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PHYSICAL SIMULATION OF MICROSTRUCTURE EVOLUTION OF THE SPECIMENS MADE OF 30MnB4 STEEL

Wire rod made of low-carbon steel used for cold upsetting should be characterized by ferritic-pearlitic structure with the carbon in the form of lamellar cementite [1]. As a result of deformation certain phenomena take place in the material which cause refinement of its microstructure. Refinement of the ferrite grain in ferritic-pearlitic structure causes the increase of durability and plasticity [2]. Additionally, after deformation it is possible to control the properties of a readymade item by using different conditions of cooling. It is necessary to determine the influence of deformation and cooling after hot deformation conditions which enable obtainment of the fine-grained ferritic structure with lamellar cementite characterized by a high level of mechanical properties.

The analysis of real conditions of wire rod production from 30MnB4 steel in one of Polish metallurgical plants showed that the temperature of the end of rolling depending on the end diameter oscillates in the range of 780–850ºC [3]. The smallest rolled diameters are in the temperature below A_{c3} (in two-phased state). The microstructure formed in this process is characterized by a great non-homogeneity, which has a negative influence on mechanical properties. Initial research [4] showed that finishing the rolling process in a higher temperature (e.g. 830ºC) at an increased cooling rate after rolling enables obtainment of homogeneous ferritic – pearlitic structure of high plasticity.

The research was carried out concerning the influence of deformation and cooling conditions on microstructure of the specimens made of 30MnB4 steel. Physical simulation was carried out using a dilatometer DIL 805A/D equipped with a plastometric device (Fig. 1).

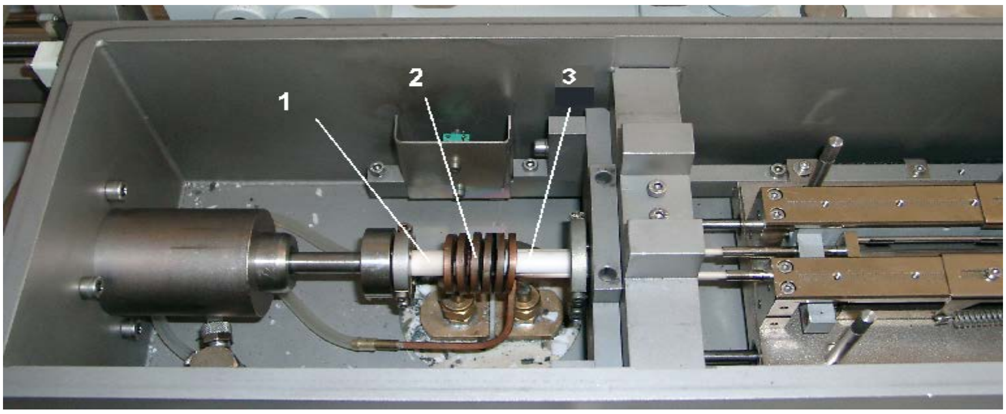

Fig. 1. The chamber of deformation dilatometer DIL 805A/D (1 – movable ceramic anvil; 2 – induction coil, 3 – ceramic anvil)

The cylindrical specimens, which diameter was 5 mm and length was 10 mm, were heated to the temperature close to the temperature of the beginning of rolling in industrial conditions (1050ºC) with the rate of 10ºC/s, preheated in this temperature for 10 minutes, and then cooled with the rate of 10ºC/s to the temperature of the beginning of deformation. In order to illustrate the history of deformations during the test, the cycle of 3 deformations was used: $\varepsilon_1 = \varepsilon_2 = \varepsilon_3 = 0{,}2$ with the deformation rate of $10 s^{-1}$ in the temperatures of 880ºC, 850ºC and 835ºC. The interval between deformations was 1 s. After deformations the specimens were cooled using different cooling rates in the range of 0,1–100^{o}C/s. Figure 2 presents a scheme of thermal-plastic processing of 30MnB4 steel.

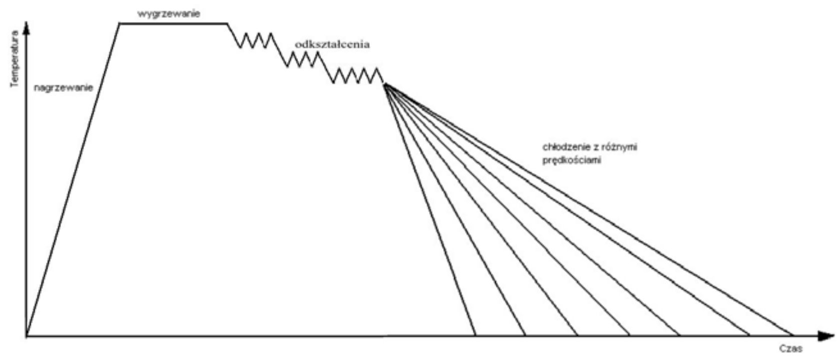

Fig. 2. The scheme of thermal-plastic processing carried out in this work using deformation dilatometer DIL 805A/D

