RESEARCH ARTICLE OPEN ACCESS

Enegy Regenaration in a Hydraulic Damper by Turbo Generator Flowpath Mechanism

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ABSTRACT
This paper develops a modification to hydraulic damper to utilize its energy lose in the form of heat. During the working of actual hydraulic damper, when the suspension fluid is compressed inside the damper cylinder in order to absorb the vibration shocks,the frictional energy of the vehicle is dissipated as heat loss by the suspension fluid in order to minimise the effect of bumps and ridges in road. So in order to harness this power loss, we have developed an energy saving hydraulic damper by modifying the existing model of hydraulic damper.We create a separate flow path with rotating turbine parallel to the damping cylinder connecting the upper and lower end of damper. When the vehicle travels down from a bump, the coil spring compresses forcing the piston to push the suspension fluid upwards and this high pressure fluid travels through the flow path rotating the turbine which in turn runs the generator for power generation. A check valve is provided at the flow path end to prevent the fluid back flow.Thus the suspension fluid kinetic energy is converted into mechanical energy by means of the turbine.
KEYWORDS: Vibrational energy, damping cylinder, backflow, hydraulic damper.

I.INTRODUCTION

Nowadays, one of the major problems in the suspension damper is the power dissipation in overcoming the vibration and shock of vehicle during bumps and ridges. The vehicle wheel traction power is dissipated as heat energy by compressing the suspension fluid in the damper Cylinder.In the past, we pay little attention to energy loss of vehicle suspension. However, how much energy is dissipated by the shock absorbers of vehicle suspension? According to reference [1], only 10-20% the fuel energy is used for vehicle mobility. One of the important losses is the energy dissipation in suspension vibration. Velinsky et al [2] concluded that the dissipated energy by suspension dampers is related with road roughness, vehicle speed, and suspension stiffness and damping coefficient. Segel et al. [3] analyzed the energy dissipation of dampers of passenger vehicle, and shown that the total power of four dampers was about 200W when running on a poor road at the speed of 13.4m/s. These data indicate that the energy dissipation of vehicle suspension can’t be ignored.Nearly 10- 15% of vibrational energy is dissipated by the damper as heat to attenuate the vibrationThe function of vehicle suspension system is to support the weight of vehicle body, to isolate the vehicle chassis from road disturbances, and to enable the wheels to hold the road surface. The suspension system is mainly the spring and damper. Conventionally, damper is designed to dissipate vibration energy into heat to attenuate the vibration which is transmitted from road excitation. The vehicle wheel traction power is dissipated as heat energy by compressing the suspension fluid in the damper cylinder. So as the energy dissipation in suspension system cannot be left without giving any importance to it, we have modelled and attached a turbo generator flow path mechanism parallel to the damper cylinder connecting the top and bottom end of the cylinderto harness this power loss in damper.

II.STUDY ON VEHICLE SUSPENSION ENERGY DISSIPATION

Road roughness causes dynamic deformations of the tires and the suspension system as well as modifying the road coefficient of friction and is, therefore, a factor in an automobile's energy requirements.So as to study the energy dissipation characteristics of suspension system.The vehicle's rear suspension is modelled as a combination of springs, viscous dampers, and Coulomb damping. The tires are modelled as springs and viscous dampers. A schematic of this model and the pertinent nomenclature is shown in Fig. 1.

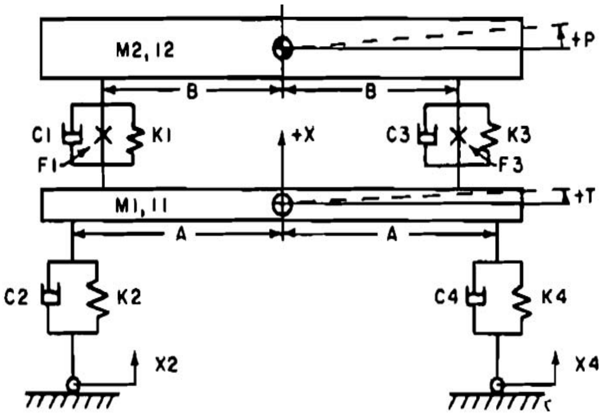

Fig.1. Mathematical model of rear axle suspension

The mathematical model of suspension system is a combination of spring with a spring rate, viscous damper and coulomb damper. Thus this study reveals that the energy dissipation in the suspension system is dominant only at lower frequency level that is below 50 km/hr.The Coulomb damping components dissipate energy directly proportional to relative velocity. The energy loss due to the suspension, SLOSS, is dependent on the dissipation. The viscous dampers and the Coulomb damping components is represented by the governing equation for the suspension energy dissipation loss[4] given as

