22nd International Conference
ENGINEERING MECHANICS 2016
Svratka, Czech Republic, 9 – 12 May 2016

EXPERIMENTAL DETERMINATION OF HEAD LOSSES IN POLYETHYLENE PIPELINE WITH NOMINAL DIAMETER DN250

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Abstract: *The article describes experimental measurements of head losses in polyethylene pipeline with diameter d280x25.4 SDR11. During experimental measurement were obtained values of frictional losses of polyethylene pipe PE100 and local pressure loss in butt welded joint. The experimental measurement results are loss coefficients in dependence on the Reynolds numbers. Measurement is continuation of long term research in determining head losses in plastic pipelines at the Faculty of Mechanical Engineering of the Czech Technical University in Prague. Obtained values of head losses in polyethylene pipelines shows that local losses represent important part of the total energy losses.*

Keywords: Polyethylene pipeline, Local head loss, Butt fusion joints, Friction loss, Internal bead

1. Introduction

Designers of plastic pipeline systems mostly do not have sufficient, comprehensive and verified data for reliable hydraulic calculation. The local head loss in plastic pipeline joints welded by butt fusion is nowadays typical example. Due to the recent problems during the operation of plastic piping system, designers often required accurate and verified data of friction losses and local head loss of butt welded joint. Hence, more accurate data are necessary for proper design of plastic piping system. One of frequently neglected minor loss is a loss of joint in butt welded pipeline system.

2. Local head loss in plastic pipelines joint welded by butt fusion

During the process of butt welding the inner and outer emanation (bead) of the pipe material is created (Figure 1c). The size of a butt weld joint bead is for certain material and wall thickness dependent on the welding process. The exact welding techniques are recommended for example by instructions of DVS (Deutscher Verband für Schweisstechnik). The inner bead in the tube represents the specific kind of inner resistance and results in additional minor losses of the fluid flow. The effect of local losses caused by butt welds on total energy balance for long pipelines is important. However, in design practice it is often underestimated or neglected (Mosler, 2014).

Allowed manufacturing tolerance of external diameter and wall thickness is prescribed by the ISO 4065 standard. The measured section was made of straight polyethylene tube *PE100 d280x25.4 DIN 0874/75 SDR11*. The average value of inner tube diameter of pipe is $d_i=227.93mm$ and inner diameter in joint $d_o=211.42mm$, average bead height $h=8.25mm$, average bead width $w=17.29mm$ and average thickness of the pipe $t=26.23mm$. Cross-sections of the pipe at the bead were taken in order to determine the real profile of bead around the entire circumference. Comparison of profiles around the circumference is shown in Figure 1b. It is obvious that internal bead is not symmetrical and the dimension of the bead varies around circumference. Comparison of the bead dimension around the circumference with the DVS standard is in figure 1a.

