Time-of-Flight & Material Properties

Current trends in ultrasonic instrumentation and signal processing make it practical to measure ultrasonic time-of-flight (TOF) variations with precision in the picosecond range. This capability opens up new possibilities for both material characterization and non-intrusive temperature measurement. The TOF variations are related to a material's thermal expansion coefficient, α, and its elastic modulus temperature coefficient, γ. Thus, by making precise TOF measurements one can estimate the variation temperature. Conversely if the temperature change is measured independently and is uniform across the propagation path, the fractional change in TOF can be used to measure the modulus temperature coefficient, γ.

The Figure shows ultrasonic data obtained on alumina over the temperature from 1000°C to 2100°C (blue). For a comparison the red curve shows the calculated fractional TOF variation using literature data for the thermal expansion coefficient, α, and the modulus temperature coefficient, γ. Literature data was only available up to a temperature of 1500°C. For the measured data, a thermocouple was used to measure the temperature up to 1000°C and an optical pyrometer used in the range from 1000°C to 2100°C. Overall, the literature derived results agree well with the measured data.

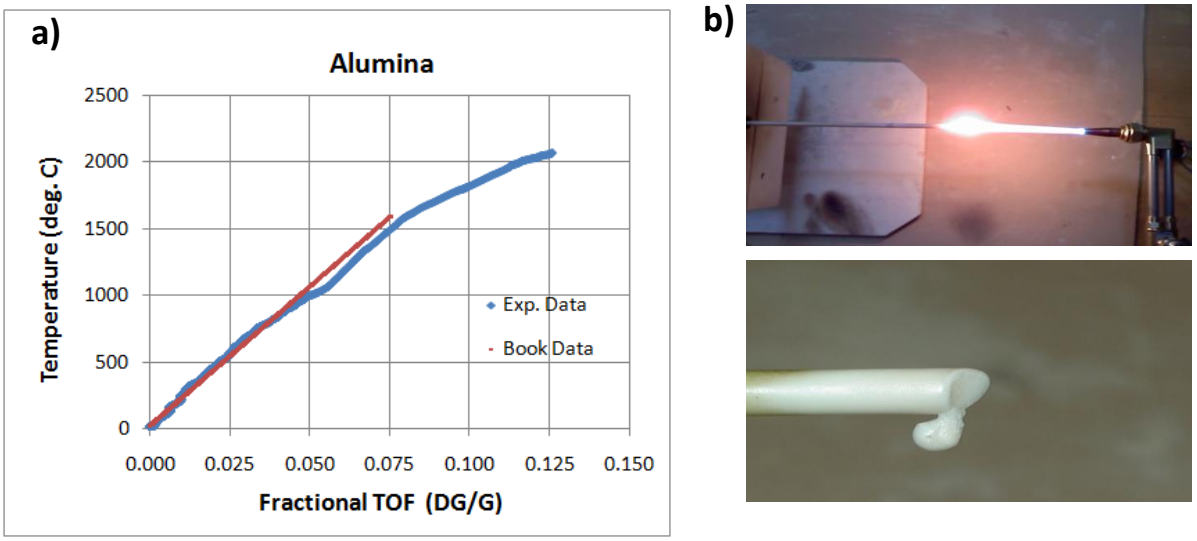

Figure a) Comparison of the measured and calculated TOF for alumina from ambient to 2100°C; b) torch-heated 250 mm long alumina rod with annular step at heated end and ultrasonic sensor attached at the opposite end. Lower micrograph shows melted tip as experiment exceeded 2100°C.