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Design of New Type of Electromagnetic Damper with Increased Energy Density

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Abstract:

This paper present design of new type of electromagnetic damper or eddy current damper which has advantages of no mechanical contact, higher reliability and stability, high efficiency and compactness. By using this damper we can minimized damping of different masses and thereby damping coefficient. The damper is composed of neodymium iron boron grade N 50 magnet .By using this damper I found greater difference in damping when experimental result are compared with analytical result.

Keywords —

Introduction

When a conductor moves in a magnetic field, eddy currents will be induced in the conductor and a magnetic drag force (damping force) will be generated, which will dissipate the kinetic energy into Ohmic heat. The dampers based on this principle have found in many applications. Compared with other types of dampers, such as viscous, viscoelastic, or piezoelectric dampers, the eddy current damper has advantages of no mechanical contact, high reliability, high thermal stability, and vacuum compatibility. However, it has disadvantages of large mass and packing size.

1.Concept and Modeling of a New Eddy Current Damper

It is a common practice in the design of transformers or electromagnetic motors to use laminated steel to reduce the eddy current losses. The reason is that by splitting the conductor, we can increase the electrical resistance of the current loops. In an eddy current damper, we would like to reduce the loop electrical resistance; that is why the area of conductors is usually several times larger than the area of the magnetic field. Inspired by the approach of "splitting the conductor" to reduce the eddy current in transformer design, we can "split the magnets" to increase the eddy current via alternating the magnetic poles.

To illustrate this idea, consider two extreme cases as follows. Figure 1*a)* shows a moving conductor in a uniform magnetic field of the same width. In Fig. 1*b*) the magnetic field is split into two with alternative pole directions. When the conductor is moving at position as shown in the figure, instantaneous electric charges are induced in both cases, as indicated in Figs. 1*a*) and 1*b*). However eddy current loop and damping exist only in case b) but not in case a) .Case a) is similar to two identical batteries connected in parallel. If the conductor plate is wider than the magnetic field, or the B flux density is not uniform, eddy current and damping force exist in both cases in Fig. 1, but the damping force in case b) will be much larger than that in case a)

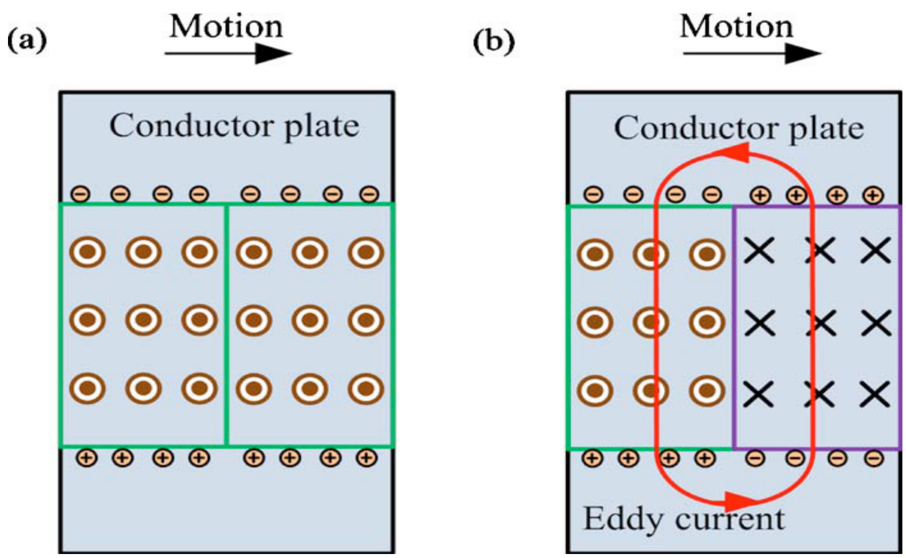

Fig.1-Illustration of two types of arrangements of magnetic field for eddy current dampers: case *a*) uniform magnetic field and case*b*) alternating magnetic field

2.1 Analysis of a Conducting Plate in a Uniform Magnetic Field.

According to our intuitive illustration based on electrical current loops, we see that the damping coefficient of a moving conductor plate in an alternating magnetic field is larger than the plate in a uniform magnetic field. In the following, we will describe the analytical model of the eddy current damper in a uniform magnetic field, and then present the modeling of the eddycurrent damper in alternating magnetic field .