The specimens were subjected to metallographic tests which revealed the obtained structure. Their hardness was determined applying the Vickers hardness test method. The database showing the influence of thermal-plastic processing on the structure and hardness of 30MnB4 steel was obtained. The dilatographs were registered. Their analysis enables determination of the range of appearance of certain phase transitions during the process of cooling after deformation of the specimens.

The specimens after their thermal processing were subjected to metallographic tests. Microstructure of 30MnB4 steel was determined after dilatometric tests. The analysis of the dilatographs was also carried out.

Fig. 3–10 present pictures of the structures revealed on the specimens after the thermal processing of 30MnB4 steel.

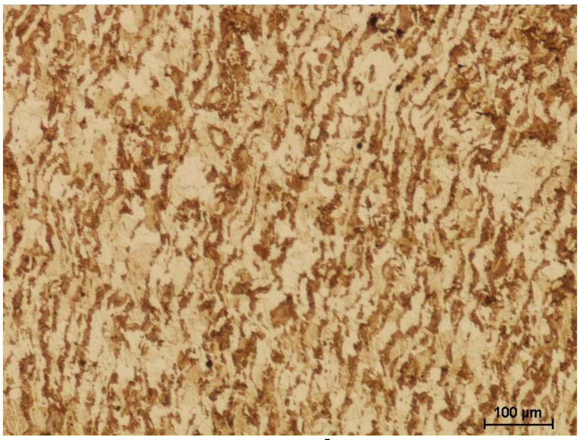

Fig. 3. Ferritic-pearlitic microstructure of the specimen made of 30MnB4 steel after a deformation cycle cooled with the rate of 0.1°C/s

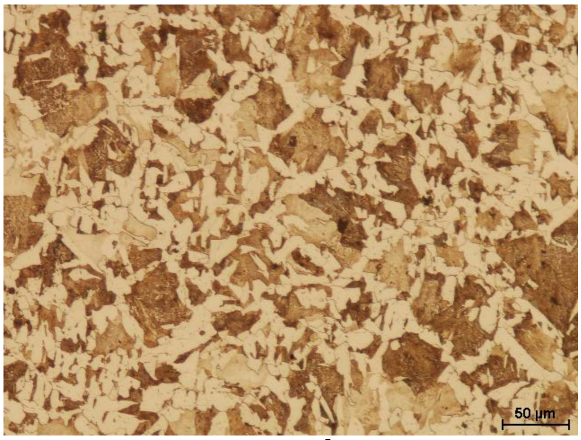

Fig. 4. Ferritic-pearlitic microstructure of the specimen made of 30MnB4 steel after a deformation cycle cooled with the rate of 1°C/s

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

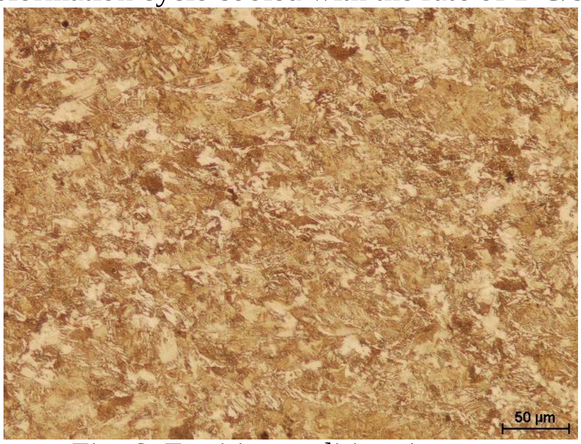

Fig. 6. Ferritic-pearlitic microstructure of the specimen made of 30MnB4 steel after a deformation cycle cooled with the rate of 10°C/s

Fig. 7. Martensitic-bainitic microstructure of the specimen made of 30MnB4 steel after a deformation cycle cooled with the rate of 80°C/s

Fig. 8. Martensitic structure of the specimen made of 30MnB4 steel after a deformation cycle cooled with the rate of 100°C/s

Fig. 9 and 10 present exemplary registered dilatographs of 30MnB4 steel which was cooled with the rates of 1°C/s and 15 °C/s, at which according to the process described in [5] temperatures of phase transitions taking place during continuous cooling were determined.

