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The kinetic of phase transformation during continuous heating from quenched state of new high-carbon alloy steel

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Abstract: In the paper kinetics of phase transformations during continuous heating (tempering) from the hardened condition has been specified in form of a CHT diagram (Continuous Heating Transformations) of a new steel containing 1,22%C. In the dilatograms of heating from hardened condition characteristic temperatures used for the CHT diagram have been pointed at. Moreover, some differences in the hardness of the researched steel samples depending on the level of advancement of changes at tempering have been shown, as well as a metalographic specification has been included.

Keywords: Tempering, Steel, ε carbide, Retained austenite, CHT diagram.

1. INTRODUCTION

Knowledge of the kinetics of phase transformations during tempering allows to carefully plan and conduct the operation of tempering, as a result of which optimum combination of resistance and plastic characteristics is obtained, including fracture toughness. According to research[1], CHT diagrams allow to intrude into the level of advancement of succeeding changes upon tempering (e.g. through changes in heating, temperature and soaking time) and thus to obtain favourable characteristics, especially high fracture toughness.

2. RESEARCH MATERIAL

Research was conducted on highcarbon steel. Chemical composition of the researched steel has been presented in table 1.

Table 1.
Chemical composition of the researched steel

mass %									
C	Mn	Si	P	S	Cr	Mo	V	$Al_{całk.}$	$Al_{rozp.}$
1,22	1,93	0,19	0,020	0,020	1,52	0,36	0,17	0,04	0,02

An inlet measuring circa 120 mm in diametre and weighing circa 50 kg produced in laboratory conditions was forged into rods measuring 20x35 mm in diametre. Material in the soft annealing condition was used for the research. In the previous research [2,3] the so called hardening series had been produced (in the range 700÷900°C) to choose best temperature to austenitize the new steel.

3. RESEARCH METHODS AND HEAT TREATMENT

CHT phase transformations diagram during continuous heating from the hardened condition (tempering) has been made with the DT 1000 dilatometre of a French company Adamel. Samples measuring ∅2x12 mm, after previous hardening from temperature 900°C (time of austenitizing was 1200s) were heated with the velocities from 0,05 to 35°C/s up to the temperature equal 700°C. Numerically registered heating dilatograms in a configuration of percentage elongation dl/l_o in the function of temperature was differentiated, which facilitated the construction of the CHT diagram of the researched steel (in the configuration time-temperature-transformation during tempering) on the basis of the characteristic points read from the differentiation curves. Hardness was measured with Vickers HPO250 apparatus. Pictures of the researched steel samples were taken with an optical microscope Axiovert 200 MAT and with a scanning microscope Stereoscan 120.

4. RESEARCH RESULTS AND DISCUSSION

Fig. 1 shows a heating dilatogram with the velocity 0.05°C/s for a sample of the researched steel previously hardened from 900°C together with the corresponding differentiation curve, which shows how to interpret dilatograms on the basis of which the CHT diagram was constructed.

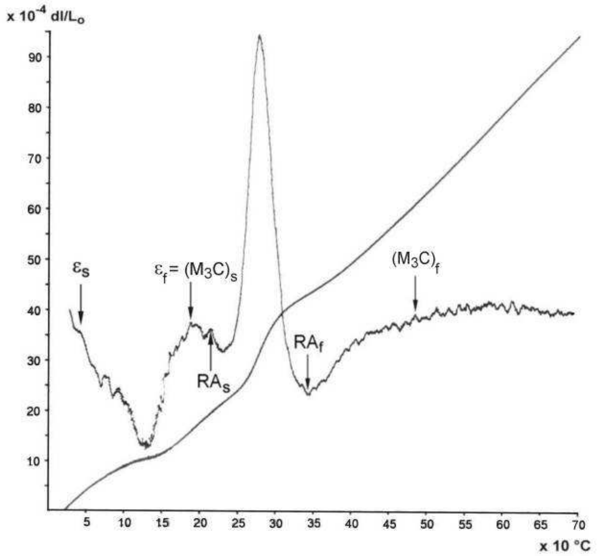

Figure 1. Dilatograms of heating with the velocity 0.05°C/s of a sample previously hardened from 900°C with the corresponding differentiation curve

