Atlantis Highlights in Material Sciences and Technology (AHMST), volume 1
International Symposium "Engineering and Earth Sciences: Applied and Fundamental Research" (ISEES 2019)

Formation of a System for Predicting the Reliability of Structural Materials

Shakurov N.G.
Department of Mechanics and Machine Building Technology
Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky
Oktyabrsky, Republic of Bashkortostan, Russia
naelsha@ya.ru

***Abstract* — As the complexity of the machines and equipment construction, the expansion of their use, increasing automation in the oil and gas sector, increasing loads and speeds the requirements for the reliability of technical facilities will continuously increase. This article resents the system of evaluation and prediction of reliability of machines and equipment, the use of which can improve the level of product quality management and provide the necessary level of reliability.**

Keywords* — *reliability; quality of primary blank; aging of materials; non-destructive methods of control; speed of destruction processes; intercrystalline corrosion; methods of forecasting.

I. Introduction

Reliability in mechanical engineering is defined as the characteristic of the object to keep in time and within the value limits of the data item, which characterize the ability of the product to perform the required functions. The most important features that characterize the reliability of machines and equipment are: infallibility, endurance capability, maintainability function and storageability. For a reasonable choice of technical systems used for oil and gas production, it is necessary to develop a quality assessment system and reliability prediction [1].

The quality of machines is understood as a set of properties that determine the ability, at the required level, to ensure their official purpose. The main indicators characterizing their quality are: power efficiency, effectiveness, endurance capability, reliability, safety.

This article discusses the problem of forming the level of reliability at the life cycle stages of the product. Reliability is understood as a feature that determines the ability to maintain over time, within the established limits, the production characteristics of machines that ensure the performance of the required functions in certain operating conditions.

In mechanical engineering, when describing the stages of creation of products, used such stages of the life cycle as: engineering design, production engineering, manufacturing, production activity, repair. At each life cycle stage a level of quality is formed, including the reliability of the product [2]. The variety of product characteristics that are formed on different life cycles makes the creation of the required level of reliability, to some extent, difficult.

To solve the problem of creating the required level of quality, it is proposed to develop a general reliability program that establishes a set of interrelated requirements and activities, indicating the stages and types of work separately at each stage of the product life cycle.

It is very important to take into account the specifics of each stage in ensuring reliability and cause-effect relationships that can affect, in the future, the performance of machines.

When adopting such a technique, it becomes possible to introduce at each stage a monitoring system and diagnostic engineering; analysis of the causes of failures and on this basis to develop measures that will make it possible to guarantee the achievement of the established level of reliability.

II. Analysis of Materials Structures and Quality Assessment Procedures of Machine Parts

One of the first stages of assessing the quality of parts can be the analysis of the chemical composition of the material details, using this methods:

- gravimetrical;
- volumetrical;
- chromatographic analysis;
- electroanalysis;
- atomic spectroscopy,

and determine whether the ratio of chemical elements and their compounds in the alloy, established for this brand of material requirements and whether the amount of impurities in the alloy within acceptable limits.

The next step in assessing the quality and reliability of materials structure is to control the structure of materials and the degree of defects in the material of blanks [3].

To analyze the structures of metals and alloys, optical methods can be used, by which are identified:

- types of stages;
- volume ratio of the stages;
- grain size;
- grain size and grain extraction distribution;

- average grain size of the second stage

and, on this basis, conclusions about the quality of the structure are formed. Along with optical methods, supersonic survey, magnetic methods and x-ray flaw detection methods can also be used to detect defects in the metal structure. In addition to internal defects in the structure of the material, visual-optical, capillary, magnetic, eddy-current and radiation methods can be used to detect defects coming to the surface of the blanks. Internal defects are determined by the types of technologies used in the blanks obtained by pressure treatment can be in the form of small breaks, overlap, cracks, non-metallic inclusions, in cast – in the form of gas inclusion, void structure, liquation, variation in wall thickness, the most significant type of determination of this type of blanks defects is the pulse-echo technique used to detect lack of adhesion [4]. It should be noted that if the welding methods and heat treatment were used in the manufacturing of the structure, this defects can appear [5]:

- void structure of welded joint
- high-temperature cracking;
- slag shots;
- faulty fusion;
- structural deformation
- cold cracking material

To identify this type of defects in practice, nondestructive inspection techniques are used.

