COMPARISON OF TRANSFORMATION DIAGRAMS OF SEAMLESS TUBES STEELS (4130, X70, P620Q)

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Abstract

Comparison of (D)CCT diagram of studied steels. Selected steels are used for manufacturing seamless tubes. Compared materials are steels 4130, X70 and P620Q. Diagrams were compared based on phases and their position. Metallographic analysis and hardness measurements were also made. Main focus of the study was dilatometric tests with(DCCT) and without(CCT) previous deformation. Third set of tests were performed to evaluate the effect of high austenitization temperature on resulting structure. Samples were heated with a constant rate to austenitisation temperature and then cooled with selected cooling rates in case of CCT and deformed before cooling in case of DCCT. Effects of the high austenitization temperature were much larger than that of deformation alone. Hardness tests showed very similar values for the samples with a deformation difference and more significant difference in the case of high austenitization temperature. Tests were made on plastometer Gleeble 3800 with optical module in VSB-Technical University of Ostrava.

Keywords: Seamless tubes, dilatometric tests, 4130, X70, P620Q

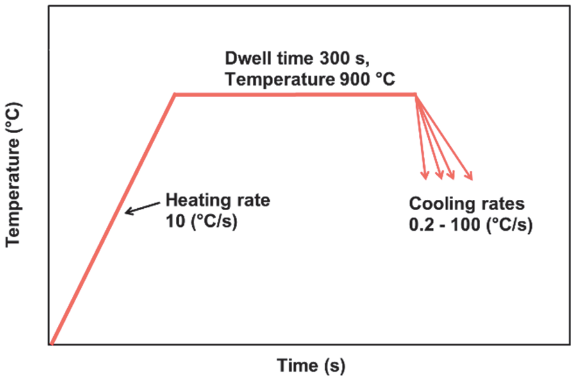
1. INTRODUCTION

Controlling of the thermo-mechanical parameters can increase the effectiveness of forming of selected types of steel, which are connected with austenite transformations. The biggest role has the chemical composition of the steel, but the combination of deformation size and chosen temperature of deformation can highly influence thermo-mechanical parameters. Conditions of cooling, especially a cooling rate, a size of the austenitic grain and previous deformation can however play indispensable role with regards to the resulting structure. Transformation diagrams of CCT type (Continuously Cooling Transformation), respectively DCCT (Deformation Continuously Cooling Transformation) can provide valuable information on resulting structure and its composition [1-6].

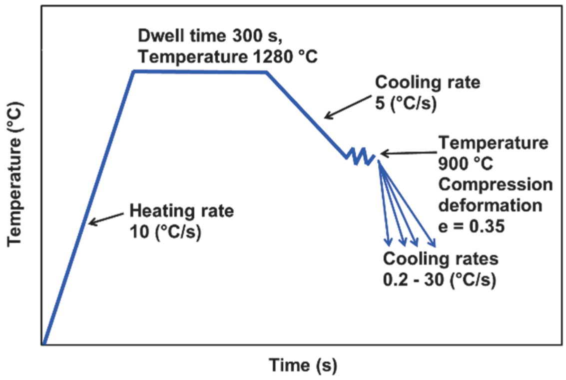
The subject of this contribution was to compare CCT diagrams of three steels used for seamless tubes manufacturing and the influence of deformation and high austenitization temperature. Chemical composition of steel X70 is specific: 0.16 C - 1.05 Mn - 0.20 Si - 0.19 Cr - 0.031 Nb - 0.046 V - 0.0093 N (in wt%). The steel 25CrMo4(4130) consist of 0.2-0.31 C - 0.56-0.94 Mn - ≥0.43 Si - ≥0.03 P - ≥0.04 S - 0.85-1.25 Cr - 0.12-0.33 Mo (in wt%). Last studied steel P620Q has a chemical composition of 0.2 C - 0.6 Si - 1-1.7 Mn - 0.8 Ni - 0.025 - P 0.02 S - 0.3 Cr - 0.1 Mo - 0.2 V - 0.02 N - 0.05 Nb - 0.04 Ti - 0.02 Al - 0.3 Cu - 0.22 > Nb+Ti+V (in wt%) according to norm EN 10 216-3 [7-9].

