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EFFECT OF AGING ON MICROSTRUCTURE OF STEEL 17-7PH WITH MODIFIED CHEMICAL COMPOSITION

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ABSTRACT
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, the influence of heat treatment will be presented through the results of microstructure of steel 17-7PH for condition TH1050 and modified condition RH 950 obtained at room temperature,. Microhardness in white zones (austenite) shows difference between martensite and austenite hardness value.
Keywords: PH steels, 17-7PH steel, precipitation hardening, microstructure, microhardness

1. INTRODUCTION
Steel 17-7PH is classified as high-strength austenite – martensitic stainless steel [1]. This material is widely used as a structural material in a variety of applications in aircraft and spacecraft, and surgical instruments, beds, springs [2]. Steel 17-7PH has excellent mechanical properties in combination with good corrosion resistance. In order to achieve good combination of tensile properties and good corrosion resistance was performed solution heat treatment at 1050°C, air cooling to room temperature. After solution annealing was performed aging treatments for getting condition TH1050 and modified cryogenic treatment RH950. The aim of this paper is to study the influence of aging treatment on the microstructure and strength of modified steel 17-7PH with modified chemical composition.

2. SEMIAUSTENITIC STAINLESS STEEL 17-7PH
Semi-austenitic 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 [3].

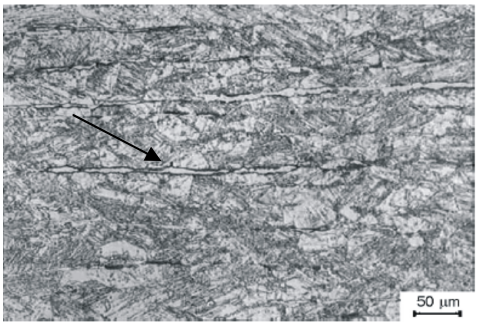


Figure 1. represents the microstructure of semiaustenitic stainless steel, etched in Villela reagent [4] which is:

- 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, and chemical composition of melt V1747 is given in table 1, which is balanced so that austenite has a low thermodynamic stability.

Table 1: Chemical composition.

	Chemical composition, wt %							
	C, max	Si, max	Mn, max	P, max	S, max	Cr	Ni	Al
BAS EN 10088-5 [5]	0,09	0,7	1,0	0,040	0,015	16-18	6,5-7,8	0,7-1,5
V1747	0,06	0,71	0,63	0,009	0,020	14,7	8,7	0,79

Figure 2. shows that its composition is right on the edge of the metastable austenite region.

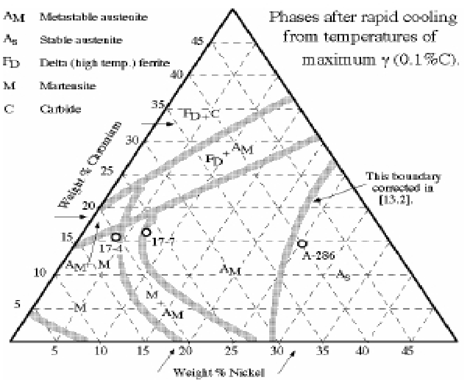


Figure 2. Composition of stainless steel [6]

2.2 Heat treatment

This stainless steel need double heat treatment, prior to the final precipitation anneal (aging). The first heat treatment solution annealing, produces an austenite matrix contains 5-20% delta ferrite. During solution annealing the second phase present in the matrix are dissolved. The second heating forms chromium carbides along the delta ferrite grain boundaries and changes the composition of the austenite matrix so that on cooling it now becomes a martensite matrix. Hence the final precipitation in the semi-austenitic stainless steels occurs in a predominately martensite matrix.

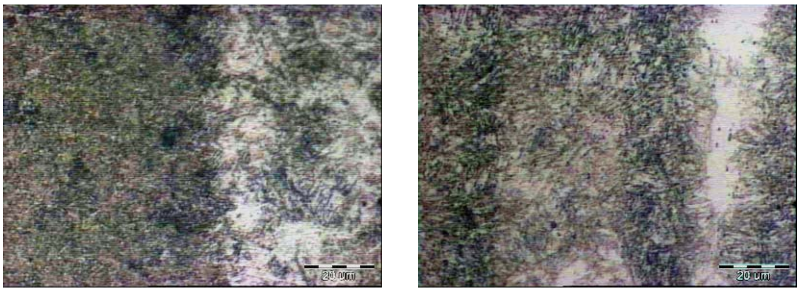
Rapid cooling suppresses the soluble phase transformation in a high-temperature phase in a phase stable at low temperature, ie. a homogeneous supersaturated solid solution at room temperature [7]. Samples rolled bars ϕ15mm, heat treated according to procedure given in table 2.

