Effects of preferred grain orientation on the on lüders bands appearance

Rešković, Stoja; Jandrlić, Ivan; Brlić, Tin; Vodopivec, Franz

Source / Izvornik: **Metalurgija, 2019, 59, 59 - 62**

Journal article, Published version
Rad u časopisu, Objavljena verzija rada (izdavačev PDF)

Permanent link / Trajna poveznica: https://urn.nsk.hr/urn:nbn:hr:115:484973

Rights / Prava: In copyright / Zaštićeno autorskim pravom.

Download date / Datum preuzimanja: **2024-07-23**

SVEUČILIŠTE U ZAGREBU
METALURŠKI FAKULTET
UNIVERSITY OF ZAGREB
FACULTY OF METALLURGY

Repository / Repozitorij:

Repository of Faculty of Metallurgy University of Zagreb - Repository of Faculty of Metallurgy University of Zagreb

DIGITALNI AKADEMSKI ARHIVI I REPOZITORIJI

S. REŠKOVIĆ, I. JANDRLIĆ, T. BRLIĆ, F. VODOPIVEC

ISSN 0543-5846
METABK 59(1) 59-62 (2020)
UDC – UDK 669.15:669.293:621.771-621.41:620.18=111

EFFECTS OF PREFERRED GRAIN ORIENTATION ON THE ON LÜDERS BANDS APPEARANCE

Received – Primljeno: 2019-05-29
Accepted – Prihvaćeno: 2019-08-15
Original Scientific Paper – Izvorni znanstveni rad

In this paper, the influence of preferential grain orientation was examined. Parallel tests were conducted on the samples from the same steel strip, taken in the direction and perpendicular to the direction of rolling the strip. Steel strip has a homogeneous fine-grained ferrite-pearlite microstructure. Using the methods of thermography it has been found that at the beginning of the plastic flow Lüders bands occur, pointing to the fact that the preferential grain orientation, in the case of steel with the fine-grained ferrite-pearlite microstructure, has no effect on the appearance of the Lüders bands.

Key words: microalloyed steel, niobium, rolling of strips, microstructure, Lüders band

INTRODUCTION

Niobium microalloyed steels have been developed in the second half of the last century. With the addition of very small quantities of the microalloying element and the proper selection of thermomechanical processing parameters at each stage, it is possible to produce steel with significantly better mechanical properties [1]. Niobium microalloyed steels have a fine ferrite-pearlite microstructure and very good mechanical and technological properties.

However, it has been noted that Lüders bands occur at subsequent cold deformation [2]. The appearance of non-homogeneous deformations, i.e. Lüders bands, represents the undesirable occurrence during metal forming. Therefore, intensive researches on Lüders bands were conducted on a variety of metallic materials, which are significant for the industry. Lüders bands were found a long time ago [3].

Later research on their appearance, linked them with the Cotler's atmospheres of carbon atoms [4]. However, the research methods at that time could not fully clarify the formation of the Lüders bands. With the development of digital technology, new methods have been discovered and existing ones were improved, so they could provide the information on how the Lüders bands are formed, and what affect the formation and propagation of Lüders bands. The methods of thermography with a static tensile test, are the most commonly used methods for research on Lüders bands [5,6]. In recent years, Lüders bands are again intensively being studied. It has been reported that Lüders bands occur in different metal materials such as steels [7], copper [8], and aluminum alloys [9]. The investigations were conducted on the influence of the sample thickness [10], strain, strain rate [11-15], chemical composition [16,17], and initial structure.

The numerous studies have been carried out on the influence of the initial structure on the appearance of Lüders bands [18-22]. Grain size has a significant influence on the appearance of Lüders bands [19]. They occur if the grain is less than 10 μm [20]. So far, the influence of the grain orientation on the appearance of the Lüders bands in steels has not been defined. With transmission electron microscopy (TEM) it is possible to determine the preferential orientation of the steel grain. Investigations on TRIP steel with a fine-grained structure have shown that, regardless of the direction of rolling, Lüders deformations occur after reaching the yielding point [21].

This paper investigates the influence of preferential grain orientation on the appearance of Lüders band in the cold deformation of hot-rolled steel strip from niobium microalloyed steel. Parallel tests were carried out on samples from same steel strip taken in the rolling direction and perpendicular to the rolling direction of the strip.

