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APPLICATION OF INTELLECTUAL SYSTEMS IN MONITORING OF OIL PIPELINES OPERATION MODES

The application of expert systems in monitoring of trunk oil pipelines operation modes increases considerably a reliability of the maintenance, due-time control, reduces costs for technical service due to the descent to the mode of "repair as per condition", enlarges possibilities of ecology monitoring and technical genetics. On the analytical basis of the up-to date technical pipeline diagnostics achievements, the methodology of the system's "training" based on the configuration (architecture) of multi-layer network is shown in this paper, allowing to describe adequately system's behaving standards, and perspectives of the informative system application are outlined.

The quantitative estimation algorithm of the functional deviation (passage contraction of offshore oil-field "White Tiger" collector identified by the Delphi technique) is explained by graphic analogues.

INTRODUCTION

Works of numerous flaw detection gurus explain the term of «Technical Condition Testing» or «Monitoring» as a diagnostics of technical object serviceability. As far as the application to a linear part of trunk oil pipelines (TPL) is concerned, all spectres of diagnostic problems, as a rule, are turned to the question of search and identification of defects of pipe walls. And it is necessary to admit that the methodology and apparatus support for searching such defects is developing rather successfully. The methods of a pipeline wall testing that have found a wide application in the pipeline transport are as follows: special in-pipe pigging, external direct examination: magnetic and magnetic-flux, radio-waving, radiation flaw detection and acoustic emission, as well as electric and thermal flaw pipe insulation detection.

However, the reason of principal impossibility of genesis tasks (technical genetics) solving and the object state prediction in the perspective of its developing is hidden in such a narrow one-way approach to the TPL monitoring problem. Widening apparent horizon of the technical TPL condition monitoring would enable to solve not only the investigation of the reasons of defects or accidents and to predict an object state in future, but to optimise quick-look parameters of object maintenance and operation, taking into consideration numerous features of each system's section as well.

Problems of all kind of diagnostics are tasks of examination of serviceability, good condition and functional correctness of the object, as well as searching of defects, that infringe serviceability, good condition, and functional correctness [1]. The strict statement of these tasks assumes: firstly, a direct or indirect defining class of possible defects and, secondly, the presence of formalised methods of building of algorithm of diagnostics, the realisation of which ensures discovering defects from the class with a required fullness or searching of the latter's with a required depth.

The question of "the functional propriety of a TPL section " is not raised due to want of the "reference [standard] state" definition methodology (or in the terms of electronic apparatus testing – KGU "Known good unit"), as well as by the evident insufficiency of the technical means of operational parameters along TPL trace verification.

The relevance of a similar control as a component of the ecology monitoring, control system for reliability of ageing TPL and increasing their operational efficiency in modern economic conditions is conspicuous.

PROBLEMS OF DETERMINED MODELS

Ecology monitoring of technical genesis is especially required to technical installations, erected in severe weather-climatic and geo-cryogenic conditions. However, problems of TPL diagnostics are not solely solved in the framework of the development of determined models. Nowadays, a series of researches have been carried out, describing a qualitative picture of pipeline interaction with permafrost (seasonal thawing out) grounds, which allow to give ecological forecasts by the way of physical and geographic comparison in general. But the determined models application of pipeline heat interaction assumes the determination of process as to it quantity. The mentioned requirement makes the task of ecological and technological monitoring extra-complicated, which is explained by a number of reasons:

Firstly, it is non-linearity of a majority of relations between unknown values and influencing factors. For example, the depth of a seasonal freezing – thawing is related by square root with the surface temperature; the same value, but from the pipeline surface – with the temperature, in power less than ½, and the ground deformation – with mechanical stresses in power more then one unit, and etc.

Secondly, it is a physical heterogeneity of grounds, regarding both along TPL trace and in the ground cross-section, of fields of temperatures and humidity, from which all properties of soil non-linear depend on.

Thirdly, it is a existence of back relations between ground features and factors, which determine them.

Fourthly, response time of all geo – cryogenic system depends on the influence of dissimilar-scale processes possessing different inertia times (relaxation), such as the dynamics of vegetable top-soils, temperature alteration of the pumped product and atmospheric air, a humidity dynamics, the development of mechanical stresses and so on.

Fifthly, influences of a technical origin in the preceding construction period and in the construction period itself are various and not predictable, as the result of which, the task to follow causal-corollary relations of such local perturbations in the system is extremely laborious.

