"Magnetic Suspension System with Electricity Generation"

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ABSTRACT

The shock absorber is an essential part of the vehicle. The different type of springs are used as a shock absorber in the vehiclesuch as helical spring, leaf spring, coil spring etc. the shock absorber is used between the axles and frame of the vehicle. Shockabsorbers are an important part of automobile and motorcycle suspensions, aircraft landing gear, and the supports for manyindustrial machines. Large shock absorbers have also been used in structural engineering to reduce the susceptibility ofstructures to earthquake damage and resonance.In the past decade, regenerative braking systems have become increasingly popular, recovering energy thatwould otherwise be lost through braking. However, another energy recovery mechanism that is still in theresearch stages is regenerative suspension systems. This technology has the ability to continuously recover avehicle's vibration energy dissipation that occurs due to road irregularities, vehicle acceleration, and braking,and use the energy to reduce fuel consumption. A regenerative shock absorber is a type of shock absorber thatconverts intermittent linear motion and vibration into useful energy, such as electricity.

Keyword: -*Magnetic Shock Absorber, Magnet,Spring,electricity generation,manetic suspension,gear pair, etc….*

1. INTRODUCTION

The idea for a magnetic shock absorber, makes use of the magnetic repulsion between dipoles to achieve shockabsorption. Often when riding on her two wheeler we used to face some problems while moving on the bumpy road dueto its unevenness.it observed that the like pole of two magnets of the same properties and strength repulse each otherand they keep constant distance between each other because of their magnetic fields this made her think that if theshock absorber are made of magnets with similar poles facing each other, it may give better performance and nomaintenance would be required for the same.

In this project two magnets are placed in a piston. One magnet is fixed with piston. Another one is movable, which isconnected with rod. With magnets are replaced by air. Our magnetic shock absorber works on the basic principle ofmagnet that "opposite poles attract each other and same poles repels each other". In this both magnets are facing samepoles (both magnets are placed facing north and north or south and south). Both magnets are same pole. When the rodmoves inside the piston movable magnet move towards the fixed magnet. Since both magnets are of same polerepulsion force is created between the magnets. So the movable magnet opposes the rod action and moves the rod up. Magnetic suspension system is mainly based on the property magnets that like poles of magnets repel each other. This characteristic of magnets is used for suspension work of system. This system also contains spring in between these two magnets to avoid direct contact of two magnets due to overloading. This system finds large number of applications in automobile industry.

In today's world automobile sector has reached its peak. In two wheeler suspensions system used in coil spring is that after some time it becomes not only harder but also reduces cushioning effect. This limitation has overcome by magnetic suspension. The cushioning effect is provided by magnetic suspension is existing for long time.

There is one magnet fixed at the top of the inner portion of the cylinder. The second magnet placed at bottom of the inner portion of cylinder that reciprocates up and down due to repulsion. The two magnets fight against each other to achieve the aspect of suspension. Causing the formation of suspension to the vibrations formed in vehicle, which are caused due the road irregularities in order to offer the comfort to both the vehicle assembly and passengers on the vehicle. This system is having the tendency to eliminate the use of conventional suspension system due to its low cost and less maintenance capacity.

The idea for a magnetic shock absorber, it makes use of the magnetic repulsion between dipoles to achieve shock absorption. Often when riding on a two wheeler we used to face some problems while moving on the bumpy road due to its unevenness. It observed that the like pole of two magnets of the same properties and strength repulse each other and they keep constant distance between each other because of their magnetic fields, if the shock absorber are made of magnets with similar poles facing each other, it may give better performance and no maintenance would be required for the same.

In this project two magnets are placed in a piston. One magnet is fixed with piston. Another one is movable, which is connected with rod. With magnets are replaced by air. Our magnetic shock absorber works on the basic principle of magnet that "opposite poles attract each other and same poles repel each other". In this both magnets are facing same poles (both magnets are placed facing north and north or south and south). Both magnets are same pole. When rod moves inside the cylinder the movable magnet moves toward the fixed magnet. Since both magnets are of same pole repulsion force is created between the magnets. So the movable magnet opposes the rod action and moves the rod up.

