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Improvement of measuring accuracy of magnetic field strength in single sheet testers by using two H coils

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IMPROVEMENT OF MEASURING ACCURACY OF MAGNETIC FIELD STRENGTH IN SINGLE SHEET TESTERS BY USING TWO H COILS

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ABSTRACT

The accuracy of the measured magnetic field strength of single sheet testers using an H coil[1-4] is examined by finite element analysis. An improved measuring method which uses two H coils is proposed from this investigation. It is clarified that the best measuring method of magnetic field strength is the improved two H coil method. The validity of the new method is confirmed by experiments.

1. INTRODUCTION

When the permeability of a specimen becomes high, the error in the measured magnetic field strength of single sheet testers using an H coil[1-4] is increased due to the leakage flux from the specimen and the air gaps between yoke and specimen[6,7].

In this paper, the magnetic field in a single sheet tester with a high permeability specimen is numerically analyzed by using the finite element method taking into account magnetic saturation, and the effects of the H coil position for various constructions and H coil length on the accuracy of the magnetic field strength measured by H coil are investigated quantitatively. An improved measurement which uses two H coils is proposed as an outcome of this investigation.

2. NUMERICAL ANALYSIS

Figure 1 shows the double-yoke type single sheet tester being analyzed. The construction of the single-yoke type tester is the same as the double-yoke type with the omission of the upper yoke, and the H coil is set on the upper side or the lower side of the specimen. The thicknesses of the specimen and the gap between the specimen and the yoke are 0.3 and 0.075(mm) respectively. The yoke is a wound core design using conventional grain oriented steel sheet type M-4. The thickness of the sheet is 0.35(mm) and the space factor is 96%.

The magnetic field in the single sheet tester was analyzed by using the two-dimensional finite element method. In the numerical calculation, the total linkage flux of the B coil is specified, and the current in the exciting winding is treated as the unknown variable [5,8]. In order to investigate the effect of quality of the specimen on the accuracy, two kinds of magnetization characteristics of highly-oriented silicon steel M-OH and amorphous metal are used in the analysis.

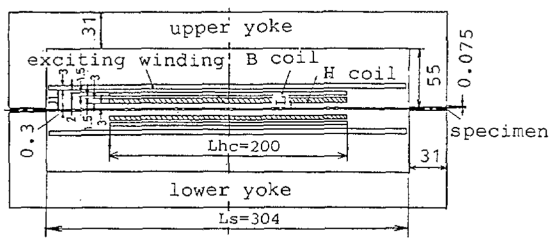

Fig.1. Double-yoke type single sheet tester.

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3. EFFECTS OF POSITION AND LENGTH OF H COIL

3.1 Position of H coil

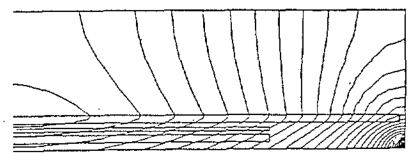
Figure 2-5 show the flux distributions in the double and single-yoke type testers. The fluxes in the yoke are not shown for easy understanding. B means the flux density measured by the B coil. One flux line represents WP(Wb/m). When the flux density is low (B=1.0(T)), the field distribution between the specimen and the H coil is not uniform because of the high permeability of the specimen. The field distribution in the single-yoke type tester is more uniform than that in the double-yoke type one, because the magnetic field near the H coil set on the upper side of the specimen is not so much affected by the yoke under the specimen.

Figure 6 shows the effects of the distance L between the H coil and the specimen on the calculated error εc in the magnetic field strength for various constructions. The error εc is defined by

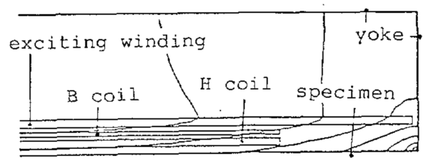
$$\varepsilon c=(Hm-Ho)\times 100/Ho(\%) \quad (1)$$

where Hm and Ho are the magnetic field strength to be measured by the H coil and the average magnetic field strength calculated along the surface of the specimen respectively.

The error εc in the amorphous metal is especially large because of the high permeability. If the H coil in the single-yoke type tester is set on the lower side

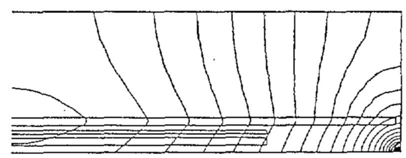


(a) B=1.0(T) (WP=5E-8(Wb/m))

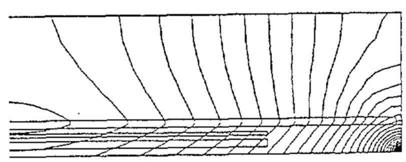


(b) B=1.7(T) (WP=5E-7(Wb/m))

Fig.2. Flux distributions for highly oriented specimen in the double-yoke type tester.



