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Research Article

A Comparative Analysis of the Hot Working Behavior of AISI 420 and AISI 304 Stainless Steels Using the Hot Torsion Test

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ABSTRACT

The complex nature of hot deformation in materials arises from their reliance on changes in strain, strain rate, and temperature. Consequently, accurately predicting material behavior under such conditions is of utmost importance. To accomplish this, various tests including tensile, compressive, and torsion tests are utilized. The torsion test, in particular, allows for higher levels of deformation or strain due to the absence of frictional limitations compared to compression and tensile tests. Therefore, this study investigates and compares the hot working behavior of AISI 420 and AISI 304 through the application of the hot torsion test. To carry out this investigation, experiments were carried out within a temperature range of 800-1000℃. Rotational speeds of 0.028, 0.28, 2.8, and 28 radians per second were selected, enabling high rotation angles of up to approximately 80 radians. Mechanical and microstructural analyses show a significant decrease in torque and flow stress when rising the temperature and proportionally decreasing the rotational speed. The flow stress and torque values of AISI 304 stainless steel are consistently higher than those of AISI 420 stainless steel across various strain rates and temperatures. Furthermore, when a sufficient strain is applied and the deformation temperature is high, dynamic recrystallization is observed in the microstructure. However, due to variations in strain across the radius of the sample, the microstructure of the deformed section appears to vary along the radial axis.

1. Introduction

Stainless steels are defined as iron-based alloys that contain a minimum of 10% chromium. They can be categorized into various main groups, one of which is known as grade 400. This particular group is highly renowned for its exceptional toughness. Among the grades within the 400 group, AISI 420 martensitic stainless steel stands out as one of the most widely utilized. AISI 420 martensitic stainless steels exhibit favorable mechanical properties and corrosion resistance across a wide range of temperatures, making them popular for diverse applications such as safety valves, pressure vessels, and heat exchangers. Another group of stainless steels, the 300 series, possess suitable ductility and

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maintain their strength even at elevated temperatures. The presence of the semi-stable austenite phase allows for the transformation of a portion of the structure into martensite, depending on the specific alloying elements and chemical composition [1, 2]. Both AISI 420 martensitic stainless steel and AISI 304 austenitic stainless steel possess numerous desirable characteristics that find utility in various construction and industrial applications. These types of stainless steel are commonly employed in the manufacturing of components requiring excellent mechanical properties and moderate corrosion resistance, such as turbine blades, pressure vessels, steam generators, and medical equipment. Furthermore, these steels are capable of withstanding high temperatures and erosive environments [2-4].

Hot metal forming processes play a crucial role in various industries, as more than 80% of metal products undergo these processes at least once during their production. The hot working of metals is conducted within a temperature range of 0.5 to 0.9 times their melting temperature, subjecting them to significant deformations and varying strain rates. Consequently, materials exhibit complex behaviors in hot metal forming processes, such as hot forging, rolling, and extrusion. Therefore, it is of utmost importance to thoroughly investigate the deformation behavior of metals at high temperatures [3, 4]. In recent years, there has been a notable focus on studying the deformation behavior of materials during hot compression. It is evident that the stress state significantly influences the flow behavior of a material. Moreover, the deformation behavior during torsion differs significantly from that observed during compression and tension tests. By employing hot torsion tests, it is possible to achieve larger strains without encountering plastic instability. These tests can be performed across a wide range of temperatures, strains, and strain rates, as they are not hindered by friction. The absence of friction allows for a deeper understanding of the deformation behavior under these conditions. The microstructure of metal materials during and after hot deformation holds immense importance due to its correlation with the mechanical properties of the final products. During hot deformation, various microstructural variations, such as dynamic recrystallization (DRX), can occur in materials with low to moderate stacking fault energy (SFE), such as austenitic stainless steel. During DRX, existing grain boundaries elongate along the deformation direction, leading to the emergence of new serrations. The microstructure evolution associated with DRX continues as the deformation increases [5-8]. Extensive research has been conducted on the hot working behavior of several metallic alloys. In a study, microstructural changes in Inconel 718 were investigated using hot torsion tests. Hot torsion tests were performed at temperatures of 850, 1000, and 1100 °C, and at strain rates of 0.01, 0.1, and 1 s^{-1}. It was observed that the dynamic recrystallization mechanism progresses with the evolution of annealing twins, and it was also observed that the peak stress decreases with increasing temperature and decreasing strain rate [9]. By conducting hot torsion tests in the temperature range of 260 to 380 °C for AZ80 magnesium alloy, with a constant decreasing temperature rate of 10 °C/s, it was observed that the average grain sizes increased by increasing the radius and the hot torsion deformation [10]. In another study, the deformation behavior of austenitic stainless steel grade X5CrNi18–10 was performed using a hot torsion test. To analyze the results of laboratory hot torsion tests, univariate and multivariate regression analysis was used and the relationships between temperature of the torsion test, torque, and number of twists until the breaking point of austenitic stainless steel samples were estimated and it was observed that in the case of optimal range temperatures the heat applied to deform the studied steels is obtained from the deformability-temperature diagrams (plasticity-temperature and resistance to deformation-temperature) [11]. The deformation behavior due to hot torsion was studied for carbon steel containing 1.3 wt. % C at high strain rates (2-26 s^{-1}) and temperatures of 1200-900 °C by Fernández-Vicente et al. It was observed that the deformation occurs with the help of two independent mechanisms: Grain boundary sliding (GBS) controlled by grain boundary diffusion and slip creep controlled by lattice diffusion [12]. In another research, industrial hot deformation processes for 321 austenitic stainless steel were investigated using a hot compression test. During the hot deformation of this steel, dynamic recrystallization (DRX) was observed, which was justified due to the low energy of the stacking fault of stainless steel 321. Then, the starting point of dynamic recrystallization was determined using the stress-strain diagram related to real stress and strain and strain rate values, in different conditions [13]. Mandal et al. [14] investigated the deformation behavior of stainless steel type 304L during hot torsion at the temperature range of 600-1200 °C and in the range of strain rate (maximum in the surface region) of 0.1-100 s^{-1}. Their results analysis showed that temperature and strain rate were the most important parameters, while strain had only a moderate effect on flow stress.

