Methods of Building Residual Life Calculation

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ABSTRACT

This paper proposed several methods of building residual life calculation, the results on the basis of which the life assessment of certain structural elements or the entire building is performed. The timely evaluation of building technical condition allows you to determine a building residual life prior to overhaul or decommissioning.

INTRODUCTION

Every year the main enterprise funds become obsolete, often within the factors which negatively affect the condition of building structures. Currently, a large number of buildings with a used standard life is operated. The accidents of these objects may lead not only to economic losses, but also to a significant harm of environment. These hazardous production facilities include almost all the main industrial buildings [1].

The issue of building residual life and the possibility of its operation period prolongation becomes urgent. Currently there are different approaches to the calculation and assessment of residual life: according to the appearance of critical defects; by defects (cracks) development period; by statistical method. Neither of these methods may clearly predict the resource and thus prevent possible accidents of structures and buildings.

The technical condition analysis of several thousand operated buildings and the results of buildings and facilities accidents investigations over the last decade has allowed to develop a methodology for residual life and the methods of its calculation.

This article is a logical continuation and development of previously published author methods [2,3,4].

Investigation methods:

The approach based on the principle of "technical condition safe operation" is proposed as the basic concept for the building residual life calculation. According to this approach, the evaluation of an object technical state is carried out by the technical state parameters, providing its safe and reliable operation in accordance with the technical and (or) design (project) documentation and residual life is determined according to certain parameters of technical condition. The parameters the change of which (separately or in a certain set) may lead to inoperable or extreme condition are accepted as technical condition parameters.

Main study:

There are the following technical condition parameters depending on extreme state criteria and an object operation conditions:
- characteristics of materials (mechanical characteristics: yield stress, stress limit, hardness, fracture toughness, endurance, long-term strength, creep limits, chemical composition, microstructure characteristics, etc.);
- safety factor (by yield strength, durability, long-term strength, creep, fracture toughness, stability, by the number of cycles or stresses at cyclic strength calculations);
- technological parameters (temperature, vibration parameters, operation modes, etc.).

The estimation of technical condition parameters and the criteria selection is performed according to technical documentation analysis results, operational (functional) diagnostics data, expert examination [5].

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The prediction of residual life or the establishment of an assigned resource is carried out in accordance with the change principles of core parameters obtained at the analysis of damage development mechanisms and (or) the functional parameters measurement results. An expert assessment is based on:

• the analysis of technical and operational documentation;
• operating conditions analysis;
• obtained data results concerning visual measuring control, instrumentation control, non-destructive testing, the determination of structure spatial position;
• verification calculation results.

The structure technical state is divided into five levels: serviceable; operational; limited use; prohibited or abnormal.

The decision to extend the operation of a building with the determination of its residual life, or the need to calculate residual life is based on obtained results and operation experience analysis. The residual life of an object must be set on the basis of aggregate information by the prediction of its technical condition according to main parameters till the attainment of an ultimate state.

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- the parameters of a building technical condition are known;
- the determining parameters of technical condition, varying according to identified mechanism of object elements damage are known;
- the criteria of an object extreme states are set the attainment of which is possible at the identified damage development.

The criteria for the metal frame building residual life calculation are:

• wear and tear;
• static strength taking into account defects and temperature effects;
• corrosion;
• fatigue.

Results:

The residual life calculation may be performed by one or several criteria. In general the choice of calculation method for residual life on a particular criterion should be justified by the accuracy and reliability of the obtained data, as well as the requirements of accuracy and reliability of projected object resource and the risk of its further operation.

The residual life calculations within extreme states criteria states are performed according to the following methods:

Residual life calculation depending on physical wear:

Overall assessment of building damage is performed by the formula
where $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_i$ are maximum damages for certain types of structures; 
$a_1, a_2, \ldots, a_i$ is the significance coefficient for certain types of structures.

Relative assessment of building damage is performed by the formula

$$\gamma = 1 - \varepsilon$$  \hspace{1cm} (2)$$

The wear constant is determined according to survey data:

$$\lambda = -\frac{\ln \gamma}{t_\phi}$$  \hspace{1cm} (3)$$

where - service life in years at the time of examination performance.

A building service life in years is determined since the beginning of operation till an according to the following formula:

$$T = \frac{0.16}{\lambda}$$  \hspace{1cm} (4)$$

**Calculation of residual life by static strength:**

The residual life by limiting state criterion which is the allowable stress makes:

$$\frac{[\sigma]}{\sigma_0} - \varepsilon$$  \hspace{1cm} (5)$$

where $\sigma_0(t)$ is tensile strength at the time of survey performance; 
$[\sigma]$ is tensile strength according to calculation; 
$\alpha$ is the rate of mechanical properties reduction.

The rate of mechanical properties reduction:

$$\alpha = \frac{\sigma_0 - \sigma(t)}{t}$$  \hspace{1cm} (6)$$

where $\sigma_0$ is standard tensile strength; 
$t$ - the time since operation start until a survey end.

**Residual life estimation by structure corrosive wear:**

Residual life of building structures subjected to corrosion is determined by the formula

$$T_c = \frac{S_p - S_p}{\alpha}$$  \hspace{1cm} (7)$$

Where $S_p$ is the actual minimum wall thickness of an element, mm; 
$S_p$ is the estimated value of a wall element, mm; 
$\alpha$ is a uniform corrosion rate, mm/year.

The uniform corrosion rate is determined as follows:

$$\alpha = \frac{S_n - S_p}{t}$$  \hspace{1cm} (8)$$

where $S_n$ is an executive wall thickness of an element, mm; 
$t$ - the time since the operation start till a survey end, years.

**Calculation of residual life by structure fatigue factor:**

Cyclic operation resource is determined by the formula

$$T_c = \frac{T_\phi \cdot [N]}{N_0}$$  \hspace{1cm} (9)$$

Where $T_\phi$ is the operation period from the beginning, years; 
$[N]$ - allowable number of load cycles; 
$N_0$ - the number of load cycles during operation period.

The remaining operation life is determined by the formula:
\[ T_{ocm}(u) = T_u - T_e \]  

(10)

Conclusions:

According to the results of residual life calculation the assessment of building structural elements of the building or the building as a whole is performed.

When the residual life is calculated on several criteria the resource is assigned by the minimum value.

On the basis of an object technical condition evaluation and the residual life evaluation a reasoned decision is taken concerning the possibility of an object further operation in accordance with the residual or assigned life or its repair, operating parameters reduction, a different purpose use or decommissioning.

REFERENCES