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AGEING OF MAGISTRAL GAS PIPELINES

Summary of Promotion Thesis

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I.PLATAIS

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CONFIRMATION

I confirm, that I have developed this Promotion Thesis, what is submitted for examination in Riga Technical University to gain the engineering doctoral degree. Promotion thesis is submitted in no other university to gain the scientific degree.

Aleksejs Batrakovs ……………………………. (Signature)

Date: ………………………

The Promotion Thesis is written on Latvian, it contains introduction, 6 chapters, conclusions, literature register, 1 appendix, 32 depictions and illustrations, total 103 pages. Literarture register contains 102 titles.

ANNOTATION

The functional safety of ageing magistral gas pipeline is associated with the strength of pipelines. The mechanical characteristics deteriorate during the operation time, what causes the development of local defects and as a result, the safety indicators of system deterioate.

The goal of promotion thesis is the development of model and methodology for calculation of strength of ageing gas pipeline at certain time of service.

To achieve the set objective, the laboratory experiments with steel samples are performed, which were taken from ageing gas pipelines. To evaluate the strength of magistral pipelines during the operation time, the factors of impact of ageing and loads were implemented. Based on data, gained through laboratory experiments, the mathematical model for evaluation of strength of ageing pipelines (with service period of 43 years) was created. Creating the model, the changes of elastic features depending on age and load were taken into consideration.

Based on developed model, the new calculation algorithm was created, as well as the methodology of evaluation of strength of ageing gas pipelines.

The developed mathematical model is adapted also to practical application and was applicated in the magistral gas pipeline Rīga – Paņevezža in year 2010, evaluating and predicting the strength of nonstationary loaded gas pipelines.

The results of research are currently in use for analysis of defect danger of magistral gas pipeline for enterprise Stock Company «Latvian Gas» in the operation department „Gas transport" where author have been working and engaged in safety problem resolutions of gas transportation system since the year 2005.

The application of methodology is the determination and predicting of strength of gas pipeline, for determination of destructive pressure in the certain period, for exact calculation of defects and it is especially important, if the investments in the reconstruction of gas pipelines, which have served the operation time, are small. The results of scientific research are applicable also in the engineering systems of oil and water pipelines .

The materials of promotion thesis are used in the engineering and master studies at the Riga Technical University in the program „Technology of heat, gas and water". The work consists of 106 pages, including 6 chapters and the register of used literature, which consist of 102 titles. The author has reported about the research results regarding the promotion thesis in 8 scientific conferences, and they are represented in 6 international publications.

CONTENT

INTRODUCTION

Nowadays the pipeline transport plays an important role in the oil and gas industry. First, it is true concerning the gas industry, where the pipelines is only gas transport method from the place of its mining site till the customer. The accidents in the gas transport magistrales leads often to the human victims, causes poisoning, environment pollutions und large economic expenses, what are associated with emergency removal and renewal of industry.

The influence of different factors is to identify from many factors determining the resource of gas pipeline, as well as the general and local physical- mechanical degradation of metal pipeline properties. The real condition evaluation of metal pipelines are restricted through their degradation during the operation, as well as often found inadequacy of metal pipeline characteristics to the characteristics determined in the certificates

Thereby, to enlarge the operation duaration of magistral pipelines, as well as, to acheive their influence on gas transport system in general, the neghative factors occured during the long time operations areto analyse correctlyi, the methods of calculations of construction operational safety are to develop, taking into consideration the operational features, diagnostic results and the possibility of lesions emergency, as well as the technology of repair is to improve, based on nowadays experimental resarchs und mathematical models.

The gas transpor system of Latvia Republic is chosen as main research object, which pipeline condition characterizes the tipically most magistral gas pipelines, what in turn allows us to ensure the wide application of gained results.

According to existing normative documents, nowadays the workability of pipelines is evaluated according to the carrying capacity. The thin coating is often used in the base of calculations, what is loaded with internal pressure. The material ageing as a result of pressure impact is not taken into account in the normative documents, as well the defects and with them associated stress concentrations.

The literature review concerning the researches of mecahnical features of constructive materials in the process of their ageing in free and loaded condition, as well as the analysis of methods of ageing effect adaptation in the physical relation, discloses the problems in the description of behavior of structurally non- stabil materials, what enabled to set exact tasks for determine of solutions within the promotion thesis. It was disclosed, that there is the lack of solutions concerning the elastoplastic problems, where the load influence should be taken into account on the metal ageing process.

The main aim of promotion thesis is the craeting of simple structurally non- stabil environment model, which refelcts the elastoplastic behavior of pipeline basic metal, taking into account the influence of load on ageing process. The gained model is to use for development of calculation method concerning the pipeline stress and deformation condition influenced by quasystatic load. One of the prioritary tasks of this work is the development of practical recommendations to ensure the secure operation of gas magistral pipeline.

<u>Work tasks</u>

- To study the causes of negative factors emergence, as well as their influence on the secure of gas transport system;
- To perform the literature analysis about ageing of magistrale gas pipeline built from low alloy construction steel;
- To perform the literature review concerning the research about the changes of metal construction mechanical features, within their ageing process in free and loaded condition;
- To perform the laboratory tests, using the metal sample cut of the the existing gas pipeline;

- To develop the mathematical model to determine the allowed pressure in the gas pipeline, which base material is ageing material, taking into account the influence of load on ageing process;
- To forecast the maximum stress in the pipelne, which basic material is ageing metal, taking into account the prehistory of non- stationary load of pipeline;
- To develop the calculation algorythm of computer programm, what is necessary, to calculate the maximal allowable pressure for long time operated pipelines

Scientific novelty

- The calculation methods concerning the pipeline stress and deformations are developed, where the influence of quasistatic load on material ageing process is taken into account.
- The forecast method concerning the limit load in the pipeline is developed, where the loading scenario during the operation of gas pipeline is taken into consideration.
- Calculation block diagram is developed, what is necessary, to calculate the maximal allowable pressure for long term operated pipelines, which have the corrosion defects, considering the loading scenario during the operation of gas pipeline. It is necessary to use this block diagram for developing the programm modul, to enhance the secure of gas transportation system.

