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Swagelining as a method of trenchless piplines rehabilitation

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ABSTRACT

Purpose: The present study outlines the advantages of using trenchless methods for the rehabilitation of pipelines made of steel, concrete, cast iron etc. The authors describe causes of carrier pipe ageing and methods of their inspection and renovation. The technical aspects of choosing the renovation methods are also presented. The paper includes a decision-making flowchart for choosing the carrier pipes renovations.
Design/methodology/approach: The 1980's and 1990's saw an explosion of new pipe installation and repair techniques which minimize the need to dig continuous trenches to bury the pipeline, so called 'trenchless technologies'. The trenchless technologies have been widely applied for the rehabilitation of various pipelines such as sewage systems, gas pipelines or water supply systems. There has been characterized the swagelining technology which is based on one of the metal working technologies and namely the sinking of pipes.
Findings: The PE pipe stress in the drawing die zone has been analyzed and an attempt has been made to analyze the mechanisms causing the elastic recovery of PE pipes. There have also been presented the diameter changes as the parameter of the elastic recovery which is a result of our own research conducted in accordance with the program developed.
Research limitations/implications: Each pipeline renovation method has its advantages and disadvantages, possibilities and limitations, depending on the application.
Practical implications: The work is an example of analysis of chosen trenchless renovation on the example of swageling technology.
Originality/value: The trenchless renovation of pipelines certainly will be more readily used in the future because of wearing out of pipelines. The other reason is the lack of space for new utilities, increasing costs and road-surface restoration requirements.
Keywords: Engineering polymers; Mechanical properties; Trenchless renovation; Swagelining

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1. Introduction

Pipelines are rather economical and eco-friendly way of transporting liquid and gaseous fluids, like natural gas, water, oil or district heating, covering long distances. Pipelines transport huge amounts of energy safely, quickly and economically. This is an extremely gentle and efficient way of transportation. High demands on operational safety and the equipment used, as well as regular intensive checks of the operating process, applying the latest techniques, assure the high safety standards of this transportation system.

If the water supply is nationwide, water galleries and transport lines installed underground connect the source to the storage and distribution spots, which are often far away. Pipelines transport oil and gas from the exploitation area to the plants for further processing. The products are handed on to the industrial or private user via further transport and distribution lines or distribution networks.

In the last two to three decades, many new underground utility construction and repair technologies have emerged that are grouped under the term *trenchless technology*. The term is used to describe those technologies that allow the installation, replacement or repair of underground utilities or conduits without the need for the excavation of a continuous trench from the surface. While the term *trenchless* certainly applies to larger bored tunnels also, the term is typically used to refer to urban-utility-scale-technologies rather than rail, metro, or road tunnel installations [1-4].

The development of these technologies provides new solutions for installing and maintaining urban utility systems but also introduces new issues into the planning, design and operation of these systems. These new issues have impacts on the engineers who plan and design the systems, impacts on the conduct of site investigations for utility work, and impacts on the long-term arrangements of urban utility systems as the techniques are used more extensively.

2. Trenchless method of pipelines renovation

Actually, rehabilitation of existing pipeline systems has already been carried out since the first installation of pipes. When a system became malfunctioning for one reason or another, upgrading of some sort was simply necessary. The international standardization body ISO, have describe and classified the several options of rehabilitation. Figure 1 is demonstrating rehabilitation options.

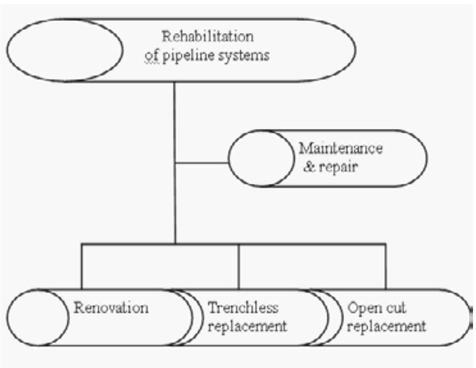

Fig. 1. Rehabilitation options (ISO) [5]

The general term *Rehabilitation* can be broken down into three areas [5]:

- Repair – rectification of local damage,
- Replacement – construction of a new pipeline,
- Renovation – improving the performance of a pipeline by inserting or applying a liner.

