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THOROUGH STUDY AND COMPARISON ON SHOCK ABSORBERS

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Abstract— **As we all are soon going to put our steps into industrial revolution 4.0, automaization and upgradation in every system will be witnessed. To be elaborately concerned in this, shock absorbers are also taking wide range of advancements. Depending upon various application areas and principal of working, shock absorbers have established. To bring this frame of machine system in very smooth working and ease in operating, these shock absorbers play vital role. Hence the paper specifies pros and cons of each type along with its region of application. This would make clear vision of shock absorbers in system. After studying the different types like mechanical shock absorber, electromagnetic shock absorber, magneto-rheological shock absorber it is understood that they add their specific advantage in operation. Reviewing industries, heavy load machines are used maximum currently. This paper will widely give idea about these absorbers and relatively put forth best absorber among all in high load applications.**

Keywords— **mechanical shock absorber, electro-magnetic shock absorber, MR fluid shock absorber, suspension system**.

I. INTRODUCTION

In current industrial scenario, amount of vehicles running is more than anything. Every type of vehicle that is in the market till date are having some common yet most important parts. The famous triangle of brakes, suspension and wheels is familiar in all sorts of vehicles. Elaborating Suspension amongst them is the core topic of this paper. Even the working principle of these shock absorbers vary vehicle to vehicle in respect to load carrying capacity, terrain and field of application. Hence we find different types of shock absorbers in every different segment of vehicles. In the early experimental period, mechanical shock absorbers got introduced and was felt to be user friendly. In later part hydraulic type, electromagnetic type, magneto-rheological type came into experience. Hence the current wide development and advancements in this field is noteworthy. This paper is about shock absorbers and their types along with applications.

II. MECHANICAL SHOCK ABSORBER

Most old yet widely used type of shock absorbers are mechanical shock absorbers. Expected work output of this element is absorbing the shock mechanically and converting it to another useful form of energy. Since the early stage type of shock absorbers used to convert this energy to heat and then dissipate it, but now researchers are succeeding in getting some amount of energy converted into energy given back to system. The working of these type of shock absorbers is further bifurcated into subtypes depending on number of piston-cylinder, fluid used inside compression chamber and material used. All of the known mechanical shock absorbers have the common problem that they are relatively complicated [1]. Most vehicular shock absorbers fall under two types: A] Twin tube or B] Mono-tube types along with considerable variations over it.

In twin tube, basic twin type consists of two nested cylindrical tubes. Internal cylinder is called ‘working tube’ or ‘pressure tube’, and external tube is called ‘reserve tube’. Inside the device at bottom there is a compression valve. When the piston is experiencing force, hydraulic fluid moves between different chambers via orifices in valves and converts this kinetic energy into heat which further transforms into heat and dissipated in due time.

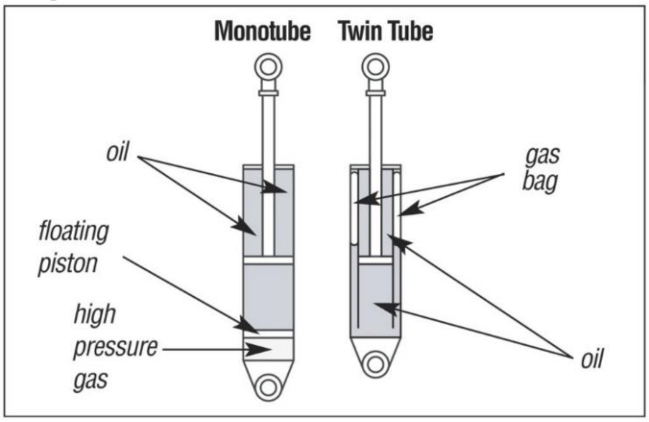

Figure 1: Mono-tube and Twin tube type Shock absorber basic design [2]