$$\text{SLOSS}=\int_0^T [C1(V1)^2 + C3(V3)^2 + F1(V1) + F3V3dT$$

Where V1 and V3 are the relative velocities across the shock absorbers at the left and right side rear suspension of the vehicle respectively.

C1 and C3 are the viscous damping coefficient at the left and right side rear suspension of the vehicle respectively.

F1 and F3 are the coulomb damping coefficient at the left and right side rear suspension of the vehicle respectively.

The percent of energy dissipation due to the tire is seen to increase rapidly with vehicle speed. More significantly, it is readily apparent that the tire is the dominant energy dissipative component for frequencies above 20 Hz (approximately 50 km/hr). Since the tire with its relatively high spring rate acts as a low pass filter to high frequency inputs. On the other hand, the suspension responds only to the low-frequency excitations due to the characteristics of the shock absorbers and the relatively low spring rate. Thus, the low frequency dominance in measurements of rear axle accelerations [5] is largely attributable to suspension characteristics rather than the tires.

Since suspension-tire energy dissipation was to be assessed relative to road roughness, an experimental investigation [6] was undertaken to measure and obtain the spectral analysis for the different road speeds.Typical spectral analysis result shown in Figs. 14 and 15 for different road speeds shows that the power spectral density drops off rapidly above approximately 30 Hz with, in some cases, a weaker peak in the vicinity of 60 Hz.These spectral plots clearly indicate the range of frequencies which dominate the suspension system's excitation.

POWER SPECTRAL DENSITY

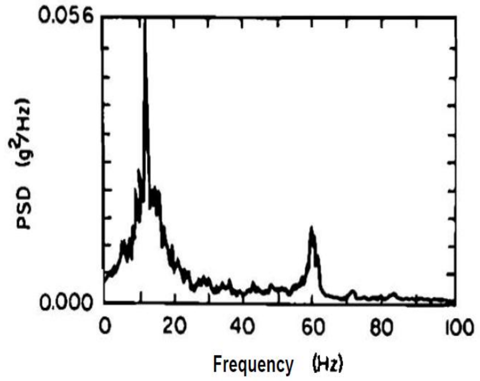

Fig.2. Power spectral density as a function of frequency at 100 km/hr

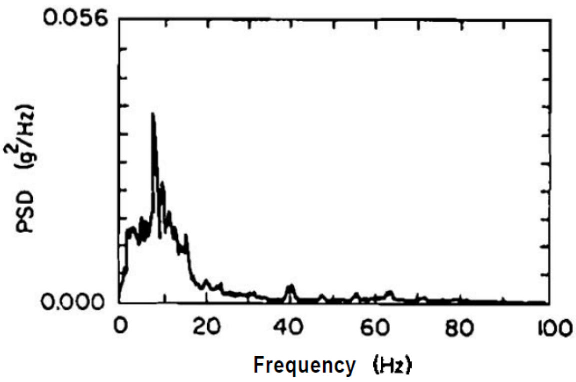

Fig.3. Power spectral density as a function of Frequency at 65 km/hr

II.PRINCIPLE

This project is based on the basic principle that the kinetic energy of the compressed suspension fluidwhich is lost as heat energy is converted into rotational energy by the application of a turbine. This energy is absorbed by means of a micro generator.

III.MODELING

We have modelled our hydraulic damper model along with the turbine generator flow path using the design software called CREO 2.0. The flow path projects from the bottom side of the damper cylinder and runs vertically upwards to the top end of the damper cylinder with a turbine chamber in the middle of the flow path. We have attached a check valve in the flow path portion which is nearer to the outlet that is top end of the damper cylinder in order to avoid the back flow of the fluid. We have also attached a spring actuated pressure relief valve in the inlet of flow path that is at the bottom end of the cylinder for pressure build up inside the damper cylinder enough to run the turbine.

