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Influence of temperature on the viscoelastic properties of drawn PE pipes

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Properties

ABSTRACT

Purpose: Purpose of this paper is to describe the free drawing process of PE pipes in the aspect of time characteristics of the viscoelastic return.

Design/methodology/approach: To determine the properties, drawing tests were conducted on chosen PE pipes, using a testing machine station. Pipe samples were preheated to a set temperature and drawn by a fixed drawing die. Changes in the pipe diameter and length of the test section were recorded for the further analysis of the pipe sample.

Findings: Obtained dependencies were assumed to be the basis for formulation of conclusions as to the choice of essential process conditions for the technological sequence of PE lining deposition in the outer coating of installation pipes or reconstruction of a transmission channel.

Research limitations/implications: Conducted research and their conclusions have a methodological value. They factually correspond to chosen spatial parameters of pipes and dies. Together with parallel tribological research on the conditions in the drawing die zone, they give a basis for building a model of the reverse drawing process with its all complexity.

Practical implications: From a practical point of view, the obtained results allow to optimize the expansive deposition process of PE pipes in production of new and renovation of damaged elements of transmission networks – in the latter case, mainly in digless conditions.

Originality/value: Original input of these works is determination of simultaneous influence of geometrical properties – the degree of inner diameter reduction of the pipe and the approach angle of the drawing die – and the temperature of the examined material on the time characteristics and participation of plastic strain in the process of viscoelastic after-deformation return.

Keywords: Mechanical properties; Engineering polymers; Reverse drawing; Viscoelasticity; Temperature of the material

1. Introduction

The topic of this paper is the process of free PE pipe drawing. It is used in renovation of pipelines with a tight-fitting method, as well as in the production of two-layer pipes. Such pipes are used mainly in the mining industry for transportation of hydraulic filling, process water with high concentration of volatile elements, etc. The supporting structure of such pipe is made of steel, with PE lining as the anticorrosive layer [1,9].

The process of deposition of the PE lining is almost the same as in digless renovation of pipelines. The main difference is in devices used for the process. The drawing machine used in production of two-layer pipes is similar in its construction to a carriage drawing machine.

The process of tight-fitting deposition of the PE lining is a combination of free PE pipe drawing with later deposition of the lining in the steel coating shell of the external pipe [11,12]. The second phase utilises the viscoelastic return effect caused by elastic and rheological properties of the plastic material in the drawn pipe and technological conditions of the process.

Two types of after-deformation return can be distinguished: circumferential and longitudinal [10,15]. The first one is particularly important in the renovation of pipelines as it determines the technology of pipe deposition, providing stable fitting of the said pipe – lining with simultaneous maximisation of the inner diameter, which – in turn – minimizes hydraulic resistance of the flow [4,5]. The longitudinal return has lesser importance in the pipeline renovation conditions, as cutting of the shrinkage allowance is cut after the anticipated period of significant shrinkage, after which the deposited sections are connected together in order to prevent further deformation. However, the longitudinal return may be important in the process of producing two-layer pipes where the production and deposition are separated by a storage period during which the pipes are influenced by various thermal conditions. Changes in the lining material that appear in these conditions may cause spatial instability of the product which, in turn, influences its quality. Due to such conditions, the production process of two-layer pipes is more complex, as it requires adequately tight fitting. That is connected with a circumferential return with simultaneous control of the longitudinal return. However, in both cases it is essential to recognise the changes in the material that appear in the drawing die zone in order to choose the proper technological process and perform proper quality control of the product. Temperature is one of the most important parameters that influence those changes [2]. In the conditions of two-layer pipe production, the temperature may be controlled. However, more often it is impossible to regulate the temperature, especially in the field conditions of old pipeline reconstruction. What can be done is to formulate some guidelines for environment conditions, including those concerning the climate, as well as to choose the right technological parameters for the operation of pipe deposition, adjusted to the ambient conditions and to the state of the deposited pipe material being a result of those conditions [7,8,13,14].

2. Research

The aim of this paper is to determine values and runs substantial for the efficiency of the examined deposition method, after-deformation circumferential and longitudinal returns in connection with the initial temperature of the drawn PE pipe. Included in the research were high-density PE pipes (PE 80) with diameter of 63 mm and thickness of 5.6 mm. The temperature of the test section was assessed after pre-heating with a cylindrical electric heater in a thermostable heating zone.

The research was conducted using a Fritz Heckert PFZ100 testing machine (Fig. 1).

Pre-heating was performed with a circumferential heater situated under the drawing zone (Fig. 2) – the initial temperatures of the pipe were: 25±2, 30±2, 40±2 i 50±2^{o} C. The tools used were drawing dies with various reduction degrees and approach angles.

Measurement of changes in the diameter in predetermined time intervals was done using a digital slide calliper. Fig. 3 shows examples of obtained runs in relationship with to the internal diameter reduction degree of a pipe (R=10%) and a set angle value for the drawing die (12.5^{o}). The charts show changes in the diameter – runs with values of <1 and changes in the length – runs with values of >1. Dimensions of the test section of pipes are given in relative values – the initial diameter of the external pipe (D = 63 ± 1,5 mm) and the length of the test section (L = 50 ± 1mm). The first time interval (0 – 3 min), during which the pipe lengthens and its diameter reduces, corresponds to the pipe drawing phase, that is load applied with an axial force. In the remaining measurement period the pipe was not under any load.

