A Dumb-Bell Shaped Damper with Magnetic Absorber using Ferrofluids

R.Karthick, P.Meenalochini, A.Manoj Prabaharan, P.Selvaprasanth, M.Sheik Dawood

Abstract: ***Damping devices are made up of ferrofluids which aid in strong magnetization and contribute greatly to minimizing magnetic vibrations. The most important and traditional applications of damping devices are used by ferrofluids and Nano magnetic materials. The combined effect of damping devices and ferrofluid materials show improved vibration minimization ratio. Here, it is observed that the basic damping device with ferrofluid materials consists of isolators, dampers, and absorbers. Moreover, novel dynamic isolation with absorption techniques is introduced in this paper. To obtain improved performance and efficiency of damping devices the use of isolators and vibration absorbers is suggested.***

Keywords: Dynamic damping applications, ferrofluids, vibration isolator and absorber.

I. INTRODUCTION

Advanced nano magnetic fluid material is popularly known as ferrofluids[1]. The fundamental advantage of choosing ferrofluid is to act with both homogeneous and heterogeneous properties. A magnetite is a particle extracted from ferrofluid which exhibits nonmagnetic fluid with mono domain suspension [2].

Steve Papell introduced stable ferrofluid which controls the environment with microgravity [3] in 19th century. Particularly, Rabinow introduced magnetorheological (MR) which fluid is a different from of ferrofluid [4] in 1948. Most of the automotive and biomedical applications MR fluid plays an import role [5].

The iron particles such as magnetite and hematite with liquid in the size of nanometers, ferrofluids are manufactured. The chemical compositions for ferrofluids are in the range of magnetic solids-5%, surfactant of 10% and carrier by volume 85% [7].

To solve complicated problems, the liquidity properties of ferrofluids give an auspicious solution. The various characteristics of ferrofluids, suggest possibilities in applying in devices like micro pumps, bearings and in almost all types of sensors. To create compact and durable devices ferrofluids play an important role. The traditional applications of ferrofluids are in the inclusion of dampers and isolators [8]. Ferrofluid with damping applications a contribution of (Raj) gives exclusive review in 1980's and also Dashpot with linear damper including rotary viscous inertia damper was proposed by Toress-Diaz et al [9] shows an excellent review of latest trends in growing field of ferrofluids which come under the broad category of microfluid(MF) systems.

Recent trends show that ferrofluids based dampers are widely used in areas of single linear vibration[8],[10]. Planar damper technique provides possible solutions for elasticity support which gives drawback instability [6].

In this paper, a novel magnetic absorber with damper structure is proposed and it's characteristics can be used to decrement the external magnetic field and fluid viscosity. Based on the experimental result, the novel structure of a dumb-bell combined with magnetic absorber has produced better result compared with state-of-art techniques. This paper is organized as follows: section 2 describes the concept of the novel magnetic absorber, section 3, gives the experimental results and the conclusion are derived in section 4.

2. A Novel Model of Magnetic Absorber

2.1 Model of Magnetic Absorber

The second order mass dumb-bell system modeled for novel magnetic absorber and it is expressed in equation 1.

$$m \frac{d^2 r(t)}{dt^2} + \frac{c\, dr(t)}{dt} + k\, r(t) = -\, m \frac{d^2 s(t)}{dt^2} \qquad (1)$$

m → mass of movable permanent magnet

k → stiffness of magnet

r(t) → relative displacement

s(t) → external excitation displacement

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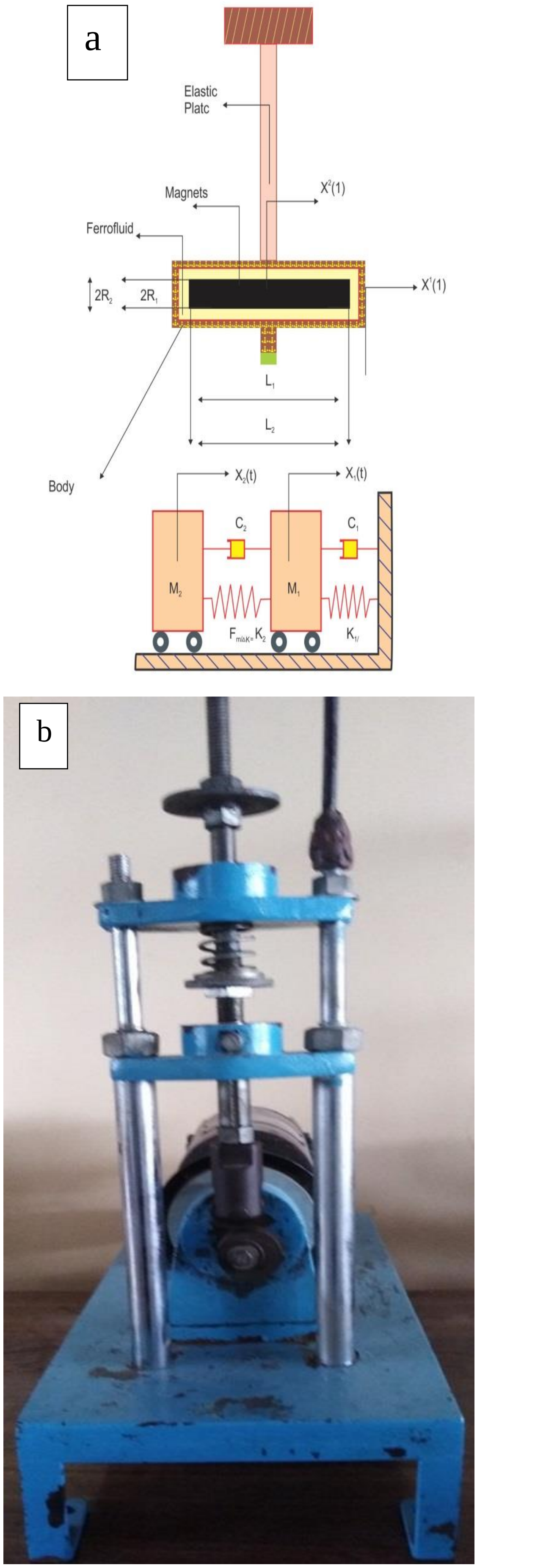

Figure. 1. A scheme of (a) the novel model of the magnetic absorber and (b) the experimental setup.

