Multilayer metal materials recrystallization mechanism

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Abstract. This project deals with various aspects of the multilayer structure during hot package rolling in the multilayer materials with over 1000 layers, as exemplified by a multilayer structure composed of the 30HGSA and 08H18 steels. The subject of analysis was the structural state maps of steels that make up the researched structure. The results of research conducted by means of the micro X-ray spectroscopy and microdiffraction analysis establish the causes of the structural damages in the samples, which are primarily related to the ongoing flattening diffusion of the alloying elements, and serve as the basis for a model of multilayer materials recrystallization, based on a hypothesis postulating that the interlayer boundary is where new dynamic recrystallization grains form. Recommendations are given on performing hot package rolling when producing multilayer materials. Key words: multilayer metal materials, hot package rolling, dynamic recrystallization, structural state maps.

1 Introduction

Production of multilayer steel materials with over 1000 layers is a difficult task in terms of both science and technology. The characteristic trait of such materials is the formation of a heat- and deformation-resistant multilayer structure, whose layer thickness is in micron and submicron ranges. This resistance can be explained through the conditions of solid-phase synthesis, which occurs at the hot package rolling temperature equal to 1000 °C [1]. The distinctive feature that justifies asserting the creation of a new material is the set of properties that were not characteristic of the materials initially comprising the original composite workpiece. According to our research, new materials produced on the basis of steels of various categories can manifest highly distinctive anisotropy of the thermal expansion values, high impact resistance to the application of percussive force under sub-zero temperatures, including cryogenic ones, as well as an exponential growth of cyclic resistance with greater numbers and layer dispersion inside the material [2 - 5].

Nevertheless, there are certain difficulties when it comes to both the production and research of multilayer structures, which arise during the combined hot shaping of steels

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differing in their composition, type, and structure [6,7]. Thus, the formation of a firm connection between separate layers with the combined plastic deformation of the multilayer workpiece is dependent on a series of mechanical, physical, and technological parameters [4].

2 Materials and methods

In order to research the conditions of the structure formation in multilayer materials, this research utilizes samples initially composed of 100 layers of alternating 30HGSA and 08H18 steels cards 0.5 mm in thickness, 200 mm in length, and 50 mm in width (50 layers of each brand). The technological means of the hot package rolling produced 2mm sheet-grade workpieces, which were used for the second cycle. Samples were taken from 10 and 2 mm rolling for the purposes of researching the structure of the resulting materials.

The experimental technology that was used achieved its aggregate deformation via a combination of fracture rolling, consisting of straining of no more than 10% of the workpiece at a time, then putting it into a furnace preheated to the rolling temperature.

The micro-X-ray spectroscopy (MPCA) and Electron backscatter diffraction (EBSD) with subsequent creation of the restored crystal orientation map were utilized to analyze the structure.

3 Results and discussion

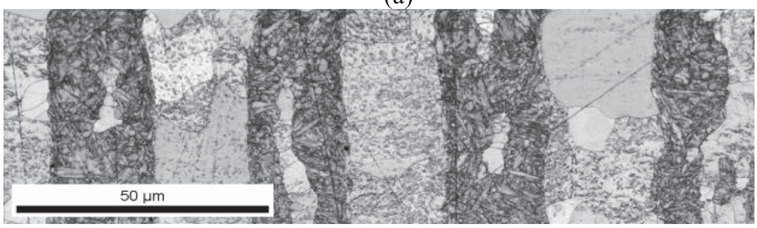
The experimental dependence of the workpiece temperature change from its thickness, achieved in the project [8], shows that achieving a workpiece less than 10 mm in width results in an abrupt decrease in its temperature up to 550 ºC after exiting the roll. Various conditions of the thermal deformation during hot package rolling in metals are known to form various types of structures which can either be the result of the ongoing dynamic polygonization or dynamic recrystallization, or post-dynamic or static recrystallization [8]. The fact that the temperature of the workpieces drops so abruptly, both during feeding them into the rolls and during placing the already rolled and cooled down workpieces into a furnace is very important, as it can cause static recrystallization to develop, if during the rolling the conditions for dynamic polygonization had been created. On the other hand, if the temperature of the workpiece has been lower than the critical mark, this effect can be amplified as a result of thermal cycling as part of the latest stages of the $\alpha \rightarrow \gamma$ transition interval, which can cause structural damage due to recrystallization. Therefore, conditions where the combined dynamic recrystallization within each layer occurs would be considered optimal. The qualitative and quantitative assessment is possible with the existing structural state maps (SSM), which help to select hot shaping parameters [9].

