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THE INFLUENCE OF HOT DIP GALVANIZING PROCESS ON TRIP STEEL WIRE STRUCTURE AND PROPERTIES

Many wire products (e.g. nets) are made from galvanized material. The hot dip galvanizing process gives the possibility of applying in a respectively thick coat of zinc (also depending on the time of staying wires in the bath) which provides the protection of the product against corrosion. In the available literature there were no research concerned with the influence of hot dip galvanizing process on the mechanical properties TRIP structure steel wires.

Therefore, an experiment was carried out in laboratory conditions allowing the determination of the influence of hot dip galvanizing process parameters on the mechanical properties (tensile strength UST and yield strength YS) of TRIP steel wires as well as on the amount of retained austenite in their structure. It has been stated that the hot galvanizing process of TRIP steel wires influences, proportionally to the time of staying wires in zinc bath, on their plastic properties (the increase in yield strength YS) as well as the decrease in the amount of retained austenite in their structure. Such a phenomenon can be caused by stresses responsible for rapid heating of the wire put in the zinc bath in temperature of 450°C and by the strengthening of the materials resulting from the transformation of retained austenite.

Keywords: TRIP steel, galvanizing process, wires, drawing process.

1. Introduction

The hot galvanizing process is carried out under industrial conditions at a temperature of 450°C and the time of staying wires in the zinc bath is varies and depends in direct proportion to the assumed thickness of zinc coating.

Might suppose, that hot dip galvanizing process doesn't influence on mechanical properties and the amount of retained austenite in wire structure, and the temperature should block the transformation of retained austenite into martensite, according to the diagram shown in Fig. 1.

We observe the transformation of retained austenite into martnesite in the range of temperatures $M_s - M_{s,\sigma}$ under the influence of the change of stress state. A rise in temperature causes the increase in stresses necessary for such transformation.

The stress required to initiate martenistic transformation is equal to the value of retained austenite yield point, for $M_{s,\sigma}$ temperature.

This is the limit value in which the transformation of retained austenite into martensite is changing form stress-induced transformation into strain-induced transformation.

Above the M_d temperature the transformation of retained austenite into martensite does not occur even if the deformation process took place. Such a phenomenon is caused by the increase in the retained austenite stability at higher temperatures. The rise in temperature to the value of above M_d causes the decrease in the driving force of transformation and increase in stacking fault energy, which makes the transformation of retained austenite into marteniste impossible and only allows its deformation.

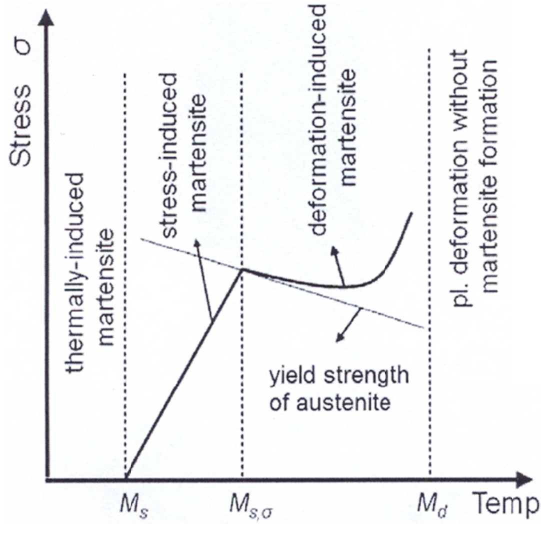

Fig. 1. Schematic diagram of the martensitic transformation induced by stress, strain and temperature [1,2]

However in the work [3] has been stated that even at the temperature 450°C we don't observe the full blocking process of transformation retained austenite into martensite in warm drawing process tests, wires were resistance heated in front of

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the die by use of the high current in the range of temperatures from 20°C to 450°C in time 2s.

The amount of retained austenite for wires drawn with 23% degree of total deformation at the temperature 450°C decreased by 47% compared to the baseline.

The transformation of retained austenite into martensite in the range of temperatures $M_s - M_{s,\sigma}$ initiated by stresses responsible for rapid heating of the wires can by one of the possible explanation such a phenomenon.

