STRUCTURE AND CORROSION RESISTANCE OF THE END OF COMBUSTION CHIMNEYS

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Abstract

There are various solutions to the endings of flue, combustion and ventilation ducts. Their location is largely high altitude installations that are often difficult to access. The study presents the results of comparative tests for diffusers - exhaust gas regulators; new and after long-term use. The tests included structural and visual assessment of diffuser plates. Changes in the geometry and thickness of sheets and corrosion resistance, in the context of the nature of behavior under the influence of temperature of exhaust gases and changing weather conditions. For these reasons, appropriate tests were carried out to check the resistance during prolonged use.

Keywords: Chimney, corrosion, diffuser, smog, combustion process

1. INTRODUCTION

The element causing turbulence in the exhaust chimney as well as ventilation pipes is their completion. The choice of the right end of the chimney is a guarantee of a laminar flow of the medium, and thus no backflow of combustion products into the interior of the accommodation. At the same time, it is a guarantee of ecological combustion regardless of the type of fuel. Thus, it ensures proper - complete and complete burning of heating means [1].

Chimney caps of various shape also protect them against changing weather conditions (rain, snow). These solutions relate to residential buildings as well as industrial solutions strategies. The thermal evaluation of the regulator is conditioned by the length of the chimney and can vary from 70 to 150°C, and even more for extremely short cables. It depends to a large extent on the type and type of fuel [2,4].

One can distinguish mainly the following system endings: roof-shaped (**Figure 1a**), for ventilation ducts (**Figure 1b**), and movable-rotating cap (**Figure 1c**) [5]. The latter meet the expectations only in the operation of fireplaces with low exhaust temperatures up to 50ºC. The endings of chimneys, regardless of their type, are subject to destruction [research and own observations] due to the impact of exhaust gases rich in sulfur and nitrogen and coal. Additionally, they are strengthened by variable working temperature - dew point and air humidity. Proper regulation of exhaust gases determines proper burning of fuel in the furnace. The regulator gives the possibility to match the chimney draft in function; hearth - length of the chimney - wind force and direction [1].

Corrosiveness of the atmosphere in Poland most strongly accentuates its presence in the foothills and areas of Silesia. It is conditioned by the configuration of the terrain and the retention of smog. Due to the above, the endings of chimney diffusers are made of acid-resistant sheets meeting the PN-EN 10088-1: 2017 and PN-EN 10088-2: 2014-12 standards [7-8].

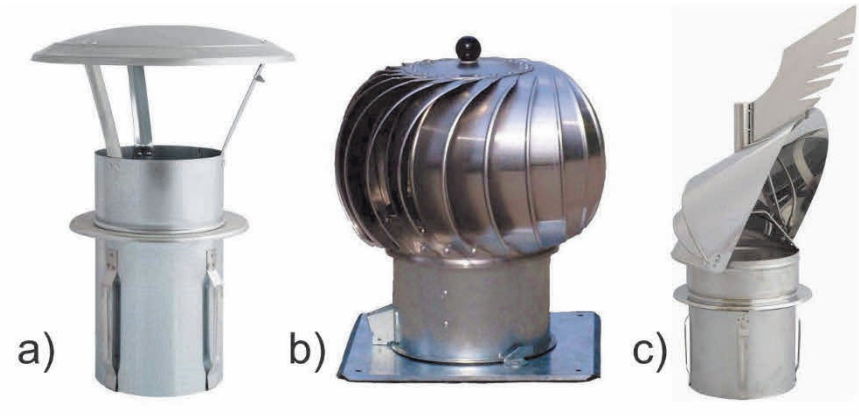

Figure 1 Examples of chimney ends used for: a) gas furnaces, b) ventilation ducts, c) chimney caps [5]

2. MATERIALS AND RESEARCH METHODOLOGY

The object of the research were diffusers - the structural endings of the flue gas regulator. The unique design solution of the regulator has been evaluated, with a wide application both in standard chimney ducts connected with heating boilers and flue pipes of domestic fireplaces. This construction is also definitely effective in cooperation with industrial boilers. It is also located in the mouths of ventilation ducts [3].