Sixthly, the influence on ground pollution, when a product spills or escapes during construction and erection works, is practically not learned, but, undoubtedly it is known, that it influences strongly on heat and mechanical properties of surrounding ground, breaking thermodynamic balance and etc.

It is necessary also to note principal impossibility of the physical simulation application for quantitative estimations by the classic Similitude Method on small scale models [2]. This is concerned with the contradiction of similarity criteria in time. Each of the processes lays own claim to time scale, which may be implemented simultaneously, provided sizes of model and nature are equal. But then, in the framework of determined models, physical simulation looses its sense, transforming into a Monte Carlo method [2].

Abstracting from calculation of the pipeline interaction with the environment which themselves bring a severe error to the prediction, it is necessary to note the principal impossibility of obtaining exact quantitative estimations of the TPL technical condition, operating with average values of heat and mechanical properties of the environment. Even a laboratory definition of these properties at local ground samples assumes an error of 25 %. Taking into consideration a quantity of input parameters (over 30 for each local TPL trace portion) and the frequency of changing of such portions (as least, 10 – 12 per a kilometre), one is surprised by an excellent (40 – 50 %) coincidence of predictions and realities.

The situation is not better with “the internal task” – the calculations of heat and mass transfer parameters at the product motion inside pipeline. Only hydraulic calculation of a stable Newton homogenous medium steady movement (having nothing common with real commercial petroleum, transported via pipes) are within the limits of 10 % error. But precisely the complications of the operation mode bring to the reduction of pumping efficiency, and are the first reason of appearance of extraordinary situations and, as the result - to a pipeline depressurisation, oil spills and damages. Possibilities of the dispatcher service in the operative diagnostics of such situations at early stages are rather limited.

PERSPECTIVES OF ARTIFICIAL NEURAL NETWORK APPLICATION

Up-to-day requirements of TPL operating state monitoring are kept well within limits of possibilities of neuro–technology - rating classification on the operational efficiency of a TPL section based on the quick-look detection of operation mode deviation from the “Reference ” (KGU). In terms of neuro-technologies, this task may be stated with the itemizing for the following stages:

1. Training and learning of behaviour samples and standards, given by external requirements,
2. Recognition of an external situation, relating it to one of the memorised ones, the selection of relevant behaviour sample,
3. Realisation of the selected sample of behaviour, supporting of standard values of variables, coming back to them after perturbations, correction of mistakes and neutralisation of external disturbances (noises).

The severe scrutiny of monitoring TPL operation mode has found out 56 typical deviations, each of which may be identified per a number of signs

1. Per genesis:

- Scheduled actions of the operative staff (the dispatcher, linear services and etc.);
- Deformation of pipes (corrugations, nicks, hollows, pittings and cracks);
- Operation mode alterations of a pumping station equipments;
- Continuity interruption of the pumped medium (sedimentation - erosion of paraffin wax, tars, gas and water inclusions and etc.);
- Change of rheologic and physical properties of the pumped medium due to the ambient alteration (hydrologic, ground, weather-climatic and cryologic).

2. Per a data capture ability by the traditional tools:

- Pressure distribution along pipeline;
- Flow rates balancing per local sections of the line;
- Product temperature distribution.

3. Per retrospective of operation pumping parameters regarding time and pipeline length.

The basis of neural artificial network is designing of corresponding configuration of "network" –a set of universal non-linear elements (centrons), designated for derivation of non-linear function of several variables $\boldsymbol{X_i}$ with adjusting parameters $\boldsymbol{C_j}$ [3]:

$$Y = f\,(X_1, X_2, X_3, \ldots X_m, C_1, C_2, C_3, \ldots C_n). \tag{1}$$

Usually, centrons are described by physiological terms. As a rule, centron has one exit $\boldsymbol{S}$ and several entrances –"sinaps", at which external influences X_j come to (from receptors and other centrons). Exit (outlet) function shall look like as follows.

$$Y_i = f\left(\sum_j C_{1,j} X_i + C_{0,j}\right). \tag{2}$$

As a functional dependence, nowadays, logistic function of the following kind is used:

$$Y = \frac{1}{1 + \exp(-K \cdot S)}, \tag{3}$$

since $S = \Sigma\,(C_{ij}X_i + C_{0j})$.