Fig.4. Energy saving hydraulic damper with turbo generator flow path mechanism

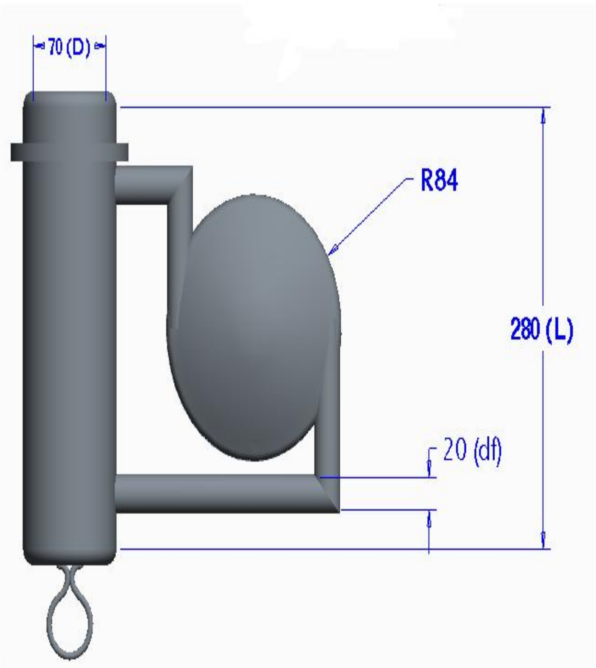

Fig.5. Turbo generator flow path- Dimensioning

IMPULSETURBINE (TURGOWHEEL)

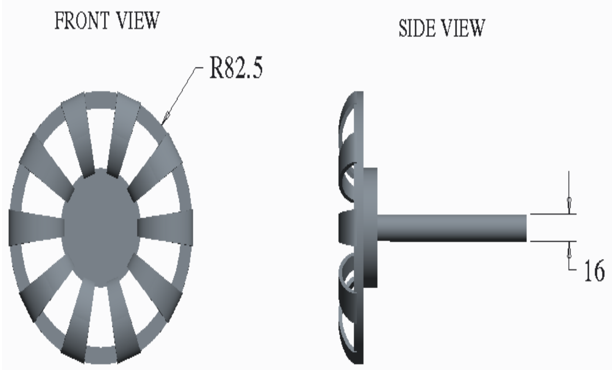

Fig.6. Impulse turbine (Turgo wheel)

This type of turbine are mainly used for generating power from impulse flow of fluids and so we have opted for this type of turbine as in our case also the flow is not continuous, it is a periodic flow only for specific time period.The wheel is made to fit a 15 mm shaft. Correct attachment to the generator shaft is important. Thick stainless steel or galvanized washers of atleast 25 mm outside diameter should be used on both sides of the wheel to distribute pressure evenly over the casting. A spring washer is essential.

The nut should be tightened to 6.5 N/m torque (firm with a 160 mm spanner).

Specifications [7]

Impeller Material: Cast Epoxy Resin Composite
Outer diameter: 165 mm (ø)
Inner hydraulic diameter: 133 mm (ø)
Shaft Diameter: 16 mm (ø)
Keyway Width: 4.76 mm (3/16th inch)
Hub Depth: 22 mm
Weight: 0.3 Kilograms

MICROHYDROGENERATOR

The Micro Hydro Generator is a power source of clean and renewable energy! This hydro generator can supply stable output voltage and output current with the help of embedded voltage stabilizing circuit and small rechargeable battery.

Fig.7. Micro hydro generator (Real component)

