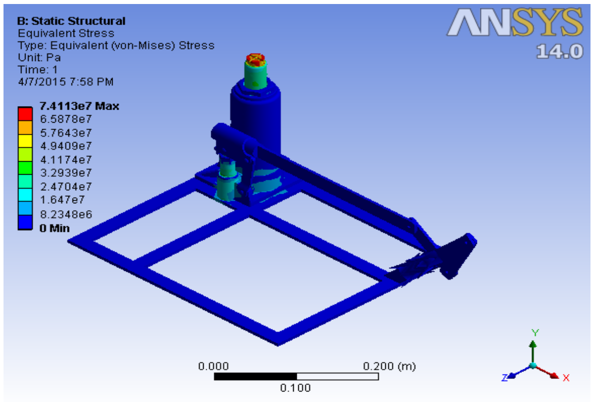

Figure-4. Oblique view of the hydraulic jack model sold subjected to static stress in ANSYS 14.0 workbench.

The calculations based on ANSYS 14.0 static stress analysis results are depicted below.

The ultimate strength of the material divided by its factor of safety gives the allowable stress.

$$S_W = \frac{S_M}{F_S}$$

Then the ultimate Strength of the material is within narrow limits, as for structural steel for which tests of samples have been made, when load is entirely a steady one of a known value, the factor of safety should be adopted as 3.

a) Testing the design

Factor of safety is, $F_S = 3$
Ultimate Yield Stress for AISI1045 Cold Drawn Steel is, $77000\ psi = 53.089 \times 10^7\ Pa$
Maximum Equivalent Yield Stress calculated from ANSYS 14.0 is, $7.4113 \times 10^7\ Pa$
Therefore, working stress is, $17.653 \times 10^7\ Pa$
Since, $7.4113 \times 10^7 < 17.653 \times 10^7$,
Hence, the design is proven safe.

4. FABRICATION AND ASSEMBLY

The required hydraulic jack was chosen according to the load, it was connected to the wiper motor of an according load rating and then finally the components were assembled on a frame to make the device compact and portable. The portable hydraulic jack selected has a 3 ton capacity. The pumping unit is connected to the hydraulic jack by means of a rigid connecting flat 150 mm long and acts as a rocker in four bar mechanism (Figure-5). The crank of the Four bar mechanism is connected to the wiper motor. The approximate lift of the ram is 90 to 120 mm. The pumping unit is a single plunger type with a detachable handle. The unit is fixed on a metal frame base which is fastened with supporting bars. The wiper motor using a worm gear reduction is connected to an RF module and a remote containing the Transmitter module controls the motor.

a) Technical specifications of the prototype

i. Hydraulic jack
Capacity: 3 Tons
Max Height: 270 mm
Lifting Height: 120 mm
Net weight: 3.3 kg

ii. Wiper motor
Operating voltage: 12 V
Operating Current: 30 Amp

iii. RF module
FS1000A Wireless Radio Transmitting Module
Operating Voltage: 2.5 V to 12 V
Operating Current: 4mA @ 5V, 15mA @ 9V
Quiescent Current: 10uA
Modulation: ASK
Max. Data Rate: 9.6K
RF Power: 20 mW at 5V

5. CALCULATIONS

The hydraulic jack consists of a handle cum lever of 15 cm length and an assembly of aforementioned dimensions. In order to determine the force exerted on the handle [4] [6],
Area of cross section of the larger piston

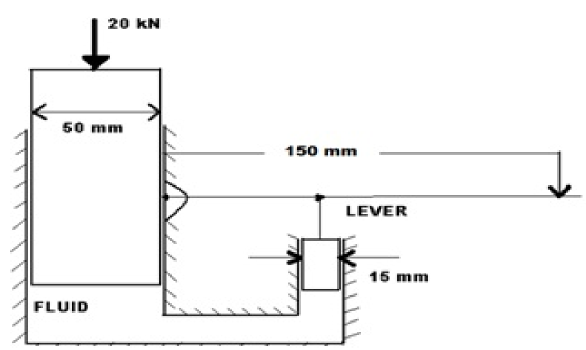

Figure-5. Cross-section of hydraulic jack with dimensions.

Pressure of the hydraulic fluid under the piston should be such as to balance the force applied on the piston. So,

$$P = \frac{20 \times 1000}{0.0196} = 10.18 \times 10^6 N/m^2$$

The force exerted on the smaller piston must be

$$F_p = P \times \frac{\pi d^2}{4}$$

$$= 10.18 \times 10^6 \times \frac{\pi \times (0.015)^2}{4}$$

$$= 1800\ N$$

The force desired to be exerted at the handle of lever should be

$$F_h = 1800 \times \frac{25}{150} = 300\ N$$

The torque required

$$T = 300 \times 0.15 = 45\ N-m$$

Torque supplied by motor

$$T = \frac{P}{2\pi N_1} = \frac{360 \times 60}{2 \times \pi \times 15} = 230\ N-m$$

Hence the torque supplied is good enough for functioning of the model.

6. RESULTS AND DISCUSSION

a) Testing the prototype

The standard voltage requirement for the wiper motor, 12 volts DC, is supplied by means of a battery. Since the motor uses only what it needs, so the need to bother about battery getting weaker is unnecessary in this operation. After attaining the required lift, using remote, further motion can be halted and the operation can be carried out. Once the task is performed, by remote control, the jack can be lowered by pressure release valve which is provided on the pumping unit.

b) Results from Stress Analysis

The CAD model of the prototype was generated using SolidWorks and then imported to ANSYS 14.0 for analysis. A static structural analysis was done on the model. The material selected was AISI 1045 Cold Drawn Steel. Keeping the base of the model as fixed support, a force of 20 kN was applied at the plunger of the Hydraulic Jack. Secondary forces of 9.2 kN and 60 N were applied at the rocker arm and connecting link respectively. The model was then meshed and solved. Equivalent stress was calculated and the model was well within the permissible stress limits for the desired factor of safety. Therefore the design was considered safe.

Figure-6. Assembled prototype of the hydraulic jack.

7. CONCLUSIONS

A handy and compact model of a remote controlled electrically operated hydraulic jack was designed, developed and fabricated (Figure-6) to serve the people thereby reducing the physical burden of using car jacks manually.

It is also possible that the wiper motor can be replaced by stepper motor to have more torque and less space consumption resulting in reduction of weight and cost, also the range of operation can be increased.

Thus, this model is a limelight of its kind with limited number of links and rather simple mechanism that could serve mankind by making the life easier.

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