Similar approach while solving above stated tasks secures the universality of a centron behaviour in the network when describing complicated non-linear responses of the system for external influences. Precisely, it is the universality of a logistic function allows not to be worried about processes, taking place in centron and neural network. In this case, the main key problem is the generation of "correct" configuration (architecture) of the network, that allows to describe adequately the system's behaviour standards. The most widespread architecture used in modern practice is a multi-layer network with the link principle "one with all" (see Fig. 1).

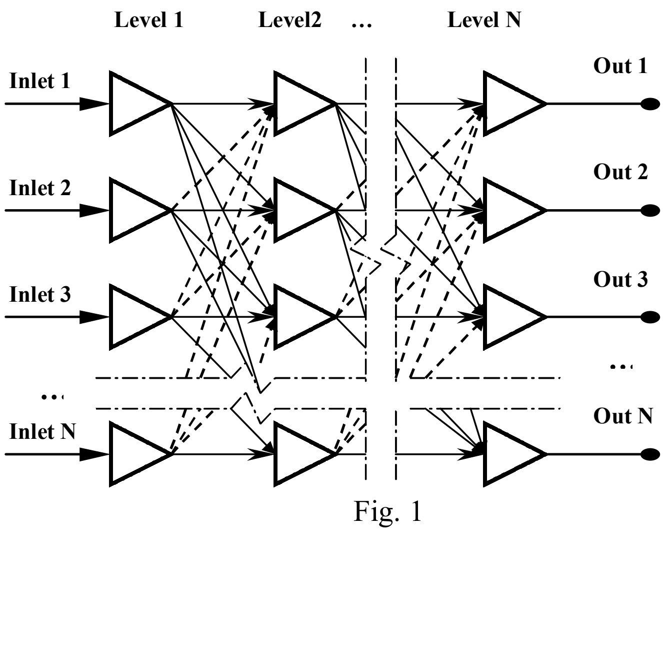

Fig. 1

The architecture of the multi-layer system is entirely defined by the array of weight coefficients C, which is formed during training of the neural network. The neural network training was carried out according to the following algorithm:

1. the References Table of the observed object (TPL section) was worked out by means of expert analysis of the alterations of monitored parameters;
2. a weight number was defined for each of standard states – for ranging of TPL states as per degree of the supposed consequences;
3. all elements of the weight coefficients array C are to be equal to unity;
4. a combination of input signals, corresponding to a considered TPL section state is delivered to the inlet layer of the neural network;
5. a signal (image) representing by itself one of the standard or template TPL state is formed at the outlet layer of the neural network. It is quite naturally, that for the initial stages of training, a probability of recognition is extremely low and high is a portion of mistakes, for correction of which a method of “inverse sweep method” is used [4];
6. corresponding elements of the array C for each neural network layer are calculated by “inverse sweep method ” as follows:

$$C_к = \frac{1}{N} * \sum_{i=1}^{N} (Ci * \frac{1}{(k-i)^2}), \quad (4)$$

since k – a number of centron examined in the current layer.

Meanwhile, number of steps of “direct” and “inverse” running should be minimised with the purpose of avoiding such diffused “harmful” phenomena during network training, like “paralysis” of the network, “pitfalls of local minimum”, “excessive training” and so on. [5]. Thus, as the result of training a neural network is formed with such values of the array C, which allows to recognise situations with the alteration of input monitored parameters occurred in TPL operation. The peculiarity of the arrangement of neural networks is the fact, that the main information is not included in centrons themselves, but it is in links between centrons – as per analogue with a nerve system of biological objects.

Sometimes during neural networks functioning a ambiguity situation may arise, e.g. such a situation, when several probable conditions of the examined object are diagnosed with the identical parameters monitored by the network. In this case, the neural network plays a role as a primitive expert system for making decision persons or as “ an adviser” for linear service personnel, and taking into account a situational rang gives out recommendations per occurred situation control for the elimination of undesirable external influence. In the last case, besides a diagnostics of the controlled object state, the service personnel is enabled to predict further development of critical and non-standard situations occurred during TPL operation.

Based on the proposed neural-network approach, the elaboration of program-apparatus complexes is being conducted for an sustained monitoring and diagnostics of TPL section states according to current operational parameters. In part of operative tracking of oil flow mode and internal surface condition of subsea collector of oil-field “White Tiger” developed on Vietnamese shelf, this system was tested in JV “VietSovPetro”. Preliminary, by the Delphi techniques, the distinctive feature of functional operation mode deviation of subsea pipelines system was determined, leading to contraction of pipe cross-section passage due to tarred-paraffin deposits. This made the task of the deviation identification narrower as well. But the algorithm of a quantitative evaluation of the functional deviation parameters has required a decision of inverse internal and external tasks of a heat-mass transfer. This algorithm shall be explained by means of graphic analogues.

