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INVESTIGATION OF PIPE MATERIAL CONDITION IN AMMONIA PLANT

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ABSTRACT
The condition of pipe material used in an ammonia production plant is analyzed. The pipes are made of high alloyed Ni-Cr and Cr-Mo alloyed steel for high temperature (523°C) and high pressure (126 bar) operation. Media inside the pipes is superheated steam that is heated by natural gas combustion. The condition of pipes that have been exposed to high pressure and temperature is analyzed, and the corrosion damages are observed at outer side of the pipe. These damages caused the decrease of the mechanical properties, and therefore, the lifecycle of the pipes also decreased.
Keywords: high alloyed Ni-Cr steel, Cr-Mo alloyed steel, corrosion damages

1. INTRODUCTION

Damages and fatigue of material occur during the operation of power plants due to working conditions of these facilities (high temperature, high pressure, continuous operation, etc.). Elevated and high temperatures occur in the power plants like: furnaces, heat exchangers, chemical and process plants, pressure vessels, piping systems, etc. These facilities must operate for a long period of time without stopping (sometimes for 20 years or longer).

With materials selection for components of these facilities, the most important are creep-rupture properties at high temperatures, corrosion and chemical resistance to different media, etc.

The mechanical properties of Alloy 800H, combined with its resistance to high temperature corrosion, makes this alloy exceptionally useful for many applications that involve long-term exposure to high temperatures and corrosive atmospheres.

In this paper, the condition of pipes in the ammonia production plant is investigated. These pipes have been in operation for a long period of time (> $2 \cdot 10^5$ hours). Since these pipes have been subjected to high temperatures and pressure, pipe material condition should be determined by laboratory testing, and an estimate of operational reliability should be given.

2. EXPERIMENTAL PART

The testing was performed in the Laboratory of Mechanical Engineering Faculty in Slavonski Brod. The pipes are part of the ammonia plant Petrokemija d.d. Kutina. The pipes are made of Alloy 800H. Superheated water steam (temperature: 535 ˚C, pressure: 126 bar) passed through the pipes. Outer side of the pipes was heated by natural gas combustion. Pipe dimension and pipe elbow dimension is Ø 73 x 7 mm. In order to determine the condition of the pipe and pipe elbow, the following testing was done: chemical composition, mechanical characteristics, metallographic testing and dimension control. Schematic representation of pipe / pipe elbow used for testing is shown in Figure 1. Numbers 1, 2, 3 show where test- tubes were taken.

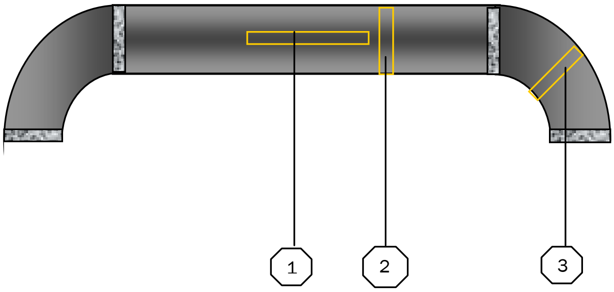


Figure 1. Pipe and pipe elbow (1, 2, 3 – test-tubes used for testing)
1 testing of tensile characteristics ($Rp_{0,2}$, R_m, A_5)
2, 3 chemical composition of material, testing of microstructure, dimension control

2.1. Chemical composition of materials

Chemical composition of the used material is given in Table 1.

Table 1. Results of chemical composition for pipe and pipe elbow, %

Test-tube	CHEMICAL COMPOSITION [%]											
	C	Si	Mn	P	S	Cu	Al	Cr	Mo	Ni	Ti	Fe
Pipe	0,083	1,088	0,002	0,014	0,021	0,518	0,201	21,28	0,227	34,87	0,289	40,75
Pipe elbow	0,075	1,267	0,419	0,017	0,018	0,541	0,274	19,43	0,274	32,29	0,415	44,53
Standard (Alloy 800H)	**0,08-0,10**	**1,00** max	**1,50** max	**0,015** max	**0,015** max	**0,75** max	**0,15-0,60**	**19,0-23,0**		**30,0-35,0**	**0,15-0,60**	**39,5 min**

Chemical composition of the used material is in accordance with the Standard Specification for Alloy 800H for the main components, while the content of Si and S is slightly higher for the pipe, i.e. Si, S and P for the pipe elbow.

2.2 Results of mechanical testing

Tensile characteristics of pipes are given in Table 2.

Table 2. Tensile characteristics of pipes

Test-tube	Test temperature [°C]			Results of testing			
	20	350	550	Yield point		Tensile strength	Elongation
				$R_{p0,2}$ [MPa]	R_e [MPa]	R_m [MPa]	Min. A_5 [%]
CP67	●			286		536	23
Pipe			●	197		405	21

Standard (Alloy 800H)	•				**205-345**	**483-690**	**30**
			538		**min. 90**	**min. 438**	

Tensile properties of test-tubes at working temperature do not meet the Standard Specification, while tensile properties at room temperature meet the Standard Specification to some extent. Elongation A_5 does not meet the Standard Specification (neither room nor working temperature).

