Study on Static Recrystallization Process in Duplex Stainless Steel 2205

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Abstract
Steel 2205 is one of the most famous duplex stainless steels. The microstructure of this steel composed of ferrite and austenite in similar amount. Therefore, in order to improve mechanical properties through microstructure, thermo mechanical processes such as controlled hot rolling and forging should be applied. It is not possible to employ the usual heat treatment. It shows the importance of our knowledge about the steel behavior during hot deformation and the effective mechanisms on the structural change. In the present study, hot compression in two pass process was performed on the 2205 specimens at the constant strain rate of 0.01 $S^{-1}$and the temperature of 950˚C, 1050˚Cand 1150˚C.The interval time between two pass were selected as 5, 10, 50 and 100 seconds and $\varepsilon_c \approx 0.7\varepsilon_p$ was chosen. The results reveal that increasing interval time causes to increase the amount of work softening before the recrystallization leads to decrease in grain size and hardness.

Keywords: Duplex stainless steel, steel 2205, Two-pass hot deformation, Static recrystallization kinetics.

1. Introduction

Two phase stainless steels are widely used in various applications such as marine, chemical industry, and power plants which is due to an excellent combination of their mechanical properties and corrosion resistance. These steels have higher strength compared to austenitic stainless steels and higher toughness compared to ferritic stainless steel, high weld ability and high corrosion resistance, which is due to the alloying elements [1)]. According to research of Fang and colleagues, the maximum value of flow curve in duplex steel is not a point but a wide range and the steady state of flow stress is never seen after softening stage. In fact, the stress is steadily reduced until failure occurred [2)].

Based on extensive researches on the microstructure of steel 2205at high temperatures and its flow behavior [3)], the first focus of deformation is on ferrite phase and there is a balance between work hardening and dynamic recovery (DRV). Then the deformation is focused on austenite phase; in this case, the dominant mechanism is austenite work hardening. In the next stage, dynamic recrystallization (DRX) in austenite begins from the maximum point at flow stress curve and at the same time, it decreases the tension surface of flow. Many studies have been done on the microstructure evolution and how flow curve changes of duplex stainless steel during deformation process in dynamic conditions. The focus of these studies is on interaction between austenite and ferrite with in restoration mechanism during deformation process; however, this effect during interval time between two passes has been less attended [4,5)]. In the present study, the effects of deformation temperature and interpass breaks on static restoration process using two-pass hot compression are investigated.

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2. Materials and methods

The chemical composition of duplex stainless steel 2205 used in this research is shown in Table1.

Table 1. Chemical composition of the used steel

C	Mo	Cr	S	P	Mn	Si	Mo
0.02	2.67	22.1	0.003	0.03	1.79	0.64	2.67
Ni	Fe	V	W	Nb	Cu	Co	Fe
4.77	Base	0.035	0.03	0.02	0.37	0.07	Base

Cylindrical specimens were prepared from roundbarsby10mmin diameter and 15 mm in height. The initial microstructure of specimens is shown in Figure 1.

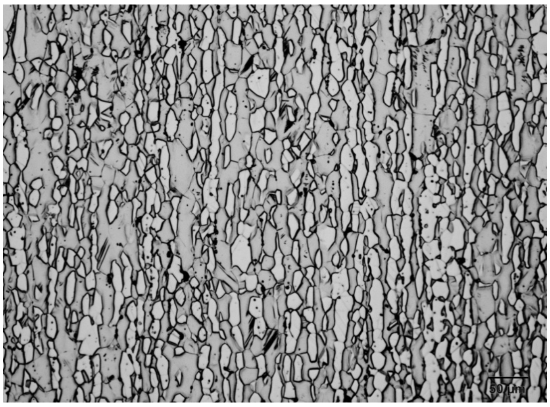

Fig. 1. Microstructure of duplex stainless steel 2205 specimen.

In order to investigate recrystallization process, a two-pass hot compression process was planned and performed by universal puller-pressure machine type Zwick/Roll, which was equipped with a resistance furnace. Figure 2 shows schematically the thermo mechanical process. The first, specimens were homogenized at 1200°C for 10 min. The temperatures of 950°C, 1050°C and 1150°C and the strain rate of 0.01S^{-1}were selected for compression in both first and second steps. In order to prevent dynamic recrystallization process during the first step, the first total strain was selected lower than critical strain (ε_c=0.2) according to previous works [1,4].In this situation, the kinetics of static softening would only be appeared in all of the experiment conditions. The strain rate was stopped during interpass time (pause time between two step of compression), which was selected as 5, 10, 50 and 100 seconds in individual tests. Engineering stress-strain data obtained from the puller-pressure machine were calculated to draw true stress-strain curves in each condition.