MATERIAL AND EXPERIMENTAL

Study was performed on low carbon steel, microalloyed with 0,048 % niobium. The chemical composition of steel is given in Table 1.

Table 1 **Chemical composition / wt. %**

C	Mn	Si	P, S	Al	Nb	N
0,12	0,78	0,18	<0,0018	0,02	0,048	0,008

Thermo-mechanical treatment was conducted and 370 × 3,0 mm strip was rolled. Metallographic analysis

S. Rešković (e-mail: reskovic@simet.hr, I. Jandrlić, T. Brlić. University of Zagreb, Faculty of Metallurgy, Sisak, Croatia, F. Vodopivec. Institute of Metals and Technology, Ljubljana, Slovenia

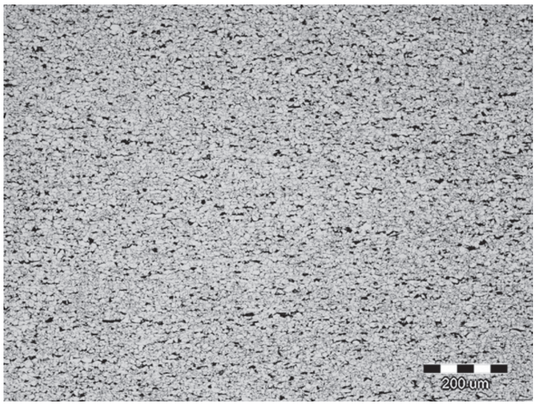
of the strip structure was performed in the direction and perpendicular to the rolling direction.

Also, the transmission electron microanalysis was carried out on the sample taken in the direction of the rolling. Samples for the investigation of the appearance of Lüders bands were also taken in the direction and perpendicular to the direction of rolling.

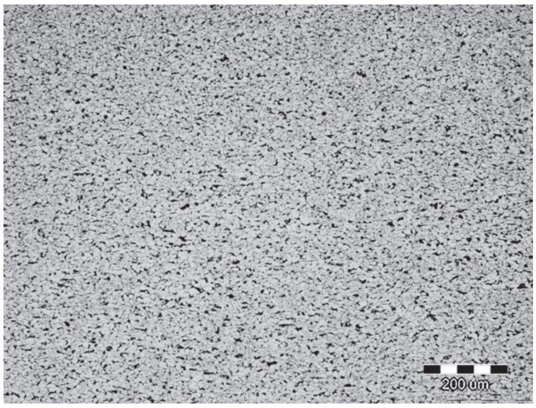
Tests were performed by metallographic analysis and transmission electron microanalysis (TEM) of the initial microstructure. The Lüders bands were investigated using thermography and digital image correction during static tensile test. Metallographic tests were performed on an optical microscope «Olympus DP70». TEM was carried out on one sample prepared by a foil method and tested on the JOEL transmission electron microscope at the electron acceleration of the 200 kV.

Samples for static tensile testing were sanded and the black matt coating with an emissivity factor of 0,95, was applied to them. The static tensile test was carried out on a Zwick 50 kN testing machine, at stretching rate of 10 mm/min.

Thermographic measurements were carried out with infrared camera VarioCAM® M82910, JENOPTIK. Before measuring, the temperature of the sample surface was measured with the contact thermometer P410, with the type K probe and the relative humidity was determined with the hydrometer. Then the camera was calibrated. Measured data was analyzed by the IRBIS 3 professional software package.



Rolling direction



Perpendicular to the rolling direction

Figure 1 Metallographic analysis of samples in the direction and perpendicular to the direction of rolling strip

RESULTS AND DISCUSSION

Results of metallographic analysis on the samples in the direction and perpendicular to the rolling direction of steel strip are on Figure 1.

From the Figure 1, it is apparent that the hot-rolled strip has a homogeneous fine-grain ferrite-pearlite microstructure, both in the direction and perpendicular to the rolling direction. Grains are approximately equal in size and less than 20 μm. Lesser structure orientation is observed in the samples taken perpendicular to the rolling direction.

Detailed research by transmission electron microanalysis on the recrystallization mechanisms, Figure 2, clearly shows that even after the cooling and phase transformation, a certain preferential orientation of the grain is present in the structure. This means that there is a certain degree of texture in the hot-rolled strip.