2. EXPERIMENTS

Samples of Ø 6 x 86 mm were used for dilatometric test after austenitization at 900 °C (1173K) / 180 s and 1280 °C (1553K) / 300 s. On **Figure 1** there are examples of the models of the dilatometric tests. Samples were heated up to austenitization temperature with a heating rate of 10 °C/s and than stayed at that temperature for 180 s or 300 s depending on the mode of the diagram. After the dwell time there was cooling phase before the deformation for the high austenitization samples. In the case of CCT diagrams, they were cooled immediately after the dwell time. The DCCT diagrams were all deformed with a size of e=0.35 and deformation rate of 1 s^{-1} at 900 °C and than cooled.



a) Mode of dilatometric tests - CCT diagram



b) Mode of dilatometric tests - DCCT diagram

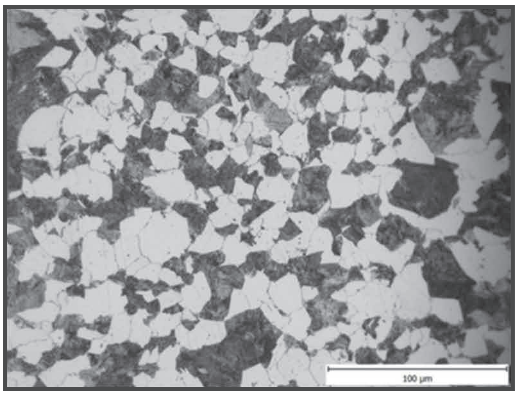
Figure 1 Examples of the modes of the dilatometric tests for the creation of transformation diagrams [8]

For CCT diagrams the cooling rates were in larger interval because of modified samples with hollow ends that enabled higher cooling rates due to additional cooling. Metallographical analyses and hardness measurements were made for selected samples to confirm the results of dilatometric tests. All dilatometric tests were analyzed with the use of CCT Software.

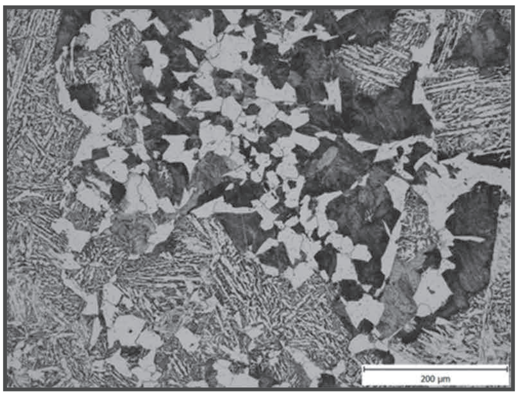
3. DISCUSSION OF RESULTS

3.1. 25CrMo4 (4130)

Comparison of two metallographical analysis of same cooling rate, with a difference in austenitization temperature and deformation is shown in **Figure 2.**



CCT with cooling rate - 0.2 °C/s



DCCT with cooling rate - 0.2 °C/s

Figure 2 Microstructures of samples with a difference in austenitization and deformation (4130)[8]

In case of CCT mode and the cooling rate of 0.2 °C/s, the whole structure is created by polyedric ferrite and pearlite. Sample that undergone high temperature austenitization and deformation had structure represented by shares of ferrite, pearlite and a mixture of bainite with acicular ferrite. It is known that origination of acicular ferrite is connected with the initial coarse-grain austenitic structure caused by higher austenitization temperature.

A comparative diagram shown in **Figure 3** was compiled for the detection of influence of the combination of high-temperature heating and consequential deformation, which combines both CCT and DCCT variants. Curves have changed due to the high austenitization temperature and deformation. Biggest change in case of DCCT was for pearlite and ferrite curves that moved to lower temperatures and slower cooling rates. Changes were also in the area of bainite (a mixture of bainite and acicular ferrite); this area was extended in the DCCT diagram up to the lower cooling rates as shown on **Figures 3 and 2. Figure 4** shows the results of hardness measurements. The results show expected trend due to the higher ratio of bainite and acicular ferrite in the structure of samples with higher austenitization temperature.

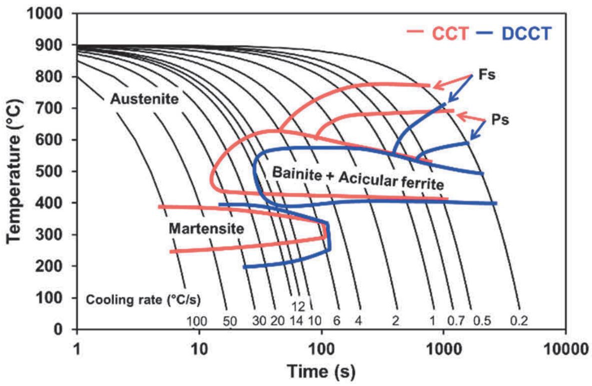


Figure 3 Comparison of CCT and DCCT diagrams of steel 25CrMo4 (4130) [8]