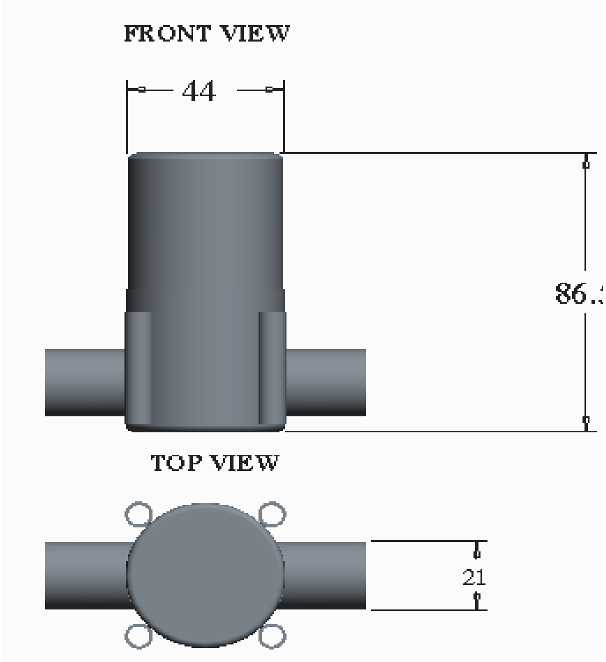

Fig.8. Micro hydro generator - Dimensioning

Specifications [8]

Weight	165 g
Output voltage	3.6V
Output current	300mA
Maximum working pressure	1.75 MPa
Working pressure	0~1.75MPa
Working temperature	0~110°C
Material	nylon/glass fiber, Polyformaldehyde POM
Recommend flow rate range	1.5~20 l/min
Dimensions	81 x 82.5 x 44 mm

CHECK VALVE

Check valves are the most commonly used in fluid-powered systems. They allow flow in one direction and prevent flow in the other direction so they are installed near the top opening of the turbo generator flow path. They may be installed independently in a line, or they may be incorporated as an integral part of a sequence, counterbalance, or pressure-reducing valve.

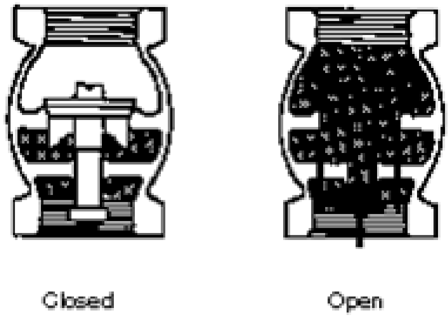

Fig.9. Check valve in open and close position

PRESSURE RELIEF VALVE

The pressure relief valve is mounted at the pressure side of the turbo generator flow path that is near the bottom opening of the flow path. It's task is to limit the pressure in the system on an acceptable value. When the damper cylinder gets overloaded the pressure relief valve will open and the suspension fluid flow will be leaded directly into the flow path.

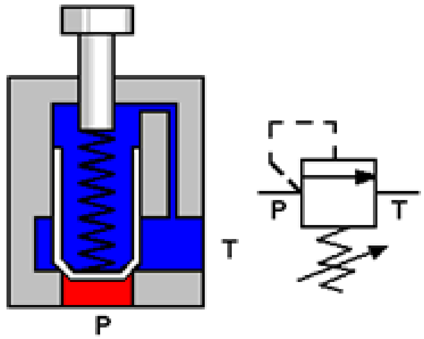

Fig.10. Schematic representation of pressure relief valve

IV.METHODOLOGY

The main principle of our idea is that we are converting the kinetic energy of the compressed suspension fluid into rotational energy by means of turbine. First when the vehicle travels down from a bump, the sprung mass connected to the upper joint of suspension member compresses the coil spring and which in turn makes the piston move vertically upwards inside the damper cylinder compressing the suspension fluid at very high pressure. This compressed high pressure fluid then enters the flow path through the upper end and then rotates the turbine in the flow path while passing through it. This high pressure fluid is released into the turbine chamber in a tangential manner from the flow path to create a radial flow for better performance. This turbine’s output shaft is coupled to the micro hydro generator for power generation. Then the fluid after rotating the turbine again enters the damper cylinder through the inlet or bottom end of the flow path. This fluid reaches the cylinder before the piston rebounds from the top as the piston takes negligible time for upward and downward stroke.