The research shown in the work should give the answer to assess the impact of hot dip galvanizing process on the mechanical properties TRIP steel wires as well as on the amount of retained austenite in their structure and in some case on the evaluation of the mechanism the transformation retained austenite into marstensite during the hot dip galvanizing process [4÷6].

2. Experimental procedure

Tests were carried out for wires made from steel with chemical composition as shown in Table 1.

TABLE 1

The chemical composition of medium carbon steel, wt.-%

C	Mn	Si	Ni	Cr	Al	S
0.293	1.430	1.320	0.122	0.100	0.045	0.011

To obtain retained austenite in the material in the quantity sufficient to assure the TRIP effect to be achieved, it was necessary to carry out two-stage heat treatment with properly selected parameters, which consisted in holding the steel within the diphase austenitic-ferritic range with subsequent soaking it within the bainitic transformation range (Fig. 2).

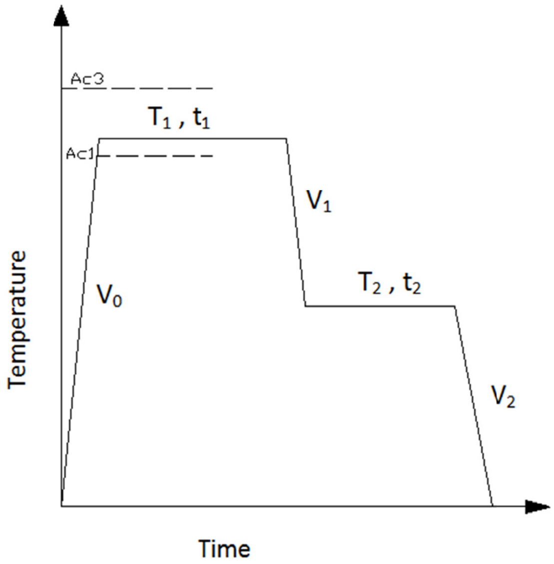

Fig. 2. Heat treatment scheme for obtaining the TRIP structure in the steel [7], Where: T_1 = 760°C, T_2 = 440°C, t_1 = 240 s, t_2 = 120 s, V_0 = 20°C/s, V_1 = 50°C/s, V_2 = 80°C/s

The wires were heat treated under laboratory conditions in resistance heating furnaces manufactured by LAC, according to the parameters established in the previous tests, which allowed a maximum amount of retained austenite to be obtained in the structure [8].

The volume fraction of the retained austenite was determined using following methods:

- pint-by-point method,
- secant method,
- application of Met-Ilo software.

The average value was calculated and equal 16.3%.

The hot galvanizing process was carried out in laboratory conditions, using lead bath instead of zinc bath, what also allowed to avoid the removal the zinc coating before analysis the mechanical properties of TRIP steel wires.

The parameters of the process like the lead bath's temperature, the time of staying wires in the bath were estimated on the base of parameters the hot dip galvanizing line working in one of the drawing plants.

- the lead bath's temperature was equal 445±5°C,
- the time of staying wires in the baths was calculated from the dependence:

$D \cdot v = 100$ (for thin zinc coat)

and

$D \cdot v = 50$ (for thick zinc coat)

where:

D – the wire diameter [mm],
v – the cruising speed of the wire through the bathtub [m/min].

The time of staying wires in the bath for thin zinc coat was established on t_1 = 4.5 s and for thick zinc coat on t_2 = 9 s, for 3 meters long galvanizing bathtub use in the drawing plant.

3. Research results and analysis

For wires after hot galvanizing process (modeled in laboratory conditions) according two variants W1 – with thin zinc coat and W2 – with thick zinc coat, the mechanical properties were estimated, the values were compared with mechanical properties of bare wires (variant W0) (Table 2, and Fig. 3).