Fig. 2a) shows the eddy current damper composed of a conductor moving with a relative velocity v (m/s) in a rectangular magnetic field

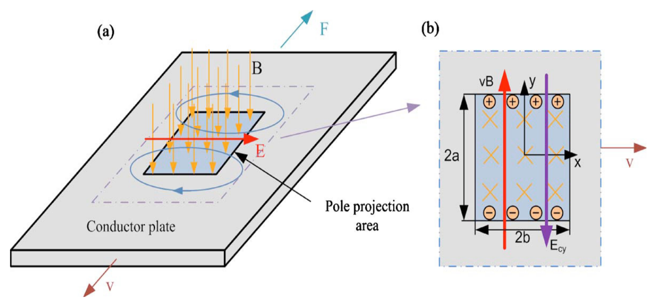

Fig. 2 *a*) Eddy current damping of a moving conductor and *b*) electric field due to eddy current

2.2. Analysis of Conducting Plate in Alternating MagneticFields.

Consider the two configurations of magnetic fields, as shown in Figs. 2*a*) and 2*b*).

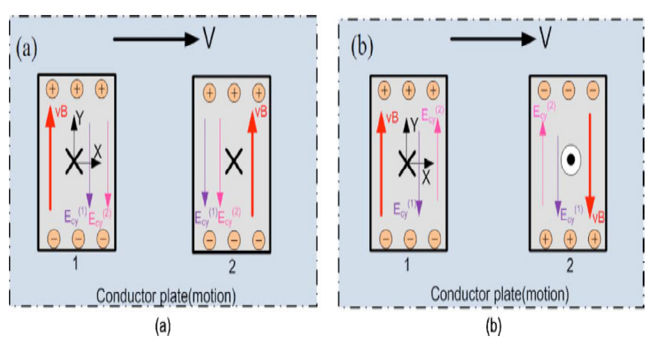

Fig. 3- Electric field distribution of the conductor plate in *a*) unidirectional magnetic field and *b)*alternating magnetic field

If the direction of two magnetic fields is the same (Fig. 3a),the electrostatic field intensity increases and they further decrease the effect of the electromotive field. As a result, the total electric field intensity and current density inside the magnetic field will be decreased.

If the direction of magnetic fields is opposed Fig.3b) the electrostatic field intensity is decreased, and the total electric field intensity and the eddy current density inside the magnetic field are increased. This is the physical interpretation that is why the eddy current damping can be improved significantly by alternating the magnet poles.

If a moving conductor plate is in an array of alternating magnetic fields, the effect of damping properties is not simply equivalent to the simple combination of two alternating magnetic fields analyzed earlier. Let us take the four alternating magnetic fields in Fig. 4)

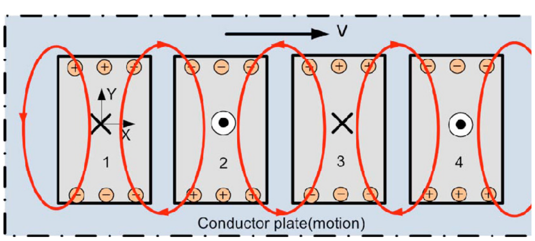

Fig. 4- Illustration of eddy current in a conductor plate moving in an array of alternating magnetic field

2.3 Methodology

We see that the damping coefficient is proportional to the square of the magneticflux density B, so it is critical to have a large flux density B, which we achieve by choosing high-intensity rare-earth magnets and by designing low reluctance magnetic loops.

Figure 5) shows a schematic view of the eddy current damper design. A total of 26 permanent magnets neodymium iron boron grade N50 are arranged one over the other on both size of copper conductor plate .The pole direction of magnets in each row is arranged in an alternating pattern. One slots with a gap of. 5 mm exist between the rows to allow the motion of the one conductor plate. Two pieces of soft iron are set in the back of the first and last rows of the magnets to reduce the reluctance of the magnetic loops. We choose copper as theconductor materials because of its high electrical conductivity . Fig 6) shows eddy current damper with mass .The overall dimension of various parts are as follows

Table- Dimension of various parts

copper plates	93×81×2 mm
Base (Wood)	48×100×16 mm
Neodymium Iron Boron Magnet	25×5×2 mm and 40×10×5
Soft Iron piece	96×93×2 mm
Wood plate on which soft iron piece is packed	100×93×12 mm
Weight used	1 kg, 2kg,3kg,4kg

