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IMPACT OF SOLUTION ANNEALING ON PROPERTIES OF DUPLEX STEEL

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ABSTRACT

This paper deals with the impact of solution annealing on properties of X2CrNiMoN2253 duplex steel. Experimental specimens were 100×100×150 mm forged and air-cooled pieces, which were solution-annealed at several temperatures changed in 20 °C steps between 1020 and 1120 °C.

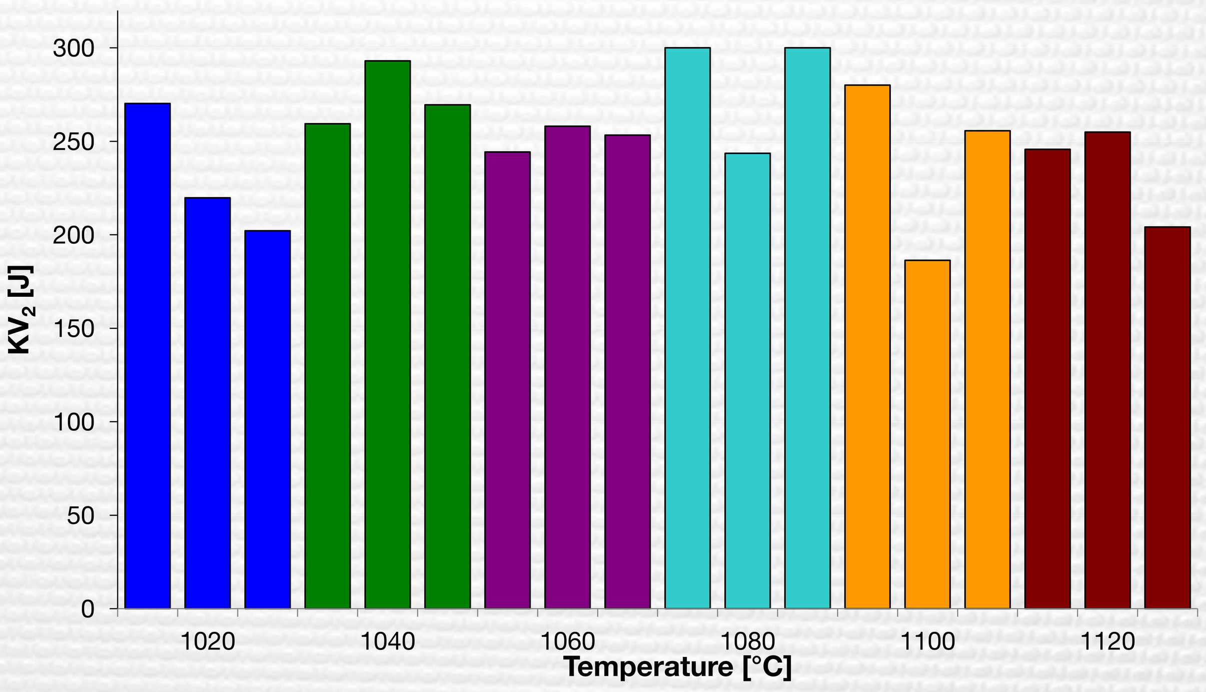
Mechanical tests conducted on these processed specimens included a tension test and Charpy impact tests at room temperature and at -46 °C. The results were compared with data stipulated in EN10088-3 standard and with minimum requirements for X2CrNiMoN2253 forgings for onshore oil and gas extraction according to technical delivery specifications. Microstructure of the specimens was explored using optical and electron microscopes and EBSD analysis.

EBSD measurement showed significant ferrite texture in some specimens, whereas no signs of texture were detected in austenite in any samples. The causes of the ferrite texture were investigated and its impact on properties of the duplex steel was explored.

