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THE IMPROVEMENT OF THE NORMATIVE PROVIDING OF NUCLEAR POWER PLANTS PIPELINES SYSTEMS SAFERTY

Offered to recommendation on the improvement of the operating safety normative providing of the pipeline systems of the power plants. On the basis of the conducted researches an algorithm is offered on determination of resource of the pipeline systems taking into account different technical parameters.

Запропоновані рекомендації по удосконаленню нормативного забезпечення експлуатаційної безпеки трубопровідних систем атомних станцій. На основі проведених досліджень запропоновано алгоритм визначення ресурсу трубопровідних систем з врахуванням різних технічних параметрів.

Introduction

In Ukraine there are 15 energyblocks with total capacity of 11,835 MW that accounting for 45,7 % of total electricity production. However, the design of reactors of nuclear power plants laid resource for 30 years. Currently, much of the power equipment of nuclear power plants in Ukraine closer to the specified service life, or have already exhausted them. In this connection raises questions about the withdrawal of their operation or life extension of power equipment, and for this it is necessary to determine their resource.

According to the IAEA requirements all work related to nuclear energy equipment must be carried out in accordance with existing regulations on safety.The existing regulatory provision for the safe operation of power equipment does not include all the technical parameters of the load on their pipelines, and therefore can not fully do a comprehensive analysis of the pipelines to determine their resource.

Problem statement

Problems related to determination of the secure terms of safe maintenance of pipelines of nuclear installations are actual presently in connection with exhausting of projected terms of their maintenance [1, 2]. One of possible approaches of decision of this problem is related to introduction of modern facilities of research of degradation of physical-mechanical characteristics of construction materials and also diagnosticians of the real technical state of pipelines with the purpose of discovery in them different sort of defects in practice of accident-free maintenance of equipment of nuclear power stations. The information got here possesses some degree of vagueness, therefore calculation-experimental approaches which are based on certainly-element models and include the followings basic stages must be used for prognostication of residual life of pipelines:

– determination of the data about the actual loading for all period of maintenance, including mechanical, temperature and radiation influences;

– determination of physical-mechanical characteristics, structure, degree of fatigue damage of main metal and welded stitches on the base of ultrasonic, acoustic, magnetic fault detection;

– construction of certainly-element models for the calculation of the tensely-deformed state and probability of damage of pipelines with the purpose of revelation of the most dangerous places;

– prognostication of individual residual life of pipelines taking into account all of possible models of destruction on the basis of probabilistic calculation-experimental approaches.

– probabilistic calculation of the lingering and static durability, multicyclic and not multicyclic fatigue taking into account erosive-corrosive wear and tear and development of other local defects.

The main part

The task of the research is to create a normative providing safe operation through the development of mathematical model and algorithm for calculating the residual life of pipelines of nuclear power plants. Mathematical model will enable to determine the ability of the product (in this work, pipelines) to perform specified functions throughout the project life cycle and to predict the resource, then it is possible to extend the project period of safe operation.

The first stage to development of method of prognostication of useful life of pipelines of nuclear power station at fatigue failures taking into account erosive-corrosive wear and tear on the basis of calculation-experimental approaches. Multilevel certainly-element models, allowing to define characteristics of the tensely-deformed state (VAT) of both pipeline on the whole and most loaded his fragments, are used. Probabilistic approaches are used taking into account possibility of statistical variation of characteristics of intrinsic pressure of pipelines, and also error of finding out the researched latent defects in the walls of pipeline.

In the process of maintenance from 1982 of the first and second (1985) blocks of South-Ukrainian nuclear power station the considerable erosive damages of bend, transitions, tees, rejections and other of areas of pipelines of warming steam of the first stage of SHS, condensation of warming steam of high pressure WHP and other of pipelines bearings both mono phases and diphase streams are exposed.

On Yuzhnoukrainskoy nuclear power station the results of ultrasonic measuring of thickness were got, metallographic analysis and modes of loading [3]. The operating parameters of pipelines and speed of erosive wear and tear are presented in a table 1.

