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Commercial Winding for Superconducting Cables and Magnets

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Abstract : Automated robotic winding of high-temperature superconductors (HTS) addresses precision, efficiency, and reliability critical to the commercialization of products. Today's HTS materials are mature and commercially promising but require manufacturing attention. In particular to the exaggerated rectangular cross-section (very thin by very wide), winding precision is critical to address the stress that can crack the fragile ceramic superconductor (SC) layer and destroy the SC properties. Damage potential is highest during peak operations, where winding stress magnifies operational stress. Another challenge is operational parameters such as magnetic field alignment affecting design performance. Winding process performance, including precision, capability for geometric complexity, and efficient repeatability, are required for commercial production of current HTS. Due to winding limitations, current HTS magnets focus on simple pancake configurations. HTS motors, generators, MRI/NMR, fusion, and other projects are awaiting robotic wound solenoid, planar, and spherical magnet configurations. As with conventional power cables, full transposition winding is required for long length alternating current (AC) and pulsed power cables. Robotic production is required for transposition, periodic swapping of cable conductors, and placing into precise positions, which allows power utility required minimized reactance. A full transposition SC cable, in theory, has no transmission length limits for AC and variable transient operation due to no resistance (a problem with conventional cables), negligible reactance (a problem for helical wound HTS cables), and no long length manufacturing issues (a problem with both stamped and twisted stacked HTS cables). The Infinity Physics team is solving manufacturing problems by developing automated manufacturing to produce the first-ever reliable and utility-grade commercial SC cables and magnets. Robotic winding machines combine mechanical and process design, specialized sense and observer, and state-of-the-art optimization and control sequencing to carefully manipulate individual fragile SCs, especially HTS, to shape previously unattainable, complex geometries with electrical geometry equivalent to commercially available conventional conductor devices.

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