DETERMINING OF THE PIPELINE EXPANSION JOINT BEHAVIOUR BY UNDERMINING

SLEDOVÁNÍ CHOVÁNÍ PRUŽNÝCH SPOJŮ POTRUBÍ VLIVEM PODDOLOVÁNÍ

Roman Ścigała [1]

Abstract

Pipelines are one of the most important objects that have to be well protected against mining damages. There are several protection methods – among them the use expansion joints is the most popular one. It is necessary to point here, that moving longwall face produces the dynamical subsidence trough on the surface, influencing the behaviour of each joint in different periods of time. One must be able to prognosticate the changes of the ground movement for each separated segment of pipeline during time. This information is necessary for designing of joints, which should ensure tightness of pipe in case of either compressive or tensile deformation. It is about of special attention in cases when sleeve expansion joints are planned to be used. In the presented paper, the calculation procedure has been shown, that can help in determining of expansion joints behaviour under mining influences. Procedure based on the author's own software enables us to simulate the advance of extraction fields and to calculate prognosticated changes of chosen deformation indices over time on the basis of W.Budryk-S.Knothe theory.

Abstrakt

Potrubí patří k nejdůležitějším objektům, které musí být dobře chráněny proti nebezpečí poddolování. Existuje několik ochranných metod – z nich patří roztažné spoje k těm nejvíce oblíbeným. Je potřebné upozornit na to, že pohyb konce dlouhého potrubí vyvolává dynamický pokles na povrchu, který ovlivňuje chování každého spoje v různé časové periodě. Takže člověk musí být schopen předvídat změny pohybu zemského povrchu během času pro každý oddělený segment potrubí. Tato informace je potřebná pro projektování spojů, které by měly zaručit těsnost potrubí pro případ jak tlakové, tak tahové deformace. Specielní pozornost je třeba věnovat případům, když se plánuje, že budou použity pružné spoje s objímkou. Předložená práce předkládá postup výpočtu, který může pomoci při sledování chování pružných spojů pod vlivem poddolování. Postup je založen na autorově vlastním sofwaru , který umožňuje simulaci postupu těžebních polí a vypočítává prognózované změny vybraných deformačních projevů v čase na základě teorie podle W.Budryka a S.Knothe.

Keywords

underground mining influences, geometric-integral theories, pipeline expansion joints deformations

1 Introduction

One of the important objects that have to be properly protected against mining damages there are different types of pipelines. It especially applies to gas piping because of the gas explosion hazard, waterlines and sewerage systems in case of tightness problems due to ground movement caused by underground extraction. So it is crucial to ensure their proper location and protection against underground mining influences. The most important methods of pipelines protection against mining influences are:

- shaping of pipeline grid;
- selection of suitable materials;
- use of anchor blocks;
- use of expansion joints.

One of the most important protection activity for pipelines located in mining areas there is dividing them into segments with using of expansion joints. Taking into account, that moving longwall face produces the dynamical subsidence trough on the land surface, one must be able to prognosticate changes over time of ground movement for each separated segment of pipeline. This data is necessary for designing of joints, which should ensure tightness in case of either compressive or tensile deformation. It is of special attention in cases when sleeve expansion joints are planned to be used.

In the presented paper, the calculation procedure has been shown, that can help in determining of expansion joints behaviour under mining influences. Procedure bases on the author's own software which enables to simulate the advance of extraction fields and to calculate prognosticated changes of chosen deformation indices over time.

2 The working conditions of pipeline expansion joint under influences of dynamic subsidence trough

Analysing the influence of dynamical subsidence trough on the single joint one can observe that if extraction field is situated directly under pipeline, it should be protected against compressive as well as tensile deformation. In this case, there are several stages in deformation process (Fig.1):

- **Stage 1** – joint is out of influence range. The pipe endings in joint are in their initial distance Δ_0.
- **Stage 2** – approaching longwall face causes maximum tensile deformation. The pipe endings are maximally distant (Δ_{max}), when face takes the position approx. 0.4 of the main influence range in front of considered joint.
- **Stage 3** – longwall face is located directly under joint. The pipe endings reach their initial distance Δ_0. There is maximum slope of subsidence trough at this stage.
- **Stage 4** – longwall face passes the joint. The pipe endings are at minimum distance Δ_{min}, when face takes the position approx. 0.4 of the main influence range behind considered joint
- **Stage 5** – longwall face moves further behind joint, so it is out of influence range. Considered joint reaches the flat bottom of subsidence trough. The pipe endings reach their initial distance Δ_0.

