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The influence of drawing speed on properties of TRIP steel wires

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Properties

ABSTRACT

Purpose: The aim of this paper is to determine the influence of drawing speed of TRIP steel wires on their properties.

Design/methodology/approach: The heat treatment of steel containing 0.09 % carbon, 1.57 % manganese and 0.9 % silicon allows to obtain TRIP type structure. The wires were drawn with different drawing speed. After drawing mechanical properties of wires were determined by the tensile test. In this work also FEM modelling was done.

Findings: The analysis of changes of mechanical properties after particular drawings stages was carried out. The increase of drawing speed cause the increase of strength properties and decreasing of plasticity properties of wires. It was shown that increase of drawing speed causes increase of: temperature, non-dilatation strain and internal stresses.

Research limitations/implications: Continuation of the investigations with the use of scanning and transmission electron microscopy makes it possible to explain the changes properties of drawn wires by analyses of structure of drawn wires.

Practical implications: TRIP steel wires, which have good mechanical properties and are dependent on drawing speed, can be used for production of connecting elements.

Originality/value: For the first time there was shown the influence of drawing speed on properties of TRIP steel wires.

Keywords: Mechanical properties; TRIP effect; Drawing speed; Mechanical properties of drawn wires

1. Introduction

Much research has been performed the few decades to develop new steels that exhibit high tensile strengths while maintaining good ductility. It has resulted in a type of multiphase steel known as a TRIP (TRansformation Induced Plasticity). The advantageous strength to ductility ratio in TRIP steels results from strain induced transformation of metastable retained austenite to martensite during plastic deformation [1-6].

A multiphase structure is formed by specialized thermal treatments that allow for the formation of austenite, ferrite, bainite and perhaps martensite. The volume fraction, morphology and stability (at room temperature) of the retained austenite have a pronounced effect on the mechanical properties of the TRIP steel. Austenite stabilization occurs by carbon enrichment during heat treatment and by the addition of ferrite stabilizers (silicon and manganese) [7].

Wire rod with a TRIP type structure is expected to exhibit more desirable mechanical properties than those exhibited by low and medium carbon steels that are cooled using conventional methods [8].

Now, the main application of TRIP steel are body sheets. In literature it can be found a lot of publications which are related to rolling and heat treatment of TRIP steel sheets. But there are few publications which are related to heat treatment of wire rod and wire drawing processes from multiphase TRIP steel [9-11].

On the basis of the literature and some given results, strain speed influences on rate of phase transformation of retained austenite into martensite (TRIP effect) and strength properties of sheet [12-15]. So that drawing speed can be one of the main parameters of drawing process influencing fundamentally properties of TRIP steel wires.

2. Experimental procedure

The material used to the investigation was wire rod about diameter 6.3 mm of low carbon steel after TRIP type heat treatment. The chemical composition of used steel in the investigation is presented in table 1.

Two-step heat treatment allowing used in wire rod TRIP type structure was realised in laboratory condition Czestochowa University of Technology in resistance furnace. The volumetric phases contain in multiphase structure was estimated by MET-ILO program, table 2.

Table 1.
The chemical composition of TRIP steel

Mass contents in %								
C	Mn	Si	P	S	Cu	Ni	Mo	Sn
0.09	1.57	0.90	0.01	0.008	0.02	0.01	0.007	0.006

Table 2.
The volumetric phase contain

Phase contain			
Ferrte, %	Bainite, %	Retained austenit + ~Martensite [1], %	Retained austenit[2] %
74.6	16.8	8.6	7.8

[1] etched LePera reagent;
[2] etched nital+ metabisulfite sodium reagent

After heat treatment and metallographic investigation which confirmed used TRIP type structure, TRIP steel wires drawn in 11 drafts with different drawing speed from diameter 6.3 mm to 1.9 mm by using classical die with sintered carbides about angle $2\alpha=12^o$. In table 3, the main parameters of drawing process are shown, where: V_c – drawing speed, $G_{pśr}$ – medium single draft, G_c – total draft.