Figure 2 The orientation of grains after rolling of steel

It is noted that within small grains there is a high density of dislocation, which is confirmed in Figure 3. Within the grains there is a high density of dislocation, and they are in contact with precipitates.

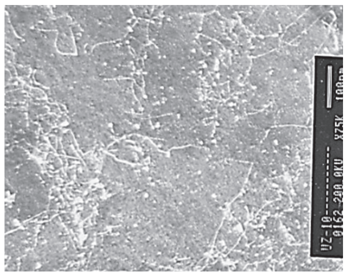
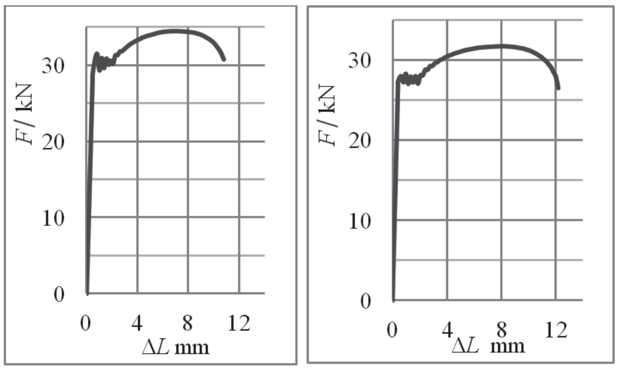


Figure 3 Precipitates and dislocations in steel [3]

Figure 4 shows the recorded force – elongation diagrams. At all samples, in the direction and perpendicular to the rolling direction, the non-homogeneous deformations are noted at the beginning of the material plastic flow. Table 2 shows the mechanical properties of the steel strip.

From Table 2 it can be concluded that the strip has homogeneous mechanical properties, both in the direction and perpendicular to the rolling direction.

The results of the research on the beginning of the plastic flow of steel by the method of thermography are shown in Figure 5.



In the direction | Perpendicular to the rolling direction

Figure 4 Metallographic analysis of the samples in the direction and perpendicular to the rolling direction

Table 2 **Mechanical properties of hot-rolled strip**

The direction of taking samples	R_p / MPa	R_m / MPa	Elongation / %
Rolling direction	552	591	25,52
Perpendicular to the rolling direction	577	634	24,55

The qualitative thermographic analysis clearly shows that in this steel, at the beginning of the plastic flow, the appearance and the propagation of the Lüders band is present. The appearance of Lüders bands was observed in all samples, regardless of the rolling direction, pointing to the fact that the orientation of the grains does not influence on the appearance of the Lüders bands.

Quantitative line analysis by thermography method shows that temperature changes are approximately equal, regardless of the direction of sampling.

When the Lüders band propagates through the entire deformation zone, the maximum temperature change behind Lüders's forehead was measured 5 °C. In the case of samples taken in the rolling direction, it is higher by 0,75 °C in relation to the measured temperatures on samples taken perpendicular to the rolling direction.

Although the conducted metallographic analysis shows the presence of the polygonal ferritic-perlitic grains in structure, it is expected that there is a certain degree of grain that is oriented. Measured differences in temperature changes may be associated with the very poorly expressed preferential grain orientation.

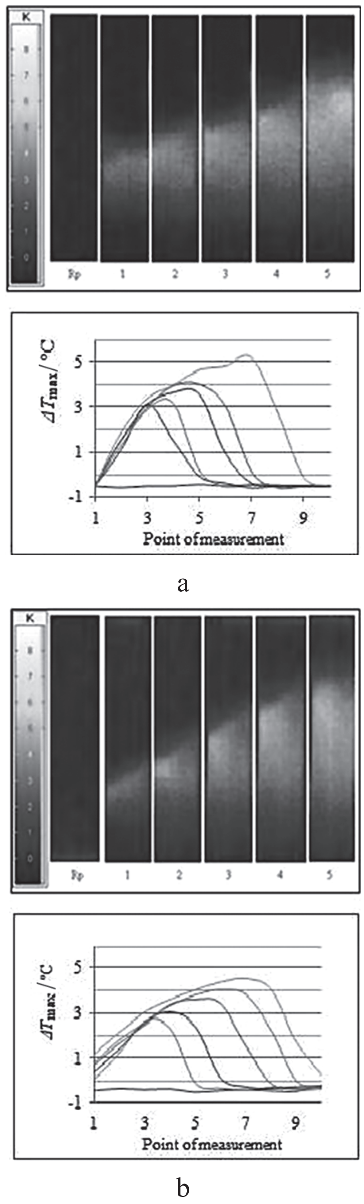


Figure 5 The appearance and propagation of Lüders bands at the beginning of the plastic flow of material: a) in rolling direction, b) perpendicular to rolling direction

A more detailed analysis of microstructure by the EBSD method will be able to clarify the observed small differences in amounts of the temperature and stresses behind the Lüders front.