The scope of work included the performance of corrosion tests, measurement of hardness and thickness of diffuser construction sheets; new and after 15 years of operation (**Figure 2**). The new ending was installed on the chimney in a single-family building for a period of 3 years. The fireplace in this configuration was fired with solid fuel. The fuel used was hardwood - seasoned. During the operation, during the winds, especially in the case of the mountain winds, the exhaust was not observed in the living quarters from the inside of the chimney.

The diffuser after 15 years of operation (**Figure 2b**) was dismantled from the 17 meter long chimney and subjected to a visual assessment, stating a large accumulation of combustion products in the form of strongly bonded soot with the surface of the sheet.

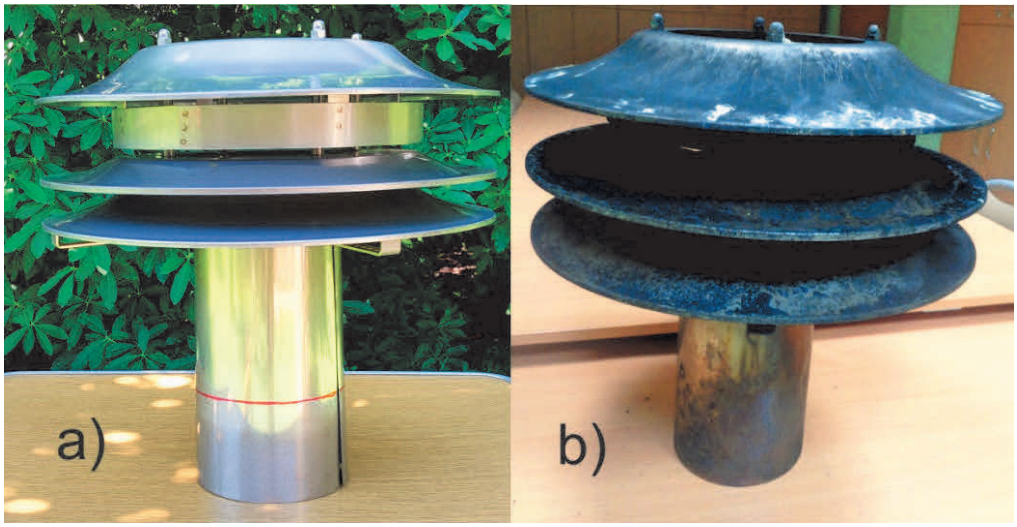

Figure 2 Chimney diffuser: a) new, b) after operating for 15 years

Analysis of the chemical composition for the tested diffuser sheets was carried out using the LECO analyzer. 15 samples with a 15.6 mm circle geometry were cut for corrosion tests. In order to assess the accelerated corrosion tests, the potentiostat PGSTAT302N, No. AUT83628 from ECO CHEMIE B.V [6] was used. The test

material coming from the chimney after 15 years was gently cleaned of carbon black with n-heptane. Then, along with the material from the new chimney, it was conditioned in a corrosive medium, which was a 5% NaCl solution, pH 6.9, for a period of 1h. The tests were carried out on the calomel electrode at 35 ° C by linear polarization method in oxygenated, as a result of free contact with the air solution. Based on the results of corrosion tests, the OCP potential, the corrosion potential of Ekor, the corrosion velocity Vp, the density of the corrosion current jkor and the polarization resistance Rp were determined.

Specimens from the new and old diffuser for microhardness measurement with dimensions 10x10mm were cut out, in the amount of 5 pieces from various construction sites. A dozen or so places were also taken to measure the thickness of the construction sheets of diffusers, with an accuracy of 0.1 mm

Structural research was also carried out - metallographic for sheet metal - a new chimney and after 15 years of operation. The samples for the tests were prepared by the classical method - the surface was etched with nital. The observations were made on an optical metallographic microscope at magnifications - 500, 1250 times, taking into account the internal structure of the sheets and the external character of the surface exposed to the influence of atmospheric influences.

3. TEST RESULTS

The conducted research allowed to present the results - comparisons of such properties as corrosion, hardness, thickness and chemical composition of diffuser sheets. **Table 1** presents the results of the analysis of the chemical composition of the diffuser material elements.

