IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 6 Ver. V (Nov. - Dec. 2016), PP 70-77
www.iosrjournals.org

Potential Energy Converter Device Using Automotive Vehicles.

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Abstract: *The quest to obtain renewable energy has increased in recent years. Areas in the field of power generation have been developed with the use of available energy taken from different sources. Our proposal offers a different source to obtain energy, today one can find bumps almost everywhere on the transit routes, these bumps are capable to transform the potential energy of any vehicle into electric energy. In recent times, we can also see multiple devices of suspension in vehicles that generate electricity with movement as well as the regenerative braking system. In shopping centers one can be observed electric generators on floors and stairs generating electricity when people walk on them. In this paper the conversion of potential energy into a mechanical energy is investigated through a new hydraulic device that can be installed on the transit routes to be operated by motor vehicles as they pass on the device.A pair of hydraulic pistons reciprocating are driven by the vehicles, generating pressure and flow which serve to move a hydraulic motor. The hydraulic motor converts fluid energy into mechanical energy that can be converted in turn into electric energy by coupling an electric generator. The results of tests with the device showed a very efficient energy conversion, due to the few hydraulic and mechanical elements used.*

Keywords: *Available energy, Bumps, Hydraulic motor, Hydraulic pistons.*

I. Introduction

Several studies predict the decrease of oil for the near future. That is why they have been implementing programs and projects whose objectives are the generation of electricity through renewable sources, where the appropriate electricity generation is done by the use of energy waste from other processes. In this project, it is designed a hydraulic device use to transform the potential energy from vehicles into electrical energy.The bumps are elements of the vehicular traffic pathway which their function is to force the driver to slow down, Figure 1. They do this through static barriers of variable heights and geometries. When the vehicle goes up the bump, it acquires a potential energy that is superior than the potential energy it previously had, as the mass of vehicles is considerable, the potential energy obtained is also the same. Therefore, it is hypothesized that potential energy from the vehicle can be transformed into electrical energy.

Figure1. Speed reducer bump. [1]

This method of obtaining energy is not renewable or "clean" as the vehicle had to consume more fuel to go over the bump. In Mexico there is no driving culture as there is in first world countries like Germany, United States, among many others; which is why we will still continue installing bumps on the roads of Mexico, being able to exploit the potential energy while performing its function of reducing the speed of motor vehicles.There are many research papers and patents on the design of bumps which generates electricity. There are designs where mechanical systems are used to convert kinetic energy or potential energy from vehicles into electric energy [2], [3] and [4] to name a few. The disadvantage of the mechanical systems is the efficiency, which is low due to friction, and that the elements are subjected to mechanical fatigue, which damages the elements and inertias of some of them are considerable. Other designs use pneumatic or hydraulic systems [5] and [6], but most of them are complex designs with many elements. The design proposed in this paper is a hydraulic device, free of mechanical fatigue, and with a few elements to make work.

II. Development

Mechanical Work.
The mechanical work needed to accelerate a system in a gravitational field is interpreted as a mechanical energy balance for a closed system [7]:

$$\Delta E_c + \Delta E_p = W_{mec} \qquad (1)$$

Where ΔE_c is defined as the translational kinetic energy of a system, is calculated as:

$$W_c = \int_{t_1}^{t_2} m \frac{d\bar{V}}{dt} \cdot (\bar{V} dt) =$$
$$= \int_{\bar{V}_1}^{\bar{V}_2} m\bar{V} \cdot d\bar{V} = \int_{V_1}^{V_2} mVdV \qquad (2)$$

The integration process between states 1 and 2 leads to:

$$W_{c,12} = \frac{mV_2^2}{2} - \frac{mV_1^2}{2} = E_{c2} - E_{c1} = \Delta E_c \qquad (3)$$

ΔE_p is defined as the gravitational potential energy of a system, it is calculated as:

$$W_g = \int_{t_1}^{t_2} -m\bar{g} \cdot \bar{V} dt = \int_{t_1}^{t_2} mgdz \qquad (4)$$

Assuming that gravity is constant between the heights and integrating the process, we have:

$$W_{g,12} = mgz_2 - mgz_1 = E_{p2} - E_{p1} = \Delta E_p \quad (5)$$

Overall, the translational kinetic energy and gravitational potential energy combine are generally call mechanical energy. As the work is a mechanism for transporting energy across the boundary of a system, the hydraulic device developed in this article converts the potential energy acquired by the vehicle passing over the bumps.