CONCLUSION

From research it can be concluded that as far as the thermo-mechanical processing of the hot-rolled strip is properly carried out, it has a homogeneous fine-grain structure. The preferred orientation of the grain has no effect on the appearance of the Lüders bands. At the same testing conditions, Lüders bands appear evenly in the samples taken in the direction and perpendicularly on the rolling direction of the strip.

It was found that preferential grain orientation has a temperature change behind the Lüders front.

Acknowledgement

This work has been fully supported by the Croatian Science Foundation under the project IP-2016-06-1270.

LITERATURE

[1] F.Vodopivec, S. Rešković, I. Mamuzić, Materials Science and Technology 15(1999) 11, 1293-1299.

[2] J. Butler, Journal of the Mechanics and Physics of Solids, 10 (1962), 313-334.

[3] A.H. Cottrell, B.A. Bilby, Physical society 62 (1948), 49-61.

[4] X.G. Wang, V. Crupi, X.L. Guo, Y.G. Zhao, International Journal of Fatigue 32 (2010), 1970-1976.
[5] M. Eskandari, A. Zarei-Hanzaki, M. Yadegari, N. Soltani, A. Asghari, Optics and Lasers in Engineering 54 (2014), 79-87.
[6] Y. Liu, S. Kyriakides, J.F. Hallai, International Journal of Solids and Structures 72 (2015), 11-25.
[7] Y.Z. Tian, S. Gao, L.J. Zhao, S. Lu, R. Pippan, Z.F. Zhang, N. Tsuji, Scripta Materialia 142 (2018), 88-91.
[8] J. Coër, P.Y. Manach, H. Laurent, M.C. Oliveira, L.F. Menezes, Mechanics Research Communications 48 (2013), 1-7.
[9] Y.L. Cai, S.L. Yang, S.H. Fu, Q.C. Zhang, Experimental Observations, Metals 2016, 6 (2016), 120, doi: https://doi.org/10.3390/met6050120.
[10] J. Zhang, Y. Jiang, International Journal of Plasticity 21 (2005), 651-670.
[11] H.B. Sun, F. Yoshida, M. Ohmori, X. Ma, Materials Letters 57 (2003), 4535-4539.
[12] N. Tsuchida, Y. Tomota, K. Nagai, K. Fukaura, Scripta Materialia 54 (2006), 57-60.
[13] E. Cadoni, M. Dotta, D. Forni, P. Spatig, Journal of Nuclear Materials, 414 (2011), 360-366.
[14] W.S. Lee, C.Y. Liu, Materials Science and Engineering A, 426 (2006), 101-113.
[15] T. Brlić, S. Rešković, I. Jandrlić, Metals and Materials International, (2019), 1-9, https://doi.org/10.1007/s12540-019-00336-w.
[16] N. Srinivasan, N. Raghu, B. Venkatraman, Mechanics of Materials, 80 (2015), 27-36.
[17] V.S. Ananthan, E.O. Hall, Acta Metallurgica et Materialia, 39 (1991) 12, 3153-3160.
[18] D.H. Johnson, M.R. Edwards, P. Chard-Tuckey, Materials Science & Engineering A, 625 (2015), 36-45.
[19] R. Hutanu, L. Clapham, R.B. Rogge, Acta Materialia 53 (2005), 3517-3524.
[20] D.H. Johnson, Lüders bands in RPV steel, Cranfield University, 1-271, https://dspace.lib.cranfield.ac.uk.
[21] F.C. Beall, Encyclopedia of Materials: Science and Technology, 200., https://www.sciencedirect.com/topics/engineering/grain-orientation.
[22] X.G. Wang, C.H. Liu, B.B. He, C. Jiang, M.X. Huang, Materials Science & Engineering A 761 (2019) 138050, doi: https://doi.org/10.1016/j.msea.2019.138050.

Note: The responsible translator for the English language is Gabriela Gladović, Zagreb, Croatia