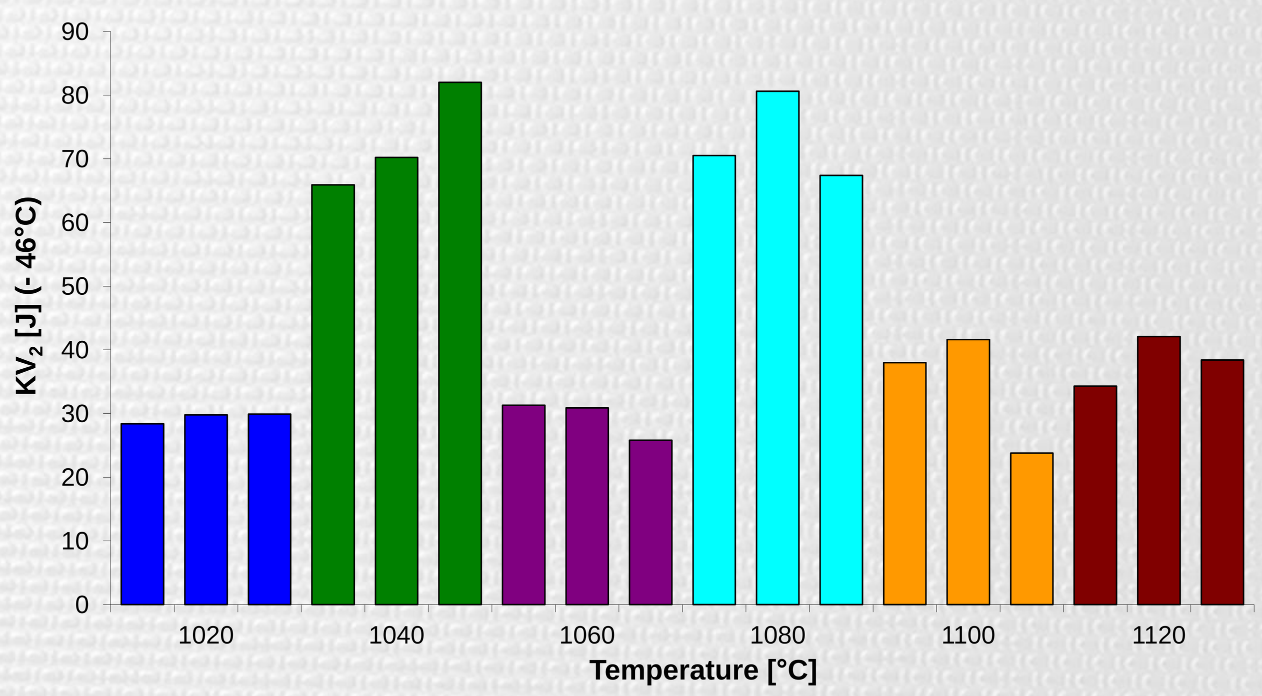
MECHANICAL PROPERTIES

Mechanical properties established by tensile and impact tests, depending on the solution annealing temperature do not differ markedly. From the comparison of the observed mechanical values and minimum values required by EN100088-3 standard it follows that all the observed mechanical values sufficiently exceed the required values.

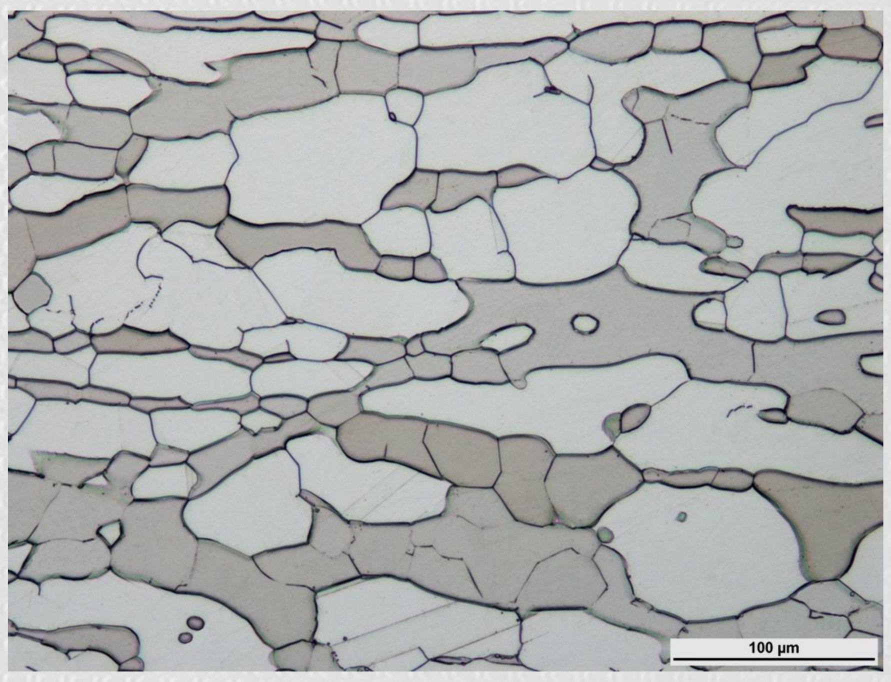
The results of Charpy impact test at reduced temperature of -46 °C differ considerably in dependence on the annealing temperature. At 1020, 1060, 1100 and 1120 ° C the measured values are very low, they do not reach even half values obtained at samples with temperatures of 1040 and 1080 ° C and they do not meet the requirements specified in customer technical delivery conditions (TDC).