Trenchless technologies lie in the deposition, fixing or renovation of underground infrastructure with a little or even zero digging operations. Fixing operations are a special case of renovation, when the technical capacity of the pipelines is restored through sealing or local repairs. A sealing up operation lies in filling undug or leaking places with a sealing material or injecting liquid sealing materials inside the pipeline. Thus, external and internal sealing up methods can be distinguished.

The trenchless technologies constitute efficient replacement to the traditional pipelines rehabilitation methods due to the substantial reduction or elimination of trenching, protection of the natural environment and considerable reduction of costs including social costs. A further proof of the increased interest in the subject techniques is the Poland's access to the ISTT – International Society for Trenchless Technology which took place at the 17th International "No-Dig" Fair '99 [6]. In order not to allow a situation where it is no longer possible to rehabilitate the pipeline using a trenchless technology detailed surveys and site investigations of the pipelines must be carried out. First an examination of the soil and water conditions must be performed as well as the depth at which the pipeline to be rehabilitated is laid must be determined. Further an inspection of the pipeline condition should be made with special attention being paid to the material, shape and length of individual sections. To this end a number of analyses of both the soil and the pipeline condition are made. The analysis of the pipeline condition is usually made by means of the CCTV (Closed Circuit TeleVision) inspection or using a sonar or a radar (used as addition to the data acquired using the CCTV) prior to which a thorough cleaning of the duct must be performed [7]. Apart from the above mentioned systems of the acquisition of data important for the pipeline rehabilitation there are also systems enabling an inspection of ducts which are partially filled. They are TV cameras used above the water surface and sonar transponders employed below the water surface. In order to chart location maps of the area of works including all obstacles located in the ground (light pipes, cables, pipes etc.) georadars are used [8, 9, 10].

A precise examination of the overall condition of the pipeline and the cause of the failure enables the optimum selection of the repair technology and a substantial reduction of costs.

The swagelining technology allows a tight fitting of the PE pipes inside the rehabilitated pipeline. This applies both to the operation stage forming in the drawing die zone and the elastic recovery after the insertion into the rehabilitated pipeline.

This study focuses on the swagelining technology which was developed by British Gas North Western Region at the end of the 1970's and introduced in the commercial scale in the 1980's.

First attempts to rehabilitate pipelines by means of that technology were made with the use of pre-heated insert "getting-through" pipes. The result of the heating process was the reduction of the drawing damages. However, the process required the additional equipment to be employed which was the reason for many problems during the reconstruction. The development of the technology and its constant improvement resulted in pulling the PE pipes into the reconstructed host pipe without additional preheating of the insert pipe. The technology of drawing PE pipes without preheating was used for the first time in Chester in 1989.There are many trenchless pipeline rehabilitation technologies available in the market. The most frequently used trenchless renovation methods are presented in Table 1.

Table 1.
Basic sealing techniques and trenchless pipeline refit methods [2, 5, 6, 7, 11]

