THE X2CrNiMo25-6-3 DUPLEX STEEL PLASTICITY - COMPLEMENTATION

STRADOMSKI Grzegorz

Technical University of Czestochowa, Faculty of Production Engineering and Materials Technology, Institute of Plastic Forming Processes and Safety Engineering, Częstochowa, Poland, EU, gstradomski@wip.pcz.pl

Abstract

Steels and other ferrous alloys are very well known as construction materials in many fields but still are widely used and in the near future this will not change [1-4]. Among the steel and cast steel resistant to corrosion most modern and dynamically developing group are ferritic-austenitic alloys, commonly known as duplex. Higher than austenitic steels, mechanical properties and good corrosion resistance in both overall and pitting make duplex steels irreplaceable material in the petrochemical industry, power, pulp and paper, food. Duplex steels and cast steels characterized by multiphase microstructure have a complex plasticity due the fact of deforming two different phase austenite and ferrite. The chemical composition of a steel containing about 0.02% C, 26% Cr, 6.5% Ni, 3% Mo, 1.4% Mn, 0.2% N guarantees that already, in the raw state, immediately after casting is obtained ferritic - austenitic structure. Because due to the fact that a substantial part of the problems associated with the production of duplex steels appears in the as cast state this state was taken as initial condition for the deformation process. In the paper [5] were presented discussed problems of the discussed steel plasticity. As the microstructure of the final product is affected, by three last deformation [6] in this paper are presented results different variant of deformation including three equal deformation 20%. In this article are presented results of microstructure changes and physical simulation of the rolling process carried out with the simulator Gleeble 3800.

Keywords: Duplex steel, innovative materials, plastic deformation, physical modeling, microstructure.

1. INTRODUCTION

The genesis and development of duplex steels is associated with the appearance of stainless steels in the early twentieth century. In UK in Sheffield was found that the addition of approximately 13% chromium causes electrochemical corrosion resistance. As a result, in the twenties 18-8 steels and in forties the first ferritic - austenitic duplex [7,8] appears. Due to the fact that these alloys are characterized by simultaneously high mechanical properties with high corrosion resistance. The main area of application of ferritic- austenitic steel and cast steel, also known as duplex are constructions and components subjected to high loads and environments conducive to stress corrosion, pitting and slitting. Under such conditions, these materials with comparable basic phases share ferrite and austenite, show better mechanical properties in comparison to conventionally used ferritic or austenitic steels. Currently, duplex stainless steels are used in many industries, not only in systems for desalination of sea water but also in the chemical industry, for example in the construction of storage tanks and vessels transporting the products with high chemical activity, eg. phosphoric acid, concentrated sulfuric acid, strongly alkaline media, or on the devices used in the petrochemical, power, pulp and paper or food [6-11].

2. MATERIAL AND METHODOLOGY OF RESEARCH

The object of the study was a ferritic - austenitic X2CrNiMoN25-6-3 cast steel, whose chemical composition is shown in **Table 1**. Cast steel was melted under industrial conditions in the medium frequency induction furnace of about 150 kg capacity. The material was cast in the Y-shaped sample with a 25.0 mm test wall thickness. Next were made rectangular, with dimensions of 10x15x20 mm, samples which were subjected to deformation using a Gleeble 3800 simulator. The **Fig. 1** are presented shape of cast and sample used during deformation tests. The microstructural analysis was made using an Nikon Eclipse Ma-200 optical microscope, on samples etched with the Mi21Fe reagent.

Table 1 The chemical compositions of tested material (mass%)

	C	Mn	Si	S	P	Cr	Ni	Mo	Cu	N
X2CrNiMoN25-6-3	0.021	1.46	0,93	0.012	0.008	26.70	6,48	3.10	0.02	0.23

