TRANSPORTATION AND STORAGE OF OIL AND GAS

Corrosion and mechanical testings of tube steel for forecasting of life of oil pipelines

V.V. Nikolayev

IFNTUOG

УДК 621.438:622

The paper shows the results of experimental studies of corrosion and mechanical and corrosion characteristics of pipe steels of the pipelines in corrosive medium models, graphic dependences are constructed for the analysis of corrosion and mechanical processes.

During the accidents at oil pipelines a three-phase system goes to the environment the which gasous phase contaminates the air basin and the liquid and solid phase – ground forming the areas of pollution therefore the studying of characteristics of corrosion and mechanical processes of the tube body which have been operating 15-20 and more years is an actual scientific task.

The seamless tubes with the wall thickness 15 mm used for the construction of pipelines are chosen to be the object of research.

To investigate the corrosion processes under the tension we used the developed computerized system KH-1 created at the base of the sytem MB-1K [1].

The testings of samples from pipeline material in air and in liquid working environments were conducted in the mode of static load by clean fold with automatic registration of the sample flexure and change of electrode potential with the help of the computer using 24-bit analogous and digital conversion of meanings number.

The flat samples from the material of different areas of linear pipeline part were used. Such a technology provides the high accuracy and given roughness of working surfaces during the using of mechanical treatment with programmed change of feeding.

In the process of static load and creep a parameter of which it is possible to define the arrow of flexure of sample δ is constantly registered. Parameter δ, working part length l_p minimum radius of sample curvature P_{min} with the correlation

$$\rho_{min} = \frac{l_p^2}{8\delta} + \frac{\delta}{2}.$$

The relative deformation of last fiber was defined at the formulation

$$\varepsilon = \frac{1}{\frac{2\rho_{min}}{b} + 1},$$

where b – sample thickness.

The complex analysis of internal and external factors which characterize the speed of corrosion of pipes material in operation environment is necessary to forecast the corrosion behavior of pipelines.

The main indicator of speed of corrosion destroying (both partial and even corrosion) is the depth of penetrating. In both cases the depth of corrosion destroying regardless of kind of metal or alloy is measured in millimeters per a year.

The speed of corrosion is defined under the formulation

$$V_{BM} = \frac{n(m_1 - m_0)}{St} \text{ кг/м}^2 \text{ рік},$$

where m_0 – initial sample mass, kg; m_1 – sample mass with the products of corrosion, kg; S – sample area, m^2; t – time of experiment, years; n – coefficient which depends of the content of products of corrosion. The preliminary preparing of experimental samples includes their mechanical treatment with the help of small-disperse abrasive, degreasing by organic solvent (acetone, toluol or benzol) and weighting on the analytical balance. The samples are placed in the glasses with the solutions which model the aggressive environment. After finishing the experiment the samples are removed from the solutions, the dimensions of surface are to be measured quickly which was dipped into the aggressive environment, the insoluble corrosion products are to be taken away from their surface by the wet sponge.

After the washing by distillate and thorough drying by the filtering paper the samples are to be weighed again at the analytical balance.

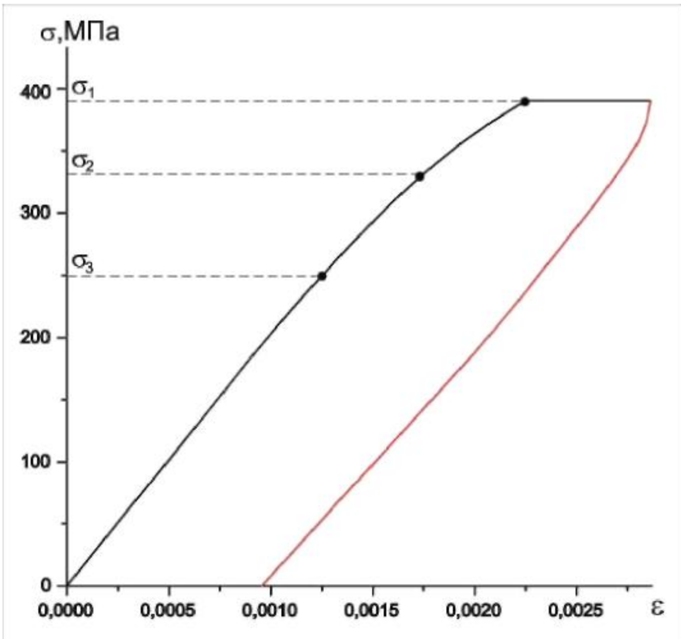

Fig. 1. Nominal diagram of deformation of steel samples of pipeline in air

During the measuring of potentials chlorsilver electrode of comparison was used.