The strength analysis of gas pipeline, considering the permanent change of operation parameters during the different phases of life cycle, to provide the possibility to manage operative and adequate the safe of system and to motivate the necessity of activities concerning the accident risk reduction.

Analyses and methods

To acheive the goal of promotion thesis the analysis method, statistic methods, mathematical modelling, evaluation and forecast methods are used.

The scientific, special and study literature, as well as statistic sources are used and data from internet sources are used in the work. The disruptive testing of material was carried out in the laboratory.

1. THE PROBLEMS OF SAFE OPERATION OF GAS PIPELINE. DETERMINATION OF RESEARCH TASKS

The research of statistic data concerning age structure of magistral gas pipelines of different regions shows, that main part of system in Latvia has served more than 30 years, it means full amortization period (see Fig.1). The system getting older, the problem of maintaining its functionality becomes more topical.

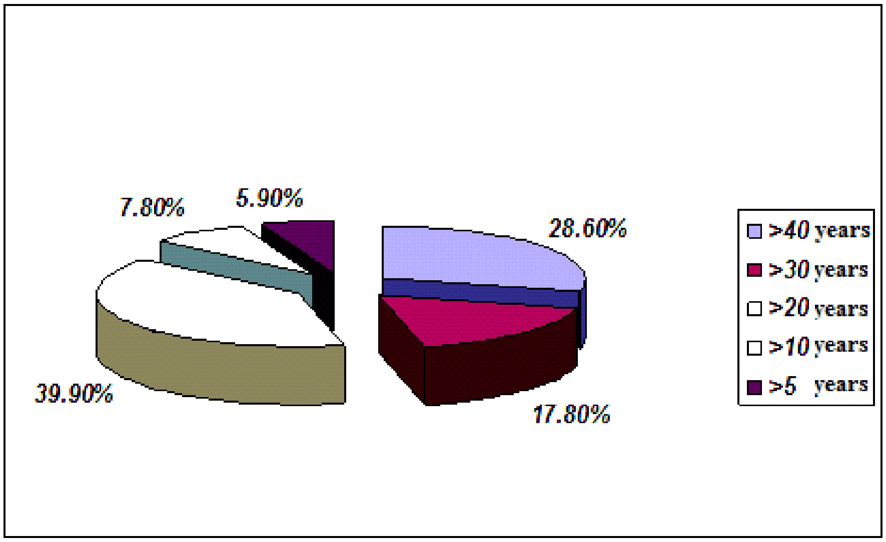


Fig. 1 The operation age of gas pipelines existing in Latvia

The workability of pipelines can be determined as the resistence of metal construction towards the formation and development of lesions in certain operation circumstances. The lesion appearance and development leads to the critical condition (accident, gas pollution atc.).

The long- term studies of gas pipelines lesions allowed to determine, that main causes of such lesions are different defects, as well as low quality of steel pipelines, what results in concentrated cracks.

The aim of promotion thesis is the development of model and methodology for calculation of maximal allowable pressure of ageing gas pipelines.

2. THE EVALUATION METHODOLOGIES OF TECHNICAL CONDITION OF LINE PART OF MAGISTRAL GAS PIPELINE

The matters concerning the natural gas in Latvia, Baltic states and wider were studies by A.Dāvis, M. Gedrovičs, A. Krēsliņš, I. Platais, P. Šipkovs, V. Zēbergs, A. Ješinska and others. The problems of strength and ageing of material studied such scientists as E. Lavendelis, J. Viba, V. Hričikovs. In the same way the scientifical works should be noted, which are developed in the sphere of construction and strength by I. Ščerbickis, A. Dolgijs, S. Krasņevskis, A. Nohrins etc. But there are relatively few such works, where the secure increasing of ageing gas pipelines are viewed and the ageing process of pipelines under the influence of quasistatic loads is described.

As a result of made internal diagnostic in the study object the large amount of pipeline walls defects is detected.

As can be seen from the chart (see Fig.2), the most defects are corrodial defects.

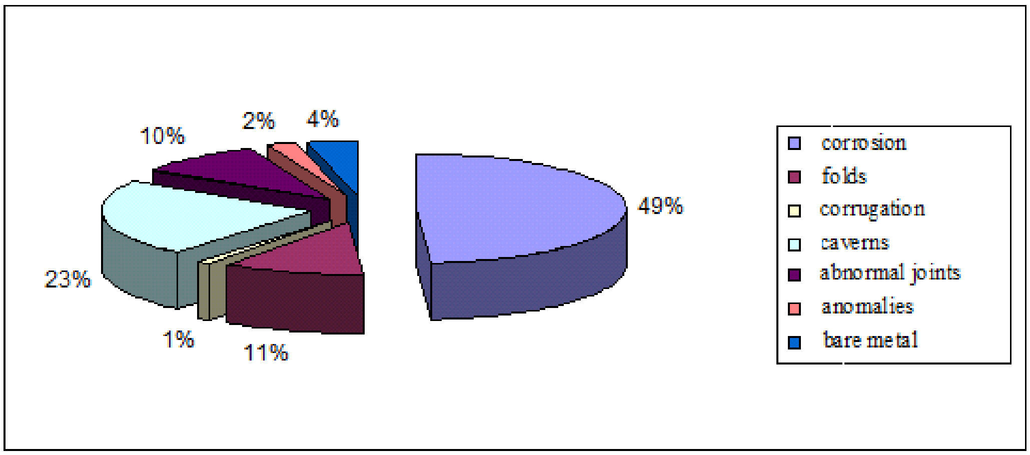


Fig. 2 The result of internal diagnostic. The defects in the magistral gas pipelines of Latvia