Table 2: Heat treatment parameters

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 -50°C in dry ice / 8hours/air to room temp	510°C/90 min/air

2.3 Metallographic analysis

The microstructure of the aged material consists martensite and austenite, elongated in the prior working direction. Figure 3 shows the microstructure of the melt V1747 in condition TH1050 and modified condition RH950.



a) TH1050 b) RH 950

Figure 3. Microstructure of melt V1747

Etchant: Villela reagent
Magnification: x 500

In samples of melt V1747 in solution annealing, condition TH 1050 and modified RH 950 was done determination the presence of amounts of magnetic phase (martensite and delta ferrite) and non-magnetic phase using FERRITSCOPE device. Percentage of different microstructural constituents, martensite, austenite and delta ferrite is determined by the optical microscope OLYMPUS PMG3 using the software Analysis 5.1 in samples of melt V1747. Results are given in table 3.

Table 3: Value of present microstructural constituents

Melt	Solution annealed					TH1050					RH950				
	Optical microscope			Feritscope		Optical microscope			Feritscope		Optical microscope			Feritscope	
	M	δ	A	M+δ	A	M	δ	A	M+δ	A	M	δ	A	M+δ	A
V1747	57	-	43	55,4	44,6	69	-	31	66,3	33,7	85	-	15	82,3	17,7

1) M- Martenzite; δ – delta ferrite; A – austenite

2.4 Microhardness testing

In order to confirm the presence of the various microstructural constituents in longitudinal section with white segregated zones (austenite) were tested microhardness HV0,2. Samples with most expressed austenite melt V1747 were tested and the results are given in table 4.

Table 4: Value of microhardness HV0,2

Melt	Condition	Austenite (white segregated zone)	Martensite
V1747	Solution annealed	278	351
	TH1050	264	386
	RH950	291	426

Diagram on figure 4 shows distribution of hardness HV0,2 in solution annealing, condition TH 1050 and RH 950 in austenite and martensite.

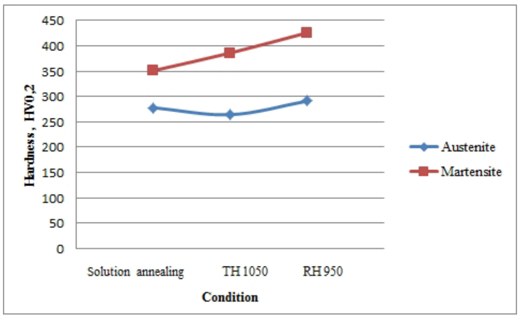


Figure 4. Diagram of hardness HV0,2

2.5 Testing the microstructure by SEM

EDS analysis of the structures in the area, which is on the optical microscope seen as white segregated zones (austenite) are given in table 5.

Table 5. EDS analysis of melt V1747

Condition	Melt		Chemical composition, [wt %]		
			Cr	Ni	Al
TH1050	V1747	EDS analysis	15,32	9,28	0,48
		Classical chemical analysis	14,7	8,7	0,79

3. ANALYSIS OF RESULTS

Classical chemical analysis of alloy with modified contents shows that nickel content of alloy V1747 is 8,7%, chromium content is 14,7 and aluminium 0,79%. After etching in Villela reagent revealed microstructure of melt V1747 are martensite and austenite. Amount of microstructural constituents depends of heat treatment. After solution annealing in melt V1747 is present about 55% of martensite. Precipitation hardening treatment TH 1050 leads to transform about 12% of austenite, and modified treatment RH 950 – criogenic treatment at -50°C help to transform 28% of austenite. Microhardness in white segregated zone – austenite is about 280HV0,2, and microhardness in martensite is from 351HV0,2 in solution annealed condition to 426HV0,2 in condition RH 950. Microstructural testing by SEM shows higher level of nickel in white segregated zones nickel content is higher for 0,58% Ni of the classical chemical analysis of melt.

4. CONCLUSION

Heat treatment at cryogenic temperatures of stainless steel 17-7PH modified chemical composition gives material with higher hardness value.
Higher value of nickel in white segregated zones indicate that austenite in that part was more stable, and did not transform to martensite during aging at treatment TH 1050 and RH 950.
Thanks to different chemical composition and different heat treatment it is possible got material with good mechanical properties and adequate microstructural constituents. Effect of aging on microstructure of steel 17-7ph with modified chemical composition is that hardness in modified condition RH950 is higher then in condition TH1050.

5. REFERENCES

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