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THE USE OF DILATOMETER DIL 805A/D FOR PREDICTION OF MICROSTRUCTURE OF THE STEEL WIRE ROD FOR COLD UPSETTING

Wire rod made of low carbon steel used for cold upsetting should be characterized by high plasticity on the one hand, and low limit of tensile strength TS, on the other. Structure of metal formed during a multistage deformation and cooling in the manufacturing line has an influence on mechanical properties and abilities to upsetting without destruction. Wire rod of low carbon steel designed for cold upsetting should be characterized by a ferritic – pearlitic structure. The carbon should be in the form of lamellar cementite. Too intensive cooling causes precipitation of supersaturated ferrite in the form of middle solid solution in dislocations and in the form of thin impurities in ferrite grains [1, 2]. It is necessary to determine cooling conditions enabling obtainment of banded structure of fine-grained ferrite with lamellar cementite.

The experiments were carried out using a dilatometer DIL 805A/D. Fig. 1 presents a dilatometer DIL805A/D and a chamber with an inductor used for heating of specimens.

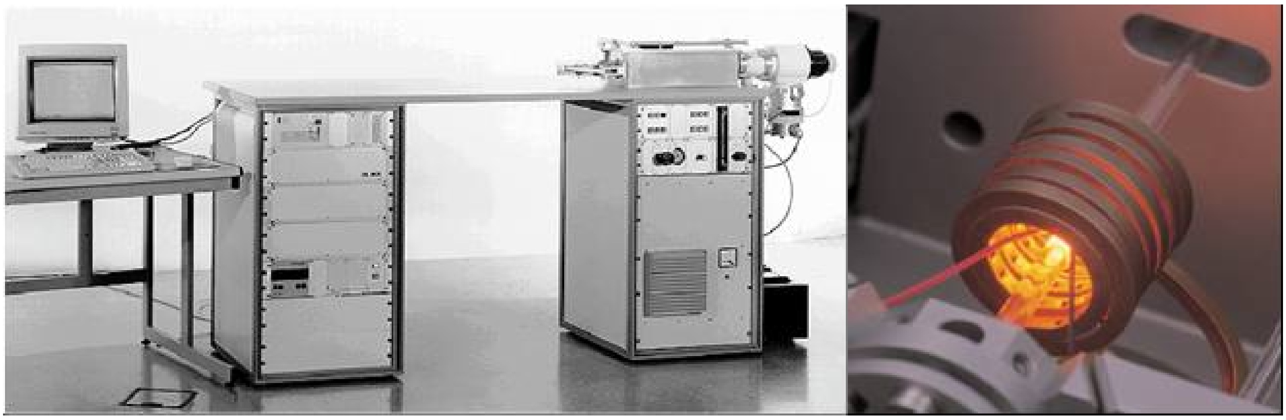
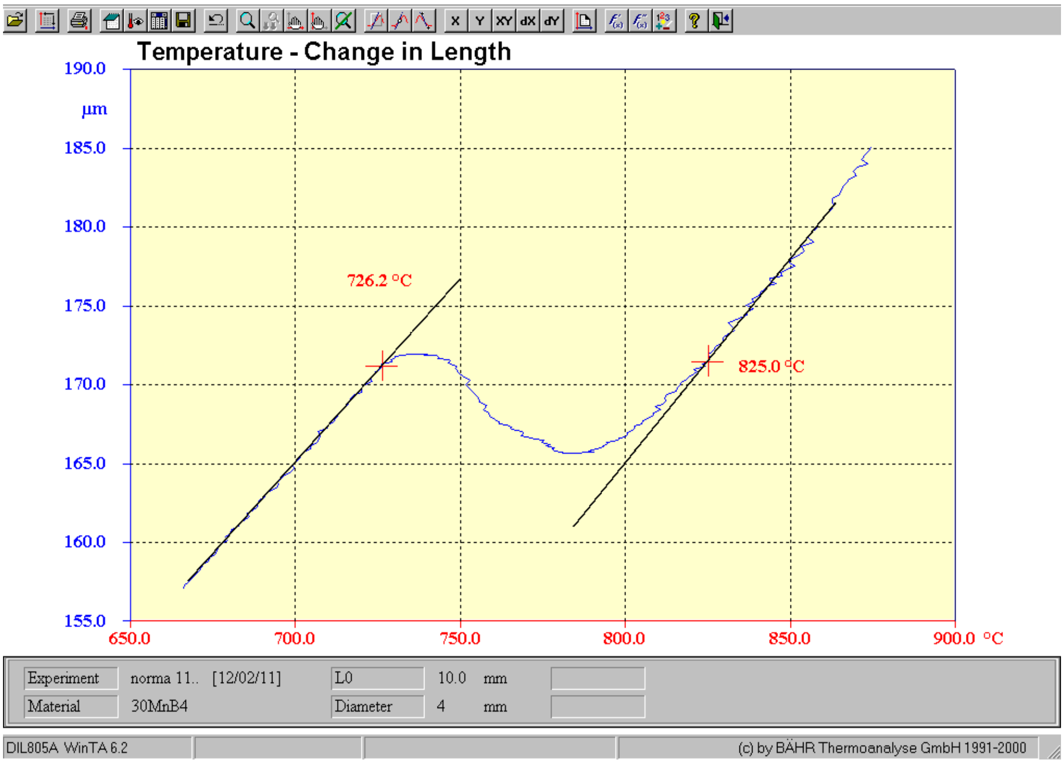