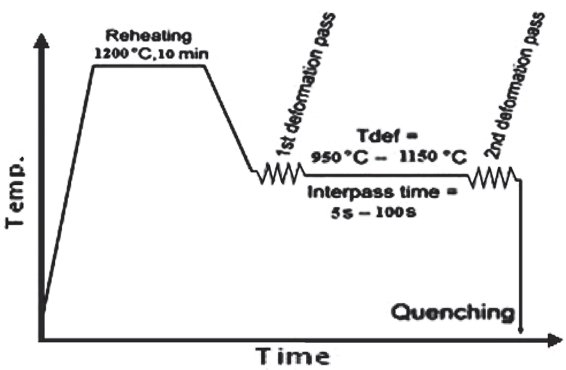

Fig. 2. Scheme of applied thermo mechanical process.

3. Results and Discussion

True stress-strain curves at temperature 950 °C and interpass times 5, 10, 50 and 100 min have been shown in Figure 3. As observed, flow stress in the second pass of deformation decreases when interpass time increases to 50 seconds; the decrease is due to static softening process. As mentioned before, to investigate the effect of temperature on static softening, two-pass hot deformation experiments were also performed at temperature1050°C and 1150°C.

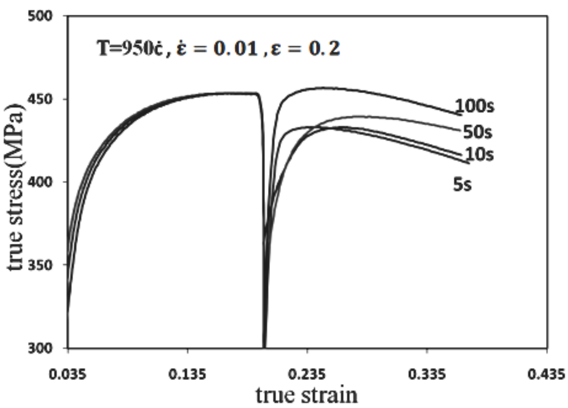

Fig. 3. True stress-true strain curves of steel 2205 resulted from two-pass hot deformation at temperature 950 °C.

Figure 4 shows the true stress-strain curve of steel2205 specimens that hot compact deformations were performed at temperature 1050 °C in different interpass pause time. It can be observed that the amount of static softening increases as pause time increases up to 10 seconds; also, increasing interpass times lead to increase in the flow stress of the second pass which indicates decreasing the fraction of work softening.

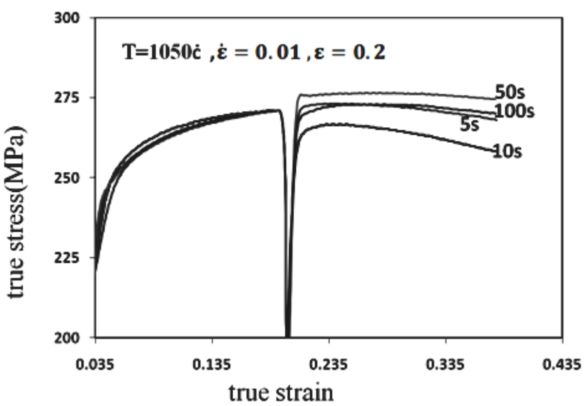

Fig. 4. True stress-true strain curves of steel 2205 resulted from two-pass hot deformation at temperature 1050 °C.

Figure 5 shows the results for two-pass compact deformation at temperature 1150 °C with different interpass times. As observed, the amount of flow stresses is increased with increasing pause time to 10 seconds. This will reduce the level of flow tension and by increasing interpass pause times (50 seconds), the level of the flow stress in the second pass of deformation increased and by increasing the interpass times (100 seconds) the level of flow stress decreased. Due to the change in flow tension in the second pass of hot deformation (Figures 3, 4 and 5), it can be explained that the amount of decreasing flow stress shows the amount of static softening occurrence in the pause time between deformation stages.

