Impact resistance of hot-work tool steels and padding layers on forging dies

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Abstract

The article represents research conclusions of impact resistance of chosen hot-work tool steels: 55NiCrMoV7, X37CrMoV5-1, layers padded with F 8-12, F-812, UTOP-38 rods and durability layout. The research of impact resistance was conducted for tool steel in the temperature of 20 ÷ 600^{o}C and the research for pad–ding layers in the temperature of 20 ÷ 250^{o}C.

Key words: impact resistance, object property, padding layers, hot-work forging dies, wear, durability

1. Introduction.

The great intensity of wear of tools used for plastic working draws more and more attention to problems of tool durability. This durability greatly influences the quality and cost of drop forgings.

The main materials used in production of forging dies are hot-work tool steels. Padding is one of the methods of dignifying and modification the padded layer of forging tools in order to heighten their durability [1, 2, 3, 4, 5]. An alternative solution proposed and used in "Glinik" forge is the production of forging dies from construction steels for hardening and tempering and padding of engraving surfaces with the proper material F-812, F-818, UTO38. The processes of padding ensure the possibility of improvement of usage values of work surfaces of forging tools through the manufacturing of the outer layer with special exploit characteristics. The main problem is the proper choice of a chemical formula of the padding materials. Because of the multitude of conditions of forging tools work and the multitude of mechanisms of wear it is necessary to use various padding materials even in one working engraving. The characteristics of padded layers encompass the scope starting with layers with good plastic values, those resistant to hot wear through those resistant to crevices, abrasion, and those resistant to fissures. The necessary characteristics can be achieved through the choice of padding materials which include the proper content of alloy elements (C, Cr, Mo, Mn, Ni, W i Co). It is surmised that the most plastic layer (resistant to crevices) should include ca. 0,10 – 0,15% C, Cr - 5 % a i Mo – 4 % and also Mn, Ni, V i Si. The second kind of padded layer should include ok. 0,10 – 0,15 % C, ok. 9,0 - 9,5 % Cr, ok. 2,15 % Mo and Mn, Ni, Si. The third kind includes ok. 0.20 - 025 % C, ok. 10 % Cr, ok. 3% Mo, ok. 1% W and Mn, Ni, Si. Through the proper conduction of the process of padding and the keeping of the proper conditions during stress relief annealing the following hardness of layers on different levels was achieved: ok. 35 – 40 HRC, 40 – 45HRC, oraz 50 – 55HRC. The accepted conditions are met by eg. rods UTOP 38, F-812, F-818, which were used in production conditions, modified some of the alloy elements with the producer. The detailed characteristics of the above materials are given in table 2.

The article shows the results of research of impact resistance of chosen hot-work tool steels: 55NiCrMoV7, X37CrMoV5-1, layers padded with rods F-812, F-818, UTOP38 on the basis of construction steel 42CrMo4 for forging dies and the durability layout in padded layers.

2. Research methodoly, aim and scope

The research was conducted in order to ascertain the influence of temperature on impact resistance for chosen hot-work tool steels 55NiCrMoV7, 37CrMoV5-1 and for layers from materials typified for padding UTOP 38, F-12, F- 818 and for working hot-work forging dies. The research also ascertains the influence of alloy elements which are decisive for tool durability. The research was conducted in conditions on the verge of real (production) conditions of die work. The characteristics of the researched materials are given in tables 1, 2 and 3.

Table 1. Chemical composition and heat treatment of the researched hot-work tool steels.

Steel designation		Chemical composition, %									
		C	Mn	Si	P	S	Cr	Ni	Mo	V	W
55NiCrMoV7		0,52	0,65	0,19	0,18	0,02	0,67	1,45	0,45	0,05	-
37CrMoV5-1		0,34	0,39	0,91	0,01	0,02	4,62	0,26	1,25	0,35	0,01
Heat treatment		HRC hardness after heat treatment									
55NiCrMoV7		46 - 49									
Hardening 860^{0}C	Drawing back 1) 460^{o}C 2) 440^{o}C										
37CrMoV5-1		50 - 53									
Hardening 1020^{o}C	Drawing back 1) 550^{o}C 2) 510^{o}C										
Analysis of chemical composition: spectral analyzer BAIRD 750FSQ											

Table 2. Chemical composition of materials for pudding of forming dies engravings

Material designation	Chemical composition, %										
	C	Si	Mn	P	S	Cr	Mo	Ni	V	W	Ti
UTOP38	0,15	0,35	0,90	-	-	5,05	4,0	-	0,20	0,15	-
F-812	0,10	0,5	0,70	-	-	9,65	2,15	0,80	-	-	0,20
F-818	0,24	0,70	0,60	-	-	10,0	3,01	1,70	0,25	1,40	0,25
HRC hardness after padding						Padding thickness mm					
UTOP38	36 - 38					8 - 10 (4 layers)					
F-812	42 - 44										
F-818	53 - 55										