In another research, a study focused on AISI 420 steel explored its hot deformation behavior through compression tests conducted at temperatures ranging from 1123 K to 1423 K and strain rates ranging from 0.01 s^{-1} to 10 s^{-1}. The results revealed that the flow stress of AISI 420 steel is significantly influenced by both the strain rate and deformation temperature. Specifically, the flow stress increases by decreasing the deformation temperature and increasing the strain rate [15]. Another study investigated the hot flow behavior of AISI 304 steel, specifically focusing on the dynamic recrystallization behaviors observed during a hot torsion test. The test was conducted at a constant temperature of 900 °C and a constant strain rate of 0.01 s^{-1}. The findings indicated that grain growth plays a vital role in softening the material after deformation, with the effect becoming more pronounced as the pressure on the hot deformed material increases [16].

As stated, due to the absence of friction and the possibility of applying high strains and strain rates compared to compression and tension tests, the hot torsion test can be a suitable choice for investigating the mechanical behavior of materials at high temperatures. Given that there is no complete investigation to compare the hot work behavior of AISI 420 and AISI 304 stainless steels, therefore, in the present study, the hot working behavior of AISI 420 martensitic stainless steel and AISI 304 austenitic stainless steel are investigated and compared by conducting a hot torsion test within appropriate temperature, strain, and strain rate ranges. The hot torsion test was chosen over other elevated temperature tests like tensile and compressive tests due to its ability to achieve higher strains. To enhance the characteristics of stainless steel, it is crucial to carefully determine the parameters for hot working and understand the behavior of steels during hot deformation. The hot flow behavior and microstructural changes of hot deformed samples are investigated.

2. Experimental Procedure

In this study, two distinct variations of stainless steel, namely AISI 420 and AISI 304, were employed. The chemical composition (in weight percentage) of these stainless steels is detailed in Table 1. Before conducting the hot torsion test, forged samples of AISI 420 and AISI 304 stainless steels were precisely machined to conform to the dimensions specified by ASTM E8 for the torsion test, as illustrated in Fig. 1(a). Subsequently, the prepared samples underwent annealing heat treatment to ensure homogenization and the development of uniform microstructures.

To determine the mechanical characteristics and stress-strain behavior of the stainless steels, hot torsion tests were performed using the HR-torsion tester. This tester is a servo-controlled electronic universal testing machine equipped with an induction furnace. Torque values were recorded using a high-accuracy torque meter (Model: SSMDJM-20kN) during the tests, with a precision of 0.01 N.m. The torque meter recorded these values at different radians per second (rps). True strain values were computed from rotation angle data provided by the computer. Before the tests, all specimens were heated inside the induction furnace at a uniform heating

Table 1. Chemical composition of AISI304 and AISI420 stainless steels (wt.%)

	Fe	C	Mn	Si	Mo	Co	Cr	Ni
AISI 304	70.78	0.025	1.14	0.41	0.36	0.21	18.40	8.19
AISI 420	85.47	0.252	0.93	0.64	0.03	0.12	12.21	0.09

rate of 50 °C/s. This ensured that the specimens had a homogeneous temperature distribution. The torsion tests were conducted within a temperature range of 800-1000 °C, at rotational speeds of 0.028, 0.28, and 2.8 rpm. The strain rates during the tests ranged from 0.001 to 0.1 s^{-1} until the fracture strain was reached. Throughout the deformation process, data and results are recorded. After the hot torsion tests, the hot-torsioned samples (Fig. 1 (b)) were quickly quenched in cool water to preserve their deformed microstructure and prevent any undesired changes such as recrystallization or grain growth.

Fig. 1 (c) visually represents the torsion test machine and its temperature controller. To ensure the reliability of experimental results, the tests and the strain rates were repeated at certain temperatures multiple times and the average results were used for analysis. To monitor the temperature during the tests, a radiation thermometer was employed to measure the surface temperature of the specimens at any given time. Additionally, the torque meter, connected to the fixed clamp of the machine, continuously recorded torque information throughout the tests.