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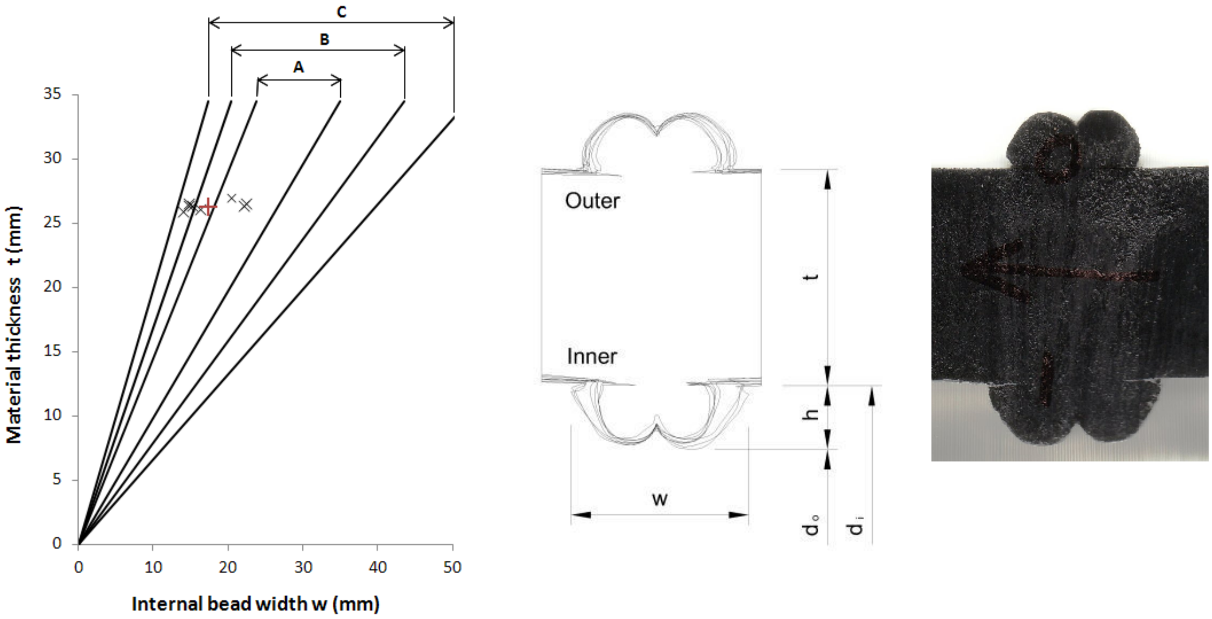

Fig. 1: a) Internal bead dimension in comparison with DVS prescription b) Cross sections of internal bead around circumference c) Cross section of butt welded joint of polyethylene pipeline dimension d280x25.4 SDR11 PE100

3. Design of experimental test loop

The test section of the circuit is composed of the proper metering pipe length sufficient straight pipeline length before and behind the jointing point where the influence of jointing point on flow pattern is anticipated. In front of this measuring section there is a straight pipeline with the corresponding length due to stabilization of the flow. Detailed drawing with distance between pressure measurement connection and jointing point is shown in Figure 2. Static pressure measuring connections in the experimental pipeline were made of four pipeline side inlets that were evenly placed. Figure 2 shows also the detailed arrangement of pressure measuring connections.

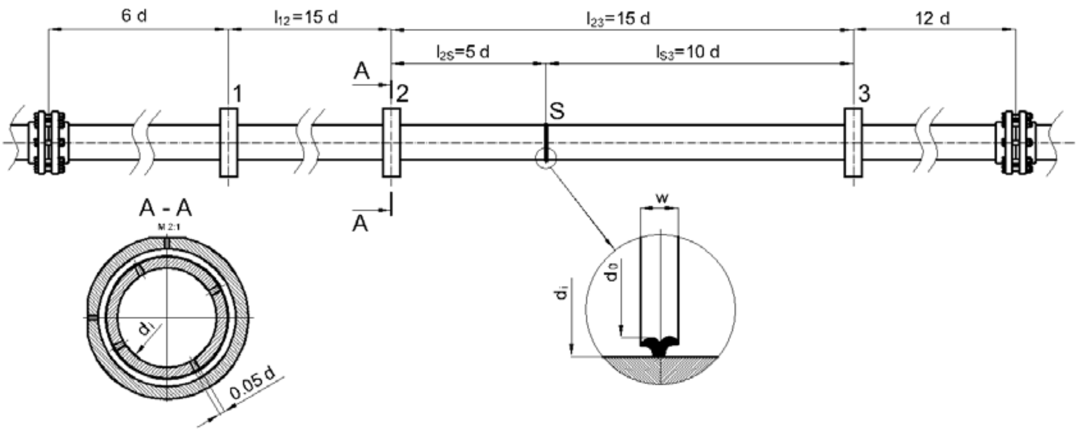

Fig. 2: Arrangement of test section with detail of pressure measuring connections

The static pressure differences Δp_{12} between the cross-section 1 and 2 and Δp_{23} between the cross section 2 and 3 were measured with the use of calibrated differential pressure sensors with range *0–16 kPa/4 – 20 mA*. The estimated accuracy of pressure difference measurements is up to *0.25 %* of a measuring range. The flow rate *Q* was measured using magnetic flow meter. The accuracy *0.5 %* of measured flow rate was guaranteed within the range of *10* to *100 %* of Q_{max}. The mercury thermometer was used to measure the water temperature in order to determine water viscosity. The analogue output signals from the magnetic flow meter and the differential manometers were compiled by A/D converter and transmitted and stored into PC using recording software (Mosler, Melichar 2014).