(a) B=1.0(T) (WP=5E-8(Wb/m))



(b) B=1.4(T) (WP=5E-8(Wb/m))

Fig.3. Flux distributions for amorphous specimen in the double-yoke type tester.

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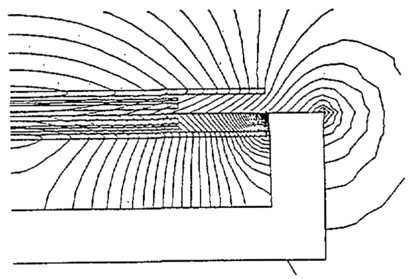
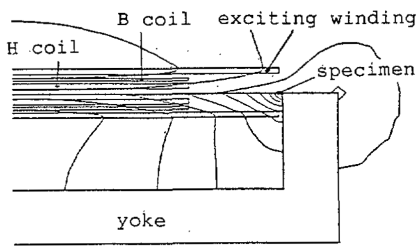
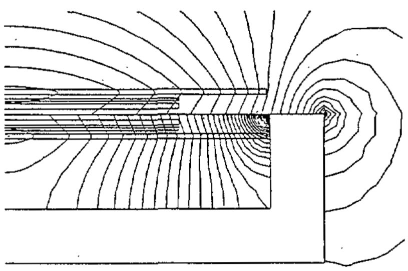

(a) B=1.0(T) (WP=5E-8(Wb/m))



(b) B=1.7(T) (WP=5E-7(Wb/m))

Fig.4. Flux distributions for highly oriented specimen in the single-yoke type tester.


(a) B=1.0(T) (WP=5E-8(Wb/m))

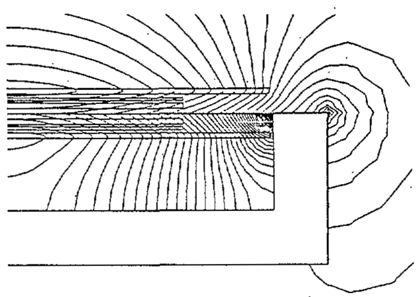
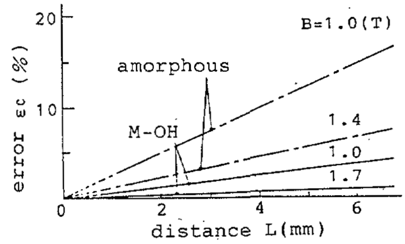

(b) B=1.4(T) (WP=5E-8(Wb/m))

Fig.5. Flux distributions for amorphous specimen in the single-yoke type tester.

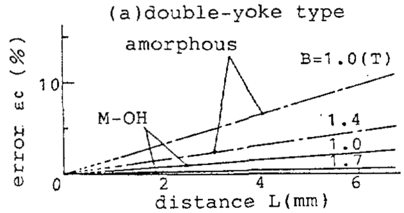
of the specimen, the magnetic field in this side is influenced by the yoke. Therefore, εc in Fig.(c) is larger than that in Fig.(b). Figure 6 shows that the most accurate tester is the single-yoke type in which the H coil is set on the upper side of the specimen. In any case, the accuracy of the magnetic field strength is linearly improved by decreasing the distance L. Therefore, the H coil should be placed as near as possible to the specimen.

3.2 Length of H coil

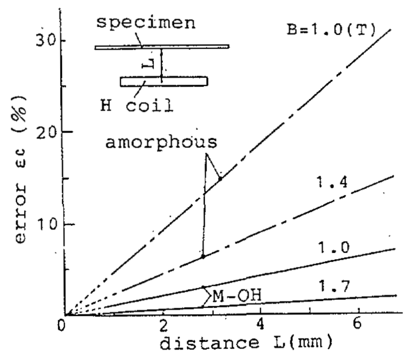
Figure 7 shows the effects of the length Lhc of the H coil on the calculated error εc. The yoke is a double-yoke type. When Lhc is large and the flux density is low, the influence of Lhc is remarkable. But, the accuracy εc is considerably improved and becomes constant when the length Lhc becomes shorter.



(a)double-yoke type



(b)single-yoke type(H coil is set on the upper side)



(c)single-yoke type(H coil is set on the lower side)

Fig.6. Effects of H coil position for various constructions.

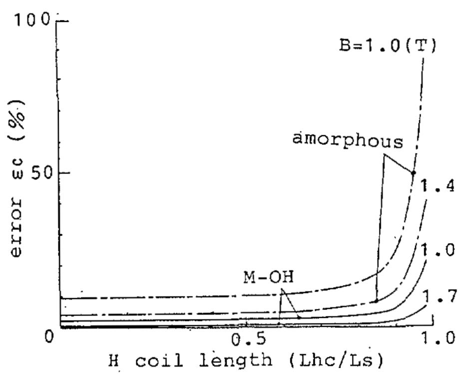


Fig.7. Effects of H coil length (double-yoke type).

