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EFFECTS OF EDDY CURRENTS IN THE SPECIMEN IN A SINGLE SHEET TESTER ON MEASUREMENT ERRORS

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ABSTRACT

The most favorable construction of the yoke of a single sheet tester has been studied by measurements and numerical analysis. It is shown that the eddy currents in a specimen affect the measurement error of the single sheet tester, and the error is increased with increase in the overhang length and with decrease in the distance between yokes. It is concluded that the single yoke type tester has a large error due to eddy currents, and the double yoke type tester is more favorable.

1. INTRODUCTION

It has been pointed out that the power loss of silicon steel measured by a single sheet tester(SST) is influenced by the eddy currents in the specimen[1]. The eddy current distribution is affected by the construction of the yokes, the overhang of the specimen[2-4], the distance between yokes, etc. We have already reported on the effect of the construction of the yokes[1].

In this paper, the effects of the overhang length of the specimen and the distance between yokes on the measurement error are examined experimentally and numerically using the 3-D finite element method[5]. Furthermore, the vertical yoke type SST recommended by the IEC standard[6] is also examined numerically.

2. MODEL

Figure 1 shows the vertical single yoke type SST called the "S-type" which was examined. The H coil and B coil are put inside the magnetizing winding[7]. The construction of the double yoke type tester which is called the "D-type" is the same as that of the S-type except for the addition of the upper yoke. The H coil is set on the same side of the yoke(Ss-type) or on the opposite side(So-type)[1]. L is the distance between yokes and Lo is the overhang length of the specimen. The yoke(wound core) is made of grain oriented silicon steel of M-4 grade. A highly oriented silicon steel sheet of M-OH grade (0.3x100x330mm) is used as the specimen. The excitation frequency is 50Hz and the maximum flux density measured by the B coil is 1.0T.

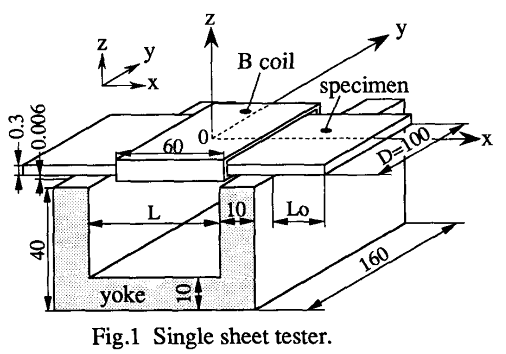


Fig.1 Single sheet tester.

3. EFFECTS OF OVERHANG

3.1 Experimental study

Figure 2 shows the effects of the overhang length Lo on the power loss W. The power loss is measured by the two H coil method[8]. The distance L between yokes is 75mm. The overhang length Lo is altered by cutting the specimen.

The power loss W measured by the D-type SST is almost constant. The power loss W measured by the Ss- or So-type SST, however, is affected by Lo, and is almost constant when Lo is over 60mm. The loss measured by the D-type is larger than that measured by the So-type and it is lower than that measured by the Ss-type. The difference of the power losses measured by these SSTs is about 30% when Lo>60mm. The difference is, however, decreased when the distance L between yokes is long enough[1].

Figure 3 shows the effects of the overhang length on the y-component Jey of the eddy current density near the edge of the B coil(x=20mm). The modified probe method[1] is used for measuring the eddy current density.

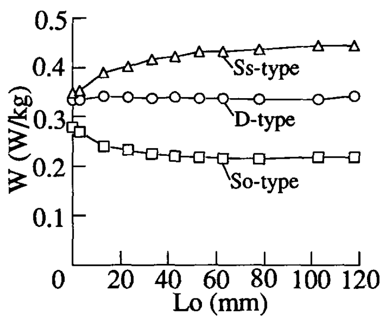
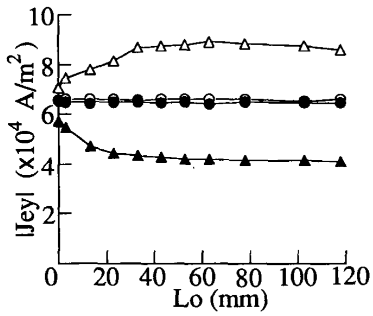


Fig.2 Effect of overhang on power loss (L=75mm).



△ : S-type (yoke side)
○ : D-type (lower side)
▲ : S-type (opposite to yoke side)
● : D-type (upper side)

Fig.3 Effect of overhang on eddy current density (measured at x=20mm, L=75mm).

