Change in the Depth of Scratch on the Polyethylene Gas Pipe after Squeezing with the Squeeze - off Tool

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This research studies the influence of scratches on the polyethylene gas pipes after squeezing with the squeeze-off tool in order to stop gas flow due to an intervention of the gas pipeline. Problem occurs when there is a need to make a decision whether it is safe to squeeze the pipe with scratches. The goal of the research is to determine the change in the depth of scratches on the polyethylene gas pipe after squeezing with the squeeze-off tool. After the experimental research it was determined that there would be a change in the depth of scratch. The change of the depth of scratch positioned on the squeeze-off ear would be considerably bigger when compared to the depth change of a scratch positioned under the upper cylinder of the squeeze-off tool. Based on the resulting data, it is a recommendation of the author not to squeeze the pipe if it has scratches. If the squeezing if inevitable on the place where there is a scratch, the squeeze-off tool needs to be positioned under the upper cylinder of the squeeze-off tool.

Keywords: scratches, polyethylene gas pipes, gas flow, the squeezing

The use of polyethylene pipes (PE) for different fluid-distribution systems is gaining more significance due to the advantages when compared to other materials: low specific mass (easy transport and assembly), good flexibility (ease adaptation to the terrain), smooth inner surface (small loss of pressure and there is no accumulation after long time), great resistance to corrosion, application temperature up to +60°C and resistance to low temperature (1).

Sometimes there are averages on the pipelines and an urgent intervention is needed to stop the gas flow. Stoping the gas flow is conveyed by squeezing the polyethylene gas pipe with squeeze-off tool. After the intervention, the squeeze-off tool is loosen and re-rounding clamp is used on the pipe. Re-rounding clamp helps to reinstate the circular cross section in order to minimaze energy loss. When squeezing a polyethylene gas pipe with the squeeze-off tool deformation occurs, as well as a change in the pipe wall thickness, figure 2a.

Previous researches established that compression of the wall of the polyethylene gas pipe that exceeds 30 % can lead to damaging the pipe by the mechanism of damage in slow crack growth even with the pipes that are more resistant to damage in slow crack growth. With polyethylene gas pipes that are less resistant to damage in slow crack growth, damages can occur when the compression of the pipe wall is less than 30%. Moreover, it was determined that the length of squeezing does not have a larger influence on the damage of the pipe [2]. To prevent permanent pipe deformation, it is recommended by the Rule Book DVGW – GW 332 [3] figure 1, that the squeezing ratio

$$SR = \frac{r}{2\delta}, \qquad (1)$$

should not be smaller than 0.8 [3]. In the equation (1) the parametres are:

r – the distance between the cylinders of the squeeze-off tool [m] and

d - pipe wall thickness [m].

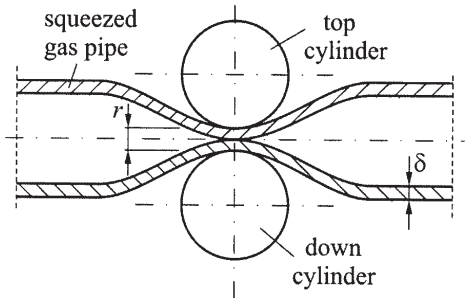

Fig. 1 Squeezing the pipes with squeeze-off cylinders

On the pipe endings there is a visible deformation and that is why this part of the pipe is called squeeze-off ear, due to its visual appearance, figure 2a. The largest damages are exactly under the surface of the squeeze-off ear. It is custom to perform a visual control of the damages after loosening the squeeze-off tool, and particularly on the places where there is a squeeze-off ear [4-7]. Pipes with thickness less than 10 mm can successfully be squeezed, while pipes with greater pipe wall thickness suffer material wrinkling [8].

There have been testings of stress of the material of the squeezed polyethylene gas pipes, as well as hydrostatic testings, in order to investigate the influence of squeezing on the long and short term characteristics of the polyethylene gas pipes. It was variated the influence of the squeezing ratio, influence of pipe outside diameter and geometry of the squeezze-off tool. Hydrostatic testings were conducted after squeezing to investigate the amount of damage on the pipe [9]. Difference in the deformation of the old and the new polyethylene gas pipes exists, which was explored by testing damages on the old polyethylene gas pipes on the places which were squeezed with the squeeze-off tool.

