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ISSN 0543-5846
METABK 52(1) 43-46 (2013)
UDC – UDK 620.17.669.784.15:621.778=111

THE MECHANICAL PROPERTIES OF HIGH CARBON STEEL WIRES DRAWN IN CONVENTIONAL AND HYDRODYNAMIC DIES

Received – Prispjelo: 2012-03-22
Accepted – Prihvaćeno: 2012-07-28
Original Scientific Paper – Izvorni znanstveni rad

In the paper the influence of the hydrodynamic die on mechanical properties has been assessed. The drawing process of ϕ 5,5 mm wires to the final wire of ϕ 2,5 mm was conducted in 7 passes, in industrial conditions, by means of a modern Koch multi-die drawing machine. The drawing speed in the last passes was 8,2 m/s. On the basis of numerical analyses wire drawing process, the redundant strain of wires has been determined. In the case of the wires drawn with hydrodynamic dies the increase of plasticity properties have been noted. It has been shown that the increase of strength properties in wires drawn with conventional die is related to the occurrence in their bigger redundant strain.

Keywords: mechanical properties, high carbon steel, wires, conventional and hydrodynamic dies, redundant strain

INTRODUCTION

A dynamic development of the metal industry in the last years and also economical and technical considerations require to search for some new production technologies of drawn products. A permanently increase of the industry requirements in the range of amount, quality and properties of drawn products i.e. steel cord, rope wires, springs have caused a necessity of the modernization of the drawing mill and the drawing tools including dies.

The modern multi-die drawing machine makes it possible to dry drawing of wire with drawing speed above 25 m/s. In practice in order to gain a certain industry standard, wire manufactures limit the drawing speed to 10-15 m/s in the last pass. The available literature on the subject indicate that high drawing speed can cause the change of the drawing conditions and properties of high carbon steel wires [1-3].

One of the main factors which cause the limitation of drawing speed is friction which result in the increase of temperature. As a result of the application of high drawing speed, a temperature on the surface wire rises above several hundred degrees Celsius [1, 4].

One of the method of reduction of the friction coefficient is drawing process in hydrodynamic dies, where during drawing almost the complete separating of the wire surface and a die occur [5].

In the literature the information concerning to the influence of the wire drawing process in hydrodynamic dies on properties of drawn wires can be found [5, 6]. The data investigation presented in the works [6] shown that the application in the wire drawing process of the hydrodynamic dies have a favorable effect on the drawing parameters and properties i.e. temperature, effective strain and residual stresses.

Therefore, the present work makes an attempt to assess the influence of the multipass drawing process in conventional and hydrodynamic dies on mechanical properties of high carbon steel wires.

MATERIAL AND APPLIED DRAWING TECHNOLOGIES

The material applied for the investigation was of C72 high carbon steel wire rod. Before drawing, the wire rod was patented, itched and boraxed. The drawing process of ϕ 5,5 mm wires in the final wire of ϕ 2,5 mm was conducted in 7 passes, in industrial conditions, by means of a modern Koch multi-die drawing machine. The drawing speeds in the last pass was 8,2 m/s.

Single drafts, Ds, total drafts, Dt, and drawing speeds, v, for wires from variants A-B are summarized in Table 1. In drafts 1-4 calcareous lubricant CONDAT Vicafil SUMAC 2T was applied while in drafts 5-7 soda lubricant TRAXIT SL 202 BS was used. The wires from variant A were drawn in conventional dies while the wires from variant B in hydrodynamic dies.

THE MECHANICAL PROPERTIES OF DRAWN WIRES

In order to establish the effect of drawing speed on mechanical properties of wires, mechanical investigation was carried on by means of Zwick Z100 testing

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Table 1 **Distribution of single drafts, total drafts and drawing speed for wires from variant A and B**

Draft	ϕ / mm	Ds / %	Dt / %	V/ m/s
0	5,50	-	-	-
1	4,92	19,98	19,98	2,12
2	4,38	20,75	36,58	2,67
3	3,90	20,72	49,72	3,37
4	3,50	19,46	59,50	4,18
5	3,12	20,54	67,82	5,26
6	2,80	19,46	74,08	6,53
7	2,50	20,28	79,34	8,20

machine, according to PN-EN ISO 6892-1:2009 standard. For wire rod and drawn wires, the following were determined: yield stress, Re; tensile strength, Rm; coefficient, Re/Rm; uniform elongation, Au; total elongation, At; reduction of area, Z.

The changing of Re, Rm and Re/Rm in total draft function are presented in Figure 1-3.

