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FLEXIBLE ALUMINIUM DUCTS AIR TIGHTNESS TESTING

PROVERA ZAPTIVENOSTI FLEKSIBILNIH ALUMINIJUMSKIH CEVI

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ABSTRAKT

The scope of the research presented in this paper are aluminum flexible ducts which have a wide application in heating, ventilation, air conditioning and process engineering. Aluminum flexible ducts consist of several alternating layers of aluminum and polyester and steel wire bent into a spiral, while the merger of layers is done using glue. The loss of energy in the air stream through the aluminum flexible duct is due to friction of air stream and air leakage through the walls of the duct. In order to reduce energy consumption after the installation of the ducts it is needed to check mechanical properties of aluminum flexible ducts right after manufacture. Checking of the mechanical characteristics of aluminum flexible ducts is done according to recommendations of standard (EN 13180, 2002). Within the standard for testing mechanical properties of aluminum flexible ducts it is predicted to check tightness of ducts and to grade duct quality from the point of tightness. The aim of this paper is to present the air tightness testing of ducts and grade duct quality from the point of tightness with proposed methodology. Testing of the samples is shown for the following aluminum flexible duct diameters: 82 mm, 102 mm, 203 mm, 315 mm and 356 mm. The proposed methodology does not take into account that the heated air in the duct could potentially affect the tightness of bonded layers of the duct wall. For this reason in the future is recommended to test air tightness of ducts with heated air at different temperatures, in order to see the effect of the air temperature on the tightness.

***Key words:** aluminum flexible tube, tube leaks, energy loss.*

REZIME

Predmet rada su aluminijumske fleksibilne cevi koje imaju veoma široku primenu u grejanju, ventilaciji, klimatizaciji i procesnom inženjerstvu. Aluminijumske fleksibilne cevi izrađuju se u nekoliko naizmeničnih slojeva aluminijuma i poliestera i čelične žice savijene u spiralu. Kroz zidove cevi dolazi do curenja vazduha na mestu spajanja slojeva, kao i kroz sam materijal zida cevi usled njegove poroznosti. Curenje vazduha iz sistema dovodi do gubitka energije, pa je potrebno da proizvođači cevi u okviru same proizvodnje urade kontrolu kvaliteta cevi sa stanovišta njene zaptivenosti. U tom duhu je Evropska Unija 2002. godine donela standard EN 13180 kojim se preporučuje metodologija provere mehaničkih karakteristika cevi. U okviru navedenog standarda preporučena je i metodologija provere zaptivenosti cevi kao i ocena njenog kvaliteta sa stanovišta zaptivenosti. Cilj rada bio je da se prikaže realizacija ispitivanja zaptivenosti cevi predloženom metodologijom i ocena kvaliteta cevi sa stanovišta zaptivenosti. Za potrebe ispitivanja korišćena je eksperimentalna metoda i uzorci cevi sledećih prečnika: 82 mm, 102 mm, 203 mm, 315 mm i 356 mm. Predložena metodologija ne uzima u obzir da zagrejan vazduh u cevi potencijalno može da utiče na zaptivenost lepljenih slojeva zida cevi. Iz tog razloga se predlaže da se u budućnosti uradi ispitivanje zaptivenosti cevi nakon zagrevanja cevi na različitim temperaturama, kako bi se video uticaj temperature vazduha na zaptivenost cevi.

***Ključne reči:** aluminijumske fleksibilne cevi, zaptivenost cevi, gubitak energije.*

INTRODUCTION

The scope of the research presented in this paper are aluminum flexible ducts which have a wide application in heating, ventilation, air conditioning and process engineering. Aluminum flexible ducts consist of several alternating layers of aluminum and polyester and steel wire bent into a spiral, while the merger of layers is done using glue.

Aluminium flexible ducts due to their flexibility have a number of advantages over air distribution channels, such as: easy bending, stretching and compression of the duct in the space, a simple installation, easy transport and storage and less weight. However, the flexibility of the ducts brings two major deficiencies compared to air distribution channels: greater energy loss and increased noise at air flow. Due to these shortcomings aluminum flexible ducts are mainly used as short connections of terminal units (diffusers and grilles) to the main canal. In most EU countries it is not even allowed the use aluminum flexible ducts in lengths greater than 1.5 m.