There have also been experimental testings with the goal to determine how much the pipe wall thickness of the polyethylene gas pipes would decrease after squeezing [11]. Polyethylene gas pipes laminate most on the squeeze-off ears after squeezing which is in accordance with the

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Table 1
TESTED SAMPLES OF POLYETHYLENE GAS PIPES

Number	Diameter (mm)	Density of polyethylene gas pipe	Standard of production	Pieces
1.	DN63	PE 80	EN 1555	A, B
2.	DN90	PE 80	EN 1555	A, B
3.	DN110	PE 100	EN 1555	A, B

information from the previous researches. It is a tendency that polyethylene pipes of greater outside diameter have less relative decrease of pipe wall thickness. In addition, pipes of greater density have lesser relative decrease of pipe wall. It was determined that the relative pipe wall thickness for the pipes with the outside diameter DN63 goes even above 20%, for pipe outside diameter DN110 and density PE80 goes slightly above 10%, while for the pipes of outside diameter DN160 and density PE80 goes up to 6%.

Information on pipe wall thickness of the polyethylene gas pipes after squeezing with squeeze-off tool are very important for designers and head managers of the distributive gas pipe line. Decrease of pipe wall thickness after squeezing with squeeze-off tool can be taken into account when dimensioning pipe wall thickness, using wear off ratio C_2 [12]. Eventhough there are no damages on the wall of the pipe and laminated pipe wall is strong enough to withhold the pressure of the gas in the pipe, possible decrease of the pipe wall may be a potential risk for damages. In favour of that claim are the latest testings of the cause of damages of polyethylene gas pipes which were located close to water pipes [13]. Due to damages on the water pipes there was leaking of water. Squirt of water under the pressure caused with the ground and sand erosive slurry which, by obstructing the polyethylene gas pipe, led to damages of the pipe.

This thesis investigates squeezing of polyethylene gas pipe with squeeze-off tool in order to stop gas flow, due to possible intervention on gas pipe lines. According to the recommendations of the standard [14] polyethylene gas pipes should not be built in the distributive gas pipe line, and niether should be elements of pipe line with damaged sharp edges. According to that, considered to be damages are scotchs and scratches deeper than

$$d_r = \frac{d}{\delta} \cdot 100\,\% > 10\,\%, \qquad (2)$$

where d depth of the scratch on the pipe [m].

Managers of construction sites and head menagers of distributive gas pipe lines are the ones to decide whether to build in polyethylene pipe after visually determining whether the scotch or the scratch are deeper that the defined allowed depth. Problem occurs when there is a built in polyethylene pipe which has scratches of allowed depth, and as such, it needs to be squeezed with squeeze-off tool in order to stop gas flow for the sake of intervention. If the squeezing of the pipe is done according to the recommendation of the Rule Book [3] there is a question whether there would be a change of depth of the scratch.

The goal of the research is to determine whether there is a change in depth of the scratch on the polyethylene gas pipe after the squeezing with the squeeze-off tool. Hypothesis of the research is that there would be a change of the depth of the scratch, where the change of the depth of the scratch positioned on the squeeze-off ear would be considerably larger when compared to change of the depth of scratches positioned under the upper cylinder of the squeeze-off tool. It is presupposed that the change of depth of scratches on the squeeze-off ears will be more noticeable and therefore those pipes would not be safe for use according to the demands of the standard [14].

Experimental part

Changes of depth of the scratch after squeezing with squeeze-off tool were tested on the new polyethylene gas pipes with the outside diameter DN63, DN90 and DN110 and density PE 80, table 1. Standard diameter ratio:

$$SDR = \frac{D}{\delta}, \qquad (3)$$

for all the pipes was SDR 11.

The pipes were produced according to recommendations of the Standard EN 1555 [15].

On the samples of pipes in table 1, with length 1m, scratches along the axis of the pipe were engraved using a miller. Scratches were 50 mm long, 1mm wide and the depth of the scratches were 10% of the pipe wall, figure 2b. Using a permanent marker, measuring points 1, 2 and 3 were drawn with distance as shown in the figure 2b. Before squeezing, the depths of scratches were measured using comparator, figure 3a. The pipes were then squeezed with the squeeze-off tool and held under the squeeze-off tool for an hour, figures 3b and 3c. After releasing the squeeze-off tool, eliptic section same as the surface amount of the cross section of the deformed pipe, figure 2a, was brought back in the circular section by using a re-rounding clamp. In the measuring points, after squeezing the pipe, measurement of the depth of the scratch was done, and then the values of depths of the scratches were compared before and after the squeezing. Testing was done in laboratory conditions, under constant temperature of the air amounting to 20°C.