Table 1 Results of the analysis of the chemical composition of the diffuser material

Old sheet			New sheet	
Species requirements 1.4310 (X10CrNi18-8) PN-EN 10088-1: 2007 [%]		Findings [%] Old sheet	Species requirements 1.4404 (X2CrNiMo17-12-2) PN-EN 10088-2:2014-12 [%]	Findings [%] New sheet
C	0.05 ÷ 0.15	0.052	≤ 0.030	0.022
Si	≤ 2.00	0.31	≤ 1.0	0.33
Mn	≤ 2.00	1.57	≤ 2.0	1.29
P	≤ 0.035	0.030	≤ 0.045	0.023
Ni	6.00 ÷ 9.00	8.2	10.0 ÷ 13.0	10.1
Cr	16.0 ÷ 19.0	18.6	16.5 ÷ 18.5	16.9
S	≤ 0.015	< 0.005	≤ 0.030	< 0.005
Cu	≤ 0.50	0.28	-	0.37
Ti	-	< 0.01	-	< 0.01
Mo	≤ 0.80	0.23	2.0 ÷ 2.5	2.0
V	-	0.066	-	0.091
Nb	-	0.079	-	0.34
Co	-	0.20	-	0.20
Fe	warp	warp	warp	warp

The results of corrosion resistance measurements are presented in **Table 2**. In contrast, the example linear polarization curves obtained in a 5% NaCl solution are shown in **Figure 3**.

Table 2 Results of corrosion resistance tests of the new chimney and after 15 years of operation

Designated parameters	New chimney	Chimney after 15 years of operation
OCP [V]	-0.259	-0.307
E_{kor} [mV]	-260	-324
rrjkor [µA/cm^2]	1680	127
V_p [mm/rok]	0.16	1.48
R_p [Ω/cm^2]	15300	4300

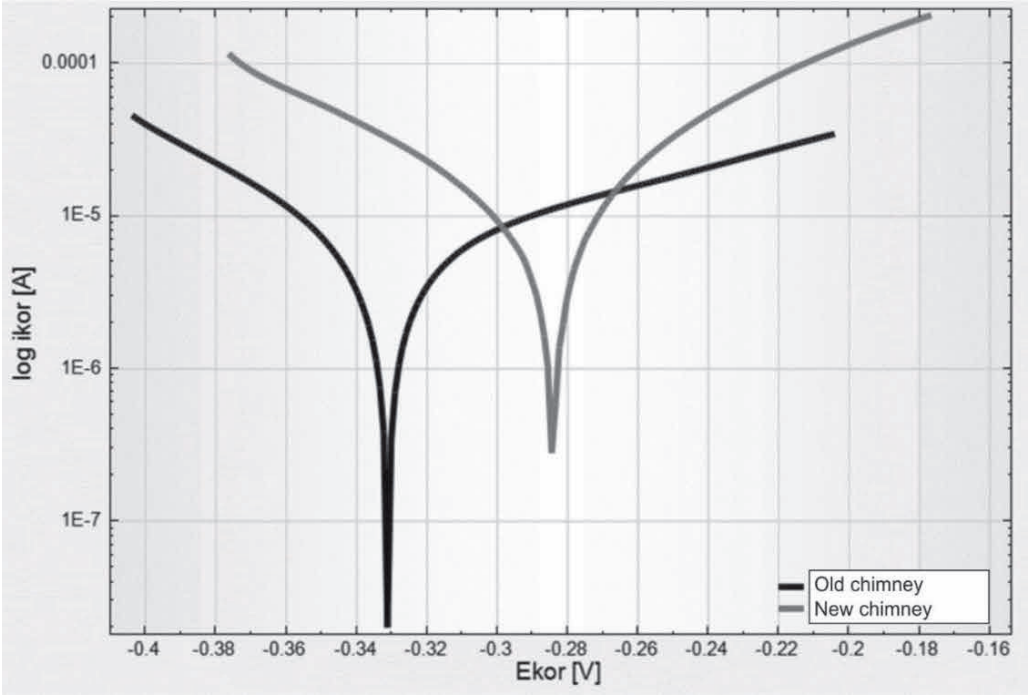

Figure 3 Examples of linear polarization curves of the new chimney and after 15 years of operation in a 5% NaCl solution