Unlike poles of a magnet attract each other and like poles repel each other. When we place two south poles or north poles facing each other and when they are brought closer they are repelled. This concept is used in magnetic suspension. In this suspension a set of magnets have been selected like poles, then it is placed into in a hollow cylinder. One magnet is fixed at the top of the inner portion of the cylinder and other one is placed at the bottom. When the two magnets are brought closer to each other they are repelled due to similar polarity and the aspect of suspension is achieved.

There is one magnet at the top of the inner portion of the cylindrical shock sleeve with the north polarity facing down towards the ground. The second magnet sits on top of the inner shock that pivots up and down. This magnet has the north polarity upwards so it's parallel with the other magnet. The two magnets fight against each other giving the forks travel. There is also an adjustment at the top of the shock, which allows the magnets to become closer, together for a stiffer travel or further apart for softer travel. Magnets are attracted or repelled by, other materials depending upon the position of poles. A material that is strongly attracted to a magnet is said to have a high permeability. Iron and steel are two examples of materials with very high permeability and they are strongly attracted to magnets. It is based on a simple concept that when two magnets of same polarity are brought together they repel each other due their magnetic field. The SI unit of magnetic field strength is the tesla, and the SI unit of total magnetic flux is the weber.1 tesla = 1000gauss = 1weber flowing through 1 square meter, and is a very large amount of magnetic flux.

The piston or cylinder is made up of non-magnetic material. The non-magnetic material will hold the magnet in both the sides. By using this type of shock absorbers the suspension will be more and the impact of vibration is very less compared with the spring loaded shock absorbers. Thus the magnetic shock absorber works, when the weight of the vehicle increases or vehicle climbs irregular surface, the wheel goes upwards and shock absorber is compressed, at this time the piston moves downwards. The magnets are made closer to each other, due to the increase of weight, the piston rod containing magnet is made to compress to certain extent. At the same time, the stainless steel spring provided is freely inside the shock absorber. The additional support for magnetic shock absorber is provided by a helical coil spring, which was compressed at this stage. So the shocks and vibrations are prevented.

Fig. 1.1 Magnetic Shock Absorber

Magnetic suspension system is mainly based on the property magnets that like poles of magnets repel each other. This characteristic of magnets is used for suspension work of system. This system also contains spring in between these two magnets to avoid direct contact of two magnets due to overloading. This system finds large number of applications in automobile industry.

In today's world automobile sector has reached its peak. In two wheeler suspensions system used in coil spring is that after some time it becomes not only harder but also reduces cushioning effect. This limitation has overcome by magnetic suspension. The cushioning effect is provided by magnetic suspension is existing for long time. There is one magnet fixed at the top of the inner portion of the cylinder. The second magnet placed at bottom of the inner portion of cylinder that reciprocates up and down due to repulsion. The two magnets fight against each other to achieve the aspect of suspension.

1.1 Feature of magnetic suspension :-

Some of the main features of electromagneticsuspensions are:

1) It prevents the road shocks from being transmitted tothe vehicle parts, thereby providing suitable ridingand cushioning effect to the occupants.

2) Keeps the vehicle stable while in motion by providinggood road holding during driving, cornering andbraking?

3) Provides safe vehicle control and free of irritating vibrations and reduce wear and tear.