The loss of energy in the air stream through the aluminum flexible duct is due to friction of air stream and air leakage through the walls of the duct. The leakage of air through the wall of the duct occurs at connecting points as well as through the pores of the material of the duct.

Great attention is recently paid to determination of how much a compressed aluminum flexible duct has a greater pressure drop than the maximum stretched one. *Abushakra et al. (2004)* have demonstrated experimentally that in the medium compressed duct, which is typical for the installation, a pressure drop can be increased by four times, while the further compressing can increase a pressure drop up to ten times. *Weaver and Culp (2007)* experimentally determined the pressure drops in ducts of diameters 6', 8' and 10' for different degrees of compression. *Culp and Cantrill (2009)* have repeated the same experimental research for ducts of diameters: 12', 14' and 16'. The authors of this study found that the pressure drop at different degrees of duct compression is higher than those obtained by ACCA (1995) and ASHRAE (2005). *Ugursal and Culp (2007)* compared the pressure drops obtained by computational fluid dynamics and experiment with different degrees of duct compression. They found that a good comply of the data were obtained for 30% degree of compression of aluminum flexible duct. Poor mechanical properties of aluminum flexible ducts may increase resistance of air flow through the duct and increase the leakage of air through the duct walls. For this reason, in order to reduce energy consumption after the installation of the ducts, it is needed to check mechanical properties of aluminum flexible ducts right after manufacture. However, even a duct with good mechanical characteristics can be damaged and a significant leakage of air through the duct wall can appear. If the duct wall is damaged then there are methods that are used to stop the leakage and the duct can be used on *(Szwedzicki and Delahunty, 2000)*.

Checking of the mechanical characteristics of aluminum flexible ducts is done according to recommendations of standard (EN 13180, 2002). Within the standard for testing mechanical properties of aluminum flexible ducts it is predicted to check tightness of ducts and to grade duct quality from the point of tightness. The aim of this paper is to present the air tightness testing of ducts and grade duct quality from the point of tightness with proposed methodology. Testing of the samples is shown for the following aluminum flexible duct diameters: 82 mm, 102 mm, 203 mm, 315 mm and 356 mm.

Nomenclature:

A (m^2) – duct envelope area
d (m) – duct nominal diameter
f (L/m^{3}s) – air leakage factor
f_{max} (L/m^{3}s) – maximal air leakage factor
l (m) – duct length
p_m (Pa) – gauge pressure
Q (L/s) – flow rate

MATERIAL AND METHOD

The duct testing of air tightness is performed on the test installation shown in Figures 1 and 2. Air tightness testing is carried out at ambient conditions, at a temperature of 20 °C. Test samples of the following aluminum flexible duct diameters: 82 mm, 102 mm, 203 mm, 315 mm and 356 mm were cut out of the ducts at length of 5 m. To the ends of the duct (1) are placed caps (2). A layer of silicone and clip carriers (3) enables air tightness. Three-level caps (2) can be used for testing air tightness of ducts with three different nominal diameters.

Right cap is attached to the air stream of positive pressure, while the left cap is attached to one end of differential pressure gauge (4). The pressure in the reservoir (6) is adjusted on the control cabinet (5) and then the compressor (7) is turned on. After reaching the desired pressure in the tank p_{m1} (6), the compressor (7) is turned off. Pressure regulator, located in the preparatory group (8), is used to adjust the air pressure in front of the air flow meter (9), and then the valve (10) is opened.

Flowmeter (9) consists of four in-parallel connected rotameters (11). Flowmeters (11) have different measuring ranges and cover a measuring range of air flow through the wall of the test ducts. In front and after each rotameter (11) are placed taps (12), which are used for putting into operation each rotameter individually. There are valves (13) on flowmeters, which are used to adjust the air pressure in the test duct (1) according to reading of the differential pressure gauge (4).

When the pressure regulator, located in the preparatory group (8), has adjusted the air pressure in front of the flowmeter (9), thanks to taps (12) certain rotameters (11) are included and excluded in order to see which rotameter is sensitive for air flow measuring through the wall of test duct (1). Once it is determined which of the rotameters (11) is sensitive, than the valve (13) on rotameter set the air pressure in the test duct according to showing of differential pressure gauge (4). Five minutes after the pressure is set and when the flow is settled and the system is stabilized, the value of the adjusted pressure p_m and flow of air Q through the duct wall (1) are measured. Air tightness testing of ducts was performed with the step of test pressure of: 200 Pa, 500 Pa, 1000 Pa and >1000 Pa (EN 13180, 2002).