On the basis of Figures 1, 2 it can be observed that the hydrodynamic dies influences essentially the strength properties of high carbon steel wires. The application in drawing process of hydrodynamic dies (variant B) results in an decrease in their strength properties, i.e. the yield stress and the ultimate tensile strength. The final wires from variant B, as compared to the wires from variants A, are distinguished by a yield point lower by 7,3 % and an ultimate tensile strength lower by 3,7 %, respectively.

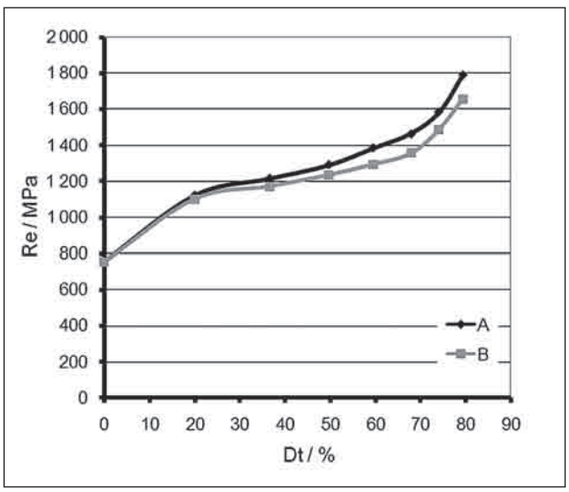

Figure 1 The changing of yield stress in total draft function for wires drawn according to variants A and B

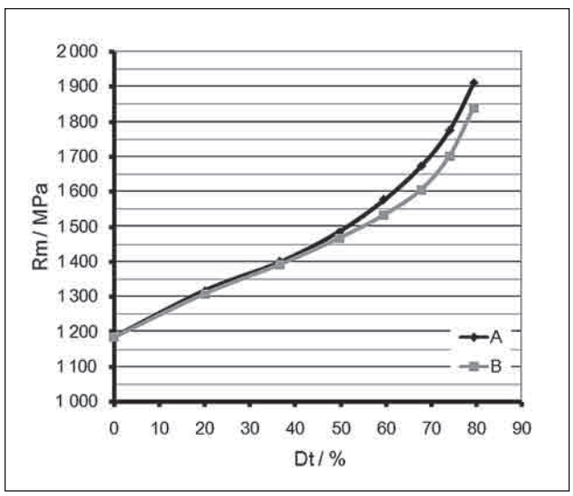

Figure 2 The changing of tensile strength in total draft function for wires drawn according to variants A and B

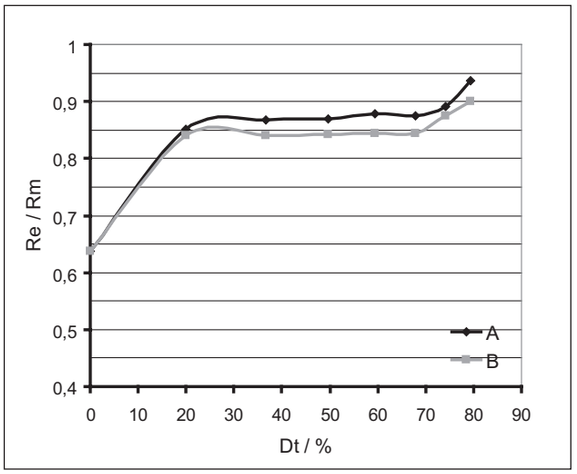

Figure 3 The changing of coefficient Re/Rm in total draft function for wires drawn according to variants A and B

Additionally in the work, the analysis of coefficient YS/UTS has been carried out. This parameter allows to estimate susceptibility of wire on plastic strain (smaller coefficient proves better plasticity properties of material). Figure 3 proves the positive influence of hydrodynamic dies on plasticity of wires. The wires from variant B have lower coefficient Re/Rm, approximately 3,8 %. The parameters which can also prove the positive influence of hydrodynamic dies on plasticity properties of wires were presented in Figures 4-6.

It can be observed from Figures 4-6 that the hydrodynamic dies improves essentially the plasticity properties of high carbon steel wires. The final wires from variant B (hydrodynamic dies), as compared to the wires from variants A (conventional dies), are distinguished by an uniform elongation higher by 13,7 %, a total elongation higher by 27,5 % and a contraction higher by 8 %, respectively. The worse plasticity properties for wires from variant A are related to their bigger work hardening (Figures 1, 2).

THE THEORETICAL ANALYSIS OF WIREDRAWING PROCESS

The experimental determination of the distribution of redundant strain on the cross-section of wire being drawn is difficult to accomplish, therefore the present work proposes a theoretical analysis of this problem based on the software Drawing 2D [7].

