INFLUENCE OF CHEMICAL CONTENT OF STEELS ON THE MS AND MF TEMPERATURES

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Abstract

5 types of steel, which were differently alloyed with chromium, molybdenum and nickel, were examined. Determination of the temperatures martensite start temperature (Ms) and martensite finish (Mf) was performed by dilatometer with the use of the plastometer GLEEBLE 3800 and relevant CCT evaluation software. In all the steels alloyed with chromium and optionally with molybdenum it was possible to graphically localise the temperature, at which the curves Ms and Mf meet. The addition of nickel dramatically changes the situation, because at low cooling rates the martensitic area is very smoothly followed by bainitic region and determination of their boundaries is difficult. Determination of the temperatures Ms and Mf is important for the exact setting of refinement processes.

Keywords: Dilatometric test, Gleeble 3800, martensitic transformation temperature

1. INTRODUCTION

The quality of the heat treatment of steel depends largely on the ability of prediction of the parameters of steel in dependence on the aggregate input information on the processed steel. One of the most valuable parameters is the martensite start temperature Ms, at which the super-cooled austenite begins to transform to martensite. This parameter is primarily dependent on the chemical composition of the steel. The temperature of the beginning of the transformation is reduced by all the elements dissolved in austenite, with the exception of aluminium and cobalt. Manganese is the most effective element reducing the Ms temperature. Apart from the content of alloying elements, an important role is also played by the carbon content. The temperature of the start of martensitic transformation is again significantly reduced by the increasing carbon content. The increasing carbon content moreover reduces the Mf temperature of finish of martensitic transformation, even more sharply than in the case of the Ms temperature. This causes that increase of the carbon content causes an expansion of the martensitic area. The position of the Ms temperature is also affected by the size of the austenite grains. Larger austenitic grain promotes martensitic transformation by an increase of the temperature of its start Ms. This means that the higher the austenitization temperature, and the longer the dwell at this temperature, that bigger increase of austenitic grain, and thus the increase of the Ms temperature [1, 2].

Prediction of the Ms temperature can be performed on the basis of the calculation according to various linear or non-linear empirical relationships. However, these equations find their use always only for specific types of steel, which are limited by their chemical composition [3, 4]. Measurements of the Ms temperature is not a common practice and it is quite challenging. Dilatometric measurements are widely used, the output of which is not only the Ms temperature but complex CCT diagrams [5-9].

2. EXPERIMENT

Dilatometric tests on the GLEEBLE 3800 make it possible to determine the temperatures of phase transformations and to build isothermal and anisothermal decay diagrams of the material [10]. The highest heating temperature, in this case, is 1400 °C, provided that the dwell at this temperature does not exceed 30 seconds. The maximum cooling rate depends on the type of used sample. Two basic types of samples are used for dilatometric tests. Solid rods with a diameter of 6 mm are used for low-speed cooling. In our case, we used the second type of samples with hollow head parts, which are used primarily for dilatometric analyses without the influence of the previous deformation, but thanks to their special design and shape they allow the use of higher cooling rates of the order of even 10^2 °C·s^{-1}. The shape of the sample can be seen in **Figure 1**.

Figure 1 Shape of the sample for dilatometry, suitable for higher cooling rates

The results are processed by the specialised software CCT, which is used for evaluation of dilatometric tests and for the subsequent construction of transformation diagrams. The CCT software works in the background of the evaluation software ORIGIN. The construction itself of transformation diagrams takes place on the basis of determination and plotting of the points of individual transformations into the diagram of the temperature dependence on time for individual cooling modes. The determination of the actual point of transformation from the obtained dilatation cooling curves can be generally be performed in several ways. The method of tangents and derivation of the obtained cooling curves is the most commonly used method. **Figure 2** presents an example of the analysed dilatation curve.

