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Design of a Mechanical System for vehicle liftingt

Diseño de un Sistema Mecánico para elevación de vehículos

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Abstract

The automotive industry has always been concerned with improving day by day all of its vehicle models, developing more comfortable systems for its users, such as rear cameras, automatic parking systems, collision detection, air bags, etc. However, it has neglected certain aspects like the replacement of tires when having a puncture, using devices that have not changed in a long time. We present the design of a protoype coupled to a bottle-type hydraulic jack to elevate automotive vehicles, replacing the mechanical energy provided by the human with electrical energy of direct current provided by the car's battery. The prototype consists of a 12 V gear motor that moves a gear train mechanism to activate a crank that will be coupled to the jack to produce the lifting.

Hydraulic jack, Gearmotor, Crank mechanism, Gear trains

Resumen

La industria automotriz se ha preocupado siempre por mejorar día a día todos sus modelos de vehículos, desarrollando sistemas más confortables para sus ocupantes como cámaras traseras, sistemas de estacionamiento automático, detección de colisiones, bolsas de aire etc. Sin embargo ha descuidado ciertos aspectos como son el reemplazo de un neumático al sufrir una pinchadura, empleando dispositivos que no han cambiado en mucho tiempo. Se presenta el diseño de un prototipo acoplado a un gato hidráulico tipo botella para elevar vehículos automotores, reemplazando la energía mecánica ejercida por el ser humano por energía eléctrica de corriente continua proporcionada por la batería del automóvil. El prototipo consta de un motoreductor de 12 V. que mueve un mecanismo de trenes de engranes para activar una manivela que será acoplada al gato para producir su elevación.

Gato hidráulico, Motorreductor, Mecanismo biela manivela, Trenes de engranes

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Introduction

Velasco (2019) defines innovation as the transformation of an idea into a marketable product or service, new or improved, or a new method that provides a social service.

Maldonado (2005) innovated a mechanical jack through some changes and ergonomic applications, so that the user has ease and comfort while lifting a car, having the certainty that by simply activating a control, it can perform the task without using physical force.

A research and design of a rotating hydraulic cylinder jack using a rod-crank mechanism, coupling a 12V electric motor was developed by Afkir (2018).

The design was carried out with the SolidWorks 2017 program, used for 3D design and for simulating finite elements, in order to verify that the different components can withstand the previously calculated forces.

Camarena and Santamaría (2012) developed a hydroelectromechanical system capable of supporting the weight of a tourist car of segments E and F, at its different loading points, in order to be an adjunct in the task of replacing a damaged tire or provide maintenance to certain auto parts.

García (2017) carried out the work which consisted in the design of a virtual prototype of a hydraulic bottle jack. This model has been chosen, because it is very easy to use, reliable and portable. This work has been done using Autodesk Software, Inventor Professional 2018. A virtual simulation is performed to check the static integrity of the machine, using finite elements. Since the jack does not work at a certain speed, but it is the user who provides it with variable acceleration and movement through manual operation, the dynamic simulation falls to an illustrative background.

Design process

Design is a fundamental phase of the product life cycle. Numerous research projects were able to highlight the influence of design on industrialization, costs and production deadlines, marketing efforts and maintenance or recycling activities of the product.

Studies show that 75% of the life cycle costs of a product are determined at the end of the design phase and are directly attributable to the decisions made; in addition, during this phase 40% savings can be made. Improving the result of this engineering process has an important impact for the company.

There are different types of design processes in the bibliography and each industrial company adopts the one that best suits its needs.

Product development corresponds to several realities and the resulting processes are multiple. Generally, this development is characterized by the type of product studied, in relation to the type of design process applied, and by the type of objectives that the customer defines for the future use of the product.

At a theoretical and practical level in the automotive industry, a design process is defined with the following stages: (figure 1)

- Needs.- Definition of customer requirements.
- Specifications.- Functional analysis is a methodology in the mechanical sector used to define the technical specifications of the product (requirements are also discussed).
- Solution search.- solution formulation and logical verification.
- Preliminary design.- Product structuring in physical components and first geometric definitions
- Detailed design.- 3D modeling and dimensioning.
- Validation.- Verification with simulation or prototypes.

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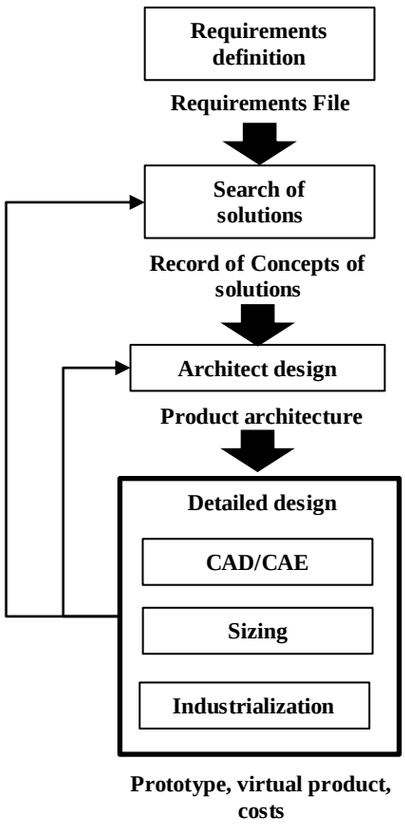

Figure 1 Development process of a new product

Requirement Definition

Designing a prototype that can be adapted to a bottle-type hydraulic jack to perform the car lifting, which is economical and easy to use.

