MICROSTRUCTURE ANALYSIS OF HEAT-RESISTANT NI-BASED ALLOY AFTER DYNAMIC RECRYSTALLIZATION

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Abstract

Dynamic recrystallization processes in heat-resistant Ni-based alloy was investigated depending on temperature, strain rate and deformation ratio. Recrystallization intensity is determined by the temperature and deformation conditions. The factors that increase the degree of dynamic recrystallization include temperature and amount of strain increasing, as well as decreasing of strain rate. Increasing the volume fraction of recrystallized structure causes a uniform fine-grained structure. Detailed microstructure analysis of heat-resistant Ni-based alloy after dynamic recrystallization was performed.

Keywords: Dynamic recrystallization, heat-resistant alloy, Ni-based alloy, stress-strain curves, slip lines, twinning

1. INTRODUCTION

Dynamic recrystallization processes during hot plastic deformation of superalloys have significant influence on the final structure formation [1-3], in particular, on the grain size, which in addition to other factors determines the mechanical properties of the material [4-6]. Therefore, it is important to investigate the processes of superalloys dynamic recrystallization depending on the temperature, rate and amount of strain.

2. EXPERIMENTAL PROCEDURE

Investigations for forged rods of heat-resistant nickel-chromium alloy were carried out in this work. The chemical composition of researched alloy is shown in the **Table 1**. It corresponds to Russian standard 5632-72.

Table 1 Chemical composition of researched alloy

Fe	C	Ni	S	P	Cr	Mo	W	Ti	Al
<4	<0.08	60.48-68.8	<0.01	<0.015	17-20	4-5	4-5	2.2-2.8	1.0-1.5

Compression of the cylindrical specimens with dimensions of Ø10×15mm was performed on the module Hydrawedge of Gleeble-3800 system, designed for simulation of thermomechanical processing. During processing samples were directly heated by passing a current through the sample to a temperature of 1200 °C, were held for 60 s and then were deformed by compression at 800 ° C, 850 °C, 900 °C, 950 °C, 1000 °C with strain rate of 0.1 s^{-1} and 0.01 s^{-1} and with amount of strain ε = 30, 50 and 70%, which are correspond to logarithmic strain ε = 0.36; 0.69 and 1.20. The force and transverse deformation of samples during tests (scheme is shown in **Fig. 1**) were continuously measured by high-precision strain gauge and load cell. With the built-in control subroutine stress-strain curves were built. They indicate the evaluation of the material resistance to deformation.

After a full cycle of samples processing micros were prepared to study the structural changes that are taken place during processing. Samples for microstructure analysis were performed on specialized equipment made by Buehler, microstructure analysis was done using optical microscope Leica DMI-5000 with magnification in the range of 50÷1000 fold. The detailed information about experiments and strain-stress curves was published in [7].