With the goal to check the changes in the depth of scratch positioned under the upper cylinder of the squeeze-off tool and on the squeeze-off ears, two arrays of samples A and B were formed, table 1. With the array of samples A, scratches were positioned under upper cylinder of the squeeze-off tool, while with samples B scratches were positioned on squeeze-off ears of the pipes, figure 2a.

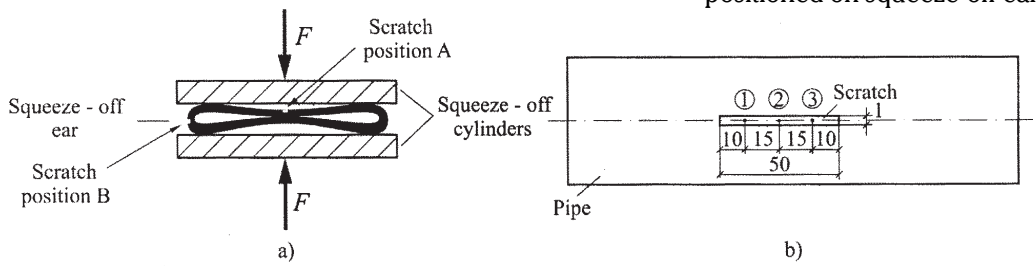

Fig. 2. Measuring pipe wall thickness of polyethylene gas pipe before and after squeezing

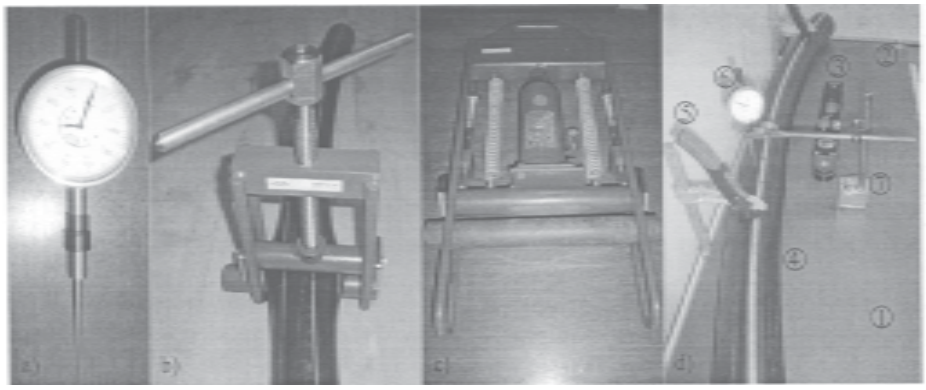

Fig. 3. Units for testing polyethylene gas pipes

The depths of scratches were measured on testing table shown in picture 3d. Pipe 4 was set on the table 1 and squeezed with clamp 5. Horizontality of the testing table was determined by setting screws and nuts 2, and was checked with water label 3. Comparator 6 is positioned by using stand 7.

The results of measuring the depth of the scratches before and after squeezing were compared and relative depth deferrence was formed:

$$\varepsilon_d = \frac{d_a - d_b}{d_b} \cdot 100\ [\%], \qquad (4)$$

where:

d_a - depth of scratch after squeezing [mm] and

d_b - depth of scratch before squeezing [mm].

Squeezing the pipes was done completely following the recommendations of Rule Book DVGW – GW 332 [3]. Squeeze-off tool of manufacturer "Georg Fischer", model S1 and model S2 was used. Model S1, figure 2b, is used for squeezing the pipes with outside diameter from DN20 to DN63 and SDR11, while model S2, figure 3c, was used to squeeze pipe with outside diameter from DN63 to DN160 and SDR 11 and SDR 17. Squeezing ratio SR is set on value 0.8 by using guard of the squeeze-off tool. After releasing the pipes, re-reounding clamps of the same manufacturer were used to bring back the circular section of the pipe for the pipes with outside diameter DN63, DN80 i DN110. Comparator of manufacturer KS was used, with resolution 0.01 mm and measuring range from 0 to 100 mm.