Table 3. Chemical composition and heat treatment of alloy construction steel 42CrMo4

Steel designation		Chemical composition, %									
		C	Mn	Si	P	S	Cr	Ni	Mo	V	W
42CrMo4		0,39	0,8	0,3	0,34	0,3	0,11	-	0,21	-	-
Heat treatment		HRC hardness after heat treatment									
Hardening 840°C	Drawing back 620°C	33 - 36									
Analysis of chemical composition: spectral analyzer BAIRD 750FSQ											

Impact resistance research was conducted in „Glinik" for-ge located in Gorlice. Test samples with Mesnager notches with dimensions 10x10x55 mm from hot-work tool steels: 55NiCrMoV7, 37CrMoV5-1 were made on Char-py's Hammer PS30 in the scope of tem-peratures 20 ÷ 600°C. Test samples with Mesnager not–ches from padding layers: UTOP38, F12-12, F-818 with dimensions 5x5x27,5 mm were made on Charpy's Ham-mer WPM 1,5 in the scope of temperatures 20 ÷ 250°C according to PN-EN-10045-1 in the Institute of Material Engineering of the Cracow University of Technology. Furthermore the hardness layout $HV_{0,01}$ was ascertained in singular padding layers, the border sphere and the base material (42 CrMo4).

3. Research results

The conducted research of impact resistance for steels: X37CrMOV5-1, 55NiCrMoV-7 are shown in ta-bles 4, 5 and figures 1, 2 and the impact resistance of test samples drawn from padding layers: UTOP38, F12-12, F-818 are shown in table 6. In table 7 and figures 3, 4 the average impact resistance is shown. The comparison of the relation between KCU impact resistance and tempera-ture for steels X37CrMoV5-1 i 55NiCrMoV7 with impact resistance of the test samples drawn from padding layers: UTOP38, F-818 and F-812 is shown on fig. 5 and the hardness layout $HV_{0,1}$ in the function of distance from the surface of padded layer is shown in table 8 and figures 6, 7 and 8.

Table 4. Impact resistance of X37CrMoV5-1 steel in different tempera-tures (average values; number of repetitions r = 2)

No.	t, °C	KCU, J/cm²
1	20	40,0
2	250	45,5
3	350	54,5
4	380	63,0
5	420	61,5
6	450	67,0
7	480	64,5
8	550	64,0
9	650	86,5

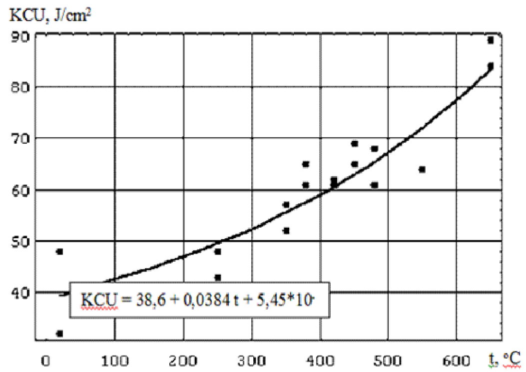

Fig. 1 The relation between impact resistance and temperature (steel X37CrMoV5-1)

Table 5. Impact resistance of steel 55NiCrMoV-7 in different tempera-tures (average values; number of repetitions r = 2 - 5)

No.	t, °C	KCU, J/cm²
1	20	24,5
2	250	30,0
3	350	31,0
4	450	28,5
5	500	31,5
6	550	39,5
7	600	63,5

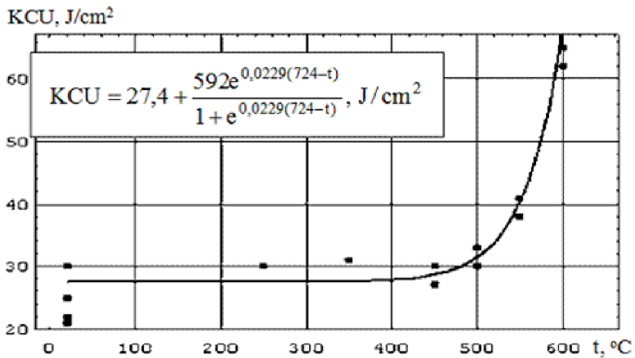

Fig. 2 The relation between impact resistance and temperature (steel 55NiCrMoV7)

Table 6. Impact resistance of samples drawn from padding layers

Layer material	Temperature, °C	Impact resistance KCU, J/cm^2
UTOP38	20	4,8 ± 1,0
	250	19,2 ± 3,2
F-818	20	9,1 ± 2,3
	250	13,0 ± 1,7
F-812	20	21,9 ± 7,7
	250	29,4 ± 4,3

The results of comparison between the average impact resistances in temperatures 20°C and 250°C given in Table 6 is shown in Table 7.