Fig 5) -Eddy current Damper

Fig. 6) -Eddy current damper with mass

3. Result And Discussion

Finally I got the following result .As frequency increases, damping get decreases. The developed eddy current damper is tested foe different masses such as 1kg, 2kg, 3kg, 4kg. Figure 6 a), b) c),d) shows decrease in damping for 30 HZ, 35Hz,40Hz, and 45Hz frequency at load of 1 kg, 2kg,3kg, and 4kg.Result are shown in following table

Result Table-

Frequency (Hz)		Damping		
	Load 1 Kg	Load 2Kg	Load 3 Kg	Load 4Kg
30Hz	3.93	5.70	7.86	9.01
35Hz	3.20	4.10	5.13	7.66
40Hz	2.87	3.18	4.07	5.43
45Hz	2.05	2.90	3.17	4.18

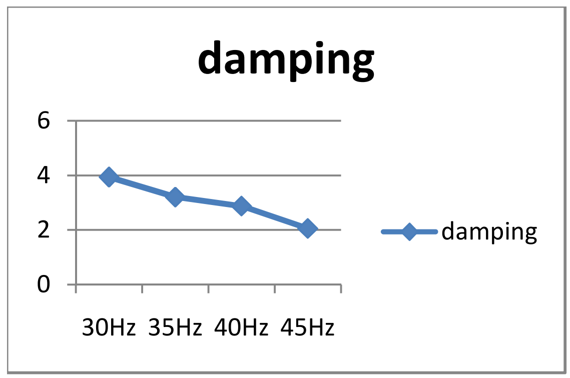

Fig-6a) Damping at load of 1kg

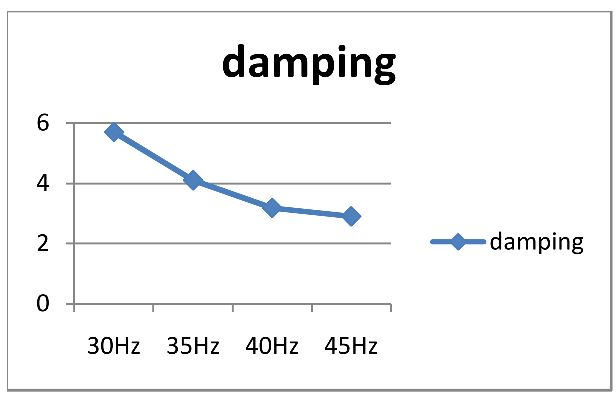

Fig-6b) Damping at load of 2kg

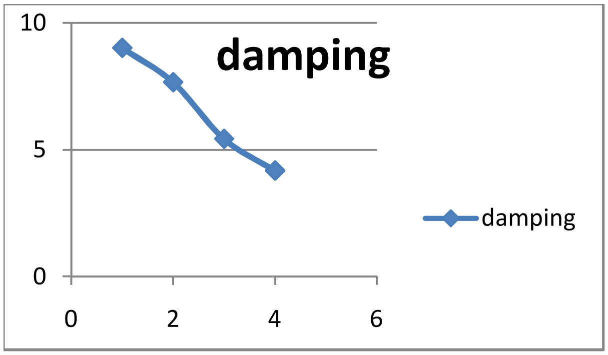

Fig-6d) Damping at load of 4kg

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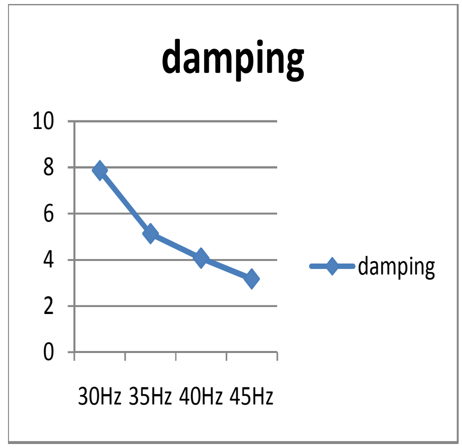

Fig-6c) Damping at load of 3kg

4. Conclusion

In this paper, I describe the design and analysis of a new type of eddy current damper with remarkably high damping density. We split the magnetic field and arrange the poles in an alternating pattern so as to shorten the eddy current loops and thus increase the damping. An analytical model of the induced eddy current damping is proposed based on electromagnetic theory. Experiments are conducted. We experimentally demonstrate that the proposed new type of eddy current damper achieves significantly high efficiency and compactness with a damping density and dimensionless damping constant Experiments also indicate that the damping coefficients decrease with increasing frequency or velocity.

6. References

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