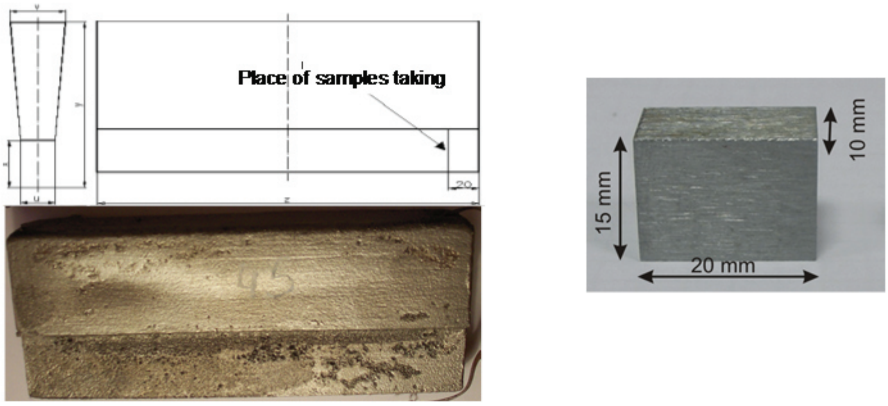


Fig. 1 Drawing of casting with the sinkhead and the appearance of the finished casting

Rectangular samples of duplex steel were deformed using a gleeble 3800 simulator. The obtained data were used to develop the material base [5] used during numerical calculations. Since during deformation of the samples was observed cracks for certain ranges of temperature and strain rate was made the evaluation of microstructure [5]. As a result, was observed significant concentrations of sigma phase in the areas of cracks. A certain amount of sigma phase was observed in the state as-cast (about 2.5%), but this amount does not exceed presented in literature "safe" amount of about 4-5% [9]. This phase is characterized by high tensile stresses 2 GPa, significantly contributes to the destruction of duplex steel microstructure. Therefore, advisable for the tested steel was to determine the parameters temperature - deformation at which evolution of that phase is observed. Based on earlier studies was determined that the deformation will be carried out according to the data presented in **Table 2**. In the **Fig. 2** are presented samples after testes.

Table 2 Range of temperature and applied deformation parameters used during research

Variant 1	850°C	$\dot{\varepsilon}=1.0s^{-1}$	ε_1= 0.2
Variant 2	1100°C	$\dot{\varepsilon}=1.0s^{-1}$	ε_1= ε_2= ε_3=0.2
Variant 3	850°C	$\dot{\varepsilon}=1.0s^{-1}$	ε_1= 0.2
Variant 4	1100°C	$\dot{\varepsilon}=1.0s^{-1}$	ε_1= ε_2= ε_3=0.2

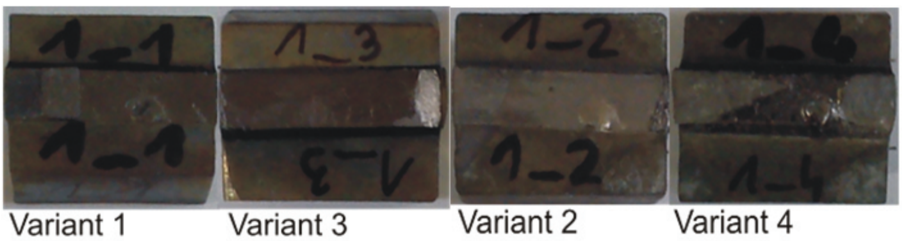


Fig. 2 The appearance of samples after deformation

3. RESULTS AND ANALYSIS

In paper [5] it was observed that the test material have a tendency to crack as a result of the deformation. Therefore, was made the microstructure analysis for the base material and after deformation. **Fig. 2** shows the results after the deformation ε = 1.3.

