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A Measuring of a Mass Flow with Geometrically Deformed Orifice Plates

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Abstract

This work aims to present an impact of an orifice plate's deformation to an accuracy of measured mass flow of an air. Measurements were analyzed at an experimental device, which was a miniature of measuring track for measuring mass flows of natural gas in high-pressure natural gas pipelines. Measurements were repeated at various mass flows and different values of deformations of orifice plates. There was prediction, that changing orifice plate's geometry could cause differences in measured pressure values, which could affect required mass flow value. This paper tries to focus on behavior of the air flowing through the pipeline's measuring track with installed differently deformed orifice plates. It compares values measured by undeformed orifice plate and differently deformed orifice plates.

Index terms— There was prediction, that changing orifice plate's geometry could cause differences in measured pressure values, which could affect required mass flo

1 I. Introduction

orldwide raising requirements for the heat and the energy have huge influence on decreasing amounts of the mineral resources and on increasing tendency of their prices. It is necessary to deal with them responsibly. One of these cases is using natural gas as an energy and heat source. Nowadays there are billions of normalized cubic meters of natural gas transferred and used every day all around the world. The most common flow measurement type, used in high-pressure pipelines, is measuring by pressure differential, which mainly uses orifice plates inserted in the pipelines. This type of measuring is still most common for the flow measurements in the transit gas lines in Slovakia and the other European countries [1].

This paper tries to focus on behavior of the air flowing through the pipeline's measuring track with installed differently deformed orifice plates. It compares values measured by undeformed orifice plate and differently deformed orifice plates.

2 II. Experimental Device

The experimental device [2] used for measuring pressure differentials is shown in Fig. **??**.

3 Fig. 1 : The experimental device

The air is transported to the air receiver (1) by the compressor. Then is the air distributed through the distributor (2) into pipeline with the inner diameter 54.5 millimeters (3) by four regulating branches. Each branch has its own throttle and regulating plate with specific hole diameter, which causes different mass flow for each branch. With the combination of opened and closed throttles it is possible to change mass flow rates from 10 to 100%. Number (4) and (5) are measuring tracks, which include plate without any deformation (4) and deformed orifice plate (5). The values of the deformation of the orifice plates were 3; 0,5; 0,7; 1 and 1,3 mm. These deformations were reached in the area around the diameter aperture [3]. Both plates are inserted into the tapings during the measuring. In this case was designed D and D/2 taping (Fig. 2), where pressures are measured in the distances

D in the inflow part before the orifice plate and D/2 in the outflow part behind the orifice plate [4]. After the air flew through the measuring tracks, it reached point where it is measured by a rotary gas meter (6) and then it comes to the outflow pipeline. All measured data are sending into data logger (8) and then to computer to analyzing.

A Flow straightener was used to reduce upstream lengths. In the experimental device was used 19-tube bundle flow straightener. The 19-tube bundle flow straightener consisted of 19 tubes arranged in a cylindrical pattern as it is given in Figure **??**. Individual tubes were welded together at the points of contact at both ends of the tube bundle. The straightener was made from copper tubes with diameter 10x1 mm and the bundle was 163.5 mm long.

An exact placing of flow straighteners was given by the European standard ISO 5167. In the figure **??** there is shown placing of two 19-tube bundle flow straighteners in both measuring tracks (C1, C2) in the distance of 12D from the D and D/2 tapping system, where D is diameter of the pipe.

4 III. Deformation of Orifice Plates

In the high-pressure natural gas pipelines are shape deformations caused by the action of huge pressure differentials of the natural gas stream. Permanent deformations of orifice plates in these measurements were caused by a deformation press, which was specially constructed for this occasion. The orifice plate is fixed by welded screws in the correct position to reach symmetric deformation. Then is plate fixed by matrix. By rotating of trapezoidal screw thread is steel extension moving upright to a surface of the orifice plate and the deformation on the orifice plate appeared. For measurement were prepared seven orifice plates with different shape deformations [3]. One of them was undeformed and six others were deformed from 0.2 mm to 1.2 mm [4]. The height of each orifice Fig. **??** : 19-tube bundle flow straightener Fig. **??** : Placing of 19-tube bundle flow straightener in the measuring tracks of the experimental device plate was measured by micrometer in four places situated in the aperture of the plate, where the deformation reached its maximum value. Then were values summed up and averaged. This measurement was repeating for each orifice plate in undeformed and then in deformed state. All necessary values of orifice plates before and after deformation are given in table 1.

