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Mechanical Characteristics of Superaustenitic Stainless Steel Type 30Cr25Ni32Mo3 at Elevated Temperatures

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Abstract: In making tubes of corrosion resistant and hardly deformed steels and alloys, the pilger rolling method is used for hot rolling of final thick-walled tubes or mother tubes of large diameters (above 300 mm) and small quantities of other size tubes when no other, more efficient tube rolling or extrusion equipment is available. To clarify individual parameters of the production process and make choice of the deformation and temperature parameters, mechanical properties of the alloy type 30Cr25Ni32Mo3 superaustenitic stainless steel at various temperatures were studied. The tests have been performed using samples taken from the forged 400 mm diameter billet to determine strength and plastic properties of the billet metal at various temperatures and its macro and microstructure. The test results will be used in the choice of optimum conditions of preheating of the billets and hot rolling of tubes. On the whole, it should be stated that as forged alloy 30Cr25Ni32Mo3 features a favorable combination of strength and plastic properties in the hot working temperature range of 1075-1200°C.

Key words: Superaustenitic stainless steel, hot deformation, mechanical properties, microstructure evaluation, diameter, equipment

INTRODUCTION

The superaustenitic grades of stainless steels provide excellent corrosion resistance as well as high strength levels (Momeni *et al*., 2010). As the austenitic steels are characterized by their low Stacking Fault Energy (SFE) (Humphreys and Hatherly, 1995), the dominant restoration processes during and after hot deformation are therefore dynamic and metadynamic recrystallizations (DRX and MDRX), respectively (Kim and Yoo, 2001; Mataya *et al*., 2003; Cho and Yoo, 2001; Najafizadeh *et al*., 2006). For the last two decades, intensive studies have been down on the changes of austenitic microstructure and mechanical properties in steels with hot working conditions.

Several thermomechanical processing technologies such as controlled rolling controlled cooling and direct quenching were developed through these studies. Some research have been done to determine the best plasticity temperature range using the thermomechanical processing such as hot compression and hot torsion tests in steels (Bernstock-Kopaczynska *et al*., 2008; Rodriguez-Ibabe *et al*., 2005; Niewielski *et al*., 2007; Yada *et al*., 2000; Schmitz *et al*., 1998). However, metallurgical studies are scarcely performed to characterize hot working behavior of superaustenitic stainless steels. In this research, mechanical properties accompanying with microstructural evaluation of the alloy type 30Cr25Ni32Mo3 superaustenitic stainless steel at various temperatures were studied. For this purpose, tensile and torsion tests at various temperatures from 800°C up to 1180 and 1000°C up to 1200°C have been done, respectively.

MATERIALS AND METHODS

The material used for virtually all the experiments in this research was a 30Cr25Ni32Mo3 super austenitic stainless steel obtained from a cross-section of the forged 400 mm diameter billet produced by EICO, IRAN. The chemical composition and as received microstructure of this steel are shown in Table 1 and Fig. 1, respectively. Mechanical properties at room temperature in as received

Table 1: Chemical composition of the material used (wt %)

C	Cr	Ni	Mo	Mn	P	S
0.025	28.00	33.00	3.50	0.60	0.028	0.0015

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Table 2: Mechanical properties of the forged metal of 30Cr25Ni32Mo3 alloy billet at 20°C

Specimen type	R_m(MPa)	$R_{p0.2}$(MPa)	Elongation (A%)	Reduction of area (B%)
Type 3	583	292	45.5	63
Type 4	579	289	46.0	64

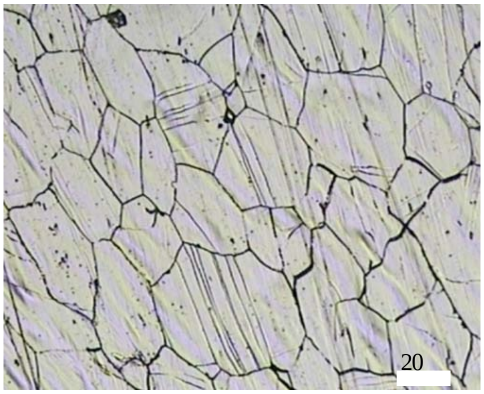

Fig. 1: Microstructure of 30Cr25Ni32Mo3 in the as received condition

condition are shown in Table 2. In tensile tests at room temperature, two types of specimens were used: conventional cylindrical specimens (type 3) and special fillet-neck specimens (type 4) designed for testing hardly deformed materials.