Results of Charpy impact test at room temperature



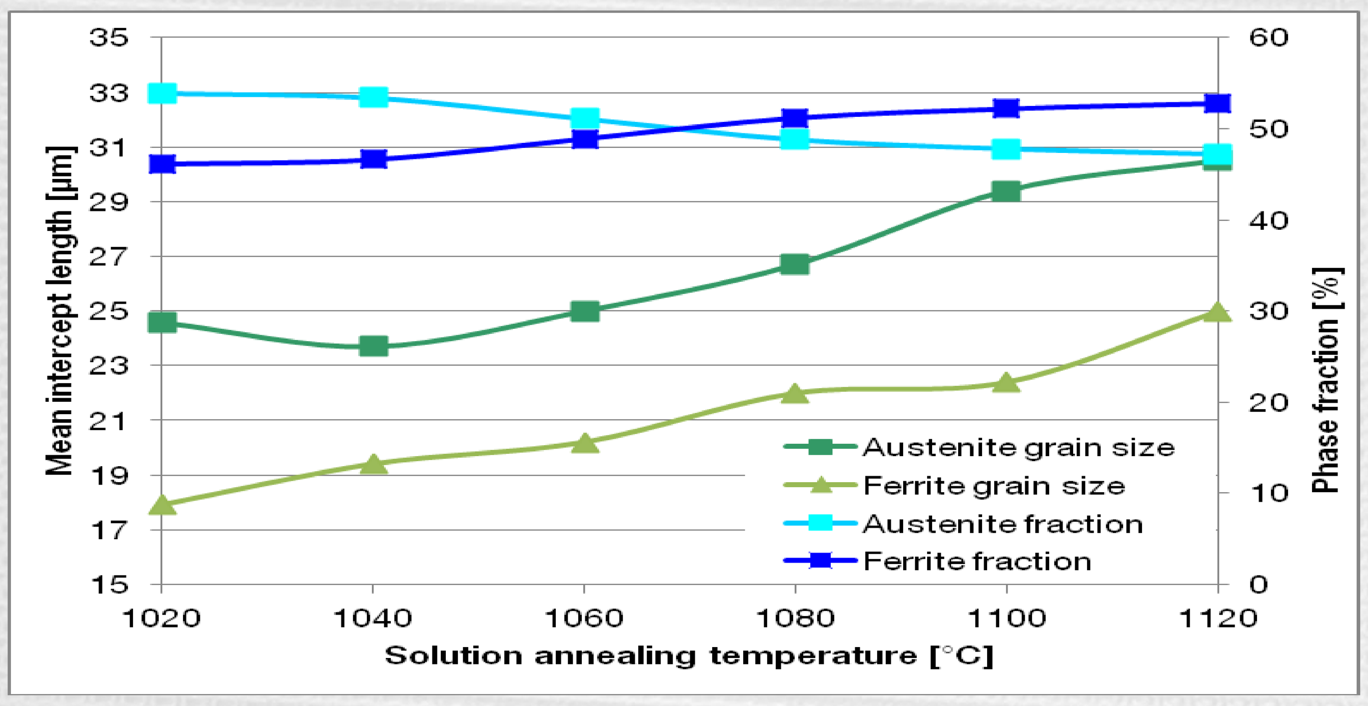
Results of Charpy impact test at -46°C



Micrograph of the specimen annealed at 1100 °C upon etching with 60 % nitric acid