The conducted metallographic researches of the dismantled metal showed that defects of microstructure weren't exposed. The microstructure of metal ferrit-perlite and it corresponds the microstructure of carbon steel 20. Contents of carbon is within the limits of 0,22 %. Quality of metal conforms to the requirements TC 14-3-190-82 and GOST 8731.

Table 1

Operating parameters of pipelines and speed of erosive wear and tear

№	Pipeline	Ø x δ_0	T_p °C	P_p MPa	*U* m/c	ρ kg/m^3	*N* mm/year
1	HHP -6 in deaerator	530x8	186	1,8	0,63	800-400	0,3-0,41
2	CV (condensate of vessels) 1st. SHS in deaerator	219x8	211	1,9	1,7	800	0,37
3	1 st. warming HHP in deaerator	273x10	211	1,9	1,1	800	0,22
4	2st. SHS in deaerator	426x14	233	3,0	1,1	800	0,39
5	2st. warming SHS	273x16	233	3,0	1,8	800	0,3

Later position and geometrical sizes of defects in a pipeline were determined on the basis of method of ultrasonic measuring of thickness, they arose up as a result of erosive-corrosive wear and tear (fig. 1), and new geometry was got in local places.

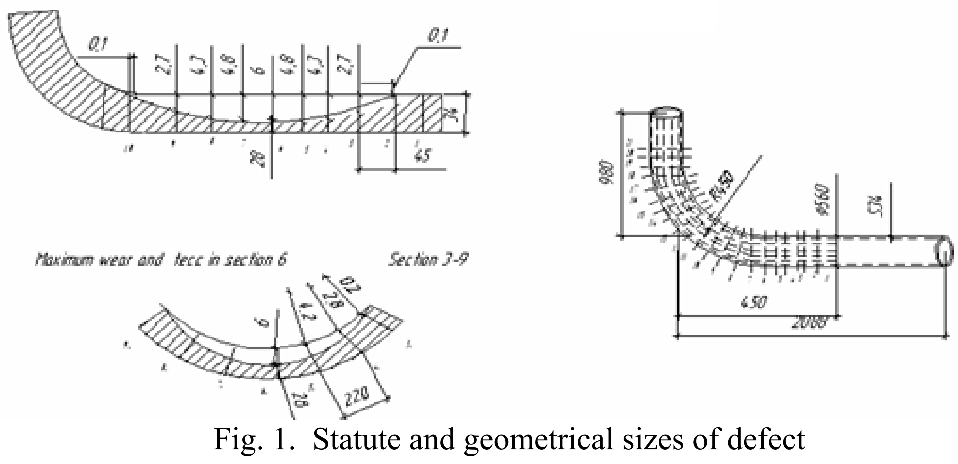


Fig. 1. Statute and geometrical sizes of defect

The second stage of the development of algorithms for the determinations of residual life was to build a model of the fragment of pipeline system reactor of VVER-1000 which is presented on a fig. 1.

Jacket 8-nodes eventual elements were used for the calculation of characteristics of VAT of all of pipeline (fig.2), being under the action of intrinsic pressure. The second level models on the basis of three-dimensional 20-nodes eventual elements were used for research of local characteristics of VAT of fragment of pipeline (fig.3). At the calculation of tensions for the separate fragments of pipeline as information about loading the values of the key moving are set in the extreme sections of fragment, which are determined from the decision of task for the whole system.

The results of calculation of amplitudes of intensities of tensions of pipeline, got on the basis of model of the first level, are presented on fig. 2.