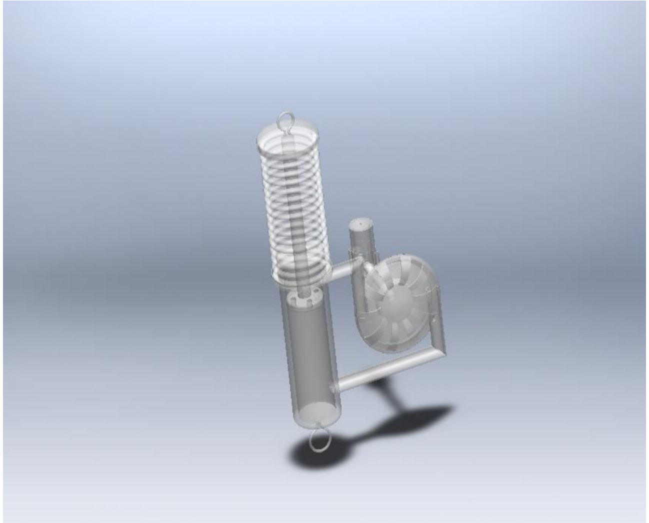

Fig.11. Assembled view of the creo model of energy saving hydraulic damper

Now as the vehicles moves over the bump, the piston moves downward compressing the incoming fluid from flow chamber. The piston while compressing the fluid downwards to a maximum limit the electronically operated valve in the piston opens allowing the fluid to pass to the upper part of the cylinder thus relieving the pressure and this valve closes immediately after all the fluid passes to the other side of piston. This fluid is prevented from entering the flow path by means of a spring operated pressure relief valve until adequate pressure builds up inside the cylinder to run the turbine. So again when the piston compresses the fluid upwards the pressure builds up and the fluid enters the flow chamber through relief valve. In this way the process continues for 3 to 4 cycles during vehicle travel over bumps and ridges.

V.CALCULATION

AREA OF DAMPING CYLINDER (A)

= $(\pi \times D^2)/4$

= $(3.14 \times (0.07)^2)/4$

= 0.003845 m²

Where D is the diameter of damping cylinder (m)

VOLUME OF THE FLUID CONTAINED IN DAMPER CYLINDER (V) =

A x L = 0.003845 x (0.28)=0.001076 m³

Where

A is the cross sectional area of the damper cylinder

L is the total length of the damper cylinder

MASS FLOW RATEOF SUSPENSION FLUID (m)

= $(V \times \rho)/(T)$

=(0.001076 x 800)/3

= 0.287kg/s

Where

T is the time for rebounding cycle(s)(ASSUMPTION)

ρ is the density of the fluid (RED synthetic oil …S.G = 0.8) (Kg/m³)

AREA OF FLOW PATH (A_F)

= $(\pi \times (df)^2)/4$

= $(3.14 \times 0.02^2)/4$

= 0.000314 m²

Where df is the diameter of the flow path (m)

VELOCITY OF SUSPENSION FLUID (v)

$m/(\rho \times A_F) = (0.287)/(800 \times 0.000314)$

= 1.142 m/s

Area of turbine $=(\pi \times d^2)/4$

= $(3.14 \times (0.165)^2)/4$

= 0.0214 m²

Where d is the diameter of turbine (m)

POWER GENERATED BY THE TURBINE PER CYCLE (P)

$(\rho \times v^3 \times A_T)/2 = (800 \times (1.142)^3 \times 0.0214)/2$

= 12.74 W

TOTAL POWER GENERATED BY TURBINE

P x (no of cycles per bump and ridges)

=12.74 x 2= 25.48 W

VI.ADVANTAGES

- Nearly 10-15 % of the fuel power which is dissipated as power loss in damper can be harnessed by implementing our impulse turbine technology to the existing hydraulic damper of off road vehicles.
- It also reduces the constant heating of the damper cylinder by making use of the kinetic energy of the suspension fluid into useful turbine work.
- Evaporation of the suspension fluid is also a minor problem faced in hydraulic dampers which occurs while compressing the fluid in order to overcoming the vibrations by means of heat dissipation. This evaporation rate can be reduced by implementing our technology.
- Our modified design of damper is also quite compact, simple and does not occupy large space.

VII.CONCLUSION:-

Conventionally, a huge amount of vibrational energy is dissipated as heat by shock absorbers which lead to a huge wastage of fuel power. Thus with our regenerative hydraulic damper we were able to harness this energy loss occurring in the suspension system. The regenerative power that is developed can be used for various secondary purposes like powering the brake light, charging the battery. Thus we were able to conserve or harness nearly 75% of the power loss in the hydraulic damper with the help of our turbo generator flow path regenerative damper. Thus we were able to harness 25W of the total energy that is being lost as heat dissipation in single suspension system to overcome the effect of road roughness. So we could be able to regenerate 100W of power for a single vehicle.

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