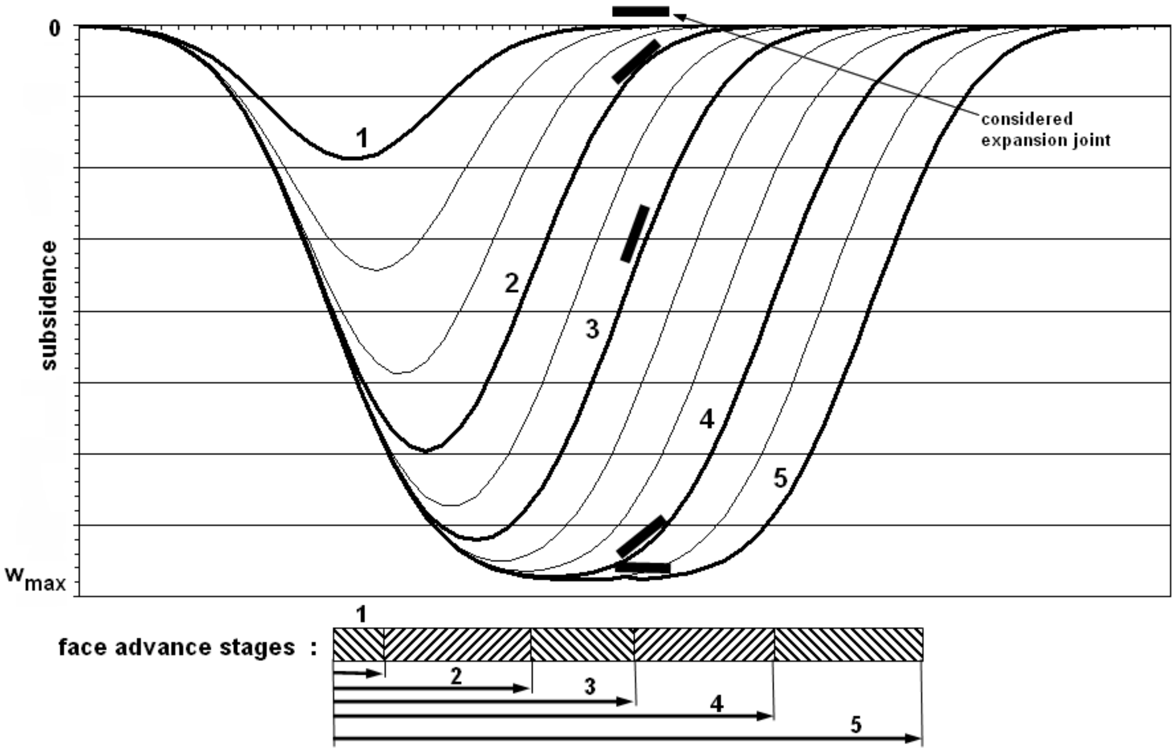

Fig 1 The characteristic stages of subsidence trough in relation to chosen expansion joint

3 The proposed analysis methodology of expansion joint work due to underground mining extraction

The calculations for kinematical analysis of expansion joints deformation should take into account two elements:

- required displacement Δ;
- required angular deformation ϕ.

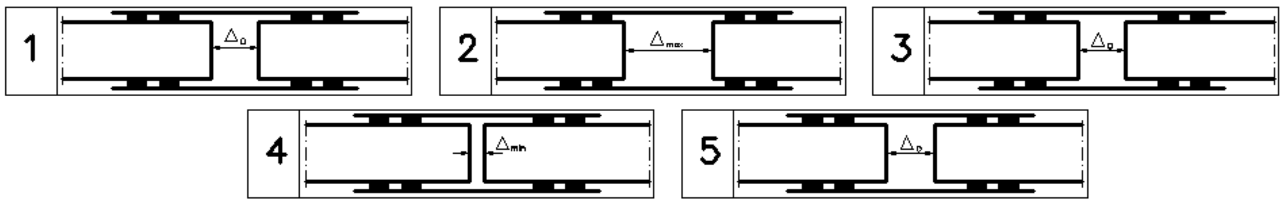

Fig.2 Characteristic stages of sleeve expansion joint work, under mining influences

Calculated values of these two parameters should be then compared with compensation possibilities of commercially available compensation equipment. In this paper the determination of first mentioned above factors has been described – the required displacement. This displacement should ensure that (Fig.2):

- expansion joint won't loose its tightness due to excessive tensile deformation (Fig.2, stage 2);
- the pipe endings inside the jointing sleeve won't come into contact due to excessive compressive deformation (Fig.2, stage 4).