A minor scatter of property readings was observed: the fillet-neck specimens had strength (R_m; $Rp_{0.2}$) levels somewhat lower and plastic property (A; B) levels higher than conventional specimens but this difference was inessential.

The standard tensile test specimens according to ASTM A370 and special torsion samples (D = 8 mm) were prepared in longitudinal direction of forged billets. Before testing all the specimens subjected to solid solution heat treatment at 1250°C soaked for 15 min followed by cooling to the hot deformation temperature at a rate of 10°C sec^{-1}. Before deformation, the specimens were held for 3 min at the deformation temperature to eliminate the thermal gradients as well as to ensure the uniform temperature of specimens.

The tensile tests were then carried out at the temperatures between 800 and 1180°C and between 1000 and 1250°C at constant strain rate of 1 sec^{-1} for torsion test. To preserve the microstructure, the samples were immediately quenched after hot deformation. The process of hot deformation test is shown schematically in Fig. 2. After hot deformation testing, the torsion specimens were cut along the longitudinal axis for electrochemical polishing. Following this, the specimens were electrolitically etched in oxalic acid to reveal the microstructures. In order to follow the microstructural changes through hot deformation, the structure of samples were studied using both optical and scanning electron microscopy.

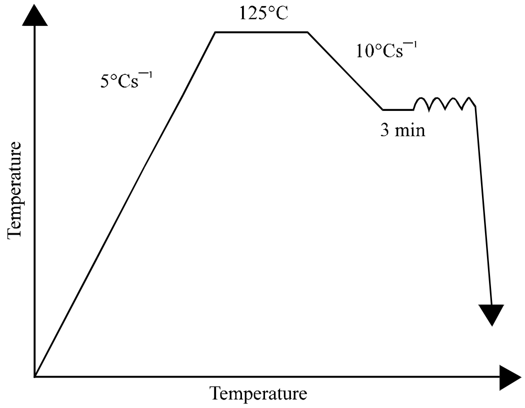

Fig. 2: Thermal and thermomechanical cycles imposed on samples in this research

RESULTS AND DISCUSSION

Hot tensile tests: Tensile test results for alloy 30Cr25Ni32Mo3 in the range of at 20-1180°C are shown graphically in Fig. 3.

Analysis of Fig. 3a shows that as the test temperature increases, tensile strength and yield strength of alloy 30Cr25Ni32Mo3 decrease gradually and plastic properties (percent elongation and reduction of area) increase as well.

Hot torsion tests: Because of a lower plasticity of corrosion-resistant austenitic steels and alloys, it is of high importance to know the temperature range of plasticity of the studied material during its hot working. In order to determine the temperature range of an optimum plasticity of alloy 30Cr25Ni32Mo3, the method of hot torsion of special specimens was used to determine the material plasticity at the hot working temperatures. The number of torsions (n) and the torsion Moment (M_{tor}) at which the specimen fracture occurs are important indices of the material plasticity. Such indices are usually determined for various metal preheat temperatures.

This test method has been developed at State Enterprise Ya.Ye. Osada Scientific Reseasrch Tube Institute (SE NITI), Dnipropetrovsk, Ukraine for mastering the technology of manufacture of tubes of hardly deformed steels and alloys and has been widely adopted in Ukrainian pipe and tube industry.

