ANALYTICAL INVESTIGATION IN BENDING CHARACTERISTIC OF TWISTED STACKED-TAPE CABLE CONDUCTOR

Makoto Takayasu\textsuperscript{1} and Luisa Chiesa\textsuperscript{2}

\textsuperscript{1}Massachusetts Institute of Technology, Plasma Science and Fusion Center, Cambridge MA 02139, USA.
\textsuperscript{2}Tufts University, Mechanical Engineering Department, Medford MA 02155, USA.

SUMMARY

An analytical model to evaluate bending strains of a Twisted Stack-Tape Cable (TSTC) conductor has been developed.

Two models, No-Slip Model (NSM) and Perfect-Slip Model (PSM), are presented, and critical current degradation due to bending is discussed.

Through a comparison with experimental results obtained for a soldered 32-tape YBCO TSTC conductor, it was found that a Perfect-Slip Model (PSM) taking into account the slipping between tapes in a stacked-tape cable during bending gives much better estimation of the bending performance compared to a No-Slip Model (NSM).

In the PSM case the tapes can slip so that the internal longitudinal axial strain can be released. The longitudinal strains of compression and tension regions along the tape are balanced in one twist-pitch and cancel out evenly in a long cable.

Therefore, in a cable the strains due to bending can be minimized. This is an important advantage of a TSTC conductor.

The effect of the cable diameter size on the bending strain is expected to be minor, and all tapes composing a TSTC conductor have the same strain response under bending, therefore the cable critical current can be characterized from a single tape behaviour.

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Analysis Modeling

Illustration of a 40 tape Twisted Stacked-Tape Cable (TSTC) conductor bent with the bending radius $r_{\circ}=500$ mm.

Schematic illustrations showing a bending model of a TSTC conductor: (a) a cross-section of a tape in a TSTC conductor bent with the radius $r_{\circ}$ (b) an enlarged view of a part of a twisted tape.

Bending Strain

(a) No-Slip Model (NSM): 2G tapes in a TSTC conductor are rigidly stacked and they do not slide between tapes.

$$\sigma_{x} = \frac{x \sin \theta + \alpha \cos \theta \cos \alpha}{r_{\circ}}$$

(b) Perfect-Slip Model (PSM): Tapes can slip so that the internal axial strain can be released.

$$\sigma_{x} = \frac{x}{r_{\circ}}$$

Critical Current

Electric-field distribution calculated from bending strain distribution along the tape of one twist pitch when the total voltage of one twist pitch reached the critical current criterion of $E_{c}$.

Bending Test Result

The critical current at 77 K of a soldered 32-tape YBCO TSTC conductor as a function of the bending strain. The arrow lines with numbers indicate the test order.

CONCLUSIONS

In the No-Slip Model (NSM) case, 2G tapes in a TSTC conductor are rigidly stacked and they do not slip between tapes. On the other hand in the Perfect-Slip Model (PSM) case, the tapes can slip so that the internal axial strain can be released.

The stacked tapes are twisted, therefore in each half cycle of the twisting the strains change from tension to compression. The internal longitudinal strains during bending can be released in a full twist-pitch even for a long cable. Therefore the strains due to a cable bending can be minimized. This is an important and beneficial consequence of the twisting of a TSTC conductor.

Strains over the width are induced during the bending of the cable. This strain causes the critical current degradation due to bending. The bending strain effect on the critical current of a TSTC conductor was evaluated for various bending diameters.

Based on the Perfect-Slip Model (PSM), the critical current of a twisted tape was calculated for one full twist-pitch length and compared with experimental results. The agreement was not great, however it was much better than what estimated with the No-Slip Model (NSM).

The calculated result for PSM showed more degradation than the experimental results. This could be due to the soft bending applied in the experiment to respect the natural irregularity during cable bending. Taking into account this observation the analytical results seem to show a fairly good agreement with the experimental results.

A narrower tape gives less degradation for bending. The twist-pitch effect on the bending strain is minor.

Further investigation to explain the discrepancy between experimental results and the model analysis will be necessary using both experiments of various TSTC conductors and Finite Element Analysis.