After meticulously polishing the hot deformed samples for metallography, the specimens underwent etching using a solution comprising 50% nitric acid and 50% hydrochloric acid. Subsequently, the microstructural images of both the prototype and tested specimens were captured utilizing a light microscope. A visual representation, designated as Fig. 2, displays the initial microstructure of AISI 420 martensitic stainless steel and AISI 304 austenitic stainless steel before the hot torsion test. Within Fig. 2, it can be observed that the presence of martensitic and austenitic structures is evident in the AISI 420 (Fig. 2(a)) and AISI 304 (Fig. 2(b)) stainless steel, respectively.

During each trial, the samples were inserted into the jaws of the torsion test machine. To heat the samples, an induction copper coil was employed. The temperature variations were measured and recorded, while the torque values were also noted at regular intervals. This entire experimental procedure was repeated three times, and the average values were then utilized for analysis.

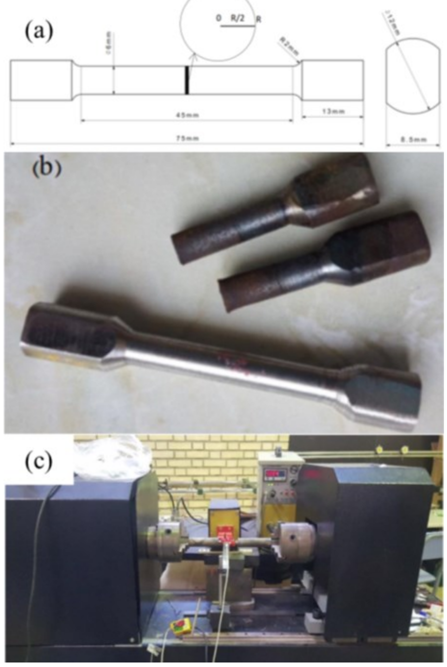

Fig. 1. Experimental set-up of hot torsion test (a) dimensions of the test specimen according to ASTM E8 standard, (b) hot torsioned sample, and (c) torsion testing machine.

Subsequently, all deformed samples were swiftly cooled by water quenching following the hot torsion test. This allowed for the examination of microstructural modifications in the deformed sample, as well as the forming conditions. In order to evaluate the microstructure, the deformed sample was cut along the normal surface to the sample axis. Additionally, in accordance with Fig. 1(a), the microstructures of three specific points were investigated along the radius of the hot-deformed rod samples.

The angles and torques obtained from the test are converted to stress and strain using Eqs. (1) and (2), respectively [17, 18].

$$\sigma = \frac{3.3\sqrt{3}T}{2\pi r R^2} \quad (1)$$

$$\varepsilon = \frac{\theta R}{\sqrt{3}L} \quad (2)$$

$$\dot{\varepsilon}^* = \frac{\dot{\varepsilon}}{\dot{\varepsilon}_0} \quad (3)$$

That σ and ε are flow stress and strain, respectively. T is the torque, R is the radius of the specimen, r is the distance from the center of the specimen, θ is the angle of rotation and L is the length of the test specimen, $\dot{\varepsilon}$ is strain rate, $\dot{\varepsilon}^*$ and $\dot{\varepsilon}_0$ are dimensionless and reference strain rates, respectively. The strain rate, denoted as $\dot{\varepsilon}$,

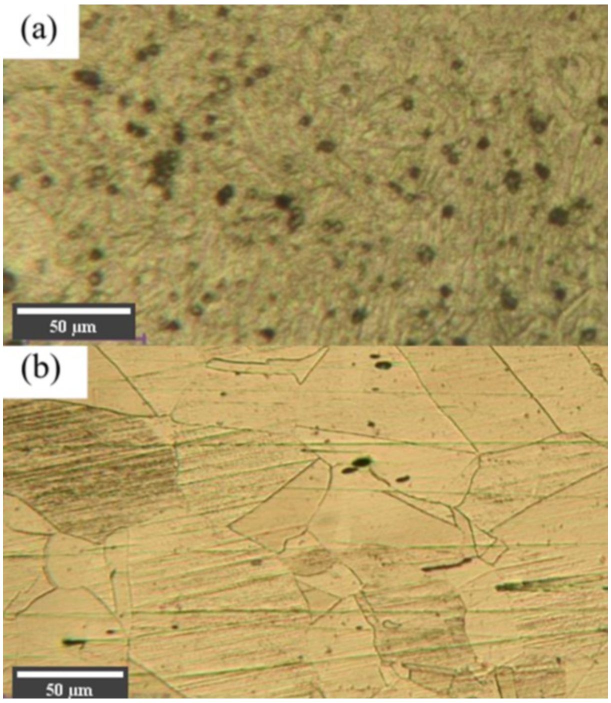

Fig. 2. Microstructure of (a) AISI 420 martensitic stainless steel, (b) AISI 304 austenitic stainless steel before hot torsion test.

represents the period required to accumulate a particular level of strain. It is characterized by the elongation per unit of time. On the other hand, the rotational speed of an object revolving around an axis is determined by the number of complete rotations the object makes within a given time frame. This measure is typically expressed as revolutions per minute (rpm), radians per second (rad/s), and so forth.