As shown, at the first stage of tempering the researched steel displays contruction related mainly to the ε carbide precipitation. As soon as ε_f temperature is reached, the second stage of contruction starts, which is related to (alloy) cementite precipitation. Therefore, it is assumed that the end temperature (ε_f) of ε carbide precipitation equals the initial temperature of alloy cementite $(M_3C)_S$ precipitation. A strong positive dilatation effect related to retained austenite transformation attracts attention. The effect is visible in the range of temperatures $RA_s \div RA_f$.

In fig. 2 a full CHT diagram of the researched steel has been presented. Ranges of ε carbide precipitation, cementite precipitation and the range of retained austenite transformation have been shown. As presented, with the increase of heating velocity from 0.05°C/s to 35°C/s beginning and end temperatures of individual transformations increase.

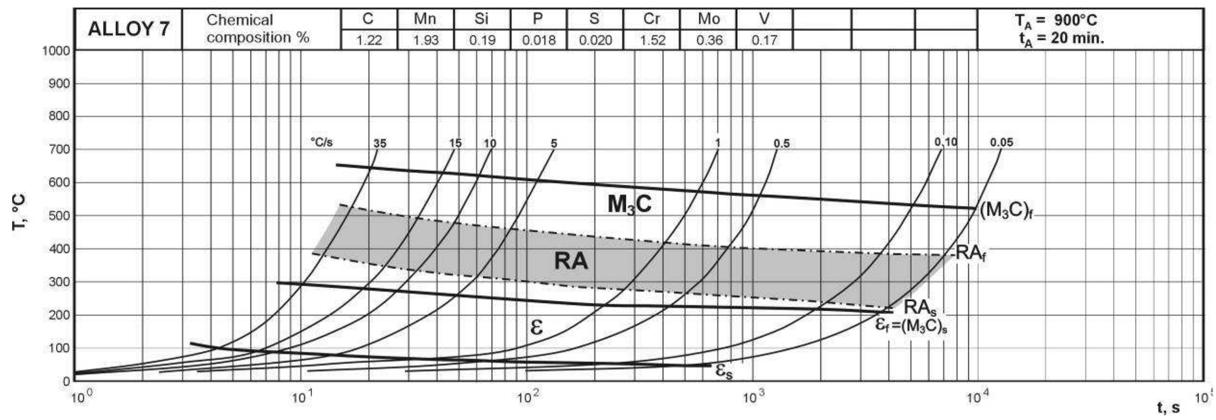

Figure 2. CHT diagram of the researched steel

Fig. 3 presents microstructures of the researched steel samples hardened from 900°C and then heated with the velocity equal 0.05°/s (compare fig.2) to 210, 370 and 520°C. These are characteristic temperatures at which for the heating velocity 0.05°/s the following have been established on the dilatograms: the end of ε carbide precipitation (before the transformation of retained austenite starts), the end of retained austenite transformation into lower bainite and the end of cementite precipitation. Photographs have been included, especially the ones from the scanning microscope (enlarged by circa 2500x) show clearly that after retained austenite transformation, a distinct relief is present in microsections, which disappears with the rise of temperature to 520°C, at which the end of M_3C cementite precipitation takes place.

