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# A Proposed Design of Electromagnetic Steering Dampers for Multiple Segments of Motorcycles

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**Abstract**

The study is focused on development of new and innovative method of steering damper systems. Primary objective is to develop a steering damper system which can vary its dampening properties based on variation of motorcycle speed. Secondary objective is to develop a dry system which does not use any kind of fluid for dampening purpose, as a dry system is easier to use and maintain. Various approaches are discussed which satisfy the purpose and the approach which is more efficient and satisfies both the objective is discussed in detail. The working of the system along with a schematic 3-D model is explained. The static structural analysis of various critical working components of the assembly is analysed for the forces that needed to be arrested and the stressed developed in them due to those forces. The analysis has resulted in the understanding of the working of the assembly and it capabilities to take up the required stresses and satisfying the objectives.

**Keywords:** Electromagnetic, Steering, Damper, Structural, Simulation

## I. INTRODUCTION

Active safety on a two wheeled vehicle is a very important topic in field of road vehicles and with the increasing performance of bikes, this has become more of a crucial issue. Accidents on a motorcycle is obviously way more dangerous than in a car as you are exposed to the surroundings. Motorcycle accidents will undoubtedly cause you severe injuries and many times it can result in loss of life. One of the prominent reasons for an accident is due to motorcycle becoming unstable due to various reasons. There are mainly two modes of instability namely weave and wobble. Weave is a low frequency oscillation of the entire motorcycle. Wobble is a higher frequency oscillation of the steering handle around its axis. It can be initiated by a simple disturbance to the ride, but at high speeds, this disturbance gets amplified very quickly and it becomes more than the natural frequency of the bike which ends in Resonance. In the most severe cases can turn into a violent movement of the handlebar from one extreme to the other, commonly called tank slapper. This is going to result in a fatal accident. To avoid such fatalities, steering dampers are installed which are basically suspension for your steering and its function is to dampen out any such disturbances before they intensify, to eliminate the possibility of wobble. The steering damper does increase the safety by many folds but also reduces the ease with which you can turn your steering handle. It makes the riding difficult at low speeds and also difficult to manoeuver the bike through streets and it can cause rider fatigue as he has to put more effort each time to turn the motorcycle. This is the main reason that steering dampers are only installed on high end sports bikes and not on all variety of bikes out there. What if there was a smart steering damper which would differ its damping depending on the conditions such as speed of the bike as the researchers want the safety of the damper at high speed and the rider comfort at low speeds. This was the motivation behind our project to design a versatile steering damper that can be installed on a street bike as well as a high end sports bike.

## II. LITERATURE REVIEW

The Journal starts discussion with the advantages and disadvantages of the MR Fluids. There are many properties of MR Fluid that are desirable. But some properties have disadvantage as well. The Journal discusses some disadvantages like poor sedimentary stability, high viscosity at off-state and low shear yield stress. The journal deals with the making of the MR Fluids. It states that the MR Fluid has two materials. One a carrier fluid and metallic materials suspended in it. The journal deals with making of MR Fluids using two carrier fluids, by adding different additives and different particle mass fraction. The variation of various properties (Sedimentary stability, Off-State Viscosity and Shear Yield Stress) on use of different carrier fluids, additives and particle mass fraction is gives as results. (Zhang Jian, 2008) [1]

The Journal deals with the properties of MR Fluids Damper. The operation principle of the damper is explained in detail along with the assembly required. The Journal gives the idea of the properties of MR Fluid required for the particular application. The damping forces that are generated by the MR Fluid and its relation between the applied magnetic Field and the assembly structure. (Yang Yan, 2007) [2]

This Journal deals with representation of the suspended magnetic particles in the carrier fluid and their arrangement of the application of magnetic field. The magnetic particles arrange themselves in a chain form thus creating a restriction in the movement of the carrier fluid thus creating a drag and giving a dampening effect. This Journal gives a brief idea of the Field restrictive fluids (ER – Electrorheological and MR - Magnetorheological) and the comparison between them. The journal discusses the various magnetic materials used in the MR Fluids. The stability and the effect of the temperature on

the MR Fluids is also discussed and the various practical fields where it is applied. (Muhammad Aslam, 2006) [3]