3. Results and Discussion

3.1. Hot deformation flow curves

The rotation angle-torque curves obtained from the hot torsion test results are shown in Fig. 3 and Fig. 4 for AISI 304 austenitic stainless steel and AISI 420 martensitic stainless steel, respectively. To examine the impact of various temperature and rotational speed parameters, a comparative analysis was conducted on AISI 304 austenitic stainless steel and AISI 420 martensitic stainless steel. The findings of this study are presented through separate curves. Specifically, the rotation angle-torque curves of AISI 304 stainless steel were examined at different temperatures (800 °C, 900 °C, and 1000 °C) and rotational speeds, as depicted in Figs. 3 (a) to (c) respectively. Upon analyzing these curves, it was observed that the highest torque value recorded during the hot torsion of 304 austenitic stainless steel at 800 °C (Fig. 3(a)) was approximately 130 N.m, at a rotational speed of 28 radians per second (rps). In contrast, the torque values obtained from other curves were comparatively lower. Additionally, the maximum rotation angle achieved at 800 °C, as shown in Fig. 3(a), was approximately 40 radians. According to Fig. 3(b), it becomes evident that at a deformation temperature of 900 °C, the maximum torque value measured was 110 N.m at a rotational speed of 28 rps for the 304 stainless steel samples. Furthermore, these samples demonstrated the ability to withstand deformation up to a rotation angle of 48 radians before failure. Upon analyzing the torsion test outcomes of 304 stainless steel specimens

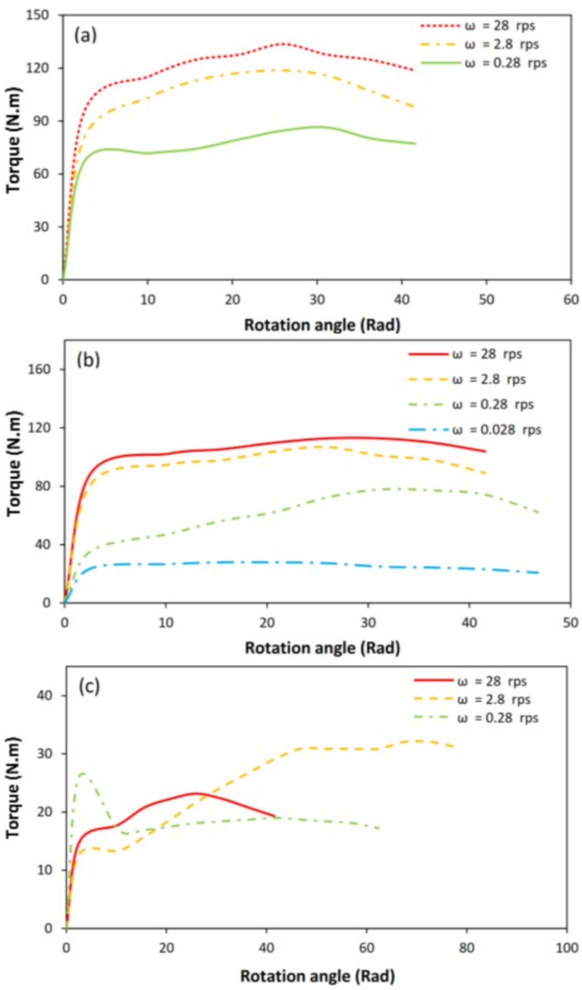

Fig. 3. Rotation angle-torque curves of AISI 304 stainless steel at different rotational speeds and temperatures of (a) 800 °C, (b) 900 °C, and (c) 1000 °C.

at a deformation temperature of 1000 °C (as depicted in Fig. 3 (c)), it is evident that the maximum torque required is 32 N.m at a rotational speed of 2.8 rps. Additionally, the highest recorded rotation angle for the 304 stainless steel sample was 80 radians. Notably, certain torque-rotation angle curves exhibit indications of dynamic recrystallization, characterized by the presence of at least one peak. Subsequently, following this peak, the flow stress experiences a decline. These experimental findings are substantiated by microstructural investigations and have also been corroborated by other researchers [19]. Furthermore, the torque-rotation angle curves demonstrate a notable decrease in torque values with an increase in the deformation temperature. Conversely, the torque values exhibit an upward trend as
the rotational speed rises. Figs. 4(a) to (c) display the rotation angle-torque curves of AISI 420 martensitic