The simulation of the multi-pass drawing process was performed for a wire with plastic properties corresponding to those of the pearlitic-ferritic steel C72 (~

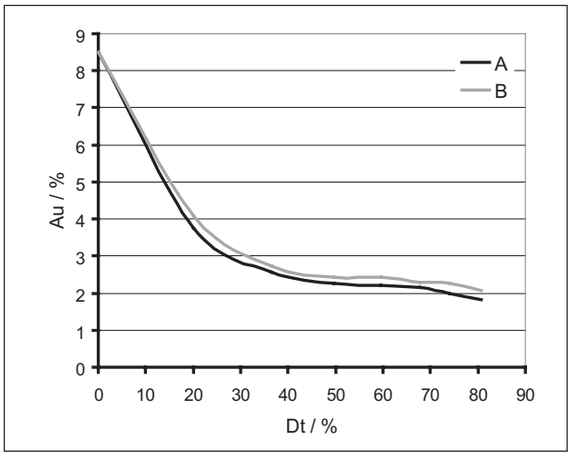

Figure 4 The changing of uniform elongation in total draft function for wires drawn according to variants A and B

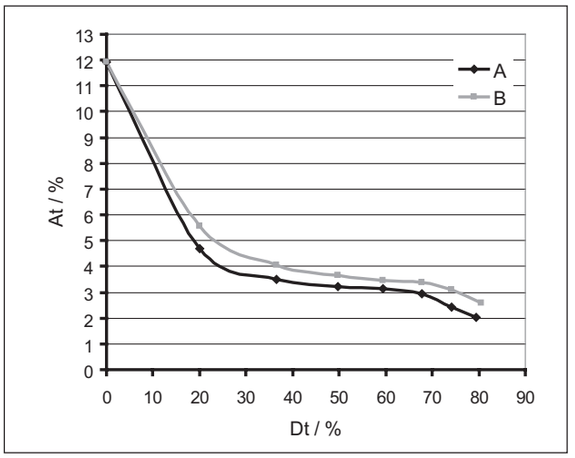

Figure 5 The changing of total elongation in total draft function for wires drawn according to variants A and B

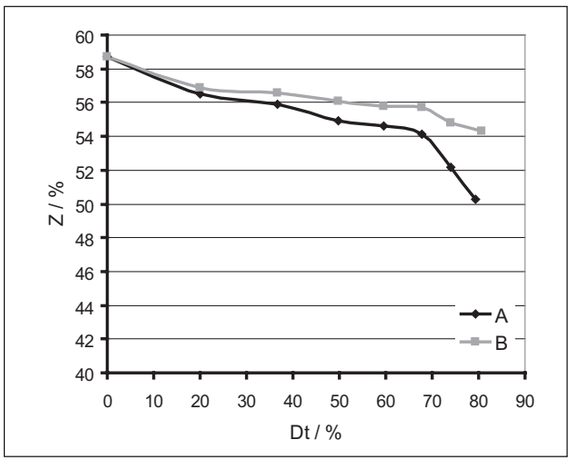

Figure 6 The changing of reduction of area in total draft function for wires drawn according to variants A and B

0,72 % C). It was assumed that the drawing process took place with the identical distribution of single and total drafts to that of the experimental tests (Table 1), with the friction coefficient of μ=0,008 for variant A and μ=0,075 for variant B.

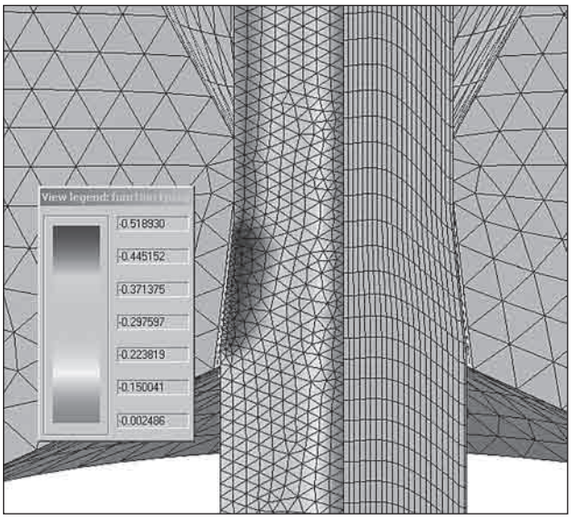

Figure 7 Redundant strain distributions on the cross-section of ϕ 2,5 mm wires drawn according to variant A

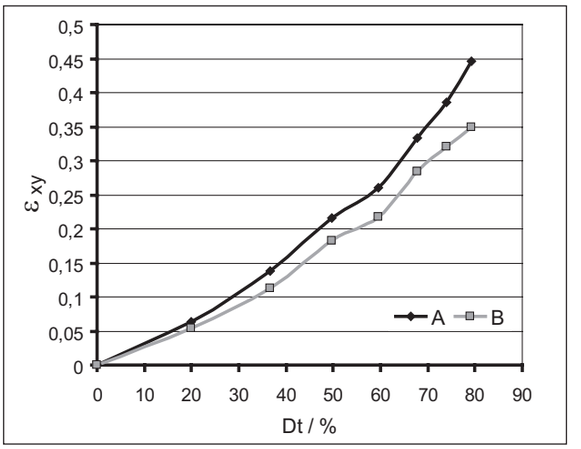

Figure 8 The change of redundant strain ε_{xy} of wire surface in total draft function for variant A and B

Figure 7 shows the redundant strain distributions on the cross-section of ϕ 2,5 mm wires drawn according to variant A.

