

Physical simulation of microstructure evolution of the specimens made of 30MnB4 steel

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Abstract

This article presents the research results of the influence of deformation conditions of the steel specimens for cold upsetting on their microstructure. Physical simulation of deformation and cooling of the MnB4 steel were carried out with the use of dilatometer DIL 805A/D. After physical simulation the specimens were subjected to metallographic analysis which revealed the obtained microstructure. The hardness of the specimens was determined using a hardness measuring instrument FV – 700. The obtained information concerning the influence of the deformation and cooling conditions on microstructure enabled creating the DTTT diagram for the 30MnB4 steel.

Key words: PHYSICAL MODELING OF MICROSTRUCTURE, DTTT DIAGRAM, WIRE ROD OF STEEL GRADE 30MNB4

1. Introduction

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 pro-

duction 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 $780 \div 850^{\circ}\text{C}$ [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. 830°C) at an increased cooling rate after rolling enables obtainment of homogeneous ferritic – pearlitic structure of high plasticity.

2. The research carried out in this work

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).

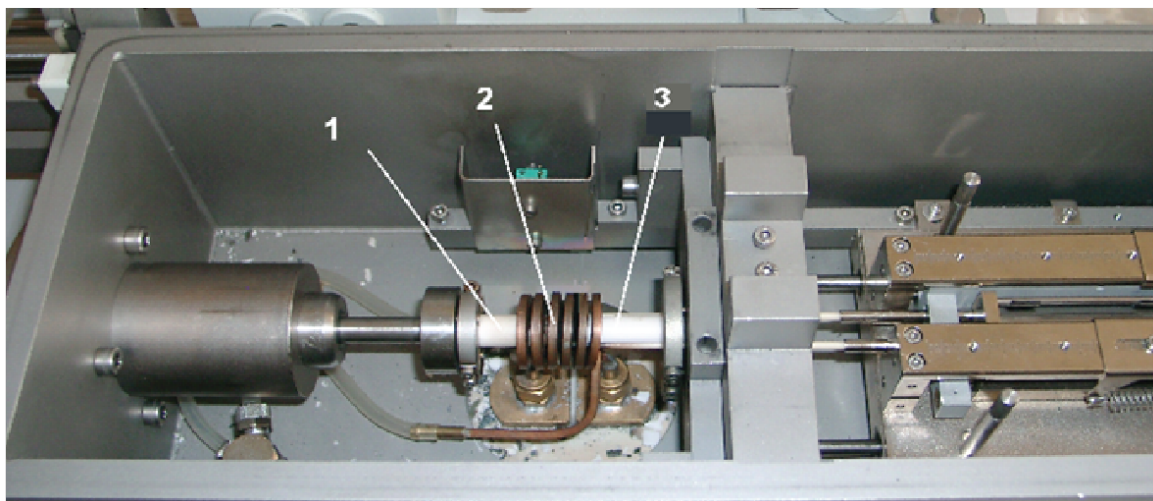


Figure 1. The chamber of deformation dilatometer DIL 805A/D:
1 – movable ceramic anvil 2 – induction coil, 3 – ceramic anvil

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 (1050°C) with the rate of 10°C/s, preheated in this temperature for 10 minutes, and then cooled with the rate of 10°C/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 10s^{-1} in the temperatures of 880°C, 850°C and 835°C. The interval between deformations was 1 s. After deformations the specimens were cooled using different cooling rates in the range of $0.1 \div 100\text{°C/s}$. Figure 2 presents a scheme of thermal-plastic processing of 30MnB4 steel.