MONITORING OF OFFSHORE OIL-FIELD COLLECTOR

Strict requirements to operational modes of Vietnamese shelf oil fields collector forced to look for non-traditional approaches to monitoring and examining of a inside condition of oil-field pipeline net. The onset of paraffin solidification within produced oils is in the range of + 35…38 ^{0}C. The possibilities of operation mode alteration are rather limited, so a capacity reduction for a long time shall inevitably bring to the product congelation in pipes. The pumping re-start is not possible by conventional means after a shutdown for a long time.

The monitoring of oil flow mode and the inside pipeline state under “White Tiger” oil-field available conditions is a vital necessity and the requirement of a reliable operation of oil collectors and the oil-field as a whole.

A required level of trustworthiness of an evaluation of the flow mode of the offshore collector can not be reached in case of the application of indirect calculations, whichever parameter is separately taken. The retrospective of values of flow rate, pressure and temperature drop of the initial and end cross-section of the pipeline is only available for the given part of the pipeline network. It is not possible to estimate the longitudinal distribution of parameters. However, it is possible to make an indirect estimation of averaged (per length) “apparent” values with such a limited volume of the information. General provisions of diagnostics for an operation condition and an estimation of “apparent” values are formulated in [6] and mean a simulation of the process for obtaining a comparative standard (KGU).

The most important parameter of the pumping mode is a power (thickness) of paraffin deposit layer on the pipeline walls, as well as a thermodynamic state of the pumped product. A passage section pipeline clogging is probable in case of its considerable contraction. However, direct methods of flow section measuring of the offshore pipeline do not exist, and the calculation under indirect parameters gives a big error. Therefore, it is suggested that the flow section diameter of a pipeline constricted with paraffin sedimentation shall be diagnosed as per summary of the estimations, both per averaged (per length) specific heat exchange per metre of pipe as well as per hydraulic resistance of pipeline section.

It is not possible to solve the inverse task of heat transfer from a transported product to the environment with obtaining a parameter sought for in the obvious form. To estimate a passage section as per heat transfer from a pipe metre, we use a well-proven approach of Leibenzon [8], which divides an extremely complicated task of heat transfer for internal and external ones. A total coefficient of heat transfer from the product to the environment taking into consideration an insulating effect of paraffin deposits has the form as follows:

$$K\pi D = \left[\frac{1}{\alpha_1 \pi D_\xi} + \frac{1}{2\pi \lambda_{nap}} \ln \frac{D_{in}}{D_\xi} + \frac{1}{\alpha_2 \pi D} \right]^{-1}, \tag{5}$$

since K – total coefficient of heat transfer, [W/(m^{2}K)];

D_ζ - dia. of pipeline passage section, [m];

$D_{in.}$- internal pipe dia., [m];

D – outside pipe dia.,[m];

α_1- internal coefficient of heat exchange, [W/(m^{2}K)];

α_2- external coefficient of heat exchange, [W/(m^{2}K)];

$\lambda_{пар}$ - thermal conductivity of paraffin deposits[W/(m·K)].

Assuming the diameter of passage section D_ζ/D, a graphic of changing a parameter $K\pi D$ can be built. Physical and rheological properties of oil and paraffin deposits are determined out of direct experiments. The internal coefficient of heat exchange from the pumped oil to the internal surface of paraffin deposits α_1 is described most adequately by L. Abramzon's equation [7], in which an influence of paraffin sedimentating on heat transfer is taken into account:

$$Nu_1 = 348Po^{-1,41}\,Pr^{0,139}\,Ec^{0,101}, \qquad (6)$$

since $Nu_1 = \alpha_1\,\lambda / D_\xi$ - Nusselt Number;

$Po = 1\text{-}\varpi / C_p\,d\xi / dT$ - Pomerantsev Number;

$Ec = V^2 / C_p / (T_f\text{-}T_w)$ - Eccert Number;

T_f, T_w - temperature of the product in a stream and on the pipeline wall, [K];

ϖ = 230300 J/kg – melting heating of paraffin;

$d\zeta/dT$-intensity of paraffin crystallisation [kg/K];

V- velosity of oil movement, [m/s];