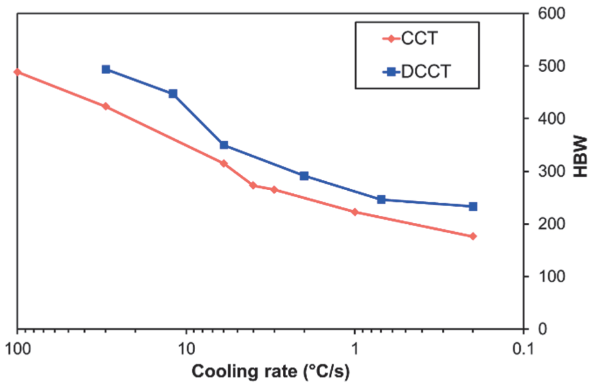


Figure 4 Comparison of influence of a combination of high-temperature heating and deformation to the HBW hardness values [8]

3.2. X70

For this steel were made two comparative diagrams for better readability. On **Figure 5** we can see that the effect of the previous deformation on the individual phase transformations after austenitization at 1173K(900 °C) is rather small. Deformation alone didn´t have significant impact on the steel X70. The situation illustrated in **Figure 6** shows dilatometric curves with different austenitization temperature. Main difference is in the ferrite area, which for higher cooling rates dropped to much lower temperatures. Also the bainite area was in the case of high austenitization temperature and deformation smaller compared to the other variants.

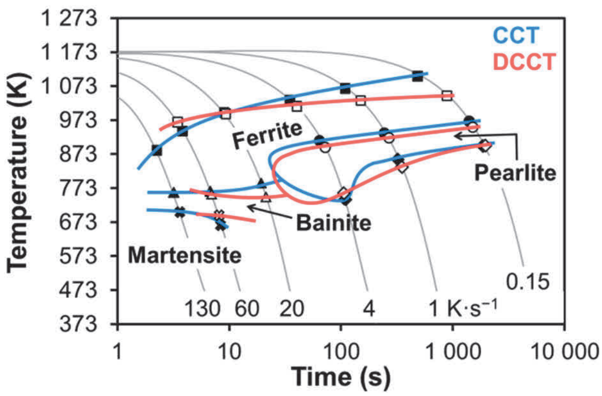


Figure 5 Comparison of transformation diagrams after austenitization temperature of 1173 K [9]

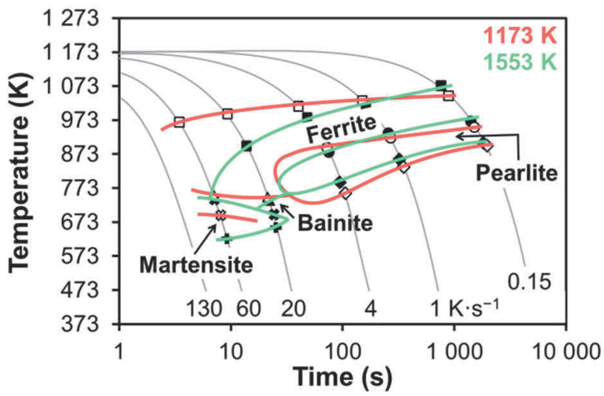


Figure 6 The effect on the preheating temperature and the initial structure on transformation temperatures [9]

Firure 7 shows the measured hardness of selected samples of steel X70. Results shows that CCT and DCCT diagrams for 900 °C (1173 K) are very alike, as were the coresponding transformation diagrams. The DCCT diagram for higher temperature however shows significant increase in hardness.

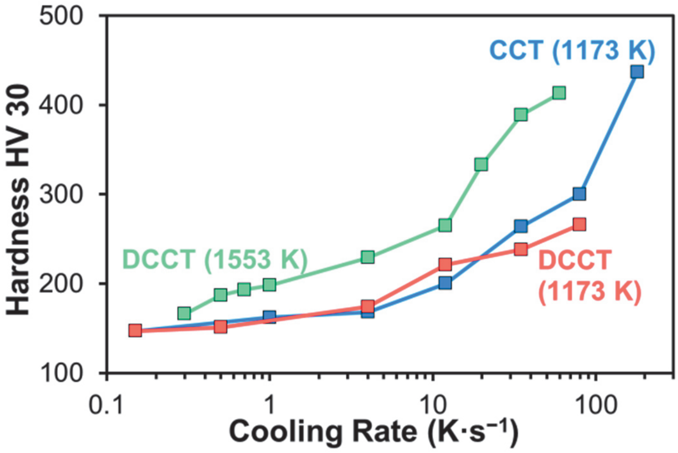


Figure 7 Comparison of hardness of the samples corresponding to three transformation diagrams [9]

3.3. P620Q

On **Figures 8 and 9** there are transformation diagrams of steel P620Q compared to each other. On **Figure 8** it is comparison with a difference in deformation and on **Figure 9** is the difference the austenitization temperature. The deformation had very similar effect as in previous steel, ferrite and pearlite curves shifted to lower temperatures for slow cooling rates and to higher temperatures for faster cooling rates. Bainite and martensite were both shifted towards lower temperature.

