Z. MUSKALSKI, S. WIEWIÓROWSKA, M. PEŁKA

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THE INFLUENCE OF DRAWING PARAMETERS ON THE PROPERTIES HIGH-MANGANESE TWIP STEEL WIRES

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The paper presents an experimental analysis of the effect of single draft magnitude in the multi-stage drawing process on the mechanical properties of the wire, and a theoretical process analysis aimed at identifying the causes of the variations in mechanical properties, made using Drawing 2D, a FEM-relying software program of high manganese TWIP steel rolling and stamping processes.

It was found that wires drawn with small partial drafts (G_p %=11 %) had a larger plasticity reserve, as defined by the $R_{0.2}/R_m$ ratio, as compared with wires drawn with large partial drafts (G_p = 26 %). A drop both in tensile strength R_m and in proof stress $R_{0.2}$ was also found to occur after a total draft of G_c = 80 % had been exceeded, which was caused by the "strain softening" phenomenon.

Keywords: drawing, properties, TWIP steel, wire

INTRODUCTION

The increasing demand by the automotive industry has resulted in searching for materials of increasingly high mechanical properties and, at the same time, high plastic deformability. These requirements are met by multiphase AHSS (Advanced High-Strength Steels). The following can be classified into the group of AHSS type steels: diphase (DP) steels, TWIP steels, hot formed (HF) martensitic steels, plastic formed heat treated (PFHT) steels, and TWIP steels [1 - 3].

Intensive investigations into the deformation mechanism and the Fe-Mn-C phase equilibrium system have resulted in the development of high-manganese TWIP steels [4, 5] that are distinguished by a high value of the $R_m \cdot A$ parameter, amounting to even more than 50 000 MPa %.

ORIGINAL INVESTIGATION

For testing the process of drawing high-manganese TWIP type steel wires, wire rod of chemical composition as shown in Table 1 was used.

Table 1 **Chemical composition of the steel tested /wt %**

C	Si	Mn	Al
0,0200	2,990	28,600	2,540

The optimal variant of wire rod heat treatment was determined, whereby the material was solution heat treated at a temperature of 1 100°C for 10 minutes.

Z. Muskalski, S.Wiewiórowska, M.Pełka, Czestochowa University of Technology, Czestochowa, Poland

The evolution of the structure, and so the mechanical properties of material being plastically deformed are influenced by the strain rate [4]. In drawing processes, the parameter influencing both the strain intensity and strain rate is the magnitude of single drafts used; therefore, drawing of 5,5 mm-diameter TWIP steel wire rod was carried out according to two variants, where in Variant A 9 draws using single drafts of about 26 %, and in Variant B 24 draws using single drafts of about 11 % were completed. In the both variants, the total draft amounted to 93,1%, and the final wire diameter was 1,44 mm.

The variation in proof stress $R_{0.2}$, ultimate tensile strength R_m, $R_{0.2}/R_m$ ratio and elongation A_{100} as a function of the total draft (G_c,%) for drawing variants A and B is illustrated in Figures 1 (a, b) and 2 (a, b).

From the testing results shown in Figures 1 and 2 it can be found that the use of small single drafts (Variant B) results in a significant decrease in proof stress $R_{0,2}$ of about 15 %, while for final 1,44 mm-diameter wires by about 10 % compared to wires drawn according to Variant A; in contrast, in wires drawn according to Variant A, a slight increase in ultimate tensile strength R_m by approx. 2 % has occurred, compared to Variant B wires.