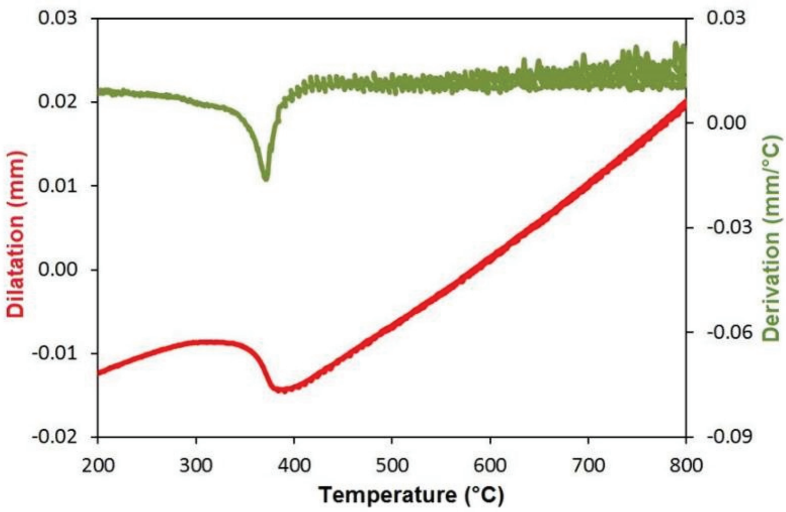

Figure 2 Dilatation at cooling of the sample from the steel 25CrMo(S)4 at the cooling rate of 50 °C/s and the first derivation of the relevant curve in dependence on the temperature

5 types of steel, which differed by their chemical composition, were examined. Material from the steels 25CrMo(S)4, 30CrNiMo8, 34CrMo(S)4, 34CrNiMo6 and 41Cr(S)4 was supplied in the form of rolled rods with a diameter 20 mm up to 52 mm. **Table 1** presents their chemical composition.

Table 1 Chemical composition of the investigated steels in wt. %

Steel	25CrMo(S)4	30CrNiMo8	34CrMo(S)4	34CrNiMo6	41Cr(S)4
C	0.22 - 0.29	0.26 - 0.34	0.3 - 0.37	0.3 - 0.38	0.38 - 0.45
Mn	0.6 - 0.9	0.5 - 0.8	0.6 - 0.9	0.5 - 0.8	0.6 - 0.9
max Si	0.4	0.4	0.4	0.4	0.4
Cr	0.9 - 1.2	1.8 - 2.2	0.9 - 1.2	1.3 - 1.7	0.9 - 1.2
Ni	-	1.8 - 2.2	-	1.3 - 1.7	-
Mo	0.15 - 0.3	0.3 - 0.5	0.15 - 0.3	0.15 - 0.3	-

Round rods with a diameter of 52 mm (steel 34CrMoS4) were longitudinally cut into four equal segments and hollow samples for dilatometry were manufactured from them by turning (see **Figure 1**). Dilatometric samples from other steels (rods of smaller diameters) were turned from the rods with a diameter of 15.8 mm, which were produced by rolling at the laboratory reversing rolling mill stand with the max. diameter of rolls of 350 mm and with the gauge flat oval - circle [11]. Rolled products from the steels 30CrNiMo8 and 34CrNiMo6 had to be annealed prior to machining by soft annealing (690 °C / 2 hours / cooling in the furnace).

Determination of the temperatures martensite start (Ms) and martensite finish (Mf) was performed by the dilatometric method. All the samples were heated to the austenitizing temperature of 850 °C at the heating rate of 10 °C/s. Dwell at this temperature was 180 seconds, and it was then followed by cooling at the selected cooling rate to the temperature of 25 °C.