2.3 Results of hardness testing (HV 0,1)

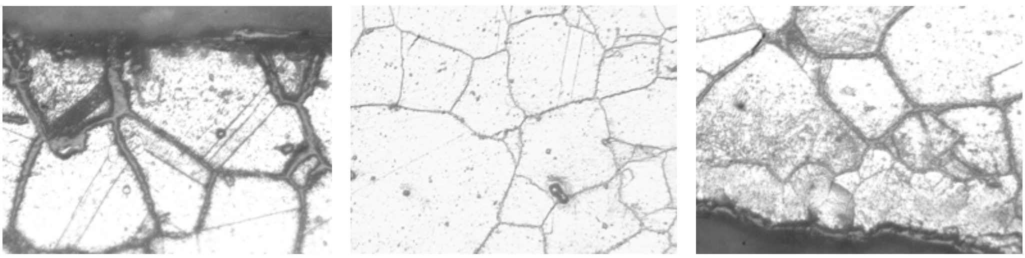
The hardness were measured using a Vickers microhardness tester (HV 0,1). Results of hardness testing are given in Table 3.

Table 3. Hardness testing HV 0,1

Test-tube	HV 0,1									
	Distance from the outer rim of the pipe wall (mm)				Middle		Distance from the inner rim of the pipe wall (mm)			
	0,05	0,1	0,2	0,4			0,05	0,1	0,2	0,4
Pipe	206	200	174	168	156	158	181	170	151	160
Pipe elbow	170	188	184	186	181	180	182	174	177	180

2.4 Metallographic Testing

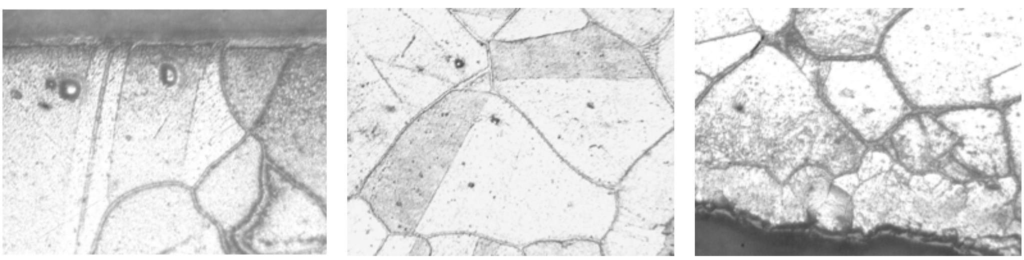
Test-tubes (Figure 1) were prepared and used for metallographic testing. Metallographic images of the pipe and pipe elbow structure are shown in Figure 2. and Figure 3.



a) b) c)

Figure 2. Metallographic images of the pipe structure, 400:1 magnification

a) outer rim of the pipe wall
b) middle of the pipe wall
c) inner rim of the pipe wall



a) b) c)

Figure 3. Metallographic images of the pipe elbow structure, 400:1 magnification

a) outer rim of the pipe elbow wall
b) middle of the pipe elbow wall
c) inner rim of the pipe elbow wall

Microstructure of the outer rim of pipe shows visible damages of the surface layer in a form of intercrystalline corrosion with depths of 0,06 mm. Microstructure after etching is similar to the average grain size (4 to 5 of ASTM scale). Large magnifications show decay of grain boundaries (particularly at the outer rim of pipe wall). Decay process (with precipitation) can be seen in the middle of pipe wall (Figure 2.). Microstructure of the pipe elbow wall (Figure 3.) shows decay and damages of the inner rim of pipe wall. Grain size varies (3 to 5 according to ASTM scale).

2.5 Dimensional control

Results of measuring of outer diameter (D_O), inner diameter (D_I) and pipe thickness (S) are given in Table 4.

Table 4. Results of dimensional control

Test-tube	D_I			D_O			S		
	min.	max.	aver.	min.	max.	aver.	min.	max.	aver.
Pipe	58,86	59,96	59,58	71,72	73,91	73,28	6,79	7,36	7,02
Pipe elbow	55,74	56,92	55,79	75,10	76,18	75,10	8,56	9,20	8,80

Dimension control did not show any significant discrepancies between the outer diameter and the pipe wall thickness.

3. ANALYSIS OF TEST RESULTS

Based on the performed testing and analysis of results, the following can be concluded:

- chemical composition of tested pipes meets the Standard Specification for material ASTM - B163 Alloy 800H, with slightly increased content of silicon and sulphur,
- tensile strength (R_m, MPa) meets the standards (at room temperature), while it is ca 8% lower than the values determined by the Standard Specification (at working temperature),
- elongation (A_5, %) at room temperature is 7 % lower than the minimum for Alloy 800H,
- metallographic testing shows strong intercrystalline corrosion of the outer side of the pipe
- strong precipitation in the process of decay.

4. CONCLUSION

Test results show that precipitation of the Cr carbides takes place at the grain boundaries when heated above 538˚C. This is known as intercrystalline destruction in certain corrosive atmosphere. Lower values of mechanical characteristics are the result of structural changes.

5. REFERENCES

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