Non-destructive Evaluation of Yield Strength on Low Carbon Steels by Using FSES Method

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Abstract

This paper presents our proposed frequency sweeping excitation and spectrogram method (FSES method) by magnetic sensor for non-destructive evaluation of yield strength on low carbon steels. This method can evaluate the magnetic properties of low carbon steels whose yield strength were changed by induction heating. It was examined by our proposed method that the degrees of yield strength on low carbon steels were varied depending on conditions of induction heating.

1 Introduction

We have developed a non-destructive material evaluation system for steels using magnetic methods and investigated its practical application [1]. Our previous studies have shown that the magnetic properties of carbon steel change in the hardened area and that these changes depend on the depth and degree of hardening. We have also shown that in the measurement of magnetic properties using alternating current, the magnetic signals depend on the used frequency component [2]. The Frequency Sweeping Excitation and Spectrogram method (FSES method) was developed to externally and non-destructively measure the changes in magnetic properties inside the samples, and the FSES method was used to qualitatively evaluate the differences in the hardened area and hardening temperature. The FSES method has been reported to be capable of qualitatively evaluating differences in hardened regions and temperatures [3]. In this paper, we focus on the evaluation of yield strength on low carbon steels, which is an important mechanical property of steels. Finally, in order to quantitatively evaluate the yield stress of a real product, a car seat frame component, we first used a sample with a known yield strength to verify whether a correlation could be obtained between the measured magnetic properties and the yield strength, which is reported in this paper.

2 Frequency Sweeping Excitation and Spectrogram method (FSES method)

Fig. 1 shows the principle of the FSES method, which is a method to sweep-excite several frequency components and finally evaluate mechanical properties from the magnetic properties measured by magnetic sensors using the spectrogram method [2, 3]. Fig. 2 shows the structure of the magnetic sensor. A B-coil for magnetic flux density and a Rogowsky-Chattock coil for magnetic field strength are installed, enabling both waveforms to be measured externally and non-destructively. Feedback waveform control by a PC was performed to ensure that the maximum value of the magnetic flux density obtained from the B-coil remained constant even when the excitation frequency and the magnetic properties of the sample were different. Therefore, magnetic properties can be compared under the same magnetic flux conditions even when the mechanical properties of the samples are different. It has also been reported [2, 3] that, when the magnetic flux density is under the same conditions, the coercive force and magnetic losses can be used to evaluate mechanical properties with nearly no influence from lift-off.

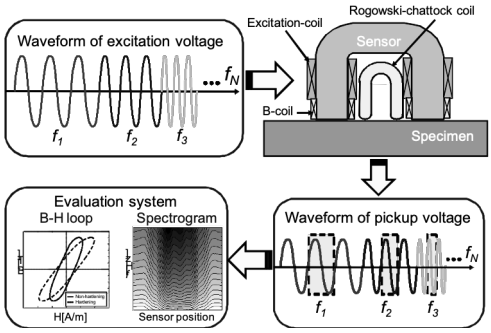


Figure 1: Principle of FSES method.

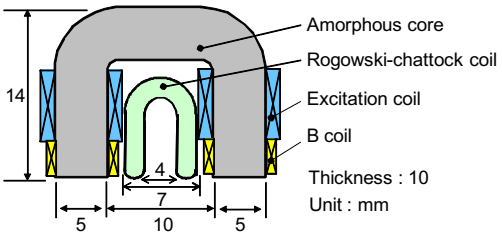
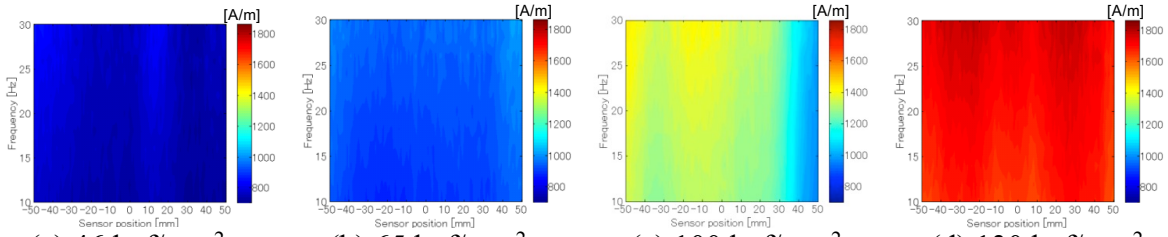


Figure 2: Structure of magnetic sensor.



(a) 46 kgf/mm^2 (b) 65 kgf/mm^2 (c) 100 kgf/mm^2 (d) 130 kgf/mm^2

Figure 3: Spectrogram of coercive force, H_c depending on yield strength.

3 Non-destructive evaluation of yield strength

The FSES method was used to evaluate the yield strength of the samples. Measurements were carried out by scanning the sensor in a straight line on an automotive low carbon rolled steel plates, SPC, at 100 mm and 1 mm intervals. The sample size was 200 mm x 130 mm and the plate thickness 0.6 mm. After longitudinal pressing, the plates were heat-treated to control the yield stress. The maximum flux density was set to be 0.1 T and the excitation frequency was selected from 10 Hz to 30 Hz, using 11 frequency components at every 2 Hz. Fig. 3 shows the spectrograms of the coercive force measured with different yield strength samples. It can be seen that as the yield strength increases, the spectrogram value of coercive force also increases. In addition, the coercive force shows almost no change in value depending on frequency, and the spectrograms are almost monochromatic. This method enables the yield strength to be evaluated qualitatively.

4 Conclusion

In this paper, a quantitative evaluation method for the yield strength on automotive low carbon rolled steels is investigated and the applicability of the method to actual products is examined, in order to make practical use of the non-destructive mechanical evaluation by the frequency swept excitation spectrogram method (FSES mehod), which is a magnetic method. Details of the results and discussions are given in the full paper.

References

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[3] Yuji Tsuchida, Taisuke Matsuda, and Masato Enokizono, Non-destructive Evaluation of Hardened Low Carbon Steels by Using Frequency Sweeping Excitation and Spectrogram Method, *Journal of The Japan Society of Applied Electromagnetics and Mechanics*, **20, 4**, (2012), pp. 665-670.