Difference in austenitization temperature shifted ferrite curve to much lower temperatures in region of high cooling rates. Pearlite shifted also, but not as much as ferrite. The curve for bainite was not detected and the martensite start was shifted to higher temperatures, which is opposite behaviour that in other two steels described in this paper. High austenitization temperature probably made coarse grains that transformed into acicular ferrite instead of bainite.

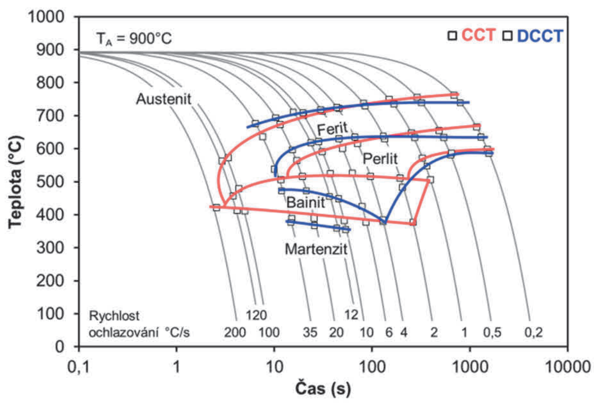


Figure 8 Comparison of CCT and DCCT diagrams same austenitization temperature (900 °C) [10]

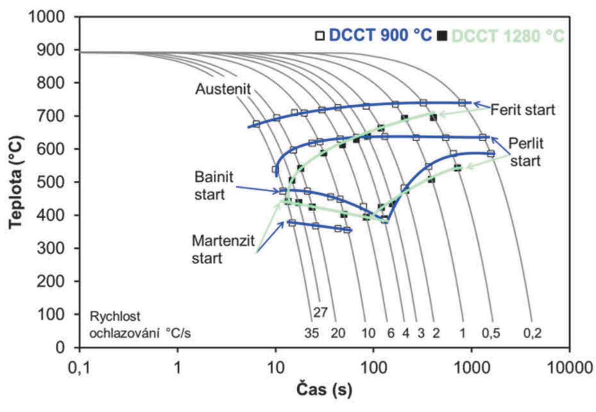


Figure 9 Comparison of DCCT (T_A=900 °C) and DCCT (T_A=1280 °C) diagrams [10]

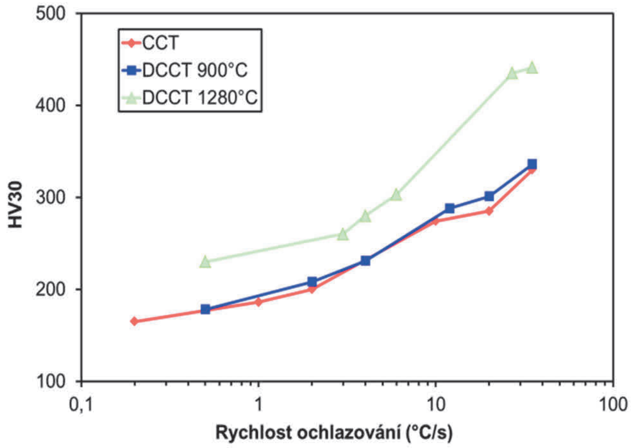


Figure 10 Graph of hardness tests results[10]

Figure 10 is showing the results of hardness tests for steel P620Q. As expected, the results correspond to the transformation diagram. CCT and DCCT diagrams with austenitization at 900 °C have similar hardness as it was in two other cases in this paper. The high austenitization temperature caused increase in hardness with a bigger difference in higher cooling rates due to the shift of martensite to higher temperatures.

4. CONCLUSION

This paper was made to compare transformation curves of three steels according to deformation and high austenitization temperature. All the steels behaved very alike, except for bainite and martensite curves for the P620Q steel. The curve for martensite shifted towards higher temperatures unlike the other studied steels in this paper and the bainite was not detected at all. That could be caused by coarse grains after high austenitization temperature. In this setting the steel probably favors the transformation to acicular ferrite rather than to bainite. Hardness tests confirmed the transformation cureves. Hardnesses of CCT and DCCT with austenitization at 900 °C were almost similar and the DCCT with austenitization at 1280 °C had higher hardness and not only slightly.

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