It was decided to innovate a hydraulic jack, through some changes and electrical applications, so that the user has ease and comfort while lifting a car, having the certainty that by simply activating a control, it can perform the task without using physical force.

The main parts of a hydraulic bottle jack are as follows: (figure 2)

Figure 2 Parts of a bottle-type hydraulic jack

Search for solutions

In this stage, we pondered the different ways of solving the problem. As a first option, it was considered to place a motor reducer coupled directly on a cam. It was calculated that the engine did not have enough torque to lift the vehicle. It was decided to place a gear train in order to increase torque, sacrificing speed.

Due to economic issues, the required materials were searched in an industrial waste center, which were the following:

1. A 12V motor with speed reducer at 50 rpm, power of 1/125 hp and torque of 10 lb/in

2. A bottle-type hydraulic jack with a capacity of 2 tons. (figure 3)

3. Straight gears of 20, 46, 26, 36, 26 and 32 teeth with equal diametral pitch.

Figure 3 Acquired Materials

Due to the conditions of the hydraulic jack, it was correctively maintained, verifying its operation.

Product architecture

The drawings of the required parts were carried out in the SolidWorks package, as well as their assembly, as shown in Figure 4

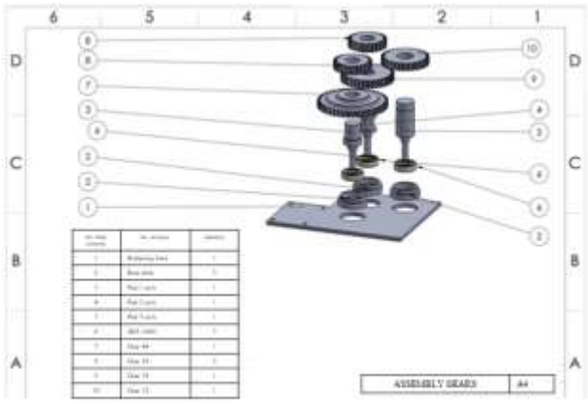

Figure 4 Assembly of parts

The gear train arrangement was as follows: z1 = 20 dte, z2 = 46 dte, z3 = z5 = 26 dte, z4 = 36 dte and z6 = 32 dte.

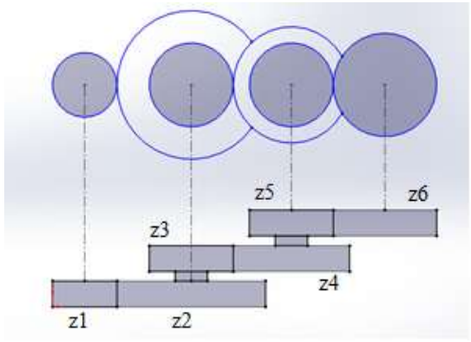

Figure 5 Gear train

With the data obtained above we know that the transmission ratio *i* is equal to

$$i = \frac{z1*z3*z5}{z2*z4*z6} = \frac{20*26*26}{46*36*32} = 0.255 \quad (1)$$

So the output speed will be

$$n6 = i * n1 = 0.255 * 50 = 12.75\, rpm \quad (2)$$

And the torque

$$T = \frac{hp*716}{rpm} = \frac{\frac{1}{125}*716}{12.75} = 0.45\frac{kg}{m} = 39lb/in \quad (3)$$

Next, we purchased the following materials for the manufacture of the prototype:

- 1018 steel plate
- 1018 steel rounds
- 1018 steel tubes
- 6001 bearings

These materials were machined and turned for the construction of the prototype according to the design specifications drawn in SolidWorks.

We purchased 14 gauge AWG cable and a plug for car cigarette lighter for the motor voltage supply. In order to start the engine, a pushbutton was used instead of a switch, so that the hydraulic jack only works when it is pressed; in this way, it is ensured that the motor, and therefore, the hydraulic jack, starts up voluntarily and avoids any type of accidents or involuntary operations.

Prototype

Figure 6 shows the assembly of the parts manufactured for the prototype construction.