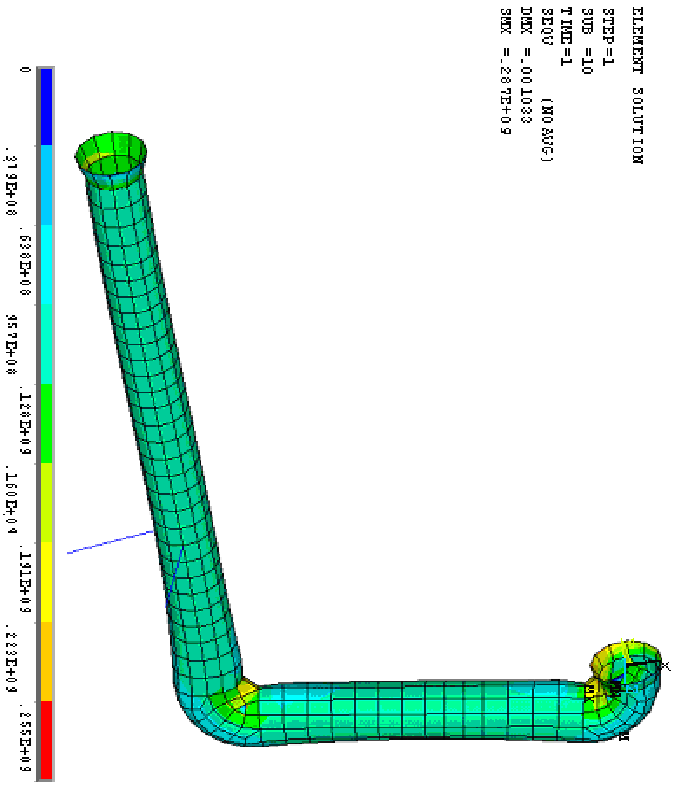
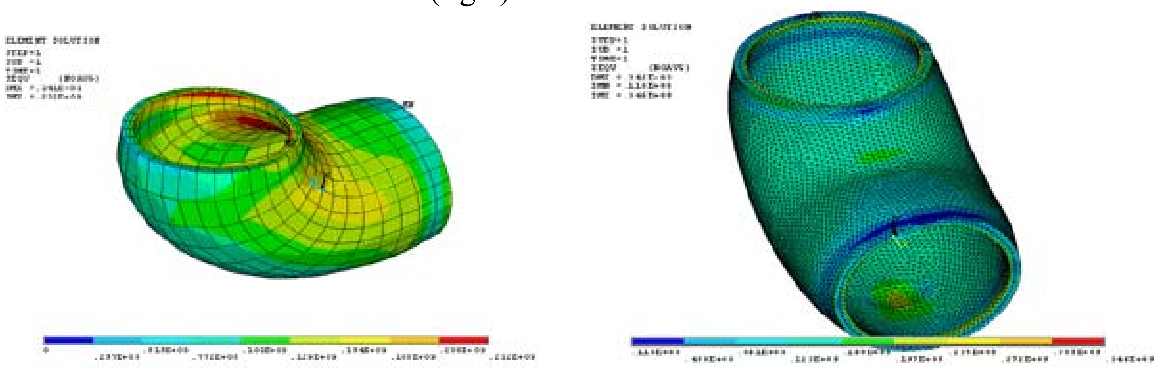


Fig. 2. Distributing of tensions on the separate area of pipeline of the first contour of power installation with the reactor of VVER-1000 at pressure – 20 MPa

The third stage was modeling defect in erosion-corrosion wear and determined maximum stresses in the fragments that most thickness of pipeline. Localization of tensions is observed in curvilinear fragments. The results of calculation of the most loaded curvilinear fragment of pipeline, got on the basis of model the second level without an account (fig. of 3a) and taking into account an erosive-corrosive wear and tear(fig. of 3b), are presented on fig. 3. As follows from the got results for a defect, appropriate thinness of wall to 35 %, there is a redistribution of a maximum of tensions in the area of local defect.

On the basis of the got results of ultrasonic fault detection and numerical analysis of VAT of construction the method of calculation of residual life is developed at the multicyclic fatigue of pipelines, which have defects as a result of erosive-corrosive wear ant tear. At a calculation statistical variation of pulsation of pressure in the system and geometrical sizes of experimentally found out defects is taken into account (fig.1).



à) b)

Fig. 3. Distributing of tensions in the curvilinear fragment of pipeline: a)–without defect; b)–with presence of defect

Fourth stage for prognostication of residual life of pipeline, containing local defects, the linear model of accumulation of fatigue damages is examined [4].

$$\frac{dz}{dt}=\frac{\sigma_a^m(t)}{T\sigma_{-1K}^m N_0}, \tag{1}$$

where, m are parameters of the fatigue curve;

$\sigma_a(t)$ is equivalent amplitude of tensions in a dangerous area, subject to the erosive-corrosive wear and tear.