For the formation of a predictive system reliability assessment of structural materials necessary to conduct studies of the degree of structure changes and defects during the time of the expiration of the service life of the part and based on the comparison of the changes in the structures and defects to provide a preliminary assessment of reliability indicators.

In metal structures, the level of reliability of parts is significantly affected by the degree of accuracy of parts. The inaccuracy of the geometric shapes of the dimensions and the location of the conjugated surfaces leads to the fact that secondary stress and accelerated wear under the influence of loads can be formed during movements.

With cutting action the top layer of the part material undergoes significant plastic deformation, as a result of which there are additional internal voltage, hardness increases, surface cracks and small breaks may appear. The rate of destruction of parts after machining depends on the structure and properties of the material.

The level of reliability of machine parts is also influenced by the change in time of mechanical-and-physical properties of materials structure during the service life or shelf life, which is called ageing.

The ageing can lead to improvement and deterioration of the individual properties of the material. The main types of transformation of the material in the solid state include:

- allotropic polymorphic transformation;
- martensitic transformation и breakage martensite structure
- break-up in solid state and breakage supersaturated solid solution.

The greatest influence, from the point of view of reliability, have ageing processes associated with the breakage of solid solutions. In ageing alloys, stress corrosion cracking is often observed, which can lead to failure. Therefore, it may be appropriate to assess the reliability of machines to carry out a system analysis of changes in the size and quality characteristics of parts and determine the possible life of their operation.

III. TECHNICAL INSPECTION AT THE STAGES OF MANUFACTURE OF PRODUCTS

The main technological stages of production include:

- work-pieces manufacture;
- machine work;
- heat treatment and thermomechanical working;
- assembly work.

And for each of them should be carried out technical control, which determines the level and quality parameters: blanks, used types of heat treatment; factors and parameters of surface treatment quality and accuracy of parts; quality of assembly and testing of products [2, 6].

For the processes used in the production of parts, the main factors of the manufacturing system directly affecting the level of reliability of products is:

- mechanical-and-physical propertiesand workability
- configuration, construction and quality of treating forming tool;
- type and performance capability of processing facilities
- technological parameters of blank's generation of geometry and working method;
- solutions, norm and quality of finishing operation
- quality control technique of parts and manufactured products.

To ensure the required level and reliability at the stages of production is necessary to develop regulatory and technical norm documentation references and quality control systems and acceptance of products.

Quantitative indicators of reliability of technological systems and their elements can be presented below (figure 1).

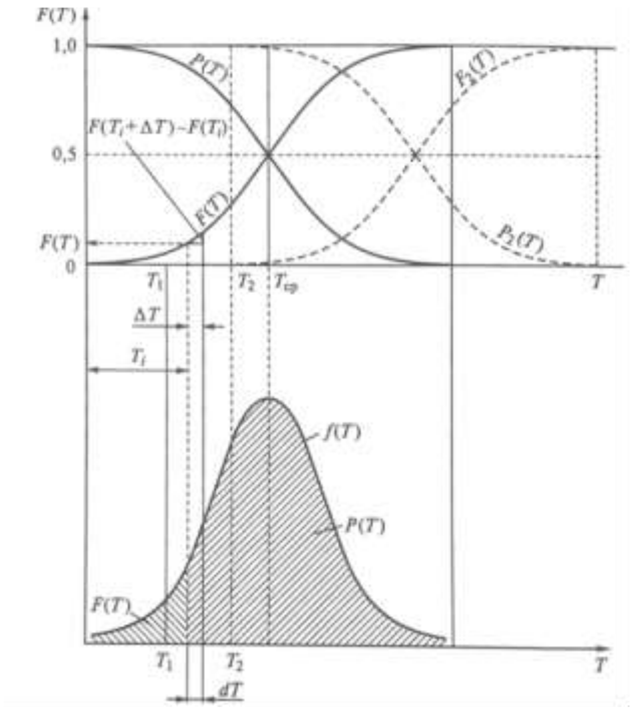

Fig. 1. Accumulated distribution and density of distribution of failure time;: F(T) - accumulated distribution to refusal; T – amount of failure time; T_i –designate level; P(T) – probability of survival; T_2 – extended utilization without faiure; P_2 – probability of survival is equate $F_2(T)$.