Exemplary method of a type	Short description	Advantages	Disadvanteges
		SLIPLINING	
Sliplining	Insertion of one long section of lining of lower diameter, made of plastic material	Non invasive for regular operations; short time of performance; relatively low cost; simple in performance; usually self-bearing method; no accurate sealing up needed.	Can`t be used for sharp curves; complex process of connection reconstruction, may require sealing up.
Shortlining WIR	Ca 0,5 m long, lower diameter pipe modulus are introduced to the pipeline.	Apart from the above options for refitting underground instalment.	Limiting ductibility of pipeline; can`t be used for sharp curves; injection needed.
		CLOSE FIT LINING	
U,C,H, Liner	Make use of longitudinal deformation of U, C, H- these are reduced linings. PE and PCV pipes can be used.	Short time of refit; high durability; lenght of refited sections up to 1000 m long wide range of diameters.	Needed pressure or increas temperature treatment; slightly reduced ductibility.
Neofit	Small, elastic pipe made of PET is introduced to the pipeline; then it is enlarged.	Provides good tightness fastness of refit; expands 2,2 times the initial diameter size; easy to perform.	Does not transmit loads, used only for water.
Swagelining	PE lining is tightly disposed in the pipeline; the pipe is dragged through a reductor decreasing the diameter; material memory; paradigm inserts are used.	Minimal number of trenches; performed quickly; no interpipe injection needed; connections are easy to perform.	The state of the pipeline determines the type of installed lining capable of transmitting loads it can be disposed.
Soft lining	Special epoxy or polyester resin impregnated sleeve is dragged the pipeline; then it is pressure-adjusted to the pipeline wall and hardened with hot water, water steam or UV.	Transmits external loads can be used for refitting curvilinear section; local contractions; small deformations of the pipeline.	Needs detailed cleaning specialist equipment; high cost; TV inspection needed.
		ONE-LINE REPLACEMENT	
Static burstlining	Refitting of steel pipes; steel pipe is cut and deflected underground.	Applicable for refitting of steel, cast iron and plastic pipelines.	Limited range of diameters; requires specialist equipment.
Hydraulic burstlining	Old pipeline is hydraulically crushed with a segment reaming head under the influence of hydraulic pressure.	No dynamic environmental impact; vibration; it can by used for compact developed civic areas; small operation area.	Needed specialist equipment, special head or dragging device.
Pneumatic burstlining	Old pipeline is crushed by a pneumatic head, after which new pipes are dragged.	Does not limit the ductibility of pipeline; a larger diameter pipeline can be installed.	Dynamic influence on utilities of other networks.
		SEGMENTAL LINING	
Sanlinick 2000	Cast iron pipeline is sealed up by a multilayer sleeve; stuck inside the pipeline.	Durability; tightness; perfect adhesiveness of lining to the pipe	For diameter over 0,2 m this methods is unprofitable, has to be done off-line.
Avonseal Two	Sealing up external bell connections with fibre.	Short time of performance	The surface must be clean, gland rings are used.
Encapsulation serie 6	Sealing up the bell surface with a tight gland band Cast iron pipelines.	Short time of performance	Gland band is used.
		SPRAY LINING	
Subterra method	Various resins or cement slurries are disposed on clean surface with a rotary head.	Controlled thickness of sprayed material; connections are easy to perform.	Specialist equipment and detailed cleaning of the pipeline are needed.
		LIVE INSERTION	
Stive Vick International Method	New pipe is driven in and out with a choking seal	The medium is being constantly transmitted through the space between old and new pipeline.	Specialist equipment needed. Dangerous.

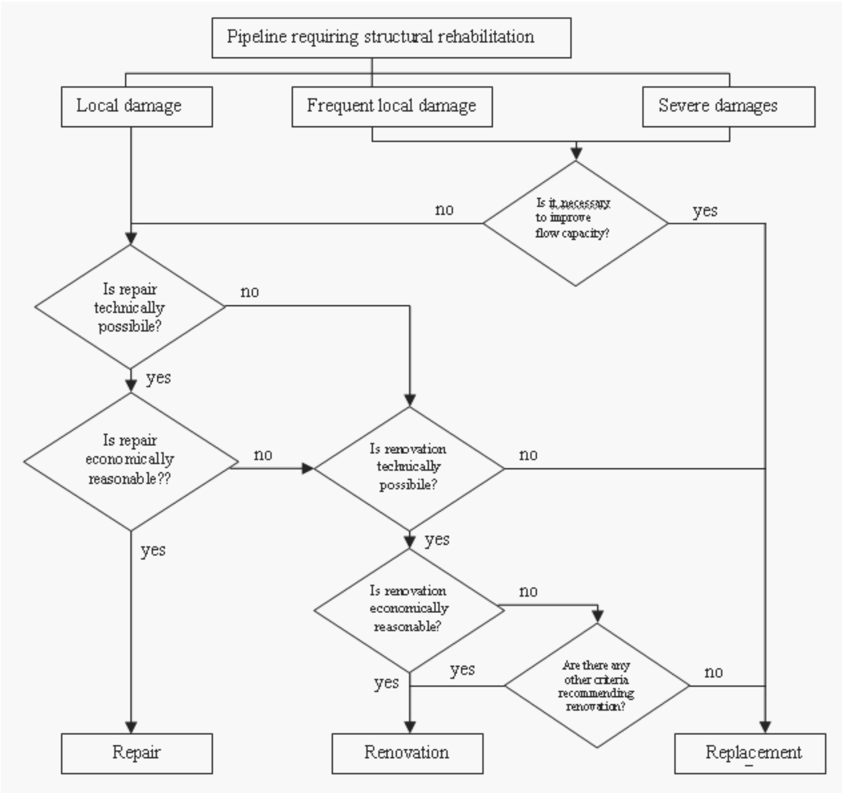

Fig. 2. Decision guide [12, 13, 14]

