ELEVATED TEMPERATURE DYNAMIC DEFORMATION OF AISI 321 AUSTENITIC STAINLESS STEEL

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Abstract

In the present work, the dynamic compression behaviour of austenitic steel AISI 321 is obtained at elevated temperatures up to 750 oC using the Split Hopkinson Pressure Bar. The material showed strain rates sensitivity in the range from quasi-static up 6200 s-1. The role of strain-induced martensite transformation on strain-hardening was studied. The % of the strain-induced martensite was found to depend on the test temperature and amount of strain. In the dynamic regime,~ 2800-5000 s-1, the amount of %transformed strain-induced martensite depended only on the test temperature and not the strain rate. This indicated that the strain-induced martensite transformation did not contribute to the drop in the rate of strain hardening at intermediate strain rates of ~2800 s-1 at elevated temperatures and its increase at higher strain rates of 5000 s-1. The Johnson-Cook material model was fitted to the obtained results and model constants were obtained using two different fitting approaches.

1. Introduction

The present work aims at determining the high-temperature dynamic flow behaviour of austenitic stainless steel AISI 321 due to its economic importance. Austenitic stainless steels are known to have good toughness, plasticity and corrosion resistance. The objective of the present work is to study the uniaxial deformation behaviour of AISI 321 at high strain rates and elevated temperatures that resemble those observed during dynamic forming processes such as hot rolling and friction stir welding processes. Uniaxial compression and tensile tests are conducted at temperatures ranging from room temperature up to 750oC and at strain rates ranging from quasi-static up to 5000 s^{-1}. To conduct these experiments, a modified Split Hopkinson Pressure Bar (SHPB) and a direct Split Hopkinson Tension Bar (SHTB) are employed. The elevated temperature dynamic compression tests are conducted using an infrared spot heating source. In order to conduct the elevated temperature uniaxial tensile tests, an induction coil heating system is employed.

2. Results

Dynamic Compression Tests

Fig. 5 shows the room temperature experiments conducted on stainless AISI 321 at different strain rates. The material shows a strong strain rate dependency. The flow stress increased by almost 50% as the strain increased from quasi-static to the highest strain rate achieved of 6200 s^{-1}. This is clearly shown from the variation of the flow stress with strain rate at a constant plastic strain of 0.15 in Fig. 6. The material shows high stiffening at higher strain rates. This makes this grade of strain as a candidate for impact-resistance applications. In addition, the strain rate hardening for the quasi-static and high strain rates are the same. This rate of hardening decreases at true strains greater than 60%.

The materials dynamic compression behaviour was characterized at elevated temperatures up to 750^{o}C. Figs. 1 and 2 show the dynamic compression of the materials at an average strain rate of ~2000 s^{-1} and ~5000 s^{-1}, respectively. There is a significant drop in the flow stress with slight temperature increase (i.e. 200^{o}C). However, with the highest temperature and strain rate, the material's strength is still higher than those at room temperature. The material's hardening behaviour at intermediate and high strain are distinct. At intermediate strain rate, shown in Fig. 7, the material shows less strain rate hardening at elevated temperature as compared to room temperature. This behaviour changes at high strain rates shown in Fig. 8, where the material's strain rate hardening at elevated temperature is similar to room temperature. A comparison between the flow behaviour at intermediate and high strain rates and elevated temperatures is shown in Fig. 9. The drop in flow stress has a nonlinear relationship with the test temperature up to 750 ^{o}C, and extrapolated to intersect with the temperature axis at the melting point of AISI 321 at 1425 ^{o}C.

