JIEE Časopis priemyselnej elektrotechniky
Journal of Industrial Electrical Engineering
ISSN 2454-0900
www.jiee.eu

Electromagnetic losses in stepper motors

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***Abstract* — First the article shortly describes stepper motors and their use in practice. The main aim of the paper is to get acquainted with the losses of hybrid stepper motors that are induced by electric and magnetic fields. Subsequently it explains the basic principles of the activity of individual losses and their possible elimination.**

***Keywords* — copper losses, eddy current loss, hysteresis loss, stepper motors**

I. INTRODUCTION

Stepper motors (SM) are often used in practice. The stepper motor is engine with relatively high efficiency and a large range of operating temperatures. Under certain conditions of stepper motor control, they are rapidly heated to a relatively high temperature. In many applications, the high temperature of engine does not affect the system with the stepper motor. However, there are some cases where the temperature of the stepper motors could negatively affect the system in which the stepper motor is located, such as automated low temperature measurement systems and other. Therefore, it is necessary to determine the heat sources in the SM and then to analyze them. By precisely recognizing the electrical losses in SM, we will be able to determine the thermal effect on the system in which the SM is located.

II. STEPPER MOTORS

Stepper motor is a synchronous motor, and their advantage is the ability to accurately set up the angle of rotation without the feedback. They have the ability to maintain torque even at zero rotation. Engine movement is discontinuous, moves with steps. The accuracy of the engine depends on how many steps you need to make per revolution. Fig. 1 shows a hybrid stepper motor. [1]

