LS-DYNA® and JMAG® Coupling Simulation for Change of SPM Motor Magnetic Properties Due to Press-Fitting

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Abstract

Press-fitting is one of the methods to keep the laminated structure of the motor core. It is known that the compressive stress due to press-fitting causes an increase of the core-losses. In this paper, the influence of the press-fitting stress on the motor magnetic properties was investigated using LS-DYNA and JMAG coupling simulation. JMAG is a comprehensive software suite for electromechanical equipment design and development. In this investigation, using LS-DYNA for press-fitting analysis, passing the results of the element data to JMAG, finally core-losses analysis was carried out by JMAG. From the results, the change of the magnetic properties due to press-fitting was clearly obtained.

Introduction

Press-fitting is one of the methods to keep the laminated structure of the motor core. It is known that the compressive stress due to press-fitting causes an increase of the core-losses [1] [2]. In this paper, the influence of the press-fitting stress on the motor magnetic properties was investigated using LS-DYNA and JMAG coupling simulation.

JMAG developed by JSOL Corporation is a comprehensive software suite for electromechanical equipment design and development. JMAG provides the latest technological ingenuities to accurately model complex geometries, material properties, as well as evaluate the thermal and structural phenomena associated with electromagnetic fields.

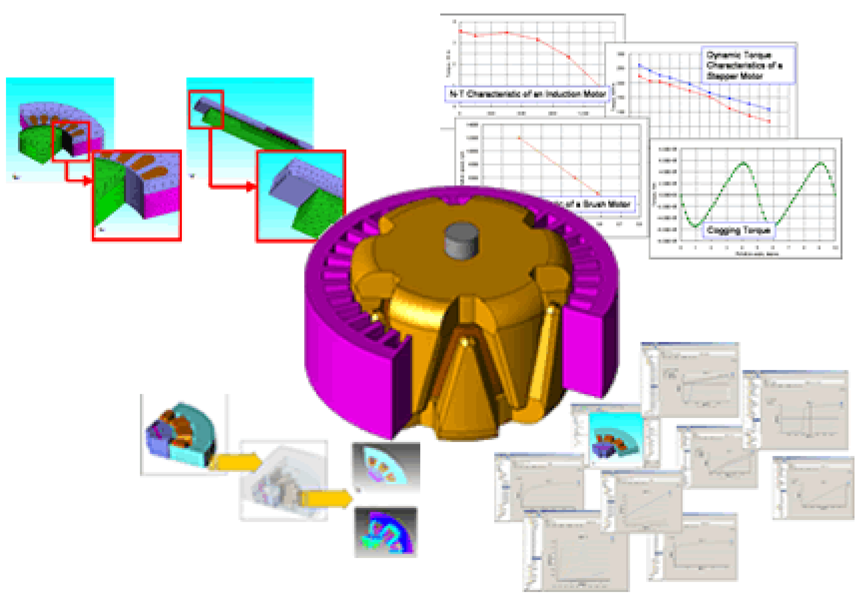


Figure1. JMAG interfaces

Analysis Approach

Figure2 shows the specification of the SPM motor used in this investigation. It is known that the compressive stress in the stator core due to press-fitting into the frame increases the core-losses of the motor.