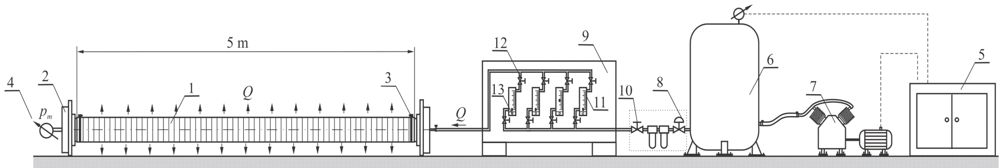

Fig. 1. Installation for duct air leakage testing

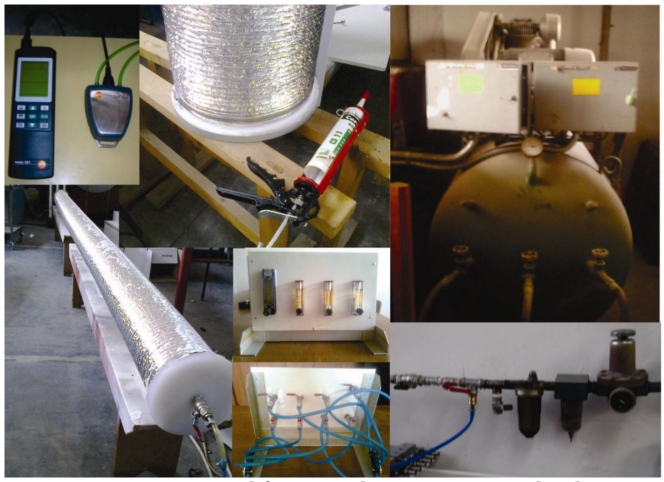

Fig. 2. Equipment used for air tightness testing and tightness grading

On the bases of measured air flow rate the duct air leakage factor was determined as (EN 13180, 2002):

$$f = \frac{Q}{A}, \tag{1}$$

where are:
Q – volumetric air flow rate [L/s] and
A – duct envelope area [m^2].

Duct envelope area is defined as:

$$A = d \times p \times l \tag{2}$$

where are:
d – duct nominal diameter [m] and
l – duct length [m]

Calculated air leakage factor is compared to maximal air leakage factor at measured pressure and duct is classified into one of three classes defined in Table 1.

Note: The minimum value of the air tightness factor has duct class C, and the maximum value has the air tightness class A. From the air tightness point of view the best duct belongs to class C.

Table 1. Air tightness classes (EN 13180, 2002)

Air tightness class	f_{max} [L/m^{2}s]
A	$0.027 \cdot p_m^{0.65}$
B	$0.009 \cdot p_m^{0.65}$
C	$0.003 \cdot p_m^{0.65}$

RESULTS AND DISCUSSION

In Tables 2 to 6 are presented results of ducts air tightness testing for standard air conditions. By comparison of air tightness factor f gained by measuring parameters at room temperature of 20 °C with maximal air tightness factor f_{max} it was concluded that all tested ducts belonged to air tightness class C.

Table 2. Results of air tightness testing of duct ϕ82

Air tightness class				A	B	C
p_m [Pa]	Q [L/s]	A [m^2]	f [L/m^{2}s]	f_{max} [L/m^{2}s]	f_{max} [L/m^{2}s]	f_{max} [L/m^{2}s]
193	0.005	1.3388	0.00373	0.8259	0.2753	0.0917
400	0.0091	1.3388	0.00684	1.3264	0.4421	0.1473
1055	0.02	1.3388	0.01493	2.4915	0.8305	0.2768
2101	0.0416	1.3388	0.03112	3.8988	1.2996	0.4332

Table 3. Results of air tightness testing of duct ϕ102

Air tightness class				A	B	C
p_m [Pa]	Q [L/s]	A [m^2]	f [L/m^{2}s]	f_{max} [L/m^{2}s]	f_{max} [L/m^{2}s]	f_{max} [L/m^{2}s]
502	0.00014	1.6654	8.4061·10^{-5}	1.5375	0.5125	0.1708
1100	0.00033	1.6654	0.0002011	2.5601	0.8533	0.2844
1520	0.00072	1.6654	0.0004323	31590	1.0530	0.3510