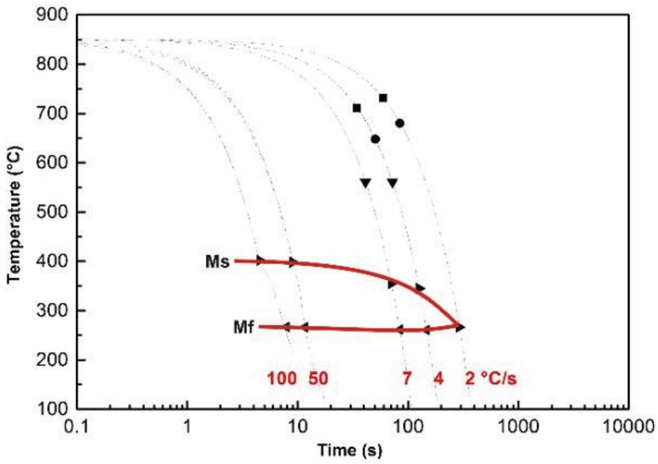

Figure 3 Curves Ms and Mf determined by dilatometer for the steel 25CrMo(S)4

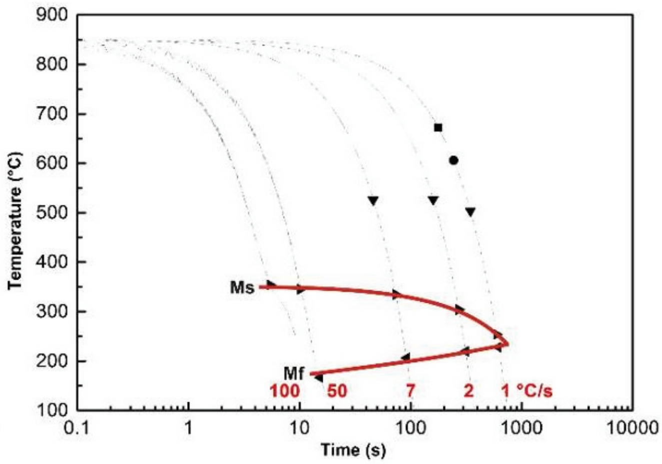

Figure 4 Curves Ms and Mf determined by dilatometer for the steel 34CrMo(S)4

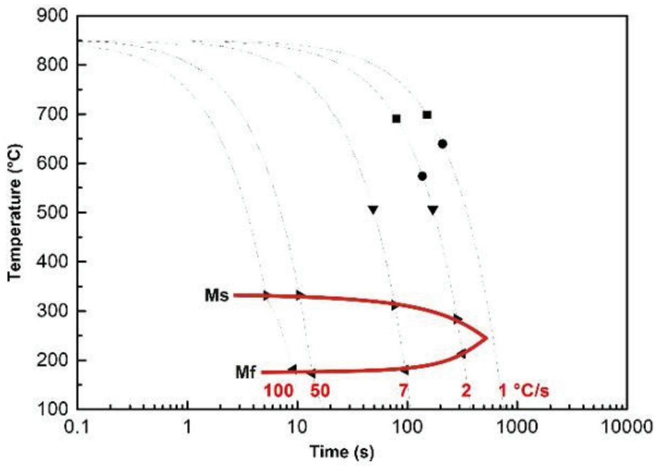

Figure 5 Curves Ms and Mf determined by dilatometer for the steel 41Cr(S)4

The graphs in **Figures 3 - 7** show only the plotted required curves Ms and Mf. The points corresponding to other phase transformations were not identified more definitely, because it would require at least additional metallurgical analyses. All the steels alloyed only with chromium and optionally with molybdenum it was possible to graphically localise the temperature, at which the curves Ms and Mf meet (**Figures 3 - 5**).

The addition of nickel dramatically changes the situation, because at low cooling rates the martensitic area is very smoothly followed by bainitic region and determination of their boundaries is difficult (**Figures 6 and 7**). The interpretation of dilatometric data for the steel 30CrNiMo8 was very complicated, when it was necessary to use the help of the CCT diagram for the allied steel Böhler V145 0.3 C - 0.5 Mn - Si 0.3 - 2.0 Cr - Ni 2.0 - 0.4 Mo (in wt.%) - see **Figure 8** [12].