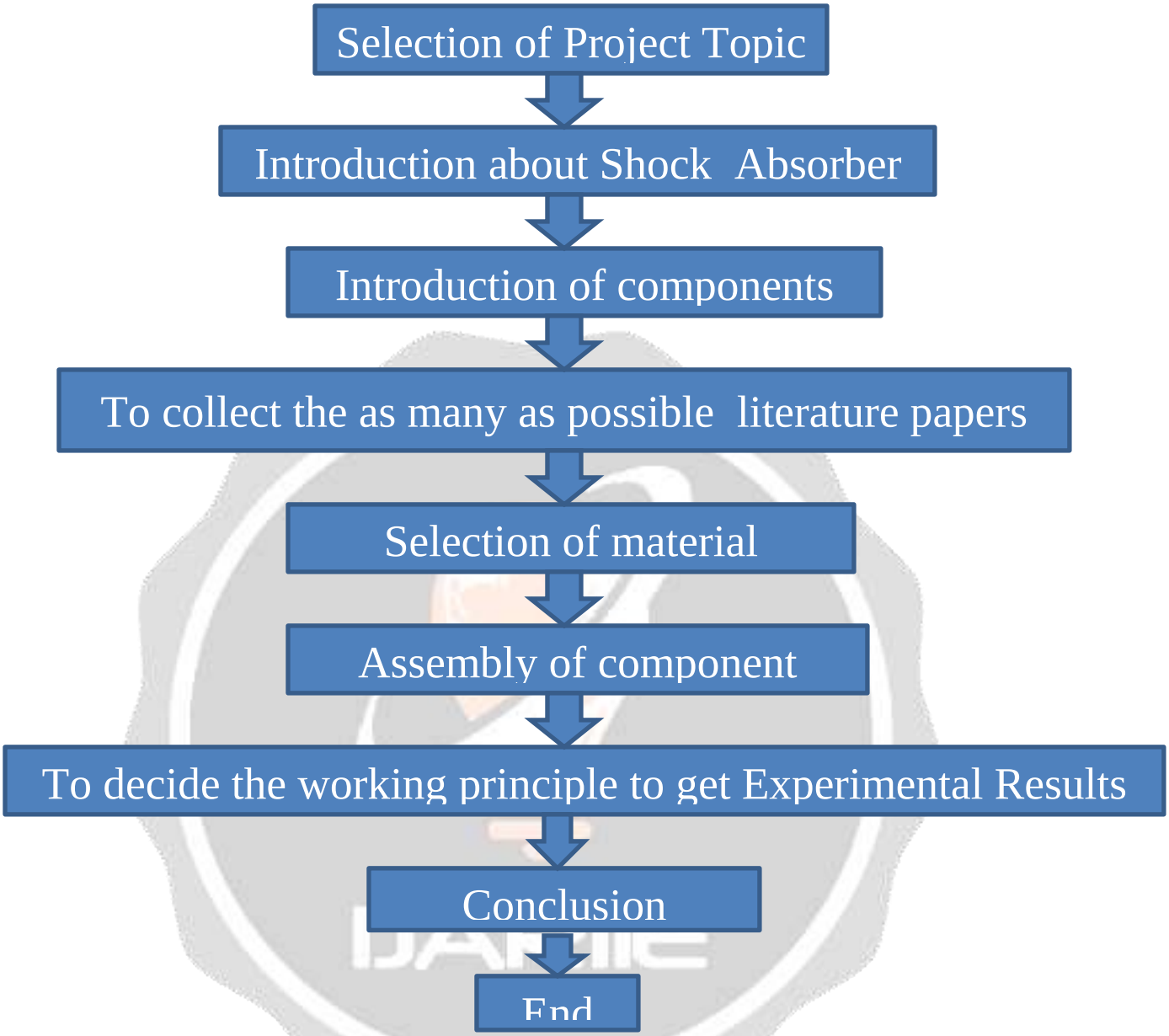
4) Easy to design and modify the design (if according to any automobile' s specifications.