It is assumed that $\sigma_a(t)$ is straight proportional pressure in the pipeline of Ð and back proportional his thickness $h(t)$ in a dangerous area

$$\sigma_a(t)=K\frac{P}{h(t)}. \tag{2}$$

The coefficient of proportion K is determined on results the decision of the higher described task of calculation of VAT of fragment of pipeline, containing a local defect. It is assumed that - is the non stationary linear casual function of time

$$h(t)=\begin{cases} h_0, & t<t_0 \\ h_0-v(t-t_0), & t\ge t_0 \end{cases}, \tag{3}$$

where v is speed of wear and tear;

t_0 is a moment of origin of defect.

At finding out a defect in the moment of time t_1 the thickness of wall in a local area is designated through h_1. The error of measurements is taken into account a task the density of probability $f(h_1)$ of casual size h_1 which is offered normal.

From data of measurements in the moment of time t_1 and expression (3) it is possible to write down linear transformation between casual sizes t_0 and h_1.

$$t_0=t_1-\frac{(h_0-h_1)}{v} \tag{4}$$

As transformation (4) is linear, density of probability $f(t_0)$ also submits a normal law with the expected value m_{t_0} and variance $\sigma_{t_0}^2$.

$$m_{t_0}=\left(m_{h_1}-h_0+vt_1\right)/v, \tag{5}$$

$$\sigma_{t_0}^2=\sigma_{h_1}^2/v^2. \tag{6}$$

Integrating expression (1) in limits $[0,t]$ taking into account expressions (2) and (3), get

$$z(t)=P^m F(t,t_0), \tag{7}$$

where $F(t,t_0)=\frac{1}{T\sigma_{-1k}^m N_0}\left[t_0 h_0^{-m}-\frac{1}{v(1-m)}\left(\left(h_0-v(t-t_0)\right)^{1-m}-h_0^{1-m}\right)\right]$.

Expression (7) allows to determine the conditional density of probability of measure of damages $z(t)$ in the moment of time, on condition that the origin of defect began in moment t_0. In functional transformation (7) taken into account, that the density of probability of random variable P submits a normal law

$$f(z,t/t_0)=\frac{1}{\sqrt{2\pi}\sigma_p}\exp\left\{-\frac{\left((z/F(t,t_0))^{1/m}-m_p\right)^2}{2\sigma_p^2}\right\}\cdot\frac{1}{m}\left(\frac{1}{F(t,t_0)}\right)^{1/m}\cdot z^{\frac{1-m}{m}}. \quad (8)$$

The absolute density of probability of measure of fatigue damages $f(z,t)$ is determined from expression [4]

$$f(z,t)=\int_0^{\infty} f(zt/t_0)f(t_0)dt_0. \quad (9)$$

Conditional probability of faultless work $P(t/t_0)$, probability of faultless work $P(t)$ and gamma-percentile residual life of pipeline T_γ are determined from expressions [4]

$$P(t/t_0)=\int_0^1 f(z,t/t_0)dz, \quad P(t)=\int_0^1 f(z,t)dz, \quad (10)$$

$$P(T_\gamma)=\gamma. \quad (11)$$

The three-dimensional graph of conditional density of probability of measure of damages $f(z,t/t_0)$ and conditional probability of faultless work $P(t/t_0)$ for the different moments of finding out a defect are presence on the basis of the got correlation (8) and numeral integration of expressions (10) on fig.4, 5.

