Deformation behaviour of α - β brass at high temperature and at different strain rates

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ABSTRACT

Deformation behavior of α - β brass containing 37.995 wt. % zinc was investigated over strain rate of 1×10^{-1} to 1×10^{-3} s^{-1} and at constant temperature of 500˚C. Ultimate tensile strength was observed to vary from 82.1 to 16.9 MPa and ductility was found to decrease from 0.060 to 0.045 %. It is also found that yield strength was highest for sample tested at 1×10^{-1} s^{-1} strain rate due to dimple formation but at strain rate 1×10^{-3} s^{-1} lower yield strength was observed due to cleavage formation. Optical image was taken for gauge and shoulder section of the test samples and found that as strain rate increases the nature of grains changes form fine at strain rate at 1×10^{-1} s^{-1} to coarser grains at strain rate1×10^{-3} s^{-1}. Thus, a decrease in strength values can be attributed to an increase in grain size of the specimen with an increase in strain rate.

KEY WORDS: Deformation behavior, strain rate, ultimate tensile strength, yield strength, optical image, dimple formation, cleavage formation.

1. INTRODUCTION

The properties like high plasticity, strength, hardness, corrosion resistance, of brass compared to pure copper made it a popular engineering material used in applications varying from machine building to decoration to architecture to electrical and electronic components. Depending on zinc content, brasses are classified into three types. These are α - brass, α - β brass, β - brass. Of the three, the most abundant and widely used brass is α - β brass with 60 % Copper and 40 % Zinc. The α - β brass mainly consists of an FCC α - solid solution of alloying elements in copper and β - phase based on electronic compound CuZn. α - β brass exhibits properties like good deformability, good machinability, relatively high strength and moderate ductility, which makes this alloy of a very special interest in research. The room temperature deformation of α - β brass is difficult due to the presence of brittle β - phase. It is also observed that, at ambient temperature, α - phase is softer than β - phase, on the contrary at high temperatures α - phase becomes soft and flow like fluid. But this alloy produces good hot workability above 450˚C, when β' transforms to β. Deformation at elevated temperatures is always accompanied with dynamic recovery and recrystallization. The α - brass exhibits dynamic recrystallization domain in the temperature range of 750˚C - 850˚C and the strain rates of 0.001 to 1 s^{-1}, on the contrary under similar conditions β - brass undergo superplastic deformation which is controlled by diffusion of zinc in β - brass. At high strain rates, it is observed that this material undergoes microstructural changes manifested as rotations at low temperature and localized shear bands at high temperature. This alloy also exhibits good machinability, if certain amount of lead is added resulting in leaded brass. The present work aim is to investigate tensile test properties of α - β brass at constant temperature and varying strain rate.

2. EXPERIMENTAL

Commercial grade α - β brass containing 37.995 Zn (w %) was procured in the form of rod of 11 mm diameter. Tensile test specimens were machined to the gauge length of 9 mm and gauge diameter of 5 mm. Tensile test were conducted with an universal testing machine. The data were obtained in the form of load elongation curve at different strain rate, which were used for getting true stress - true strain curve. Tensile test were conducted at constant temperature of 500 ˚C, which were controlled to an accuracy of ± 3 K. Metallographic sample were prepared by mechanical polishing. Etching was performed by using 3% $FeCl_3$ and 10% hydrochloric acid solution, which shows α phase to be bright and the β phase to be dark. The fracture surfaces of the specimens deformed to failure were examined for evaluating the fracture behaviour in scanning electron microscope SEM.

3. RESULTS

Nature of true stress - true strain curve: Tensile specimens were deformed to failure at different strain rates of 1×10^{-1} to 1×10^{-3} s^{-1}. At each strain rate and at 500 ˚C temperature, the tensile tests were conducted. Fig. 1 represent engineering stress - engineering strain curve obtained under these test conditions. It is observed that the ultimate tensile strength and yield strength were highest for the sample tested at 1×10^{-1} s^{-1} strain rate, due to dimple formation as shown in Fig. 2 (a) but at strain rate 1×10^{-2} s^{-1} and 1×10^{-3} s^{-1}, lower ultimate tensile strength and yield strength were observed brittle fracture due to cleavage formation as shown in Fig. 2 (b) and (c) respectively.