Hydraulic device.
The power transmission through the hydraulic (incompressible fluids) is efficient and instantaneous, regardless of shape or length of the components. The pressures that can be achieved in these systems are around 700 bar pressure (10,000 psi). Hydraulic systems are anti-fatigue, life is very long, very reliable and a simple structure [8]. Due to these reasons, our research had been selected to work with a hydraulic system.The hydraulic device to generate electricity consists of two bumps placed one after another on any transit route Figure 2. It will be call *first bump* to the bump which have the first contact with the vehicle and the other bump will be call *second bump*. For purposes of interpretation, the two bumps are illustrated connected by a lever-rocker, but the device development is hydraulic.

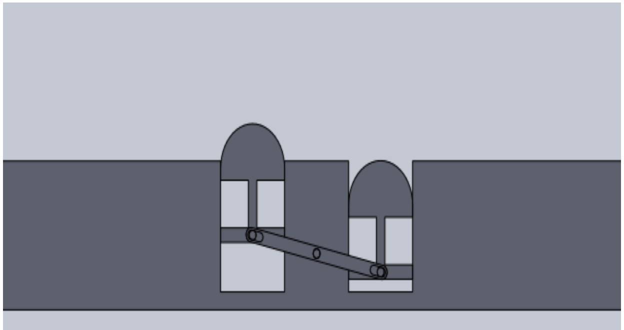

Figure 2. Mechanical representation

The hydraulic diagram of the device designed in this research is shown in Figure 3. The device consists of a hydraulic piston under each bump. Each bump is joined to a piston rod mechanically. The pistons are joined together hydraulically through a bidirectional hydraulic motor.

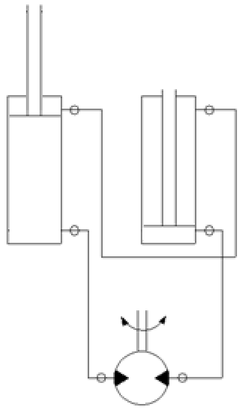

Figure 3. Diagram hydraulic device.

The pistons must be preloaded before connecting hydraulically, this means that they should be completely fill with fluid in both pistons chambers, in order to move air out of the system. Furthermore, pre-charging should be on both, the hydraulic motor and the hoses. All this is done to have all the system volume with incompressible fluid to have high efficiency system.The sequence of activation of the hydraulic device is as follows. Passing the front wheel of a car over the first bump, it moves downward because it is mechanically connected to the first piston rod, the piston moves any fluid from the chamber to the second piston chamber through hoses. When the fluid arrives to the second piston chamber it causes the second piston rod to rise. As the second bump is mechanically connected to the second piston rod, the bump rises with it.

As the vehicle moves forward, the first bump stops being activated and now the front wheel passes over the second bump, moving it down making the same operation but in a reverse way. At this time, the front wheel has passed through the two bumps and leaving them in the same configuration as in the beginning (first bump outside and second one inside). The rear wheel of the vehicle makes the same sequence.If a bidirectional hydraulic motor is connected in one of the hoses that connects the hydraulic pistons, it will rotate as the fluid passes from one piston to another. For each wheel passing through the set of bumps, the hydraulic motor will make two movements. Therefore, the motor will rotate four times every time that a motor vehicle of two axles passes through the hydraulic device.Hydraulic systems have the disadvantage of being slow in comparison to other systems, but they have the advantage of handling pressures values, and therefore forces and torques that are too high.

Hydraulic components.

Hydraulic components used to develop the electricity generating device are shown in Table 1.

Table 1. Components of hydraulic device.