An important role in identifying these causes is played by the Pareto diagram, which reflects the weight of various factors on their contribution to the decline in quality.

Factors that affect the quality of products – parts from the spool unit or from the products as a whole, part defects, causes of defect, production operations of part cutting, performers, etc. – are located on the diagram by the decreasing degree of their influence on the level of negative consequences, which may be the amount of losses due to defects, the number of failures, failure rate, etc. Thus, in the left part of the diagram are grouped factors that are more likely to be subjected to analysis (figure 2).

So, on the diagram (Fig. 2) one can see that two of the ten components account for 75% of the total amount of losses. Likewise building diagrams, in which the abscissa shows numbers instead of the names of the parts, as indicated in Fig. 2 are defects on one of the components, for example: low external diameter; there are sticks on the cutting point; high thread pitch; the increased bevel, etc., or causes a specific defect, for example: obsolete drawing; offset of copier; error in machine operation; operator inexperience; the inaccuracy of the machine; the inaccuracy of the instrument, etc.

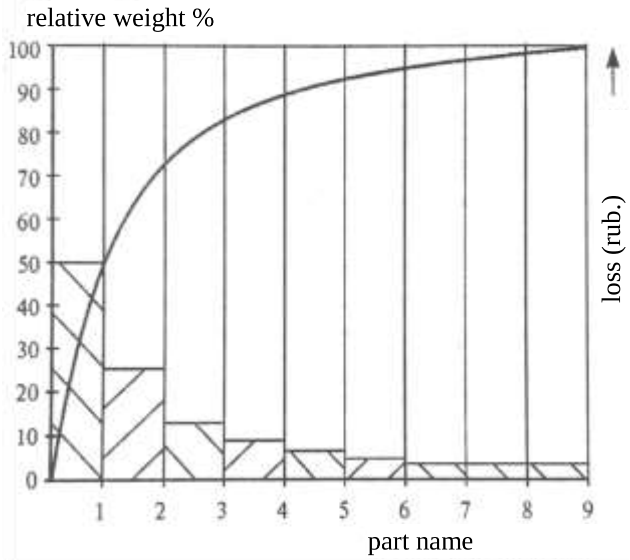

Fig. 2. Pareto's chart

To speed up the processes of debugging and ensure the level of reliability inherent in the construction, it is necessary to develop and implement an data retrieval system (DRS) based on a computer with a perfect information retrieval base as part of the overall information system of the enterprise. This system includes a drive and direct and feedback channels. Information about defects and proven measures to prevent them is systematized in the storage (data bank). And, of course, the more statistical data in the bank, accumulating the experience of the industry, the higher the probability of determining the cause of newly emerging defects. Through the direct communication channel, the request is sent to the system with a description of the defect – the part, manufacturing technology, dislocation and the nature of the defect. Information on the causes of the defect and measures to prevent it is provided through the feedback channel, if appropriate information is available.

IV. Control of the shape and size of parts

It should be noted that a special place in the solution of the problem of ensuring the required level of reliability is occupied by the system of maintenance and repair of machines. Therefore, for the formation of an effective program to ensure reliability, it is necessary to conduct a complete analysis of the state of the machine and make the choice of an effective system.

When analyzing the reliability of the structure, it is proposed to carry out measurements, since during operation the structure, shape and dimensions of the parts change under the influence of loads or due to changes in the structure of the material [3, 7]. This is especially true of the problem of tribological failures. As practice shows, wear is one of the main causes of failures and limit conditions

Wear is classified into the following types: abrasive, w hydroabrasive, hydro erosion, gas erosion, fatigue, wear or seizing, fretging corrosion, corrosion-mechanical, electro erosion, hydrogen.

Failures functionality of the products on tribological criteria, are the events with the achievement of wear of the mating member of the structure to the maximum possible values, violations of the conditions of lubrification and the onset of the period of intensive wear, with cutoff value of the coefficient of friction.