In the case of a bad technical state of pipelines, the most suitable renovation method can be selected on the basis of the inspection results. The use of trenchless methods of pipelines renovation, as compared with the traditional ones, gives the following advantages:

- less social inconvenience (traffic, commerce),
- less interference with cables and other services,
- less disruption of nature and the environment (trees, waterways),
- independent organisation (no work on other services underground required),
- less time and money needed.

To select the best rehabilitation method, an attention should be paid to the number of pipelines data. The flow chart in (Fig. 2.) helps decision makers to find the appropriate solution for a particular problem.

3. Technolgy characteristics

The swagelining method belongs to the group of close fitting renovation techniques. It means that a lining set in the result of an installing process closely adheres with its external surface to the renovated pipeline internal surface. Due to it, a reduction of a renovated pipe cross section is limited to minimum what is of great importance in the case of renovation of pipelines the flow capacity of which has not to be reduced or reduced in a small rate only.

In the swagelining method, a polyethylene pipe is used as a standard lining. In dependence on a technical state of a pipeline submitted to renovation, there may be applied a structural lining – being able to carry out all internal and external loads by itself or an interactive lining– which has to co-operate with the construction of an old pipeline because it is not able to carry out either internal loads or external loads by itself. Figure 3 is presenting idea of renovation in swagelining method [15].

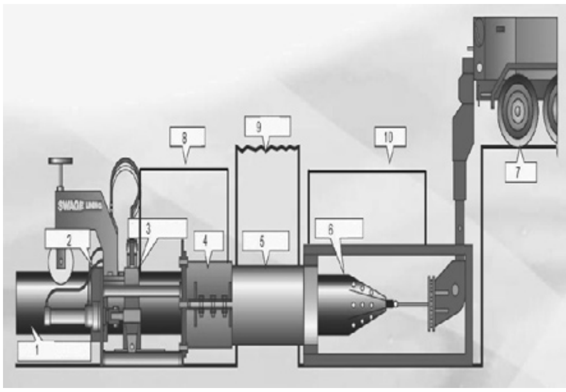

Fig. 3. Idea of renovation in swagelining method [15]: 1 – new PE pipe, 2 – reducing die, 3 – hydraulic pusher, 4 – clamp, 5 – original pipe, 6 – towing cone,7 – winch, 8 – entry pit, 9 – ground level, 10 – exit pit

The interactive lining (a polyethylene pipe having wall of small thickness) is inserted in the case when the old pipeline strength will remain sufficient within further tens years and the decision to carry out renovation works was taken because the pipeline shows leakages or requires a corrosion protection or shows an excessive pipe inner surface abrasive wear. In such situation, even an improvement of pipe hydraulic characteristics will occur due to relatively thin pipe wall and low roughness of pipe inner surfaces. It is not expected to meet an emergency case before expiration of ca 50-year period because an abrasive wear of polyethylene is very low (this material shows the highest resistance to the abrasive wear among commonly used installation materials). The structural lining is installed in the case wherein the pipeline strength condition reaches a critical state or when such state is expected in nearest years [16-19].

The swagelining method consists in a close setting of polyethylene linings inside old pipelines. In order to obtain such effect, standard polyethylene pipes having the outer diameter only somewhat greater than the inner diameter of a renovated pipeline are welded into a section longer by several meters than the renovated pipeline section. After cutting-out outer excessive ends of the pipe, (i.e. PE pipe ends), it is pulled through a pull-plate in order to reduce its cross-section (obtaining 12%- diameter reduction). Due to it, the temporary deformed lining may be pulled-in into a renovated pipeline without difficulties. On completion of this process, ends of the lining are fitted with suitable shape-elements and the lining is filled-up with water throughout blind flanges in order to accelerate a lining reversion process by maintaining suitable pressure inside (the lining will return then to its initial shape). The recovery process is completed in the moment, when the lining outer surface will come into contact with the old pipeline inner surface because the renovated pipeline inner diameter is somewhat greater than the lining initial diameter. With this way, the close fitting effect is obtained. Fig. 4 is presenting how does swageling works [20-24].