Table 7. Results of comparison of average impact resistances in temperatures 20°C i 250°C (α = 0,1)

No.	Material	Test t of importance of differences
1	UTOP 38	$t = 8{,}305^{***} > t_{0,1;7} = 1{,}895$
2	F-818	$t = 2{,}100^{*} < t_{0,1;12} = 1{,}782$
3	F-812	$t = 1{,}986^{*} > t_{0,1;8} = 1{,}860$

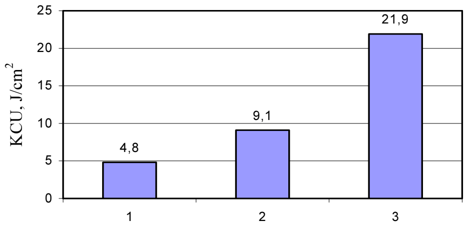

Fig. 3 Impact resistance of samples drawn from padding layers (t = 20ºC): 1 - UTOP38, 2 - F-818, 3 - F-812

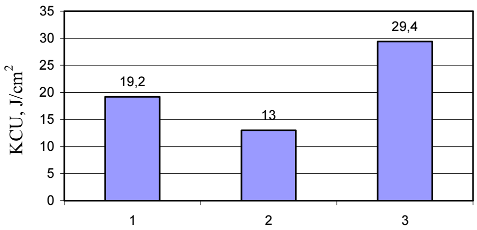

Fig. 4 Impact resistance of samples drawn from padding layers (t = 250ºC);1 - UTOP38, 2 - F-818, 3 - F-812.

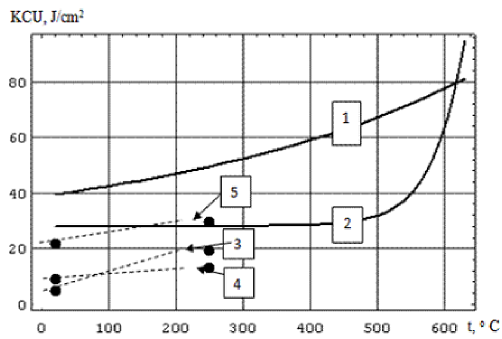

Fig. 5 Comparison of relations between KCU impact resistance and temperature for steels X37CrMoV5-1 (1) i 55NiCrMoV7 (2) with impact resistance in 20°C i w 250°C of the samples drawn from padding layers: UTOP38 (3), F-818 (4) i F-812 (5)

Table 8. Results of research of hardness layout $HV_{0,1}$

Material	Hardness $HV_{0,1}$			
	Max.	Min.	At surface*	Average
UTOP38	650	438	472	-
F-812	704	479	508	-
F-818	767	614	733	675
Steel 42CrMo4 (base)	-	-	-	367**

* In depth 0,02 - 0,07 mm
** 86 % results of the measurements are in scope: $300 < HV_{0,1} < 400$

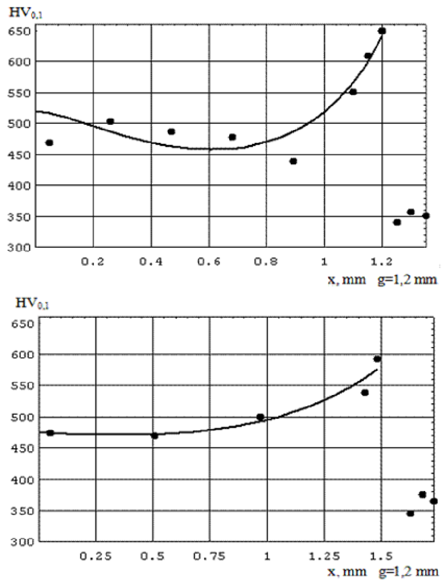

Fig. 6 Hardness $HV_{0,1}$ in the function of distance from surface of the padding layer UTOP38 and the base (steel 42CrMo4); g – thickness of padding layer