The value of the corrosion potential of Ekor samples of the new chimney and after 15 years of operation was -260 mV and -324 mv respectively (**Table 3**). The smallest value of corrosion potential is shown by samples taken from the chimney after 15 years of operation, which indicates higher susceptibility to corrosion in relation to the new chimney. The presented state of affairs is unambiguously confirmed by the remaining results of corrosion tests listed in **Table 3**, i.e. OCP, current density, corrosion rate, polarization resistance and the linear polarization curves shown in **Figure 3**.

Assessment of the thickness of the chimney end plates - new and after construction are presented in **Table 3**. The results of measuring the hardness of new and old sheet metal for chimney diffusers are shown in **Figure 4**.

Table 3 Thickness of the regulator plates

New sheet metal	0.4825 [mm]
The sheet is old before exploitation	1.01 [mm]
Sheet after 15 years of operation	0.99 [mm]

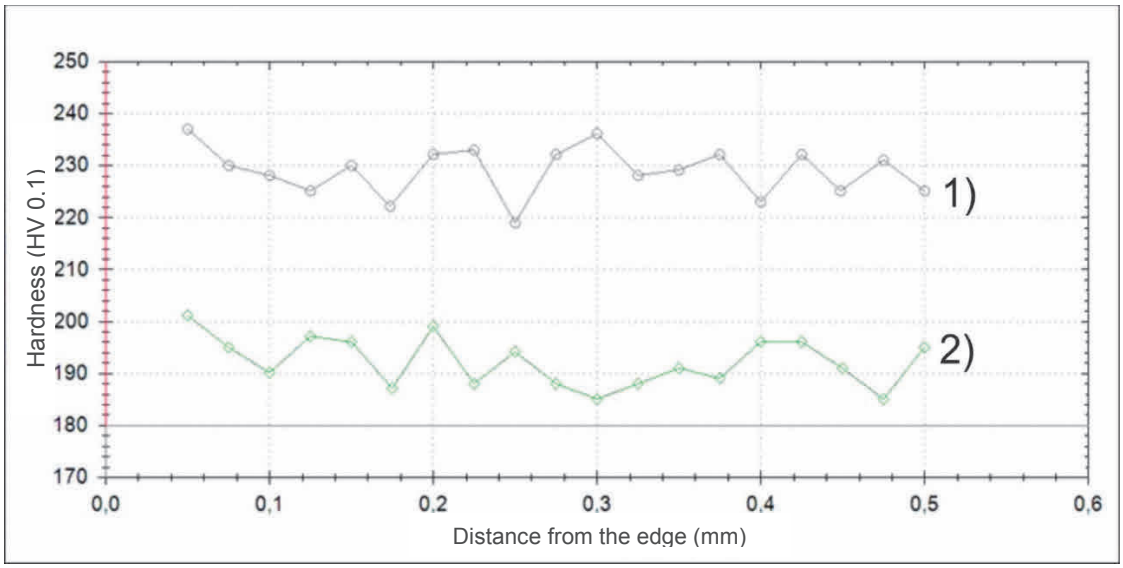

Figure 4 Measurement of sheet hardness: 1) sheet new, 2) old sheet

The results of metallographic tests at 500 and 1250 magnifications are shown in **Figures 5-8.**