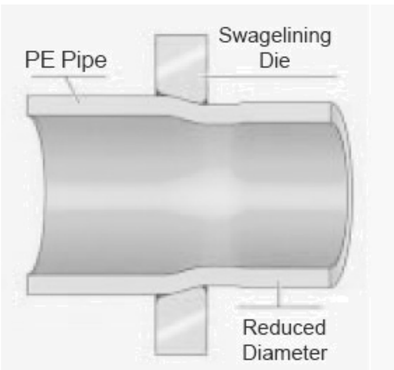

Fig. 4. Action of swageling [15]

4. Experimental setup

The drawing process causes the material to deform due to following external forces: efforts (active forces) (F – drawing load) and reactions (F_r – tool reaction, F_t – friction force) – Fig. 5.

The above forces cause the internal stresses to occur in the material drawn. The axial – symmetric stresses are characteristic for the sinking of pipes where the following stresses are observed [25]:

- axial stresses (tensile stresses) σ_1,
- radial stresses (compressive stresses) σ_r,
- circumferential stresses (compressive stresses) σ_φ,

The value of the drawing load F depends on the properties, dimensions, size and viscoelastic recovery of the material drawn as well as on the tool geometry. There is also a significant, indirect dependence on the process temperature.

The process analysis shows that the material in the die zone is partially plasticized. On leaving the die, a rapid diameter increase or swelling are observed and therefore the pipe remains under load.

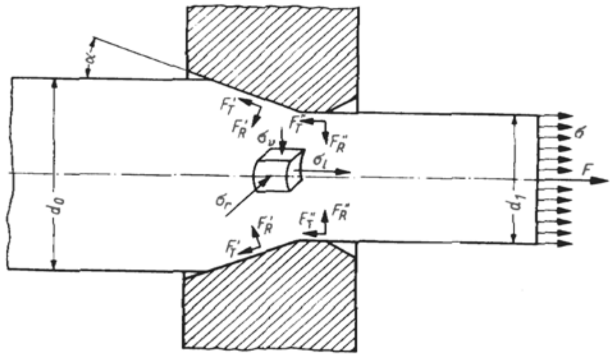

Fig. 5. Forces and stresses in the drawing (sinking) process [25]

Such a natural return is the result of the viscoelastic recovery. During the process the elastic recovery is more rapid after the leaving of the die zone and on releasing the tension. In the remaining time, when lacking the tension – after the complete release of the pipe - or under the conditions of the tension being fixed, the recovery is slower. Eventually this is to ensure a tight fitting of the inserted PE pipe in the pipeline being rehabilitated. The process analysis may not, however, disregard the plastic strains causing permanent reduction of the inserted pipe diameter. Such strains are the result of the partial plasticizing of the material in the die zone.

The actual stresses inside the wall of the pipe being pulled in depend on the drawing speed. The speed influences the time the pipe remains inside the die and the speed of strains as well as the extent of the plastic strains.

Consequently, a conclusion can be drawn that it takes the properly adjusted drawing speed enabling an insertion of the pipe into the rehabilitated pipeline with simultaneous elastic recovery to achieve an efficient drawing process.

5. Own research

An attempt was made under this study to create a basis for the rational selection of the conditions of the pipe drawing as the trenchless method of the rehabilitation of pipelines.

