

Forecasting Resource as a Method of Increasing the Security of Technical Devices

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Abstract. The article shows a method of increasing the safe operation of technical devices at various stages of the life cycle according to the proposed classification parameters of the resource by applying the model of resource prediction. The model takes into account the presence of defects, the rate of corrosion and corrosion resistance of the material, the volume of technical diagnosis, the degree of risk in case of failure or damage of technical devices. The article shows the application of the model resource of the technical device from the manufacture to the end of its service life.

Introduction

In accordance with the Federal norms and rules in the field of industrial safety [1, 6-8] technical device should be safe during the whole service life. The generalized factor of safety of technical devices is risk. The risk increases when a critical technical condition of the device. Technical condition (TC) is determined by the strength and reliability of bearing elements for a nominal (normal) and abnormal (emergency) situations [2].

In [3] proposed a deterministic risk analysis of chemically hazardous facilities with the introduction of the following main assumptions: the allowable resource $[\tau]$, which is defined in the design, takes into account the degree of damage accumulation during the operation of technical devices. Over time the resource τ is reduced according to a linear law:

$$D_T = F_D \left\{ \frac{\tau}{[\tau]} \right\} = C_D \frac{\tau}{[\tau]}, \quad (1)$$

where C_D — severity rate given the degree of damage.

At each time interval τ measured in years, the conditional probability of reaching the limiting state will be equal to:

$$P = \frac{1}{n_\tau \cdot [\tau]} \tau, \quad (2)$$

Where value: $\frac{1}{n_\tau \cdot [\tau]}$ this increment in the conditional probability of reaching a dangerous state in a year. Resource n_τ taken in the range $2 \div 10$.

Thus the allowable design resource $[\tau]$ is determined by the time n_τ achieve the limiting state of formula:



$$[\tau] = \frac{\tau_{op}}{n_{\tau}}. \quad (3)$$

The life cycle in [2] is determined by the regularity of reducing the technical condition in the process of operation to the limit when reaching the resource, is equal to zero, at which the operation becomes dangerous.

In the section shown an explanation of how the reduction of the period of safe operation depending on the reduction of stocks of thicknesses and strength reserve of the walls, considered in work [2].

The thickness of the vessel wall with wear and tear due to corrosion (chemical or electrochemical) or mechanical effects (erosion) reduced time intervals between the first, second and subsequent time interval and is determined by calculation.

The time intervals between the first (t_1), – second (t_2), ..., – i – m (t_i), if $k=1\dots i$.

Data for calculation of reserves of strength are taken from measuring the actual thickness of the vessel walls during technical diagnosis. To determine the time intervals between overhauls designed the classification parameters resource at all stages of the life cycle of TU [2], which is given in the table.

Table. The classification parameters of the resource at various stages of the life cycle technical device

Stage of the life cycle	Option technical state	Design parameters wall			The estimated parameters resource	
		Thickness	Reserve of wall thickness	Reserves of strength		
Design	Design	S_p	n_p^s	n_p	Design	T_p
Manufacture	Initial	S_u	n_u^s	n_u	Initial	T_u
Service life	Actual	S_k	n_k^s	n_k	Remaining	T_k
Service life termination	Limit	S_p	n_n^s	n_n	Residual	T_o
Damage probability	Critical	S_{min}	n_{lim}^s	n_{lim}	Limiting	T_{lim}

In accordance with the table in the time intervals from the start of operation until the end of the current resource, then before the end of residual life and on up to the end of the full resource, determine the stock sizes of wall thickness, and reserves of strength. Conversely, knowing the intervals between the value of the stocks of wall thickness and reserves of strength, determine the time intervals from the start of operation until the end of the current resource, then before the end of residual life and on up to the end of the full resource.