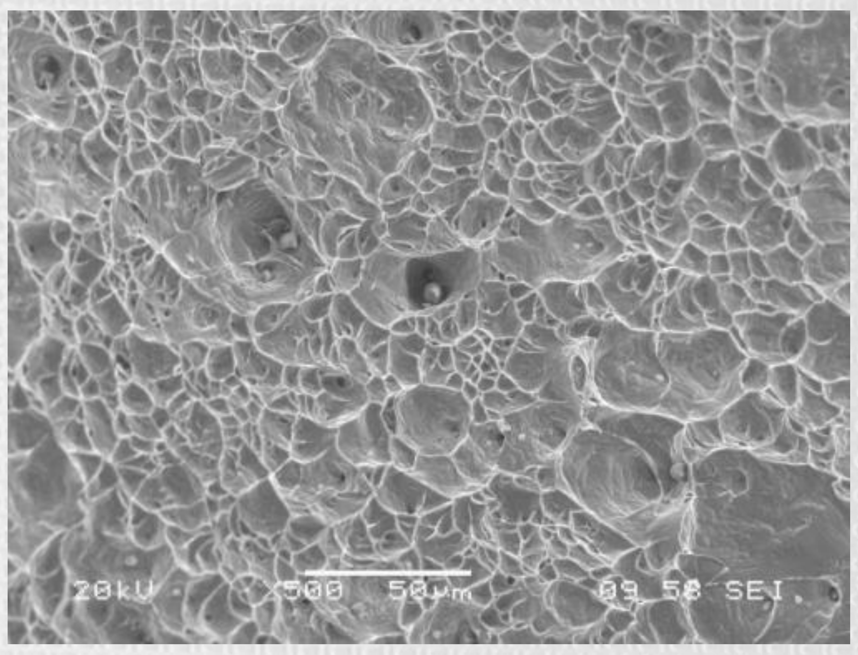
METALLOGRAPHIC ANALYSIS

From the results of evaluation of grain size and phases proportion in the annealed samples it follows that the grain size of both the austenite and ferrite increases when solution annealing temperature grows up. This growth is, however, very small, just by one G grade at ferrite and a half G grade at austenite. With the increasing solution annealing temperature the proportion of austenite in the microstructure also declined and thereby the proportion of ferrite increased. All the established microstructural changes caused by different annealing temperature were slight.

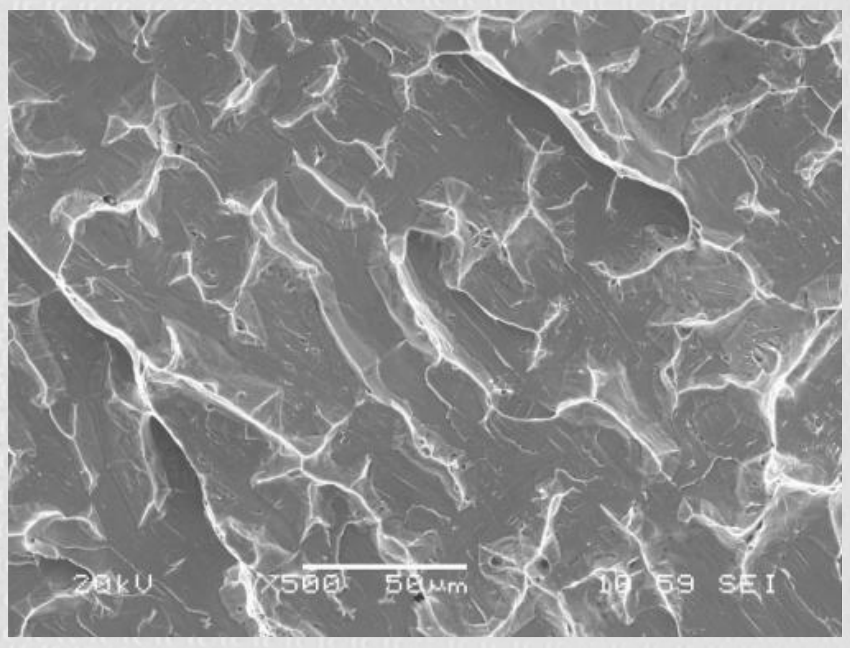


For samples where low values of impact energy were measured at -46°C, a strongly developed texture of ferrite was found, and austenite did not show the texture. Therefore the ferrite texture, at these samples prepared in the longitudinal forming direction initiates the formation of brittle fracture, because ferrite cleavage planes are parallel to the plane of crack propagation. In samples of duplex steels annealed for 1080 and 1040 ° C neither ferrite nor austenite structure was observed.