The paper basically talks about the design, circuitry, and working of a coilgun in order to optimise the velocity of the projectile. Basically a Coil gun is a projectile accelerator and as the name suggests, it could be used as a weapon. It consists of a single coil or multiple coils, evenly spaced from each other which have current passing through them, creating a solenoid. A ferromagnetic projectile is placed inside the coil and once there is voltage supplied in the coil, through one or more capacitors there is magnetic field generated inside the coil which accelerate the projectile. As it is known that in a solenoid, the magnetic field is strongest in the middle (equilibrium position), so as the projectile passes through the equilibrium position, the magnetic field, decelerates and stops the projectile and pulls it towards the equilibrium position, which is not ideal. The authors want the projectile to leave each coil with an increased velocity. Therefore to achieve that, once the projectile reaches the equilibrium position, the voltage supply in the coil should be cut off so that the coil doesn't pull the projectile back towards the equilibrium position. In order to cut off the supply, a laser beam is used to monitor the projectile, which automatically cuts the current when the projectile reaches the equilibrium position. This setup can therefore be used to achieve higher velocities of the projectile and a better efficiency. (Marcelo Bender Perotoni, 2017) [4]

The journal elaborates on Axiomatic Design approach to analyse the critical aspects and to propose the working of the radial type steering damper but with an innovative architecture using MR Fluids for the damping process and fully integrated in the steering head of the motorcycles. The damping coefficient of the steering damper is therefore basic for the stability of motorcycles, especially at high speeds. However, the damping action has also some disadvantages, such as an excessive hardness of the steering during stationary manoeuvres or in the traffic, an increased rider wearying in winding roads and a reduced feeling of the hardness of the steering). All these aspects can be summed in a lower riding comfort in normal riding conditions (i.e. without wobble). (Cosimo Montia, An Axiomatic Design Approach for a motorcycle steering damper, 2015) [5]

## III. METHODOLOGY

*First Approach*

Our first thought was to use MR (Magneto Rheological) Fluids as the damping fluid for the mechanism. Our plan was to use MR Fluid in conjunction with an electromagnet for the magnetic field, which would be controlled with a microcontroller depending on the parameters. MR (Magneto-Rheological) Fluid is a type of fluid that changes its viscosity on application of Magnetic Field. Thus, variable restricting force is (damping) available on variation of magnetic force, as viscosity of MR Fluid varies with variation of applied magnetic field. The assembly was a piston cylinder arrangement similar to the one shown in Figure 4. The electromagnetic coil was wound around the piston. The MR Fluid can flow from one side of the piston to the other side via orifices (due to motion of the piston along the cylinder). As the MR Fluid passes through the orifices a restricting force (drag) is generated. The amount of drag that is required can be varied by the amount of magnetic field that is applied. Thus, a variable dampening can be achieved. Implementation of this system leads to excessive loading which has an adverse impact on the efficiency and practicality, on the other hand, the MR Fluid technology increases the overall cost of the vehicle to an exponential level which goes against the primary objective of the research project.

*Second Approach*

Our second approach was using the concept of a coil gun. A coil gun is simply a projectile accelerator. A coil gun is a series of coils that are excited one after the other as a conductive projectile made from a magnetic material passes by them. Each coil works on the principle of a solenoid. Current loops induce magnetic flux through the centre of coils.

Researchers used a similar principle to design our mechanism for the steering damper. In the coil gun, the solenoid is the stationary part and the projectile is the moving part, but in our design, Researcher assumed if the researchers kept the projectile stationary and the solenoid coil would move along the projectile when current is passed through it. Below is the basic sketch of the mechanism the researchers thought about.

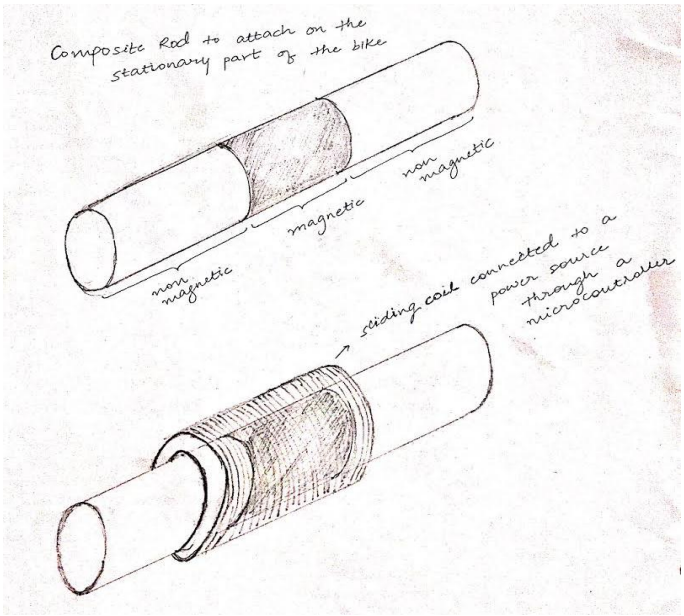


**Figure 1-** Sketch of our design of Steering Damper using the concept of solenoids

The rod with the sliding coil as shown in the sketch would be attached transversely on the steering column as shown in Figure 3. The sliding coil which is the solenoid would be connected to the steering handle by the help of connecting rods. The rod basically has three sections, 1st and 3rd being non-magnetic and the middle section being magnetic. When there is supply of current in the sliding coil, it should get attracted to the middle section which is magnetic and will stay there until the supply is ON due to magnetic forces. This means the bike steering handle will stay in the straight position. This way it will refrain the