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Figure 4 shows schematic diagrams of eddy current distributions on the yoke side of the specimen[3]. The eddy current in this figure is induced by the flux ϕ which passes from the specimen to the yoke. As the eddy current in the specimen of Lo=0mm concentrates at the edge of the specimen as shown in Fig.4(b), the voltage drop at the edge due to the eddy current is increased. Then, the voltage drop due to the eddy current which flows near the centre (x=0mm) is decreased, because the induced voltage around the flux ϕ is constant. Therefore, the eddy current density Jey decrease in Lo as shown in Fig.3. As Jey on the yoke side is decreased, Jey on the opposite to yoke side is increased, because the total voltage drop around the specimen should be the same. As a result, the power loss measured by the Ss-type SST is decreased with decrease in Lo as shown in Fig.2. On the contrary, the power loss is not affected by the overhang in the case of the D-type, because the eddy current distribution is not changed by Lo as shown in Fig.5(a) which will be mentioned later.

3.2 Numerical study

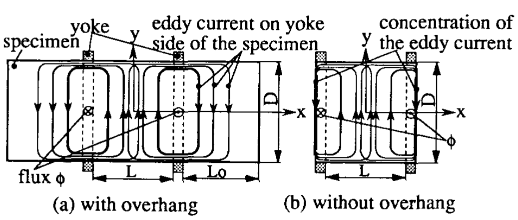
The 3-D eddy current distributions are analyzed using the $\mathbb{T}$-Ω method[5]. The conductivity of the specimen is 2.22×10^6S/m and that of the yoke is assumed to be zero, because it is laminated. The relative permeabilities of specimen are assumed to be $\mu x=6\times10^4$, $\mu y=\mu z=10^3$. The gap between the specimen and the yoke is assumed to be 0.006mm which is deduced from the space factor(0.96) of a core. The analyzed region is 1/4 in the S-type and is 1/8 in the D-type because of the symmetry of the model.

Figure 5 shows the distributions of the eddy current density vectors on the surfaces of the specimen. The eddy current flows from one surface to the opposite surface. In the case of the D-type, the x-component Jex of eddy current density in the specimen is negligibly small, and there is little eddy current in the overhang area as shown in Fig.5(a). On the contrary, in the case of the S-type, the x-component Jex appears, and there is some eddy current in the overhang area.

Figure 6 shows the y-component Jey of eddy current density along the x-axis. Jey of the S-type means the eddy current density on the yoke side of the specimen. The eddy current is normalized by Jeyo which is the eddy current density at x=0mm of the double yoke type SST(Lo=0mm, L=75mm), because the eddy current density of the double yoke type is little affected by Lo as shown in Fig.5(a). The Figure shows that the eddy current density of the S-type is increased with increase in Lo, because the eddy current path is affected by the overhang as shown in Fig.5(b). However, as the eddy current path of the D-type is not affected by Lo, Jeyo of the D-type is not affected by the overhang length Lo.

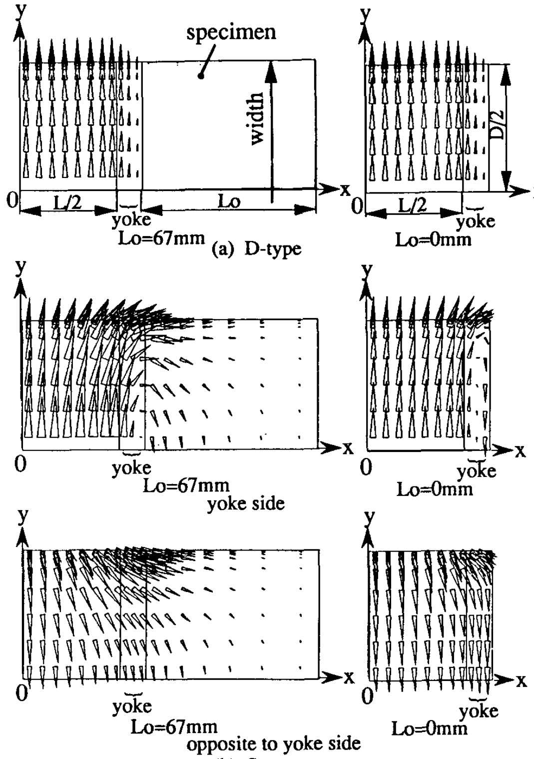
4. EFFECTS OF DISTANCE BETWEEN YOKES

Figure 7 shows the effects of the distance L between yokes on the distribution of eddy current