Results and discussions

The results of measuring the depths of scratches before and after squeezing are shown in tables 2, 3, 4 and 5. Tables 2 and 3 show depth of scratches before squeezing, while tables 4 and 5 show depths of scratches after squeezing.

By using the equation (4) relative difference of depths of scratches before and after squeezing with squeeze-off tool was calculated. Table 6 shows relative difference of measured depths of scratches positioned under the cylinder, while table 7 shows relative difference of measured depths of scratches positioned on ears of the pipe.

In table 6 it is noticeable that, due to squeezing, there is a change of depth of scratches that are located under the cylinder of the squeeze-off tool. Values of the relative differences are negative which shows that squeezing of the pipes that have scratches under the cylinder of the squeeze-off tool leads to decrease of the depth of the scratch. This result could be expected by looking into the results of the previous researches. By squeezing the pipes, it was determined that considerable decrease of pipe wall thickness is directly under the cylinder [11], while decrease of pipe wall thickness directly under after squeezing led to decrease of depth of the scratch after squeezing.

To compare the values to the allowed border values, ratio was calculated according to condition (2), with new depths of scratches, and shown in table 8. It can be noticed that the changes of depths are as such that the values are around border values and in some cases they are unallowed values.

Table 2

DEPTH OF SCRATCH – SCRATCHES UNDER UPPER CYLINDER (ARRAY A)

Diametar/Measuring point	d_1 [mm]	d_2 [mm]	d_3 [mm]
DN63	0.58	0.61	0.60
DN90	1.01	1.1	1.2
DN110	1.01	1.11	1.25

Table 3

DEPTH OF SCRATCH – SCRATCHES ON SQUEEZE-OFF EARS (ARRAY B)

Diametar/Measuring point	d_1 [mm]	d_2 [mm]	d_3 [mm]
DN63	0.6	0.58	0.8
DN90	0.87	0.78	0.92
DN110	1.3	1.5	1.45

Table 4

DEPTH OF SCRATCH– SCRATCHES UNDER UPPER CYLINDER (ARRAY A)

Diametar/Measuring point	d_1 [mm]	d_2 [mm]	d_3 [mm]
DN63	0.51	0.49	0.39
DN90	1.00	1.01	0.9
DN110	0.89	1.21	1.38

Diametar/Measuring point	d_1 [mm]	d_2 [mm]	d_3 [mm]
DN63	0.82	0.81	0.55
DN90	2.32	2.47	0.97
DN110	1.6	3.4	3.61

Table 5
DEPTH OF SCRATCH– SCRATCHES ON SQUEEZE-OFF EARS (ARRAY B)

Diametar/Measuring point	d_1 [%]	d_2 [%]	d_3 [%]
DN63	-12.06	-24.48	-35
DN90	-0.99	-8.18	-25
DN110	-11.88	-9	-10.4

Table 6
RELATIVE DIFFERENCE OF MEASURED DEPTHS – SCRATCHES UNDER UPPER CYLINDER (ARRAY A)

Diametar/Measuring point	d_1 [%]	d_2 [%]	d_3 [%]
DN63	36.66	39.65	-31.25
DN90	78.46	64.66	5.43
DN110	23.07	126.66	148.96

Table 7
RELATIVE DIFFERENCE OF MEASURED DEPTHS – SCRATCHES ON SQUEEZE-OFF EARS (ARRAY B)

Diametar/Measuring point	d_{r1} [%]	d_{r2} [%]	d_{r3} [%]
DN63	8.79	8.44	6.72
DN90	12.19	12.13	10.9
DN110	8.9	12.1	13.8

Table 8
RATIO OF NEW DEPTH OF SCRATCHES AND PIPE WALL THICKNESS – SCRATCHES UNDER UPPER CYLINDER (ARRAY A)

Diametar/Measuring point	d_{r1} [%]	d_{r2} [%]	d_{r3} [%]
DN63	14.13	13.96	9.48
DN90	28.29	30.12	11.82
DN110	16	34	36.1

Table 9
RATIO OF NEW DEPTH OF SCRATCHES AND PIPE WALL THICKNESS – SCRATCHES AT SQUEEZE-OFF EARS (ARRAY B)

It is easy to notice from table 7 that with all measuring points, except number 3 at outside diameter DN63, there is a relative change of the depth of the scratches which have positive values. Positive value of change of depths of the scratches shows that there is an increased depth of the scratch after squeezing with squeeze-off tool. As the depths of the scratches were at allowed border-value before the squeezing, noticed increase of depth leads to the conclusion that the pipe are damaged after the squeezing and should not be built in. To illustrate this constatation, ratio according to the condition (2) was calculated, with new depths of the scratches, and shown in the table 9.

