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CHANGE OF MICROSTRUCTURE OF NB MICROALLOYED STEEL AT START OF THE PLASTIC FLOW DURING THE COLD DEFORMATION

[1]LJERKA SLOKAR BENIC, [2]STOJA RESKOVIC, [3]MARIJAN MARCIUS, [4]TIN BRLIC

[1,2,4]University of Zagreb Faculty of Metallurgy, Alejanarodnihheroja 3, 44000, Sisak, Croatia
[3]Ruđer Bošković Institute, Bijeničkacesta 54, 10000 Zagreb, Croatia
E-mail: slokar@simet.hr

Abstract - Microstructure has significant impact on the properties and behavior of materials, so it is a subject of intensive investigation nowdays. In this paper, special attention is paid to study on the beginning of the plastic material flow in Nbmicroalloyed steel during the cold deformation. Specific behavior of this steel can present a significant problem during the metalworking in terms of inhomogeneous deformations appearance. Due to many available methods now it is possible to observe what is happening during the deformation of certain material. Hence, investigation of material flow and stress distribution in deformation zone is growing up today. Therefore, the aim of this work was to establish the change of microstructure of low carbon steel microalloyed with niobium at start of the plastic flow during the cold deformation. For that purpose Nbmicroalloyed steel was hot rolled into strip and then static tensile test was carried out. Thermography method was used to study the changes of temperature during the deformation. Microstructure before and after deformation was observed by scanning electron microscope. These investigations showed the fine grained ferrite-pearlitic microstructure and its significant changes at start of the plastic flow during the cold deformation.

Keywords - Cold Deformation, Microstructure, Niobium Microalloyed steel.

I. INTRODUCTION

Due to advances in metallurgy and producing techniques as well, strength of steels has rapidly increased in order to satisfy the market for lighter and stronger steels. Therefore, high strength low alloy steels containing very low carbon content and small amounts of alloying elements were developed. The significance of these steels is in their use in a wide variety of applications, such as in: construction, heavy duty vehicles, storage tanks, railroad cars, oil rigs etc.[1,2]

Since the microstructure has significant impact on the properties and behavior of any material, it is a subject of scientist's intensive research.

In this work, study of the start of the plastic material flow in low carbon steel microalloyed with niobium regarding the microstructure is performed. Reason for this investigation could be found in the practical problems. Namely, specific behavior of this steel can present a significant problem during the metalworking in terms of inhomogenous deformations appearance. Therefore, the aim of this investigation is to establish the change of microstructure of Nbmicroalloyed low carbon steel at start of the plastic flow during the cold deformation.

II. DETAILS EXPERIMENTAL

2.1. Materials and Procedures

Material used in this investigation was low carbon steel microalloyed with 0.048 % Nb. Its chemical composition also include 0.12 % C, 0.78 % Mn, 0.18 % Si, 0.011 % P, 0.018 % S, 0.02 % Al and 0.008 % N. Niobium is used as a microalloying element since it forms carbides and carbonitrides that improve grain refinement, precipitation strengthening, control the temperature of transformation and minimize the possible embrittlement caused by the presence of nitrogen. [3,4].Nbmicroalloyed steel was hot rolled into strip and specimen for static tensile test was cut from the 3 mm thick strip.

2.2. Static tensile test

The static tensile test was done on the testing machine EU 40 mod with a nominal force value 400kN at stretching rate 20 mm/min. For that purpose specimen was taken from hot rolled strip and cut out inrectangular cross section samples with dimensions: 45 mm x 20 mm x 3 mm.

2.3 Thermography

Changes of temperatures in the specimen during the deformation were recorded by infrared camera VarioCam M82910. The rate of recording was 50 fps. Infrared camera was calibrated at ambient temperature and has temperature sensitivity of 80 mK. Black matte coating of emissivity factor 0.95 was used for thermography.

2.4. Metallography

In order to study the change of microstructure of low carbon steel microalloyed with 0.048 % of niobium at start of the plastic flow, two samples were used. Sample 1 was cut from the specimen before deformation (point 1 on Fig.1), while sample 2 was undergo the start of plastic flow (point 3 on Fig.1).These samples were mounted in the conductive carbon mass using the hot press Buehler SimpliMet 1000. Grinding was performed during the 5 min at load 10 N with water cooling on the grinding/polishing machine using the SiC papers: 120, 240, 400, 600, 800, 1000. Polishing was done with the Al_2O_3 water suspension until the mirror gloss. Then etching was performed in nital reagent. Finally, microstructure was analysed using the scanning electron microscope TESCAN VEGA 5136MM.