2 Double effect pistons.
Parker 1.503L4A8.0 Medium Duty Hydraulic Cylinder Series 3L.
1 Bidirectional hydraulic motor .
Parker TB0050.
Accessories Parker
Manometers , hoses , Connections, Flowmeter

The used piston is shown in Figure 4 and the used hydraulic motor in Figure 5.

Figure 4. Double-acting piston.

Figure 5. Bidirectional hydraulic motor.

Experimentation.
In this first stage of the project, the hydraulic power generating device has been tested on a workbench. The installation and connection of the hydraulic components in test are shown in Figure 6.

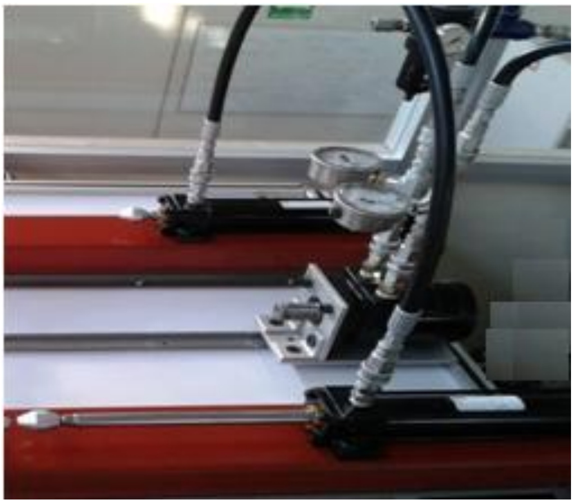

Figure 6. Electricity generator hydraulic device.

As the hydraulic device is not mounted on any traffic route, they have been tested by simulating different weights of vehicles through other external hydraulic pistons, Figure 7.

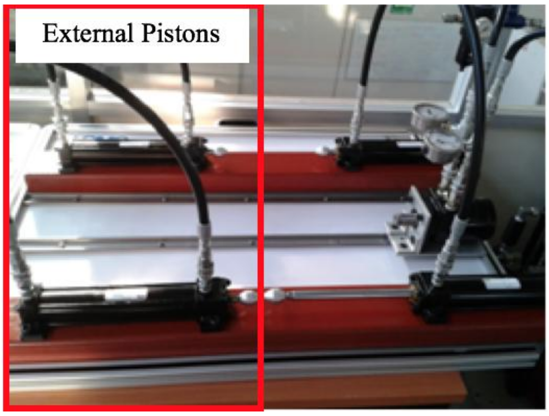

Figure 7. External Pistons simulating the passage of the wheels over the hydraulic device.

These external pistons are operated by two hydraulic mono-stable valves 4/2. We have a hydraulic power unit to develop external pressure to the pistons and therefore the forces necessary for the electric generator hydraulic system. Figure 8 shows the complete installation of the workbench for the various tests. Figure 9 shows the hydraulic power unit.

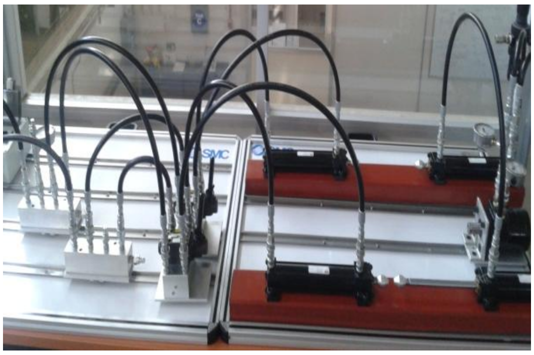

Figure 8. Test bench.

Figure 9. Hydraulic Power Unit.

To start with testing, we must first select the operating pressure of the hydraulic power unit. This working pressure will develop force in the external pistons. These forces will simulate the pressure apply by the wheels of vehicles on each bump.To understand the forces that the wheels of motor vehicles will exert on the bumps we use a dynamic analysis Figure 10 [9]:

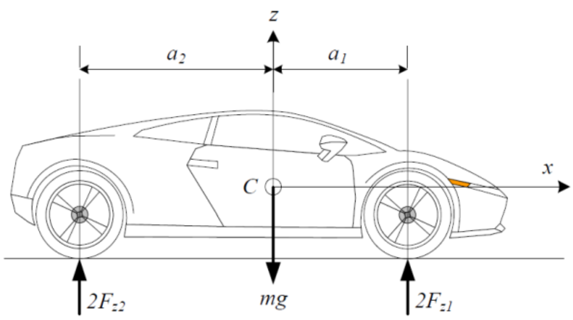

Figure 10. Dynamic Analysis.