a) *b)*

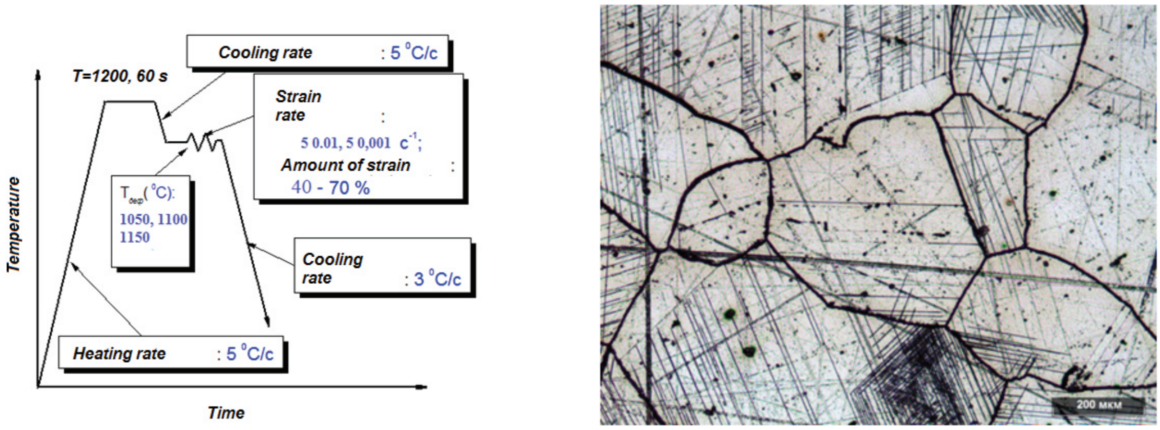


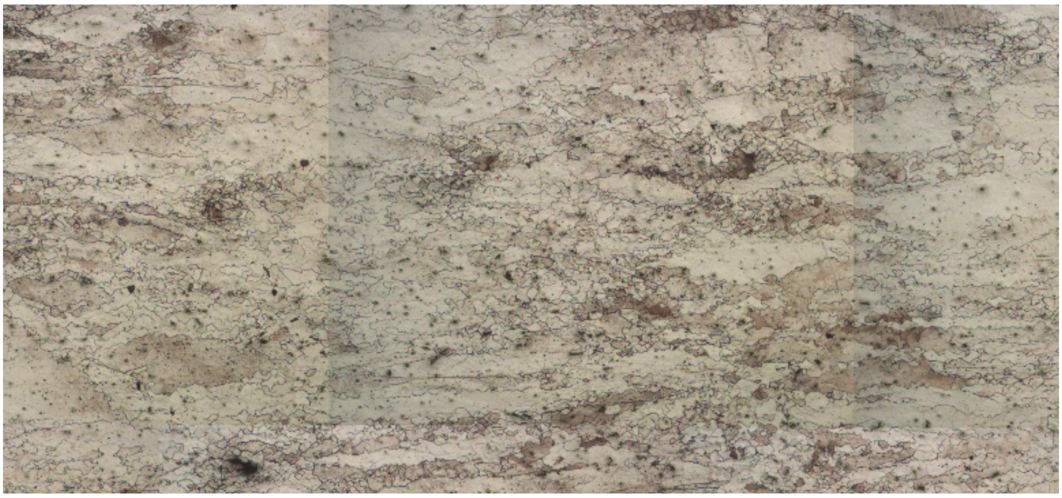
Fig. 1 Scheme of processing on Gleeble 3800 system (a) and researched alloy microstructure in the initial state (b), × 100

The panoramic images of the samples cross-sections subjected to the most intensive thermomechanical treatment are presented on **Fig. 2, 3**.

The nonuniform structure could be seen at panoramic images of the sample deformed with the amount of strain ε = 50% and the strain rate $\dot{\varepsilon} = 10^{-2}$ s^{-1} (**Fig. 2a**) according to the formation of figure "forging cross" which is characteristic of compression tests. The large not recrystallized grains could be seen on the peripheral part of the sample, the large deformed grains with the big amount of fine recrystallized grains which were formed along their boundaries (**Fig. 2b**).

Increasing the amount of strain up to ε = 70% leads to the decreasing of the sample cross-section dimensions (**Fig. 2**) and formation of a fully recrystallized microstructure which consists of small uniform grains in the central part (**Fig. 2d**).

a)



b)

c)

d)

Fig. 2 Panoramic images of the samples (a, b) (x50) and the microstructure of sample central part (b, d) (x100) after deformation at 1100 °C, the amount of strain ε = 50 (a, b) 70% and (c, d) and the strain rate $\dot{\varepsilon} = 10^{-2}\ s^{-1}$

Decreasing the strain rate to $\dot{\varepsilon} = 10^{-3}\ s^{-1}$ the intensity of recrystallization processes increases. The fully recrystallized microstructure which consists of fine uniform recrystallized grains is observed in the central part of the sample after deformation with amount of strain ε = 50% (**Fig. 3b**). Increasing the amount of strain up to ε = 70% fully recrystallized microstructure which consists of fine uniform recrystallized grains is observed in the central part, but the grain size is increased. This fact could be explained by the finishing of the dynamic recrystallization processes and starting of the secondary recrystallization initial stage, which is usually accompanied by increasing of grain size.

a)

b)

c)

d)

Fig. 3 Panoramic images of the samples (a, b) (x50) and the microstructure of sample central part (b, d) (x100) after deformation at 1100 °C, the amount of strain ε = 50 (a, b) 70% and (c, d) and the strain rate $\dot{\varepsilon}$= 10^{-3} s^{-1}

Thus, the relaxation processes caused by the formation of slip lines, twinning and dynamic recrystallization during the deformation of heat-resistant nickel-chromium alloy CrNi67MoWTiAl were observed. The intensity of these processes is determined by the temperature and deformation conditions. The factors that increase the degree of dynamic recrystallization include temperature and amount of strain increasing, as well as decreasing of strain rate. Increasing the volume fraction of recrystallized structure causes a uniform fine-grained structure. Full recrystallization to form a uniform fine-grained structure for the researched heat-resistant nickel-chromium alloy is observed under next conditions: test temperatures is 1100 °C, the amounts of strain are 50 and 70% and the strain rate is $\dot{\varepsilon}$ = 10^{-3} s^{-1}.

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