III. RESULTS AND DISCUSSION

3.1. Static tensile test

Fig.1 shows a diagram of static tensile test during the deformation of investigated Nbmicroalloyed steel. Studied points are marked as 1, 2 and 3 that designate different stages of deformation. Initial stage of investigated sample before deformation corresponds to the point 1, while point 2 corresponds to the proportionality limit. In point 3 a plastic deformation is present.

3.2. Thermography

After the static tensile test was carried out, the analysis was performed by thermography method to obtain the distribution of temperature change, i.e. stress changes in the tested samples.

Fig.2 shows the change of maximum temperature in the deformation zone during the deformation process. It is clear that in the investigated niobium micro-alloyed steel there is a sudden increase in temperature change at the start of the plastic material flow. The qualitative thermographic analysis of the samples was performed (Fig. 3) besides the quantitative thermographic analysis.

Fig.3 clearly shows that at the moment before the deformation itself and at the moment of reaching the proportionality limit there is no change of temperature in the deformation zone. A significant change in temperature occurs in point 3, which clearly shows Fig.3 in the form of a different coloration in the part where a significant change in temperature or a change in stress has started.

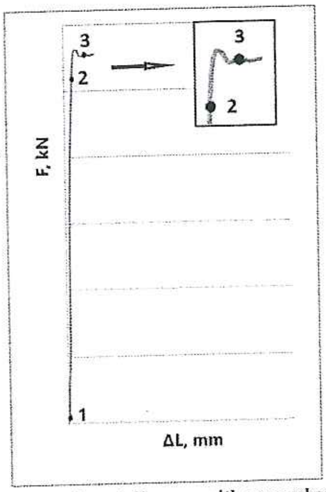


Fig.1. Static tensile test diagram with researched points.