As the Drawing 2D software, with the visualization of distribution of a particular parameter, provides the possibility of reading out the numerical value of that parameter for each of the triangular grid nodes, the redundant strain on the wire surface was determined in the work.

In Figure 8 the change of redundant strain ε_{xy} of wire surface in total draft function for variant A and B has been shown while in Figure 9 redundant strain distributions on the cross-section of ϕ 2,5 mm wires drawn according to Variants A and B has been presented.

On the basis of Figures 8, 9 it can be observed that the application of hydrodynamic dies reduce the redundant of strain. The wires from variant B, as compared to the wires from variants A, exhibit lower redundant of strain by 22 %. The biggest differences were found in the sub-layers of drawn wires. The increase of redundant strain in wires drawn in conventional dies cause

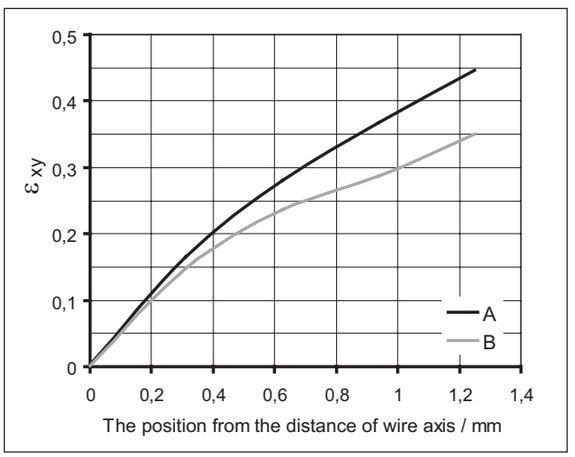

Figure 9 The distributions of the redundant strain ε_{xy} on the cross-section of ϕ 2,5 mm wires drawn according to Variants A and B

the increase of additional work hardening. And it is the reason why for wires from variant A the higher strength properties was found.

CONCLUSIONS

From the theoretical studies and experimental tests carried out, the following findings and conclusions have been drawn:

The application in the multipass drawing process of the hydrodynamic dies influences essentially on the mechanical properties of high carbon steel wires.

The wires from variant B (hydrodynamic dies), as compared to the wires from variants A (conventional dies), are distinguished by a yield stress lower by 7,3 % and an ultimate tensile strength lower by 3,7 %, respectively. The decrease of strength properties of wires from variant B caused their improvement of plasticity properties, an total elongation by 27,5 % and a reduction of area higher by 8 %, respectively.

The increase of strength properties in wires drawn in conventional dies is related to the occurrence of their bigger redundant strain which caused the increase of additional work hardening.

The obtained data of investigations can be applied in wire industry while implementing the new technologies of manufactures of high carbon steel wires.

REFERENCES

[1] M. Suliga, The influence of the high drawing speed on mechanical-technological properties of high carbon steel wires, Archieves of Metallurgy and Materials, 3 (2011), 823-828.

[2] I. Nemec, B. Golis, J.W. Pilarczyk, R. Budzik, W. Waszkielewicz, Effect of high-speed drawing on properties of high-carbon steel wires, Wire Journal International, 12 (2007), 63-68.

[3] R.N. Wright, Physical conditions in the lubricant layer, Wire Journal International, 7 (1997), 88-92.

[4] S.K. Lee, D.C. Ko, B.M. Kim, Pass schedule of wire drawing process to prevent delamination for high strength steel cord wire, Materials and Design, 30 (2009), 2919-2927.

[5] J. Łuksza, Elementy ciągarstwa, Wydawnictwo AGH, Kraków (2001).

[6] M. Suliga, The influence of the multipass drawing process in classical and hydrodynamic dies on residual stresses of high carbon steel wires, Archieves of Metallurgy and Materials, 4 (2011), 939-944.

[7] A. Milenin, Software Drawing2D - general tool for analysis of technological processes of multi-pass drawing, Metallurgist-Metallurgical News, 2 (2005), 100-103.

Note: The professional translator for English language is Krzysztof Skorupa, studio tłumaczeń, Myszków, Poland