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Improvement of the magnetic core for eddy current losses decreasing in cylindrical linear actuators.

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Abstract: In this paper, a method for reducing the eddy current losses in cylindrical linear structure is presented. It is based on one or several slots in the magnetic circuit. This method has been applied in a multi-rod actuator. The comparison between several slot configurations will be presented in the final paper.

1 Introduction

Numerous new linear actuator topologies need cylindrical magnetic circuit shapes. Those topologies have very interesting mechanical behaviors. Hence, we have developed a new multi-airgap actuator: the multi-rod actuator. However, as soon as the speed (and the power) increases, the iron losses become high [1].

One classical method for reducing the eddy current losses is the magnetic circuit lamination. Unfortunately, for those topologies, lamination is problematic.

An other solution is the use of soft magnetic composite material. But the industrialization of such actuators remains difficult, especially in large size.

In this paper, we propose a simple approach to reduce the eddy current losses in a longitudinal flux multi-rod actuator and to compute improvement.

2 The linear cylindrical multi-rod actuators

Linear cylindrical structures present numerous advantages:

- They are compact, compared to square section structures.
- They allow good mechanical precision.

They allow cylindrical coils shape, which is the optimum shape for the flux/copper losses ratio.

Hence, we have used the cylindrical shape for our new multi-airgap prototype [2]: the multi-rod actuator. We have succeeded to reach very high force volume ratio (around 1kN/dm^3). The cylindrical shape of the airgaps has permit to realize small airgaps. The overall cylindrical shape has given a very compact actuator. Figure 1 presents volumic performances of two PM synchronous actuators types : one-airgap (split coil actuators, classical topology) and global coil multi-airgaps actuators. Thus, by increasing the airgap surface (the number of rodes) these curves show higher performances of multi airgaps, specially for the large volumes.

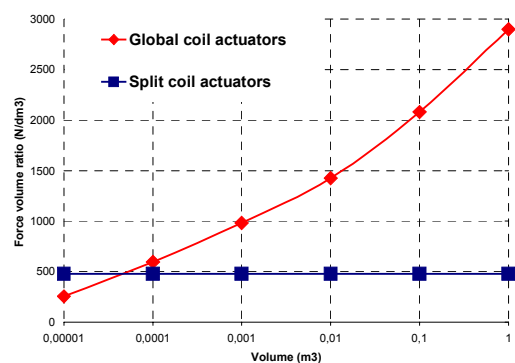


Fig. 1: Scale effect on force-to-volume ratio for of linear actuators

The actuator is synchronous with global coil and permanent magnets. These last are on the same side as the coil. The mobile part is composed of several completely passive identical rods (see fig. 2). The elementary pattern in the two extreme characteristic positions are represented on figure 3.

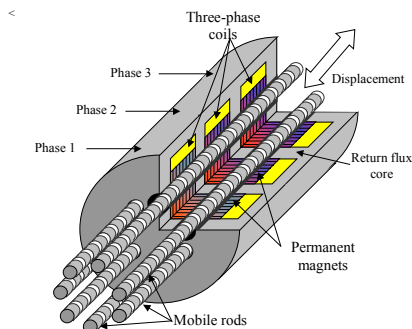
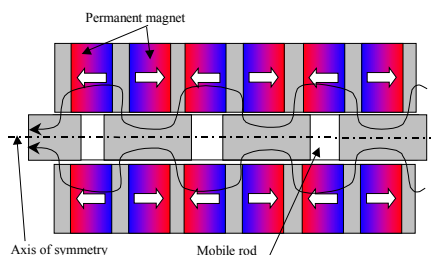


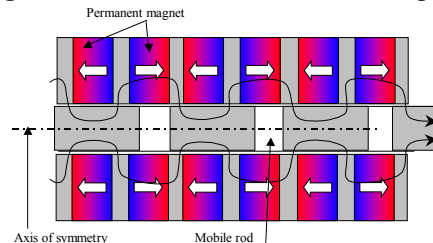
Fig. 2a: The multi-rod linear actuator principle



Fig. 2b: The multi-rod linear actuator prototype



(3a): Positive conjunction



(3b): Negative conjunction

Fig. 3: Elementary pattern of actuator

However, as soon as we want to use those structures for middle and high frequency applications, iron losses become very high (400Hz for a speed of 2 m/s). This is mainly due to the fact that the cylindrical symmetry is well adapted to eddy current development. The Finite Element Method has been used to calculate the eddy current losses. The final paper will give more results on those calculations

3 Application to the multi-rod actuator

This method has been partially applied to the multi-rod actuator. The return flux part has been slotted.

Concerning the active part, two origins of flux can be separated: the magnetic reaction of the global coil, and the permanent magnets flux, which depend on the rod positions. Hence, several slots should be made, as shown in figure 4. The final paper will present an estimation of the eddy currents losses in such a structure for various kinds of slots. It will also show the application of this method to other kind of low cost actuators like, small Transverse Flux Motors (TFM) used in stepper motors.

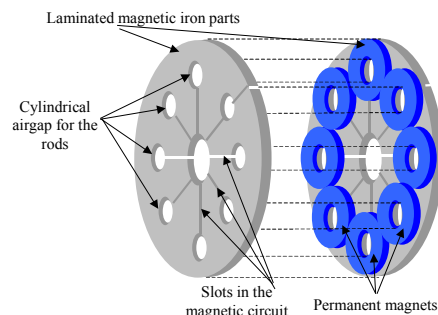


Fig.4 Exploded view of the slotted active part

4 Conclusion

This paper has presented a cheap way of reducing eddy current losses in unconventional low cost actuators. This method has been applied to a linear multi-rod actuator. The final paper will give experimental results on this actuator. The extension of this technique to low cost interior global coil actuator will also be presented.

5 References

[1] W.N.Fu, Z.J.Liu : "Estimation of Eddy-current losses in Permanent Magnets of Electric Motors Using Network-Field Coupled Multislice Time-Stepping Finite-Element Method", IEEE Transaction on Magnetics, Vol. 38, n°2 March 2002 pp1225-1228
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