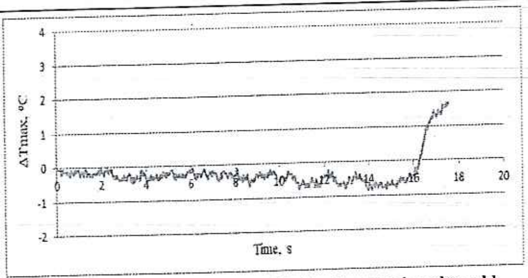


Fig.2. Temperature changes with the time during the cold deformation

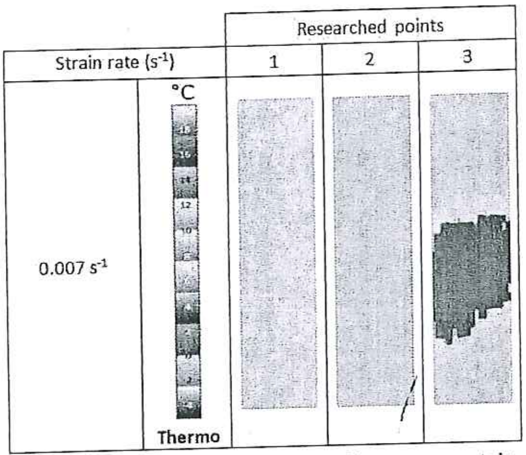


Fig.3. Qualitative analysis of thermographic measurements in researched points

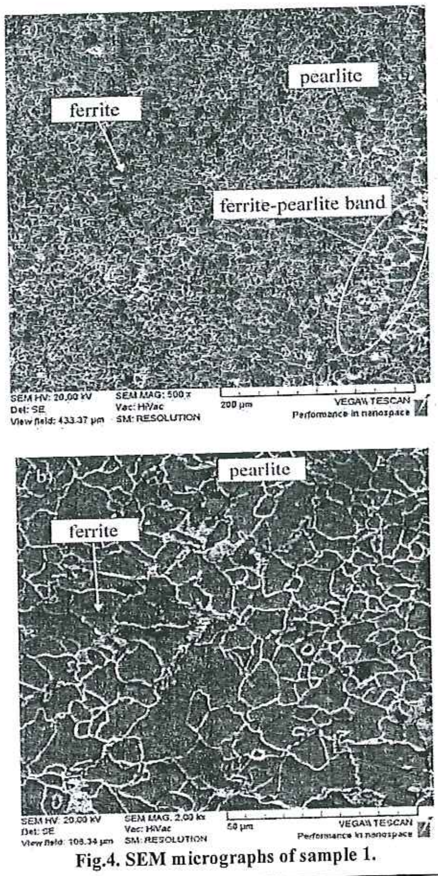
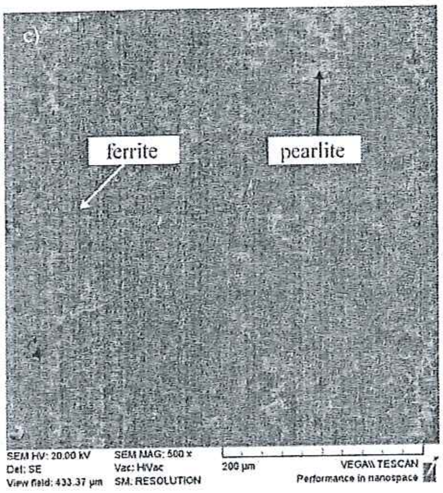


Fig.4. SEM micrographs of sample 1.

Considering the more significant change in temperature change at point 3 during deformation, microstructural tests were performed on the sample taken at the moment of deformation at point 3. In order to compare the microstructure before and after a certain degree of deformation, microstructural analysis with SEM at point 1 before deformation was performed.

3.3. Metallography

Microstructure was studied on sample before cold deformation and on sample during the start of plastic flow. Observed microstructures were shown in Figs. 4 and 5.



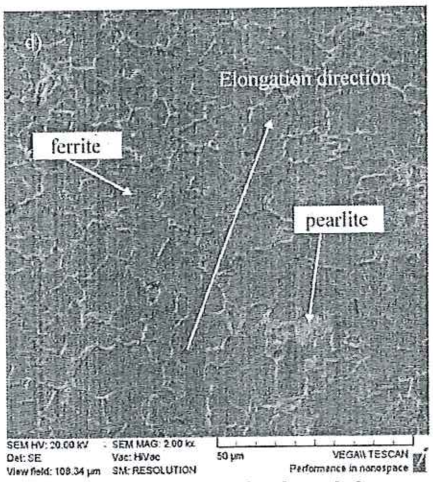


Fig.5. SEM micrographs of sample 2.

Fig.4a shows that microstructure of sample before cold deformation is homogenous ferrite-pearlite consisting of fine equiaxedferrite grains with nearly negligible volume fraction of pearlite. This is a commonly observed in hot rolled steels[5]. Fig.4b shows the same microstructure, but at the larger magnification (2000 x). It can be clearly seen that grains of ferrite are uniform, and that there is a small volume fraction of pearlite. Fig.5.a shows that microstructure of sample after cold deformation is also ferrite-pearlite, but also there is a visible a change of grains orientation. This could be better seen in Fig.5b at larger magnification. Namely, after a cold deformation ferrite grains are slightly elongated since during the deformation distortion of crystal lattice occurs. In the microstructure of sample 1, ferrite-pearlite band can be noticed. This feature has been observed in some other studies [5-7]. According to them, this banding occurs due to the microsegregation of alloying elements (Mn, Si, S, P), austenite grain size smaller than microchemical band spacing and slow cooling rate. Study [5] showed that 0.052 % of niobium is too much to lead to the formation ferrite-pearlite bands, but 0.02 % clearly results in these bands. Since in this work, steel is microalloyed with 0.048 % of niobium, it obviously enough to form ferrite-pearlite bands.

IV. CONCLUSIONS

Investigations of microstructure of low carbon steel microalloyed with 0,048 % Nb at start of the plastic flow conducted in this research showed that added fraction of niobium (0.048 %) is enough for the formation of the ferrite-pearlite bands in the microstructure of the studied steel. Further, there was a change in microstructure cause by cold deformation primarily in terms of elongation of grains.

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