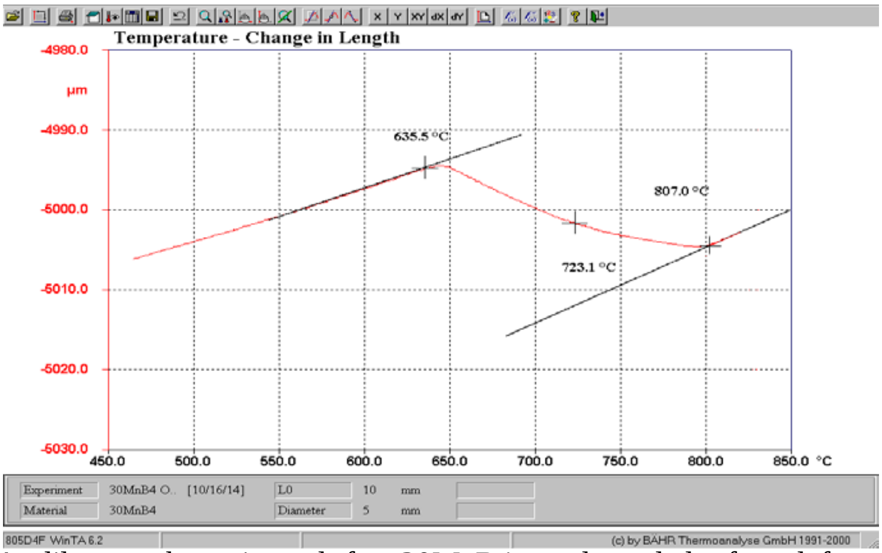

Fig. 9. A dilatograph registered for 30MnB4 steel cooled after deformation from the temperature of T_D=830°C with the rate of 1°C/s

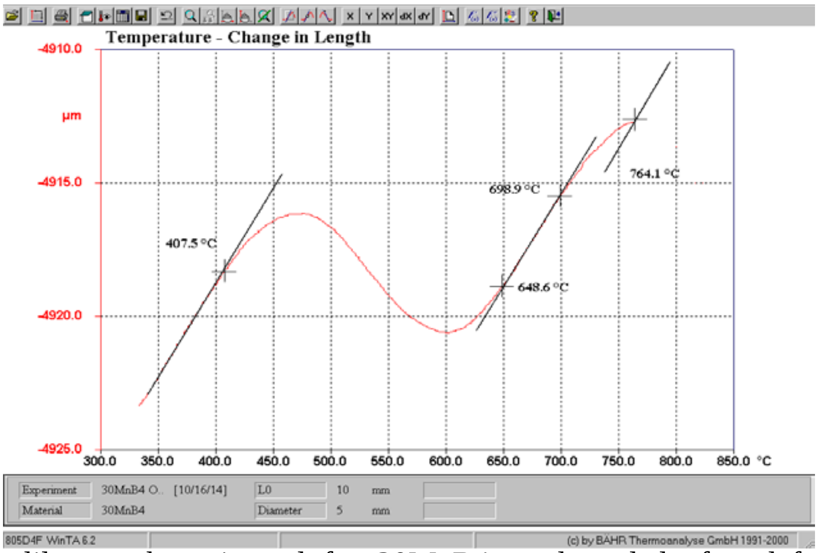

Fig. 10. A dilatograph registered for 30MnB4 steel cooled after deformation from the temperature of T_D=830°C with the rate of 15°C/s

Table 1 shows typical temperatures obtained on the basis of the dilatograph analysis of 30MnB4 steel cooled after a cycle of deformations from the temperature of 830ºC and the measured hardness of the specimens.

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 830ºC

Cooling rate Cr [ºC/s]	Typical temperatures [ºC]	Hardness HV5
100	Ms=366 Mf=196	547.0
80	Bs=502 Bf= Ms=375 Mf=214	531.0
50	Bs=508 Bf= Ms=382 Mf=214	520.0
30	Fs=772 Ff=697 Bs=513 Bf=Ms=378 Mf=265	417.0
15	Fs=736 Ff=Ps=644 Pf=Bs=535 Bf=407	289.0
10	Fs=745 Ff=Ps=669 Pf=Bs=550 Bf=482	220.0
5	Fs=765 Ff=Ps=650 Pf=545	205.0
1	Fs=807 Ff=Ps=723 Pf=635	170.0
0.1	Fs=803 Ff=Ps=720 Pf=664	152.0

As a result of the carried out dilatometric and metallographic tests of the specimens after thermoplastic processing, measurements of hardness and analysis of the obtained dilatographs real diagrams of phase transition kinetics which takes place during continuous cooling of the specimens made of 30MnB4 steel after their deformation were worked out.