5) It provides you the maximum safety and comfort ability when compared to the other conventional suspension systems

1.2 Overview Modern Suspension System

When people think of automobile performance,they normally think of horsepower,torque and zero-to-60acceleration. But all of the power generated by a pistonengine is useless if the driver can't control the car. That'swhy automobile engineers turned their attention to thesuspension system almost as soon as they had mastered thefour-stroke internal combustion engine .The job of a car suspension is to maximize the
friction between the tires and the road surface, to providesteering stability with good handling and to ensure thecomfort of the passengersIf a road were perfectly flat, with noirregularities, suspensions wouldn't be necessary. Butroads are far from flat. It's these imperfections that applyforces to the wheels. According to Newton's laws ofmotion, all forces have both magnitude and direction. Abump in the road causes the wheel to move up and downperpendicular to the road surface. The magnitude, ofcourse, depends on whether the wheel is striking a giantbump or a tiny speck. Either way, the car wheelexperiences a vertical acceleration as it passes over an imperfection.

1.3 Methodology



2. LITERATURE REVIEW

Zhigang Fang and Xuexun Guo et.al. [1] presented a new kind of shock absorber, hydraulic electromagnetic energy-regenerative shock absorber (HESA), which can recover energy from vibration of vehicles. The road excitation frequency, load resistance and damping ratio are found to greatly affect the energy recovery of HESA. Based on a quarter-car model, the optimal load resistance and damping ratio for maximizing the energy-recyclable power are discussed. The results indicate that for any excitation frequency, the energy-recyclable power first increases then decreases with the load resistance increase, and the optimal load resistance is changeable as the excitation frequency changes. Moreover, the energy-recyclable power is more sensitive to excitation frequency than to damping ratio, and the ideal excitation frequency for energy recovery is around the wheel resonant frequency. The exploration of active control of HESA confirms that the damping force varies with the load current magnitude, and the active control can be realized by appropriate matching.

KAVYA.T.T, PANDURANGA H.D. et.al. [2] concluded that shock absorber is a mechanical device (one kind of dashpot) design to smooth out or damage shock impulse, and dissipate kinetic energy A magnetic unit comprising a plurality of groups of permanent magnets such as neodymium magnets arranged in a pair one above the other

relationship with like poles facing each other .Group of neodymium magnets with like poles facing each other so that the group of magnets respectively repel or attract one another. A pair of neodymium magnets is mounted on nylon shaft (outer cylinder hollow), another pair of neodymium magnets is mounted on nylon shaft (inner cylinder) in a telescopic way. When load is applied on the shaft, it tries to compress. The shock absorbers duty is to absorb or dissipate energy The main objective of this project is to develop a magnetic unit which is used as a shock absorber or load leveler for a vehicle and is capable of handling the road shocks smoothly with minimum effort and avoids the unwanted shocks to the vehicle structure . The uniqueness of the Permanent Magnetic Shock Absorber platform has become the reason for many researchers to continue investigates this nature of the system. The idea of a Permanent Magnetic Shock Absorber has come in the research world for a few years. Due to its new technology, many advantages are incurred in that.

Pradeep khande , Gopal Sahu et.al. [3] studied that the shock absorber is an essential part of the vehicle. The different type of springs are used as a shock absorber in the vehicle such as helical spring, leaf spring, coil spring etc. the shock absorber is used between the axles and frame of the vehicle. Shock absorbers are an important part of automobile and motorcycle suspensions, aircraft landing gear, and the supports for many industrial machines. Large shock absorbers have also been used in structural engineering to reduce the susceptibility of structures to earthquake damage and resonance.

Meghraj P.Arekar and Swapnil Shahade et.al. [4] presented that the electromagnetic linear generator and regenerative electromagnetic shock absorber is disclosed which converts variable frequency, repetitive intermittent linear displacement motion to useful electrical power. The innovative device provides for superposition of radial components of the magnetic flux density within a coil winding array. Due to the vector superposition of the magnetic field and magnetic flux from a plurality of magnets, a nearly fourfold increase in magnetic flux density is achieved over conventional electromagnetic generator designs with a potential sixteen fold increase in power generating capacity. As a regenerative shock absorber, the disclose device is capable of converting parasitic displacement motion and vibration encountered under normal urban driving condition to a useful electrical energy for powering vehicles and accessories or charging batteries in electric and fossil fuel powered vehicles. The disclosed device is capable of high power generation capacity and energy conversion efficiency with minimal weight penalty for improved fuel efficiency.