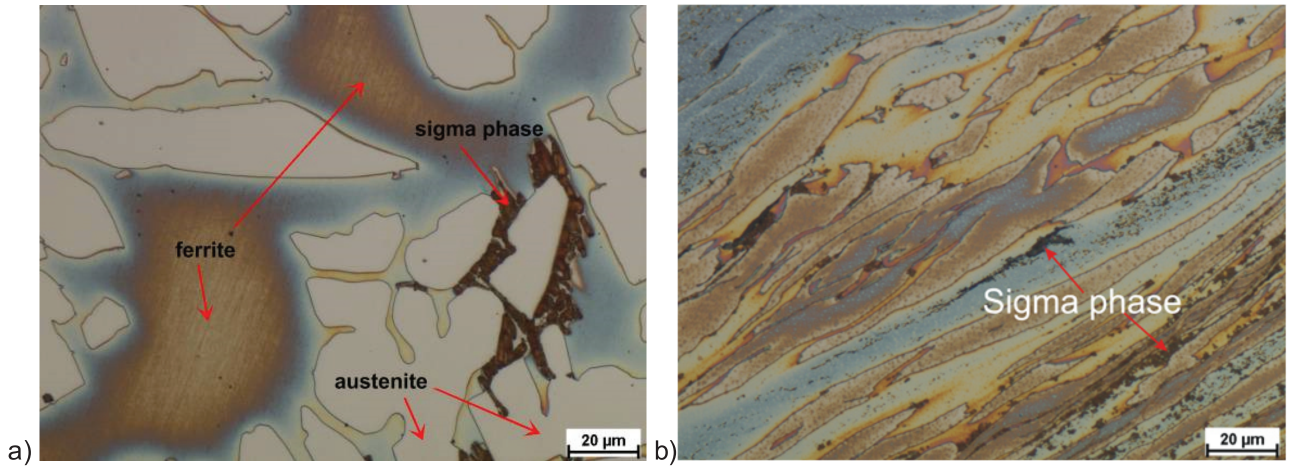
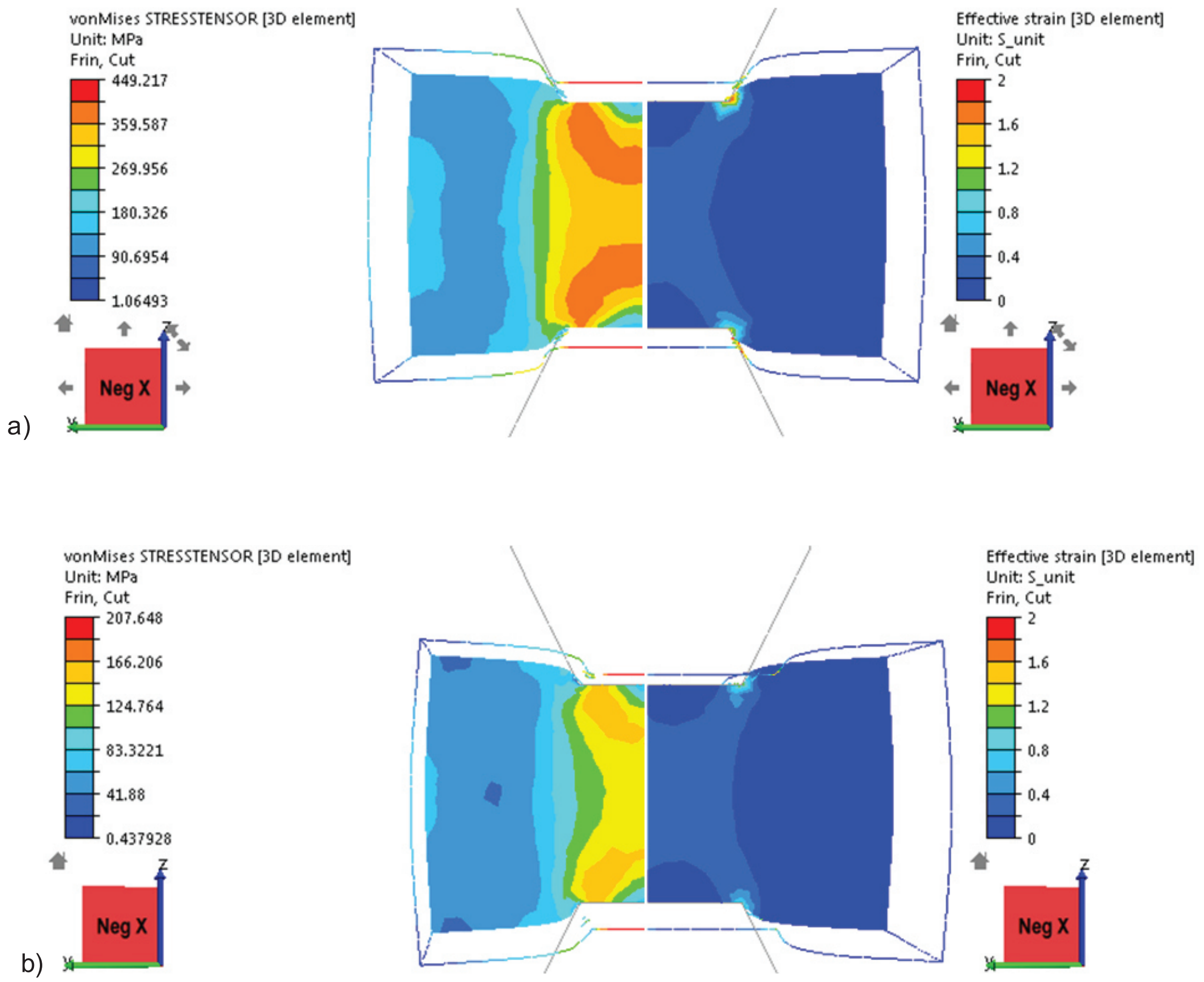
