18th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2014, Budapest, Hungary 10-12 September, 2014

INFLUENCE OF HEAT TREATMENT ON THE PROPERTIES OF STEEL 17-7PH WITH MODIFIED CHEMICAL COMPOSITION

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ABSTRACT
Possibilities of the application of new materials in the automotive industry place challenges in front of researchers of our times. Modification of the chemical composition and different variants of heat treatment allows achieving improved mechanical properties. Steel 17-7PH is austenitic - martensitic steel with high strength (750-1500 MPa) and hardness (34-49HRC), which is achieved by controlled phase transformation and complex heat treatment of precipitation strengthening. In this paper, through the results of tensile properties of steel 17-7PH for condition TH1050 and modified condition RH 950 obtained at room temperature, the influence of heat treatment will be presented.
Keywords: PH steels, 17-7PH steel, precipitation hardening, mechanical properties, microstructure

1. INTRODUCTION
Stainless steel are defined as iron based alloys containing at least 10,5% chromium and a maximum of 1,2 % carbon. Stainless steels may contain nickel as another major alloying element, with a content of up to 38%, plus other alloying elements and stabilisers. The chromium content renders stainless steels corrosion resistant [1,2,3].
Steel 17-7PH is classified as high-strength austenite – martensitic stainless steel. The high strength, hardness, resistance to fatigue and corrosion resistance are achieved by precipitation hardening.
Research of different combinations of the chemical composition of materials and the temperature variation of heat treatments offer the possibility of modelling high-performance materials with lower cost of production and a wider field of application. In this paper, through the results of tensile properties of steel 17-7PH for condition TH1050 and modified condition RH 950 obtained at room temperature, will be presented to the influence of heat treatment.

2. SEMIAUSTENITIC STAINLESS STEEL 17-7PH
Semi-austenitc stainless steel 17-7PH, contains both a martensitic and austenitic microstructure as its chromium-nickel ratio prevents the formation of the fully austenitic phase. This 17-7PH stainless steel was developed to have corrosion resistance as well as significant mechanical strength but principally better stress corrosion resistance.

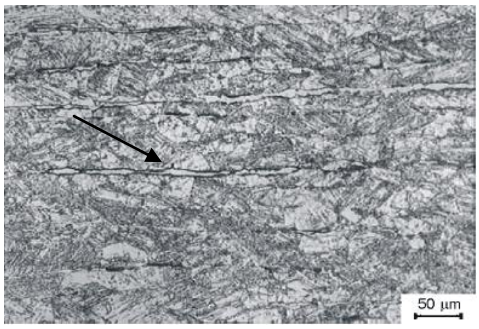


Figure 1. represents the microstructure of semiaustenitic stainless steel, etched in Villela reagent [4] which is:
- solution annealed at 1065 ºC,
- 955 ºC hold 10 minutes, air cold,
- -75 ºC hold 8 hours, air heat to room temperature,
- 510 ºC hold 60 minutes, air cold.

Arrow shows stringer of delta ferrite in martensitic matrix [4].

Figure 1. Microstructure of 17-7 PH steel

2.1 Chemical composition

Standardized chemical composition of semi-austenitic stainless steel 17-7PH is given in table 1, which is balanced so that austenite has a low thermodynamic stability.

Table 1: Chemical composition of stainless steel 17-7 PH [2].

	Chemical composition, %							
	C, max	Si, max	Mn, max	P, max	S, max	Cr	Ni	Al
BAS EN 10088-5	0,09	0,7	1,0	0,040	0,015	16-18	6,5-7,8	0,7-1,5
Specific interval of content of Cr, Ni and Al in planned experiment						14-15	7,5-8,5	0,75-1,25

Modification of chemical composition is reflected in the changing of chromium, nickel and aluminium content in comparison with standardized composition given in table 1. In produced batches was achieved content of chromium is in range 13,8 to 15,7%Cr, nickel is 7,3 to 9,1%Ni and aluminium from 0,61 to 1,53%.