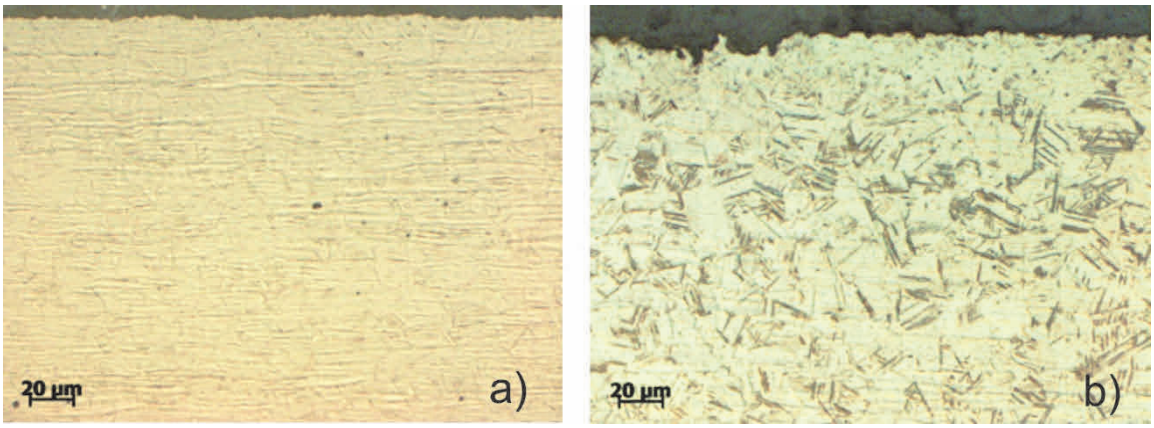

Figure 5 Material structure was digested with nital - magnification 500x: a) new sheet, b) sheet after 15 years of operation

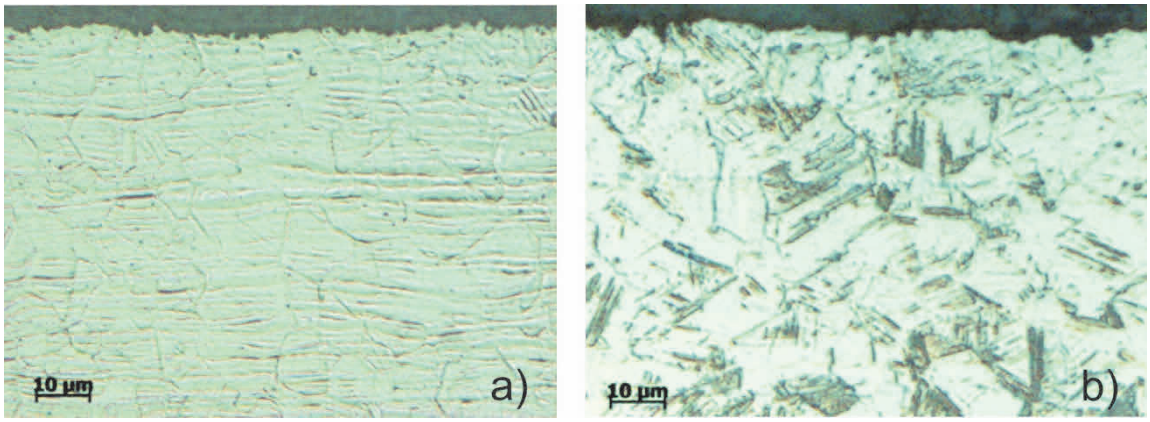

Figure 6 Material structure was digested with nital - magnification 1250x: a) new sheet, b) sheet after 15 years of operation

4. SUMMARY AND CONCLUSIONS

In the previous publications, no substantive information was provided regarding long-term operation in changing thermal conditions and chemical evaluation of acid-resistant sheets, in the area of end-use of chimney diffusers [3-4]. The chemical composition of both materials is similar. The distinguishing feature is the element molybdenum - (new sheet) - it increases the corrosion resistance.

Due to the chemical composition, we note that the material of the chimney after 15 years of operation shows greater susceptibility to corrosion than the material of the new chimney (2% Mo).

It can be claimed that regardless of the type of fuel used, the ending after 15 years of chimney exploitation was exposed to very intensive sulphurisation and carburizing and surface decarburization, which was documented in corrosion and hardness tests. **Figure 3** shows that the hardness in the materials tested, however, differs and remains in the range 195 - 220 HV 0.1 [9].

The end of the chimney should be simple and reliable in the installation, guaranteeing no return of the fumes regardless of atmospheric conditions. When designing diffusers - chimney ends, take into account: change of external pressure, change of air humidity (haze), frost (hoarfrost) and many others.

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