For calculation of displacement Δ in simple cases one can use simplified solution and take into account maximum horizontal displacement calculated for theoretical extraction in the shape of so called infinite half-plane (Nowakowski, 2002):

$$\Delta_{\min}^{\max} = \pm 0.4 w_{\max} \times \sin \frac{\pi\lambda}{r} \tag{1}$$

where:

w_{max} – maximum subsidence;
λ – the half of pipe segment length;
r – the radius of main influence range.

In real extraction cases, especially when there is extraction of several longwalls planned, this approach is not sufficient. In these cases it is necessary to consider the changes over time in values of longitudinal horizontal displacement caused by successive extraction of several coal faces. It can be done by using dedicated software for prognoses of deformation caused by underground extraction and processing of their results. Then, the calculation of required displacement Δ in general leads to determination of differences of horizontal ground displacement **u** in the longitudinal direction of pipe for two adjoining pipe segments:

$$\Delta = u_{i+1} - u_i \tag{2}$$

The displacements $\mathbf{u_{i+1}}$ and $\mathbf{u_i}$ can be calculated as displacements of ground points situated in the middle of adjoining pipe

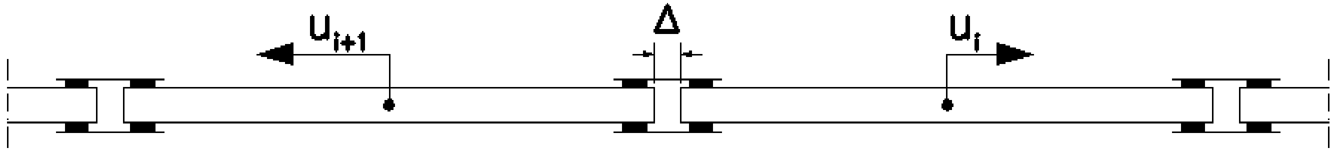

Fig.3 The sketch illustrating calculation of pipe endings distance changes

segments – fig.3.

In the next point, the example of calculation of the required displacement has been presented. The calculations have been done by using author's software, which enables, among other features, carrying out the simulation of face advance for any number of coal fields. As a result, user gets the prognosticated distribution of chosen deformation indices over time.

Two computer programs were used for the analysis:

- program DEFK-Win (Ścigała, Strzałkowski, 2000; Ścigała, 2003) for calculation of prognosticated changes of deformation indices over time. This program enables forecasting the values of several deformation indices. The calculation algorithm uses W.Budryk – S.Knothe theory (Knothe, 1953) for final state of deformation as well as for transient state. Calculations can be done for scattered points, for points along specified line and for defined grid. One of the important application feature is the simulation possibility of longwalls advance, thanks to that it is possible to observe prognosticated changes over time for chosen deformation indices.
- program KOMPENSATOR for estimation of required displacement Δ on the basis of the results obtained from program DEFK-Win. It reads out the prognosis result files which consist of distribution of longitudinal horizontal displacement over time for two calculation points situated in the middle of adjoining pipe segments. These results are processed then for determining the changes of distance between pipe endings over time. As the final result, two charts on the screen are presented (Fig.4):
  - o upper with the distribution of horizontal longitudinal displacement over time
  - o lower with the changes of distance between pipe endings over time