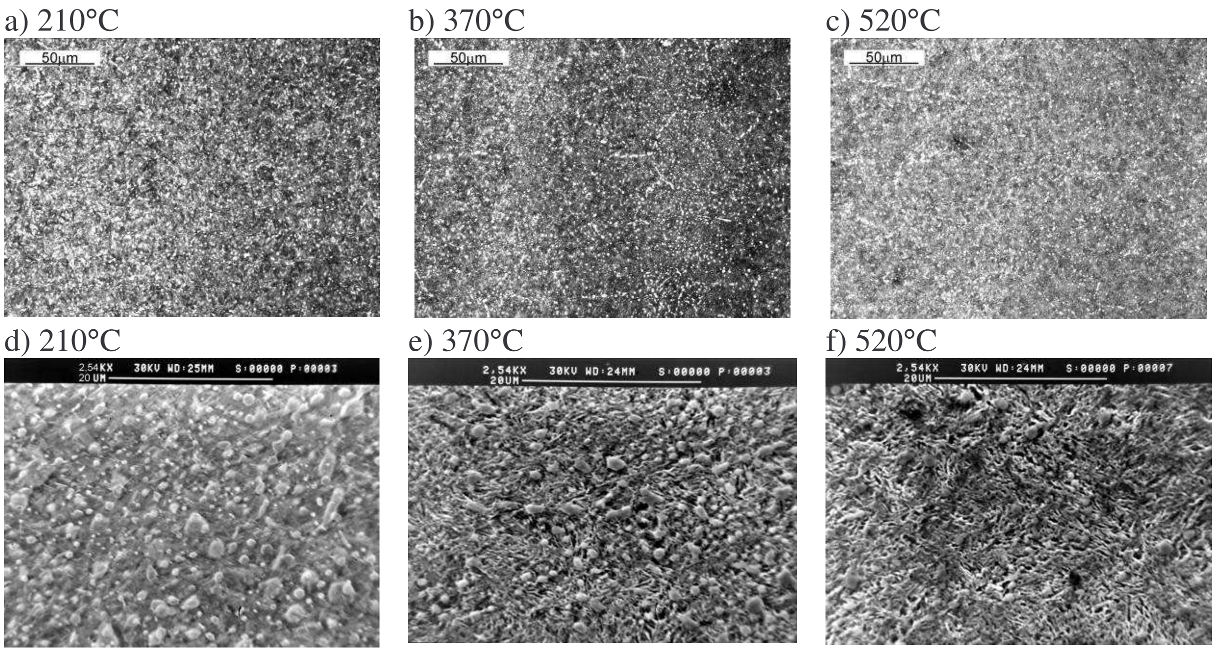

Figure 3. Microstructures of the researched steel after hardening from 900°C and heating with the velocity 0,05°C/s to different temperatures after nital etching a), b), c) light microscope, d), e), f) scanning microscope

In table 2 the results of HV30 hardness have been presented. As shown, hardness after hardening (890HV30) is very high. After heating to 210°C when ε carbide stopped precipitating from martensite hardness decreases by 143HV30. After the researched steel is heated to 370°C, in spite of the considerable advancement of M_3C cementite precipitation, hardness decreases only by further 111HV30 thanks to the transformation of the whole amount of retained austenite. After the end of M_3C cementite precipitation at 520°C hardness of the researched steel (533HV30) remains high.

Table 2.
Hardness of samples of the researched steel after hardening from 900°C and heating to 210, 370 and 520°C

	Heat treatment			
	hardening	hardening + tempering from v=0,05°C/s to 210°C	hardening + tempering from v=0,05°C/s to 370°C	hardening + tempering from v=0,05°C/s to 520°C
HV30	890	747	636	533

5. CONCLUSIONS

1. Upon heating of the researched steel from a hardened condition the presence of three basic transformations has been observed i.e. ε carbide precipitation related to the first stage of the contraction of samples, M_3C cementite precipitation to which the second stage of the contraction of samples relates and retained austenite transformation accompanied by a strong positive dilatation effect.
2. On the basis of the registered dilatograms it is possible to produce a CHT diagram showing the kinetics of phase transformations during continuous heating from the hardened condition.
3. Retained austenite transformation takes place in the range of temperatures of cementite precipitation.
4. Reduction of hardness decrease with tempering temperature is related to the gradual transformation of big quantaties of retained austenite which transformed into lower bainite in the range of temperatures of M_3C cementite precipitation.

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