Table 4. Results of air tightness testing of duct ϕ203

Air tightness class				A	B	C
p_m [Pa]	Q [L/s]	A [m^2]	f [L/m^{2}s]	f_{max} [L/m^{2}s]	f_{max} [L/m^{2}s]	f_{max} [L/m^{2}s]
235	0.0583	3.3145	0.01759	0.9387	0.3129	0.1043
434	0.1	3.3145	0.03016	1.3987	0.4662	0.1554
980	0.1833	3.3145	0.05531	2.3749	0.7916	0.2638
1390	0.25	3.3145	0.07542	2.9807	0.9935	0.3311

Table 5. Results of air tightness testing of duct ϕ315

Air tightness class				A	B	C
p_m [Pa]	Q [L/s]	A [m^2]	f [L/m^{2}s]	f_{max} [L/m^{2}s]	f_{max} [L/m^{2}s]	f_{max} [L/m^{2}s]
335	0.000166	5.1433	3.2404·10^{-5}	1.1820	0.3940	0.1313
515	0.000305	5.1433	5.9300 ·10^{-5}	1.5632	0.5210	0.1736
975	0.000796	5.1433	0.0001548	2.3671	0.7890	0.2630
1345	0.004666	5.1433	0.0009073	2.9176	0.9725	0.3241

Table 6. Results of air tightness testing of duct ϕ356

Air tightness class				A	B	C
p_m [Pa]	Q [L/s]	A [m^2]	f [L/m^{2}s]	f_{max} [L/m^{2}s]	f_{max} [L/m^{2}s]	f_{max} [L/m^{2}s]
230	0.000181	5.8127	3.1253·10^{-5}	0.9257	0.3085	0.1028
600	0.001666	5.8127	0.0002867	1.7264	0.5754	0.1918
1110	0.005166	5.8127	0.0008888	2.5752	0.8584	0.2861
1470	0.0075	5.8127	0.0012902	3.0911	1.0303	0.3434

CONCLUSION

In this paper is described ducts air tightness testing and grading of ducts quality from the point of tightness according to methodology proposed in standard EN13180. The experimental research was presented on samples of aluminum flexible ducts of 5 m in length and of the following diameters: 82 mm, 102 mm, 203 mm, 315 mm and 356 mm. Testing was conducted at room temperature of 20 °C. The results showed that all of the samples of investigated aluminum flexible ducts have the highest tightness class C.

The proposed methodology does not take into account that the heated air in the duct could potentially affect the tightness of bonded layers of the duct wall. For this reason in the future is recommended to test air tightness of ducts with heated air at different temperatures, in order to see the effect of the air temperature on the tightness. If it is determined that the air temperature affects the coefficient of duct tightness, then the equations for determination of maximum coefficient of tightness should be adjusted so that not only pressure is taken into account but the temperature as well.

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REFERENCES

Abushakra, B., Walker, I. S., Sherman, M. H., (2004). Compression Effects on Pressure Loss in Flexible HVAC Ducts. International Journal of Heating, Ventilating, Air-Conditioning and Refrigeration Research, 10, (3), 275 – 289, ISSN 0001-2491.

Culp, C. H., Weaver, K. E., Cantrill, D. E., (2007). Static Pressure Losses in Nonmetalic Flexible Ducts, ASHRAE Final Report RP-1333.

Culp, C., and Cantrill. D., (2009). Pressure losses in 12’, 14’, and 16’ non-metallic flexible ducts with compression and sag. ASHRAE Transactions. 115, (1), 622 – 628, ISSN 0001-2505.

ACCA, (1995). Residential Duct Systems. Manual D. Air Conditioning Contractors of America. Washington, DC.

ASHRAE, (2005). 2005 ASHRAE Handbook of Fundamentals. Atlanta: American Society of Heating Refrigerating and Air-conditioning Engineers, Inc.

Ugursal, A., Culp, C., (2007). Comparative Analysis of CFD ΔP vs. Measured ΔP for Compressed Flexible Ducts, ASHRAE Transactions, DA-07-049.

EN 13180, (2002). Ventilation for buildings. Ductwork. Dimensions and mechanical requirements for flexible ducts.

Szwedzicki, T., Delahunty, D., (2000). Elimination of air leakage through flexible ducting, Mineral Resources Engineering,. 9, (3), 335 – 342, ISSN 0950-6098.

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