It is noticeable that only in the third measuring point, on the pipe with diameter DN63, the depth of the scratch is under the allowed 10 % when compared to the pipe wall thickness. In other cases, the depths of the scratches after squeezing go above the allowed border value. The extreme measuring point 3 on the pipe with outside diameter DN110, relative change of depth amounts to 148 %, table 7. New depth of the scratch is 36.1 % of the pipe wall thickness. Not only is the previous value three times higher than the allowed border value recommended by the standard, but there is an initiating of a scotch, figure 4.

Conclusion

After a conducted experimental research, it is concluded that squeezing the pipe with squeeze-off tool to stop the gas flow, results in changing the depth of the scratches on the pipe. Hypothesis of the reasearch is proven, and it was confirmed that the change of the depth of the scratch positioned at the squeeze-off ears would be considerably larger when compared to the change of the depth of the scratch positioned under the cylinder of the squeeze-off tool.

When the scratch is positioned under the cylinder of the squeeze-off tool, then, due to the compression of the material directly under the squeeze-off tool, there is a change in the depth of the scratches on the pipe. When the depth of a scratch is at the allowed border value before squeezing, then, after the squeezing, the depth is decreased even under the allowed border value.

When a scratch is positioned at the squeeze-off ear of the pipe, the place where during the squeezing, strenching

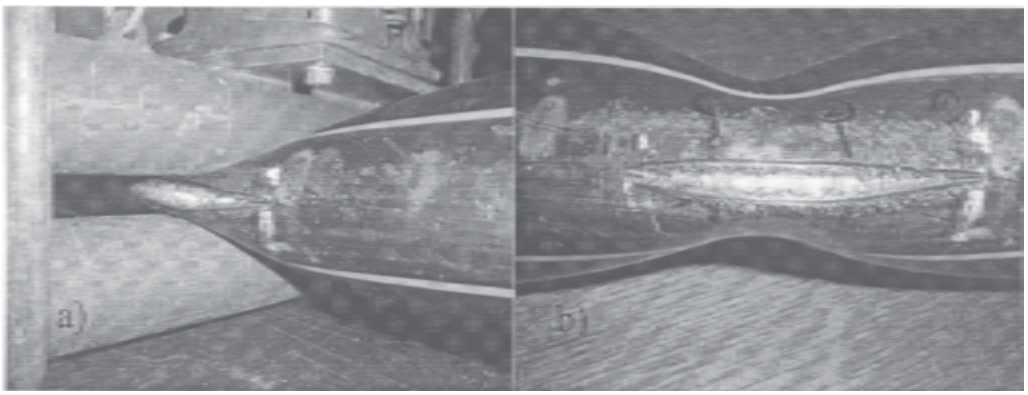

Fig. 4 Forming of a scotch at scratches on squeeze-off ears on pipes with outside diameter DN110

of the material occurs, then the depths of the scratches on the pipe increase when compared to the depth before the squeezing. If the depth of the scratch before the squeezing is at the allowed border value, then after the squeezing the depth increases even 3 times when compared to the initial value of the depth, for scrathes on the pipes with outside diameter DN110. In the above mentioned case, the scratch even turns into a scotch.

Due to relaying on visual control of the scratches on polyethylene gas pipes, judging whether the pipe is damaged or not is a very difficult task for the head managers of the distributive gas pipe lines and the managers of the construction sites. This problem becomes even more complicated when there is a need to squeeze with a squeeze-off tool a pipe that already has scratches, in order to stop gas flow. Based on the gained data, the author recommends not to squeeze the pipe if it already has a scratch. If the squeezing is necessarry due to an intervention, then the squeeze-off tool should be set in such a way to position the scratch under the upper cylinder of the squeeze-off tool.

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