Effect of magnetic property on the accuracy of induction heating analysis

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Abstract :
Relative permeability and B-H curve are often used as magnetic property of workpiece on induction heating analysis. Thus, analysis accuracy is compared between relative permeability and B-H curve for identical specimens. As a result, it is revealed that analysis result with B-H curve agrees well with the experiment result. In contrast, there is defference between analysis with relative permeability and experiment result around Curie temperature.

Overview

FEM is one of the tools for evaluating the coil geometries or heating conditions of high-frequency induction heating in simulations, and its effectiveness depends on the accuracy of the obtained results.

Recently, magnetic properties draw attention as factors involved in the accuracy of electromagnetic field analysis. Previously, relative permeability is applied for magnetic properties in many cases, but relative permeability does not represent the feature of the electromagnetic material such as nonlinearity or saturation of the magnetic flux density. For that reason, BH curve is often applied instead of relative permeability. BH curve accurately represents the magnetic properties of the electromagnetic materials, and improvement of the analysis accuracy can be expected.

So, we carried out two different analyses, the one applying relative permeability for magnetic properties and the other doing B-H curve, and compared the results with the experiment result to evaluate the analysis accuracy.

1. BH curve measuring

We measured the magnetic properties of JIS SUJ2 with a DC magnetic flux meter and a Vibrating Sample Magnetometer. Combining these measurement results allowed us obtain a BH curve from room temperature to the Curie point within the magnetic field range of approx. ±300 kA/m. Fig. 1 shows the BH curve that is obtained with this measurement at room temperature, 500 degrees C, and 750 degrees C.

2. Measuring temperature and analysis conditions

We used a SUJ2 circular ring (dia. 56 x dia. 46 x t16) and a deep groove ball bearing inner ring (6206: dia. 40 x dia. 30 x t16) made of SUJ2 as specimens. We heated both materials from the outside by using a turning coil. We measured temperature with a thermocouple that was welded on the material surface. The measurement positions are the outside surface and end plane of the circular ring, as well as the groove bottom and outside surface of the deep groove bearing's inner ring. We carried out electromagnetic and thermal conduction with 2D axisymmetric models.

3. Results

Figures 2 and 3 show the experiment and analysis results of the circular ring and the deep groove ball bearing inner ring. With both specimens, the analysis results where we used the BH curve as the magnetic property highly agreed with the experiment results. In the case of applying permeability, the analysis results considerably differed from the experimental results at a temperature range of around 700 to 900 degrees C.

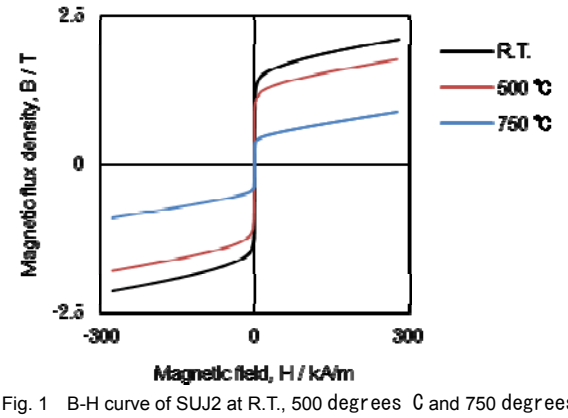

Fig. 1 B-H curve of SUJ2 at R.T., 500 degrees C and 750 degrees C

4. Conclusion

These results revealed that an analysis using the BH curve reflects the surface temperature around the Curie point (770 degrees C) more accurately. For heat treatment of machine parts, thermal management around 800 degrees C is very significant, so BH curves should be used instead of permeability.

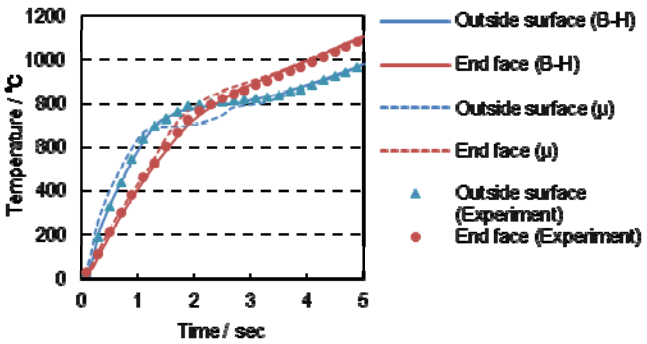

Fig. 2 Experiment and analysis results of circular ring

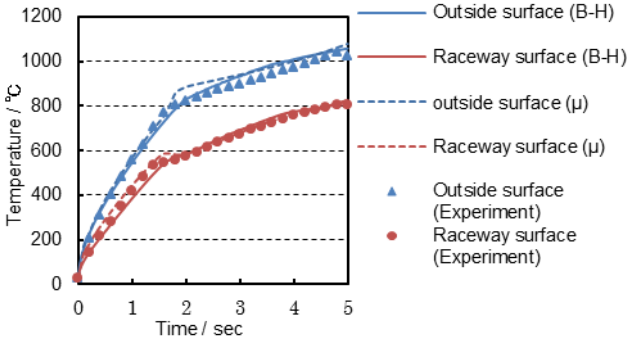

Fig. 3 Experiment and analysis results of ball bearing inner ring