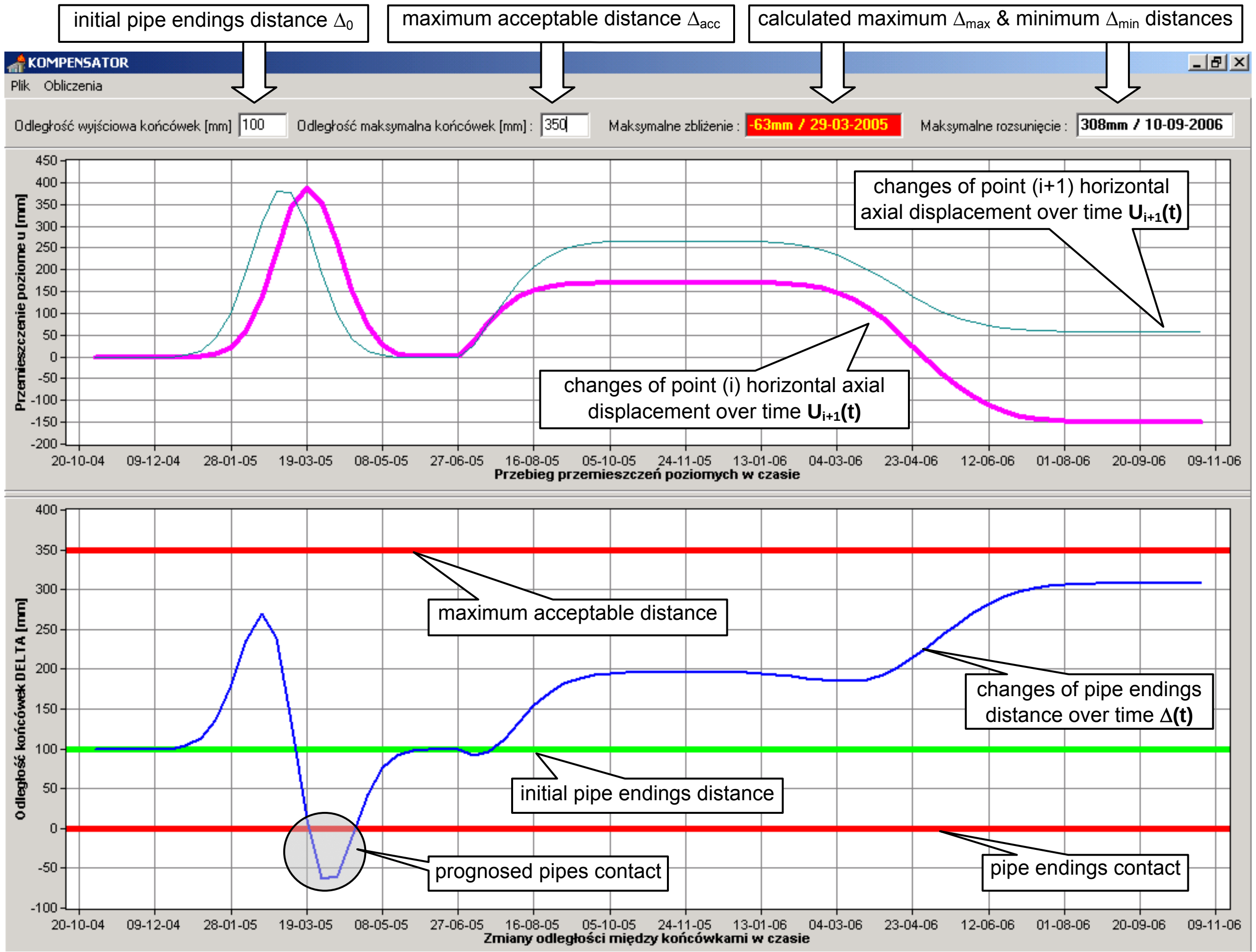

Fig.4 The user interface of Kompensator program

By using prognosticated values of $u_i(t)$ and $u_{i+1}(t)$ user can estimate the initial, minimum, maximum and final distance between pipe endings for considered expansion joint. In the lower graph in fig.4, two horizontal red lines: upper and lower represents critical situations:

- maximum acceptable distance, when pipe endings could be "pulled off" joint sleeve ($\Delta_{acc.}$) and
- pipes contact inside joint sleeve (Δ=0). The fragment of graph surrounded by filled circle shows the situation, where pipes can come into contact (Δ<0), and it is necessary to correct (in this case increase) the initial distance between pipe endings for this expansion joint.

Horizontal green line marks initial distance of pipe endings Δ_0 and blue curve presents the distribution over time of pipe endings distance inside joint sleeve – $\Delta(t)$ taking into account current data supplied by the user in suitable edit fields. So, in this way it is possible to determine proper values of initial and maximum distance between pipe endings for any extraction cases.

