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DYNAMIC HIGH TEMPERATURE BEHAVIOUR OF HEAVY SINTERED MATERIALS

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1. Introduction

The introduction in recent years of new, extremely energetic particle accelerators such as the Large Hadron Collider (LHC) required the development of advanced methods to predict the behavior of Beam Intercepting Devices (BID) in case of direct beam impact. BID are designed to operate in harsh radioactive environment highly solicited from thermo-structural point of view. This context gives impulse to the development and testing of refractory metals and alloys based on molybdenum, tungsten and copper. In this perspective, in this work the experimental results of a tests campaign on Inermet® are presented: since the extreme loading conditions in which the material could operate (e.g. thermo-mechanical shocks in accident situations [1]), the investigation of the mechanical behavior was performed in a wide range of strain-rates and temperatures. Inermet® 180 is a commercial tungsten heavy alloy, which combines excellent thermal and mechanical properties with high density. The material is obtained by liquid-phase sintering of a powder mixture composed of tungsten (95%), nickel (3.5%) and copper (1.5%); 70-100μm-large tungsten grains are immersed in the low-melting W-Ni-Cu binder phase (Figure 1), which provides thermal and electrical continuity and represents the ductile connection between the brittle W grains [2].

Figure 1: SEM observations of Inermet® 180 microstructure; experimental setup for dynamic tests at high temperature.

2. Experimental tests

The experimental test campaign was performed on dog-bone specimens with a gage diameter of 3 mm and a gage length of 5 mm [3]. A unique specimen geometry was used for all the performed tests, in order to avoid the influence of geometry and dimensions and to have the possibility to directly compare the results coming from different loading conditions. The tensile tests varying the strain-rate were performed using different testing machines, in function of the strain-rate range. All the tests were performed in the DYNLab Laboratory of the Politecnico di

Torino. Overall six orders of magnitude in strain-rate (between 10^{-3} and 10^{3} s^{-1}) were covered, starting from quasi-static up to high dynamic loading conditions. The low strain-rate tests were performed using a standard electro-mechanical testing machine, the tests at medium speed with a standard servo-hydraulic machine and finally, high strain-rate tests with a standard Hopkinson Bar setup in the configuration for direct tensile tests.

The heating of the specimens in quasi-static condition was obtained with an induction coil system, designed to concentrate the heat flux in the gage length of the specimen. A feedback loop, based on measurements from thermocouples directly welded on the specimen, was used to control the temperature. The temperature range varied between 20 and 800 °C. In the perspective to perform also tests in mixed loading conditions, in this work, a methodology for testing materials at high temperature (between 20 and 600 °C) and high strain-rate was adopted [3] (Figure 1).

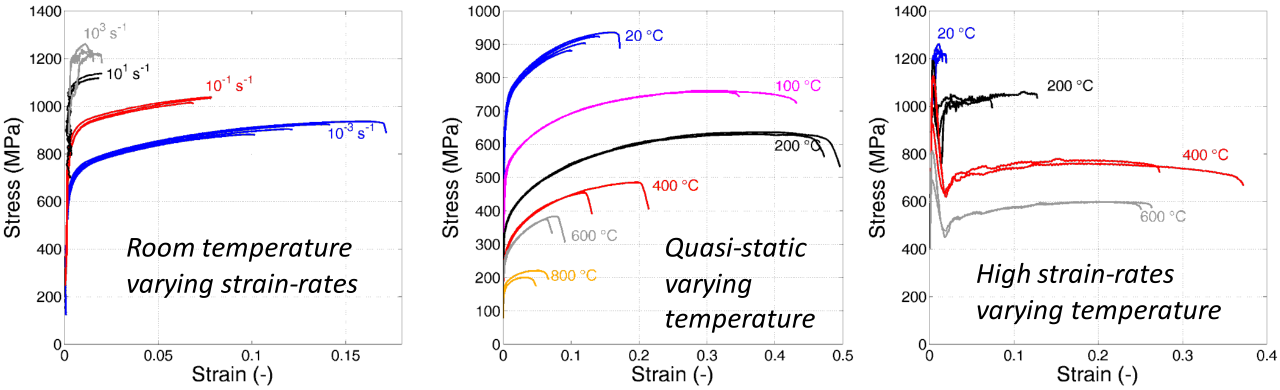

Figure 2: Experimental results in terms of engineering stress-strain curves.

3. Results and discussion

The results in terms of engineering stress-strain curves of the material are reported in Figure 2, from which it is possible to notice that, the material behavior is repeatable with a low level of scattering in terms of stress vs. strain curve, except for dynamic tests at room temperature. On the contrary, a significant scattering in the strain at failure is found for all the testing conditions. As expected, the yield strength of the material is both temperature and strain-rate sensitive. The material behavior at room temperature shows a level of failure strain between 10 and 15%, which is considerably reduced increasing the strain-rate. The failure strain, both in quasi-static and dynamic loading conditions, grows increasing the test temperature until reaching a maximum, and then it decreases with a further increase the temperature. The behavior of the material in terms of flow stress and damage is a consequence of the complex interaction between the behavior of the two phases, depending on the values of strain-rate and temperature. These type of materials could show different types of failure modes [4]: tungsten-tungsten grain boundary separation, tungsten grain cleavage, tungsten-binder interfacial separation and matrix fracture. Depending on which of these failure modes becomes predominant, the ductility of the material is more or less pronounced.

4. References

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