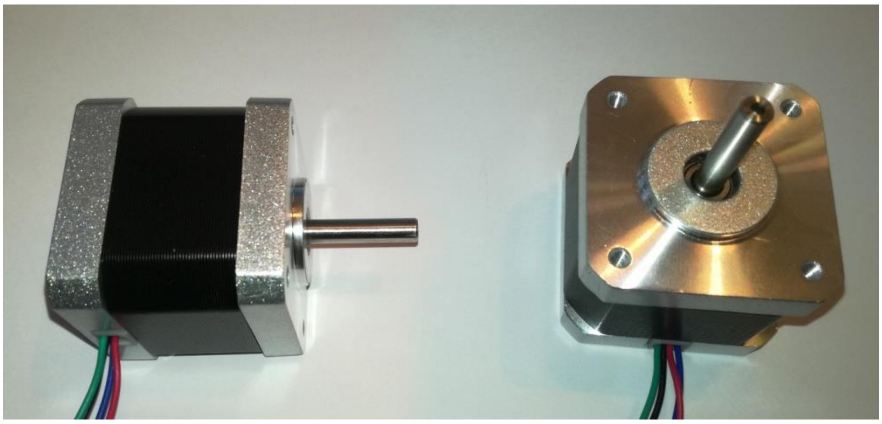

Fig. 1 Stepper motor

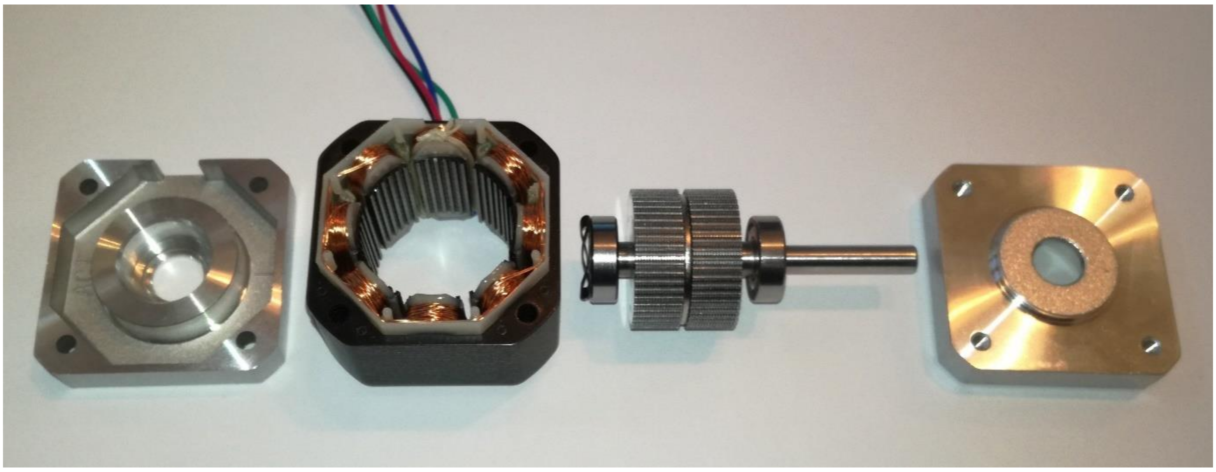

Fig. 2 Parts of stepper motor

Fig. 2 shows the individual parts of the engine. The motor stator consists of laminated iron material, the grooves on which the copper coils are wound from the inside of the stator. The rotor consists of a permanent magnet which is embedded in the iron laminated core. The whole structure of the engine holds the side shields in which the bearings are placed.

III. ELECTROMAGNETIC LOSSES IN STEPPER MOTORS

Fig. 3 shows the dividing of losses in stepped motors generated by the electric and magnetic field. The copper losses is generated by the current flowing through the coil and the iron losses are caused by the change of the magnetic flux in the core. Magnetic flux changes by rotating the rotor or changing the direction of the current flowing through the stator winding. [2]

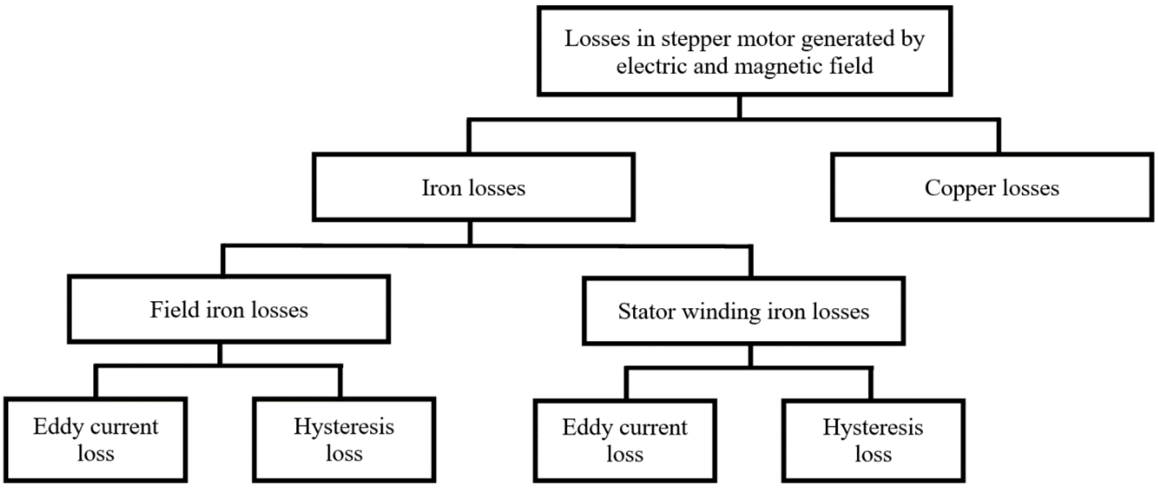

Fig. 3 Dividing of electromagnetic losses

Iron losses are divided into eddy current losses and hysteresis losses. These can be created by rotating the rotor, which changes the magnetic flux or strong magnetic field generated from an external source, these losses we call field iron loss. Another possibility of loss are the losses caused by the change of current flowing through the coils of the stator winding, which also changes the magnetic flux in the iron. The losses created by the change of the current in the stator coils are called stator winding iron losses. In the following subchapters, we will define the principles of each type of loss.