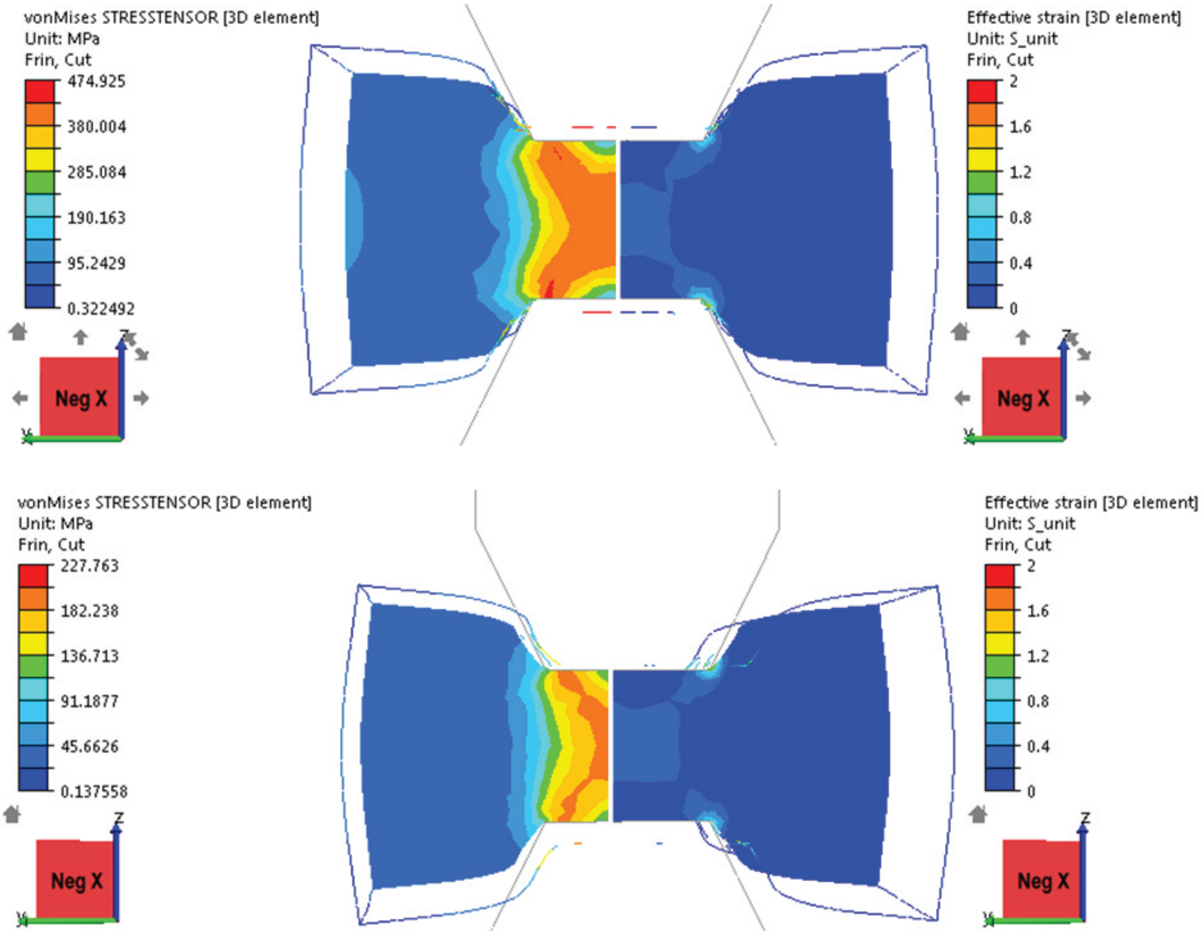