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– reserve of wall thickness:

$$T_p^s \geq T_u^s \geq T_k^s \geq T_o^s \geq T_{lim}^s = f(n_p^s \geq n_u^s \geq n_k^s \geq n_n^s \geq n_{lim}^s); \quad (4)$$

– reserves of strength:

$$T_p \geq T_u \geq T_k \geq T_o \geq T_{lim} = f(n_p \geq n_u \geq n_k \geq n_n \geq n_{lim}). \quad (5)$$

Under the terms of the (2, 3) proposed the prediction model of the resource [2]. Figure 1 shows the model diagram of the service life forecasting based on transition regularities from the initial and actual technical state to the limit technical state.

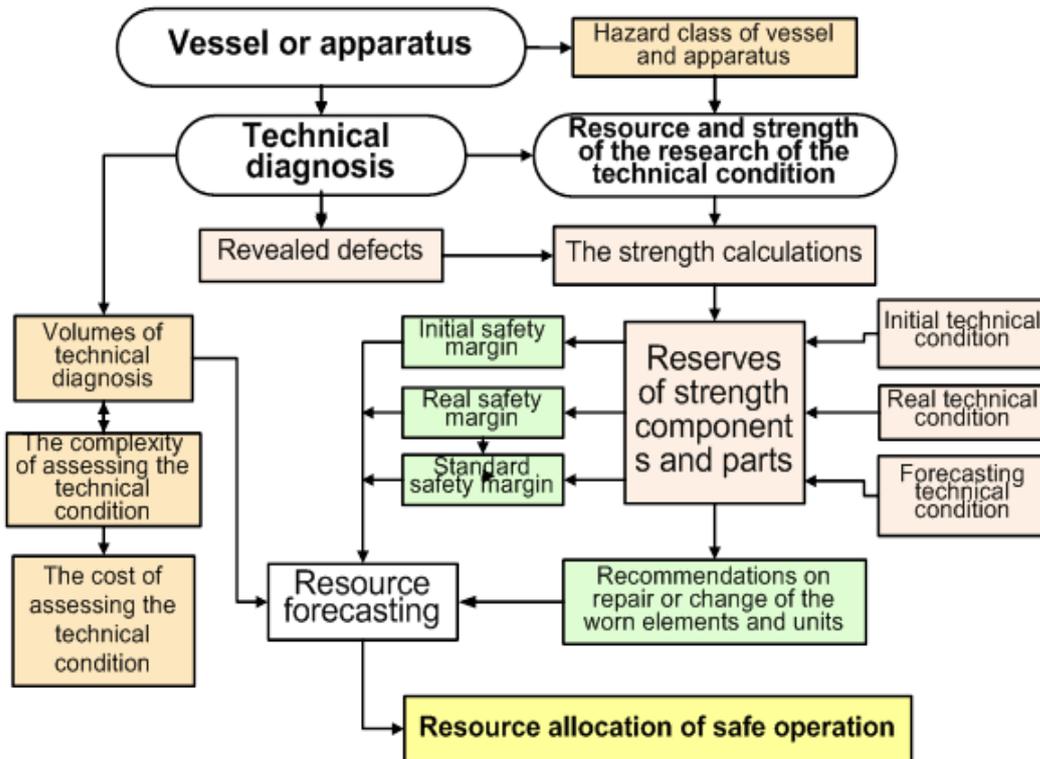


Fig. 1 - The model diagram of the service life forecasting based on transition regularities from the initial and actual technical state to the limit technical state

To implement the model is applied to the transition function from the initial (source) and the actual (real) the technical condition. The model shows the relationship between the past the technical condition (before commissioning) and the present technical state (moment of technical diagnosis), to predict the future of the technical condition under which a high probability of failure. The model allows to calculate the residual life and to determine the time of further safe operation of technical devices.

As you know, reserves of strength as wear of the walls decrease with time and are fixed parameters determined at specific points in time, the technical diagnosis, but for predicting the resource they are not enough. Therefore, for the generalized characteristic for the resource definition in [4] first applied the rate of reduction in reserves of safety and reserves of the wall thickness, which ensure the safety of the technical device for the subsequent period of operation, that is, from the current technical inspection (technical diagnostics) to achieve the future technical condition, in which a high probability of failure.