The corrosion calculations of pipelinesare detailed described in the metodologic guidelines DNV-RP-F101 Corroded pipelines and USA standartd ASME B31 G. These methods reviews the demages caused by corrosion defects under the influence of internal loading with pressure. All viewed calculation methodologies are based on „theory of cylinders". It enables to determine the maximum pressure or allowed thickness of wall, taking into account during the time unchangeable properties of metal, start sizes of pipelines and even distribution of stress on the walls of pipeline.

$$P_{rob} = 2\sigma_{в} S_0 / D_0 , \quad (1)$$

where P_{rob} – maximum value of internal pressure, MPa;

$\sigma_{в}$ – tension, MPa;

S_0 – thickness of pipeline wall, mm;

D_0 – diameter of pipeline, mm.

None of mentioned methodologies takes into account the effect of material ageing under the pressure. More precise calculations of allowed working pressure is needed to take into consideration the changes of mechanical features of construction material in the ageing process, what acknowledges the topicality of this thesis.

3. THE CHANGES OF MECHANICAL FEATURES OF CONSTRUCTION MATERIALS WITHIN THE AGEING PROCESS

Lot of works is devoted to forecasting of the construction characteristics, considering the ageing of material. Most of them contain assumption, that the material features change during the time as a result of some internal processes, which do not depend by impact of pressure, but it happens unpredictable.

The examination of methods concerning the adaptation ageing effects attracts the interest in the universal (for wide group of material), as well as for separated (for certain materials) physical consequences. Associated with aged materials the large number of different physical linear dependence are offered and significantly less non- linear dependence. Therefore the linear models of aged materials are not considered in this dissertation are not considered.

Model of V. Hričikovs

The physical dependence is represented in such way:

$$\sigma(t) = Q^{(1)}\left[\underset{\tau=0}{\overset{t}{\varepsilon}}(\tau)\right] + Q^{(2)}\left[\underset{\tau=0}{\overset{t}{\varepsilon}}(\tau), t\right] + Q^{(3)}\left[\underset{\tau=0}{\overset{t}{\varepsilon}}(\tau), t\right], \tag{2}$$

A small number of general model is known, which can describe material behavior, taking into consideration the influence of load on ageing process. Only model of author V. Hričikovs allows to apply well- known, well- studied model for material which are invariant within time. The separated model developed by V. Hričikov, where the well- known theory of small elastoplastic deformations is used, is only, which taking into account the influence of load on ageing process, allows to gain numerical results within the calculations of construction strength. The general model of author allows to describe the behavior of ageing material in connection with small, as well as with large deformations and taking into consideration physical non- linearity. However, the loads on changes of elastic features within the ageing process of elastoplatic material was not considered within the saparate model of author. It does not allow to apply the separate model for calculations of pipeline parameters, which elastic features change significantly within ageing process. To maintain the topicality of this model within the calculations of pipeline parameters, the changes of elastic features within the ageing process were regarded in this promotion thesis.

4. THE ELASTOPLASTIC BEHAVIOR OF AGED MATERIAL. CREATION OF MATHEMATICAL MODEL

As relation for model creation concerning the elastoplastic behavior of pipeline ageing material we use relation (2),

where $Q^{(1)}$ –characterizes reaction of material, not taking into account the ageing;

$Q^{(2)}$ – determine pertuberation, caused by material ageing, not taking into account influence of load on ageing process;

$Q^{(3)}$ – the influence of deformation process on ageing process.

If $Q^{(1)}+ Q^{(2)} >> Q^{(3)}$, then the pertuberation (mathematical) model can be applyed for calculations or so called method of small parameter. This non- equality means, that the load (funkcional $Q^{(3)}$) affects less the ageing process. The linear continuity functionals of such type are the most common and well explored:

$$Q^{(3)} = \int_0^t K(t-\tau)\varepsilon_{in}(\tau)d\tau\,, \qquad (3)$$

where K(t-τ) – core, what characterizes the tipical for material influence ε(τ) memory within the time moment $0 \le \tau \le t$.

If the influence of load is not large, then the third summand is accepted in linear form of sequences, and it is considered as pertuberation. This circumstance automatically indicates on adequate iteration algorythm of task solving.