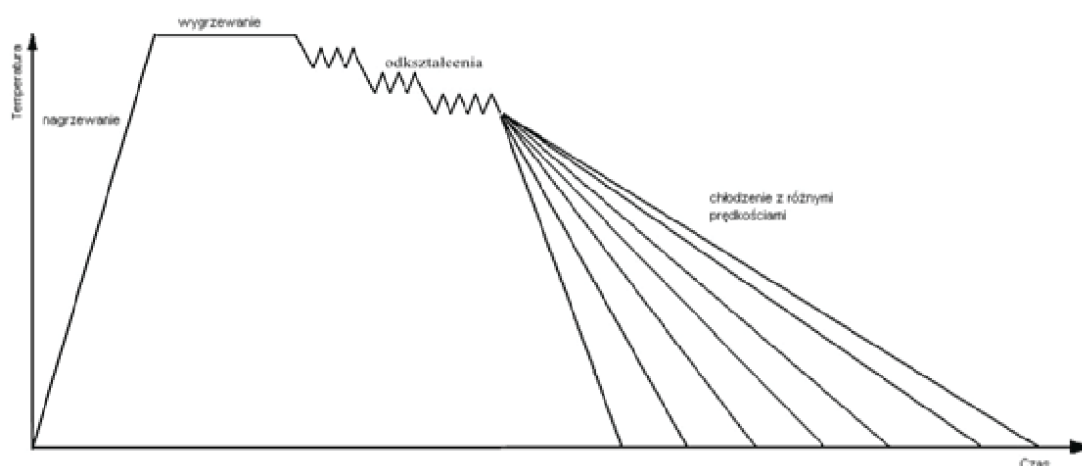


Figure 2. The scheme of thermal-plastic processing carried out in this work using deformation dilatometer DIL 805A/D

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 defor-

mation of the specimens.

3. Research results

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.

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

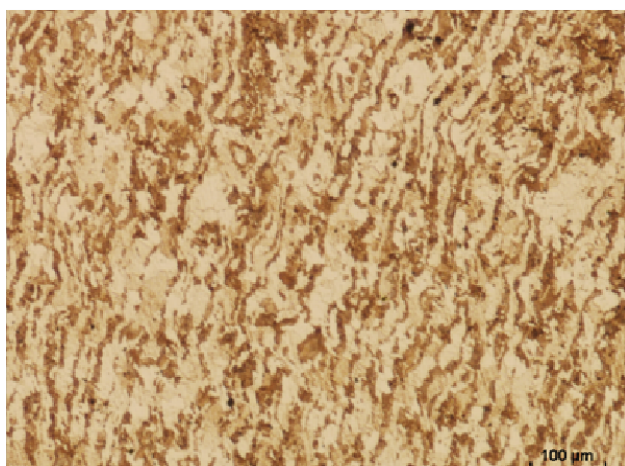


Figure 3. Ferritic-pearlitic microstructure of the specimen made of 30MnB4 steel after a deformation cycle cooled with the rate of 0.1°C/s



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



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

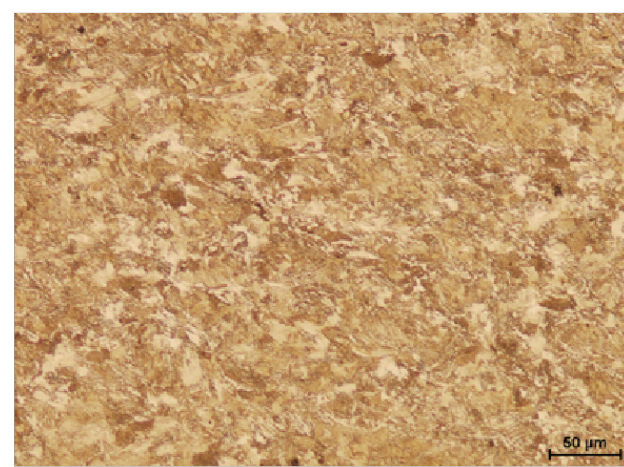


Figure 6. Ferritic-pearlitic microstructure of the specimen made of 30MnB4 steel after a deformation cycle cooled with the rate of 10°C/s

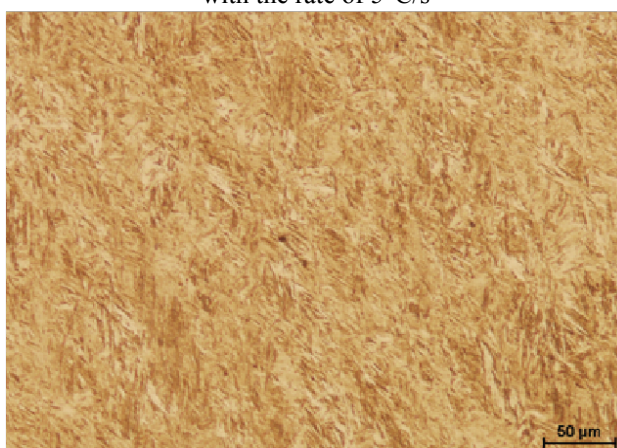


Figure 7. Martensitic-bainitic microstructure of the specimen made of 30MnB4 steel after a deformation cycle cooled with the rate of 80°C/s



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

Figures 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.