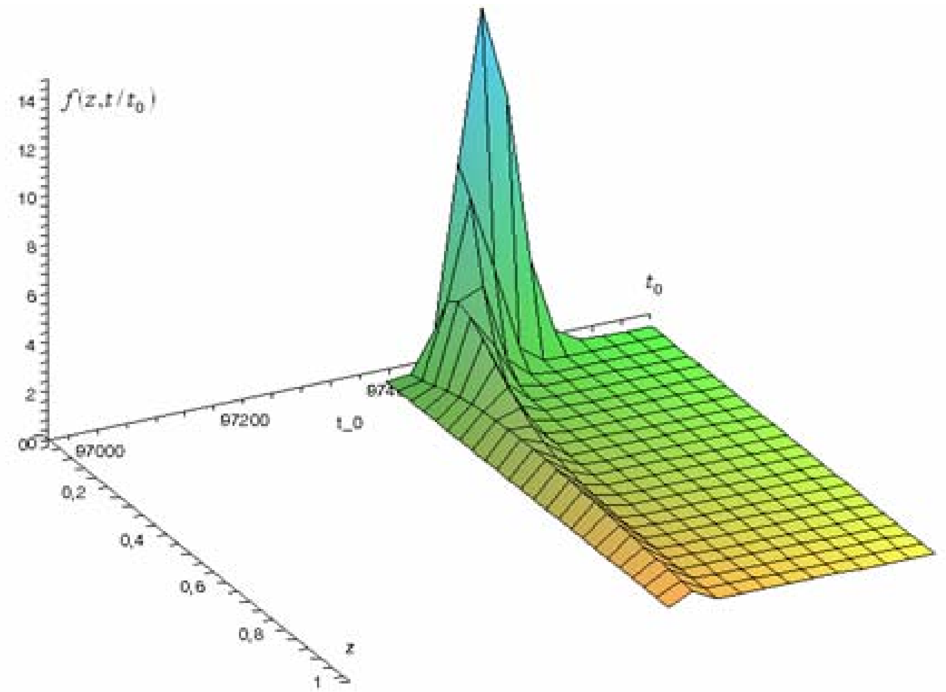


Fig. 4. Conditional density of probability of measure of fatigue damages

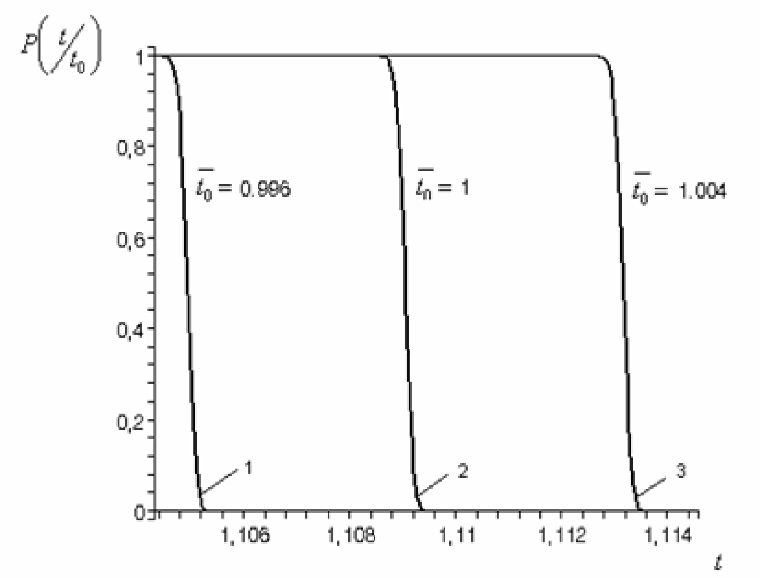


Fig. 5. Conditional probability of faultless work for the different moments of time of origin of defects

Conclusions

Calculation-experimental probabilistic approach of prognostication of individual useful life of pipelines of nuclear power station is offered at a multicyclic fatigue taking into account the erosive-corrosive wear and tear of internal surface. Probabilistic variation of geometrical sizes of experimentally found out defects and pulsations of intrinsic pressure are taken into account. The conducted numeral researches testify to effectiveness of the developed approach for prognostication of individual residual life of the pipeline systems and may be use for determaining anothers pipelines systems different fields idustry. This research became the basis for the development of industry normative documents for exploring of pipeline systems operating on different cycles.

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УСОВЕРШЕНСТВОВАНИЕ НОРМАТИВНОГО ОБЕСПЕЧЕНИЯ БЕЗОПАСНОЙ ЭКСПЛУАТАЦИИ ТРУБОПРОВОДНЫХ СИСТЕМ АТОМНЫХ СТАНЦИЙ

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Предложены рекомендации по усовершенствованию нормативного обеспечения эксплуатационной безопасности трубопроводных систем атомных станций. На основе проведенных исследований предложен алгоритм по определению ресурса трубопроводных систем с учетом различных технических параметров.

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