IV. Copper loss

Copper losses depend on current flowing through windings. Hence, even when increasing the load, copper loss is increased due to increasing of current flowing through the winding. This phenomenon describes Joule-Lenz's law, the wording of which is as follows: When free electrons pass through the conductor, the other conductor particles collide (conductor resistance). With each collision of the electrons, energy is transferred to the other particles, with the current flowing increasing the total energy of the particle of the driver, as well as the temperature of the driver. [4]

V. Eddy current loss

The eddy currents are a manifestation of the magnetic induction generated in the metallic objects placed in the time-changing magnetic field. In the metal object surfaces perpendicular to the direction of the magnetic flux B, generate induced currents I. In Fig. 4 is shown drawing of the generated eddy currents which have the form of closed curves. Size of the induced current depends mainly on the size of the subject in which they are induced, by its resistivity and rate of change of magnetic field. The largest currents are formed around the circumference of the subject and the smallest in its center. Therefore, to limit the size of the eddy currents, are used laminated sheet structures. In Fig. 4 are shown to the right laminated sheets and in their generated eddy currents. Insulated sheet have smaller wire size, thereby reducing the size of eddy currents. [5]

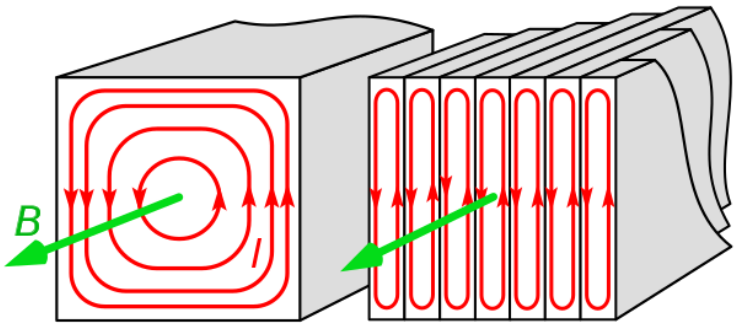

Fig. 4 Eddy current in solid core and in laminated core [3][3]

VI. Hysteresis loss

It is known that in ferromagnetic environments the magnetic flux does not increase directly in proportion to the increase in magnetic stress. The properties of the ferromagnetic material describe the magnetization characteristic shown in Fig. 5. It depicts the dependence of magnetic induction B on the magnetic intensity H.[5]

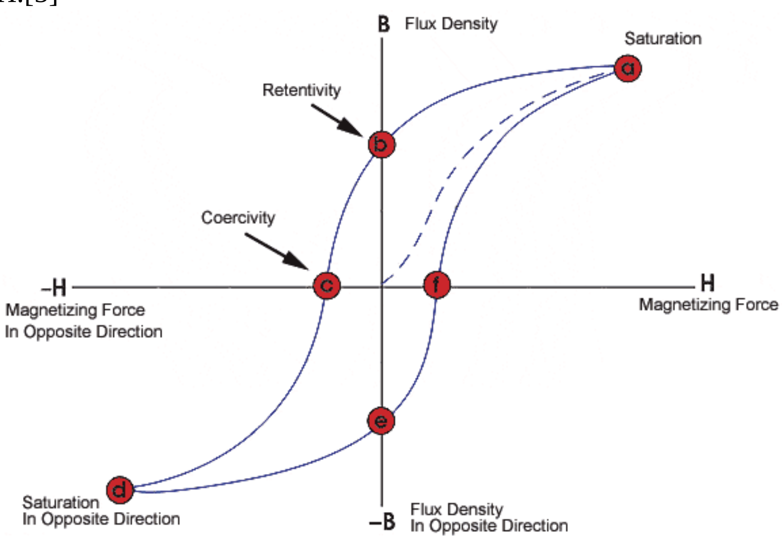

Fig. 5 Hysteresis loop [3]

In terms of stepper motors in ferromagnetic materials, alternating magnetization occurs. The change of B from H in the magnetization and de-magnetization indicates a hysteresis loop. Its width depends on the matetial's property. Materials with a narrower hysteresis loop are more suitable for alternating magnetization. Hysteresis losses are directly proportional to the area bounded by the loop. Hysteresis losses result is an increase the temperature of the ferromagnetic material which is used.[5]

VII. CONCLUSION

Detailed analysis of the aforementioned losses in a permanent step motors can create a detailed thermal model of stepper motors. The model will be able to simulate the thermal heating of the engine and its thermal effect on its surroundings.

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