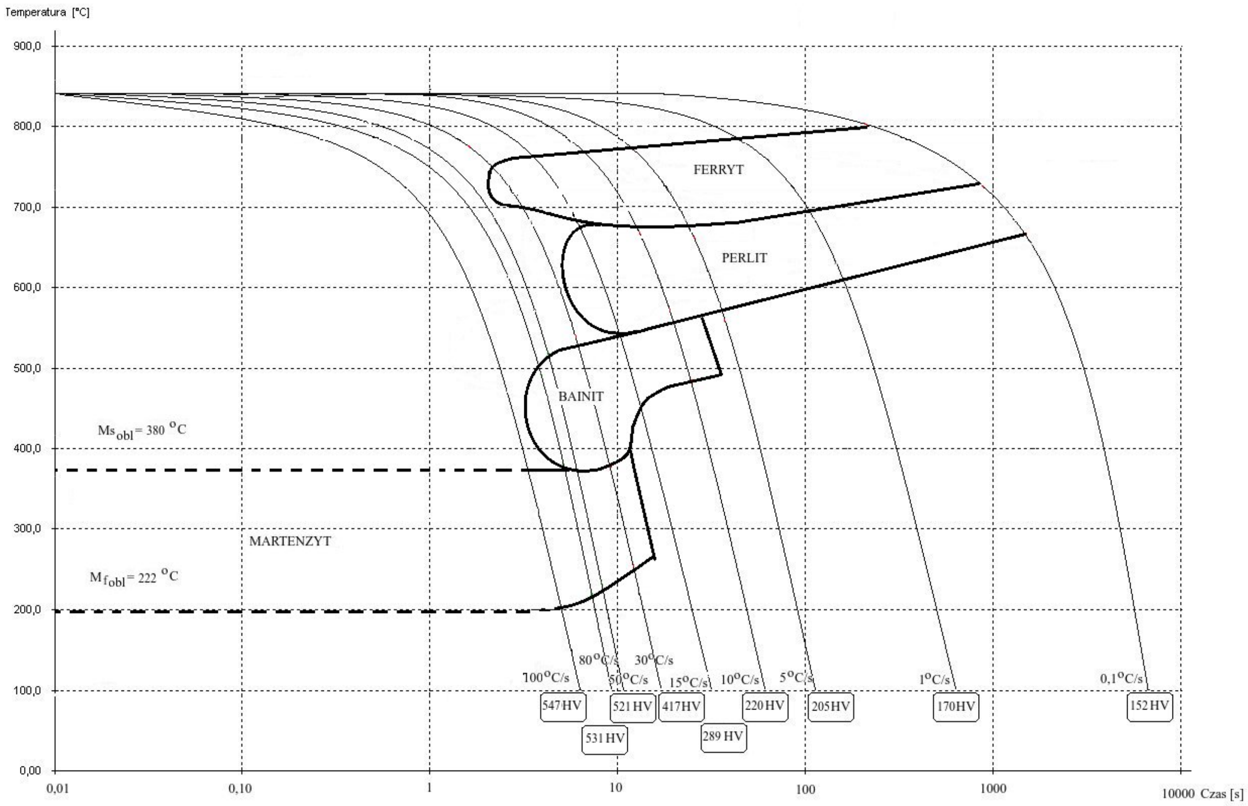

Fig. 11. The DTTT diagram for 30MnB4 steel worked out on the basis of dilatometric tests

SUMMARY AND CONCLUSIONS

Physical simulation was carried out which aim was to determine the influence of thermal-plastic processing and hot deformation parameters on the type and morphology of the final microstructure of the 30MnB4 steel for cold upsetting. On the basis of the analysis of the obtained structures and the range of phase transitions which appear in the 30MnB4 steel for cold upsetting the ranges of cooling rate were determined. They guarantee the obtainment of the structures which enable further cold plastic processing.

In the specimens cooled with the cooling rate in the range of 0,1–5 ^{o}C/s there appeared ferritic-pearlitic structures and the fibers appeared only at the slowest cooling rate. The most advantageous structure which guarantees high vulnerability to upsetting was observed for the specimens cooled after deformation with the rate of 1–2,5 ^{o}C/s. Bainitic-martensitic structures appeared in the specimens cooled with the rate in the range of 30–80 ^{o}C/s. The use of higher cooling rates caused the appearance of martensitic structure. It is necessary to point out that the use of deformation before different variations of cooling caused an increase of hardness. In the range of cooling rates used in industrial conditions (1–5 ^{o}C/s) which guarantee the obtainment of ferritic-pearlitic structure of the specimen made of 30MnB4 steel the hardness was in the range of 152–205 HV.

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