4 The exemplary analysis for single expansion joint

As an example, designed extraction from one of Polish coal mines has been considered as shown in fig.5. Extraction is planned in this area up to the year 2023. The considered water pipeline is located directly above planned extraction, as shown in fig.5. The most important mining-geological data used for forecasting purposes is shown in table 1. For calculation purposes, an exemplary location of the expansion joint was chosen (see fig.5). As stated above, two middle-points of adjoining segments were chosen for calculations. For these points the computer simulation of extraction was carried out by using DEFK-Win program. In the simulation, the distribution of deformation indices over time for both points has been calculated: subsidence, curvature, tilt, horizontal strain and - in particular - longitudinal horizontal displacement $u_i(t)$ and $u_{i+1}(t)$.

Table 1: Basic mining – geological data of planned extraction

Seam	Wall No	Start extr.	Finish extr.	Thickn. extr. [m]	Dip ang. [deg]	Depth extr. [m]	Roof control. system
403/3	B-6	01-01-2011	01-10-2011	1.9	5	820	caving
404/1	B-4	01-10-2011	01-10-2012	2.0	5	805	caving
404/1	B-5	01-01-2013	01-08-2013	2.0	5	815	caving
404/2	B-1	01-06-2012	01-04-2013	2.0	5	780	caving
404/2	B-2	01-07-2013	01-07-2014	2.1	5	795	caving
404/2	B-3	01-10-2014	01-10-2015	2.1	5	810	caving
404/2	B-4	01-01-2016	01-02-2017	2.1	5	835	caving
404/2	B-5	01-05-2017	01-11-2017	2.2	5	865	caving
404/2	B-6	01-02-2018	01-09-2018	1.6	5	830	caving
404/2	B-7	01-12-2018	01-07-2019	1.6	5	830	caving
404/2	P-1	01-01-2021	01-02-2022	1.3	8	1000	caving
404/2	P-2	01-05-2022	01-01-2023	1.3	8	950	caving
404/4	B-1	01-01-2018	01-05-2019	2.5	5	850	caving
404/4	B-2	01-08-2019	01-12-2020	2.5	5	840	caving
404/4	B-3	01-02-2021	01-02-2022	4.0	5	860	caving
404/4	B-4	01-05-2022	01-05-2023	4.0	5	870	caving
405/1	B-1	01-07-2021	01-08-2022	1.7	5	820	caving
405/1	B-2	01-11-2022	01-12-2023	1.7	6	840	caving
407/4	S-1	01-04-2018	01-05-2019	2.1	6	950	caving
407/4	S-2	01-08-2019	01-01-2021	2.1	6	960	caving