Failures of machinery and equipment can also occur due to the destruction of parts under the influence of corrosion, when the allowable thickness of the metal under the influence of corrosion below the set level. The most common types of corrosion are:

- gas corrosion;
- utdoor corrosion;
- electrocorrosion;
- current-stray corrosion;
- contact corrosion;
- corrosion at friction;
- fretting corrosion;

Depending on the state of the corrosion process, along with other types of exposure, when assessing the reliability of the isolated:

- corrosion cracking of metal with simultaneous exposure to corrosive environment and external or internal stresses;
- corrosion fatigue – reduction of the metal fatigue limit that occurs when the corrosive environment and mechanical loads are simultaneously exposed;
- corrosion embrittlement of the material;
- Corrosion under stress: corrosion of metal under the simultaneous action of corrosive environment and mechanical loads.

Machines and equipment of oil and gas fields can be significantly subjected to corrosion, which leads to premature wear of the units of installations, reduces the overhaul time of equipment on pipelines. There are basic types of corrosion: pitting, local, undersurface, sellective, intercrystalline corrosion, spot corrosion, corrosion cracking, which can lead to lower levels of equipment reliability [8, 9].

V. Development of reliability system of details

To ensure the necessary level of quality of machinery and equipment, it is necessary to form a reliability system:

- to analyze the main factors determining the reliability of machinery and equipment;
- determine the systematic relationship between the level of reliability and the state of the design;
- take possible measures to reduce the level of accident rate of machinery and equipment.

In addition, it is necessary to create an effective system of maintenance and repair, for the implementation of which it is necessary:

- provide availability and removability of structural elements, possibility of replacement of details, units, assembly units for application of high-quality assembly;
- the possibility of using effective repair technologies that provide the required level of reliability at an acceptable cost;
- provide the required level of quality of the restored and non-repaired details which are subject to replacement at repair of the product;
- to apply methods of the accelerated analysis of reliability of a product after carrying out repair;
- to ensure the testability of the repaired units and parts;
- use the possibility of using effective diagnostic systems to assess the maintainability of the product;
- to form requirements to ergonomics of the repaired products;
- to determine the possibility of creating mechanized and automated systems for the development and Assembly of products;
- create automated systems to restore the size and quality of materials and surface condition of parts.

When assessing the level of reliability and forecasting, it is necessary to take into account that many parameters for which reliability is calculated are random variables, and therefore it is necessary to determine the laws of distribution of random variables and apply methods of regression, correlation analysis and methods of statistical modeling.

The objectives of standardization in the field of reliability of equipment are:

- development and updating of the regulatory framework to regulate the interaction of stakeholders (developer, manufacturer, supplier, consumer, customer) while ensuring reliability at all stages of the product life cycle;
- regulation of methods for solving typical reliability problems as a basis for the development of appropriate rules, procedures, etc., used in the creation, testing and operation of specific products;
- ensuring the level of reliability of products, the requirements for which are established by state bodies.

To achieve these goals, standardization in the field of reliability solves the following main tasks:

- establishes the provisions and requirements of organizational, terminological, technical, technological, economic and legal nature, aimed at ensuring the reliability of equipment as a basis for the interaction of the parties involved in its development, production and operation;

- prescribe the ways and methods of solving typical problems of reliability, which confirmed the effectiveness of the necessary testing (experimental, practical experience, scientific and technical expertise). It meets modern scientific and technical level. And also, it is adequate for practice;

- establishes quantitative restrictions on the level of reliability and methods of its control in the standards of the type of Trade and Technology Division for products. The requirements for them are determined by state bodies.

Standardization in the field of reliability should be integrated and interlinked with standardization on safety, survivability, technical diagnostics, statistical and other methods. At the same time, it should be considered as an integral part of the overall standardization of quality management.

V. THE RESULTS OF THE STUDY

The conducted research can contribute to the formation of a safe and effective system of oil and gas production, in which there are accidents or failures of equipment of oil and gas fields or transport systems, which can lead to significant material damage and environmental disturbances. It is necessary for all types of equipment to establish the composition of tests for reliability, failure criteria, to determine the calculation methods of evaluation and on the basis of comparison with the actual data to clarify them [1, 10].

To assess the actual condition of the equipment, it is proposed to use methods of technical diagnosis, which include:

- carrying out visual and measuring control in order to identify defects;

- application of acoustic emission control to monitor the development of defects in the operation of the equipment.

Using the results of research to determine measures to restore the technical condition of machines and equipment and ensure the required level of reliability.

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