In order to model stress and corrosion processes with the highest accuracy we made the analysis of formation waters and subbottom water at different stages of transportation of crude oil. At this base 3 model environments were chosen which correspond the formation water of the well, and subbottom – at the stage of transportation and selection at the pumping station [2].

Table Composition of model environments (ME)

Model environment	Sample origin	pH	SO42–	NO3-	Cl
1	Selection for ME	6,2	2,8	4,8	4,0
2	Formation water	6,0	3,6	7,6	5,1
3	Subbottom water	6,1	7,5	5,3	5,1

The long-lasting action of loads and influences in ground massive to the pipeline metal causes various structural changes including deformation and relaxation of tensions. Therefore the studying of mechanisms of change of physical and mechanical properties of the material of pipeline in the process of long-lasting operation will give an opportunity to forecast more precisely the remaining life of work of the available pipelines. In current conditions when the essential part of pipelines have being operated 15-20 years and close to the exhaustion of its work life according to the preliminary data, the studying of their corrosion and mechanical behavior is the actual scientific task.

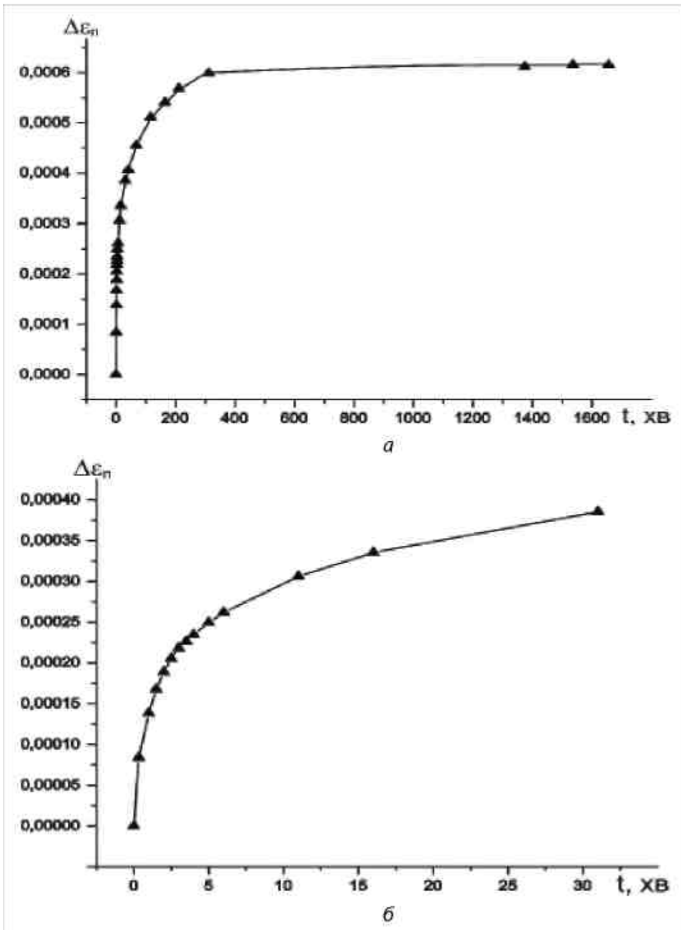

Fig. 2. Kinetics of creep of pipeline steel in air of: general (*a*) and initial stage (*б*): T = 293 K; σ= 390 MPa

To build the nominal diagrams of deformation the apparent staged load (unload) of sample was used (fig.1) by clean fold when with the decrease of supporting of sample, the load which passes to is not decreased. With the increase or decrease of load for one level the nominal tensions were changed on the value $\Delta\sigma$= 20 MPa for time $t_{н\text{-}р}$ = 1 c. Curing time at each level was $t_{в}$ = 19 c, and total time $\Delta t = t_{н\text{-}р} + t_{в}$ = 20 c. Such a mode of load gives an opportunity to consider the backlog of deformation of the tension in time and study profoundly the processes of deformation strengthening and creep.