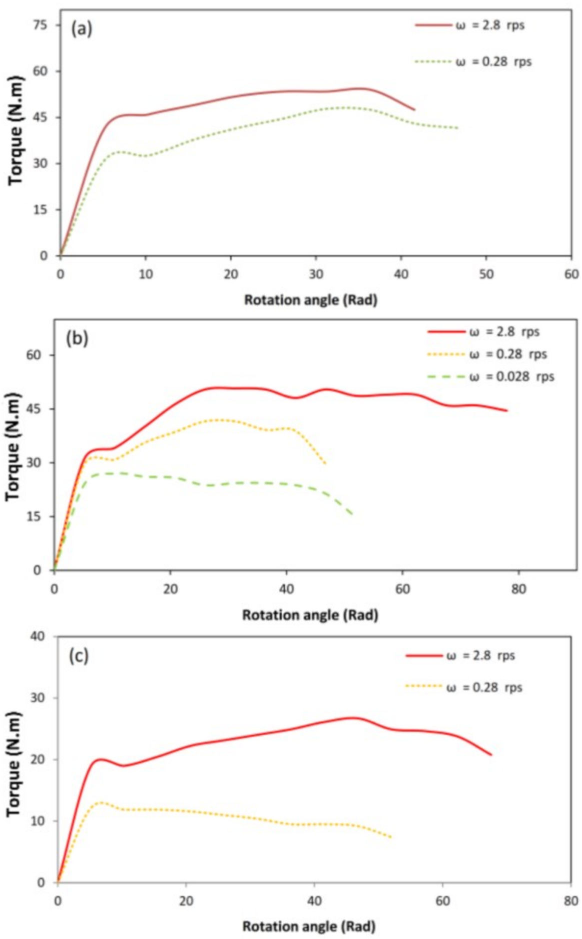

Fig. 4. Rotation angle-torque curves of AISI 402 stainless steel at different rotational speeds and temperatures of (a) 800 °C, (b) 900 °C, and (c) 1000 °C.

stainless steel at various rotational speeds and temperatures (800 °C, 900 °C, and 1000 °C). In Fig. 4(a), which represents the hot torsion test at 800 °C, the maximum torque value is approximately 55 N.m at a rotational speed of 2.8 rps. The recorded torque values at other points are lower than this maximum value. Moreover, at a temperature of 800 °C, the maximum rotation angle is approximately 50 radians. The maximum measured torque value at a rotational speed of 2.8 rps and 900 °C is about 52 N.m (Fig. 4 (b)). As it is obvious in Fig. 4, the maximum rotation angle values change from approximately 40 radians at 800 °C to about 80 radians at 900 °C and 1000 °C for AISI 420 martensitic stainless steel. It is worth noting that certain curves exhibit the rotation-torque angle behavior associated with dynamic recrystallization, featuring a peak point or peak followed by a decrease in torque value. These experimental results have been confirmed by microstructural studies and reported by other researchers [19]. Analyzing the curves of 420 martensitic stainless steel has made it apparent that torque values decrease as the deformation temperature increases, while these values increase with higher rotational speeds. Hot torsion tests are commonly utilized to achieve high levels of strain, which cannot typically be attained through hot compression or hot tensile tests. By utilizing Eqs. (1) to (3) to convert rotation angle-torque curves into flow stress-strain curves, flow stress-strain curves of AISI 304 and AISI 420 stainless steels were obtained and depicted in Figs. 5 and 6, respectively. These figures indicate that the flow stresses of both stainless steels increase as the strain rate rises and the temperature decreases. The highest flow stress value was observed in AISI 304 stainless steel at a strain rate of 1 s^{-1} and a deformation temperature of 800 °C. Conversely, the lowest flow stress value was recorded in AISI 420 stainless steel at a strain rate of 0.01 s^{-1} and a deformation temperature of 1000 °C. Figs. 5 and 6 show the stress-strain curves for AISI 304 and AISI 420 steels under different strain rates and temperatures, respectively. Three strain rates, namely 0.001, 0.01, and 0.1 s^{-1}, were considered for temperatures of 800, 900, and 1000 °C. These curves

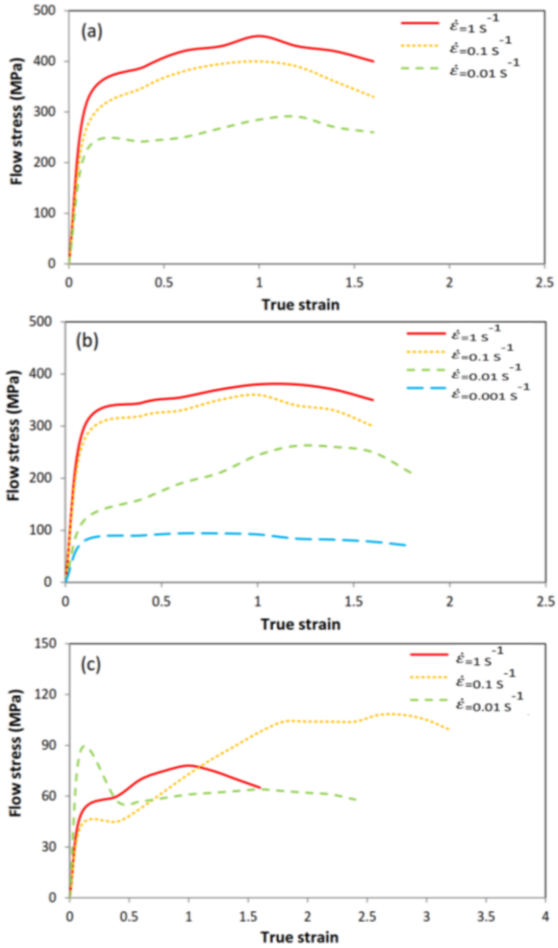

Fig. 5. True stress-strain curves of AISI 304 stainless steel at different strain rates and temperatures of (a) 800 °C, (b) 900 °C, and (c) 1000 °C.

