§24. A Problem on Current Imbalance in Insulated Multi-Stranded Superconducting Conductor

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We have been investigating a current imbalance phenomenon in an insulated multi-strand superconducting cable conductor using several types of solenoid coils wound by insulated multi-strand copper cable. As a result, we found that the current distribution in a multi-stranded conductor is strongly dependent on a magnetic coupling coefficient between strands when the resistance of each strand can be assumed to be zero. Especially, for the case of the coupling factor larger than 0.99, the current imbalance becomes conspicuous although the dispersion of inductance is smaller than 0.5%[1].

This time, we have carried out several experiments to investigate the current imbalance phenomenon using multi-stranded conductor with 9 insulated NbTi superconducting strands [2]. Its cabling formation is double twisted (3×3). The main purpose of this investigation is to make clear the relation between the current imbalance and the impedance distributions among the strands taking into consideration the contact resistances at terminals. So, the current and the inductance of each strand were measured by shunt resistor (60-80 μ Ω) and by a high- accuracy LCR meter, respectively. The experiment was carried out both in DC and AC conditions at 4.2K.

Fig.1 shows the some samples of DC current test results. As shown in the figure, the measured current in each conductor agrees well with the calculated result obtained by the calculation of the inverse of the impedance matrix placing the frequency zero. From this result, it is confirmed that the current distribution in strands depends purely on the shunt resistance distribution. So, by adjusting the every shunt resistance to the same value, the current in each strand can be made uniform for the DC excitation.

From the impedance characteristics of each strand, the current distribution characteristics in the conductor can be calculated. So, we carried out the calculation of current distribution using the inverse matrix of the impedance matrix. Fig.2 shows the calculated frequency characteristics of current distribution in the conductor. Calculated results indicate that the amplitudes are almost constant for the frequency ranges smaller than 0.1Hz and larger than 1Hz. The calculated results show that the effect of the resistance component on current distribution becomes dominant in low frequency region lower than 0.1 Hz. On the other hand, the inductance component becomes dominant in the frequency region higher than 1Hz. The current distribution in the frequency region from 0.1Hz to 1Hz shows an intermediate state between the resistance dominant state and the inductance dominant state.

Next, we carried out AC experiment in the frequency range from 0.1Hz to 1Hz. In this Fig.2, some marks such as ○,□,△, are the experimental value. From the experimental results, it is recognized that the characteristics for 0.1Hz agree well with the calculated results. On the other hand, the characteristics for 1Hz have some differences from calculated results. According to the experimental results in low frequency range, the values of resistance in the strand can be regarded exact enough. Therefore, it seems that the difference between the calculated and the experimental current distribution results at 1Hz would be due to the error of the inductance measurement.

From these experimental and theoretical results, it is estimated that the difference between the experimental and the calculated result would be due to the errors in the inductance measurement. Therefore, it would be necessary to measure the inductance distribution more precisely. If this measurement was done precisely enough, the current distribution in an insulated multi-strand superconducting conductor can be estimated exactly before an actual operation.

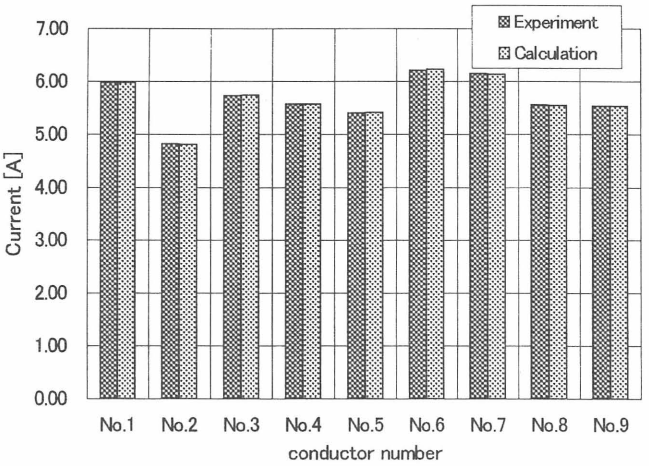

Fig.1 DC test result

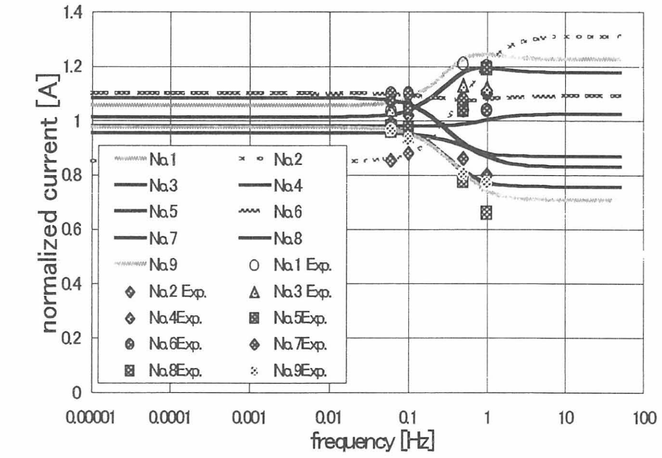

Fig.2 AC test result

Reference

1) A.Ninomiya, S.Yamaguchi, et al, IEEE Trans. On Applied Superconductivity, Vol.19, No.2, June 1999,pp583-586.
2) T.Ishigohka, A.Ninomiya, S.Yamaguchi, et al, MT-16, September 26-30, 1999.