sliding coil from moving to either left or right (would refrain the motorcycles handle from moving left or right) in case of a disturbance that could initiate a possibility of weave or wobble. The supply of current would be dependent on the speed of the motorcycle. Since the researchers don't want any dampening at slower speeds because it would make manoeuvring the motorcycle difficult on the streets. Researchers tried making a physical model which didn't work as planned as the solenoid mechanism was hampering with other mechanisms for its connection to the motorcycles steering. So the researchers went back to the design board thinking about a different approach.

*Third Approach*

Our third approach was a totally different take on designing an electromagnet steering damper. This time the researchers designed an axial mechanism which would dampen the steering by restricting the steering rod itself.

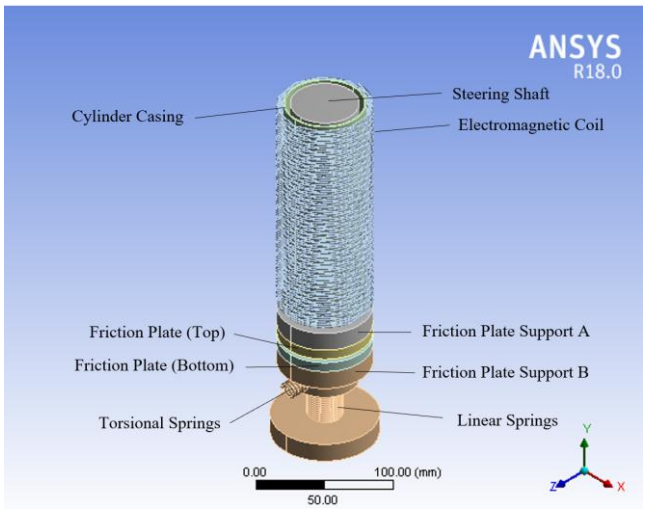


**Figure 2:** – Complete Design of Steering Damper System (Isometric View)

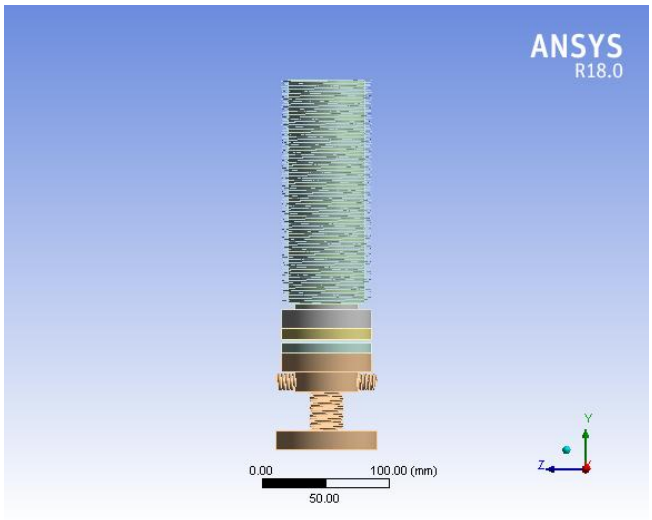


**Figure 3-** Complete Design of Steering Damper System (Side View)

There is a steering shaft which is the part that rotates along its axis with the motorcycles steering. It is made out of a magnetic material. There is a cylindrical casing around the steering shaft which is wound with an electromagnetic coil along its length. This turns the casing into an electromagnet. A and B are just for supporting the two friction plates. They are made out of ferromagnetic material. A is joined to the steering shaft, B is connected to a linear spring. They will have a rotational motion along their axis. B will also have a linear to and fro motion along the axis. The linear spring is a tension spring that means it will basically only allow for spring extension but not compression. This is joined to a rigid support from the other end and this support is a part of the outer casing, which means it will not have any motion. B is connected to two torsional springs whose other end will be connected to the outer casing (not shown in the figure) which is stationary because that will be connected to the motorcycles frame.

