Estimation of Iron Loss of PMSM Used for Deep-sea Electromagnetic Propeller

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Abstract —A permanent magnet synchronous motor used for deep-sea electromagnetic propeller was investigated in this paper. Operating under the deep-sea, the submersible motor was compressed by high pressure of sea water. The high pressure compressed on the stator core could influence the iron loss. In this paper, the stress distribution in the stator core was calculated by a 2D FEM model, and the influences of compressive stress on magnetic properties of iron steel, such as BH curves and BW curves, were measured in some experiments. And then the effect of compressive stress on stator iron loss of the motor was calculated using FEM analysis, and the iron losses were also measured in experiments. Both the calculated and measured results show that stator iron loss could increase obviously under the increment of compressive stress, but the rate of increase is reduced when the stress is increased.

I. Introduction

PMSMs are usually used for electromagnetic propellers in deep-sea vehicles due to the excellent properties, such as high efficiency and high power density. These submersible motors are usually oil filled. Fig. 1 shows the inner structure of the oil-filled submersible motor. Operating under deep-sea, the oil in the motor and the sea water outside the motor could compress the stator core. The high compressive stress could deteriorate the magnetic properties of the iron steel and increase the stator iron loss [1, 2].

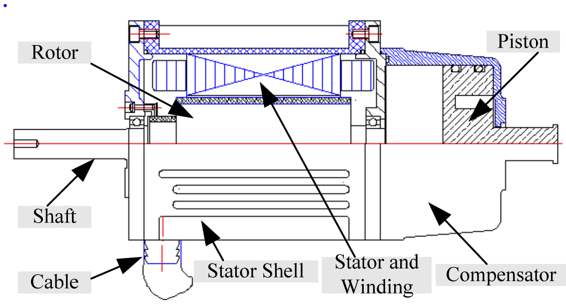

Fig.1. Inner structure of the oil-filled submersible motor

II. Stress Distribution in the Stator Core

Taking the press fitting and the compressive stress by the oil and the sea water into account, the stress distribution in the stator core was calculated based on a 2D FEM model. Fig. 2 shows the result of stress distribution in the stator while the motor operated at the depth of 7000m under the sea. The result showed that maximum compressive stress in the stator is up to 170Mpa.

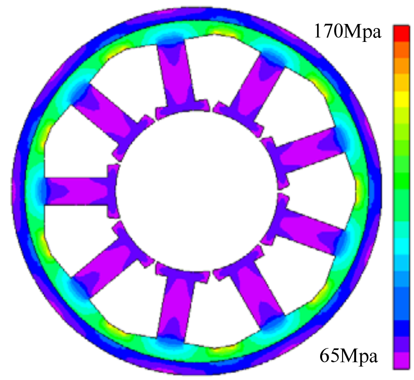

Fig. 2. Stress distribution in the motor.

III. Influences of Stress on Magnetic Properties

In this paper, the influences of compressive stress on the magnetic properties of iron steel, such as the permeability, B-H and B-W curves, were tested in experiments using the laminated specimen of iron steel [3-5]. Fig. 3 is the test specimen of iron steel and experiment high pressure tin. The specimen was compressed in the tin and the iron loss was measured.

Fig. 4 is the BH curve and Fig. 5 show the effect of compressive stress on the permeability of non-oriented electrical steel sheets. The permeability is rapidly decreased even by small stress, and the rate of decrease is reduced when the stress is increased.

Fig. 6 shows the measured B-W curves of stator core for different stress levels (at 400 Hz). The iron loss is increased by the stress. In the extended paper, the B-W curves were all measured at the frequencies of 50Hz, 100Hz, 200Hz, 300Hz and 400Hz. These results showed that large compressive stress had deteriorated the properties notably.