Nidhin Abraham Mammen and Steve John et.al. [5] studied that in the past decade, regenerative braking systems have become increasingly popular, recovering energy that would otherwise be lost through braking. However, another energy recovery mechanism that is still in the research stages is regenerative suspension systems. This technology has the ability to continuously recover a vehicle's vibration energy dissipation that occurs due to road irregularities, vehicle acceleration, and braking, and use the energy to reduce fuel consumption. A regenerative shock absorber is a type of shock absorber that converts intermittent linear motion and vibration into useful energy, such as electricity. Conventional shock absorbers simply dissipate this energy as heat. Regenerative shock absorbers utilize piston cylinder arrangement or generation of electricity. Piston undergoes compression and expansion with movement of vehicle. The system is designed in SOLIDWORKS. When used in an electric vehicle or hybrid electric vehicle the electricity generated by the shock absorber can be diverted to its power train to increase battery life. In non-electric vehicles the electricity can be used to power accessories such as air conditioning. Several different systems have been developed recently, though they are still in stages of development and not installed on production vehicles. This could be used on electric or hybrid vehicles (or normal vehicles) to capture energy which would otherwise be absorbed and wasted, and then convert it into electricity. The regenerative shock absorbers can harvest the power in a continuous way. We analytically determine the pressure and velocity at 0.5Hz and 1Hz. A graph is plotted between pressure and velocity. Analysis is performed in CFD and values are determined.

Ashwani Kumar and S K Mangal [16] presented that design, testing and evaluation of a Magneto-Rheological (MR) shock absorber. The devices, which fill the gap between purely passive and fully active control Systems, offer a reliability of passive systems and yet it maintains the versatility and adaptability of the fully active devices. These devices are popularly known as semi-active control systems. In these devices, after application of a the magnetic field, the fluid changes from liquid to semi-solid state in milliseconds thus results in an infinitely variable, controllable shock absorber capable of generating large variable damping forces. The advantage of the MR shock absorbers over the conventional fluid shock absorbers are many, e.g., simple in construction, needs little power, quick in response, few moving parts.

3. Working Principle

On the contrary, electromagnetic regenerative suspension transforms the shock energy into electric energy that is more convenient to store and reuse, and has high performance, increased efficiency, less space requirements, and so

on. In recent years, electromagnetic suspension (EMS) system has drawn worldwide attention. Permanent magnets motor is favoured in EMS to provide active force in actuator mode or damping force in generator mode. The damping force can be simply changed by tuning the shunt resistances

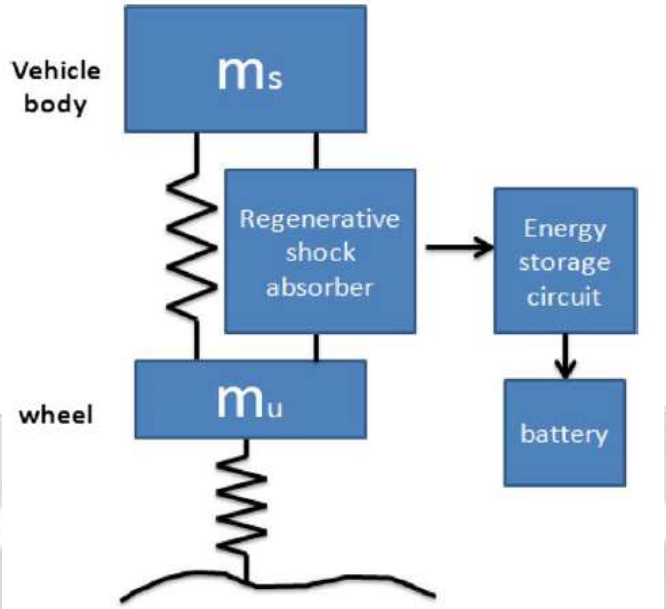


Fig -1Working principle of magnetic shock absorber

3.1 MATERIAL

Material for spring: - Mild steel

Reasons:

- readily available in market
- low cost
- Available in standard size
- Good mechanical properties
- Moderate factor of safety
- High tensile strength
- Low co-efficient of thermal expansion

4.3 Magnetic Material Properties:
Neodymium magnet used fir suspension.
4.4 Material for Hollow Shaft:
Mild steel is used for hollow shaft. It covers the whole system and protects the magnets & spring from dust.

4. DESIGN

4.1 Design of Main Spring

The spring in between two magnets to avoid impact of magnets. The outer diameter can be selected considering the clearance between casing diameter and spring for avoid jam.
Outer diameter of spring, = 40 mm
For cold drawn wire steel,
Wire diameter d = 5 mm…… (Design data book)
Inner diameter of spring

$$D_i = 40\text{-}10$$

$$D_i = 30 \text{ mm},$$

Calculating load bearing capacity of spring for service life,

Shear stress = $0.5 \times S_{ut}$

$$=0.5\times1190$$
$$=595 \text{ N/mm2}$$

Spring index,

$$C=D_O/d$$
$$= 40/5$$
$$C = 8$$

Wahl's correction factor for spring,

$$K_w = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$
$$K_w = 1.18$$

Now find out load holding by spring τ,

$$\text{Shear stress} = K_w \times \frac{8PC}{\pi d^2}$$
$$595 = 1.18 \times \frac{8\times P\times 8}{\pi\times 5^2}$$
$$\tau = 618.79\text{N}$$

Deflection of spring (δ)

$$\delta = \frac{8PD^3N}{Gd^4}$$

Assuming

$$G=82000\ N/mm^2$$
$$=\frac{8\times618.79\times40^3\times9}{82\times10^3\times5^4}$$
$$\delta = 56.97\text{mm}$$

Spring rate = $\frac{P}{\delta}$

$$=11\text{N/mm}$$

stiffness

$$K = 11\text{N/mm}$$

Number of turns

$$N = 9$$

spring has square and ground ends
number of Inactive turns = 2
Total number of turn,

$$NT = N + 2$$
$$= 9 + 2$$
$$NT = 11$$

Solid length of spring,

$$L_s = NT\times d$$
$$= 115$$
$$L_s = 55\text{mm}$$

Free length

$$L_f = \text{solid length} + \text{deflection} + \text{axial gap}$$
$$= 55 + 56 + 0.15(56)$$
$$= 55 + 56 + 0.15(56)$$
$$L_f = 120\text{mm}$$

Pitch of spring

$$L_f = PN+d$$

Pitch of spring

$$p = 12.77\text{mm}$$

4.2 Design of Magnet:
Power of Magnet Pair =10,000 GP (Gauss Power)
Weight of Vehicle Body =110kg = 1080N
Weight of Person Sitting On Vehicle = 140kg =1374N
Total Load = Weight of Vehicle Body + Weight of Person Sitting On Vehicle
=1080+1374

Total Load

$$=1080+1374$$
$$=2454 \text{ N}$$

Rear Suspension

$$= 65\% \text{ of } 2454 \text{ N}$$
$$=1595.1 \text{ N}$$

Considering Dynamic Loads Double (W) 1595.12 N

$$=3190.2 \text{ N}$$

For Single Shock Absorber Weight (W/2)

$$=\frac{3190.2}{2}$$
$$= 1595.1 \text{ N}$$

Take Factor of Safety = 1.2
So Design Load=1914.92N
Magnetic Power /Unit Area $=2N/mm^2$
So Area Required for Suspension of 300kg load

$$2 = 1914.12/A$$
$$A = 957.06mm^2$$
$$A = \frac{\pi}{4}d^2$$
$$957.06 = \frac{\pi}{4}d^2$$
$$d = 34.90\text{mm}=35\text{mm}$$
$$d = 35\text{mm}$$