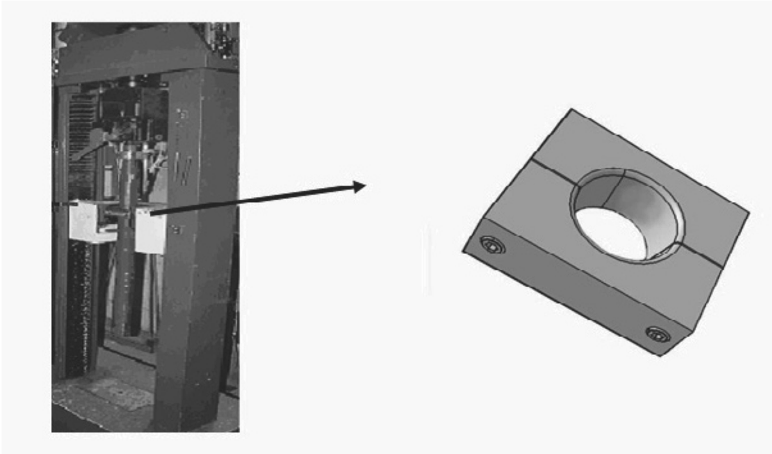

Fig. 6. Test stand and die

The research was carried out in the laboratory of the Derpartment of Processing of Metals and Polymer Materials. A Heckert FPZ 100/1 testing machine (Fig. 6.) was adapted for the purpose of testing. A tensile test was performed with the die mounted in the traverse cassette.

The machine speed – being at the same time the speed of the die – was 530 [mm/min]. In order to determine the dependence of the elastic recovery on the geometric parameters of the die, different die generator inclination angles were used and the reduction ratio was diversified – see Table 2.

Table 2
Geometric parameters of die

ANGLE	12.5º	15º	17.5º
REDUCTION RATIO		10% 15% 20%	

The assessment was made basing on the data published and the research performed, taking into account geometric parameters of the die, drawing force and speed, properties of the material the pipe was made of as well as the pipe dimensions.

Under the research, in order to determine the subject elastic recovery, the following PE pipes were used: PE100Ø63 SDR 11 and SDR 17 manufactured by ELPLAST PLUS in Jastrzębie Zdrój. The tests were carried out in the ambient temperature of 21ºC ± 2ºC. During the testing the outer diameters were measured in specific intervals and the tensile force was recorded.

The results of the tests performed enabled the determination of the drawing force on the geometric parameters of the die and the series of the pipes tested – see Fig.7.

There are two areas visible in the figure, first of them for SDR 11 – values from 6.8 kN to 10.9 kN and the other one - for SDR 17 with significantly lower force values ranging from 4.3 kN to 7.4 kN which is the result of the wall thickness.

In order to determine the elastic recovery of the pipe the outer diameter was measured. The diameter was measured in fixed intervals counted from the drawing process completion. Due to the ovality of the pipes drawn the arithmetic mean of five measurements was assumed.

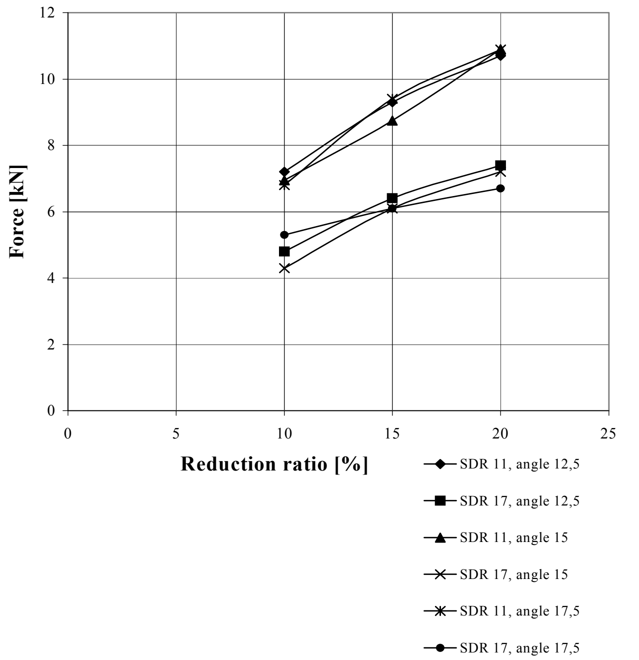

Fig. 7. Drawing force and the reduction ratio

The process analysis demonstrates that the material in the die zone is plasticized. Further stage is the process of the viscoplastic recovery under conditions of the axial load and after the release thereof.