Table 3.
The parameters of drawing process

Variant	Drawing method	V_c, m/s	Drafts number	$G_{pśr}$, %	G_c, %
A	ZWICK/Z100	0.02	11	19.5	90.9
B	Bull block	0.75	11	19.5	90.9
C	Bull block	1,6	11	19.5	90.9

In order to estimate the influence of drawing speed on mechanical properties of wires with TRIP effect, described relationship between tensile strength R_m, yield strength $R_{0,2}$, contraction Z, uniform elongation A_r in total draft function for wires drawn according to variant A (V_c=0.02 m/s), B (V_c=0.75 m/s), C (V_c=1.5 m/s).

For better estimation of the influence of drawing speed on properties TRIP steel wires in the work, modelling of wire drawing process (in Drawing 2D program) has been carried out. It has been estimated: temperatures, non-dilatation strain and internal stresses drawn wires. Used in program model multi passes drawing (with a few following after themselves single draft) allows to dissolve coastal task with the range of theory of plastic forming with complied contact, friction and transfer heat between material and tool conditions, and also heating material which is related to plastic strain.

3. Results and discussion

In figures 1-2 the changes $R_{0,2}$ and R_m in total drafts function for different drawing speed were shown.

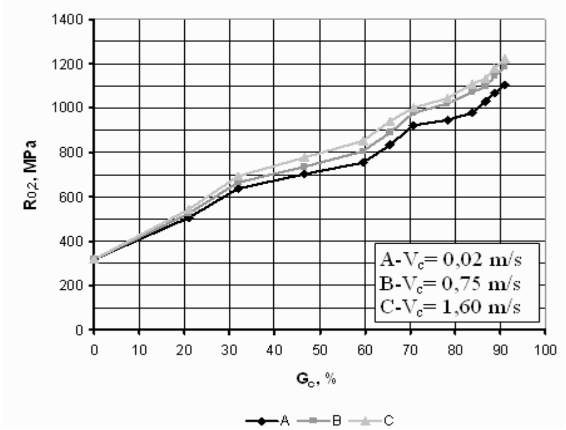

Fig. 1. The changing of yield strength $R_{0,2}$ wires in total draft function for drawing variant A, B and C

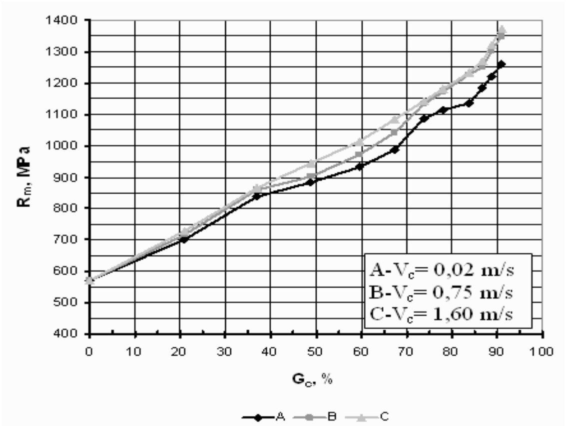

Fig. 2. The changing of tensile strength R_m wires in total draft function for drawing variant A, B and C

On the basis of data investigation shown in fig. 1-2 it was found that using in drawing process TRIP steel wires higher drawing speed causes the increase of their strength properties. Wires from variant A (drawing speed 0.02 m/s) have in comparison to wires from variant C (drawing speed 1.5 m/s) significantly lower value yield strength and tensile strength (approximately 9-10 %). Analysing obtained values $R_{0,2}$ and R_m TRIP steel wires it can be affirmed that the increase of drawing speed remarkable increases their strength properties, especially after total draft G_c=40 %.

In figures 3-4 the changes Z and A_r in total drafts function for different drawing speed were shown.