λ, C_P – heat conductivity and capacity of oil, determined by Krego's formulae [8]:

$$\lambda = \frac{0,157}{\rho_{15}^{4}}(1-0,47\cdot10^{-3}T_{cp}) \quad ; \qquad (7)$$

$$C_\lambda = \frac{1}{\sqrt{\rho_{15}^{4}}}(0,762+3,39\cdot10^{-3}T_{cp}),$$

since ρ_{15}^{4} - oil specific gravity;

$T_{aver.}$ – averaged product temperature per a section length, [K]:

$$T_{cp} = T_0 + \frac{T_H - T_K}{\ln\frac{T_H - T_0}{T_K - T_0}}. \qquad (8)$$

Asymptotic temperature T_0 should be calculated with Leibenzon's correction [8], taking into account friction heat due to pumping of a viscous liquid:

$$T_0 = T_{окр} + \frac{G\cdot i\cdot g}{K\pi D}, \qquad (9)$$

since $T_{окр}$ – sea water temperature at the depth of collector location, [K];

G – mass flow-rate of oil, [kg/s];

i – slope;

g – gravity acceleration.

In case of non-availability of trustworthy data about sea currents, an external coefficient of heat transfer may be estimated as per regression dependence ,obtained for a free convection [9]:

$$Nu_2 = 0{,}523(Gr\,Pr)^{0{,}25} \tag{10}$$

since $Gr = gD^3\beta\Delta T/\nu^2$ - Grashof Number, calculated per water parameters;

$Pr = \nu/a$ –Prandtl Number.

The proposed model may be interpreted in a form of dependence of the specific heat exchange per meter of pipeline $K\pi D$ on relation of the diameter of the flow section to the pipe internal diameter $D_\xi/D_{internal}$ (Table 1).

Table 1.

Dependence of specific heating exchange per a meter of the pipeline on power (thickness) of paraffin deposits on pipes' walls

$D_\xi/D_{вн}$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
$K\pi D$, W/(m·K)	0,624	0,878	1,153	1,479	1,893	2,452	3,264	4,566	7,020	13,32

By using dispatcher's data, let's determine a range of the actual parameter changing out the solution of the inverse task $K\pi D$[8]:

$$K\pi D = \frac{G \cdot C_P}{L}\left[\ln\frac{T_H - T_0}{T_K - T_0} + \frac{\varpi}{C_P}\int_{T_K}^{T_H}\frac{\xi(t)dt}{t - T_0}\right], \tag{11}$$

since $\zeta(t)$ – a curve of paraffin crystallisation.

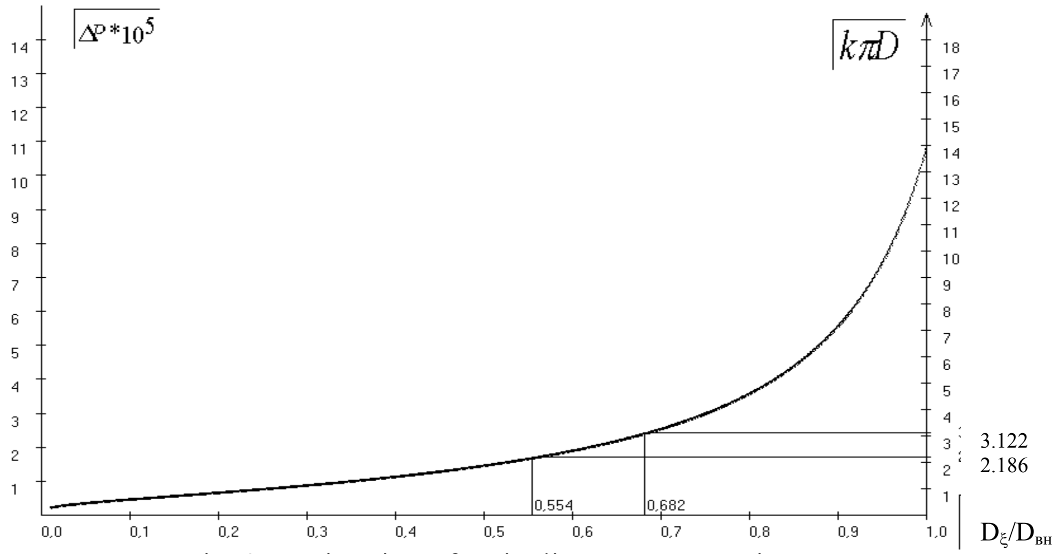

Fig. 2. Estimation of a pipeline passage section as per gradient of the temperatures of the product pumped.