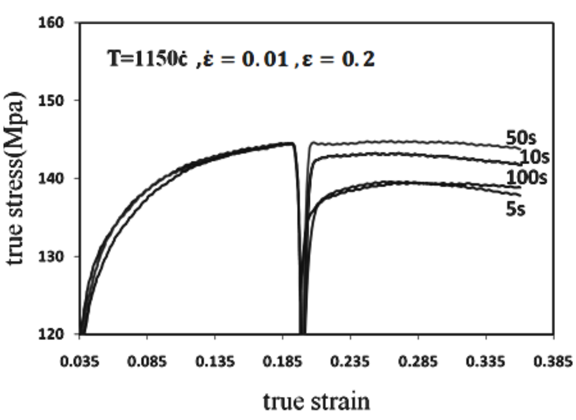

Fig. 5. True stress-true strain curves of steel 2205 resulted from two-pass hot deformation at temperature 1150 °C.

Static softening fraction (Fs) can be defined as decrease in the flow stress of specimens after pause times which is expressed by the following equation [6,7]:

$$Fs = \frac{(\sigma_m - \sigma_2)}{(\sigma_m - \sigma_1)} \qquad (1)$$

Where σ_m is the maximum stress in the first stage of deformation, σ_1 and σ_2 are yield stress 0.2% offset respectively in the first and second pass of deformation. It has been shown the amount of calculated static softening fraction (Fs) for different conditions of experiments in Figure 6 using the data of true stress-strain curves (Figures 3 to 5). As observed, work softening fraction will be increased at 950 °C when interpass times increase and it decreases only at interpass time 100 seconds. It can be explained that in the first pass, ferrite is mainly in terms of work hardening and austenite also suffer some work hardening. So, both ferrite and austenite phases at interpass time to 10 seconds experience the static recovery (SRV) at the first time. At more time up to 50 seconds, static recrystallization (SRX) begins in ferrite grains and maybe it begins with delay in austenite grains. The fine grains formed during SRX in ferrite and austenite at longer times increase the yield strength of the second pass and decreases interpass restoration channels. The situation of experiments done at temperature1050 °C is similar to temperature 950 °C. However, higher temperature causes the higher rate of dynamic recovery in ferrite, which decreases the amount of restoration caused by SRV in interpass pause. At 50 seconds for interpass time, again the strength of second pass goes up because of ferrite fine grains produced after the start of static recrystallization in the microstructure. It can be said that for interpass time 100 seconds, the increase of recovery fraction is due to the start of grain growth which has more potential at this temperature than temperature 950 °C. At high temperature 1150 °C, due to high temperatures every things goes faster and even at 10 seconds, SRX in ferrite and austenite is possible. SRV in ferrite and austenite would be fast in the interpass time 5 seconds and increases restoration fraction. In longer times of 50seconds, SRX is completed and causes to form fine microstricture which is a reason for higher strength at the second pass. Grain growth would occur at 100seconds and makes lower strength at second pass again. However, the interpass restoration fraction increases.

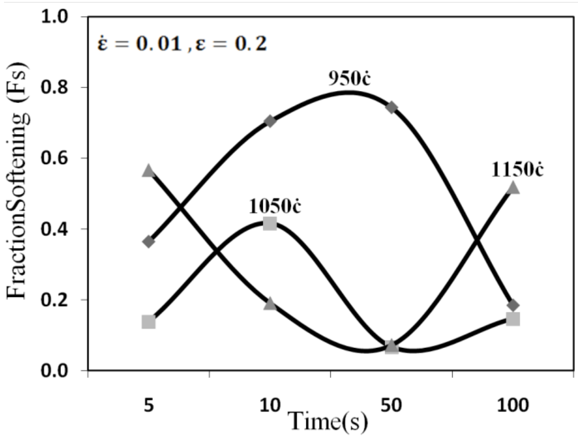

Fig. 6. Softening fraction curve of steel 2205 at different interpass pause times.

4. Conclusions

In this study, a two-pass hot pressure test was done to investigate the effect of deformation temperature and interpass stop time on the static recrystallization process in duplex stainless steel 2205.

Two-pass pressure test results showed that increasing deformation temperature will be increased static recrystallization process; it will also be occurred at the higher rates. When interpass time increased by starting static recrystallization and microstruchure formation, the strength of second pass increased; and the work softening increases by growing the crystallized grains.

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