The cause of the differences in the mechanical properties between the wires drawn according to Variant A and Variant B are probably the higher non-dilatational strain values in wires drawn with larger single drafts. Therefore, an analysis of the variation in non-dilatational strain ε_{xy} as a function of the total draft was made for the both drawing variants, A and B, using Drawing 2D [5], an FEM based software program. An over 10 % increase in non-dilatational strain was found in the subsurface later of wires drawn with large single drafts

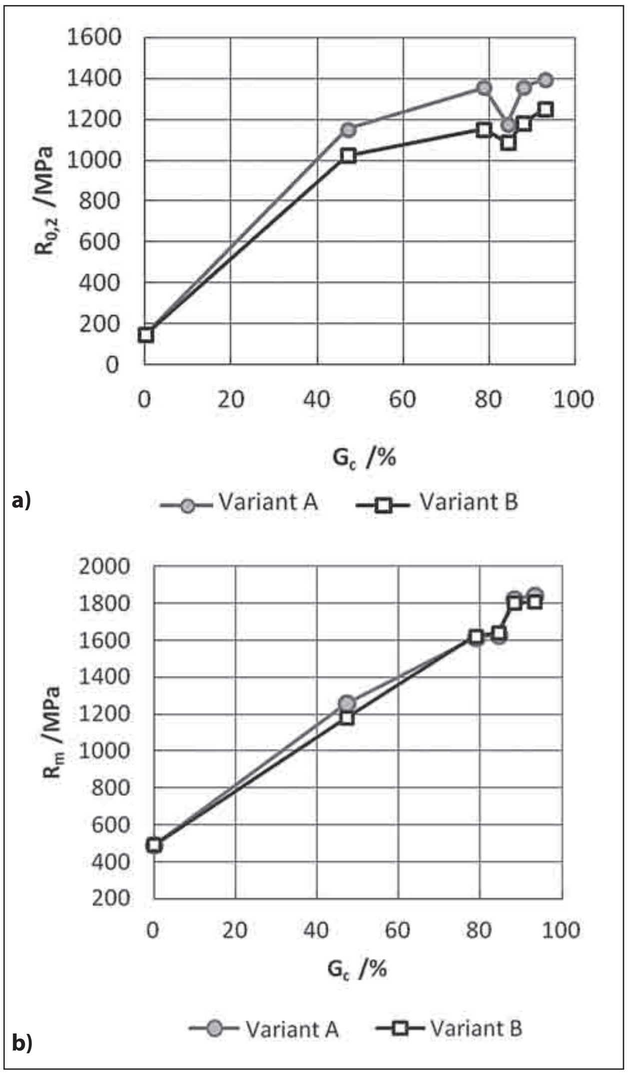

Figure 1 Variation in the proof stress $R_{0.2}$ and ultimate tensile strength R_m of wires drawn according to Variants A and B as a function of the total draft