Analysis of dispatcher's data as per parameters G, T_H, T_K determines a range of alteration of parameter KπD (2,186…3,123 W/(m·K) and relevant to its range estimations of the diameters of passing section $D\xi/D_{internal}$, which are within 0,557…0,686.

An analogous prediction, but in another coordinate space – as per analysis of the hydraulic resistance of a section of the sub-water pipeline, does not only increases trustworthiness of the received estimations, but it helps to make a series of conclusions as well as per a mode of the liquid movement in the pipeline.

The evaluation method means a process simulation for receiving a standard of comparison (KGU) [6] as well. But due to non-availability of trustworthy data as per mode of oil flowing in pipes, a necessity arises to use two models - laminar and structured oil flow.

A pressure drop in the investigated pipeline section when oil moves in laminar movement mode is simulated under known analytic dependencies [8]:

$$\Delta P = 4{,}15\frac{Q \cdot \nu_{н} \cdot L \cdot p \cdot g}{Shu \cdot D_{\xi}^{4}}[Ei\{-u(T_{н} - T_{0})\} - Ei\{-u(T_{к} - T_{0})\}], \qquad (12)$$

since Ei – exponential integral [10];

Shu= KπD L/(G C_p) –Shukhov Number;

u – coefficient of viscogram in Filonov-Reynolds equation.

In the tabulated field, values $D\xi/D_{internal}$ are known out of previous calculations of values of parameter KπD, therefore there are no difficulties with the calculation of parameter of Shukhov.

In Table 2, one may follow behavior of a pressure drop when oil moves in a subsea section of the collector in a laminar mode of its movement.

Table 2

Dependence of pressure drop at the ends of the subsea section of the pipeline in the laminar mode of the product flow on thickness (power) of paraffin deposits on pipes' walls

$D_\xi/D_{вн}$	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
ΔP,bar	296	13,13	1,976	0,487	0,156	0,058	0,024	0,009	0,004	0,001

In general case in the pipeline, where a "hot" non-Newton liquid is being pumped, various flow modes may be observed. The laminar stady mode may be observed at high temperature (over 58 ^{0}C). A structural flow mode may take place under temperature lower than the onset of paraffin solidification. In this case oil moves in the form of a freeze structural mass of paste-like state.

Energy losses at structural oil flow in pipes are calculated by G.D. Rozenberg - B.I. Mitelman's method [8]:

$$\Delta P = 4{,}15\frac{Q\cdot\nu_{н}\cdot L\cdot p\cdot g}{Shu\cdot D_{\xi}^{4}}[Ei\{-u(T_{н}-T_{0})\}-Ei\{-u(T_{к}-T_{0})\}]+$$

$$+\frac{16\varepsilon\cdot L}{3D_{\xi}\cdot Shu}\exp\{-s(T_{0}-273)\}[Ei\{-s\}(T_{н}-T_{0})\}-Ei\{-s(T_{к}-T_{0})\}] \quad , (13)$$

since ε – marginal stress of shear in model of V.G. Koten [8];
s - steepness of static shear stress [8].

The calculation results as per given model are shown in the Table 3.

Table 3

Dependence of pressure drop at the ends of an investigated pipeline section in the structural flow mode of the product on thickness (power) of paraffin deposits on pipes' walls

$D_\xi/D_{вн}$	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
ΔP,атм	417,3	56,25	23,88	13,29	8,16	5,20	3,34	2,08	1,20	0,57

In order to predict a thickness (power) of paraffin deposits on the pipeline's walls, let us use registered dispatcher's readings of pressure drop at the ends of the pipeline ($\Delta P \subset [4{,}0\ldots13{,}5]$,bar). The estimation of the averaged (per length) passage section in the assumption of the laminar oil movement is lying much more in the left side $D_\xi/D_{internal} \subset [0{,}19\ldots0{,}27]$, which puts in doubt the existence of a stable laminar flow in the examined pipeline section. (See fig. 3).