Twin-tube gas charged otherwise called 'gas cell two-tube' is critical progression over the essential twin-tube. Nitrogen gas

added in reserve tube of same device results in reduction of 'foaming' and 'aeration' along with increment in absorption and decrement in overheating. Position sensitive damping (PDS) consists of similar nested tubes and filled with nitrogen gas. A supplementary set of grooves has been added to the pressure tube. These grooves allow the piston to move relatively free in the middle range ensuring comfort of ride. Whereas in case of Acceleration sensitive damping had high sensitivity of bumps experienced by an individual. This resulted in diminishing the worry of 'comfort vs control' and reduced pitch during vehicle braking and roll during turns. Coilover shock absorber among these is twin-tube gas charged shock absorber along with helical spring. They are common on motorcycles and scooter rear suspensions in cars.
Briefing about Mono-tube shock absorber consists of only one tube, pressure tube, along with two pistons. One of the pistons is working piston and other is floating piston. These pistons move relatively in response to changes in road smoothness. Unlike twin-tube, its design is much complex and large in size making its adjustment in the system more challenging. But it does not have any directionality as twin-tube has. Hence it can be mounted either way.

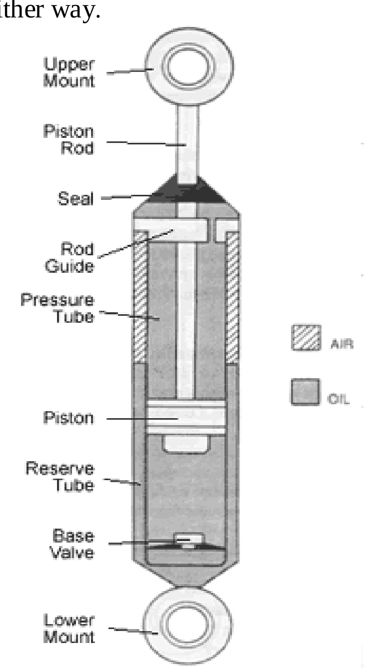

Figure 2: Shock absorber with air and oil as working fluid [3]

Following are the parameters taken into consideration:

1. Mechanical components: piston, cylinder, working fluid, compression valve, helical spring. Let us brief about helical spring. The materials used commonly in automobile springs are Beryllium Copper, Phosphor Bronze, Titanium, Inconel etc. Titanium which is very effective and performs well is seldom used pertaining to its high cost. The future of the shock absorber depends largely on the helical coil spring [4]. With the growth and advancement in the automobile industry, there is a larger need for better materials which are lighter, having more stiffness, more durable, corrosion resistant, resilient and having more strength [5].
2. Thermal factor like Heat dissipation also plays crucial role in dampers.
3. Manufacturing, cost structure, durability, precision and efficiency over a period of time also accounts.

Applications:
- Many industrial machines
- Landing gear of aircrafts
- Heavy load vehicles
- Two wheelers
- Buildings
- Bridges and other structures to make them earthquake resistant [6]

III. ELECTRO MAGNETIC SHOCK ABSORBER

The output energy of magnetic shock absorber is to convert kinetic energy created by bumps into electrical energy. This is done by ball screws, gears and two overrun clutches in the transmission modules. This system converts reciprocating vibrations into unidirectional motion of generator. The variation in pitch of screw results into different damping coefficients for upward and downward progress. Hence, the shock absorber ensures full utilization of elastic elements to improvise vehicle comfort when compressed and quickly absorbs fluctuations when stretched. The electric energy converted by generator is then directed towards super capacitors to charge the battery and uplift the range of electric vehicles. The mechanical properties of the full-scaled manufactured model were concentrated by using a mechanical testing and detecting installation. A normal force yield of 3.701 W in 1Hz-3mm sinusoidal vibration input and a pinnacle proficiency of 51.1% and normal effectiveness of 36.4% were accomplished in a seat tests. The range can be around loosened up by 1 mile for each 100 miles when EV is driving all over town of class B with a speed of 60km/h, indicating that the proposed high-adequacy regenerative shield is valuable for harvesting reasonable force source, and practical and enormous for widening the extent of EVs [7].
The first sub branch of this is called as 'Linear electromagnetic regenerative shock absorber'. The basic working principle of it is to generate electricity directly via coils of magnetic wire. Its efficiency is stated to be highest but its damping coefficient is extremely small in comparison. A design proposed by Zhang et al in [8] used a rack and pinion mechanism which had damping coefficient of 30 N·s/m. This was extremely low in comparison with standard value. In [9] Tang et al. put forth a linear vibration energy harvester with an efficiency of 70-78%. Still, the highest damping coefficient was only 940 N·s/m under short circuit conditions. Low damping coefficient creates limitations in shock absorption requirements in various vehicles.