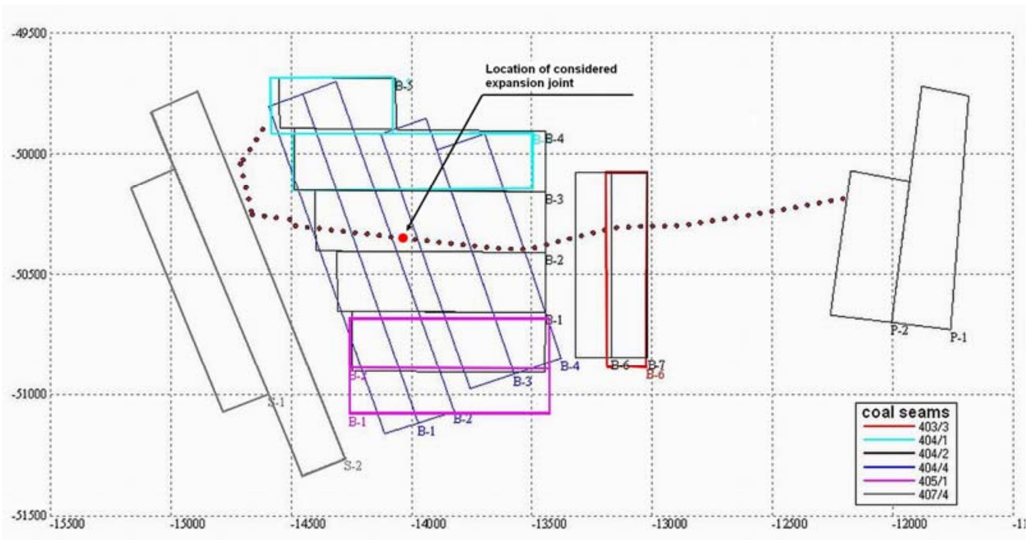

Fig.5 The sketch of designed extraction and pipeline location

The calculated values of $u_i(t)$ and $u_{i+1}(t)$ were used then as the input data for program KOMPENSATOR. Then, valid initial position of pipe endings as well as their maximal acceptable distance due to tensile and compressive deformations was determined. The lower chart in fig.6 shows the resulting graph with determined values: Δ_{init}= 200 mm, Δ_{acc} = 350 mm and the course of $\Delta(t)$ with these constraint data taken.

5 Conclusions

The exemplary analysis of pipe expansion joint behaviour under influence of underground extraction has been shown in this paper. The analysis bases on the distribution over time of horizontal longitudinal (axial) displacement for middle-points of adjoining pipe segments. Presented calculation procedure could be the foundation for determination of the length of jointing sleeves in expansion joints used in pipelines located in mining areas. Author's own software used in this example makes possible to consider complicated mining extraction cases and calculate required parameters for any number of pipe joints in a relative simple way.

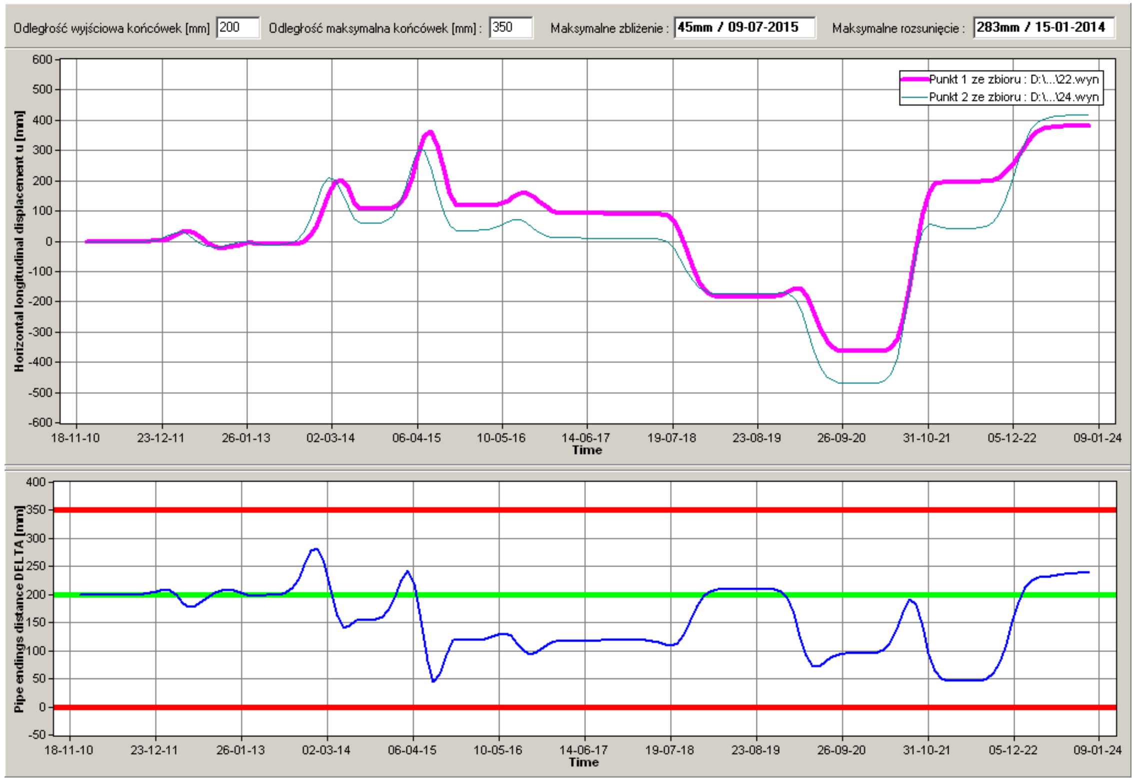

Fig.6 Final results of Δ(t) analysis for considered expansion joint

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Authors

[1] Dr inż. Roman Ścigała, Silesian University of Technology, Poland, 44-100 Gliwice, Akademicka 2, e-mail: roman.scigala@polsl.pl