Fig. 1. Dilatometer DIL805A/D [3]

This device enables registration of phase transitions and structural changes taking place during physical modelling of thermal processing treatments. The phenomenon of appearance of specific volume differences of the phases which appear in metals and their alloys is used for the analysis of the obtained results. The phase transition becomes visible on the dilatometric diagram in the form of a saltatory change of the specimen's length. The dilatometer has a software which enables visualization of the results.

The dilatometer is also used for physical modelling of microstructure changes and mechanical properties. A scheme or schemes selected on the basis of computer simulations of deformation can be implemented with the use of this device. The specimens after the treatment were subjected to metallographic tests and their mechanical properties were also estimated. The results of the tests were helpful when designing technologies for manufacturing assortment of a certain steel grade which guarantees high level of mechanical properties at limited number of technological samples [3, 4].



Experiment norma 11.. [12/02/11]
L0 10.0 mm
Material 30MnB4
Diameter 4 mm

Fig. 2. A dilatometric curve of 30MnB4 steel registered during dilatometric tests and typical temperatures

Cylindrical specimens were used for the analysis. Their diameter was 4 mm and their length was 10 mm. The first stage was to determine typical temperature values A_{C3}, $A_{C1,}$ in the time of heating. The steel specimens were heated and cooled after austenitization continuously with a constant rate of 3°C/min. During the process changes in length were observed in the function of temperature. As a result of the tests dilatographic curves were obtained. Their analysis was carried out according to the procedure presented in [3]. The determined values of temperatures A_{c3} became the basis for determination of temperature values of austenitization of the specimens during dilatometric tests. The results of these tests helped determine the temperatures of phase transitions which took place during continuous cooling. Figure 2 presents the registered dilatometric curves.

On the basis of the obtained results using the dependence (1) the temperature of austenitization was determined during the dilatometric tests, on the basis of which TTTc diagrams were designed. The temperature of austenitization for 30MnB4 steel was assumed to be T_A=880 ^{o}C.

$$T_A = A_{r3} + 40\ldots60^0 C \qquad (1)$$

The research was carried out using a dilatometer DIL805A/D. The specimens after thermal treatment were subjected to metallographic analyses revealing their obtained structure. Additionally, a number of dilatometric curves was obtained. Their analysis enabled creating real TTTc diagrams. After preheating in the temperature of austenitization T_A for 10 minutes the specimens were cooled at different cooling rates in the range of 0.1…100^{o}C/s. The specimens after dilatometric tests were subjected to metallographic tests revealing the obtained structure. Their hardness was determined using Vickers method. A number of dilatometric curves was obtained, on the basis of them it was possible to determine the range of appearance of certain phase transitions during the cooling from the temperature of austenitization.

The specimens after the thermal treatment were subjected to metallographic tests. Microstructure of 30MnB4 steel was determined after dilatometric tests. Additionally, the analysis of the obtained dilatometric curves was carried out. Figures 3–10 show the pictures of the structures revealed in the specimens after the thermal treatment of 30MnB4 steel.

