IMPACT OF SURFACE-MOUNTED PERMANENT MAGNETS IMPERFECTIONS ON THE MACHINE

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Abstract: Study sums up issues of mounting permanent magnets onto rotor surface of permanent magnet synchronous machine. Fully parametric model of rotor with surface mounted permanent magnet was created. Model was subjected to analysis of offset of permanent magnet, wrong magnetization and manufacturing width tolerance. Fourier transformation was performed with the results to separate the imperfections via cogging torque and induced voltages.

Keywords: magnet imperfections, cogging torque, induced voltage, FEM, synchronous machine

INTRODUCTION

Surface-mounted permanent magnet synchronous machines have a very wide spectrum of use. They are greatly popular due to high torque/volume density. But the design of permanent magnet machines has a few disadvantages. One of them is cogging torque, which is a result of interaction between magnetic field created by rotor permanent magnets and stator slotting. Cogging torque leads to undesirable vibrations and noise. Most of the motors are still produced by manufacturing and that can cause many different imperfections. Manufacturing imperfections highly increase the effect of cogging torque, so it‘s important to determine the impact of those imperfections. With knowing their impact it is possible to prevent them in design phase by applying certain measures.

1. HARMONIC COMPONENTS OF COGGING TORQUE

Cogging torque as a periodical phenomenon can be analyzed via Fourier transformation. Harmonic components of cogging torque depend on design, manufacturing and assembly tolerances. In order to characterize the impact of imperfections it is important to separate individual components from each other. Cogging torque harmonic components can be divided into native (NHC) and additional (AHC) harmonic components. [1]

$$T_{cog}(\alpha) = T_{NHC}(\alpha) + T_{AHC}(\alpha) \qquad (1)$$

Native harmonic components are always present in the machine. Their origin is in the design of the machine. Additional harmonic components are caused by manufacturing and assembly imperfections of permanent magnets. Both components affect specific harmonic orders of cogging torque. Native harmonic components have orders: [1]

$$N_{NHC\,i} = LCM(Q,P) \cdot i \qquad (2)$$

Where LCM stands for the least common multiple, Q is number of stator slots, P is number of magnetic poles and i is an integer.

Orders of additional harmonic components are:

$$N_{AHC\,rot\,i} = Q \cdot i \tag{3}$$

2. PARAMETRIC MODEL

A 2D parametric model was developed for this purpose. A synchronous machine with number of stator slots Q=36 and magnetic poles P=6 was chosen as a subject for analysis. It has four flat surface-mounted magnets per pole. The rotor model that was created is fully parametric. It allows unrestricted movement of permanent magnets and even different magnetization direction option.

This parametrization gives freedom to create the majority of possible setups of magnet imperfections. This study is focused on two main manufacturing imperfections that affect cogging torque the most.

The first setup is the offset of permanent magnet. This imperfection is caused by a worker using too much glue. Simulation via FEM is performed on one magnetic pole and magnet has only two possible states, 0mm and 1mm offset. That gives 2^4 possible combinations.

The second setup is false magnetization direction. This fault is a manufacturing tolerance. Simulation was performed on one half of the magnetic pole. Magnetization fault has three possible states, -10° direction from default, +10°, and the correct one - 0°.

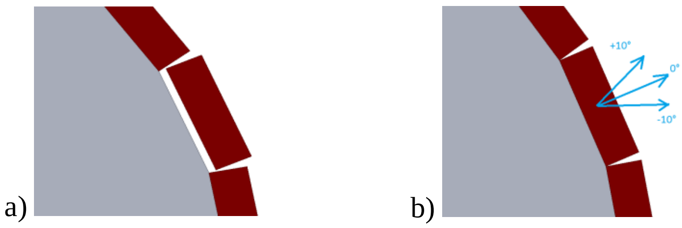

Figure 1: Simulated magnet imperfections a) offset b) false magnetization

3. SIMULATION RESULTS

A combination with the greatest influence from each simulation was chosen to demonstrate the result. Concerning the offset setup, an option when three magnets on one pole are affected by the fault and one of the middle magnets is mounted correctly. From the magnetization fault setup, the most influential combination is the one where magnetic flow diverges.