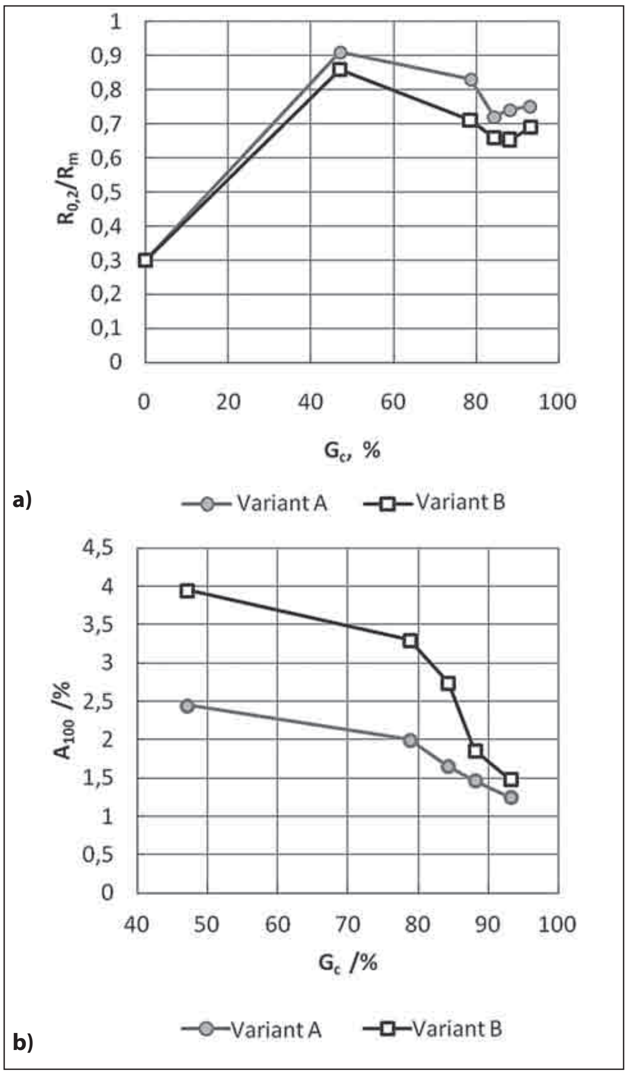

Figure 2 Variation in the $R_{0.2}$ / R_m ratio and the total elongation A_{100} of wires drawn according to Variants A and B as a function of the total draft

(Variant A), which confirms the proposition put forward (Figure 3).

The analysis of the mechanical test results of wires drawn according to Variants A and B showed also that a local increase in plasticity, called "strain softening", took place in the strain range of 78 ÷ 84 %.

The observation of the wire microstructure (Figure 4) revealed deformation bands extending through the sample in two different planes relative to the wire axis, which suggests two different deformation systems being activated simultaneously. The material existing between the bands is characterized by lower strain harden-

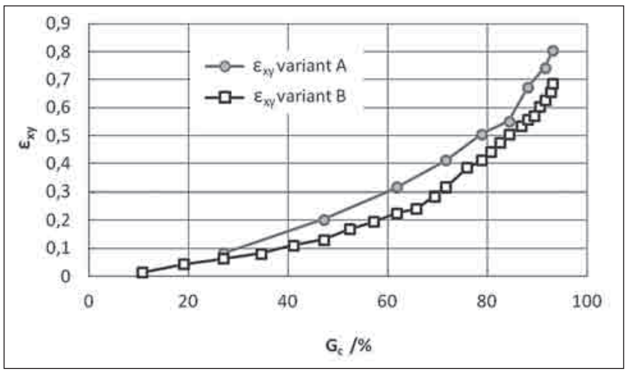

Figure 3 Variation in non-dilatational strain ε_{xy} in the subsurface layer of wires drawn according to Variants A and B, respectively

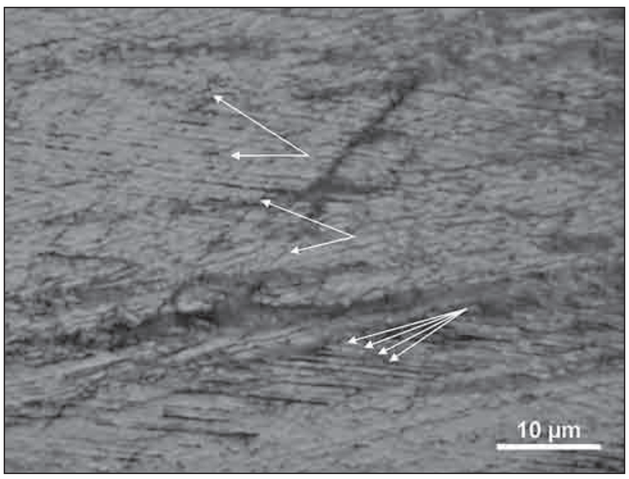

Figure 4 Microstructure of TWIP steel wire deformed with a draft of G_c = 78,1 % (the arrows indicate the deformation bands), mang. 1500 x

ing. The higher strain hardening of deformation bands by mechanical twinning occurring in them forces the material to deform beyond these bands. This means that, at large deformations, a division of the material occurs into bands being deformed at a high strain rate and passive regions with a low strain rate, which exists until the both regions have reached the identical strain hardening level.

CONCLUSION

By running the drawing process with a varying single draft magnitude, both the mechanical and plastic properties of final wire can be influenced.

The progress of the "strain softening" phenomenon is accompanied by a distinct decrease in the proof stress, resulting in an increase in the plasticity reserve. The higher plasticity allowed the continuation of the drawing process, and thus the obtaining of a larger total strain of final wire.

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Note: The professional translator for English language is Czesław Grochowina, Studio – Tekst, Poland