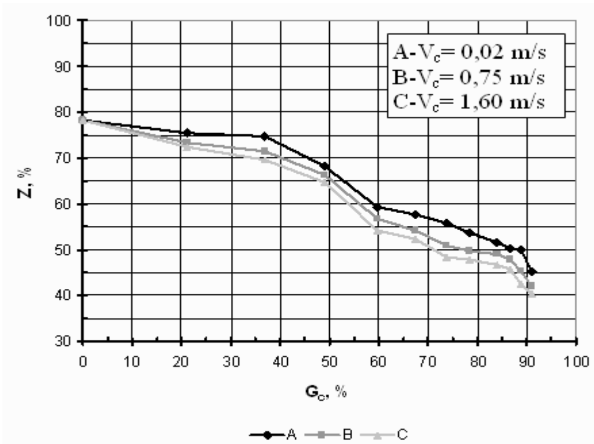

Fig. 3. The changing of contraction Z wires in total draft function for drawing variant A, B and C

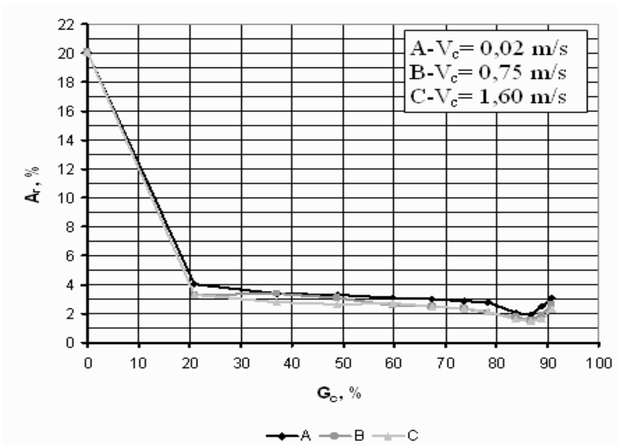

Fig. 4. The changing of uniform elongation A_r wires in total draft function for drawing variant A, B and C

On the basis of the curves shown in fig. 3-4 it was found that the increase of drawing speed deteriorates plasticity properties of wires. For total draft G_c=90.9 % wire of variant B and C have worse plasticity properties than wires of variant A. The increase of drawing speed from 0.02 m/s (variant A) to 1,6 m/s (variant C) caused significant decrease contraction about 10.6 % and uniform elongation about 17 % final wires ϕ1,9 mm.

The obtained data investigation received from the tensile test allow to find that higher drawing speed of TRIP steel wires causes a significant increase of work hardening cause deteriorates plasticity properties.

For better estimation of the influence of drawing speed on the mechanical properties drawn TRIP steel wires were made, on the basis of data from modelling, figures defining relationship between temperatures, non-dilatation strain and internal stresses in total draft function for wires drawn according to variant A, B, C; figures 5-7.

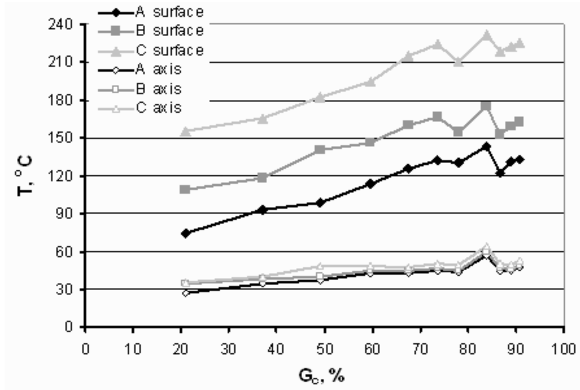

Fig. 5. The changing temperature on surface in axis TRIP steel wires on exit form gauging cylinder of die wires drawn according to variant A, B and C in total draft function