The force on each front wheel is:

$$F_{z1} = \frac{1}{2} mg \frac{a_2}{a_1+a_2} \qquad (6)$$

And the force on each rear wheel is:

$$F_{z2} = \frac{1}{2} mg \frac{a_1}{a_1+a_2} \qquad (7)$$

Usually, the center of mass of the two-axis motor vehicle, moves to the part where the engine and transmission are located, as it is heavier in that area.As an example we have selected the simulation of a motor vehicle with 2,000 pounds of mass (907kg). Substituting the values in equations 6 and 7 the force is obtained in each front and rear wheel respectively.

$F_{z1} = 666.66\ lb_f$
$F_{z2} = 333.33\ lb_f$

These forces are the forces that the wheels of a vehicle mass of 2000 lb exerted on the hydraulic device. These forces will have to be developed by external pistons for testing on the workbench. As there are a variety of vehicle configurations on the market (different masses and mass centers) the forces of the external pistons will vary in many tests around these values, F_{z1} y F_{z2}, in order to observe the behavior of the hydraulic power generating device. The area of the external piston used in this work is 1,767in^2. Thus, knowing the operating pressure we can easily find the forces that develop on the external piston to the bumps by the following equation:

$$F_p = P_T \cdot A \qquad (8)$$

III. Results

Six different tests were done; the results are shown in Table 2.

Table 2. Results of the tests performed on the workbench.

P_T (psi)	F_p (lb_f)	Q_m (Gal/min)	P_m (psi)
200	353	0.48	31
300	530	0.52	66
400	707	0.58	100
500	883	0.66	133
600	1060	0.74	190
650	1148	0.76	200

Where P_T is the working pressure, F_p is the force exerted by the external piston on the bump, that is, the force of the wheel on the bump, Q_m is the flow of incompressible fluid flowing through the hydraulic motor when applying the force on the bump and P_m the pressure which develops the engine inlet simultaneously.

With these tests can be found the power developed by the hydraulic motor. As is known, the transmitted power in a shaft in a moment of time is [7]:

$$\dot{W}_{eje} = \frac{\partial w_{eje}}{dt} = \tau\omega = 2\pi\dot{n}\tau \qquad (9)$$

Where τ is the torque of the shaft, ω is the angular velocity (rad/s) and y $\dot{n}$ the number of revolutions per time unit. Therefore, it is necessary to know the torque and the revolutions per minute on the shaft of the hydraulic motor to know its power. These two values can be obtained directly from the motor shaft via proper instrumentation. Another way to obtain these data is through the characteristic engine curve that the manufacturer provides. It should be remembered that these curves are created through precise instrumentation from its manufacturer. Figure 11 shows the characteristic curve of the engine used in this research.

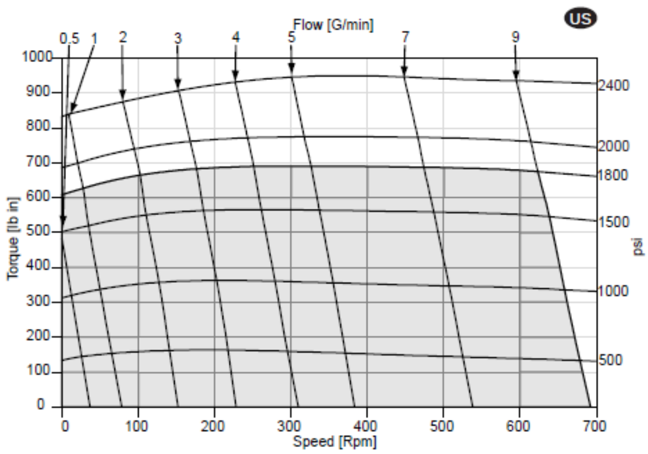

Figure 11. Characteristic Curve of the hydraulic motor.