4. Calculation of local head loss from measured values

The head losses can be expressed in terms of fluid specific energy Y_z $(J.kg^{-1})$, which is consumed in a given pipeline section. The concrete values of Y_z are determined by computation from the measured values of pressure difference, Δp_{12} and Δp_{23}. The pressure drop between cross sections 1 and 2 due to frictional losses can be computed from the Darcy-Weisbach equation

$$Y_{zf} = \frac{\Delta p_{12}}{\rho} = \lambda \cdot \frac{l_{12}}{d_i} \cdot \frac{c^2}{2} \tag{1}$$

The friction factor λ in the case of turbulent flow in hydraulically smooth straight pipeline depends only on the Reynolds number.

The head loss generated at the joint of straight pipeline (local loss) is given by an increase of the loss at the straight pipeline section with given local loss against frictional loss at the same system without local loss. Pressure loss caused by the inner butt weld projection can be expressed as follows:

$$\Delta p_s = \Delta p_{23} - \Delta p_{12} \tag{2}$$

For the local loss computation in a given pipeline joint Y_{zl} it is possible to use the common formula where ξ is local loss coefficient of the joint (Melichar et. al. 2006).

$$Y_{zl} = \xi \cdot \frac{c^2}{2} = \frac{\Delta p_s}{\rho} \tag{3}$$

5. Results of experimental measurements

Results from the measurement of the friction factor of polyethylene pipeline *d280x25.4 SDR11* in dependence on Reynolds numbers is given in Figure 3. The results shows, that measured friction factor is higher than friction factor in hydraulically smooth pipes. Comparison with hydraulically smooth pipe friction factor given by Blasius's and Advani's formulas (Kolář, Vinopal 1963) is in Figure 3.

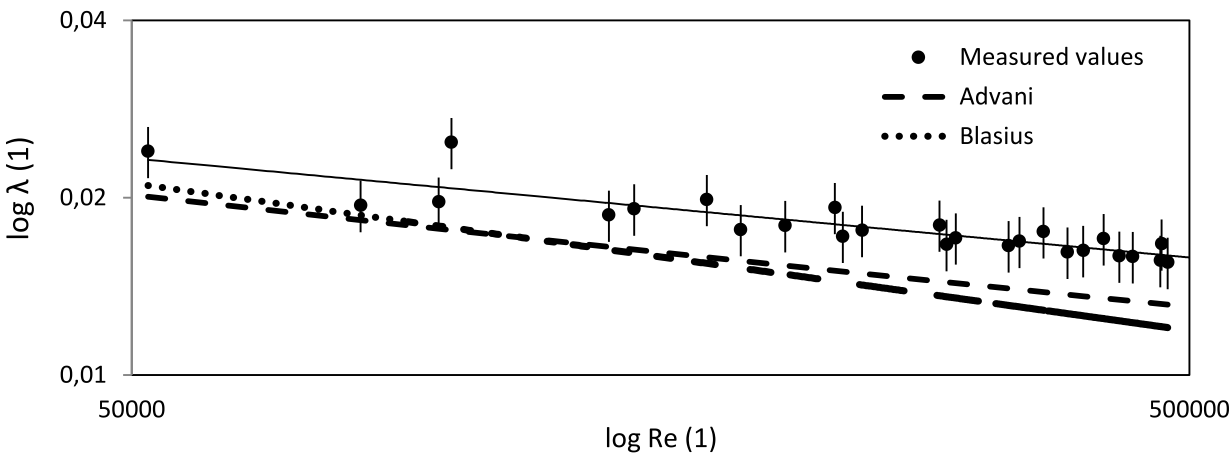

Fig. 3: Measured values of the friction factors in straight pipeline test section of length l_{12} in dependence on the Reynolds number compared to hydraulically smooth pipe