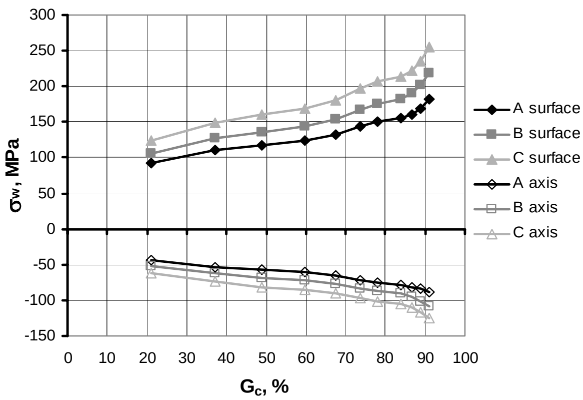

Fig. 6. The changing longitudinal internal stresses σ_w on surface and axis wires drawn according to variant A, B, C in total draft function

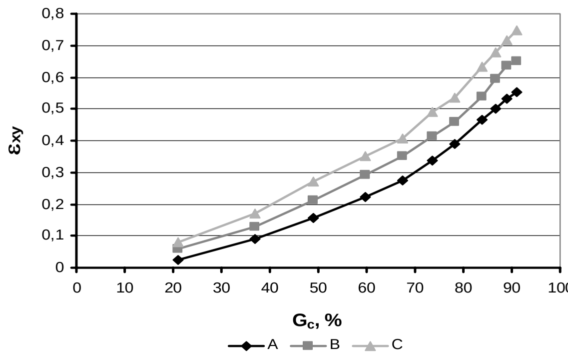

Fig. 7. The changing non-dilatation strain ε_{xy} (absolute value) on surface wires drawn according to variant A, B and C

In fig. 5 it was shown that drawing speed influences on the wire temperature. Wires drawn according to variant C (V_c=1.6 m/s), in comparison to the wires of variant A (V_c= 0.02 m/s) have higher temperature, on surface the increase about 60 % and in axis about 12 %. Higher temperature value in axis and on a surface of wires of variant B and C, in comparison to wires of variant A, is caused smaller losing the heat to tool, which is related to shorter time of wire and die contact.

In fig. 6 it was shown that drawing speed influences on longitudinal internal stresses in wires. For wires of variant C (V_c=1.6 m/s), in comparison to wires of variant A (V_c= 0.02 m/s) has the increase of longitudinal internal stresses approximately about 30 %. One of the factors, which can influence on the increase longitudinal internal stresses in drawn wires, is temperature. After drawing process on the wire surface can form tensile stresses which are related to changing coefficient of expansion heated of steel. So that when temperature is higher on surface wires the longitudinal internal stresses are higher.

In fig. 7 it was shown that drawing speed influences on non-dilatation strain. For wires drawn with the highest speed (variant C), in comparison to wires of variant A (V_c= 0.02 m/s), the increase of non-dilatation strain on the wire surface amount approximately about 30 %. The increase of non-dilatation strain, especially in the surface layer, caused increase of strain hardening, which had influence on the increase of strength properties of wires, e.g. R_m and $R_{0,2}$ and deterioration of their plasticity properties, e.g. Z and A_r. Moreover, the increase of longitudinal internal stresses in wires of variant C can be related not only to increase of temperature but also with their higher non-dilatation strain in surface layer.

4. Conclusions

1. The increase of drawing speed of TRIP steel wires causes the increase of their strength properties; the increase of drawing speed from 0.02 m/s to 1.6 m/s caused the increase of yield strength and tensile strength approximately about 9-10 %.
2. The increase of drawing speed deteriorates plasticity properties of wires. By total draft G_c=90.9 % wires of variant B and C have worse plasticity properties e.g. Z and A_r, in comparison to wires of variant A approximately about 10-17 %.
3. The enlargement drawing speed causes the increase of: wire temperature (especially on surface), longitudinal internal stresses and non-dilatation strain.
4. Along with increasing drawing speed, increases non-dilatation strain, especially in surface layer. It causes additional work hardening of wires. So that wires of variant C (V_c=1.6 m/s), in comparison to variant A and B, have the highest tensile strength. However, this additional work hardening, which is related to non-dilatation strain, caused deterioration of their plasticity properties.
5. Along with increasing drawing speed, the increase of longitudinal internal stresses can be noticed. It is caused not only by increase non-dilatation strain but also by higher temperature on the wire surface.

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