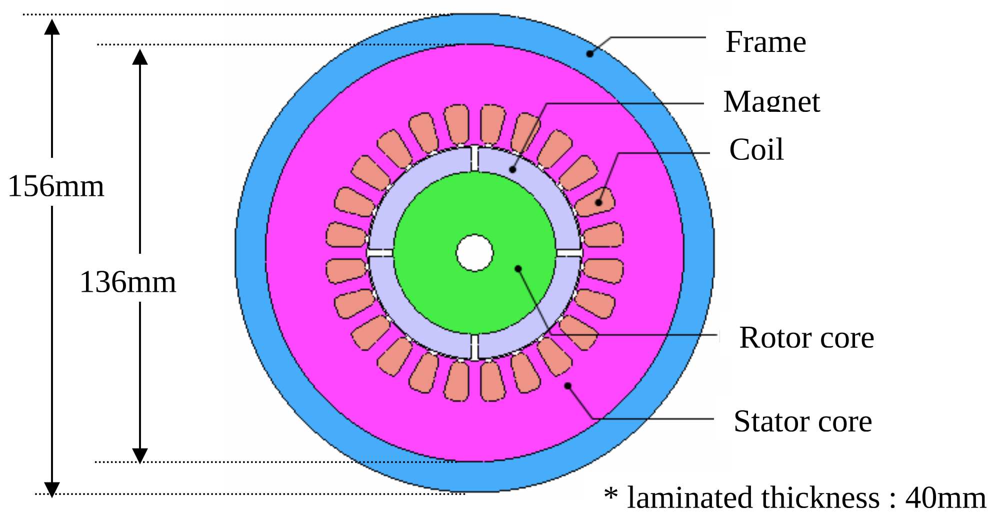


Figure2. SPM Motor

Figure2. Specification of the motor

Part	Magnetizing property	Mechanical property
Rotor core	Relative permeability: Nippon Steel 50H600	-
Magnet	Recoil relative permeability: 1.05 Coercive force: 963 kA/m	-
Stator core	Relative permeability: see Figure3 for BH curve	Density: 8,030 kg/m^3 Young's Modulus: 1.197×10^{11} N/m^2 Poisson Ratio: 0.34
Frame	Relative permeability: 1	Density: 2,710 kg/m^3 Young's Modulus: 0.69×10^{11} N/m^2 Poisson Ratio: 0.28
Coil	Relative permeability: 1	-

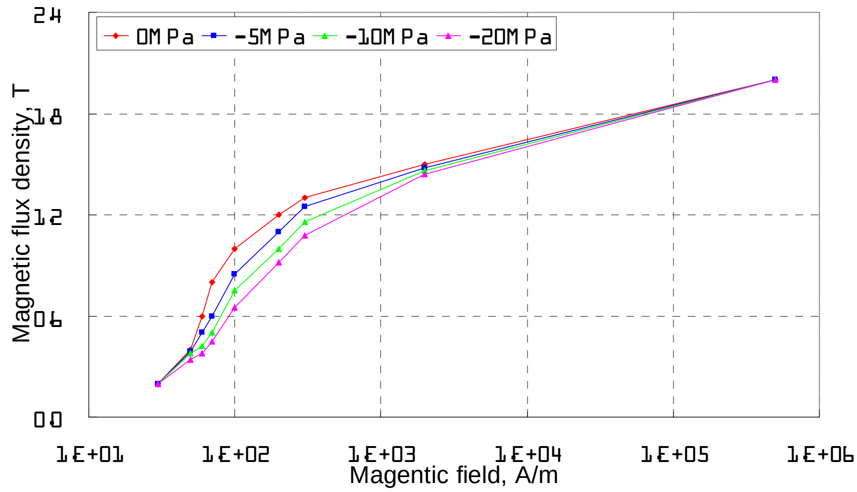


Figure3. Stress Dependent BH Curve (stator core)

At first, press-fitting between the stator core and a frame was calculated by LS-DYNA. After that, the result, the stresses in the stator core, was converted to JMAG file format. Finally, core-losses analysis was carried out by using JMAG (See Figure4). The detail of each phase is described below.