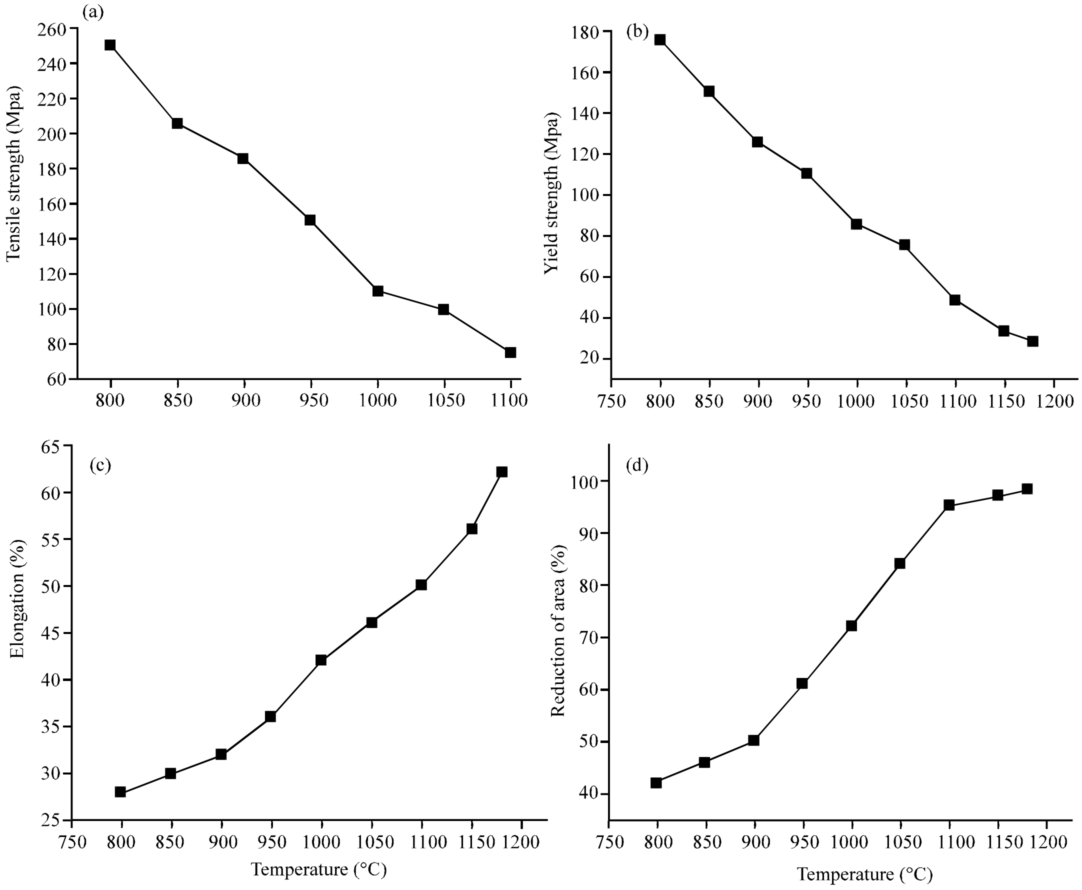

Fig. 3: Tensile properties of alloy 30Cr25Ni32Mo3 at elevated temperatures. a) tensile strength, b) yield strength, c) percentage elongation and d) reduction of area

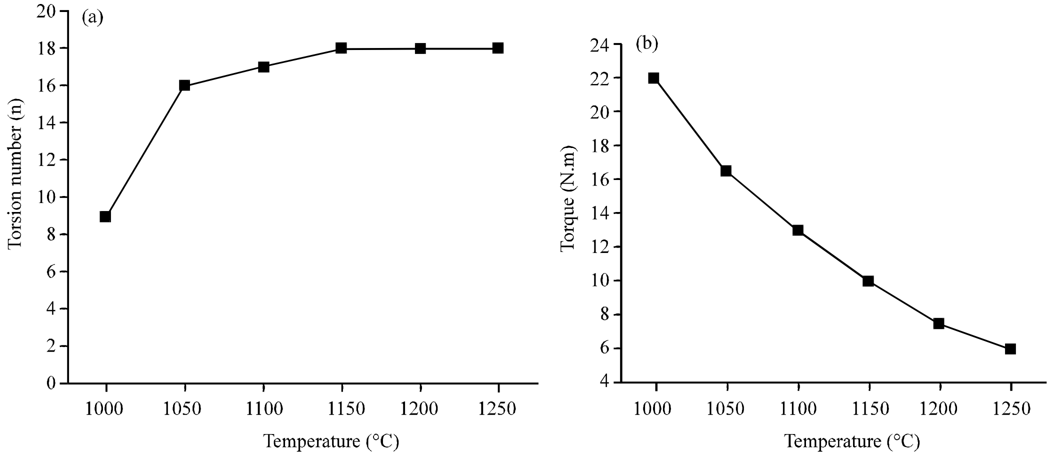

Fig. 4: The test results of hot torsion of specimens made of alloys 30Cr25Ni32Mo3. a) Torsion number and b) Torque

The tests were carried out with the use of special 8 mm diameter cylindrical specimens. The hot torsion test results are shown in Fig. 4. Alloy 30Cr25Ni32Mo3 reaches its maximum plasticity at test temperature of 1200°C and retains it up to 1250°C. But it should be pointed out that minimal values of torque (MSKR) characterizing deformation resistance of alloy 30Cr25Ni32Mo3 are observed within the temperature range of 1100-1175°C.