5 IV. Measurement

An experimental confirmation of an impact of the deformation was performed by the experimental device with two measuring tracks joined to the pipeline's system in serial way. For measuring 7 orifice plates were used as it was described in previous part. During the measurements was air receiver in constant gaugepressure in the range from 5.3 to 5.5 bar. A regulation of a flow was given by four regulation branches, where each one had specific diameter of aperture. The measurement of each orifice plate consisted of measurements with five different mass flows. These mass flows were set to values 56, 106, 156, 206 and 256 kg.h -1 .

To eliminate errors of measuring devices and sensors there was used only one sensor of pressure differential and one sensor of absolute pressure for both measuring tracks. By three-way valves was possible to change measuring from undeformed measuring track to deformed and backward. Each measurement took five minutes after stabilization, then it was changed to measure on deformed orifice plate. To eliminate errors caused in measurement was this part measured once again. Value recording was set to 10 seconds time step. From each measuring part was taken area with 20 recorded values, what means in total 40 values for undeformed orifice plate and 40 for deformed orifice plate. An arithmetic average was calculated from reached values, which eliminated fluctuation values and created medians in final results. In table 1 there are given pressure differences Î?"p between differential pressures of all deformed orifice plates and undeformed one. In a case, where values have positive signs, is differential pressure of deformed orifice plate bigger than in undeformed one. On the other hand, where minus sign appears, the differential pressure of deformed orifice plate is smaller than in undeformed orifice plate.

In the figures 6 and 7 are shown dependences of the mass flow impact to the pressure difference Î?"p between differential pressures of deformed and undeformed orifice plates. An increment of difference differential pressures Î?"p has got similar behavior in the deformations with higher values. This specific behavior is given by trend lines, which were set from the measured values at the experimental device. From trend lines were set polynomials of third grade. At the deformation of 0.6 mm started to appear lower influence of the deformation to a final difference of pressure differential and a result is, that a profile of shown line is A way of specifying mass flow from measured pressure differential is given in standard ISO 5167:2003 [5,6], where for various types of pressure tappings are given different conversion equations to calculate required mass flow. In the following table 3 are given percentage differences of mass flows between mass flow measured at deformed and undeformed orifice plate. Differences between measured values were in range from -4.6 % to +3.4 %. This inaccuracy is much bigger than standard inaccuracy of orifice plates, which is in the range 0.6 ÷ 0.8 %.

6 V. Conclusion

Measurements showed, that deformation of the orifice plate has huge impact to the mass flow value of the transported air through pipeline system. In smaller mass flows negative percentage difference and in higher mass flows positive percentage difference appeared. In smaller mass flows were percentage differences higher for smaller deformations on the other hand for bigger mass flows were percentage differences higher for bigger deformations of orifice plates. This should be useful knowledge to set up adequate mass flows of natural gas measuring stations to suppress impact of the deformation. [1]

2

Figure 1: Fig. 2 :

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Figure 2: Fig. 5 :