4. IMPROVED MEASUREMENT OF THE MAGNETIC FIELD STRENGTH

4.1 Two H coil method

In order to improve the measuring accuracy of the magnetic field strength, we propose the "two H coil method" which uses two H coils as shown in Fig.8.

As the magnetic field strength Hm changes linearly near the surface of the specimen as shown in Fig.6, the

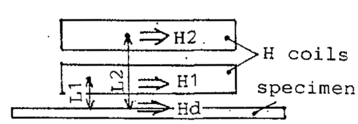


Fig.8. Arrangement of H coils in two H coil method.

true magnetic field strength Hd on the surface of the specimen can be extrapolated by the following equation from the two measured values H1 and H2 at positions L1 and L2 which are the distances between each H coil and the specimen respectively as shown in Fig.8.

$$Hd=H1-L1(H1-H2)/(L1-L2) \quad (2)$$

Figure 9 shows the errors εc of the two H coil method in which the magnetic field strength Hm is deduced by Eq.(2). Figure 9 shows that the magnetic field can be measured precisely. There is no practical difficulty in inserting the additional H coil.

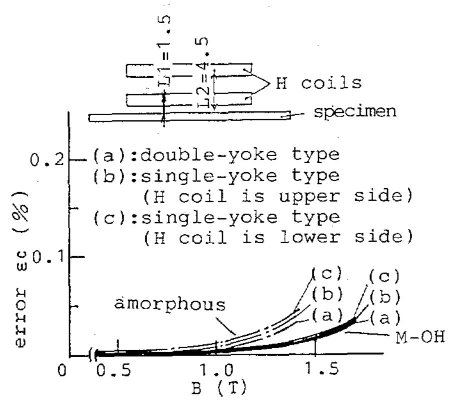


Fig.9. Errors of two H coil method.

4.2 Experimental examination of linearity of magnetic field distribution

The two H coil method is based on the principle that the magnetic field is distributed linearly between the specimen and the H coils. Then the distribution of the magnetic field in this part is examined experimentally.

The single sheet tester used in experiment is the same as shown in Fig.1 except for the position of the exciting winding. The exciting winding is set apart from the specimen so that the H coil can be moved. Figure 10 shows the effects of the distance L between the H coil and the specimen on the errors εc and εm in magnetic field strength. The error εm is defined by the same equation as Eq.(1) except that Hd in Eq.(2) is used instead of Ho, and Hm is measured experimentally. Figure 10(b) is obtained experimentally by moving the H coil from 1.5 to 12(mm). The trend of the calculated errors agrees fairly well with that of the experimental errors.

5. CONCLUSIONS

The magnetic field in a single sheet tester is analyzed by using the finite element method, and the effects of position and length of the H coil on the accuracy of the measured magnetic field strength using an H coil have been investigated quantitatively. An improved measurement which uses two H coils is proposed.

The obtained results are summarized as follows.

(1) The accuracy of the magnetic field strength is linearly improved by decreasing the distance between the H coil and the specimen.

(2) The H coil should be set nearer to the specimen.

(3) When the H coil length becomes shorter, the measuring accuracy of the magnetic field intensity is considerably improved.

(4) The accuracy of the improved two H coil method is best.

(5) The validity of the new method is confirmed by experiments.

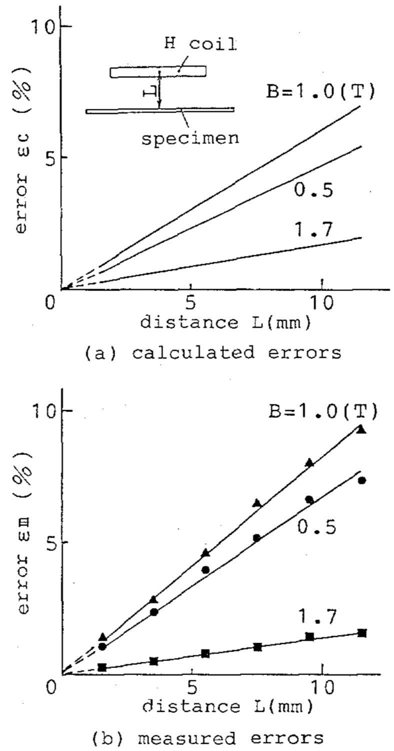


Fig.10. Effects of H coil position for highly oriented specimen.

Our two H coil method will be included in the next versions of the IEC standard[9] and JEM standard[4].

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