Marian Apostol

Strain rate and temperature dependence of the compression behavior of fcc and bcc metals. Development of experimental techniques and their application to materials modeling

Tampere University of Technology (Finland)

Contact: marian.apostol@tut.fi; veli-tapani.kuokkala@tut.fi

Within the past decades, immense progress has been made in the field of materials science and engineering, but there still remain scientific and technical challenges to develop even more sophisticated and specialized materials to meet new and ever increasing requirements for higher strength, better formability, lighter weight, better impact resistance, and enhanced environmental friendliness. One particular field of research is studying the effects of dynamic (high strain rate) loading and temperature on the mechanical behavior of materials. High strain rate loading has a great effect on the mechanical response of materials. For most materials, the energy absorption capacity depends on the speed of the impact, i.e., the faster the deformation, the more the material strengthens. Temperature has also a major effect on the strength of most materials, which decreases when the temperature increases. For scientific aims, studying the mechanical behavior of materials at high strain rates and at low or high temperatures provides a deeper understanding of the laws and mechanisms governing the deformation processes in such conditions.

In this thesis, a compressive Split Hopkinson Pressure Bar apparatus with recovery and low/high temperature capabilities has been developed and is described in details. A large number of test results for several metallic materials (pure aluminum, aluminum alloy, structural steel and pure copper) obtained with the above mentioned equipment are presented in order to demonstrate the accuracy, operation, and repeatability of this testing system. However, to cover a wider range of the behavior of the studied materials, several tests were made also at quasi-static strain rates using a commercial servohydraulic materials testing machine. Finally, two commonly used constitutive materials models were used to describe the behavior of two different types of materials (a structural steel and pure copper) deformed in a wide range of strain rates and temperatures. For the structural steel, the Johnson-Cook model was applied. For pure copper, the mechanical threshold stress (MTS) was determined to demonstrate that also the structure of the material (storage of dislocations) is affected by the strain rate, and thus the steep increase seen in the plot of flow stress at constant plastic strain versus logarithmic strain rate partly arises from the microstructural evolution of the material as a function of strain rate.