Table 3 shows the potency developed by the hydraulic motor from tests.

Table 3. Potency developed by the hydraulic motor.

F_p (lb_f)	τ (lb_f·in)	$\dot{n}$ (rpm)	$\dot{W}$ (W)
353	17	35	7.04
530	26	38	11.68
707	35	41	16.97
883	44	44	22.9
1060	53	47	29.46
1148	62	50	36.67

Through the table above, one can graph the power in the hydraulic motor due to the force applied to the bump, Figure 12.

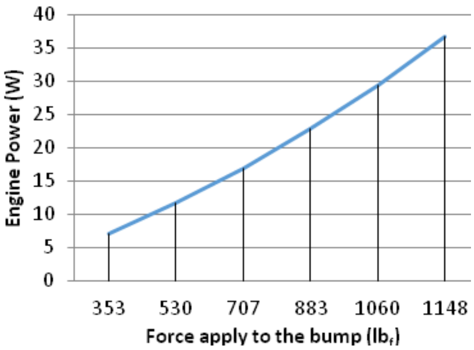

Figure 12. Graph of engine power do to the force applied to the bump.

Seeing the above graph, we get to know the power developed by the hydraulic motor when any motor vehicle goes over the hydraulic device. Two devices on the vehicular road, will be installed, one for each side of the vehicle. The selected motor vehicle simulation, was a 2000 pound-mass, with front and rear forces F_{z1} y F_{z2}, respectively, then we had the total power obtained on the vehicle which is:

$$W_T = 4W_{z1} + 4W_{z2} = 4(16W) + 4(6W)$$

$$W_T = 88 \; watts$$

Where W_{z1} y W_{z2} and are the potencies that develop forces to the front and rear wheel respectively.

IV. Conclusions

The real mechanical energy generated by the hydraulic device is small, but throughout the day, and even more with heavy fluent traffic, the amount of energy is considerable. To the real energy obtained in this research we had to subtract the efficiency with which the electrical generator will convert this mechanical energy into electrical energy, but it must be remembered that the efficiencies of electrical machines are high. As an increasing overall weight of the vehicle goes over the hydraulic device, the flow and pressure increase in the hydraulic motor. Therefore, it increases both torque and revolutions per minute in the motor shaft, thus increasing the power delivered by the hydraulic motor. The location of the center of mass in the vehicle is not important for the development of power in the hydraulic motor, this is because the vehicle is taken as a closed system.The connections between the various hoses and hydraulic components have integrated check valves (male and female component hydraulic hose). These check valves have a small cross section through which the fluid goes through them, probably reducing the flow that moves the piston engine. If the flow is not restricted at all, the shaft would rotate the hydraulic motor more times per minute, thus increasing the power in the hydraulic motor. The diameters and lengths of the hoses must be the correct ones to maintain laminar flow as far as possible to reduce friction losses.The electric machine (generator) to be used in this device is an automotive alternator type, since this device can generate direct current when is rotated in both directions.As a future research, is the implementation of the hydraulic device in a path of vehicular traffic, as well as obtaining other models of pistons and engines for testing and selecting the optimal models for different weights of vehicles passing through this transit route.

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Nomenclature.

a_1 distance from the rear axle to the center of mass.
a_2 distance from the front axle to the center of mass.
A plunger piston area.
F_p piston force.
F_{z1} force in the front wheel.
F_{z2} force on the rear wheel .
$\bar{g}$ gravity vector.
m mass.
$\dot{n}$ number of revolutions per unit time.
P_T work pressure.
P_m engine pressure.
Q_m motor flux.
t time.
$\bar{V}$ velocity vector.
W_{mec} mechanical energy.
W_{eje} work axis.
$\dot{W}_{eje}$ shaft power.
W_{z1} power developed by the force of the front wheel.
W_{z2} power developed by the force of the rear wheel.
z_2 state height 2 .
z_1 state height 1.
ΔE_p translational kinetic energy.
ΔE_c gravitational potential energy.
τ engine torque.
ω angular velocity.