Experimental researches of creep phenomenon which results have being used recently more and more often in the engineering calculations and for optimization of pipelines constructions are conducted mainly during the stretching.

The creep is often considered as slow metal flow. As it is known the opinion of flow surface is in the base of the theory of plastic flow. In the process of static fold the regular moving of the surface of flowing occurs, id est its evolution.

The specific curves of creep in the coordinates of growth of creep $\Delta\varepsilon_{\text{п}}$–time t is depicted on fig.2-4. The duration of tests in air was defined by the character and kinetics of the processing of each specific case which gave an opportunity to conduct the series of experiments for relatively short time and calculate the parameters of area of low-temperature creep.

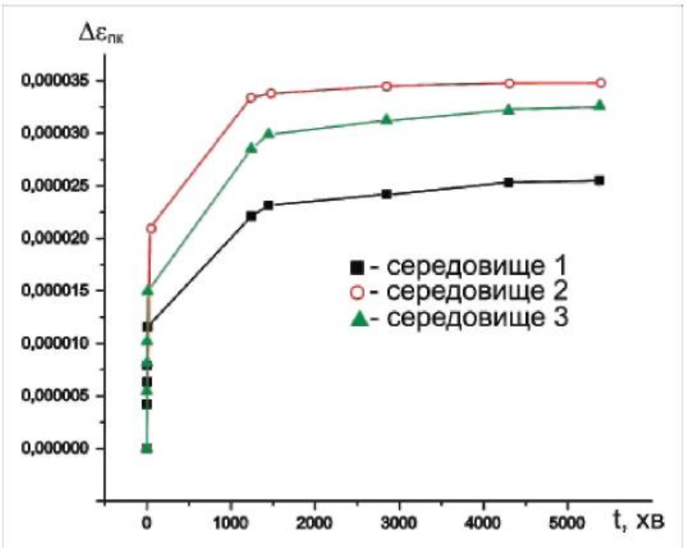

Fig 3. Creep of pipeline material at nominal tensions 250 MPa

General growth of deformation $\Delta\varepsilon$ for time t for this range of tensions can be defined at the formulation $\Delta\varepsilon = \Delta\varepsilon_{\text{пр}} + \Delta\varepsilon_{\text{пл}} + \Delta\varepsilon_{\text{п}}$,

where $\Delta\varepsilon_{\text{пр}}$ and $\Delta\varepsilon_{\text{пл}}$ – correspondingly the growths of elastic and plastic deformation during the reaching of given level of tensions $\Delta\varepsilon_{\text{п}}$ – creep growth.

It was set that the creep of the main metal in corrosive and active environment as in air has a staged character. The influence of environment is felt on stages of both stable and unstable creep. As the researches showed the pipeline steel shows the biggest tendency to low-temperature corrosion creep in MC2 and the smallest – in MC3.

The duration of the first stage depends more of the value of nominal tensions and less – of the chemical composition of environment. The studying of dependencies of the growth of corrosion creep of the value of nominal tensions and chemical composition of environment give an opportunity to make conclusion that its maximum synergetic influence is observed in MC2, and the minimum – in MC1.

For the best studying of chemism of the process of internal stress-corrosion of pipeline steel and defining of the most dangerous operation environment from chemical point of view the kinetics of electrode potential was researched. It is known that lower metal potential and quicker the process of dis-elevation, the probability of corrosion processes is higher and consequently the unsafety of arising of corrosion damages.

As it is seen from the graphics the synergetic action of corrosion active environment and applied mechanical tensions takes place here also.

Now we'll study the influence of mechanical factor upon the process of diselevation. We'll compare the kinetics of electrode potential at $\sigma = 1{,}6\ \sigma_{0,2}$, $1{,}35\ \sigma_{0,2}$ and $1{,}05\ \sigma_{0,2}$. The results of researches testify that with decrease of level of nominal tensions the speed of process of diselevation in MC2 is practically unchanged, and in MC3 and especially in MC1 it is decreased significantly.