Fig. 3 Example of samples microstructures. a) Sample not deformed., b) Sample deformed sample deformed at 950 °C with strain rate 1.0 and ε=1.3

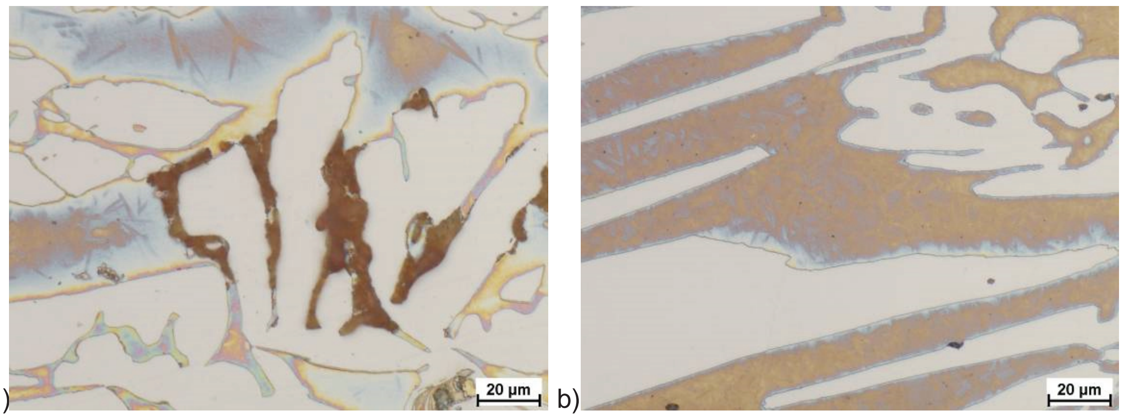




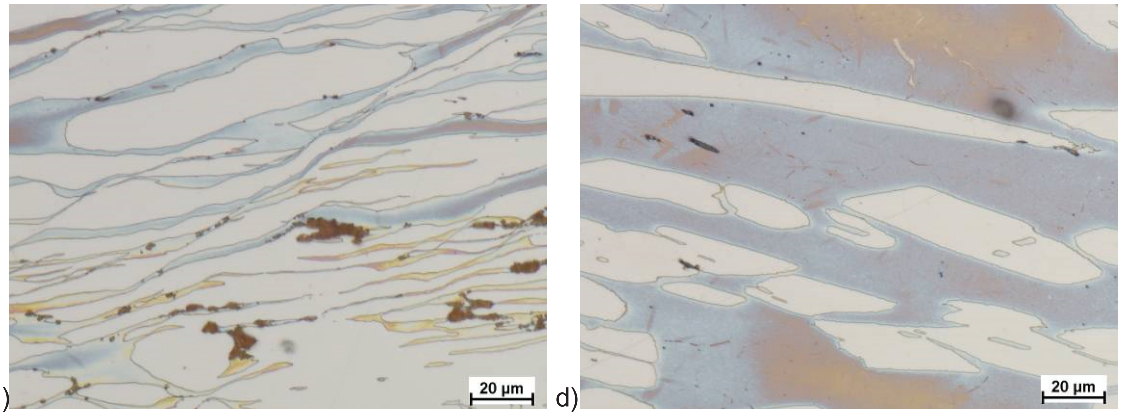
c)
d)

Fig. 4 The value of the intensity of stresses and effective strains for: a) variant 1, b) variant 2, c) variant 3, and d) variant 4

Due the fact that duplex steels have a complex formability and the problems observed during the tests were performed computer simulations of the process Hydrawedge. Numerical investigations were made using the Forge® and the results were used to evaluate the distribution of internal stresses and strains within the samples during deformation (**Fig. 4**). The data obtained in combination with the microstructure of samples allowed for easier identification of the observed phenomena.



a) b)



c) d)

Fig. 5 Microstructure of the tested steel after deformation: a) variant 1, b) variant 2, c) variant 3, d) variant 4

Due to the fact that, despite some up to about 2.5% of sigma phase in the starting material, was not observed any cracking of the samples, was performed an analysis of the microstructure presented in **Fig. 5**.

Numerical studies have shown that as the temperature drops significantly grow observed stresses in the material. Between the temperature 850°C and 1100°C is observed almost of twofold increase in stress intensity for both variant 1 and 2 and 3 and 4. The observed distributions in **X** arrangement of both studied parameters are important during assessment of area of microstructure changes. Assessment of the microstructure showed that as a result of deformation at 850°C are observed new embryos of sigma phase. Their size is very small about 2 microns and their distribution is always at the phase boundary ferrite - austenite. Secretion of sigma phase during the plastic forming was shown inter alia in [12, 13]. During deformation at 1100 °C, there was no sigma phase precipitations detected. What is important in material (deformed in 850 °C), despite the presence of sigma phase precipitations, after deformation of ε = 0.2 %, both single and three times, were not observed any cracks.