TABLE 2

The mechanical properties of bare TRIP steel wires (W0) and TRIP steel wires after hot galvanizing process according two variants W1 and W2 made from TRIP steel

Variant	UTS, MPa	YS, MPa	A, %	YS/UTS
W0	714.6	226.0	20.96	0.316
W1	706.8	296.0	19.65	0.419
W2	703.6	369.9	18.50	0.526

The amount of retained austenite in wires structure was determined based on structural analysis including the quantitative analysis of retained austenite in the structure of the heat treated

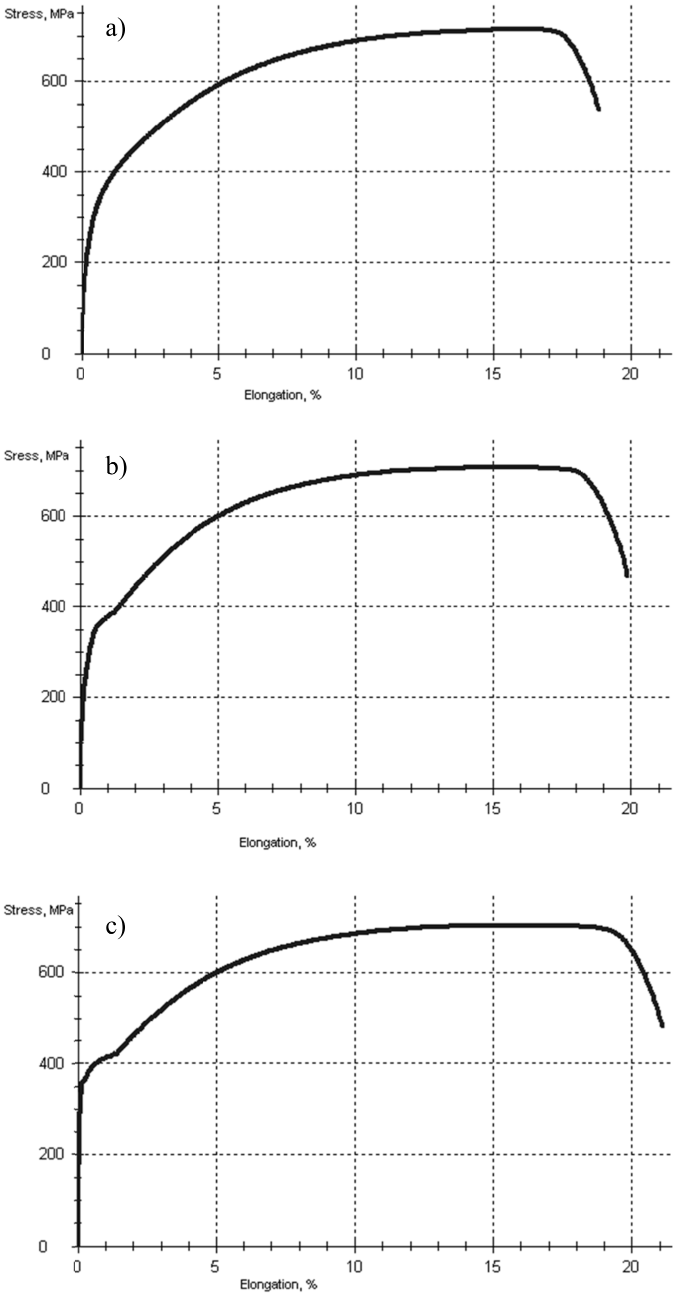

Fig. 3. Work hardening curves for wires: a) variant W0, b) variant W1, c) variant W2