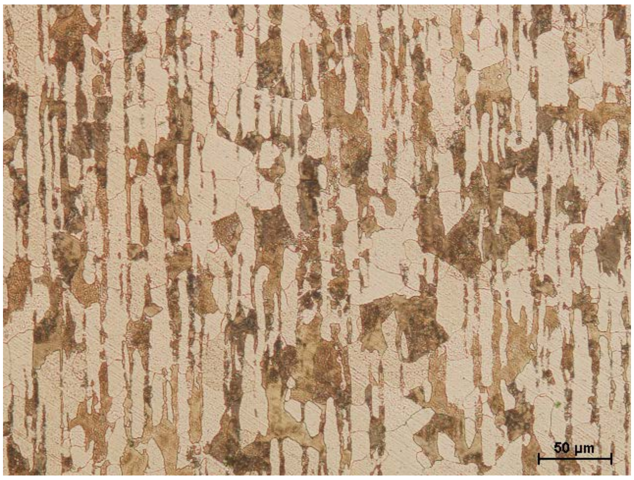


Fig. 3. Ferritic-pearlitic microstructure of the specimen made of 30MnB4 steel cooled with the rate of 0.1°C/s

Fig. 4. Ferritic-pearlitic microstructure of the specimen made of 30MnB4 steel cooled with the rate of 1°C/s

Fig. 5.Ferritic-pearlitic microstructure of the specimen made of 30MnB4 steel cooled with the rate of 5°C/s

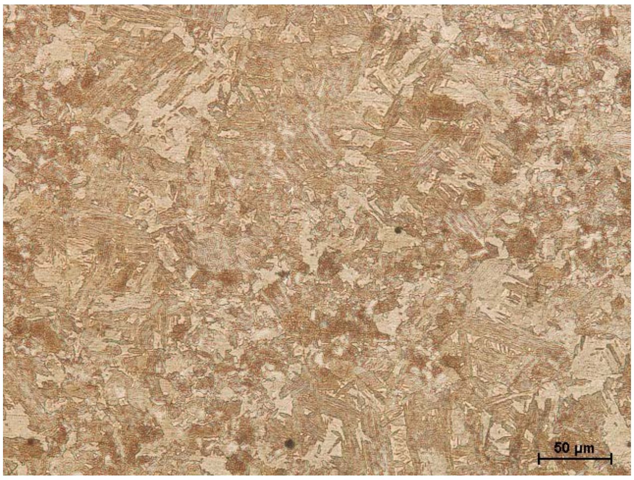


Fig. 6. Bainitic microstructure with pearlite and ferrite of the specimen made of 30MnB4 steel cooled with the rate of 10°C/s

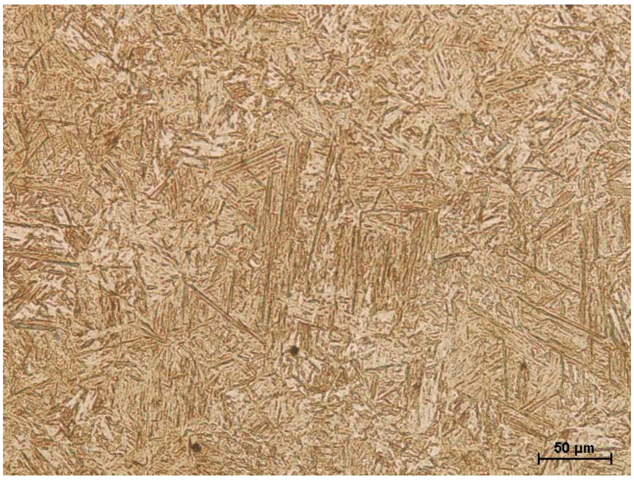


Fig. 7. Bainitic-martensitic microstructure with a small amount of ferrite and single pearlite grains of the specimen made of 30MnB4 steel cooled with the rate of 30°C/s