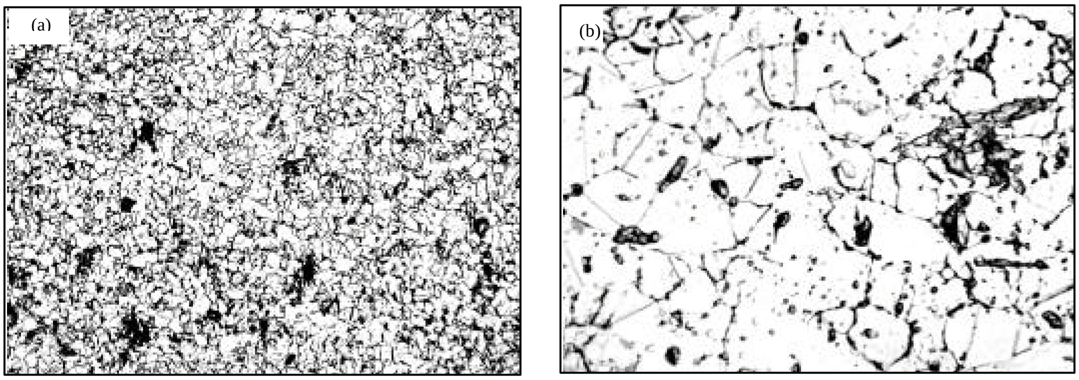

Fig. 5: Microstructure of the specimens made of alloy 30Cr25Ni32Mo3 after hot torsion tests at 1050°C; a) number of torsions 8.5 and b) number of torsions 34

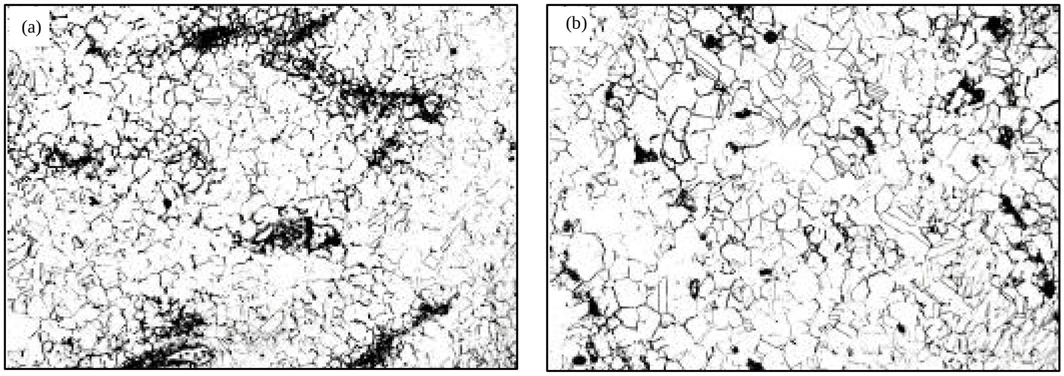

Fig. 6: Microstructure of the specimens made of alloy 30Cr25Ni32Mo3 after hot torsion tests at a)1100°C and b) 1150°C

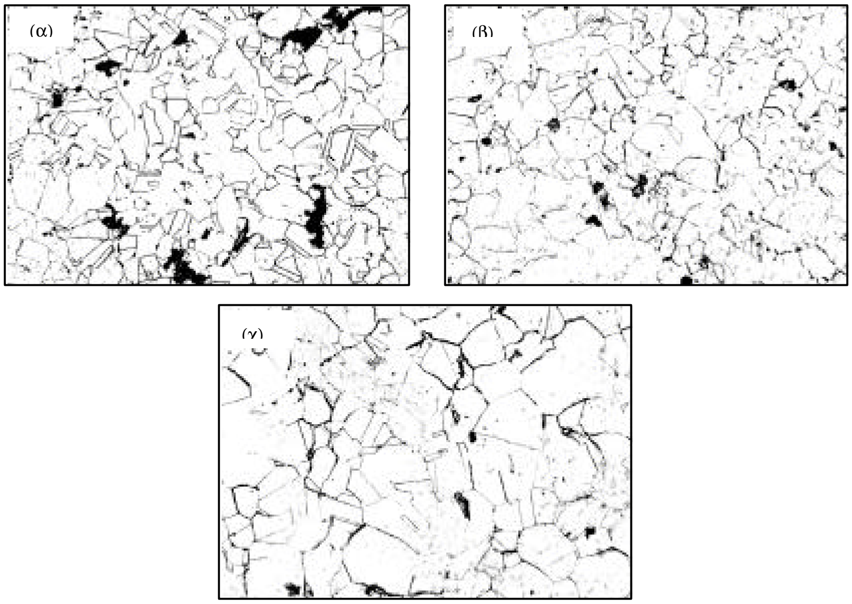

Fig. 7: Microstructure of the specimens made of alloy 30Cr25Ni32Mo3 after hot torsion tests at a) 1200°C, b) 1230°C and c) 1250°C