The selection of combined shaping of multilayer materials can be effected on the basis of the values of the temperature limits of the dynamic polygonization (DP) and dynamic recrystallization (DR) of the related structural state maps.

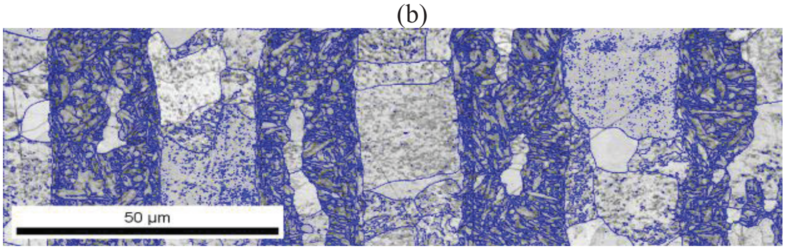
The research conducted on the samples of the 30HGSA and 08H18 composition with 2 mm thickness (layer thickness ≈ 20 μm), shows that the chemical composition (where substitution elements are concerned) of separate layers was mostly intact by the end of the first technological cycle, with the exception of chromium, whose contents in the 30HGSA steel increased by approximately 0.4 % versus the initial composition on account of the interlayer diffusion from the 08H18 steel, whose contents of chromium have decreased.

The microdiffraction analysis of the samples with that composition showed that the coloration of the grains within the multilayer material layers 30HGSA+08H18, provided on the EBSD-maps, indicates the absence of any predominant crystallographic orientation (Fig.1, a).

(a)



(b)



(c)

Fig. 1. Result of the microdiffraction analysis (EBSD) of a 30HGSA and 08H18 composition cross-section sample; number of layers: 100, layer thickness ≈ 20 µm: restored map of crystalline misorientation in the layers of sample (a), structural layers "quality" map (b), "quality" map with a large angular boundaries overlay (misorientation exceeding 15°) (c).

The "quality" map built upon the contrast of peak diffraction values (Fig. 4, b), demonstrated the presence of crystal structure with low deficiency rate and better structure (lighter pixels on the map), compared to the patches with less contrast. Such areas are present both in the layers if steel that was initially the 08H18 steel, and in the 30HGSA layers. Meanwhile, in the layers that were initially the 30HGSA steel, a structure of bigger grains, equal to the thickness of the layer, similar to the "bamboo" structure (Fig. 4, c), can be observed. The formation of such a structure can be explained through the hot package rolling creating conditions for accumulative recrystallization to take place within the layer.

4 Conclusion

Thus, the results, obtained from the 30HGSA and 08H18 composition cross-section samples that underwent detailed MPC and EBSD analyses, provides opportunity to suggest a multilayer material interlayer boundary disruption mechanism.

As it has been established from the samples of the first technological production cycle (2mm thick workpiece, number of layers: 100, layer width: 20 µm), for each specific type of steel the dynamic recrystallization is different, as evidenced by the different chemical makeup of the layers and is confined to the boundaries of that layer. Meanwhile, the birth and growth of new grains starts from the boundaries and develops towards the center of the layer. The second cycle samples (10 mm thick workpiece, number of layers: no less than

1500, layer width: 5 µm) disruptions of the multilayer structure can be observed; after the subsequent rolling up to 2 mm, a complete degradation of the multilayer structure is observed.

Acknowledgements

Experimental research was conducted with the equipment of the Center of Collective Use of Scientific Equipment “Composition, structure, and properties of construction and functional materials” NRC "Kurchatov Institute" – CRISM "Prometey" with funding from the Ministry of Science and Higher Education – agreement No. 13.ЦКП.21.0014 (075-11-2021-068). Unique identification number - RF----2296.61321X0014.

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