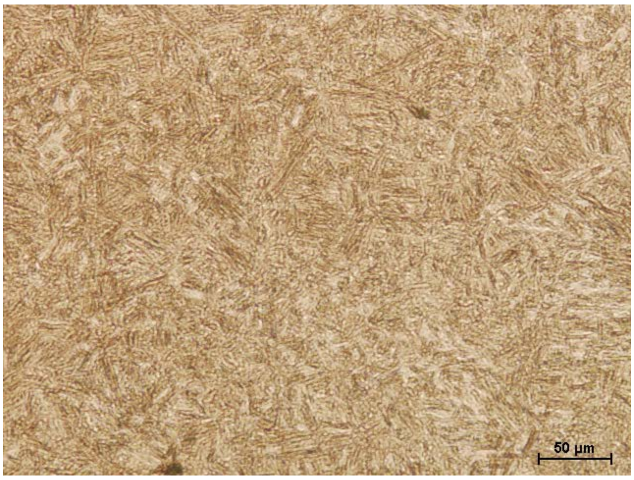
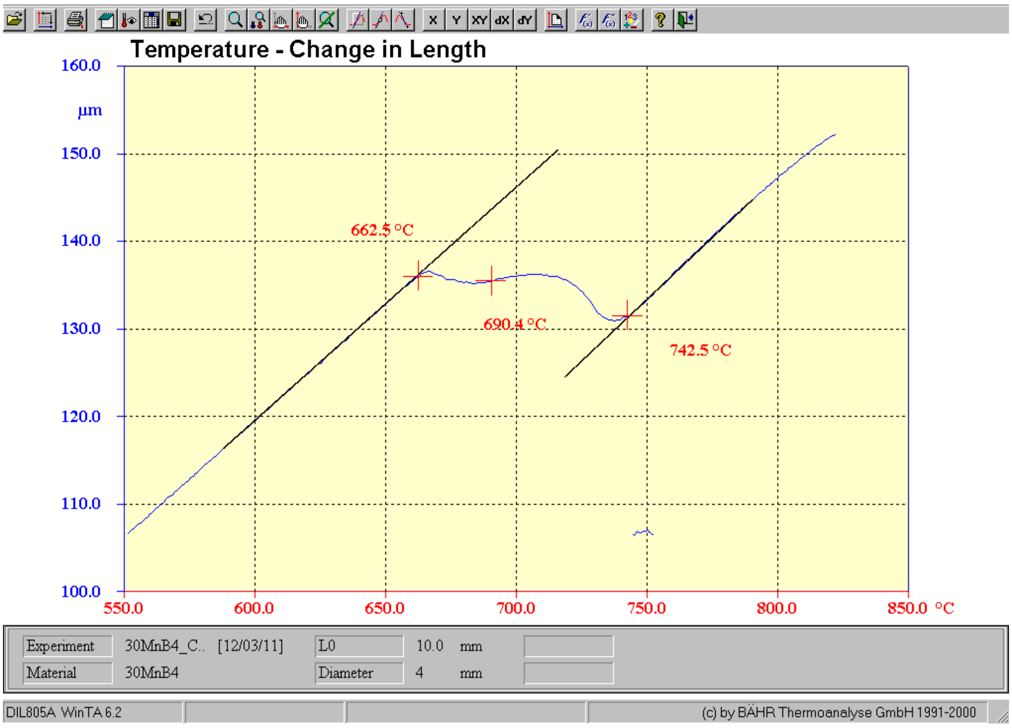


