THE FRAGMENTATION OF WIRES BY HIGH PULSED CURRENTS

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The phenomenon of the wire fragmentation by high, pulsed currents received considerable attention over the past 30 years. Experimental studies with aluminium and copper wires indicated that currents of relatively low magnitude, $I \sim$ 1–10 kA, may shatter metal wires in the solid state. The phenomenon occurs in slow explosions, on a μs- or a ms- time scale. The experimental evidence shows that (i) wires break due to tensile stress, (ii) no significant melting occurs at the fracture surfaces, (iii) the number of wire pieces produced during the explosions varies from 2 to 100, depending on the magnitude of the current, and (iv) after a fracture occurs, the air gap is immediately filled with an arc, so that there is no break in the total electric current during the explosion. Our aim is to review theoretical work on the wire fragmentation by high, pulsed currents.

When electric current passes through the wire, it induces stress waves owing to Joule heating and the Lorentz forces. Although thermal expansion is the predominant mechanism of the wire disintegration, there are many different scenarios leading to the fragmentation depending on the current risetime, its relation to the skintime, the geometry of the external circuit, and other factors. One of the most important factors, however, is whether the wire ends are clamped or free.

Wires with free ends break owing to standing thermo-elastic stress waves. The electromagnetic force creates stress waves of lower magnitude than the thermal expansion, and is unlikely to be a cause of wire fragmentation. However, it does create additional tensile stress, which may alter the exact position, where fracture fist occurs, and the timing of fracture. The skin effect is important as it leads to both qualitative and quantitative nature of the stresses.

Wires with clamped ends break due to thermal buckling instability. Initially, the wire goes into compression owing to thermal expansion, and then buckles when the accumulated compressive stress exceeds a critical value defined by the stability criterion. Once this happens, very strong tensile stresses appear, which may lead to fracture. In addition, magnetic fields induced in the external electric circuit may increase the values of tensile stress.

When the fracture occurs, arcs strike between the wire ends at the break. Stress waves resulting from the combination of unloading, and heating of the ends by arcs may lead to a cascade of further fractures.