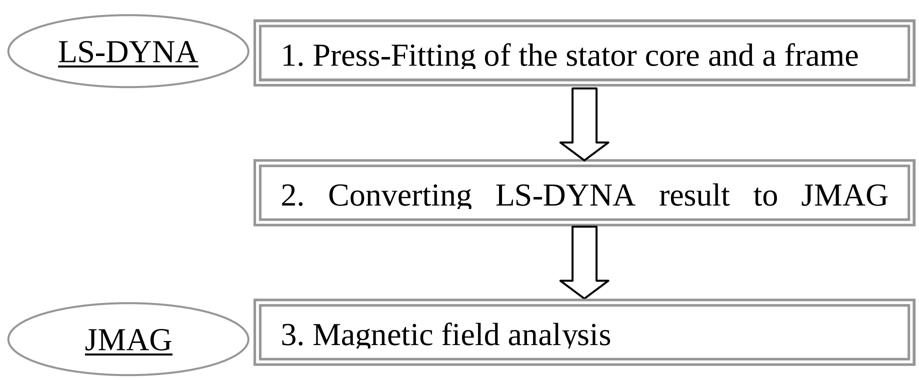


Figure4. Analysis Procedure

1. Press-Fitting simulation by LS-DYNA

At first, press-fitting simulation was carried out using LS-DYNA. In this phase, only the stator core and the frame were modeled as elastic materials. A quarter model was used because of the symmetric geometry. Number of elements is about 86,000.

Small penetrations were introduced between two parts, then *CONTACT_SURFACE_TO_SURFACE_INTERFERENCE and *CONTROL_DYNAMIC_RELAXATION were used to solve the press-fitting. (See Figure5)

The analysis method was very simple, and the results were obtained in very short time. The dynain file of the stator core obtained from the analysis was used for the next phase.

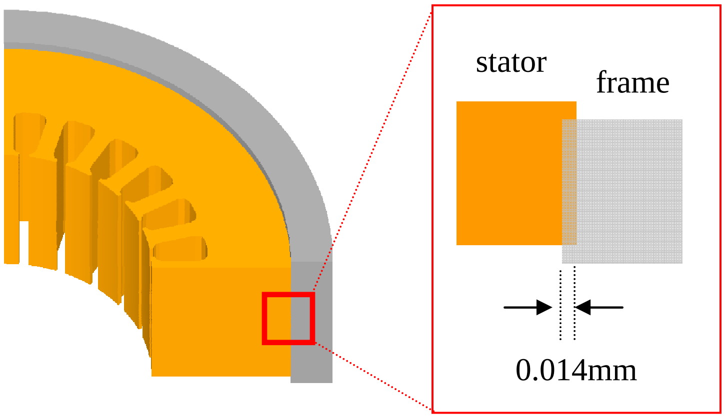


Figure5. Small Penetration between Stator core and Frame

2. Converting LS-DYNA result to JMAG input file format

After press-fitting analysis, the stress data in dynain was converted to JMAG input file format. The conversion was carried out using the brief perl script.

3. Magnetic field analysis

After conversion, the magnetic field analysis was implemented by JMAG. The same mesh data of LS-DYNA analysis cannot be used in the magnetic field analysis, so it is necessary to map the stress information into the other mesh data for the magnetic field analysis. In this investigation, the mapping operation was carried out by JMAG with the converted stress data. (See Figure6)

The core-loss was calculated using the magnetic flux density distribution obtained from the magnetic field analysis. By setting the core-loss condition, the core-loss is automatically calculated as soon as the magnetic field analysis is done. The example of the core-loss conditions used in the analysis are shown in Figure7(a) and 7(b).