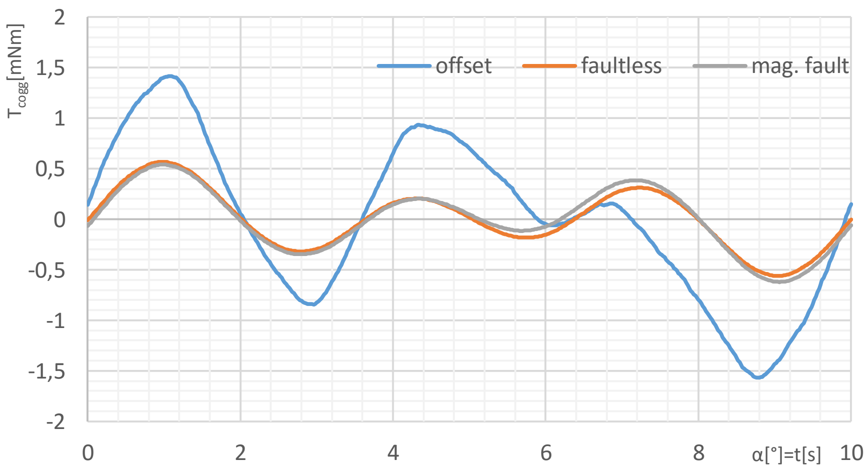

Figure 2: Cogging torque

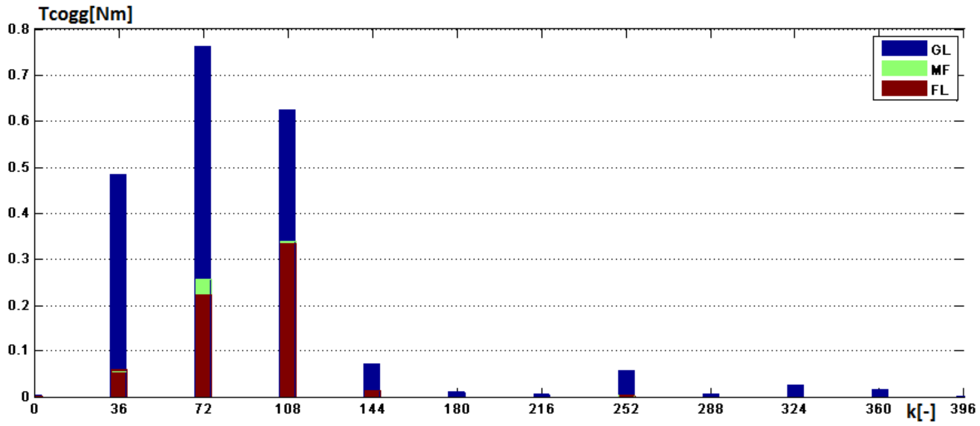

Figure 3: Cogging torque harmonic analysis

It is possible to see in Figure 2 and 3 that the offset imperfection (GL) affects cogging torque the most. Each harmonic order of cogging torque corresponds to equations in chapter 1. As for the design of the motor, native and additional harmonic components affect the same harmonic orders, because the least common multiple of number of stator slots and number of poles is the same as number of stator slots.

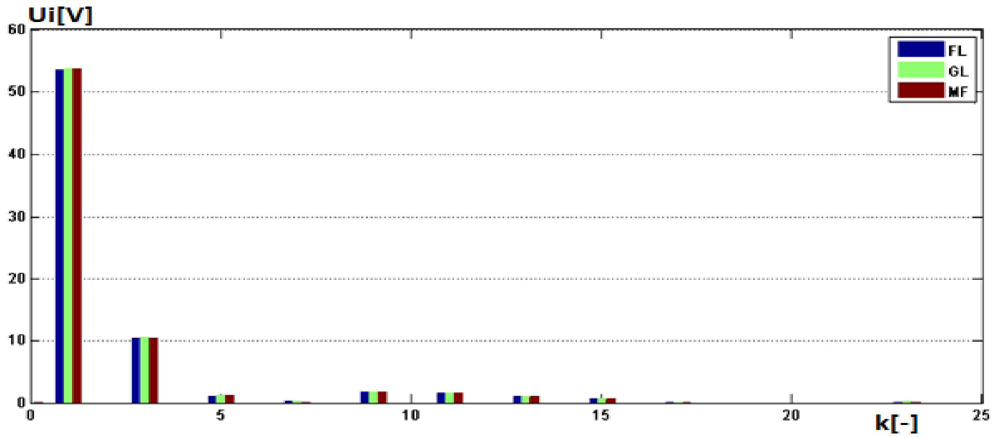

Figure 4: Harmonic analysis of induced voltage of phase A

In Figure 4 there is a harmonic analysis of induced voltages. The induced voltages are not affected as much as cogging torque. Closer examination shows that the offset imperfection slightly increases 1st, 3rd, and 5th harmonic. On the other hand, magnetization fault slightly increases 1st and 5th harmonic a slightly decreases 3rd and 7th.

4. CONCLUSION

Simulations proved that surface-mounted permanent magnet imperfections have a significant affect on cogging torque. The biggest influence comes from the offset of permanent magnet. All simulation results were subjected to harmonic analysis. It is possible to see that each imperfection affects different harmonic orders of induced voltage. This could be the first step for detecting magnet imperfections via induced voltages.

REFERENCES

[1] Gasparin, L.; Cernigoj, A.; Markic, S.; Fiser, R., "Additional Cogging Torque Components in Permanent-Magnet Motors Due to Manufacturing Imperfections," *Magnetics, IEEE Transactions on* , vol.45, no.3, pp.1210,1213, March 2009