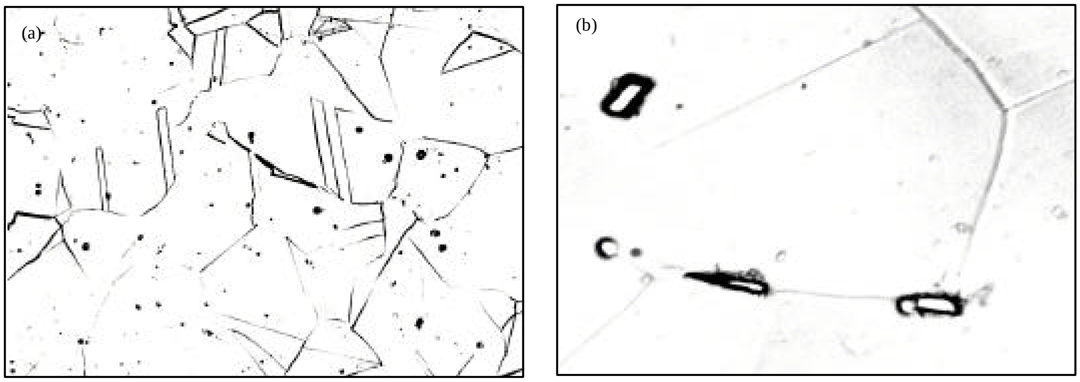

Fig. 8: Microstructure of the specimens made of alloy 30Cr25Ni32Mo3 after quenching at 1200°C from a separate heating: a) general view and b) phase precipitates

Microstructural observations: The results of metallographic analysis of hot-torsion test specimens have shown that structure inhomogeneity remained in various specimens at 1050°C. In a specimen fractured after 8.5 turns, grain variation was observed (Fig. 5a). In a specimen fractured after 34 turns, fine-grained and homogeneous structure with twin boundaries (Fig. 5b) was present. Such condition of the alloy structure has influenced the test results. (Fig. 6a, b).

As the test temperature grows, a significant coarsening of austenite grains (Fig. 7a-c) and redistribution of alloying elements between the phases and the solid solution occur which explains the higher number of torsion turns. To reveal probable fusion of the grain boundaries in the structure of metal of the investigated of alloy 30Cr25Ni32Mo3, quenching of the specimens heated to 1200°C was done first (Fig. 8). Next, structure of the specimens torsion-tested at 1230°C (Fig. 7b) and 1250°C (Fig. 7c) was examined. Structure examination of the specimens heated to 1200-1250°C has shown coarsening of austenite grains and presence of twin low-energy boundaries and phases in the structure. No grain boundary fusion in metal of alloy 30Cr25Ni32Mo3 was revealed.

CONCLUSION

As the test temperature increases, tensile strength and yield strength of alloy 30Cr25Ni32Mo3 decrease gradually and plastic properties (percent elongation and reduction of area) increase as well. Alloy 30Cr25Ni32Mo3 reaches its maximum plasticity at test temperature of 1200°C and retains it up to 1250°C. But it should be pointed out that minimal values of torque (MSKR) characterizing deformation resistance of alloy 30Cr25Ni32Mo3 are observed within the temperature range of 1100-1175°C. The results of metallographic analysis of hot-torsion test specimens have shown that structure inhomogeneity remained in various specimens at 1050°C. In a specimen fractured after 8.5 turns, grain variation was observed.

In a specimen fractured after 34 turns, fine-grained and homogeneous structure with twin boundaries was present. As the test temperature grows, a significant coarsening of austenite grains and redistribution of alloying elements between the phases and the solid solution occur which explains the higher number of torsion turns. Structure examination of the specimens heated to 1200-1250°C has shown coarsening of austenite grains and presence of twin low energy boundaries and phases in the structure. No grain boundary fusion in metal of alloy 30Cr25Ni32Mo3 was revealed.

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