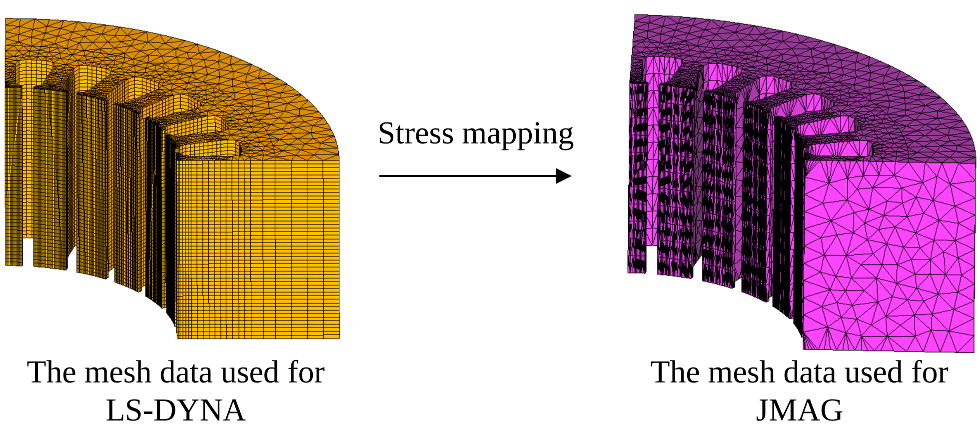


Figure6. FE Models used in each Analysis Step

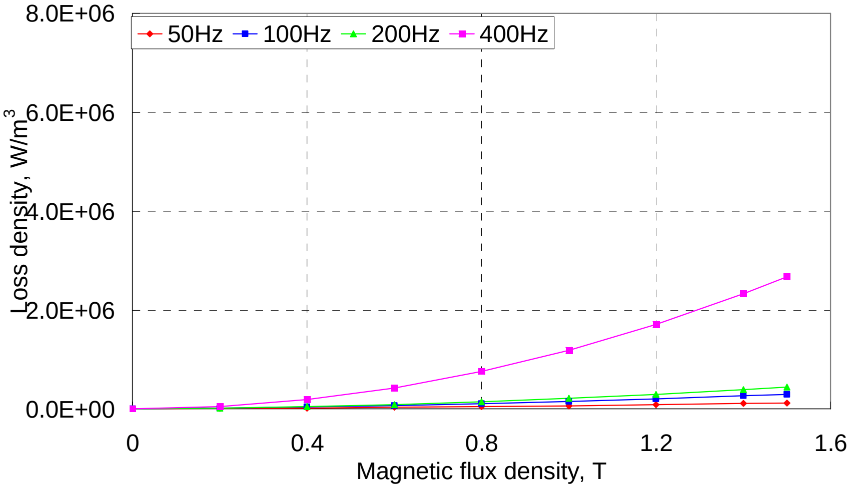


Figure7(a). Core-Loss of the Stator Core (stress: 0 MPa)

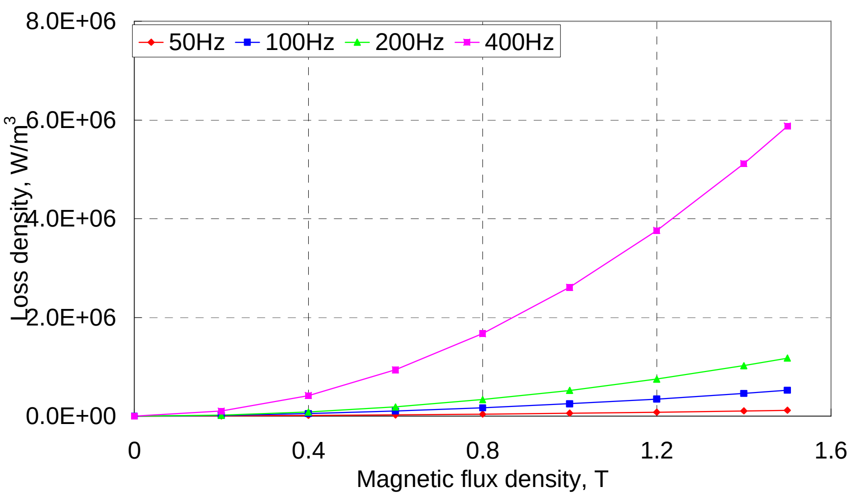


Figure7(b). Core-Loss of the Stator Core (stress: -10 MPa)

Results

The Figure8 shows the compressive stress distribution and Figure9 shows the principal stress vector distribution obtained from LS-DYNA analysis. The stress in the yoke is stronger than that in the frame and teeth. Especially, the stress is concentrated at the yoke facing the slots. This is because the stress decreases towards the tip of the teeth, meanwhile the stress is concentrated around the slots. As shown in the principal stress vector plot, the compressive stress is dominant around the slots and the tensile stress is dominant in the frame.

Figure10 is the mapping stress distribution, and Figure11 shows the core-loss distribution obtained from JMAG analysis. The core-loss density distribution is significantly affected whether the stress is applied or not. The result shows that about 12 percent increase of the core-loss when the stress is applied. This is because the core-loss increases when the compressive stress is applied.