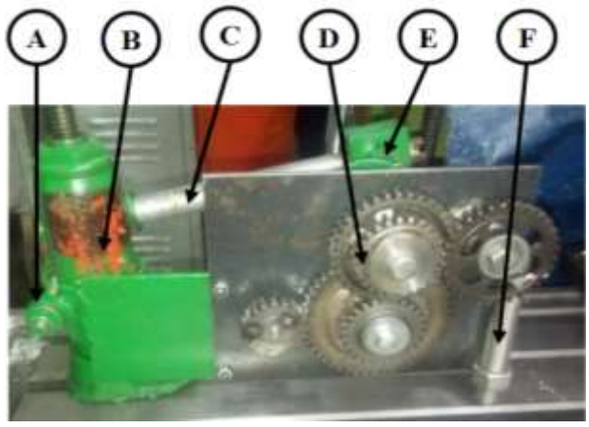

Figure 6 Final assembly

The components are:

a. **Tightening screw**. Allows the prototype to be mounted to any type of hydraulic bottle jack with a capacity of 2 tons.

b. **Bottle-type hydraulic jack**. It is responsible for lifting the vehicle to perform maintenance or changing the damaged tire.

c. **Drive lever**. It lifts the hydraulic jack by means of an alternative linear movement.

d. **Gear train**. They are responsible for reducing speed and increasing torque.

e. **Crank**. Uses a follower to perform the movement of the operating lever.

Leveling screw. Used to level the prototype with the hydraulic jack.

Costs

This part of the report presents the prices of the components used, both acquired as new and reused.

Regarding the reused materials, they were acquired, as previously mentioned, in an industrial waste plant, so we show the difference between these and the costs of the new materials: (Table 1)

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Material	Price for new product	Price Found in recycling
Hydraulic jack	$ 550.00	$ 100.00
12v motor	$ 469.00	$ 50.00
Gears	$ 600.00	$ 150.00
Total	$ 1,619.00	$ 300.00

Table 1 Reused material costs

As it can be seen in the total costs, there was significant savings when acquiring these materials.

After this, we established in different places the budget for the purchase of the necessary materials for the manufacture of the base where the motor was mounted and the coupling to make the movement conversion (Table 2). Below are the materials used, as well as their description and price:

Component	Description	Cost
Circular plate	d=4" espesor =1/4"	$ 40.00
Cold square roll	1 ½ x 1 ½ L=2"	$ 50.00
Steel plate	15x15 cm L= 12cm	$ 50.00
Round	D=1/2" x L=2	$ 30.00
Round	D=5/8" x L=1	$ 20.00
License plate	10x10 cm x¼ espesor	$ 60.00
Tube	D=32mm L=33cm	$ 50.00
Screw	D= 5/8 in x 4 in	$ 45.00
Screw	D = ½ in x 3 in	$ 21.00
4 pieces screw	D = 5/16 in x 1 ½ in	$ 16.00
Connector	Plug para encendedor de auto	$ 14.00
Switch	Switch push botón	$ 35.00
Cable (5 m)	Duplex 14 AWG	$ 120.00
3 pcs bearing	Rodamiento 6001	$ 105.00
	Total	$ 656.00

Table 2 Cost of materials used

Performance

For the operation and performance of the hydraulic jack driven by the lifting prototype, the following steps are required;

- The load to be lifted must never exceed the nominal force of the jack.
- The maximum jack travel must never be exceeded.
- The jack must rest on a firm, regular, horizontal surface, free of unnecessary elements and a well lit area. Never rest the jack on a surface that can sink.
- Make sure there are no people in the vehicle. Disconnect the engine and fully brake the vehicle. Wear shims if necessary.
- Do not enter the vehicle or start the engine while it is supported by the jack.
- Place the jack below the lifting point recommended by the vehicle manufacturer and make sure it is not damaged, dirty or with grease. This point should be centered on the jack's head of support.
- Adjust the leveling of the jack with the screw that is welded to the plate. (Figure 7)

Figure 7 Prototype operation

- Connect the plug to the car's electrical outlet.
- Close the discharge key.
- Insert the lever into the jack and the prototype crank.
- Activate the switch to start the engine and watch the crank go up and down.
- To lower, pull the jack lever and crank and slowly turn the discharge key with the lever counterclockwise.
- During the lifting and lowering of the load, it is necessary to take all kinds of measures to avoid displacement of the vehicle load
- The jack must be used without the user being forced to introduce any part of their body under the vehicle.
- In case of vehicle movement, it is necessary to interrupt the lifting.

Conclusions

The methodology used for the development of a new automotive product was followed, which is the one that adapts to the requirements of this prototype.

The prototype was tested in four different types of cars to verify its operation; it was observed that in all cars the survey was carried out successfully.

It was also verified that there was no engine heating due to the work performed.

Being a direct current motor, to achieve a high torque, large reductions were made, which resulted in low output revolutions.

The time it takes for the jack to travel the entire spindle race is 10 minutes, rising approximately 2 centimeters per minute.

No effort is required by the user to lift the car, since the energy required is provided by the car's battery.

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