In the tests performed the tension was released after one minute time which is reflected in the presented diagram of the diameter change as a function time (see Fig. 8). The diagram illustrates the successive stages of the elastic recovery – pulling through the die (die), "swelling" (up to 1 min after leaving the die), tension release (after 1 minute), further return to the original diameter (from 1 minute to 3000 minutes).

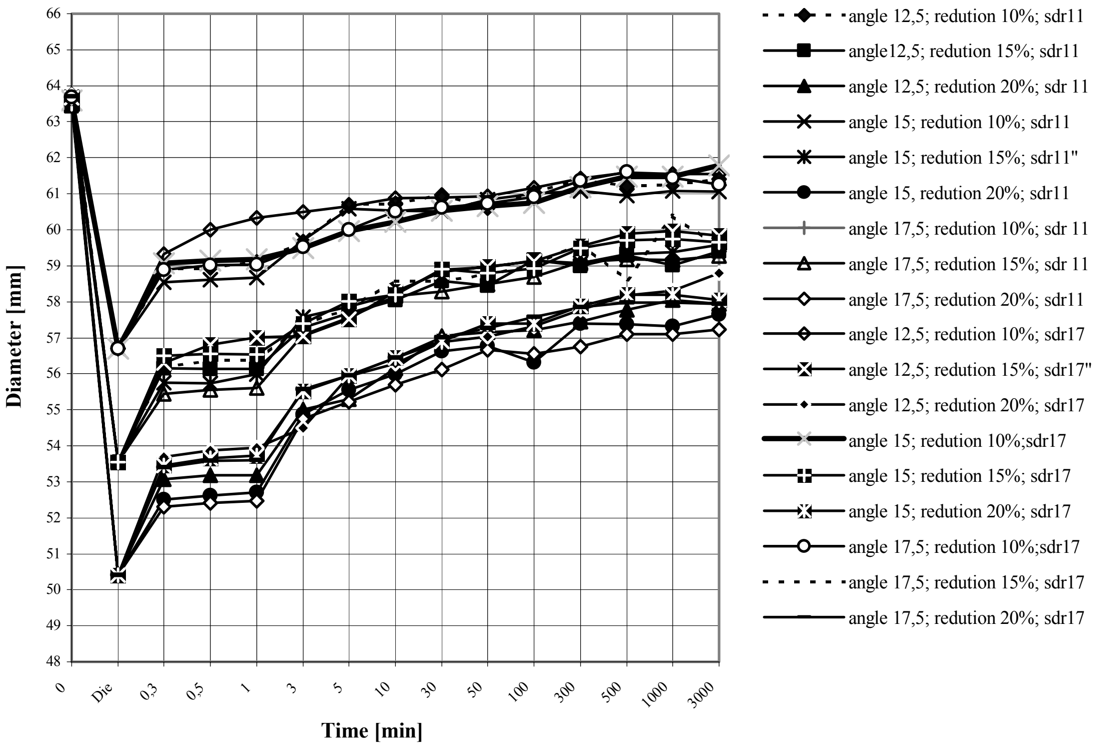

Fig. 8. Drawing force and the reduction ratio

6. Conclusions

The elastic recovery varies according to the die angle and the reduction ratio. The elastic recovery increases as the die angleand the reduction ratio increase. The thicker the wall the more intense the recovery.

The most intense elastic recovery of the pipe tested takes place during the initial 30 minutes after the completion of the drawing test.

Quantitative characteristics of the process will be used in the procedures of selecting tools and materials for individual reconstructions.

When rehabilitation of pipe system is required for one reason or another, renovation using plastics pipes shall certainly be considered as a possible solutions. In most cases it is much more cost-effective and it only violates the environment to a small extent.

Pipelines renovation techniques are more and more commonly applied in Poland. Among the most important advantages of these techniques are:

- minimized noxiousness for the citizens,
- little or zero chance to damage cables and other underground utilities,
- minimum environmental impact,
- little co-operation with other technical services,
- time and money savings.

Each pipeline renovation method has its advantages and disadvantages, possibilities and limitations, depending on the application.

To conclude, the trenchless renovation of pipelines certainly will be more readily used in the future because of the mass aging them. The other reason is the lack of space for new utilities, increasing costs and road-surface restoration requirements.

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