demonstrate that the flow stresses of both stainless steels increase as the strain rate rises and the temperature decreases. At a temperature of 800 °C, the maximum stress values were approximately 180 MPa and 440 MPa for strain rates of 1 s^{-1} and 0.1 s^{-1}, respectively (Figs. 5 (a) and 6 (a)). Other stress values recorded during the experiment were lower than these conditions. Moreover, the experimental results show that strain values increase with temperature. At 800 °C, the highest strain value for both steels was around 1.6, which increased to about 3 at 1000 °C. In the tested conditions, the AISI 420 specimen could withstand deformation up to a strain of approximately 3.2. Torsion test analysis revealed that for a specimen at a deformation temperature of 1000 °C (Figs. 5 and 6 (c)), a maximum stress of 88 and 98 MPa was necessary for AISI 304, reaching a strain value of about 3.2. Some curves exhibited the characteristic behavior of dynamic recrystallization, with a peak followed by a decrease in flow stress, consistent with microstructural studies conducted by other researchers [19, 20]. The plotted curves indicate that the tolerable stress of the part decreases with increasing deformation temperature, while it increases with higher strain rates. Notably, the stress-strain plot reveals recrystallization during the test, evident by the peak formation and subsequent decline. Additionally, certain charts exhibit an overall bullish trend, suggesting a recovery trend during the experiment.

As it is clear in these figures, the flow stress and torque values of AISI 304 stainless steel are consistently higher than those of AISI 420 stainless steel across various strain rates and temperatures.

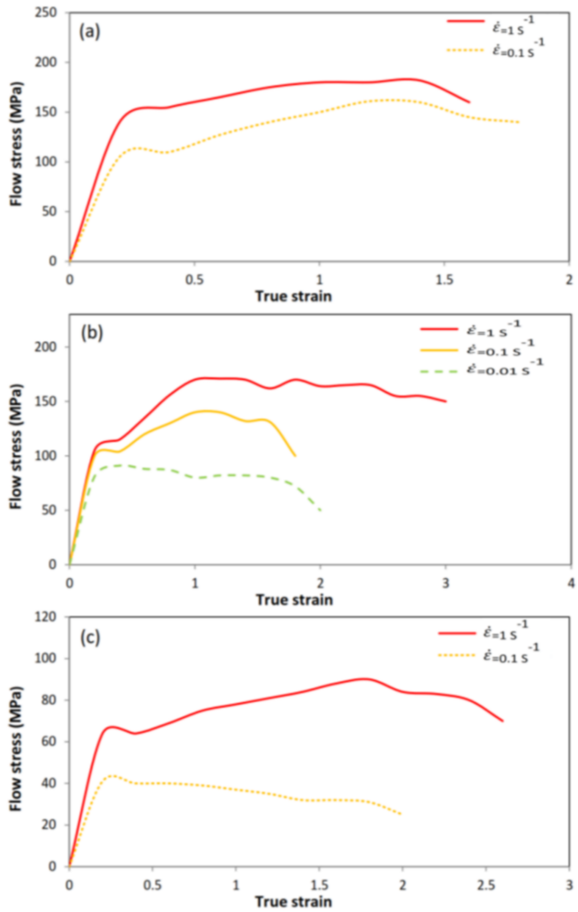

Fig. 6. True stress-strain curves of AISI 402 stainless steel at different strain rates and temperatures of (a) 800 °C, (b) 900 °C, and (c) 1000 °C.

3.1. Microstructure investigation

Figs. 7 to 10 show optical micrographs of specimens that underwent hot deformation in different regions along the radius of the samples. These regions range from the center (r=0) to the surface (r=R), and the observations were made at various temperatures and strain rates. Upon microscopic examination, it is evident that the central region of both hot-deformed stainless steel samples did not undergo significant microstructural changes. However, as to move further away from the center, the extent of microstructural changes increases considerably. This can be attributed to the fact that the strain values increase with distance from the center line of the hot deformed sample. Since the strain value in the central region is zero, minimal microstructural changes are observed there, whereas the surface regions exhibit the maximum microstructural changes due to the maximum strain value. The microstructural investigation showed that the process of grain refinement becomes apparent as the temperature of deformation increases. This occurrence is particularly noticeable when the temperature exceeds 900 °C. Below this critical temperature threshold, the material showcases elongated grains due to the temperature dropping below the recrystallization temperature. Detailed images displaying the metallography of the specimen are captured from the central region, specifically at part (a) in the provided figures. Furthermore, part (b) of the image is taken at a distance of half the radius (R/2) from the center, while part (c) is captured at a distance of the full radius (R) from the center. In Fig. 1(a), the precise location of R is indicated, representing the point where the test sample is divided. The microstructures of the hot deformed samples for AISI 420 and AISI 304 stainless steel are depicted in Figs. 7 to 10.

