ABSTRACT

Hot Workability of Tool Steels

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Four worked tool steels (A2, D2, M2 and W1) were deformed on a closed-loop computer-controlled servo-hydraulic torsion testing machine. The temperature range of the tests was 900 - 1200°C at strain rates in the range 0.1 to 4 s^{-1} for the most part with a few tests performed at a higher strain rate of 40 s^{-1}.

The specimens were heated in an argon atmosphere in five minutes to 1200°C by a dual elliptical radiant furnace, held for five minutes, brought to test temperature in one minute and held for five minutes before deforming.

Isothermal continuous tests were performed to characterise the materials in terms of strength, ductility, workhardening and dynamic restoration. Isothermal interrupted tests were performed to determine the static restoration kinetics. Multistage tests were performed with declining temperature to simulate industrial conditions. Optical and electron microscopy were done to determine the microstructure.

The flow curves exhibited workhardening, a peak, worksoftening and steady state, characteristic of dynamic recrystallization where grain size is a function of the steady state stress. The flow stresses and activation energies of the

alloy tool steels, because of the presence of carbides, were considerably higher than the carbon tool steel which exhibited low strength and high ductility due to high diffusivity of carbon. The alloy steels experienced low ductility, which peaked between 1000°C and 1050°C decreasing gradually with decrease in temperature before the peak ductility (due mainly to voids associated with the carbides) but decreasing more sharply with increase in temperature after the peak due to incipient melting. Dynamic recrystallization occurs relatively quickly due to nucleation around the carbides but static restoration is sluggish. Peak strength is related to deformation parameters by the classical hot working hyperbolic sine function and related to peak strain by a linear function.

Each of the alloy tool steels contains different amounts of $M_{23}C_6$, M_6C and MC carbides at different temperatures. The dependence of strength, ductility and restoration on temperature, strain and strain rate can be related to the carbides.