We consider the cylindric body in loaded condition (see Fig.3), which internal radius is a, external radius is b, loading pressure is P. We consider the material of pipeline as not compressible. The material is decribed at each fixed at each time moment t=const with Prandtl diagram with elasticity parameter and fluidity parameter in such way:

$$G_* = G_0 + f_G(t) + \int_0^t G(t-\tau)\varepsilon_{in}(\tau)d\tau\,,\; G_0 + f_G(t) >> \int_0^t G(t-\tau)\varepsilon_{in}(\tau)d\tau\,, \qquad (4)$$

$$S_T^* = S_T + f_T(t) + \int_0^t S(t-\tau)\varepsilon_{in}(\tau)d\tau\,,\; S_T + f_T(t) >> \int_0^t S(t-\tau)\varepsilon_{in}(\tau)d\tau \qquad (5)$$

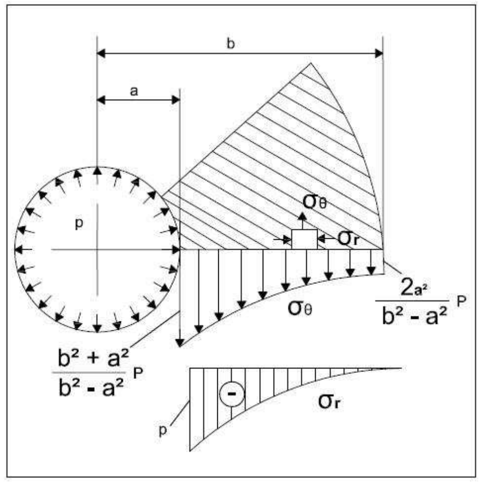


Fig. 3 Stress devision epir

Algorythm of task solution will consist of two parts:

1. Based on linear- elastic Lame equation the intensity of deformation ε_i is determined ε_{in} at G*=G0+fG(t), what includes (4) and (5).

2. At the found (4) and (5) values the limit state of pipeline is determined.

At each fixed time moment Lame equation for long elastic pipeline is following:

$$\left.\begin{aligned} \sigma_r &= \frac{Pa^2}{b^2-a^2}\left(1-\frac{b^2}{r^2}\right), \\ \sigma_\theta &= \frac{Pa^2}{b^2-a^2}\left(1+\frac{b^2}{r^2}\right), \\ \sigma_z &= 0, \end{aligned}\right\} \tag{6}$$

The stress graphic is shown on Fig. 3 .

We accept, that b = a+δ,

where δ –pipeline wall thickness for thin wall pipeline.

$$\sigma_r \approx 0,\ \ \sigma_\theta \approx p\frac{a}{\delta},\quad \sigma_z = 0, \tag{7}$$

and stress intensity:

$$\sigma_{in} = \frac{1}{\sqrt{2}}\sqrt{(\sigma_\theta - \sigma_r)^2 + (\sigma_r - \sigma_z)^2 + (\sigma_z - \sigma_\theta)^2} = P\frac{a}{\delta}, \tag{8}$$

where σ_{in}~ε_{in} root, not taking into account the load influence on ageing process (solution without perturbation).

$$\sigma_{in} = 3(G_0 + f_G(t))\varepsilon_{in},\ t = const, \tag{9}$$

The deformation intensity is found in this equation:

$$\varepsilon_{in}(t) = \frac{\sigma_{in}}{3(G_0 + f_G(t))} = \frac{a}{3\delta(G_0 + f_G(t))} P(t), \qquad (10)$$

where P=P(t) – given loading history in elastic area.

We limit relation with Huber-Mizes criteria:

$$\sigma_{in} = S_T^*, \qquad t = const, \qquad (11)$$

At the given loading history relation (5), taking into account (10), gain such form:

$$S_T^* = S_T + f_T(t) + \frac{a}{3\delta}\int_0^t S(t-\tau)\frac{P(\tau)}{(G_0 + f_G(\tau))} d\tau, \qquad (12)$$

(8), (12) inserting (11), we gain plasticity criteria:

$$P(t)\frac{a}{\delta} = S_T + f_T + \frac{a}{3\delta}\int_0^t S(t-\tau)\frac{P(\tau)}{(G_0 + f_G(\tau))} d\tau, \; t = const, \qquad (13)$$

Accepting, that at t=const no material ageing happens, according to relation (13) we gain the limit value of pipeline load:

$$P^*(t,P) = \frac{\delta}{a}\left(S_T + f_T + \frac{a}{3\delta}\int_0^t S(t-\tau)\frac{P(\tau)}{(G_0 + f_G(\tau))} d\tau\right), \qquad (14)$$

At t=0 relation (14) leads to to the result what is invariant within time. At f_G=0 the the elastic features are not changing within the ageing process.

5. LABORATORY TESTS. USE SAMPLES OF MATHEMATICAL MODEL

To gain numerical results, using formula (14), and to evaluate the strength of pipeline in total, we have to know the changes mechanical features of pipeline steel within the time according to recomendations. For this purpose, the laboratory tests of cut sample of gas pipeline being operated some time under pressure is toperform. To apply fully such methdology, we have to know also start mechanical features (archiv data, pipeline supply certificate). More exact, we have to know the fluidity limit R and elsticity modul E or shift module G, shock resistence. Besides we have to clarify the features of metal aged without load. The mechanical studies for metal samples, which were taken from ageing gas pipeline were performed in the laboratory of Minsk Physical- Technical Institute, as well as in Riga Technical University, in the laboratories of Transport and Engineering Faculty (Fig. 4).

The mechanical features of base metal were determined after cuts from operated pipelines from following magistral gas pipelines (MG): 1 – MG "Vireši– Tallina", streight seam pipe 720x7,0, steel X60; 2.1 – MG "Pleskava – Rīga", seamless pipe 720x9,0, st."Ц"; 2.2 – MG "Pleskava – Rīga", straight seam pipe 720x8,0, st.17GS; 3 – MG "Rīga–Daugavpils", seamless pipe 530x7,5, st."Ц"; 4 – MG"Iecava - Liepāja", seamless pipe 529x8,0, steel «C"; 5– MG "Iecava - Liepāja", seamless pipe 377x9,0, steel 2sp. the operation time of pipeline is given in the chart 1.