In general comprehension, the amount of stress imposed on the sample is not uniformly distributed across its radius. Instead, it fluctuates from a zero at the center to a maximum value at the surface. These changes in stress remain unaffected by factors such as temperature and the rate at which deformation or strain occurs. Figs. 7 to 10 present microstructural images of AISI 420 Martensitic stainless steel and AISI 304 austenitic stainless steel after undergoing a hot torsion test. The presence of these fine grains in the microstructure indicates that dynamic recrystallization took place

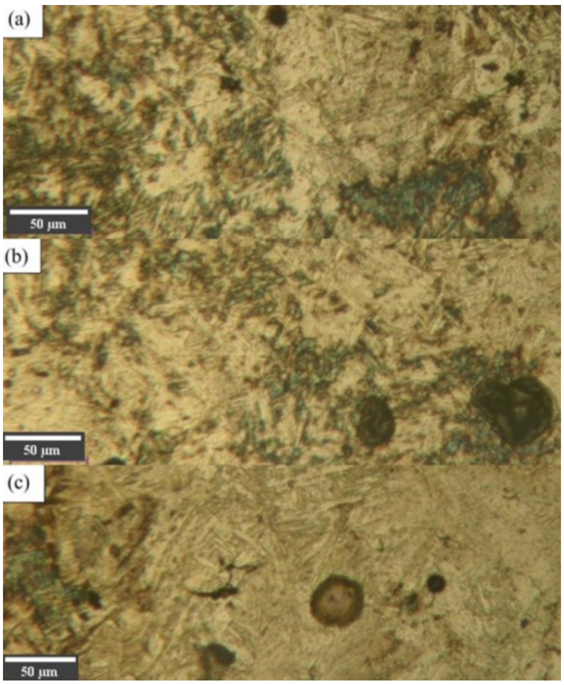

Fig. 7. Microstructure of the (a) center (r=0), (b) r= R/2, and (c) surface (r=R) positions of hot-deformed AISI 420 stainless steel at 1000 °C and strain rate of 0.1 s^{-1}.

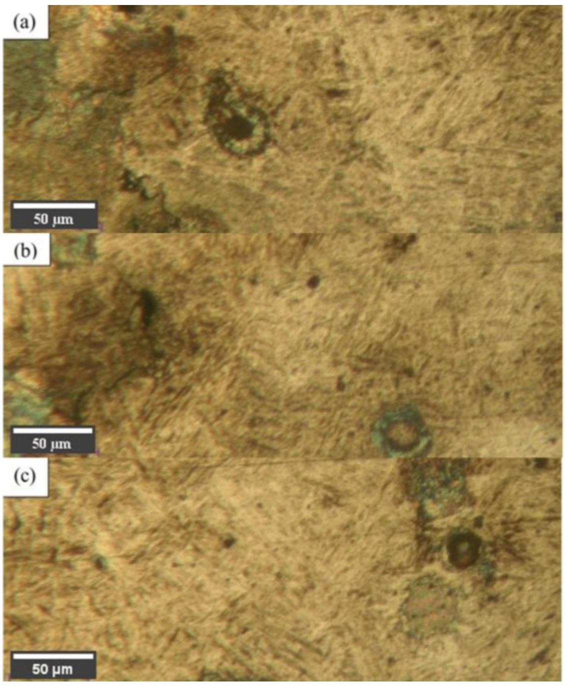

Fig. 8. Microstructure of the (a) center (r=0), (b) r=R/2, and (c) surface (r=R) positions of hot-deformed AISI 420 stainless steel at 1000 °C and strain rate of 0.01 s^{-1}.

during deformation, as the specimens were promptly quenched in cold water after the test and did not have sufficient time for static recrystallization. To facilitate a thorough examination, the microstructural images are displayed at three positions of hot deformed samples at different deformation temperatures of 1000 °C and two strain rates of 0.1 s^{-1} (Fig. 7) and 0.01 s^{-1} (Fig. 8) for AISI 420, and also at 800 °C and 0.1 s^{-1} (Fig. 9) and 1000 °C and 0.1 s^{-1} (Fig. 10) for AISI 304. Upon careful observation of Figs. 10(a), 10(b), and 10(c), the grain size is measured at 25, 15, and 10 microns, respectively. This shows that, clearly, different dynamic recrystallization percentages occur at different positions of the hot deformed samples along the sample radius depending on the deformation or strain values. Hence, the highest percentage of dynamic recrystallization is observed on the surface of the sample and the lowest value is observed in the central position of the hot deformed samples. Therefore, a fine grain structure is observed at the surface of deformed samples and grain size values increase from the surface to the center of deformed samples, progressively. The microstructural investigation shows that the percentage of dynamic recrystallization and consequently the grain size of different positions of the deformed samples depends on the strain and temperature values in these positions.

By comparing Figs. 9 and 10, it becomes evident that the size of the grains generally increases with increasing deformation temperature, irrespective of their distance from the center. The examination of the microstructures reveals that the number of twins within the microstructure increases as one moves from the center of the tested samples towards the outer surface, in the direction of radius R. Therefore, it can be inferred that the number of twins in the sample also increases with the application of more strain. In the microstructural results of hot deformation samples, it is observed that the grain size decreases and the number of twins increases with the increase of the applied strain as this phenomenon has been reported by other researchers [20, 21].