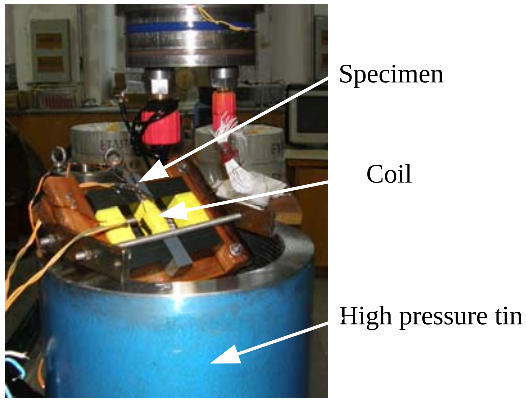

Fig.3. Test specimen of iron steel and experiment high pressure tin

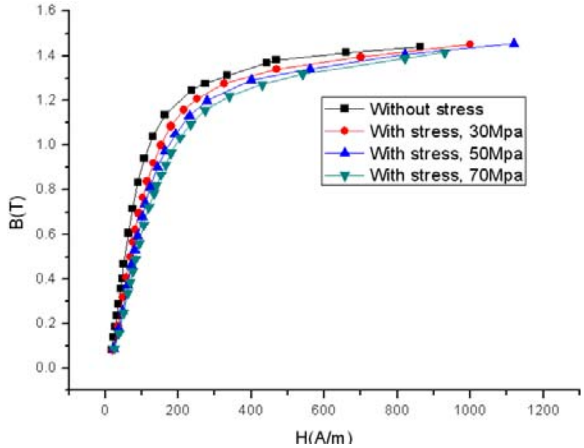

Fig. 4. B-H curves

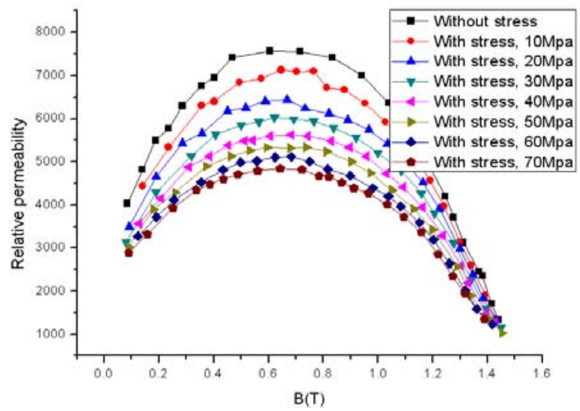

Fig. 5. Relative permeability

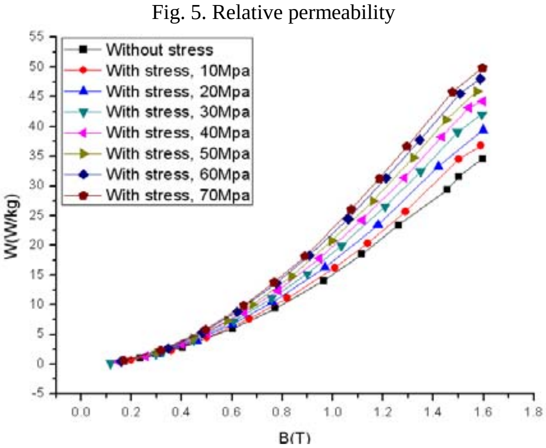

Fig. 6. Test B-W curves of stator core under different stress pressure

IV. EFFECT OF COMPRESSIVE STRESS ON IRON LOSS

According to the results of stress distribution and measured magnetic properties, the iron losses under different compressive stresses were calculated using FEM analysis. Fig. 7 shows the calculated result of iron loss density distribution under the stress pressure of 70Mpa, and Fig. 8 shows the test and calculated iron losses under different stress. It can be clearly seen that stator core loss could increase obviously with the increment of stress pressure, but the rate of increase is reduced when the stress is increased.

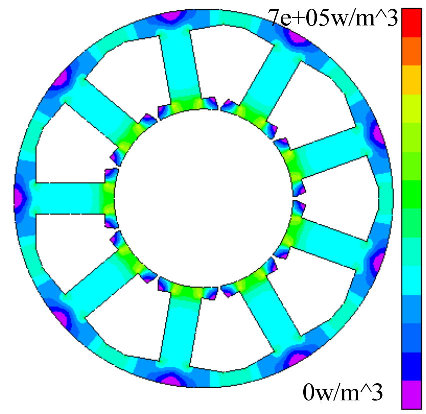

Fig. 7. Iron loss density distribution

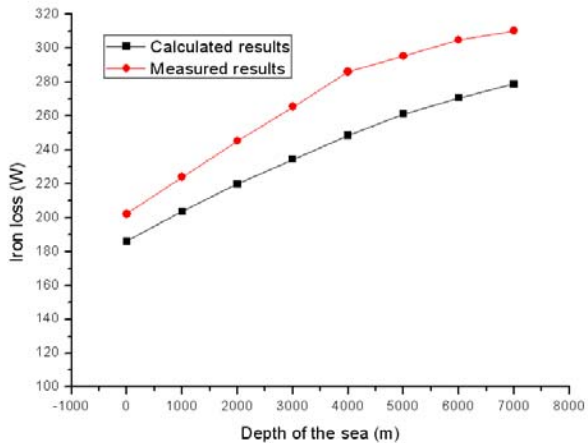

Fig. 8. Measured and calculated results of iron loss under different compressive stress.

V. CONCLUSION

Operating under deep-sea, the stator core was compressed by large stress. The compressive stress deteriorated the magnetic properties of the iron steel, and thus the stator iron loss increased to about 1.5 times at the stress pressure of 70Mpa. Furthermore, the rate of increase is reduced when the stress is increased.

VI. REFERENCES

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