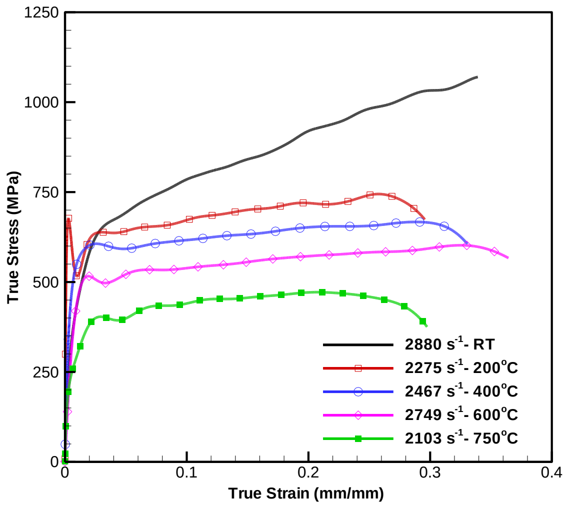

Fig. 1: Dynamic compressive response of 321 stainless steel at elevated temperature at relatively low strain rates

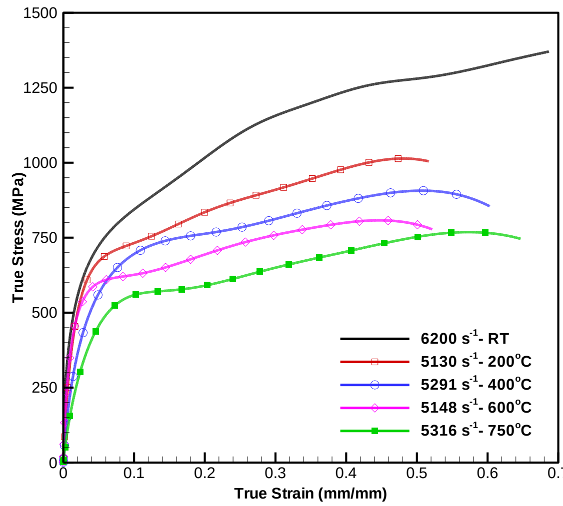

Fig. 2: Dynamic compressive response of 321 stainless steel at elevated temperature at relatively high strain rate

Role of deformation-induced martensite transformation

Austenitic stainless steels such as AISI 321 are known to suffer from deformation-induced martensite transformation during plastic deformation. The metastable austenite phase transforms to α`-martensite by plastic deformation. Fig. 3 shows the % of the strain-induced ά-martensite phase. The % of the strain-induced martensite depends both on the test temperature and amount of strain. In the dynamic regime, έ ~ 2800-5000 s^{-1}, the amount of %transformed strain-induced martensite depends only on the test temperature and not the strain rate. This contrary to the work by Chen et al. [18] on SUS304 stainless steel, where at high strain rates, the % of the strain-induced martensite transformed is independent of the test temperature and are higher than those at quasi-static strain rate for the same test temperature.

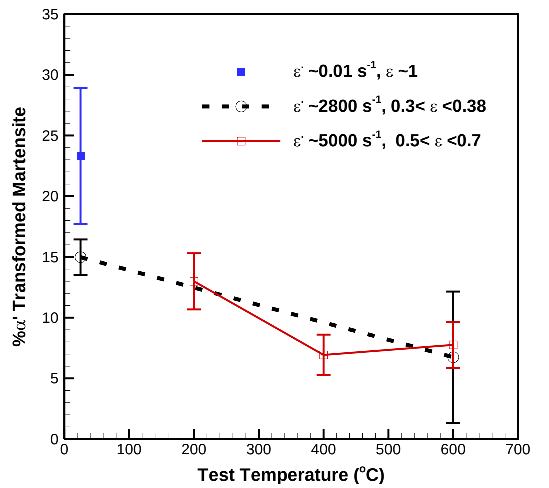

Fig. 3. Percent of strain-induced transformed

3. Conclusions

Elevated temperatures high strain rate compression tests were conducted on AISI 321 austenitic stainless steel to obtain its mechanical properties at conditions similar to those encountered in processing or working conditions. The SHPB was successfully used to obtain the stress-strain flow behaviour at test temperatures up to 750 oC and strain rates up to 6200 s-1. The materials showed strain-rate sensitivity and strain-hardening changes with strain-rate and test temperature. This behaviour was found not to be correlated to strain-induced martensite transformation in this stainless steel alloy. In the dynamic regime, the amount of %transformed strain-induced martensite depends only on the test temperature and not the strain rate.

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