Observations show that when the grains exceed a certain critical strain, recrystallization is evident in the microstructure of the sample. Furthermore, the density of the recrystallized grains increases with increasing

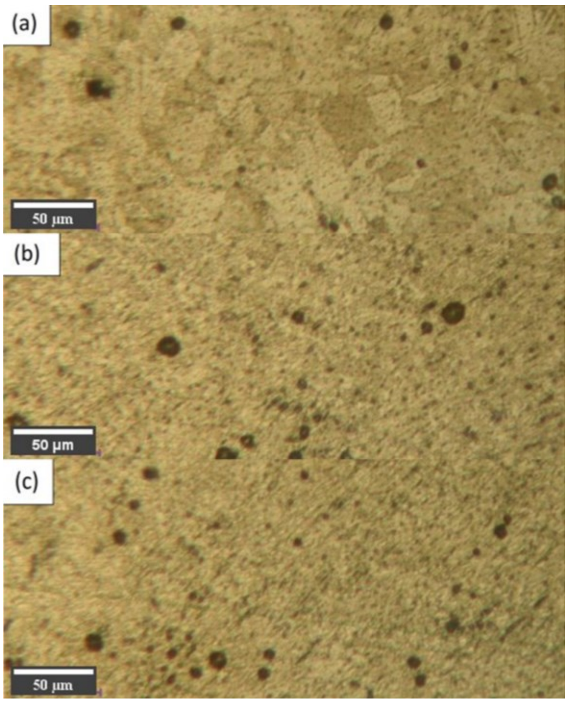

Fig. 9. Microstructure of the (a) center (r=0), (b) r=R/2, and (c) surface (r=R) positions of hot-deformed AISI 304 stainless steel at 800 °C and strain rate of 0.1 s^{-1}.

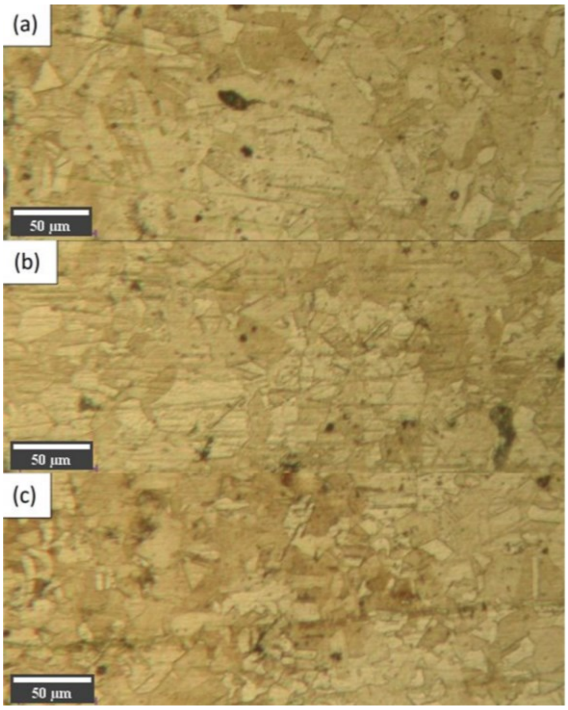

Fig. 10. Microstructure of the (a) center (r=0), (b) r=R/2, and (c) surface (r=R) positions of hot-deformed AISI 304 stainless steel at 1000 °C and strain rate of 0.1 s^{-1}.

strain. Consequently, a comprehensive analysis of the microstructure findings derived from hot deformed steel substantiates the outcomes of stress-strain curves and affirms the presence of dynamic recrystallization within the microstructure. On the other hand, as shown in Fig. 9, the dislocation density increases with increasing strain and strain rate at low-temperature values. In the end, it was observed that AISI 304 steel presented higher stresses than AISI 420. The degree of work hardness and dynamic recovery in these two alloys were significantly different. The findings showed that grain growth plays a vital role in the softening of the material after deformation, and this effect becomes more obvious with the increase of torsion on the hot deformed material.

4. Conclusion

In this paper, the hot working behavior of AISI 420 martensitic stainless steel and AISI 304 austenitic stainless steel were investigated and compared using hot torsion tests at the temperature ranges of 800 to 1000 °C and the strain rates of 0.001 to 1 s^{-1} and in strains of high values. Some of the results of this research are as follows:

- The experimental rotation angle-torque curves show an interesting trend. As the temperature decreases or the rotation speed increases, the torque experienced by the steels increases. This shows a strong correlation between temperature, rotation speed, and torque.
- It was observed that the flow stresses of both steels increase as the deformation temperature decreases or the strain rate increases. Notably, when the deformation temperature reaches 1000 °C, the curves exhibit a phenomenon known as dynamic recrystallization. On the other hand, at low temperatures or high deformation rates, the curves indicate a state of hardening and recovery mechanisms.
- The flow stress and torque values of AISI 304 stainless steel are consistently higher than those of AISI 420 stainless steel at different strain rates and temperatures.
- The microstructural investigation of the deformed sample reveals interesting changes. The microstructure shows different conditions from the center to the surface of the sample. This difference can be attributed to the strain changes that occur from the center to the surface, which varies from zero to maximum. Moreover, at low temperatures and high strain levels, the microstructure is restored and a high density of dislocations is revealed.

Conflict of Interest

The authors declare no conflict of interest.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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