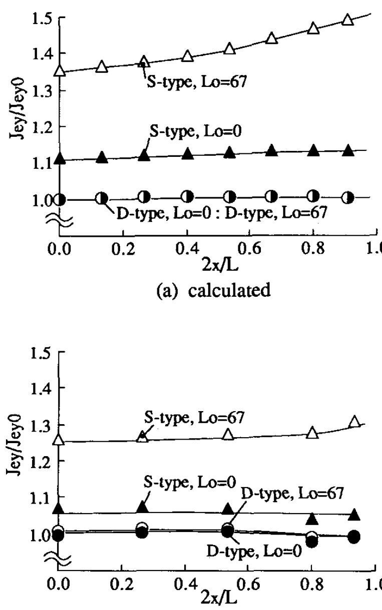
(a) with overhang (b) without overhang

Fig.4 Eddy current distributions of S-type SST (yoke side).



(b) S-type

Fig.5 Distributions of eddy current density vectors on the surfaces of the specimen.



(b) measured

Fig.6 Effects of overhang length Lo (L=75mm).

density Jey(calculated). Almost the same results are obtained by experiment. Jey of the D-type is little affected by the distance L, and Jey is almost constant along the x-axis(0<2x/L<1). Jey of the S-type is affected very much by the distance L, and it is larger than that of the D-type. Jey of the S-type approaches that of the D-type when the distance L is increased, because the eddy current near the centre(x=0mm) of the specimen is decreased when the distance L is increased as shown in Fig.8.

Figure 7 suggests that the measurement error of the S-type can be reduced, if shorter B and H coils (within 2x/L=0.4) are used. This is because Jey of the S-type is nearly the same as that of the D-type, if L is large enough and 2x/L is small.

5. STUDY OF THE IEC MODEL

A single sheet tester which can measure a wide specimen(500x500mm) is recommended by the IEC[6]. The effects of the overhang length Lo on the eddy current density Jey of the IEC model(L=450mm, D=500mm) are shown in Fig.9. The distribution of Jey is almost the same as that in Fig.6(a). This is because the distance L is nearly equal to the width D of the specimen in both cases, and the distributions of the eddy currents are almost the same. Therefore, large measurement errors occur, if the S-type SST of the IEC standard is used.

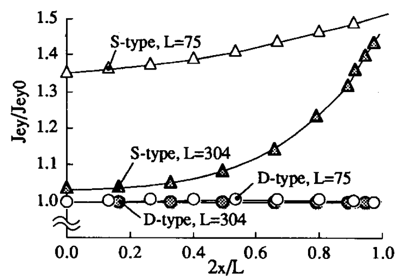


Fig.7 Effects of yoke length L (calculated, Lo=67mm).

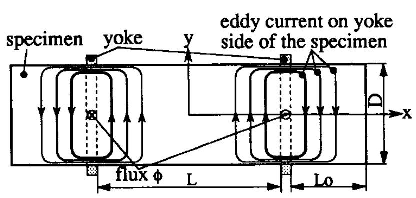


Fig.8 Eddy current distribution of S-type SST with long distance L between yokes (yoke side).

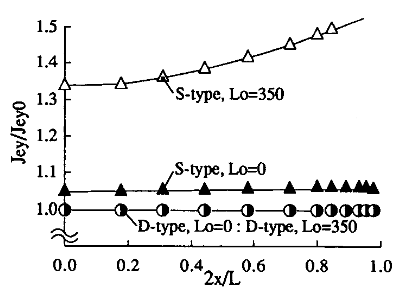


Fig.9 Effects of overhang length Lo (calculated, IEC model (L=450mm, D=500mm)).

6. CONCLUSIONS

The effects of the overhang of the specimen and the distance between yokes on the measurement error have been investigated quantitatively by experiment and by numerical analysis. It is shown that the error for the single yoke type SST is increased with increase in the overhang length and with decrease in the distance between yokes.

When the power loss is measured by the single yoke type SST of the IEC standard, large measurement errors occur. Therefore, the double yoke type tester is preferable for the IEC standard. If a single yoke type SST is used, the lengths of B and H coils should be decided so that the power loss measured is not affected by the eddy currents in the specimen.

This paper gives valuable guidance for revision of the IEC standard.

ACKNOWLEDGMENT

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