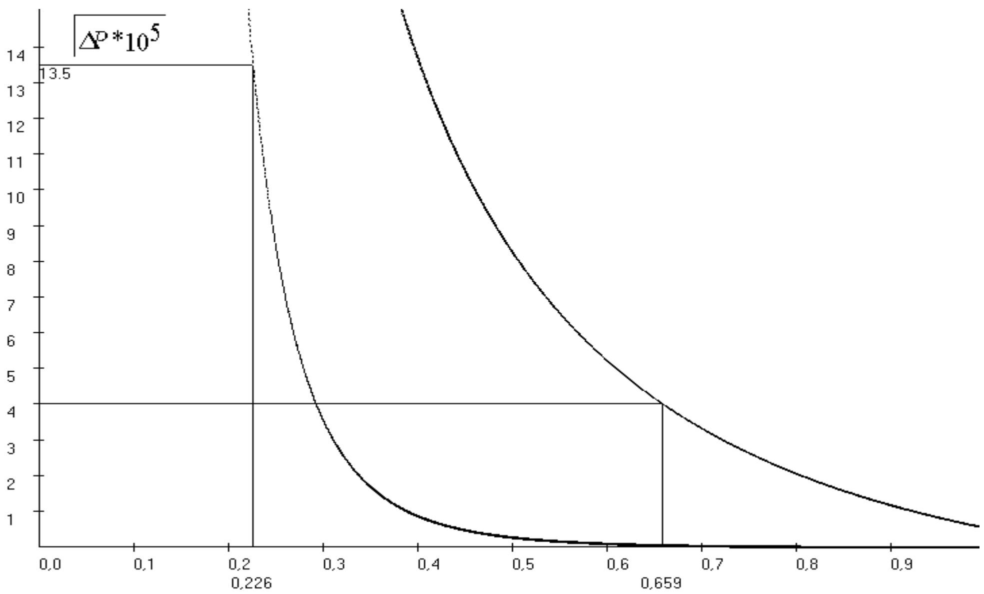

Fig. 3. Estimation of pipeline passage cross-section by pressure drop

Estimations per gradient of temperatures and per gradient of pressures coincide in the assumption of structural mode of oil flow in the subsea section of the collector $D_\xi/D_{internal} \subset [0{,}39\ldots0{,}66]$. Combined graphics with the estimations of power of paraffin deposits in two coordinate spaces are shown in Fig. 4.

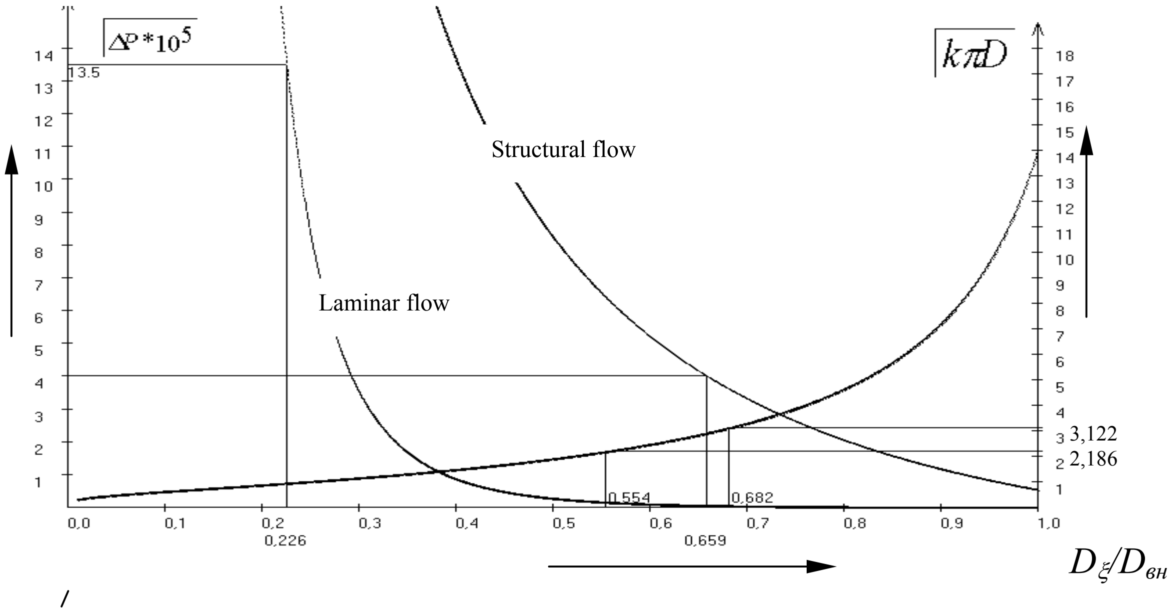

Fig. 4. Combined graphics of simulation of pressure and temperature drops at the pipeline

Re-calculation in two coordinate spaces makes more precise the estimation per length of the averaged passage cross-section diameter, which is necessary to be taken as an area of overlap of two especial estimations: $D_{\xi}/D_{internal} \subset [0{,}557 \ldots 0{,}659]$. Besides, a motivated conclusion of a structural oil flow can be made, at least, at a considerable part of the length of the investigated pipeline.