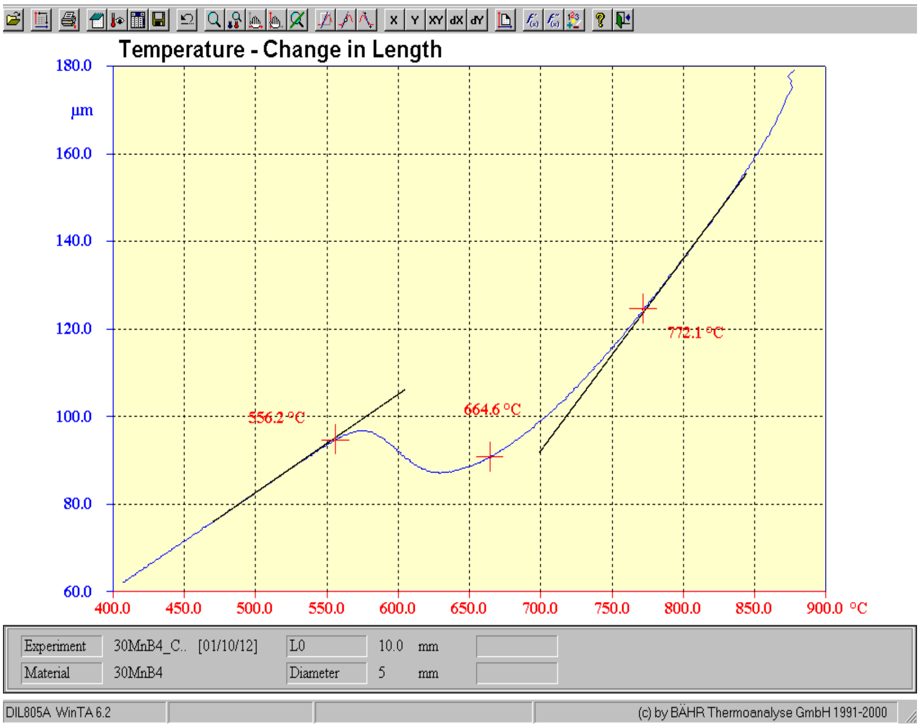
Fig. 8. Martensitic microstructure of the specimen made of 30MnB4 steel cooled with the rate of 100°C/s



Experiment 30MnB4_C.. [12/03/11] L0 10.0 mm
Material 30MnB4 Diameter 4 mm
DIL805A WinTA 6.2 (c) by BÄHR Thermoanalyse GmbH 1991-2000

Fig. 9. A dilatometric curve registered for 30MnB4 steel cooled from the temperature T $_A$=880°C with the rate of 0.1°C/s

Figures 9 and 10 present exemplary registered dilatometric curves of the 30MnB4 steel cooled with the rates of 0.1 °C/s and 15 °C/s at which according to the procedure described in [5,6] the temperatures of phase transitions which take place during continuous cooling were determined.



Experiment 30MnB4_C.. [01/10/12] L0 10.0 mm
Material 30MnB4 Diameter 5 mm
DIL805A WinTA 6.2 (c) by BÄHR Thermoanalyse GmbH 1991-2000

Fig. 10. A dilatometric curve registered for 30MnB4 steel cooled from the temperature T$_A$=880 °C with the rate of 5 °C/s

Table 1 shows typical temperatures obtained on the basis of dilatometric curves' analysis of 30MnB4 steel cooled from the temperature of 80°C. Hardness of the specimens was also measured.

Table 1

Typical temperatures obtained on the basis of dilatometric tests and hardness of the specimens made of 30MnB4 steel cooled from the temperature of 880ºC

Cooling rates Cr [ºC/s]	Typical temperatures [ºC]	HardnessHV5
100	Ms = 379 Mf = 230	515
80	Bs = 540 Bf = Ms = 366 Mf = 200	510
50	Fs = 709 Ff = 668 Bs = 573 Bf = Ms = 383 Mf = 191	513
30	Fs = 735 Ff = Ps = 668 Pf = Bs = 565 Bf = Ms = 386 Mf = 270	480
15	Fs = 746 Ff = Ps = 624 Pf = Bs = 514 Bf = Ms = 380 Mf = 293	417
10	Fs = 750 Ff = Ps = 663 Pf = Bs = 531 Bf = 422	315
5	Fs = 772 Ff = Ps = 664 Pf = 556	229
1	Fs = 775 Ff = Ps = 708 Pf = 616	174
0.1	Fs = 750 Ff = Ps = 703 Pf = 660	152

As a result of the carried out dilatometric tests, the analysis of metallographic tests of the specimens after their thermal treatment, measurement of their hardness and determination of typical temperatures on the basis of the obtained dilatometric curves a real diagram of kinetics of phase transitions which take place during the process of continuous cooling of the specimens made of 30MnB4 steel was determined.