Diameter of magnet (d) = 35mm

4.3 Design of shaft

shaft subjected to pure bending stress
Design force = 1914.12 N
Bending length = 165 mm
Bending moment

$$M = F\times L$$
$$= 1914.12 \times 165$$
$$= 315829.8\text{N.mm}$$
$$M = \frac{\pi F d^3}{32}$$
$$315829.8 = 32599.13d3$$
$$d = 18\text{mm}$$

4.4 Design of hollow shaft:

$$M = F_b \times l$$
$$M = 1914.12\times200$$
$$M = 382824\text{N/mm}$$

Assuming $d_o = 85mm$

$$M = \frac{\pi {d_o}^3 \sigma_b(1-C^4)}{32}$$
$$382824=\frac{\pi\times85^3\sigma_b(1-0.89^4)}{32}$$
$$\sigma_b = 17.04 \text{ N/mm2}$$
$$\sigma_b = 20 < 35\text{N/mm2}$$

Induced stress less than allowable stress then design of hollow cylinder is safe.

4.5 Design of Power Transmitting Shaft

$$P = 0.5 \text{ KW} = 0.5 \times 10^3 \text{ Watt},$$

$$N = 80 \text{ rpm},$$

Θ = angle of lap = 180° = 180× $\frac{\pi}{180}$ = π rad/sec,

μ = coefficient of friction = 0.3,

τ_B = 35 N/mm^2

Radius of pulley = $\frac{D}{2}$ = $\frac{80}{2}$ = 40 mm

Power transmitted, P = $\frac{2\pi NT}{60}$

$0.5 \times 10^3 = \frac{2 \times \pi \times 80 \times T}{60}$

T = 59.68 N-m,

T = 59.68× 10^3 N-mm

Torque T = (T_1-T_2) R

$\frac{T_1}{T_2} = e^{\mu\theta} = e^{0.3 \times \pi}$

$\frac{T_1}{T_2}$ = 2.566

T_1 = 2.566 T_2

T = (2.566 T_2-T_2) 40

= 62.64 T_2

59.68× 10^3 = 62.64 T_2

T_2 = 952.74 N

T_1 = 2.566 × 952.74 = 2.44 × 10^3 N

Total load on pulley = W = T_1+ T_2 + W_P

= 2.44 × 10^3 + 952.74 + 25

= 3.41 × 10^3 N

Bending moment = M = W × L

= 3.41 × 10^3 × 200

= 682 × 10^3 N-mm

Equivalent twisting moment (T_e) as shaft is subjected to both twisting and bending moment

$T_e = \frac{\pi}{16} \times \tau_{max} \times d^3 = \sqrt{(682 \times 10^3)^2 + (59.68 \times 10^3)^2}$

$\frac{\pi}{16} \times 35 \times d^3 = \sqrt{(682 \times 10^3)^2 + (59.68 \times 10^3)^2}$

$$\frac{\pi}{16} \times 35 \times d^3 = 684.60 \times 10^3$$

$$d = 46.35 \text{ mm}$$

5. CONCLUSIONS

1. Unlike conventional shock absorbers, regenerative shock absorbers preserve the energy and it can be utilized further. This is the main difference between them.
2. It can be simply understandable by report conventionally, the vibration energy of vehicle suspension is dissipated as heat by shock absorber, which wastes a considerable number of resources.
3. Regenerative suspensions bring hope for recycling the wasted energy. Regenerative suspensions, especially electromagnetic suspension, and their properties are reviewed in this project.
4. With improvement of technology, regenerative suspension may become one of promising trends of vehicle industry.

As the mechanism is saving energy, it ultimately increases efficiency of vehicle. It can be called as a vista of green technology.

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