ANALYSIS OF COMPETITIVE DEVELOPMENTS

Finally let us mention the highest developments in monitoring of some non-nominal flow modes, achieved by JSC "Sibnefteprovod", specialists of which with the participation of "Energoavtomaica Ltd" at the pipeline "Torgili" – PS "Yurgamysh" with the length of 250 km of UBKUA TPL and NKK of 1220 mm diameter introduced a leakage diagnostics system [11]. The diagnostics algorithm is based on the analysis of the slope. The initial data are: a longitudinal distribution of pressures wtithin TPL, capacities of pump units, discharge, oil viscosity and density, as well as valves state on the pipeline trace. The information gathering was implemented over all pipeline sections by means of the telecommunication system MicroSCADA of ABB firm (Germany). As known, a hydraulic calculation of the steady mode gives an flow-rate error the approx. 10%, though the authors declare sensitivity two times better.

In essence, best results are achieved by firm Combit AB (Sweden), which suggested a system of leakage detection out of 990 LD pipeline, based directly on the analysis of TPL flow rates kept a check by the universal ultra-sonic flow meter "Uniflow", firm Controlotron [12]. The system is introduced at trans-Alpine two-lined TPL " Trieste - Munich". The method declared a sensitivity – 1%. The analogous flow meters are developed by domestic collectives as well, for example "Contact-free flow-meter of gas and liquid streams RGZh-001" [13]. However, the monitoring task of the operational mode of the trunk oil pipeline as a whole as a system of genesis, diagnostics and prognosis of the object technical state in the interaction with the environment requires not only principally a new equipment provision, but new methodological approaches to its implementation.

CONCLUSIONS

1. The development of the identification algorithms for functional deviations of operational modes allows increasing control serviceability and reliability of oil transport systems considerably.
2. It is reasonable to make a quantitative mutual estimation of the detected functional deviations by means of the decision of inverse tasks both heat and hydraulic pipeline system accounts.
3. An overlay of especial estimations in two (three) coordinate spaces (as per quality of the registered pumping parameters) make deviation prognosis more precise, that lies in the area of these especial estimations overlap.

REFERENCES

1. Technical means of the diagnostics: Reference book/V.V Kliuyev.-M: Mashinostroyeniye, 1989.-672p.
2. Geocryologic prognosis for West-Siberian gas-bearing region / S.E. Grechishev, N.G. Moskalenko, Yu.L. Shur– Novosibirsk: Nayka, 1983.-127p.
3. Golitzyn G.A. The application of neural-network technology in E.S.// Proceedings of the seminar “Expert systems of real time”. – M.: RDZ,1995.
4. Trelieven P. Neurocomputers. –L.: University Colledge, 1989.
5. Golitzyn G.A., Fominykh I.B. Integration of neural-network technologies with expert systems // Proceedings of 5th National conference on II. – Kazan, 1996.
6. Kutukov S.E. Quick-look deviation diagnostics for TPL operation /Proceedings of Over-Russian scientific and technical conference “Novoselovskie chteniya” – Ufa: USPTU, 1998.- 12-13p.
7. Abramzon L.S., Yakovlev V. A. About paraffin deposits in pipelines. NIItransneft, Issue 3, -M.: Nedra, 1964.
8. Tugunov P.I. Non-steady modes of crude oil and petroleum pumping.-M.: Nedra, 1984.-222p.
9. Jaluria Y. Natural convection. Heat- and mass exchange. Transl. From Engl.- M.: Mir, 1983. - 400p.
10. Reference book on special functions with formula, graphics and math. Tables./ Under reduction of M. Abramovich, I. Stigan.- M.: Nauka, 1979. –830p.
11. Experimental verification of the applied program algorithms provision per diagnostics oil leakage in pipelines. A.S. Losenkov, A.G. Trefilov, V.P. Narkhov and others// Oil pipeline transport. 1996.- No 11. – P.7-10.
12. Prokhorov B.M. Universal ultra-sonic flow meter for monitoring and control of oil leakage in pipelines.// Oil pipeline transport. 1996. - No 11.– P.32-34.
13. Micro-wave techniques for gas industry / I.N. Moskalev, I.P. Loritkin and others // Gas industry. 1997.- No 4.– P. 56-58.