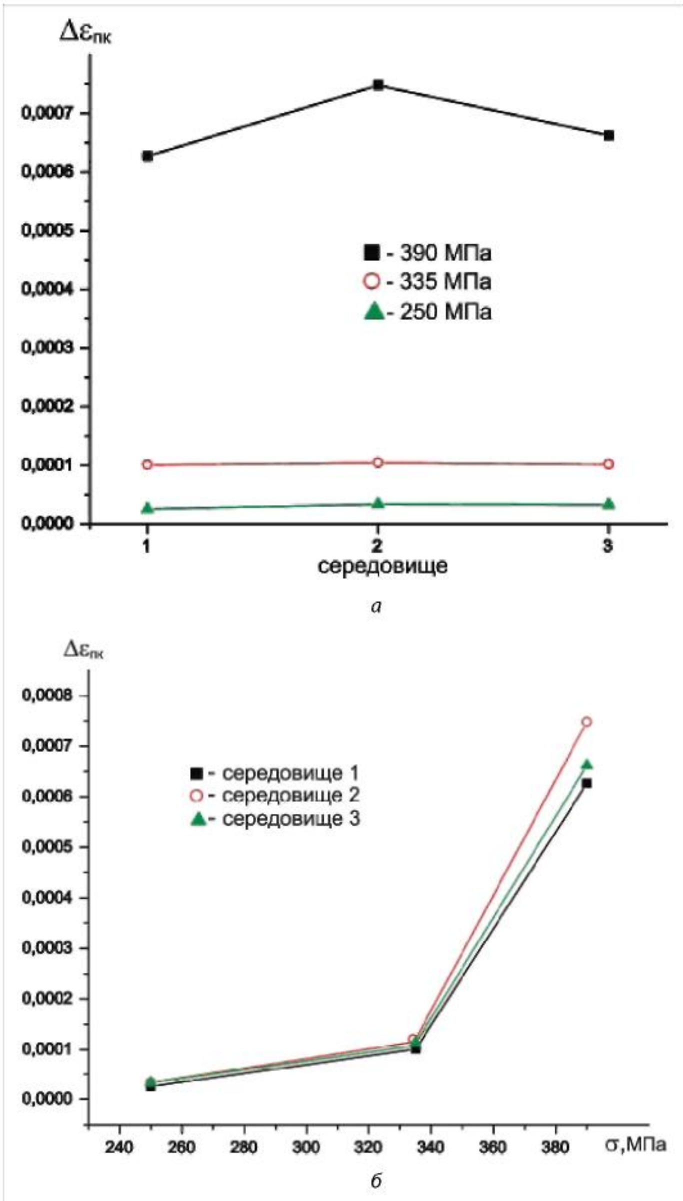

Fig. 4. Dependence of the creep rate on the stress level (a) and the chemical composition of the medium (b): t = 5000 min

Thus MC2 is the most dangerous environment from chemical point of view, because the process of diselevation in it is controlled by the corrosive factor. It means that at minimum level of mechanical tensions the corrosion will occur rather intensely. In MC1 we observe the mixed control with the accent on mechanical factor. From chemical point of view it is frankly speaking is the most safety from our environments. In MC3 the situation is practically analogous but the very diselevation is less intensive.

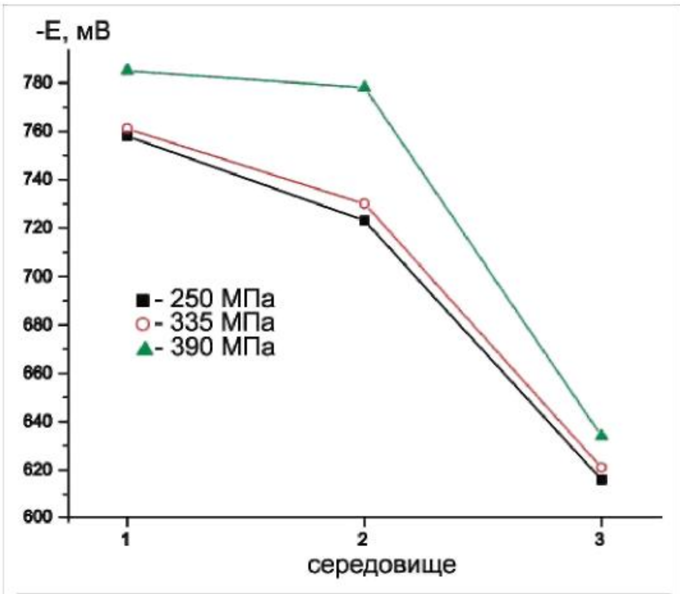

Fig.5. Influence of mechanical factor on the stabilizing potential of pipeline steel.