Fig. 1. The test stand

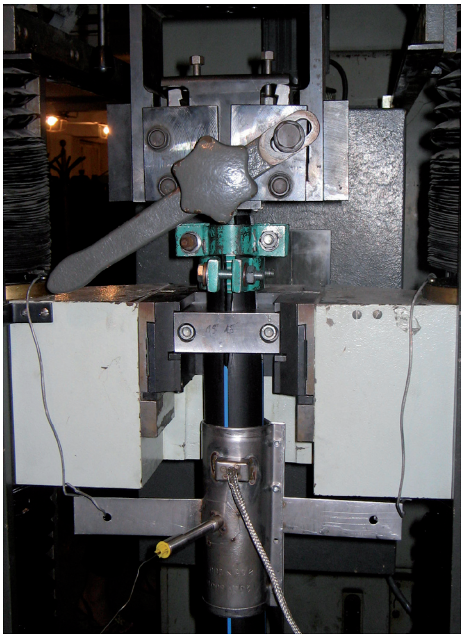

Fig. 2. The sample in a fastening grip and the pre-heating zone

3. Analysis of the results

Analysis of the return runs indicates their similarity as far as temperature range 20-40^{o} C is concerned. Uniform decrease of the modulus of elasticity and the yield point in the said temperature range [3,6], and in the conditions in which the drawing speed and reduction level are constant, may explain the deformation state after drawing. Moreover, the after-deformation return has a similar course in balanced temperature conditions, which indicates lack of significant and permanent changes in the viscoelastic properties of the material. However, a process running in conditions with the initial temperature of 50^{o} C shows a significantly different course. Local loss of pipe stability effect was observed during the drawing in the section with increased temperature. Local reduction of diameter occurred that can be called "formation" and which does not reflex the assumed description method of the diameter change diagram (Fig. 3). Moreover, the lengthening value increased significantly, which means that softening started and the sample plasticity increased considerably. On the basis of the determined properties of after-deformation returns, both circumferential and longitudinal, it was found that the temperature should not exceed 40^{o} C, as far as efficiency of the process is concerned. Estimation of the best temperature value requires assessment of other properties of the process, such as the drawing force and changes of the strength properties of the material. In order to examine even closer the deformation mechanism which occurs in the drawing die zone and which is essential for the latter pipe diameter and length reversion, it is necessary to determine the thermal conditions in that zone. They depend on the initial temperature of the material but also on the drawing conditions – type of the material, tools, drawing speed, etc. Further research of that issue is anticipated, taking into consideration analysis of the actual temperature profile in the drawing die zone measured with use of the infrared mapping technique.

4. Conclusions

The functional effect of the conducted research is a possibility of rational choice of conditions during a reverse drawing operation, as far as the deposition effect of the drawn pipe in lining canals with considerable rigidity is concerned. It is realised with tight fitting of a drawn pipe after the load of drawing ends and when the pipe temperature levels with the ambient temperature.

The research proved necessity of individual design of operations for particular geometrical and material conditions. In such cases, the temperature of the material is an essential value, yet – in some circumstances - it may be altered as fit.

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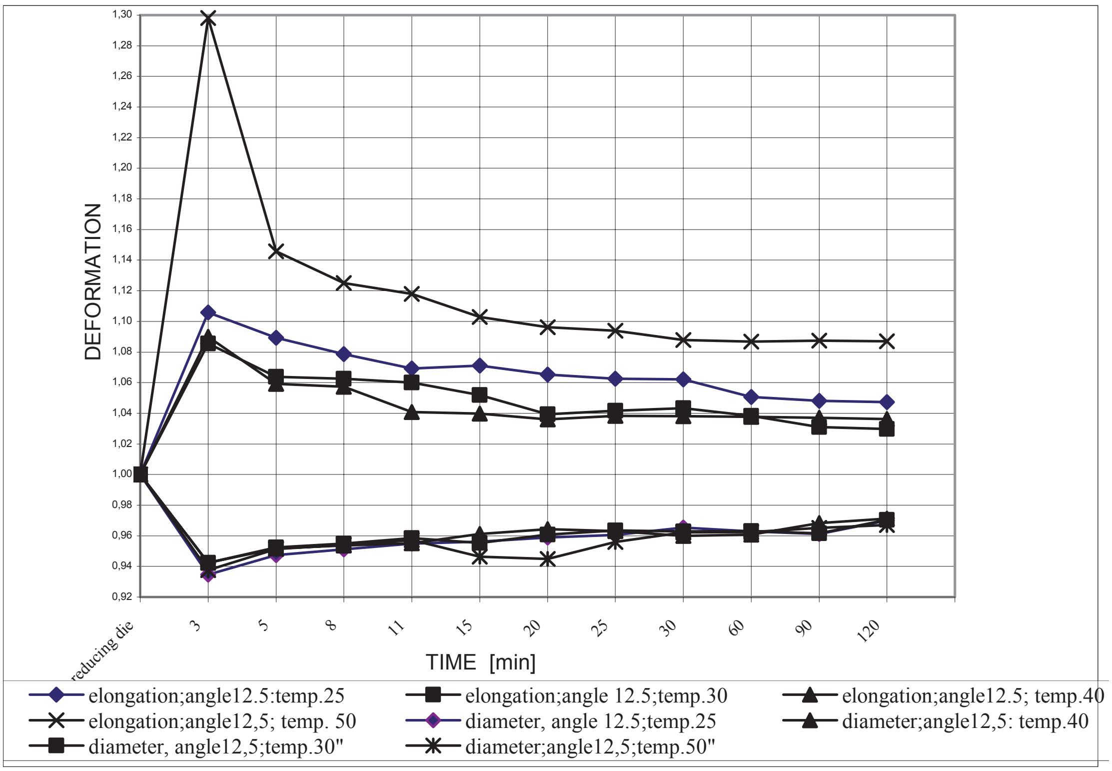

Fig.3. Course of changes of pipe length and diameter during drawing and free viscoelastic return for drawing dies with 12.5^{o} angle and 10% reduction

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