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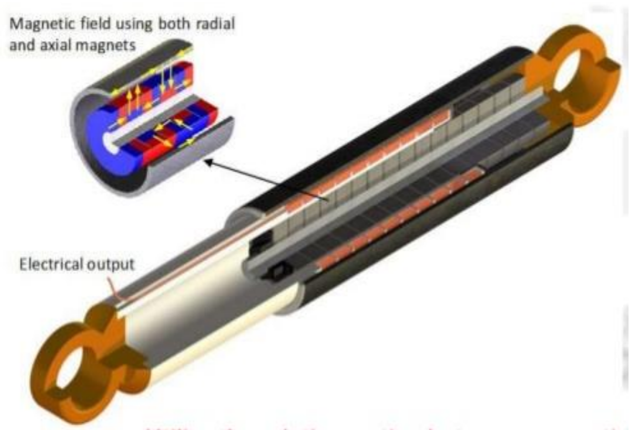

Figure 3: Electro-magnetic shock absorber [10]

The second type under electromagnetic is 'Bidirectional rotatory regenerative shock absorber'. This had overcome the limitation of linear shock absorber. This basically consisted of transforming irregularly reciprocating linear oscillations into two-way high speed rotation. It required elements like rack and pinion, ball screws and novel structures. An experiment done combining ball screws with Faraday's law of electromagnetic induction achieved a significant damping coefficient ranging from 3200-7400 N·s/m along with efficiency ranging from 41-81% [11]. Shock absorber system proposed by Audi in [12] named eROT utilized a lever arm mechanism for absorbing vibrations of wheel carrier. Power output was 100-150 W on average during testing on field. On one hand it increased value the damping coefficient but on the other hand its response characteristics resulted into extreme disorder and unbalance due to bidirectional rotation.

The third classification is unidirectional turning regenerative safeguards, which change unpredictably responding straight vibrations into unidirectional revolution. Subsequently, this sort of generator consistently turns a single way, which expands the productivity of the vitality collecting framework and diminishes the reaction between transmission structures contrasted with the subsequent class.

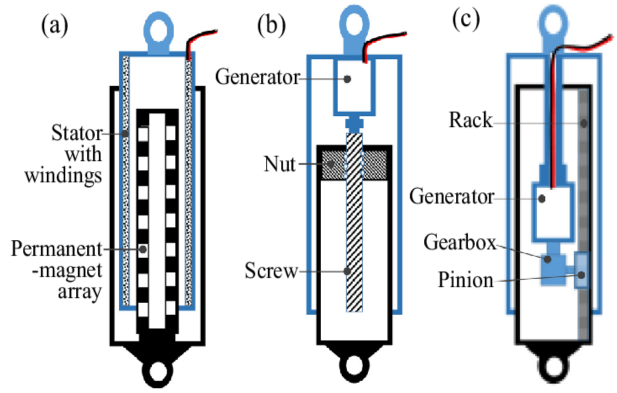

Figure 4: The general layout of different electromagnetic regenerative dampers**.** (a) Linear motor, **(**b**)** ball screw, and **(**c**)** rack-pinion [14]

Design parameters

As this system is influenced by magnets converting vibrational energy, magnetic material has precisely its importance in design parameters. As and when we set criterion for magnetic material, its physical as well as magnetic properties at various stages is considered. Variation in result of the fundamental elements or combination of two materials is also considerable fact in this process. Along with it, magnetic coil, its approximate length and windings is taken into calculations. Wire that is connected to generator is accounted in this.