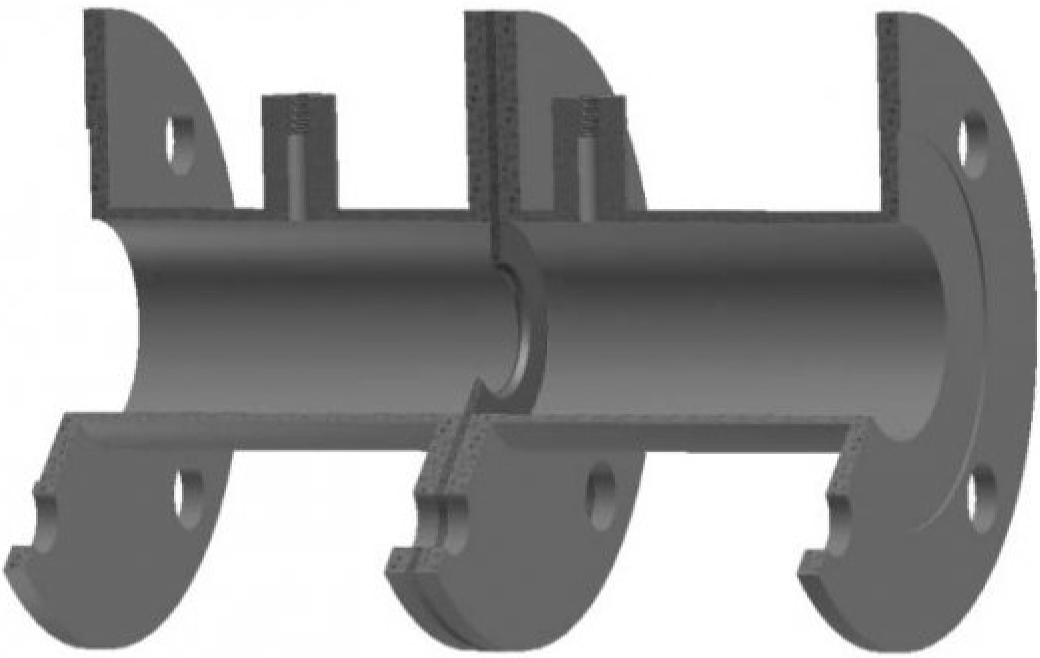

Figure 3:

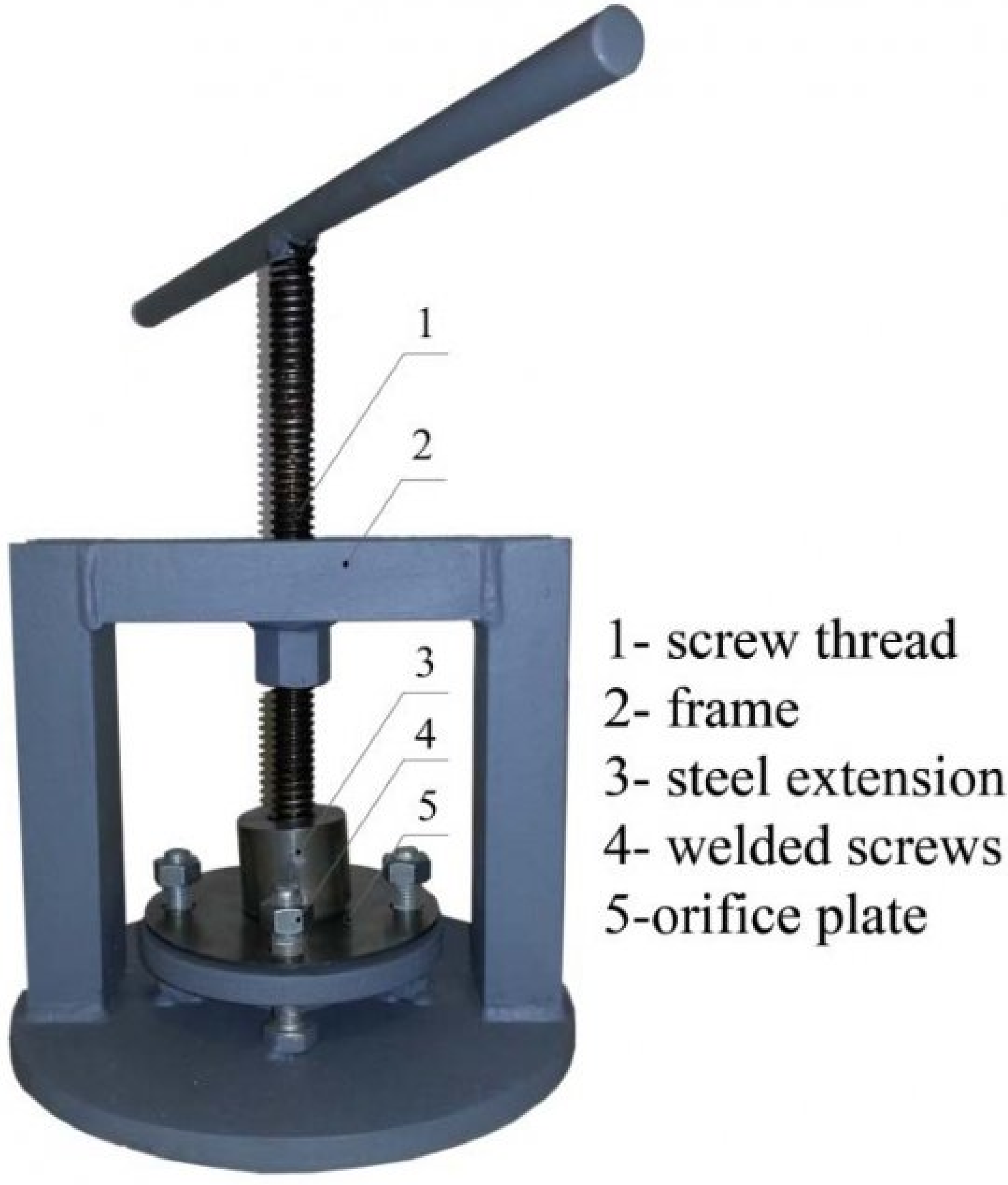

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Figure 4: Fig. 6 :

1

n.	d 1	d 2	d 3	d 4	diameter	d 1	d 2	d 3	d 4	diameter differe
	Undeformed orifice plate					Deformed orifice plate				
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
1.	2.05	2.05	2.05	2.00	2.04	3.25	3.25	3.30	3.25	3.26
2.	2.07	2.08	2.07	2.09	2.08	3.08	3.05	3.03	3.05	3.05
3.	2.07	2.06	2.05	2.07	2.06	2.74	2.88	3.00	2.83	2.86
4.	2.06	2.05	2.05	2.05	2.05	2.70	2.60	2.65	2.75	2.68
5.	2.15	2.14	2.17	2.20	2.17	2.65	2.50	2.53	2.58	2.57
6.	2.03	2.03	2.03	2.03	2.03	2.23	2.23	2.20	2.18	2.21
7.	2.03	2.02	2.02	2.02	2.02	2.03	2.02	2.02	2.02	2.02

Figure 5: Table 1 :

2

		and undeformed orifice plate				
Deformation [mm]	1,2	1	0,8	0,6	0,4	0,2
Orifice plate n.:	1	2	3	4	5	6
Mass flow [kg/h]			Î?”p			
56 kg/h	3	2	-10	-14	-28	-38
106 kg/h	11	-5	-19	-44	-87	-134
156 kg/h	141	107	52	12	-84	-181
206 kg/h	402	358	267	189	-44	-139
262 kg/h	833	755	741	584	333	31

Figure 6: Table 2 :

3

		and undeformed orifice plate				
Deformation [mm]	1,2	1	0,8	0,6	0,4	0,2
Mass flow [kg/h]			Î?”q m [%]			
56	-0.5	-0.5	-1.8	-2.1	-3.6	-4.6
106	0.3	-0.1	-0.4	-1.1	-2.2	-3.3
156	1.5	1.2	0.6	0.1	-1.0	-2.0
206	2.6	2.3	1.8	1.2	-0.2	-0.9
262	3.4	3.1	3.0	2.4	1.4	0.1

Figure 7: Table 3 :

.1 Acknowledgment

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