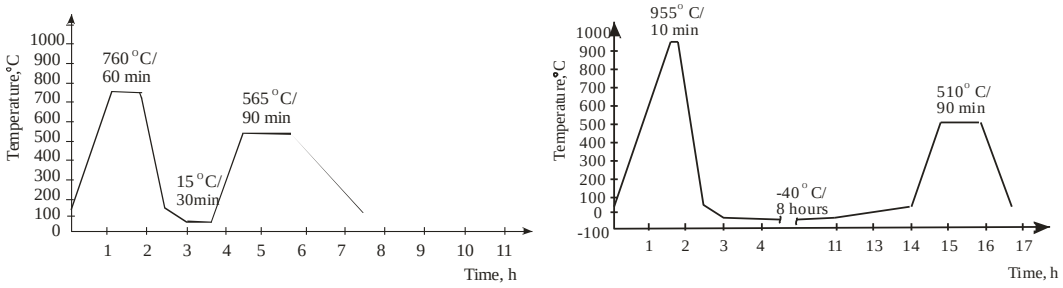
2.2 Heat treatment

Heat treatment of stainless steel PH is performed in order to achieve different levels of mechanical properties. The first step is solution annealing, during which dissolve the second phase, present in the matrix, in order to obtain a solid solution of γ. Rapid cooling from the annealing temperature suppresses the soluble phase transformation in a high-temperature phase in a phase stable at low temperature, ie. a homogeneous supersaturated solid solution at room temperature [5]. Samples rolled bars ϕ15mm, heat treated according to procedure given in table 2.

Table 2: Heat treatment procedures

Heat treatment	Austenite conditioning	Transformation from austenite to martensite	Precipitation hardening- aging
TH 1050	760°C/ 60 min/air	Within one hour of cooling to 15±3°C and holding at least 30 minutes	565°C/90 min/air
Modified RH 950	955°C/ 10 min/air	Within one hour of cooling to -40°C in dry ice / 8hours/air to room temp	510°C/90 min/air

The diagrams of performed heat treatment are given on figure 2.



a) TH1050 condition *b) Modified RH950 condition*

Figure 2. Heat treatment

Values of mechanical properties of stainless steel 17-7PH, for bars and properties for modified chemical composition are given in table 2.

Table 3: Mechanical properties of stainless steel 17-7 PH [1] and stell with modified chemical composition.

Batch	Cr [wt,%]	Ni [wt,%]	Al [wt,%]	Condition	Rm [N/mm^2]	$R_{p0,2}$ [N/mm^2]	HRC/HV10
Metals Handbook				TH 1050	1170	965	25-38
				RH 950	1275	1030	41
V1781	14,3	7,4	0,96	TH1050	1378	1287	372
				RH 950	1526	1473	492
V1782	14,4	7,5	1,00	TH1050	1390	1298	382
				RH 950	1547	1527	521
V1772	15,7	7,5	0,61	TH1050	1170	1139	340
				RH 950	1371	1352	464
V1773	15,7	7,6	0,7	TH1050	1205	1095	321
				RH 950	1426	1377	485
V1749	14,4	9,1	0,87	TH1050	1304	1292	373
				RH 950	1358	1298	459
V1754	14,2	8,3	0,8	TH1050	1288	1271	448
				RH 950	1430	1389	466
V1774	14,6	7,8	1,53	TH1050	1411	1345	437
				RH 950	1636	1555	535
V1775	14,6	7,3	1,27	TH1050	1123	926	445
				RH 950	1475	1375	512
V1747	14,7	8,7	0,79	TH1050	1093	927	369
				RH 950	1306	1270	446
V1755	15,1	8,2	0,8	TH1050	1291	1224	427
				RH 950	1408	1395	453
V1760	15,5	7,6	1,22	TH1050	1275	1185	389
				RH 950	1526	1487	536
V1783	15,6	7,4	1,18	TH1050	1419	1276	370
				RH 950	1562	1495	541
V1752	14,1	8,9	1,11	TH1050	1414	1261	365
				RH 950	1462	1292	457
V1753	13,8	8,3	1,19	TH1050	1322	1222	411
				RH 950	1517	1469	495
V1750	14,6	9,1	1,23	TH1050	1157	984	384
				RH 950	1554	1463	528
V1756	15,2	8,3	1,3	TH1050	1176	961	330
				RH 950	1556	1520	514

3. ANALYSIS OF RESULTS

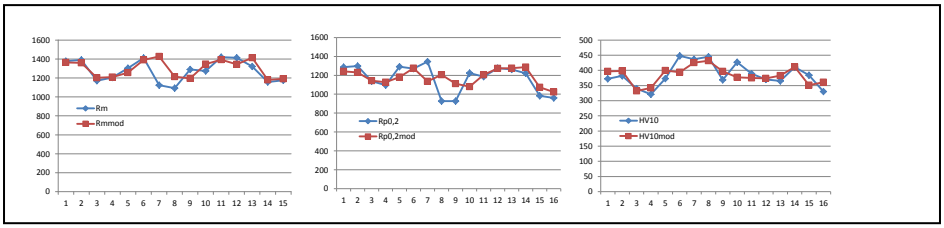
Based on the results of tests of mechanical properties at room temperature, it is evident that the heat treatment affects the value of Rm, $Rp_{0,2}$ and HV10 at steel of the same chemical composition. Modified RH950 cryogenic heat treatment [6], cooling to -40°C and subsequent aging of the resulting values are much higher mechanical properties compared to the heat treatment TH1050, where the samples are cooled to 15°C and aging.