Fig.4 Laboratory tests in laboratories of RTU. Stretching of material (engine „Zwicк z150")

Stretching test at room temperature (+23°C ± 5°C)

After results of tests with metal sample, which was cut out of aged gas pipeline the testing protocol is compiled. The material real properties are summarized in the chart1.

Chart 1

Strength and plasticity of basic characteristics

Sample cut-out direction	**R, MPa**	**R_m MPa**	**A , %**	$\varepsilon_к$	**Operation duration, years**
transv. (pipe 1)	445	564	27,1	1,31	14
long. (pipe 1)	446	564	32,8	1,51	14
transv. (pipe 2.1)	332	530	29,5	1,03	35
transv. (pipe 2.1)	340	530	33,2	1,16	35
transv. (pipe 2.2)	427	617	25,4	1,28	35
long.(pipe2.2)	410	619	30,2	1,42	35
transv. (pipe 3)	356	557	21,7	1,24	21
long (pipe 3)	364	568	24,3	1,13	21
transv. (pipe 4)	348	521	27,0	1,34	41
long. (pipe 4)	**327**	**518**	**35,5**	**1,2**	**43**
long. (pipe 5)	290	487	33,5	1,0	41

Impact elasticity tests

The impact elasticity tests are widely used, to evaluate the metal tendency to the brittle failure under the influence of low temperature.

The method is based on destruction of cut- out sample with one pendullum hammer blow. The impact elasticity tests are performed according to EN 10045-1 standard with purpose to ensure the repeatability of experiments and possibility to compare the results. The impact elasticity tests were performed in laboratory of Minsk Physical- Technical Institute applying test complex AK15/30.

Cahrt 2

The curves of basic metal strengthening and everage values of elasticity parameters

Sample cutting direction	**A, MPa**	**n**	**Wp, MJ/m^3**	**KCV, MJ/m^2**
transv. (pipe 1)	917	0,177	1106	2,04
long. (pipe1)	958	0,201	1366	—
transv. (pipe 2.1)	861	0,179	767	0,65
long. (pipe 2.1)	886	0,189	884	—
transv. (pipe 2.2)	950	0,146	747	0,425
long. (pipe 2.2)	1027	0,186	1217	—
transv. (pipe 3)	889	0,163	1080	0,525
long. (pipe 3)	896	0,160	927	—
transv. (pipe 4)	965	0,211	948	0,545
long (pipe 4)	**947**	**0,236**	**930**	**—**
long. (pipe 5)	928	0,260	682	0,335

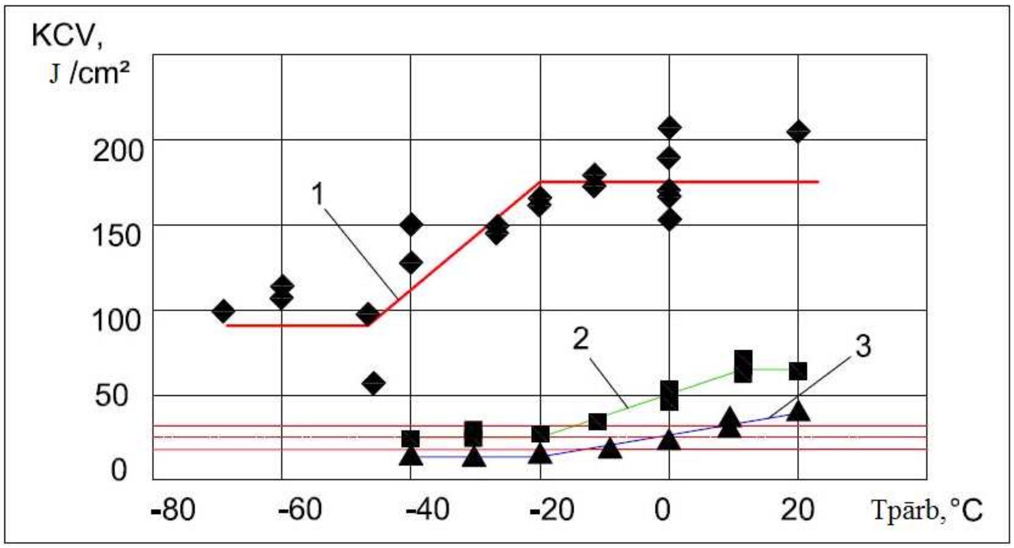


Fig. 5 Impact elasticity dependence KCV on testing temperature for pipe basic metal of magistral gas pipeline.

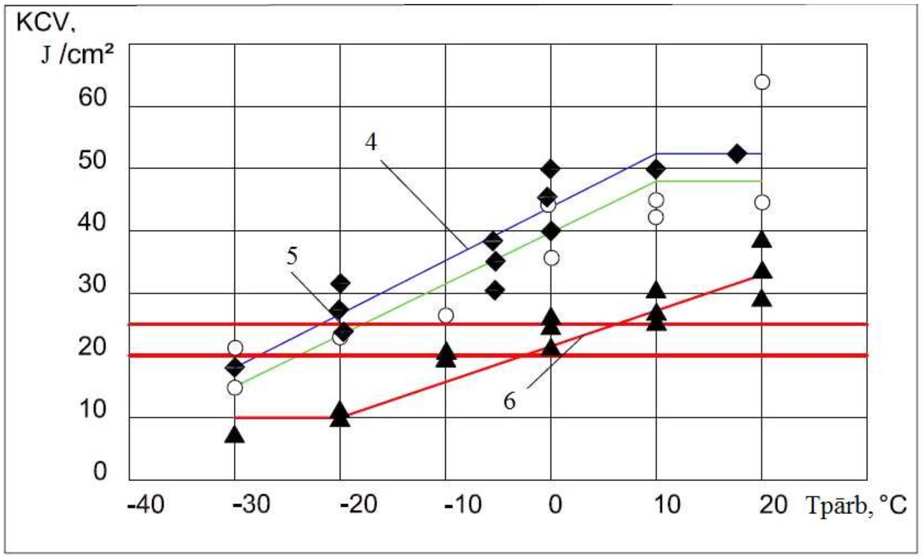


Fig. 5.1 Dependence of impact elasticity KCV on testing temperature for basic metal of magistral gas pipeline