When the parameters are reached i.e. when the bike's speed is more than a set value, there will be current supply in the coil. This will turn the steering shaft into an electromagnet. Since the part B is made out of a magnetic material, it will be attracted upwards. As the part B moves up, it will bring the lower friction plate into contact with the upper friction plate thus creating a frictional contact. Also the part B is connected to the stationary outer casing by torsional springs of very high stiffness, the rotational movement of the part A will be restricted which in turn will restrict the movement of the steering shaft. In case of a disturbance or any circumstance which can initiate an aggressive wobble, it will be dampened out as the rotational motion of the steering shaft is restricted. When the speed of the bike is less than the set value, there will be no current in the coil and hence there will be no contact of the frictional plates, so the part A along with the steering can rotate freely as if there was no steering damper. So, the researchers have got the safety at high speed and have got the ease of riding through the streets at low speed which was the primary objective of the design.

The graph shows a relation between Torque and Angular Velocity of the Steering Shaft. There are two concerns here for working of a motorcycle steering damper i.e.; Safety & Comfort concern. At lower speeds the Steering should be comfortably rotated without any restriction, So, that the motorcycle can be easily manoeuvred through the traffic. But at higher speeds Safety consideration takes into consideration. As, at higher speeds more angular velocity is result of disturbances (weave and wobble). Hence, more restricting torque is required to stop the rapid movement of the handle bar. Thus, according to the graph at higher velocity of the motorcycle (Safety) a restricting torque of 50 N-m is required to restrict the handle bar movement of 10 rad/s. The height h and outer diameter (DE) of a standard steering tube, whose typical values vary respectively from 120 to 180 mm and from 50 to 80 mm. (Cosimo Montia, An Axiomatic Design approach for a motorcycle steering damper, 2015) [6]

Solid modelling of individual parts, components and their assembly operation was executed on Solid Works 18. A .step geometry file was saved in Solid Works and imported in ANSYS Workbench steady state static structural standalone system. A medium sized global mesh was applied on the

imported geometry of the damper assembly. The model was subjected to simulations and results were obtained.

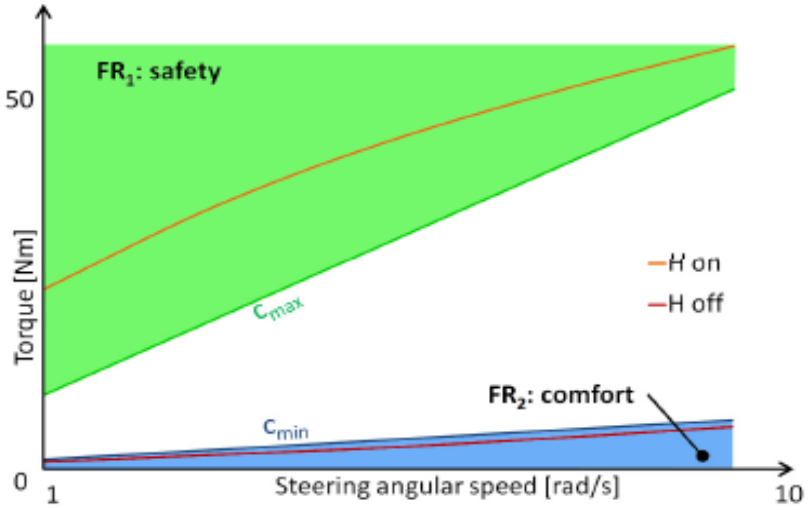


**Figure 4 –** Relation between Torque and Angular Velocity

## IV. RESULTS

Table 1 gives a description of Equivalent von Mises and Total Deformation in the multiples components of the assembly analysed.

**Table 1-** Simulation Result Chart

| Components | Total Deformation (mm) | | Equivalent Von Mises Stress (MPa) | |
|---|---|---|---|---|
| | Min. | Max. | Min. | Max. |
| Friction Plate | 0 | 2.4625e-006 | 1.6812e-003 | 4.05e-002 |
| Torsional Springs | 0 | 3.8956 | 1.0182e-002 | 4355.1 |
| Linear Springs | 0 | 29.022 | 3.8753e-005 | 297.86 |
| Steering Shaft | 0 | 4.7677e-003 | 0.1024 | 3.5565 |

## V. CONCLUSIONS

By making various attempts to make the motorcycle steering damper system. A system is made in which the objectives of motorcycle steering dampers i.e.; Safety (At high Motorcycle speeds) and Comfort (At low Motorcycle speeds) is achieved along with the aim to make a dry system which doesn't use any kind of fluid for its working. Analysis of various components of the steering damper assembly with proper materials, state that the components are capable to sustain the required amount of loads, torques and stresses.

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