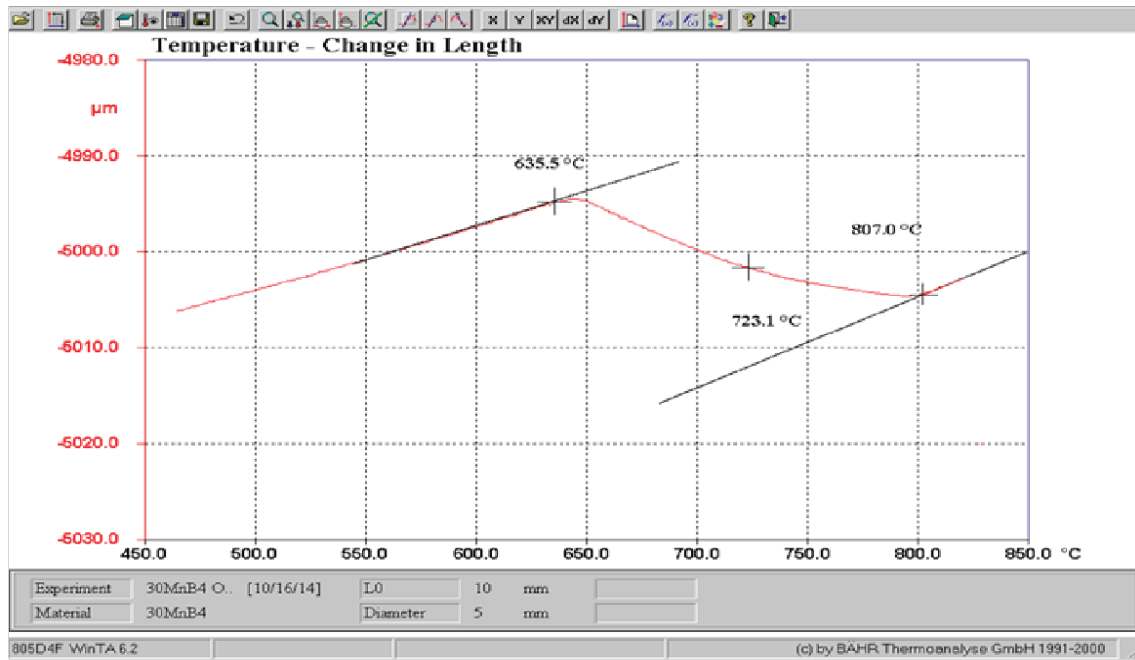


Figure 9. A dilatograph registered for 30MnB4 steel cooled after deformation from the temperature of $T_D=830^{\circ}\text{C}$ with the rate of 1°C/s

