Fatigue Properties of Cold-Rolled Cu-Zr Alloy Sheets

R. Niu[1], V. J. Toplosky[1], J. Toth[1], and K. Han[1],
1. National High Magnetic Field Laboratory, FSU;
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In our resistive magnets, Cu and Cu alloys are widely used as conductor sheets that require high mechanical strength. Under certain fabrication conditions, Cu may have identical mechanical strength to Cu alloys. In addition to high-tensile strength, however, fatigue is a critical issue for conductor sheets. The fatigue behavior of Cu alloy conductor sheets, such as cold-rolled Copper Zirconium (Cu-Zr)—key for resistive magnet applications—remains underexplored, especially under stress-controlled conditions mimicking operational hoop stresses. This study investigates the fatigue properties of cold-rolled Cu-Zr sheets with varying tensile strength and compares them to cold-rolled Cu, aiming to establish fatigue life relationships and cyclic deformation behavior under stress control.

Cold-rolled Copper Zirconium (Cu-Zr, or 15100) with different strength levels and Cu (10700) were used to compare the fatigue properties. Cu-Zr sheets were classified by tensile strength levels: "H" (~490 MPa), "M" (440–490 MPa), and "L" (<440 MPa). Because of lower strength in the longitudinal direction, fatigue tests (stress ratio R = 0.1) were performed along this direction at 1 Hz.

Both the Cu-Zr and the Cu showed cyclic hardening in the stress-controlled condition during tension-tension fatigue tests. The presence of Zirconium improved fatigue life by stabilizing microstructure and retarding the formation of cracks during fatigue cycling, thus positioned Cu-Zr alloys as much stronger candidates than Cu for resistive magnet conductors, such as the conductors for the D coil in the 45 T hybrid magnet. “H” Cu-Zr’s fatigue life, for example, was about three times that of Cu. For Cu-Zr sheet themselves, the higher the tensile strength, the longer the fatigue life and the lower plastic strain range **(Fig. 1).**

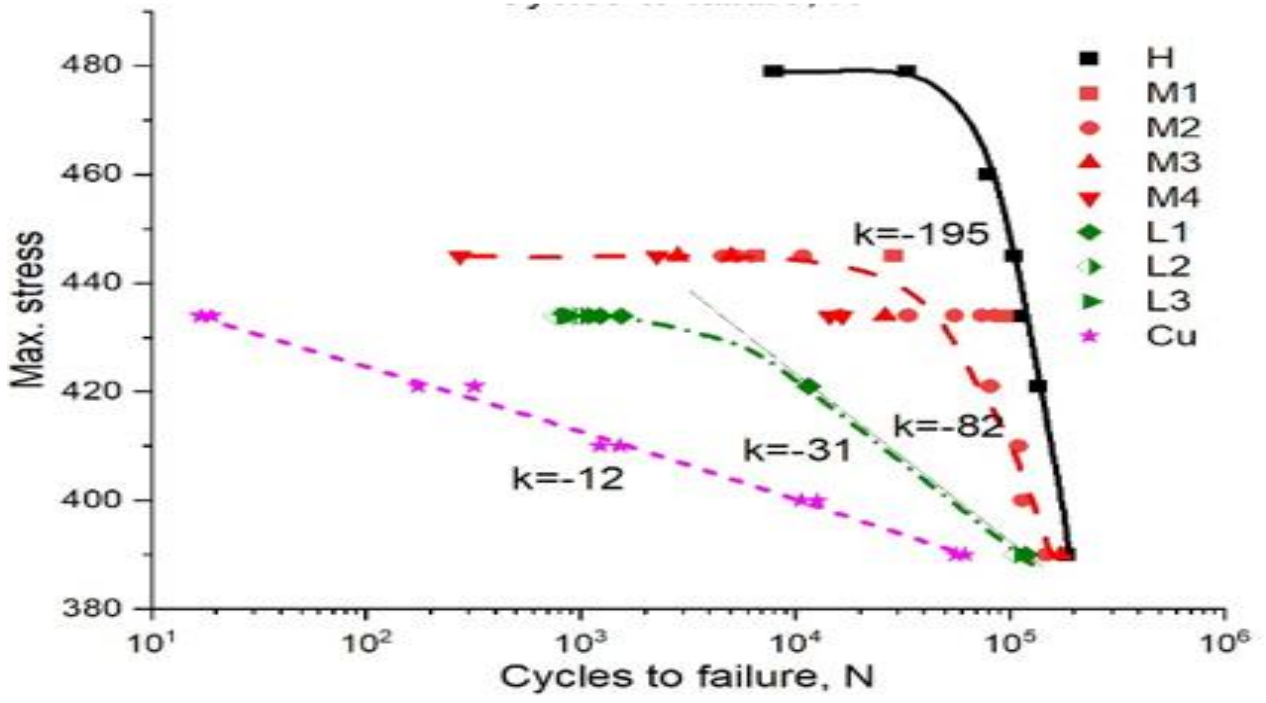


Fig. 1. The dependence of fatigue cycles, N, on the maximum stress at the stress ratio R = 0.1. Maximum stress levels in our tests are between 480 and 390 MPa. Our magnets are designed to operate at an average maximum strength level of 390 MPa for Cu-Zr sheets. Cu-Zr sheets are classified by tensile strength levels: “H”(~490 MPa), “M” (440–490 MPa), and “L” (<440 MPa). M1-M4 and L1-L3 identify magnet sheet in each category. The slope (k) of the declining part of maximum stress vs. log (N) depends on the strength of the materials involved.

Facilities and instrumentation used: Materials characterization facilities in Magnet Science and Technology. **Citation:** Niu, R.; Han, K.; Toplosky, V.J.; Toth, J., Fatigue Properties of Cold-Rolled Cu-Zr Alloy Sheets, IEEE Transactions on Applied Superconductivity, 36 (3), 115293 (2025) doi.org/10.1109/TASC.2025.3636496