The degree of reduction in reserves of strength and the degree of reduction of the stock of the wall thickness can be determined by the formulas:

$$K_k = \frac{n_k}{n_u - n_k} \text{ and } K_k^S = \frac{n_k^S}{n_u^S - n_k^S}. \tag{6}$$

where k - the ordinal number of technical diagnostics and the resource of stress research, defined as $k=1...i$;

n_u and n_u^S - initial reserves of strength and the reserves thickness of the wall at the time of manufacture of the vessel;

n_k and n_k^S -the current reserves of strength and reserves of the wall thickness;

n_n and n_n^S -regulatory reserves of strength and reserves of the wall thickness.

The degree of reduction in reserves of strength K_k and the degree reduction of stock of the wall thickness K_k^S show the wear for the period from the initial or current state, and the limiting state, and the adopted as a safety factor, as proposed in [3].

The degree of reduction in reserves of strength K_k and the degree reduction of stock of the wall thickness K_k^S show the wear and tear of the vessel wall, which is possible over a period of time from the initial or the current state until reaching a limit state. These values are taken as the safety factor that has been proposed in [3].

Applying the formula (4) as a radical expression, obtain a quadratic dependence for calculation of the resource of the technical device first shown in [4], which is represented by the formula:

$$T_k = t_k \sqrt{\frac{n_k}{n_u - n_k}} \tag{7}$$

The results and discussion

According to the formula (5) is designed and constructed by the exponential dependence of the resource from the reserves of wall thickness. A graph of the resource from the current stock of wall thickness is shown in figure 2.

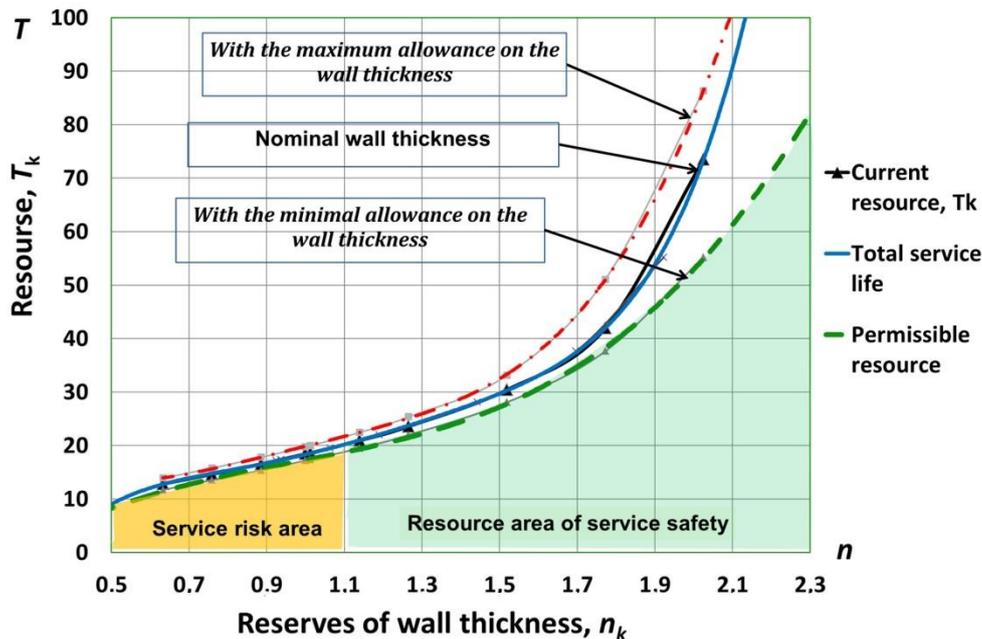


Fig. 2 - A graph of the resource from the current stock of wall thickness

However, the formula (5) does not reflect the impact on the resource volume control in the technical diagnostics and does not reflect the impact of defects and the degree of danger of destruction of technical devices, as shown in the diagram (figure 1) and is given by formulas (2, 3). To improve the reliability and accuracy of the calculation of the resource [4], shows the formula, which takes into account the volume control in the technical diagnostics, the presence of defects and the degree of danger of destruction of technical devices:

– original (source) of the resource at time of manufacture technical devices:

$$T_u = f(n_n, n_u, W_f, \xi, \beta); \tag{8}$$

– current (settlement) of the resource for the period of technical diagnosing at time k :

$$T_k = f(n_n; n_k; W_{fk}; \xi_k; \beta_k); \quad (9)$$

– residual life determined by the results of the initial or subsequent technical diagnostics for a period of time $(k+1)$:

$$T_o = f(n_n; n_{(k+1)}; W_{f(k+1)}; \xi_{(k+1)}; \beta_{(k+1)}), \quad (10)$$

where n_k – the stock (strength, stability, etc.) specified for the period of technical diagnosing at time k ;

$n_{(k+1)}$ – stock (strength, stability, etc.) in specified for a period of time $(k+1)$, which will come over the next technical diagnosis;

W_f – effective technical diagnostics;

ξ – coefficient, of responsibility of the technical device;

β – coefficient taking into account the presence of valid or invalid of defects identified during the technical diagnostics that will be addressed during the repair.

For example, the vessels depending on the capacity or nominal diameter, and also depending on the maximum allowable working pressure is determined by the category or categories of risk (1st, 2nd, 3rd and 4th), which in [2] are characterized by the coefficient of responsibility. Because the definition (refinement) of the corrosion rate can be made at various stages of the life cycle of a technical device, respectively, and the allowable resource can be defined (to be refinement) at different stages of the life cycle.

Substituting in the formula (5) reserves of strength or thickness of the housing wall and that the reduction factors (6, 7, 8), we obtain formulas for the calculation:

– original (source) of the resource at time of manufacture technical devices:

$$T_u^s = [\tau_u] \cdot \sqrt{W_f \cdot \beta \cdot \left(q \frac{s_p}{s_u - s_p} \right)^\xi}. \quad (11)$$

– current (settlement) of the resource for the period of technical diagnosing at time k :

$$T_k^s = [\tau_k] \cdot \sqrt{W_k \cdot \beta_k \cdot \left(q_k \cdot \frac{s_k}{s_u - s_k} \right)^\xi} \quad (12)$$

– residual life determined by the results of the initial or subsequent technical diagnostics for a period of time $(k+1)$:

$$T_o^s = [\tau_o] \cdot \sqrt{W_o \cdot \beta_o \cdot \left(q_o \frac{s_o}{s_u - s_o} \right)^\xi}. \quad (13)$$

Thus, the prediction model of the resource of the technical device can be implemented at any stage from design to achievement of a limit state.

On the given formulas it is possible to estimate the resource with the replacement or strengthening of worn-out elements of the technical device in the process of repair.

According to the proposed method from 2002 to 2011 was carried out to estimate the technical condition of the devices in number 3677 pieces, which are operated at hazardous production facilities of petrochemical industry. Evaluation of the resource was carried out by results of technical diagnostics and strength calculations of elements with respect to the amount of technical diagnostics, groups and classes of risk, indicators of corrosion and corrosion resistance of the metal, the presence of defects and other factors that caused the deterioration of elements of technical devices.

Conclusions

1. It is shown that the knowledge of the actual reserves of strength and reserves of the thickness of the walls, increases the accuracy and reliability of the assessment of the resource, and assignment of term of safe operation throughout the entire life cycle from manufacture to disposal.

2. The proposed method of predicting resource makes it possible to reduce the risk in operation of technical devices of hazardous production facilities throughout the entire life cycle from manufacture to disposal.

3. It is proposed the improvement of existing and creation of new guidelines for predicting resource of technical devices of hazardous production facilities, which is shown in the materials of all-Russian scientific-practical conference "Actual issues of industrial safety" [5].

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