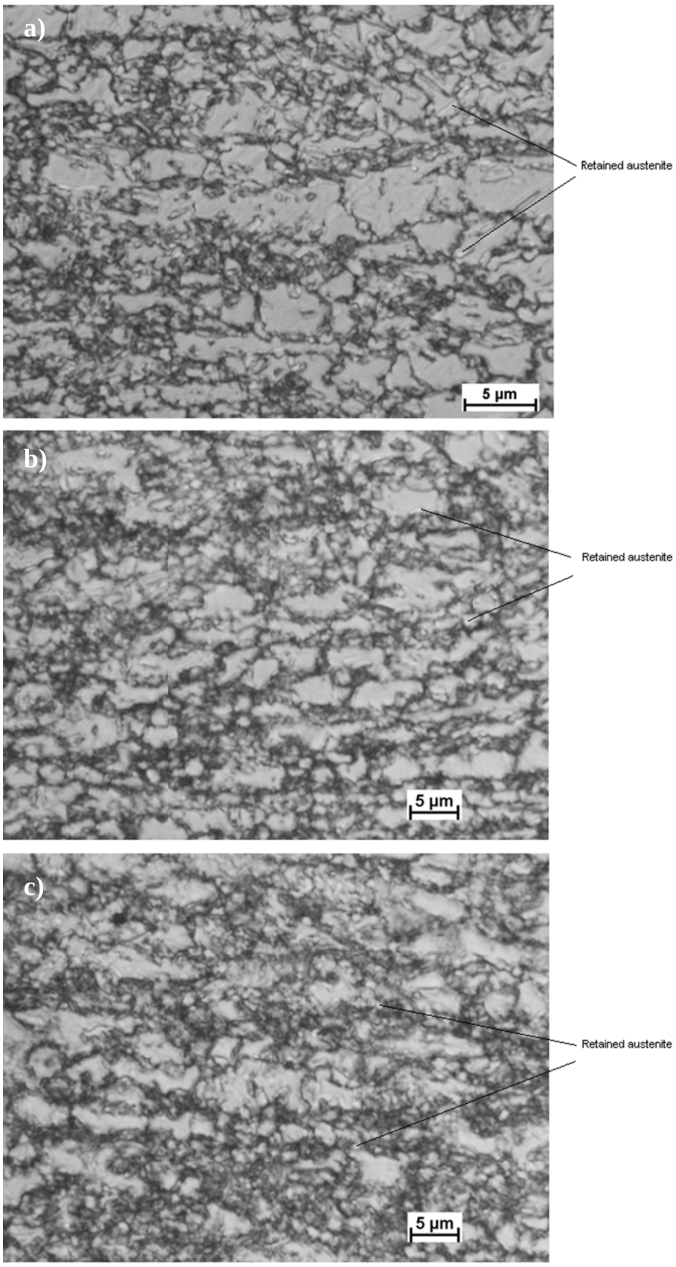

Fig. 4. Microstructure of bare TRIP steel wires for wire surface a) and TRIP steel wires after hot galvanizing process according two variants W1 b); and W2 c); (magn. 1500×)

steel using light microscopy. An Axiovert 25 optical microscope was used for the examinations. The examples of microstructures shown on Fig. 4. The volume fraction of retained austenite for wires is shown Table 3.

TABLE 3

The volume fraction of retained austenite for bare TRIP steel wires (W0) and for TRIP steel wires after hot galvanizing process according two variants W1 and W2 made from TRIP steel

Variant	Volume fraction of retained austenite, %
W0	16.3
W1	11.8
W2	8.4

Based on the results of the mechanical properties presented in table 2 and Fig. 3, it can be stated that modeled hot galvanizing process for TRIP steel wires does not significantly affect on values of tensile strength. A decrease UTS values for W1 variant of about 1,1% and for W2 variant of about 1,5% in relation values of UTS for variant W0 (bare wires) was observed.

The temperature and time of hot galvanizing process affect on decrease of wires plastic properties in significant way. For variant W1 the increase of yield strength YS of about 31% and the decrease of elongation of about 6,25%, for variant W2 the increase of yield strength $R_{0,2}$ of about 64% and the decrease of elongation of about 11,7% in relation for variant W0 was observed. The decrease of plastic properties was well reflected in the growth of values YS/UTS ratio.

The microstructure analysis doesn't indicate differences in grain size for bare and galvanizing wires, but the significant decrease volume fraction of retained austenite for wires after galvanizing process was observed (for variant W1 of about 27,6%, for variant W2 of about 48,5%).

Such significant decrease volume fraction of retained austenite in wire surface influenced on mechanical properties of wires and on the nature of hardening curves and can be caused by the thermal stresses of wires after putting them in zinc bath.

For variant W1 and W2 the clear yield point appears together with decrease plastic properties of wires. Such phenomena is not observed for bare wires.

4. Summary

The hot galvanizing process influences on the decrease in the amount of retained austenite in wires structure. The decrease of the amount of retained austenite in wire structure is proportional to the time of staying wires in zinc bath. The hot galvanizing process does not influences in a significant way on the values of tensile strength (UTS) processed wires, but it can be observe the significant differences in values of yield strength (YS) and in YS/UTS ratio.

The decrease in the amount of retained austenite and the increase in the values of yield strength after hot galvanizing process for TRIP steel wires is probably caused by the transformation retained austenite into martensite initiated by stresses in the range of temperatures $M_s - M_{s,\sigma}$ occurred as an effect of rapid heating of the wires from 20°C to 450°C after putting them in zinc bath.

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