<u>Example of application of mathematical model. Restriction – material in free condition during the time maintain their start parameters.</u>

The limit load for case being studied after relation (14):

$$P^*(t,P) = \frac{\delta}{a}\left(S_T - \frac{a}{3\delta}\int_0^t S(t-\tau)\frac{P(\tau)}{G}\cdot d\tau \right) \quad (15)$$

<u>Example of application of mathematical model. Material being in free condition has changed its parameters within the time</u>

The limit load for case being studied after relation (14):

$$P^*(t,P) = \frac{\delta}{a}(S_T - k_1 t - \frac{a}{3\delta}\int_0^t S(t-\tau)\frac{P(\tau)}{(G_0 - k_3 t)}d\tau), \quad (16)$$

<u>Example of application of mathematical model. Material being in free condition has changed its parameters within the time. Non- stationary load</u>

Pressure P in the pipe within the opeartion time can change. We have to view P = P(t). As the sample we view the non- stationary loading of gas pipeline of Latvia viewed in the previous examples. The chart of pressure changes is shown on Fig. 6. Curve t_1 , gas pipeline operation 3 months, t_2 = 6 month (predictable).

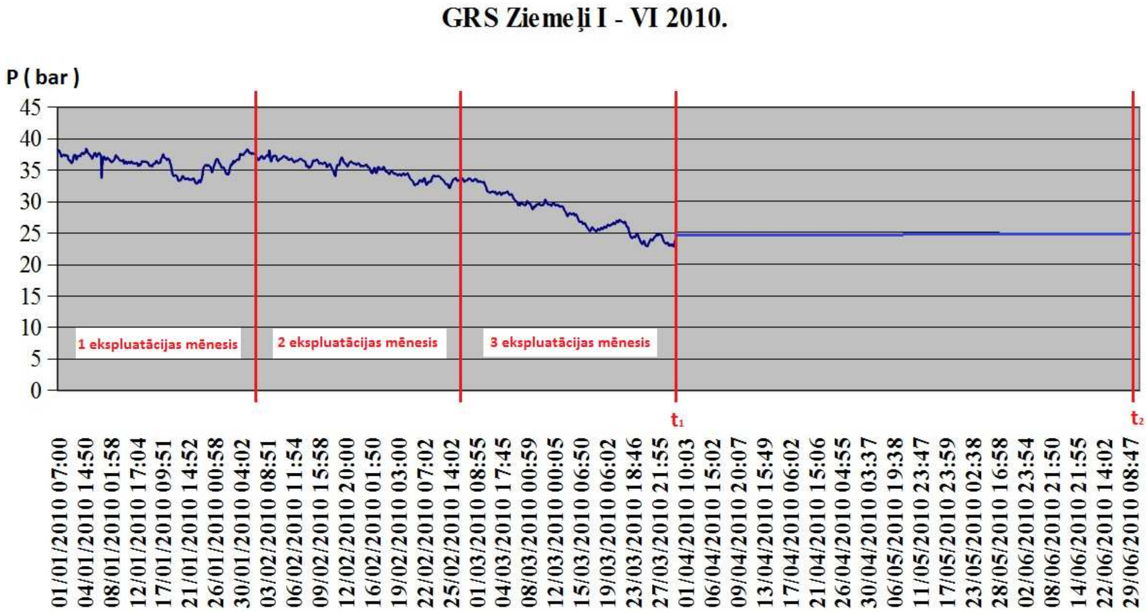


Fig. 6 Non- stationary loading of ags pipeline. Pressure changes at PRS Ziemeļi

The polynomial of the second turn is gained in such way:

$$P(t) = 38{,}4-39{,}65t-51{,}48t^2 \text{ bar},\ t \leq 3/12 \text{ years}, \tag{17}$$

The limit load expression we accept after relation (16):

$$P^*(t,P) = \frac{\delta}{a}\left(S_T - k_1 t - \frac{a}{3\delta}\int_0^t S(t-\tau)\frac{P(\tau)}{(G_0 - k_3\tau)}d\tau \right), \tag{18}$$

Or, taking into account the relation (17) we gain:

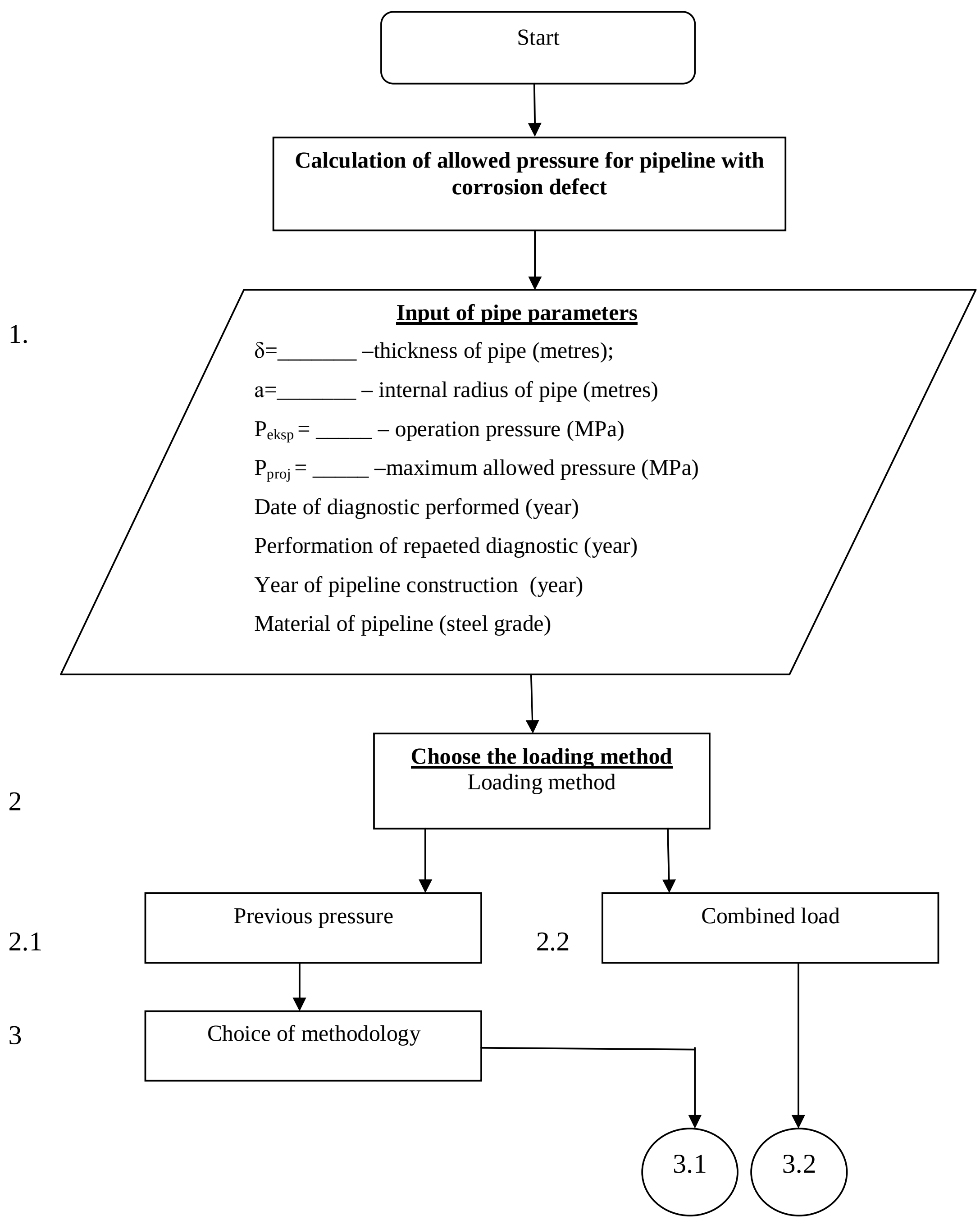
$$P^*(t,P) = \frac{\delta}{a}\left(S_T - k_1 t - \frac{a}{3\delta}\int_0^t k_2 \frac{38{,}4 - 39{,}65\tau - 51{,}48\tau^2}{(G_0 - k_3\tau)}d\tau \right), \tag{19}$$

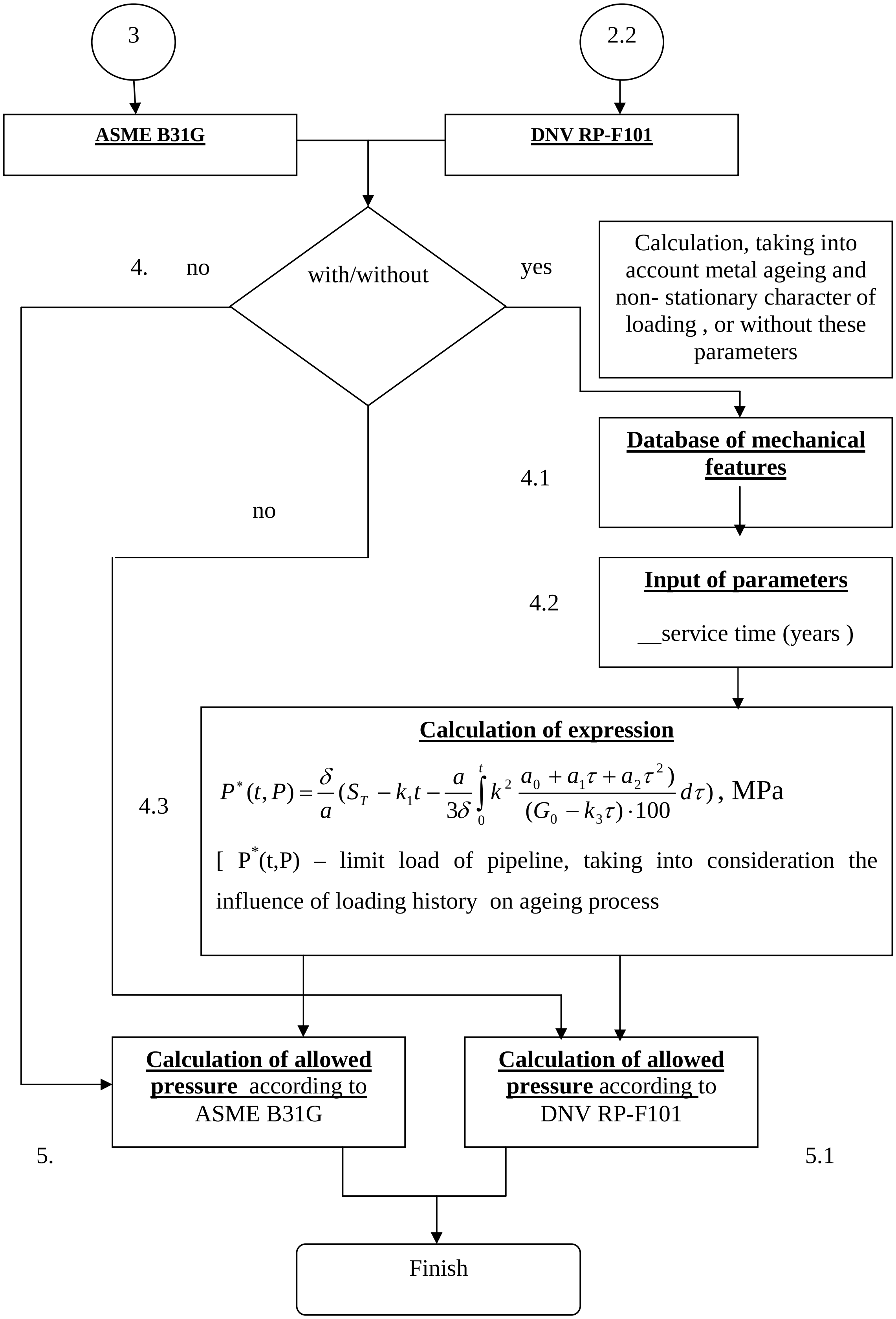
Integrating (19), for example, at t=3/12 years, we find the border load for pipeline. The limit load of sample viewed in the promotion work is equal:

$$P^*(t_1 = 3/12 \text{ gadi},\ p(t)) = 11{,}135 MPa, \tag{20}$$

6. CREATION OF ALGORYTHM FOR INCREASE OF SAFETY OF GAS SUPPLY SYSTEM

To accelerate calculations and model adaptation for practical application, we have to use programme complex, which is possible to create based on limit load calculation algorythm for gaspipeline aged under the influence of pressure offered in this chapter (using experimental data). The methods ASME B31 G and DNV RP-F101described in the 2nd chart are used as calculation model for pipeline with corrosion defects.




3
2.2
ASME B31G
DNV RP-F101
4.
no
with/without
yes
Calculation, taking into account metal ageing and non- stationary character of loading , or without these parameters
Database of mechanical features
4.1
no
Input of parameters
4.2
__service time (years)
Calculation of expression
4.3
$P^*(t,P) = \frac{\delta}{a}(S_T - k_1 t - \frac{a}{3\delta}\int_0^t k^2 \frac{a_0 + a_1\tau + a_2\tau^2)}{(G_0 - k_3\tau)\cdot 100} d\tau)$, MPa
[$P^*(t,P)$ – limit load of pipeline, taking into consideration the influence of loading history on ageing process
Calculation of allowed pressure according to ASME B31G
Calculation of allowed pressure according to DNV RP-F101
5.
5.1
Finish

CONCLUSIONS

1. The detailed screening and workability evaluation of magistral gas pipeline existing in Latvia were performed within the promotion thesis, applying the actual normative regulationsand practical experience. It was proposed, to introduce for more precise calculation of maximal allowable pressure of gas pipeline, which age achieved 43 years, the material ageing factor and factor of load influence on gas ageing within the operation process.

2. The laboratory tests were performed with metal samples, which were taken from aged gas pipelines. The mechanical testing was peformed in the laboratory of Minsk Physical- Technical Institute, as well as in the laboratory of Riga Technical University at the faculty of Transport and Engineering. The results were approved, and they are still used in the operation department „Gas transport" of Stock Company (A/S) «Latvijas gāze» for defects danger analysis of magistral gas pipeline.

3. The performation methodology of laboratory tests, processing and analysis of data gained is invented in the enterprise „Latvijas gāze" and it is used for reserach of changes of mechanical features of aged gas pipelines.

4. The research analysis shows, that main mechanical features (yield strength and tensile strength), what determines the static durability of gas pipeline, has changed, but meets the demands of standards, which were applied within the period of gas pipeline construction and designing period. The everage actual value of yield strength of material being examined is 327 MPa. The value of actual yield strength differs from yield strength of non- aged pipes- by 20%. In turn, the impact elasticity for samples Nr. 2.2 and 5 decreased till critical value, what influences negative the safety of gas pipelines. (coefficient of impact elasticity reserve is $k \geq 0,9 - 1,1$.)

5. Based on data, as well as taking into account existing model for materials which are invariant within the time, The mathematical model for evaluation of maximal allowable pressure of ageing gas pipeline is createdi. There is the dependence of elasticity properties $E=E(t)$, $G=G(t)$ from age and loading taken into consideration within the model, what is associated with ageing process. It is proposed to use linear- elastic Lame solution for determination of deformation intensity ε_{in} .

6. The developed mechanical model gained also practical application in the year 2010 within the magistral gas pipeline Rīga – Paņevežis, evaluating and predicting the maximal allowable pressure of non- stationary loaded gas pipeline.

7. Based on developed within the work, the calculation algorythm was developed, as well as the methodology of evaluation concerning the maximal allowable pressure of ageing gas pipelines. The application of methdology is intended for determination and prediction of limit load of gas pipeline, for exact calculation of defects, and it is particularly topical, as the investments into reconstruction of gas pipelines, which have served the operation time, are insufficient.

8. The resarch results are aplicable within the engineering systems regarding oil and water supply.

9. The materials of promotion thesis are used within the engineering and master studies in RTU according to study program „Heat, gas and water technology”.

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