In stable state condition Permanent Magnet (PM) lies in the inner layer and fixed in axial direction. If any movement occurs, lower region oscillates along with horizontal force F, i.e.

$$F = \frac{\mu_0 Q^2\ r}{4\pi\ (r^2+d^2)^{\frac{3}{2}}} \quad (2)$$

From the above equation, k is called as constant magnetic stiffness (k=F/r) for movable and fixed permanent magnet.

2.2 Theoretical analysis

The Ferrofluid magnetic absorber has properties of both magnetic and non-magnetic materials in the cylindrical body. The center of body requires support for stability during vibration. By an external vibration, the magnet moves from initial position due to changes that occur in the body then restoration to the original position.

The elastic plate designed at one end is fixed and other end is open and free, through which we can measure performance parameters of magnetic absorber. The important task of absorber model is made by below assumption

a) Collinear magnetization
b) Steady – state ferrofluid flow
c) Constant temperature
d) Change in viscosity

2.3 Calculation of magnetic elasticity:

If no external vibration, the magnetic forces show an equilibrium effect because of symmetrically distributed ferrofluid. The overall restoring force is given by,

$$Fm= \oint(Pn+Pm)n\ ds = \oint(\tfrac{1}{2}\mu_o M_{n^2} + \mu_o \int_0^H M\ dH\ )\ n\ ds \quad (3)$$

Whereas,

Pn $=\mu_o M_{n^2}/2$ is known that normal magnetic traction and

Pm $=\mu_o \int_0^H M\ dH$ is termed as fluid magnetic pressure

n → unit vector to the magnetic surface.

In case Pn<< Pm, it is well known and re-written as

$$Fm = \oint P_m\ \ n\ ds = \oint(\ \mu_o \int_0^H M\ dH\ )\ n\ ds = \mu_o \int M\nabla\ Hdv \quad (4)$$

II. RESULTS

The new dumb-bell shape of ferrofluid is present in between the inner layer with magnetic absorber[11],[12],[13]. Due to magneto static force, there is a change in an axial direction of moving permanent magnet. If ferrofluid mass increases the damping co-efficient decreases. The mass of 3.1g ferrofluids present on the permanent magnet reaches the saturation state. If the container height decreases from 10mm to 8.5 mm with mass of 3.6g ferrofluids, the damping co-efficient raises above 3 times.

In this experiment, the frequency reading noted due to oscillations are 4.2 Hz and starting amplitude is 6.5mm. the ferrofluids drop of mass 3.6 g and an inner layer height 8.5 mm attained by magnetic absorber. The experimental setup for proposed magnetic absorber, the overall system oscillations are unstable. The oscillating time can be minimized by 90% when weight of ferrofluid is 35g.

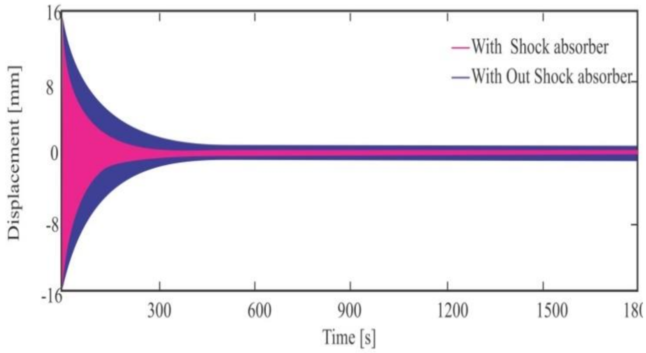

Figure 2.Diagram of beam oscillations (blue) without shock absorber and (pink) with shock absorber.

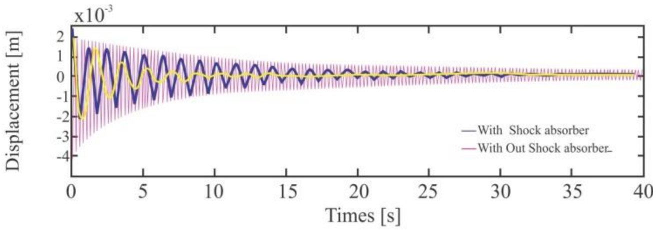

Figure 3. Diagram of ferrofluid damper (pink) without shock absorber (blue) with shock absorber.

Figure. (2) and (3) shows the beam oscillations with and without the damper based magnetic absorber. The optimization of magnetic absorber with the parameters of distance ‘d’ as 30 mm and radius ‘r’ as 12.5mm. The oscillating duration is four times smaller in (pink) and (blue).

III. CONCLUSIONS

In this paper, a novel ferrofluid damper based magnetic absorber is proposed and the theoretical analyses are made clearly. Some properties of damper based magnetic absorber are analyzed by theoretical as well as practical experimentation. An exclusive device was fabricated and its absorber characteristics were practically measured. According to the experimental values, our system shows improved performance and when external magnetic field is applied and also very susceptible to the attenuation. The system with improvised techniques requires one-third time than a conventional absorber to dissipate the shock. Better performance will be achieved in future and moreover, the magnetic absorber is planned to be put to use in satellite application.

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