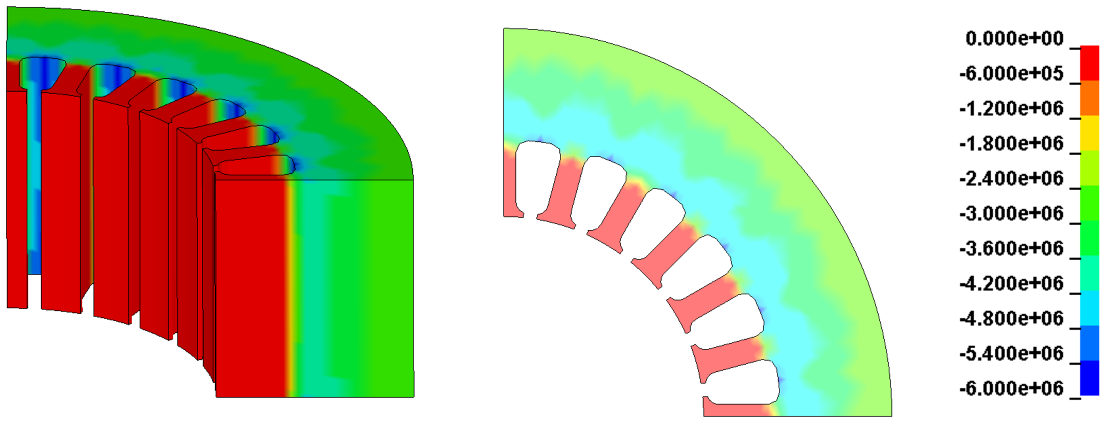


Figure8. Compressive Stress Distribution (Pa)

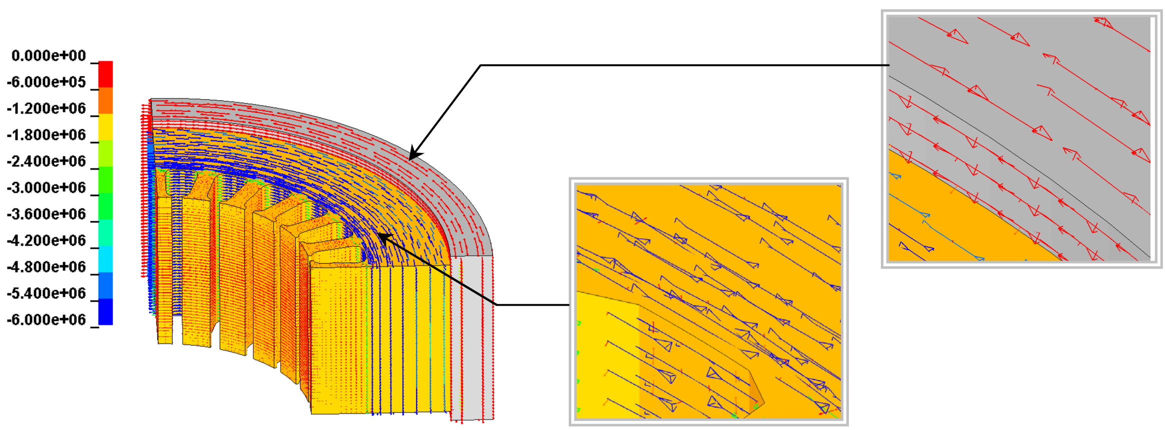


Figure9. Principal Stress Vector Distribution (Pa)