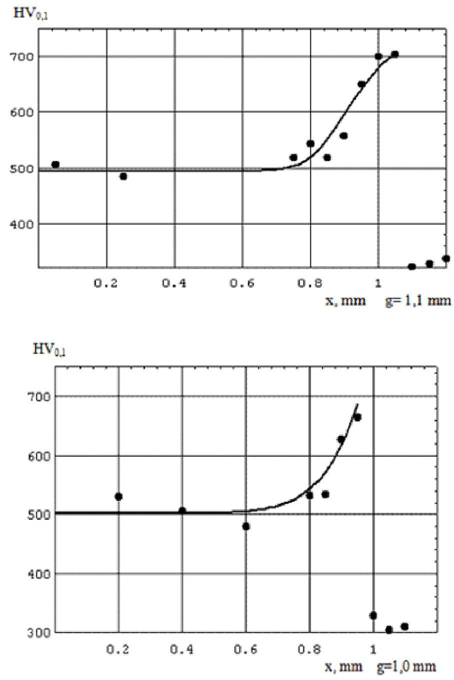

Fig. 7 Hardness $HV_{0,1}$ in the function of distance from surface of the padding layer F-812 and the base (steel 42CrMo4); g – thickness of padding layer

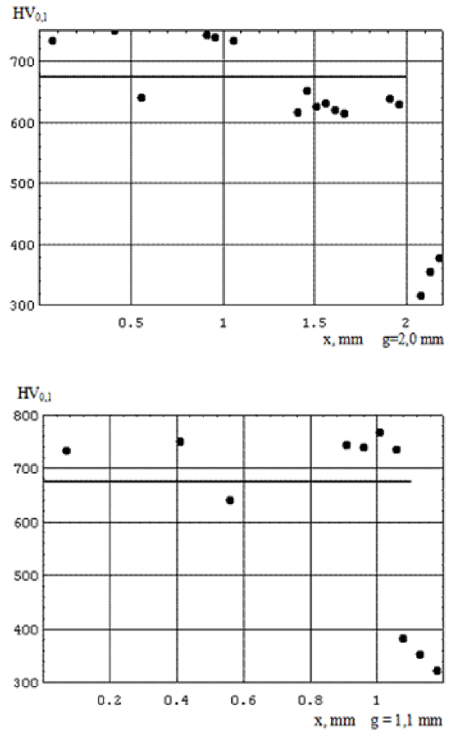

Fig. 8 Hardness $HV_{0,1}$ in the function of distance from surface of the padding layer F-818 and the base (steel 42CrMo4); g – thickness of padding layer

Summary and conclusions

The conducted research allowed to ascertain the impact resistance of chosen tool steels of padding layers used in construction and production process of forging dies. The conditions in which the research was conducted (temperatures) relate in approximation to the conditions in which dies work. The impact resistance of steel grows simultaneously with the growth of temperature, whereas the impact resistance of steel 37CrMoV5-1 is greater when compared to steel 55NiCrMoV7. Also the progress of values of these parameters in relation to temperature of work have a different character for the analysed types of steel (fig. 1, 2). The comparison of impact resistance values shows that the greatest impact resistance which comes close to steel 55NiCrMoV7 is attributed to layer F-812 both in 20 as in 250°C and the lowest in 250°C to layer F-818. The analysis of microhardness $HV_{0,1}$ layout in cross sections of the selected layers (singular) has shown that:

– for layers UTOP38 and F-812 near the border with the base a growth in microhardness to ca. 650 – 700, whereas near the surface these values are respectively 472 and 508 (tab. 8, fig. 6 and 7);

– in layer UTOP38 a decrease in microhardness in the middle zone can be spotted;

– the microhardness of layer F-818 does not change with the distance from the surface and its average value is 675 (tab. 8 and fig. 8).

The microhardness of the base (42CrMo4) is included in all cases in the values between 300 – 400 (average 367). The characteristics of microhardness layouts specified above are in close relation to the microstructure of padding layers.

The research analysis was used in production conditions in "Glinik" forge, where forging dies from construction steel 42CrMo4 with padded surfaces of engravings in place of traditional hot-work tool steels are made. This allows to achieve the proper high durability of dies with the simultaneous decrease in tool costs and direct costs.

[1]. Dobrzański L, A., Labisz K., Piec M.., Klimpel A.: *Poprawa własności warstwy wierzchniej stali narzędziowej stopowej do pracy na gorąco,* Przegląd Spawalnictwa, 2-14, 2008.

[2]. Dobrzański L. A.: *Metalowe materiały inżynierskie*, WNT, Warszawa, 2004.

[3]. Bonek M., Dobrzański L.A., Klimpel A.: *Structure and properties of hot-work tool steel alloyed by WC carbides by a use of high power diode laser,* Journal of Achievements in Materials and Manufacturing Engineering, 2007.

[4]. Turek J.: *Trwałość matryc kuźniczych do pracy na gorąco (praca niepl.),* Kuźnia Glinik, Gorlice, 2006.

[5]. Turek J: *Trwałość matryc kuźniczych z wykrojami napawanymi*. Praca doktorska. Politechnika Krakowska. Kraków 2010.