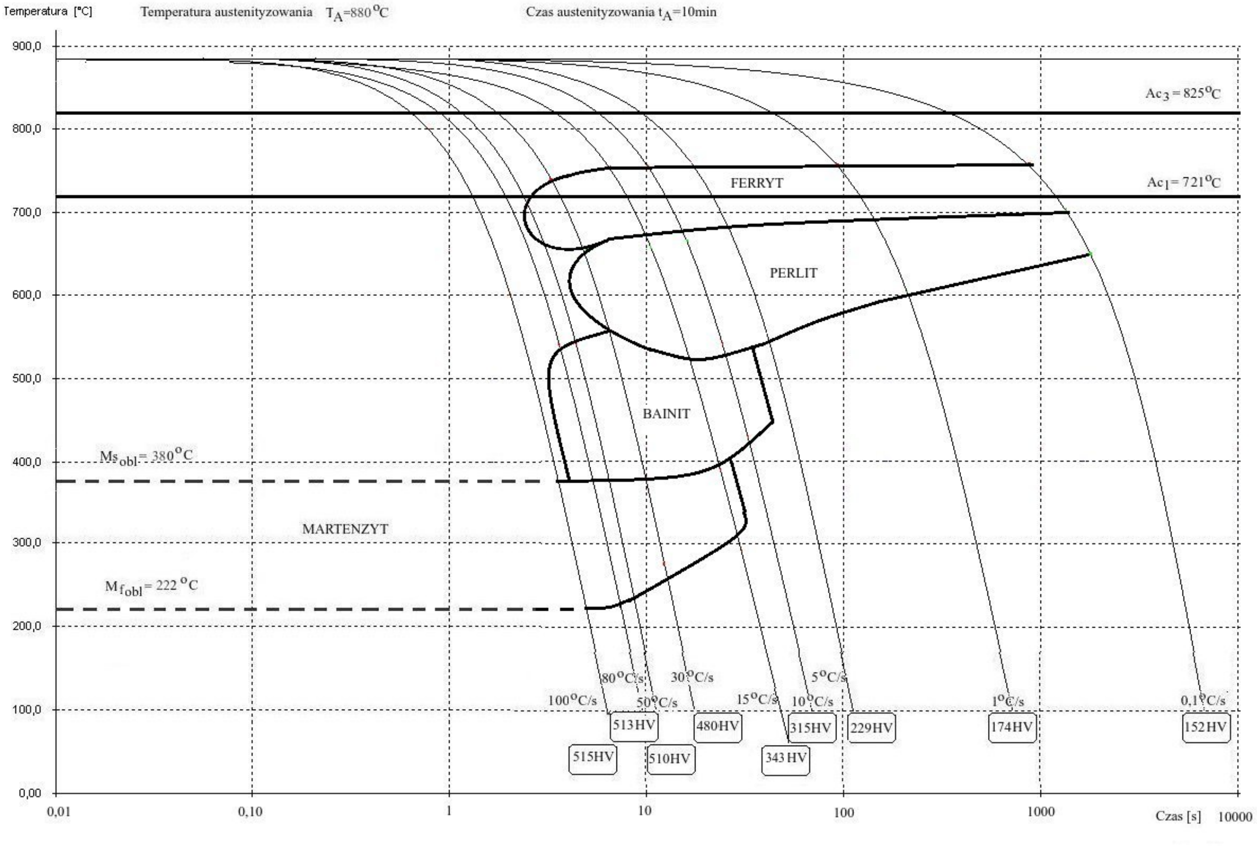


Fig. 11. A TTTc diagram for the 30MnB4 steel determined on the basis of dilatometric tests

SUMMARY

On the basis of the analysis of the obtained structures and the range of appearance of phase transitions in the steel 30MnB4 used for cold upsetting the ranges of cooling rates were determined. They guarantee the obtainment of the structures which enable further cold plastic treatment. In the specimens made of 30MnB4 steel cooled with the rate in the range of 0.1...5°C/s ferritic-pearlitic structures appeared. The banded structure appeared when the specimens were cooled with the rates of 0.1…1°C/s. A homogeneous structure guaranteeing high vulnerability to upsetting was observed only for the specimens cooled with the rate of 5°C/s. The structures being a mixture of ferrite, pearlite, bainite and martensite were revealed in the specimens cooled with the rate in the range of 10…80°C/s. The use of higher cooling ranges caused the appearance of martensitic structure. In the range of cooling rate used in industrial conditions (1…5°C/s) which guarantees obtainment of ferritic-pearlitic structure of the specimen made of 30MnB4 steel the hardness was in the range of 152…229 HV. For higher cooling rates the specimens' hardness increased and oscillated in the range of 315…515 HV.

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