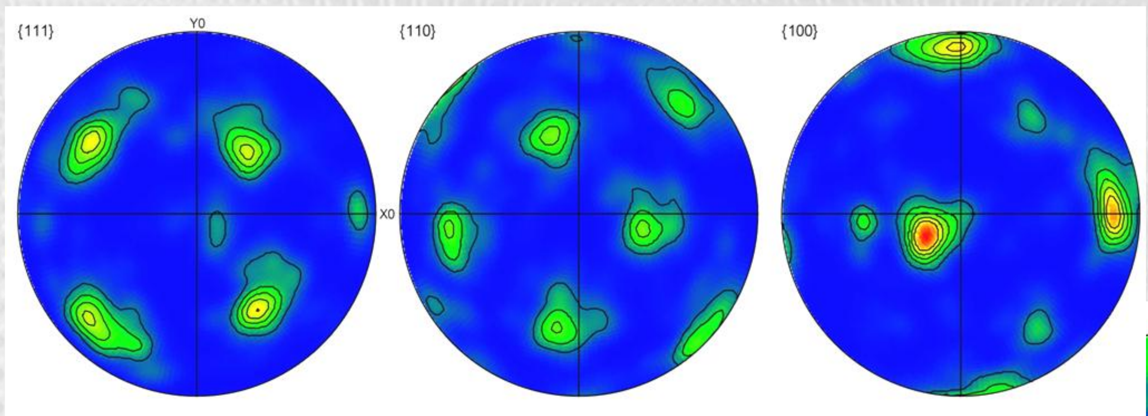
A mixed transcrystalline fracture (areas of both ductile and brittle failure can be found) occured on the fracture surface of samples where low values of impact energy were measured at reduced temperature of -46 ° C. However, unequivocally the prevailing mechanism is a fragile transcrystalline disruption. The fracture at 1040 and 1080 samples is also mixed transcrystalline, but unlike the previous samples areas of ductile fracture are larger. The proportion of ductile and brittle fracture at the fracture area is a crucial factor that affects the achieved values of impact energy.

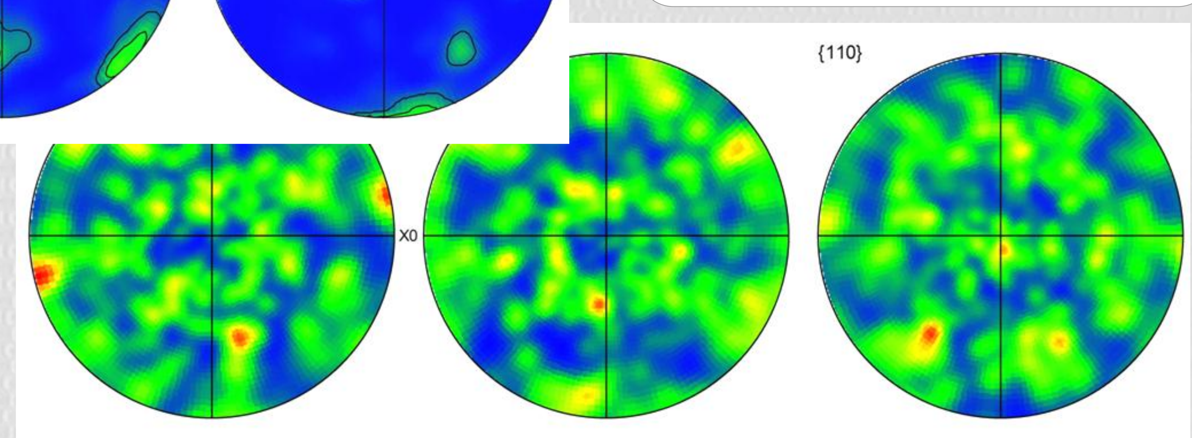


Fracture area of transcrystalline ductile fracture



Fracture area of transcrystalline brittle fracture





Pole figure of ferrite and austenite orientation

CONCLUSION

- Mechanical properties satisfy the requirements of EN100088-3 at room temperature
- The results of Charpy impact test at reduced temperature do not meet the requirements specified in customer technical delivery conditions (TDC)
- The temperature height of solution annealing had a low influence on the steel microstructure
- At samples which did not satisfy the requirements of TDP the thick texture was found in ferrite while in austenite the texture was not observed
- The texture of ferrite was probably the cause of the unsatisfactory impact toughness values at lower temperature

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