Experimental values of local loss coefficient ζ for examined pipeline joint in dependency on the Reynolds numbers are shown in Figure 4. The results in Figure 4 show values of the local loss coefficient ζ within a range of *0.01* to *0.03* for measured values of the Reynolds number within a range of $1.10^5 < Re < 5.10^5$ and/or flow velocity $0.2\ m\ s^{-1} < c < 2.4\ m\ s^{-1}$.

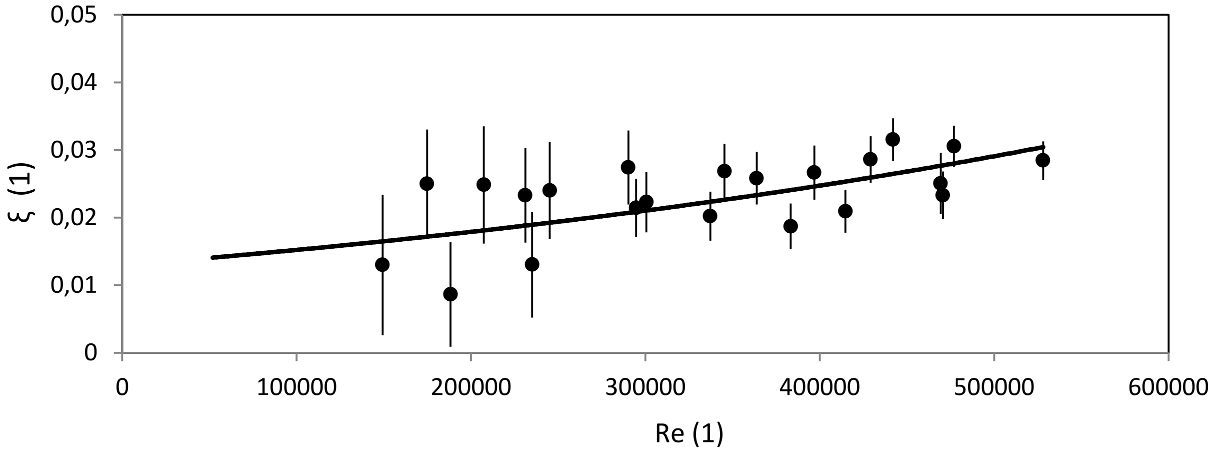

Fig. 4: Values of local loss coefficient for tube joint in dependence on the Reynolds numbers

6. Conclusions

The measured values show that the local losses in butt welded joints represent indispensable part of the total energy losses. This is significant in particular for long pipeline systems. For examples the pipeline with nominal diameter DN250 with butt-welded joints may result increase of head losses about 6% for the above-mentioned Reynolds numbers in comparison with the same pipeline without butt welds. The influence of local losses in butt welded joints is more significant in pipe with smaller diameter then in the larger one.

The paper shows result values of the local loss coefficient for the tube joints with butt welds that were experimentally determined for turbulent flow with Reynolds numbers within the range of $1.10^5 < Re < 5.10^5$. The local loss coefficient at pipeline joints had for the above-mentioned range of the Reynolds numbers the average value of $\zeta = 0.023$. This value was determined for tube *PE100 d280x25.4 SDR11* with average inner diameter of $d_i = 227.93mm$ and for the joint and diameter proportion $d_0/d_i = 0.93$.

Acknowledgement

Experimental measurement was supported by the specific university grant provided by Czech Technical University No.: SGS13/063/OHK2/1T/12.

Appropriate equipment and instrumentation has been taken from Centre for research of multiphase flow and thermodynamic processes in renewable sources and energetic – NEW ENERGY reg. n. CZ.2/16/3.1.00/22130 supported by European Union.

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