4. CONCLUSIONS

As a result of studies was observed an increased presence of sigma phase in the material after a significant deformation ε = 1.3 which according to the author was the reason for the appearance of cracks. In order to determine for the X2CrNiMoN25-6-3 steel temperature - deformation parameters for which the secretion of sigma phase appear was made the tests according to four variants (**Table 2**) by use of Gleeble 3800 simulator. For the given parameters was not observed any cracks.

The use of numerical analysis showed a significant, almost double increase of material's stresses and was identified the areas in samples from the physical simulation, with the strongest influence of deformation state on the microstructure. It was also found that there are significant differences in the formability of the tested steel according to the change of process temperature.

The microstructure analysis disclosed with the Mi21Fe reagent showed that the samples deformed at a temperature of 850 °C have at the borders of ferrite - austenite new sigma phase secretion not observed before. The size of precipitation was about 2 microns. The use of the strain rate of 1 s^{-1} strain ε = 0.2, even triple, for a material with a low 2.5 % of initial (generated during casting) sigma phase content did not generated cracks of samples. The sigma phase precipitation in the material deformed at 1100 °C was not observed. This suggests that during heating they were dissolved and during deformation at this temperature they do not appear.

REFERENCES

[1] LABER K., DYJA H., RYDZ D. Analytical and numerical methods of determining the distribution of temperature of air cooled strip. Metalurgija, Vol. 44, 2005, pp. 31-35.

[2] SZAREK A. Chosen Aspekts of Biomaterials. Publish. House Education and Science, 2011.

[3] MROZ S., SZOTA P., KOCZURKIEWICZ B. Modelling of rolling and cooling processes of the bulb bars HP220. NUMIFORM '07: Materials Processing and Design: Modeling, Simulation and Applications, Pts I and II Book Series: AIP CONFERENCE PROCEEDINGS, Vol. 908, 2007, pp. 1243-1248.

[4] BOROWIECKA-JAMROZEK J. Microstructure and Properties of Hot Pressed Fe-50 % Co Materials. In METAL 2013: 22nd Internat. Conf. on Metallurgy and Materials. Ostrava: TANGER, 2013, pp. 426-432.

[5] STRADOMSKI G. The assessment of the X2CrNiMo25-6-3 duplex steel plasticity. In METAL2014: 23rd Internat. l Confer. on Metallurgy and Materials. Ostrava, TANGER, 2014, pp. 425-430.

[6] KUZIAK R., PIETRZYK M. Zastosowanie nowoczesnych metod modelowania matematycznego do optymalizacji procesu walcowania blach na gorąco. Walcowanie i przetwórstwo blach i taśm. Poraj k. Częstochowy 1995.

[7] NOWACKI J. Stal dupleks w konstrukcjach spawanych. Wydawnictwo Naukowo-Techniczne Warszawa 2013.

[8] OLSSON J., SNIS M. Duplex - A new generation of stainless steels for desalination plants. Science Direct Desalination 205, 2007 p. 104-113.

[9] STRADOMSKI Z. Mikrostruktura w zagadnieniach zużycia staliw trudnościeralnych. Wydawnictwo Politechniki Częstochowskiej 2010.

[10] PACZYŃSKI P., STRADOMSKI G., KAWAŁEK A. Numeryczna oraz fizyczna analiza procesu symetrycznego walcowania blach grubych ze stali duplex 1.4462. Walcownictwo 2014, Ustroń 2014. pp. 21-26.

[11] STRADOMSKI G., SOIŃSKI M.S., NOWAK K., SZAREK A. The assessment of tendency to develop hot cracks in the duplex casts. Steel Research International 2012, pp. 1231-1234.

[12] TEHOVNIK F., ARZENSEK B., ARH B., SKOBIR D., PIRNAR B., ZUZEK B. Microstructure evolution in SAF 2507 super duplex stainless steel. Materials and Technology, Vol. 4, 2011, pp. 339-345.

[13] CHIH-CHUN H., DONG-YIH L., WEITE W. Precipitation behavior of σ phase in 19Cr-9Ni-2Mn and 18Cr-0.75Si stainless steels hot-rolled at 800°C with various reduction ratios. Materials Science and Engineering, Vo. 467A, 2007, pp. 181-189.