Applications:

The straight electromagnetic BOSE suspension framework with engine game plan responds rapidly enough to counter the impacts of knocks and potholes, keeping up a mollified ride

IV. MAGNETO RHEOLOGICAL SHOCK ABSORBER

Magneto-rheological Fluid:

Magneto-rheological fluid often referred as MR fluid type shock absorber falls into a class of smart fluids whose rheological properties like elasticity, plasticity, and viscosity change in the presence of a magnetic field. These are suspended particles of oft particles having a diameter of 1-5 mm. They are carried specially only in liquids like water, mineral oil, synthetic oil and glycol. When they are exposed to external magnetic field these soft particles become semi-solid material due to the increase in apparent viscosity. Thus, it behaves like a non-Newtonian fluid and reverses its physical state as soon as the effect is gone. This instantaneous response feature makes MR fluid to be utilized in suspension. Similar to the mechanical shock absorbers, MR shock absorbers also have subtypes as:

1. Mono tube: As the name suggests, it has only one reservoir for the MR fluid and also has some way to allow for volumetric change resulted from piston rod movement. Accumulator type piston is used here to accommodate this change in volume. Also, it provides barrier between MR fluid and a compressed gas; which is mostly nitrogen.
2. Next type is twin tube: Similar working as like mechanical twin tube type, it contains MR fluid in both volumes of internal and external cylinders. It is generally used in upright position.
3. Double ended MR damper: It consists of 2 piston rods of equal diameter protruding through both ends of damper. It does not require an accumulator or any similar arrangement. It is prominently used in bicycles, gun recoil applications and other similar.

4. Double ended MR damper with MR-Hydraulic hybrid damper: These are dampers in which a small MR damper controls a valve that, in turn, is used to regulate the flow of hydraulic fluid. Military applications and seismic applications are its highlighting applications.

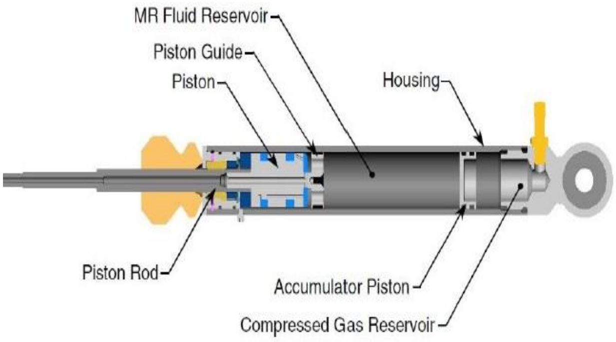

Figure 5: MR Fluid Reservoir [16]

V. COMPARATIVE ANALYSIS

The fundamental and extraordinary contrast between these two is mechanical safeguard changes over dynamic vitality into heat while attractive safeguard changes over same active vitality into electrical vitality.

In examination of productivity, mechanical safeguard is having least proficiency among all. While, MR liquids costs most elevated in all as it requires seals, pole surface completion, exactness mechanical resistances, electromagnet get together, shafts and transition channel, and the volume of MR liquid notwithstanding essential framework.

Likewise, concerning component, mechanical safeguard incorporates frictional misfortunes and liquid misfortunes. Though electromagnetic is without grinding in view of magnets and generator. Likewise, MR liquid safeguard experiences with issue of strength. Substantial suspended particles settle down quicker anyway little than that takes division of time more.

VI. CONCLUSION

J.D. Force and Associates reports that by 2025, more than 33% of traveler vehicles will be furnished with elective powertrains and worked with elective fills. About 17.5 percent of the vehicles will be gas/electric half and halves and module crossovers. Plug-in electric hybrids will comprise about a five percent share [17]. Hence as it is clear that now onwards mostly EVs are going to be of importance, electromagnetic shock absorbers will be uplifted and upgraded to absorb slightest of vibration for converting it into electrical energy. Also increment in efficiency and sustainability will be further part of research.

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