§28. Experimental Study on Stress Change of Wires in A CIC Conductor by Being Twisted

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Cable-in-conduit (CIC) conductors with Nb_3Sn wires have been developed for large high-field magnets. The major disadvantage is the reduction of critical currents (I_c) by large thermal strain due to heat treatment up to 650°C for production of the A15 phase. In order to prevent the further increase of the strain, the heat treatment is usually carried out after winding. Nevertheless, a "react and wind" method is preferred for a helical coil to avoid a huge oven for the heat treatment. In this concept, the heat treatment of CIC conductors are carried out on a bobbin, the circumference of which is same as the length of one pitch of the helical coil. After that, the conductor are wound into the helical shape with being pulled aside, that is, being twisted. Since the superconducting wires in the conduit are multi-stage twisted, their strain should be changed by twisting the conductor. If the thermal strain of the wires is reduced by twisting, the react and wind method can increase I_c of CIC conductors for a helical coil.

In order to investigate the strain change of the twisted wires in CIC conductors by twisting the conduit, a sub-size sample of CIC conductor is prepared. As shown in Fig. 1, six sub-cables made of 3x4 copper wires are twisted around a SUS304 pipe of the diameter of 6 mm, and they are inserted into a SUS304 pipe of the diameter of 17.3 mm. The cable is fixed to the conduit with epoxy resin at both sides. Two copper wires are replaced to manganin wires to measure the strain. Two 1-axis strain gages are attached on a copper wire around the center in length. The conductor sample is twisted or pulled and pushed with a special tool as shown in Fig. 2. The upper end of the sample is fixed, and the lower end is rotated with a set of worm gear and wheel. The longitudinal strain is varied with the stud bolts at the upper position.

Almost pure shear stress is induced in the conduit (SUS304 pipe), as the lower end is rotated with the upper end being fixed to the outer cylinder. The strain change of the conduit is proportional to the rotation angle of the flange, as shown in Fig. 3. The tensile or compressive strain is induced in the wire by twisting the conduit in the same or counter direction to the wire twisting direction, respectively, as shown in Fig. 4. A hysteresis loop is observed in the strain change. It should be caused by friction between wires. The strain change of wires is in the order of 1/10 of the conduit. The wires should move to reduce the strain. The larger void fraction is considered to allow larger movement.

In order confirm the reduction of thermal strain by twisitng, I_c measurement of real CIC conductors with several different torsional deformations is planned. React and wind method is expected to be applicable to a helical coil by setting the twisting direction of the Nb_3Sn wires same as the twisting direction of the CIC conductors in winding.

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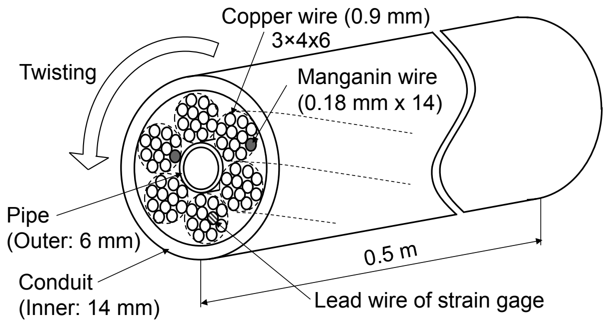

Fig. 1. Concept of CIC conductor sample.

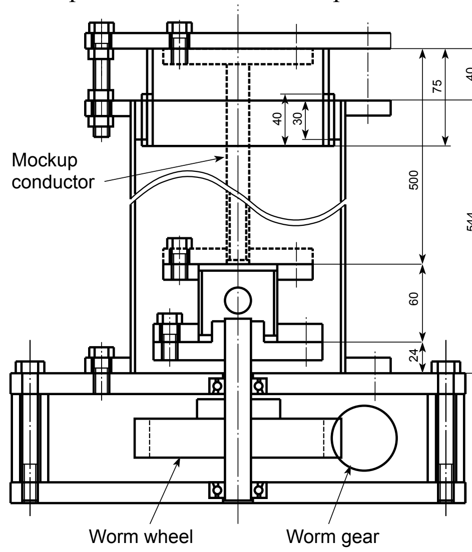

Fig. 2. A twisting jig for CIC conductor samples.

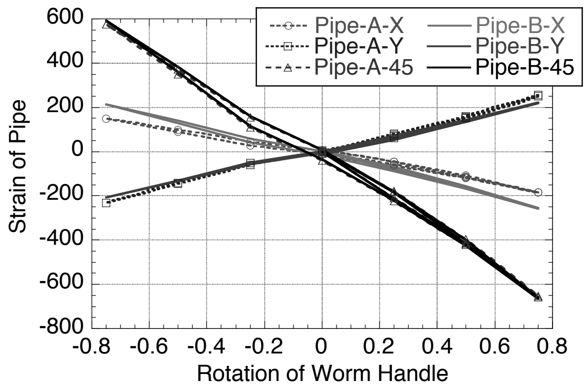

Fig. 3. Strain on the outer surface of the pipe in rotating.

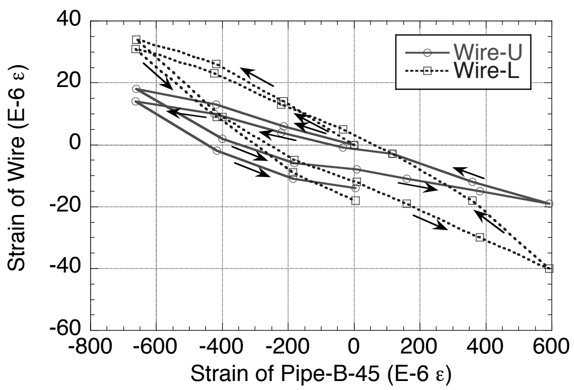

Fig. 4. Strain of wire versus the strain on pipe.