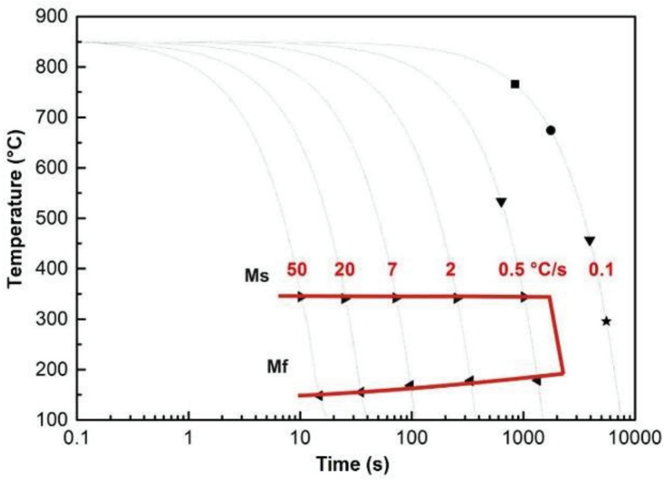

Figure 6 Curves Ms and Mf determined by dilatometer for the steel 34CrNiMo6

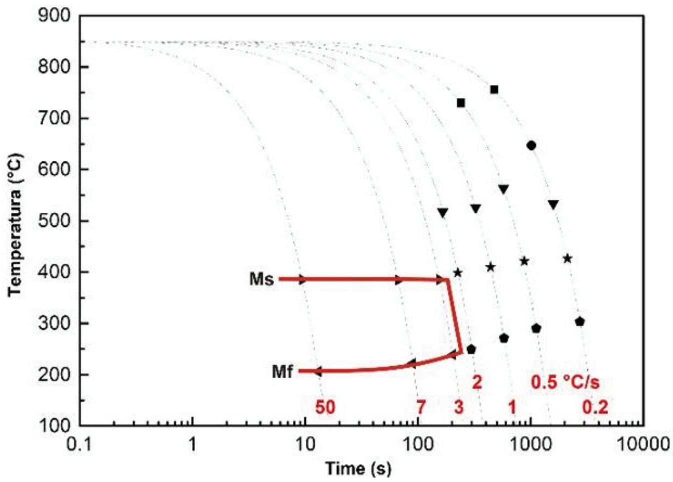

Figure 7 Curves Ms and Mf determined by dilatometer for the steel 30CrNiMo8

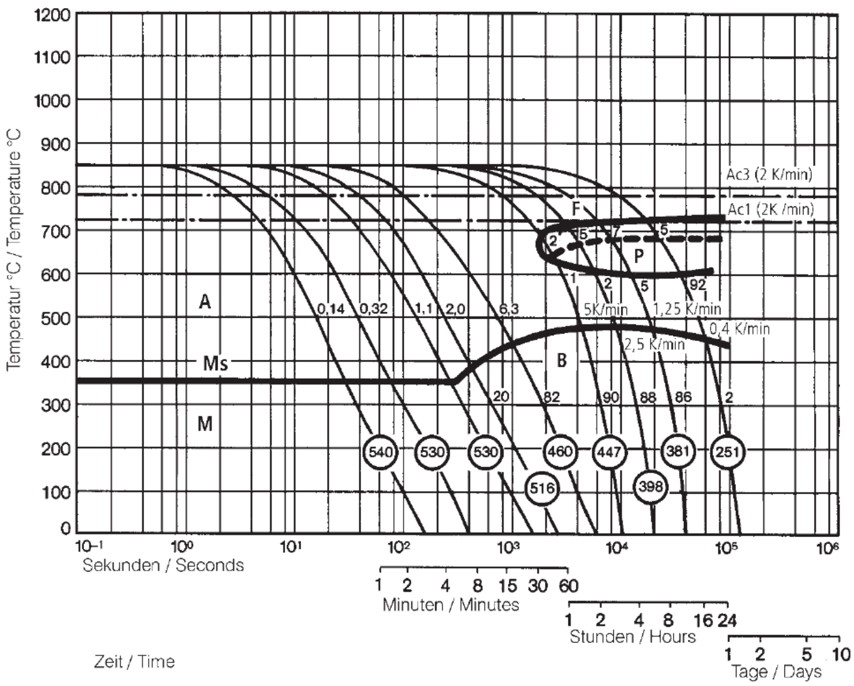

Figure 8 CCT diagram of the steel Böhler V145 [12]

3. CONCLUSIONS

For the steels 25CrMo(S)4, 30CrNiMo8, 34CrMo(S)4, 34CrNiMo6 and 41Cr(S)4, such parts of the ARA diagrams were determined by dilatometer, in which it was possible to mark the desired curves martensite start and martensite finish. The delivered rods mostly re-rolled to a smaller cross-section, and for the steels alloyed with nickel it was necessary to include also a soft annealing, because without it, it would have been impossible to machine the samples from this steel.

At construction of decay diagrams it appeared that the initial estimate of the necessity of four dilatometric tests for each steel was underestimated, and in reality, in most cases a larger number of tests, was needed. However, on the other hand, the range of experimental conditions created the pre-requisites for the effective construction of full-valued ARA (CCT) diagrams for the examined steels. For this, it would be sufficient to supplement the work with a few dilatometric tests, metallographic analyses and hardness measurements on the samples, which are already largely available.

Mutual comparison of the curves corresponding to the temperatures Ms and Mf showed in the examined steels a very noticeable influence of the addition of nickel on the evolution of phase transformations. At low cooling rates, the martensitic area is smoothly followed by the bainitic region and determination of their boundaries only from the course of their curves that is without additional structural analyses is difficult. In the steels alloyed only with chromium or optionally with molybdenum, an expected gradual closing of the martensite region occurs with the decreasing cooling rate, and thus narrowing of the differences between the Ms and Mf temperatures.

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