Fractograph of α - β brass: Fig. 2 (a), (b) and (c) represents the fractographs of samples test performed at strain rate 1×10^{-1} s^{-1}, 1×10^{-2} s^{-1} and 1×10^{-3} s^{-1} and at 500˚C temperature. Fig.2 (a) shows ductile fracture due to dimple formation, but Fig.2 (b) and (c) shows brittle fracture due to cleavage formation.

Metallographic study: Optical image for the gauge section of sample test performed at strain rate 1×10^{-1} s^{-1}, 1×10^{-2} s^{-1} and 1×10^{-3} s^{-1}. Fig. 3 (b), (d) and (f) represents optical image for shoulder section of sample test performed at strain rate 1×10^{-1} s^{-1}, 1×10^{-2} s^{-1} and 1×10^{-3} s^{-1}. It can be observed from the optical image that the grain size vary from strain rate 1×10^{-1} s^{-1} to 1×10^{-3} s^{-1}. As the strain rate increases, the nature of grains changes from fine at strain rate 1×10^{-1} s^{-1} to coarser grains at strain rate 1×10^{-3} s^{-1}. Thus, a decrease in strength values can be attributed to an increase in grain size of the specimen with an increase in strain rate.

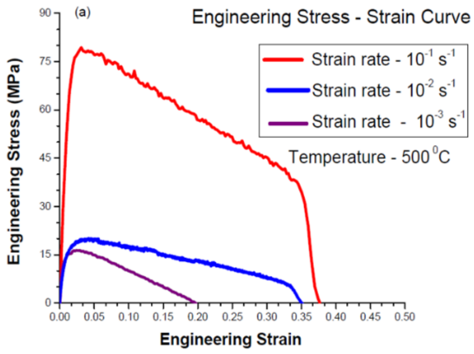

Fig.1. Engineering stress - engineering strain curve of α - β brass at 500˚C temperature and at strain rate 1×10^{-1} s^{-1}, 1×10^{-2} s^{-1} and 1×10^{-3} s^{-1}

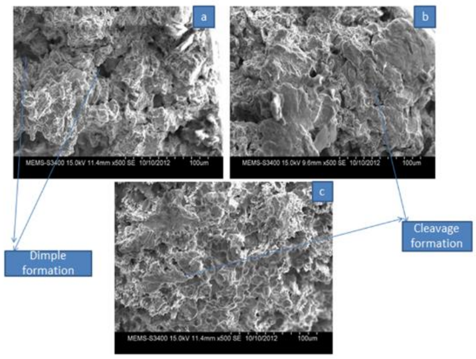

Fig. 2 (a), (b) and (c). Fractograph of α - β brass at 500 ˚C temperature and at strain rate 1×10^{-1} s^{-1}, 1×10^{-2} s^{-1} and 1×10^{-3} s^{-1}

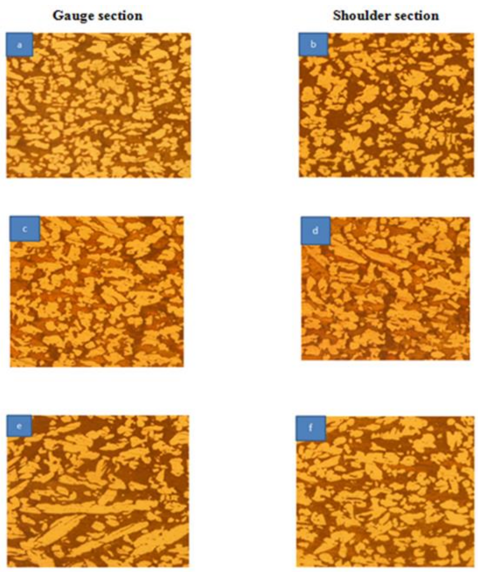

Fig.3 (a), (c) and (e) Optical micrograph of α - β brass for gauge section and (b), (d) and (f) for shoulder section at 500 ˚C and at strain rate 1×10^{-1} s^{-1}, 1×10^{-2} s^{-1} and 1×10^{-3} s^{-1}

4. CONCLUSIONS

a) Ultimate tensile strength, yield strength and ductility values were found to decrease with increase in strain rate.
b) It is found that ductile fracture due to dimple formation and brittle fracture due cleavage formation.
c) The nature of grains changes form fine at strain rate at 1×10^{-1} s^{-1} to coarser grains at strain rate1×10^{-3} s^{-1}.
d) Decrease in strength values can be attributed to an increase in grain size.

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