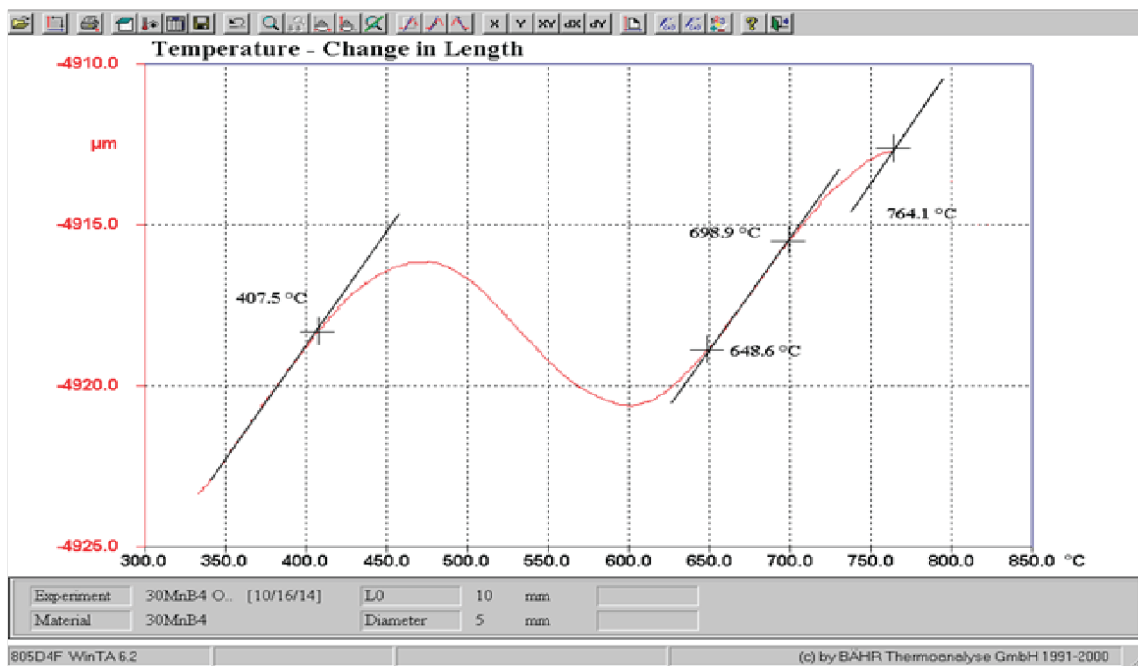


Figure 10. A dilatograph registered for 30MnB4 steel cooled after deformation from the temperature of $T_D=830^{\circ}\text{C}$ with the rate of 15°C/s

Table 1 shows typical temperatures obtained on the basis of the dilatograph analysis of 30MnB4 steel cooled after a cycle of deformations from the tem-

perature of 830°C 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 830°C

Cooling rate Cr [$^{\circ}\text{C/s}$]	Typical temperatures [$^{\circ}\text{C}$]	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	F _s =772 F _f =697 B _s =513 B _f =M _s =378 M _f =265	417.0
15	F _s =736 F _f =P _s =644 P _f =B _s =535 B _f =407	289.0
10	F _s =745 F _f =P _s =669 P _f =B _s =550 B _f =482	220.0
5	F _s =765 F _f =P _s =650 P _f =545	205.0
1	F _s =807 F _f =P _s =723 P _f =635	170.0
0.1	F _s =803 F _f =P _s =720 P _f =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.

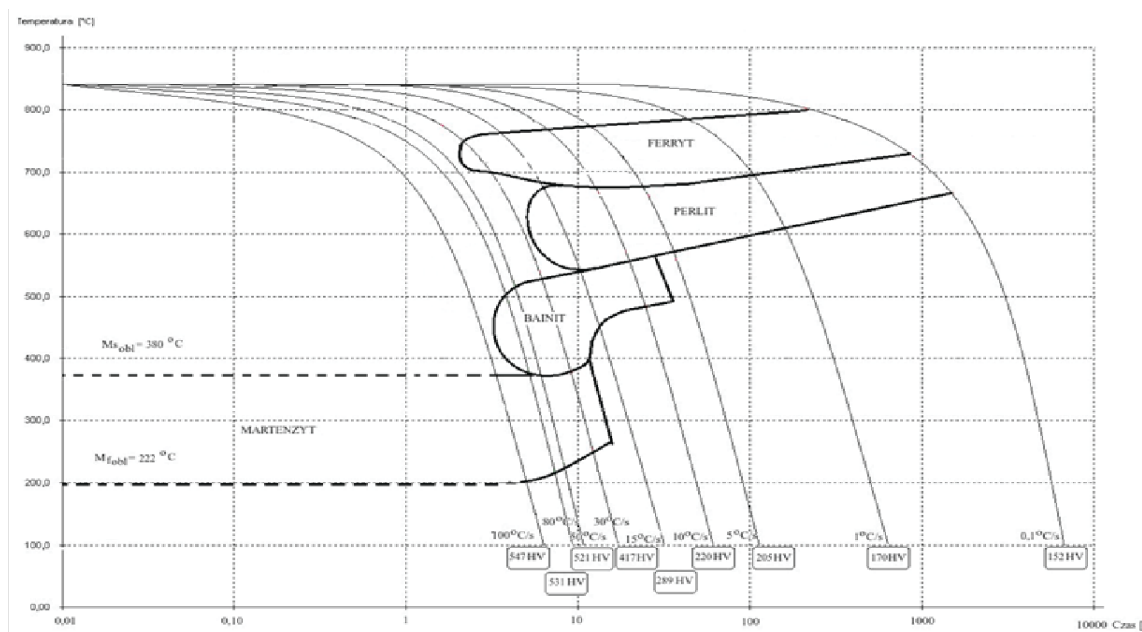


Figure 11. The DTTT diagram for 30MnB4 steel worked out on the basis of dilatometric tests

4. 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 °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 °C/s. Bainitic-martensitic structures appeared in the specimens cooled with the rate in the range of 30 ÷ 80 °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 °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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Determination of integral characteristics of stress state of the point during plastic deformation in conditions of volume loading

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