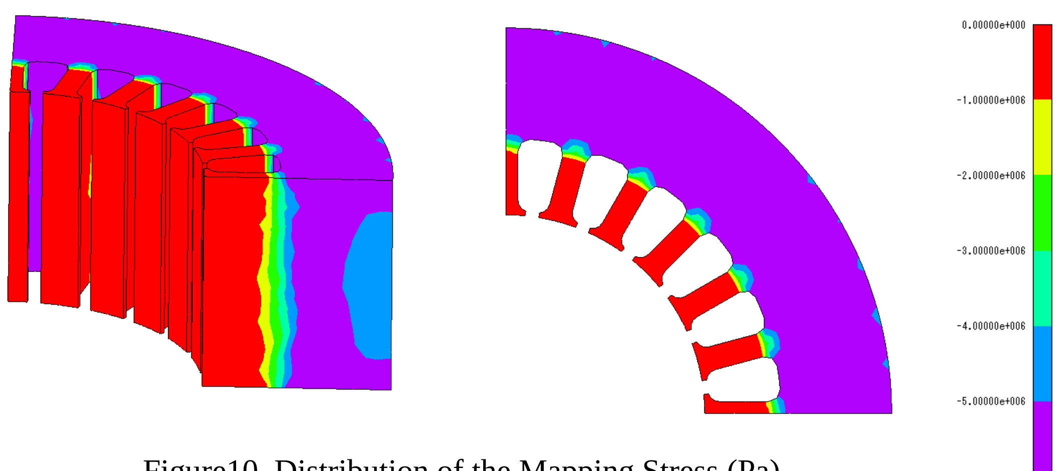
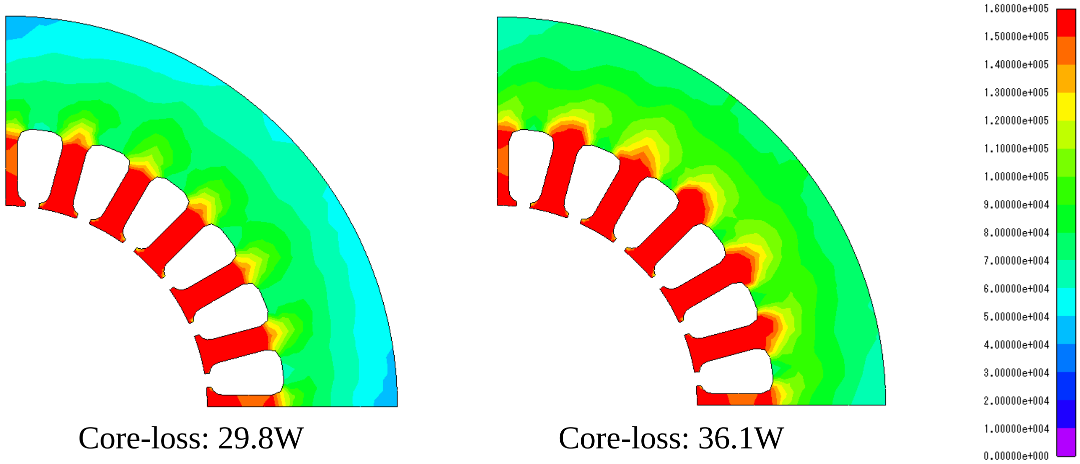


Figure10. Distribution of the Mapping Stress (Pa)



Core-loss: 29.8W Core-loss: 36.1W

Figure11. Iron Loss Density Distribution (W/m^3)
(Left: without stress, Right: with stress)

Summary

The influence of the press-fitting stress on the motor magnetic properties was investigated using LS-DYNA and JMAG coupling simulation. From the result, the change of the magnetic properties due to press-fitting stress was clearly obtained. We will keep investigating, and try to evaluate not only press-fitting but also shrink-fitting, which also influences on the magnetic properties of motor as well as press-fitting.

References

[1] Hiroshi Fujimura, Hiroyoshi Yashiki, Hiroshi Kojima and Taisei Nakayama (Sumitomo Metal Industries, ltd.): Effect of shrink-fitting stress on ring core magnetic properties of non-oriented electrical steel sheet, The papers of Technical Meeting of Magnetics, IEE Japan, MAG-05-103, pp.1-6, 2005.

[2] Hiroshi Fujimura, Hiroyoshi Yashiki, Hiroshi Kojima and Taisei Nakayama (Sumitomo Metal Industries, ltd.): Effect of interlocking shape on magnetic properties of non-oriented electrical steel ring core lamination, The papers of Technical Meeting of Magnetics, IEE Japan, MAG-06-138, pp.39-44, 2006.

[3] JSOL Corporation: JMAG Application Note Iron Loss Analysis of an SPM Motor Including the Effect of Press-fitting Stress, http://www.jmag-international.com/catalog/.