The regression analysis of influence independent variables content of Cr, Ni and Al on depend variables Rm, $Rp_{0,2}$ and hardness at room temperature for condition TH 1050 and RH950, applying software package MINITAB, was performed. Regression analysis showed different effects of elements Cr, Ni and Al on Rm, $Rp_{0,2}$ and HV10. In the heat treatment TH1050 any element having a dominant statistically significance on the value of Rm, $Rp_{0,2}$ and HV10, but when acting together, the observed range, their combined influence is statistically significant and reliable (Fisher value) which shows the resulting regression model and diagrams given in Figure 3. For the modified heat treatment RH950 significant influence of Cr, Ni and their interaction is statistically significant on the dependent variables. Obtained regression models are given in table 3.

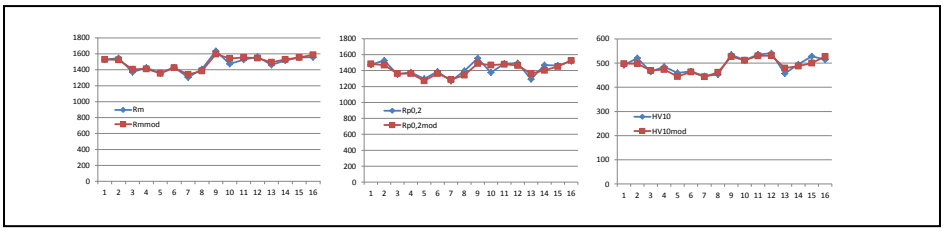
Table 4. Obtained regresion models

Condition TH1050	Modified condition RH950
$Rm = 56{,}7 \cdot Cr + 422{,}4 \cdot Ni - 14355{,}9 \cdot Al - 25{,}8 \cdot CrNi + 1070{,}2 \cdot CrAl + 1745{,}3 \cdot NiAl - 129{,}5 \cdot CrNiAl$	$Rm = 287{,}7 \cdot Cr + 483{,}7 \cdot Ni + 1120{,}8 \cdot Al - 58{,}5 \cdot CrNi - - 227{,}5 \cdot CrAl - 397{,}2 \cdot NiAl + 48{,}2 \cdot CrNiAl$
$Rp_{0,2} = 156{,}7 \cdot Cr + 758{,}6 \cdot Ni - 24658 \cdot Al - 60{,}4 \cdot CrNi + 1660{,}0 \cdot CrAl + 2723{,}0 \cdot NiAl - 183{,}9 \cdot CrNiAl$	$Rp_{0,2} = 292{,}6 \cdot Cr + 535{,}8 \cdot Ni + 7882{,}9 \cdot Al - 62{,}5 \cdot CrNi - 691{,}2 \cdot CrAl - 1338{,}1 \cdot NiAl + 112{,}0 \cdot CrNiAl$
$HV10 = -54{,}5 \cdot Cr + 10{,}1 \cdot Ni - 2060{,}6 \cdot Al + 9{,}1 \cdot CrNi - 56{,}2 \cdot CrAl - 168{,}7 \cdot NiAl + 1{,}3 \cdot CrNiAl$	$HV10 = -77{,}1 \cdot Cr + 143{,}4 \cdot Ni - 199{,}2 \cdot Al - 16{,}0 \cdot CrNi - 17{,}5 \cdot CrAl - 71{,}3 \cdot NiAl + 9{,}5 \cdot CrNiAl$

Based on the obtained models can be predicted the value of Rm, $Rp_{0,2}$ and HV10 for the observed interval value of their content. The values obtained experimentally and the value of the regression model are given in diagrams on figure 3.



TH1050 condition



Modified RH950 condition

Figure 3. Matching diagrams of measured and predicted values

4. CONCLUSION

Heat treatment at cryogenic temperatures of stainless steel 17-7PH modified chemical composition, is given greater values of Rm, $Rp_{0,2}$ and HV10. Modified heat treatment RH950, with cooling to -40°C instead of the -75°C, achieved value of Rm, $Rp_{0,2}$ and HV10 like in standardized heat treatment and standardized chemical composition, but in standardized heat treatment TH1050, there have been some results with smaller value than is prescribed for standardized chemical composition. Regression analysis showed, at heat treatment TH1050, that no element alone or their dual combination do not significantly affect the mechanical properties, but when acting together, the observed range, their combined influence is statistically significant and reliable.

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