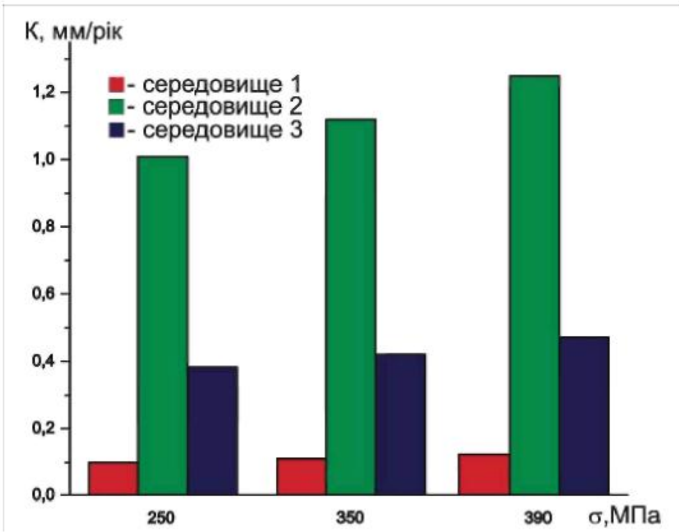

Fig.6. Dependence of decrease of thickness of wall of pipeline of the chemical content of environment

As for the corrosion activeness it has the intermediate place.

The dependence of stabilizing potential of pipeline steel of its tension and deformed state is illustrated on fig.5.

As we can see it is rather notable especially in MC1 and MC2.

As we forecasted considering the kinetics of the potential the biggest speed of corrosion is observed in MC2, the smallest – in MC1. The low speed of corrosion in the latter case confirms our suppost that the fast decrease of electrode potential in MC1 is mainly connected with the processes of plastic flowing in pipeline steel which is accompanied inevitably by the creation of uvenile surfaces and submicrotracks, the newly created surface of which has much more lower potential as well as by the biggest relative content of chloride ions which prevent its fast passivation.

As for the decrease of the thickness of wall of pipeline we can see here that even at minimum level of tensions it can reach from 0,125 to 1,25 mm/year depending the chemical content of the environment and level of nominal tensures (fig.6).

It is set that with increase of value of nominal tensions of 1,05□0,2 to 1,6 □0,2 the increase of general speed of corrosion in model environments van reach 25%.

Thus, during the calculation of remaining life of available pipelines and projecting of new ones we must not in any way neglect the mechanical factor. It is also necessary to consider the permanent intense movement of corrosive environment at which:

The constant washing-off of unsoluble products of corrosion id est the pasivation of surface becomes worse;

the tendancy to localization of corrosion processes occurs because the place damaged initially can not be pasived and therefore constantly has thye less potential of the neighbouring nondamaged areas;

a galvanic element is created in which the damaged area becomes anode and the nondamaged one – cathode;

the speed of local corrosion can 2-8 times exceed the speed of general one.

Considering that under unfavourable conditions which we can not neglect the mechanical factor and factor of movement of the environment will reinforce mutually the corrosion processes it is not difficult to define that the spped of local corrosion and consequently the value of decrease of wall thickness can increase 2,5-10 times.

References

1. **Крижанівський Є.І.** Удосконалена автоматизована випробо- вувальна система з ЕОМ для дослідження корозійно-механічного руйнування/ Є.І. Крижанівський, Л.Я. Побережний, В.А. Ровінський // Вісн. Кременчуцького державного політехнічного університету: Наукові праці КДПУ. – Кременчук: КДПУ, 2002. – Вип. 1 (12). – С. 292–294.

2. **Капцов И.И.** Анализ загрязнений магистральных газопроводов / И.И. Капцов, Б.Н. Гончаров // Газовая промышленность. – 1979. – № 8. – С. 89–90.

Author of article

Nikolayev Vitalii Viktorovych

Post-graduate of Ivano-Frankivsk National Technical University of Oil. Main sphere of scientific researches: studying of processes which occur with tube metals in pipelines during theit longlasting operation; development and introduction of methods of repair of trunk pipelines without stopping of transmitting of the product to the consumer.