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ON THE REGULARITY OF THE SERVICE LIFE SCATTERING OF A BATCH OF ENGINEERING PRODUCTS

Ugurlu Nadirov*[1] & Nariman Rasulov[2]
[1]Department of Engineering Graphics, Azerbaijan Technical University
[2]Department of Mechanical Engineering, Azerbaijan Technical University

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ABSTRACT
Taking into account the direct dependence between the service life of the products with the manufacturing quality parameter limiting it and the probability of the occurrence frequency of the products with certain parameters and quality, the regularity of the change of the service life of all products in the aggregate, are determined depending on the quality of manufacture.

KEYWORDS: service life, limiting quality parameter, scattering curve, frequency of occurrence

I. INTRODUCTION
Usually qualitative indicators of products are distributed according to the normal law. In a number of cases (for example, when the failure of a product is related to the wear and tear limiting it) the relationship between the service life (durability) of products and the manufacturing quality parameter limiting it obeys a direct law (normal wear period) [1,6,9,8]. For example, the service life of the plunger-bushing pair is limited by the limiting value of the gap between the friction surfaces of the parts. Since the limiting quality indicator for a certain set of similar products can vary at some acceptable limit, their service life will also vary within a certain range. The study of the laws their change for the set of products produced has both theoretical and practical significance. Since there is not enough information about the patterns of changes in the reliability of products, it is impossible to choose effective improvement.

II. GENERAL STATEMENT OF THE PROBLEM
Products of an equal name, purpose and size (for example, CK3-200x16 gate valves, etc.) are manufactured by various machine-building plants with different qualities, even sometimes with different tolerances. The difference in the values of technological parameters, characterizing the quality of manufacturing of products and limiting their reliability, determines the difference in performance indicators, including the service life. Qualitative indicators inherent to each product, forming a level of utility and reliability of the product, being the main output technological parameters of manufacture, serve as basic technological criteria for its evaluation and comparison with similar products [12, 13]. In the modern world with highly developed level of science and technology, the determination of the utility level of the use of a batch (or even more) of products in the aggregate produced by an enterprise, comparison with similar results of another enterprise, and the assessment of the use of the activity of the manufacturer's enterprise are topical problems of the day. The solution of these problems would play a special role in the implementation of ISO standards in the field of quality management [4-11]. Improving the quality of manufacturing products and thus improving their performance, is an unchanging task of engineering. Each operated product demonstrates performance indicators corresponding to its own manufacturing quality.
The purpose of the work is to identify the general relationship between the service life and its quality of product manufacturing parameter limiting it in the aggregate and its analysis.

III. THE SOLUTION OF THE PROBLEM
The relationship between the total service life of all products and the quality limiting index (x) depends on the frequency of occurrence of the quality indicator (m / n, where -n is the number of products in the main population, m is the number of products with quality parameters that fell into the accepted group interval) and on the functional relationship between the service life of the product (y) and the manufacturing quality index.

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$$U_{\sum} = \sum y\{x\} = f\{x, y(x)\} \tag{1}$$

If we assume that the quality parameter of the products is distributed according to the Gaussian law, and the change in their own service life obeys the law of the straight [2,5,7], then the change in the total service life of the products for the whole population will be determined according to the formula:

$$U_{\Sigma} = (b - kx) \cdot \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-a)^2}{2\sigma^2}} \tag{2}$$

where b and k are the parameters of linear dependence,
a- the mathematical expectation of a qualitative parameter of products,
σ - the standard deviation of the quality parameter.

Formula (2) is a mathematical model of the service life of engineering products. In formula (2), the second factor expresses the frequency of the appearance of the limiting quality parameter (curve 1), and the second (the line 2) their lifetime in Fig.1.

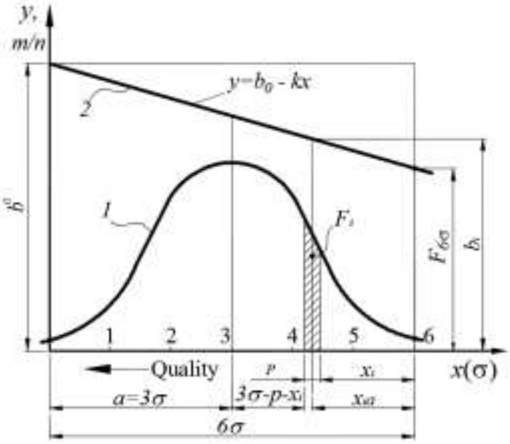

Fig. 1. Scheme to determine the regularity of changes in the total service life of products

It is known that the solution of the second factor of the dependence (2) is realized using the Laplace function using the data of the corresponding tables [2,5,7]. Therefore, there is a need for a tabular solution of the dependence (2). To simplify the procedure of problem solving, we assume that the manufacturing quality parameter changes in the interval $[(-3\sigma,\ 3\sigma)] \in T$ (where T is the tolerance for the quality parameter) and the ordinate axis of the coordinate system passes through the points of the abscissa (-3σ) of the normal law (Fig. 2). In this case, the dependence (2) takes the form:

$$U_{\Sigma} = (b_0 - kx) \cdot \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-3\sigma)^2}{2\sigma^2}} \tag{3}$$

where b_0 is the service life of the product with the best quality parameter (the longest service life of the products),
k- is the coefficient expressing the slope of the straight line (2),
x-variable, expressing the quality parameter of the product manufacturing, in the adopted coordinate system. According to the initial conditions accepted, the solution of the problem is: $a = 3\sigma$ and $(-3\sigma) \le x \le 3\sigma$. According to the scheme shown in Fig. 2., the total service life of products whose manufacturing quality parameters are in the interval $[x_i; (x_i + P)]$ (where P is the interval value, is the step of the group) is equal to

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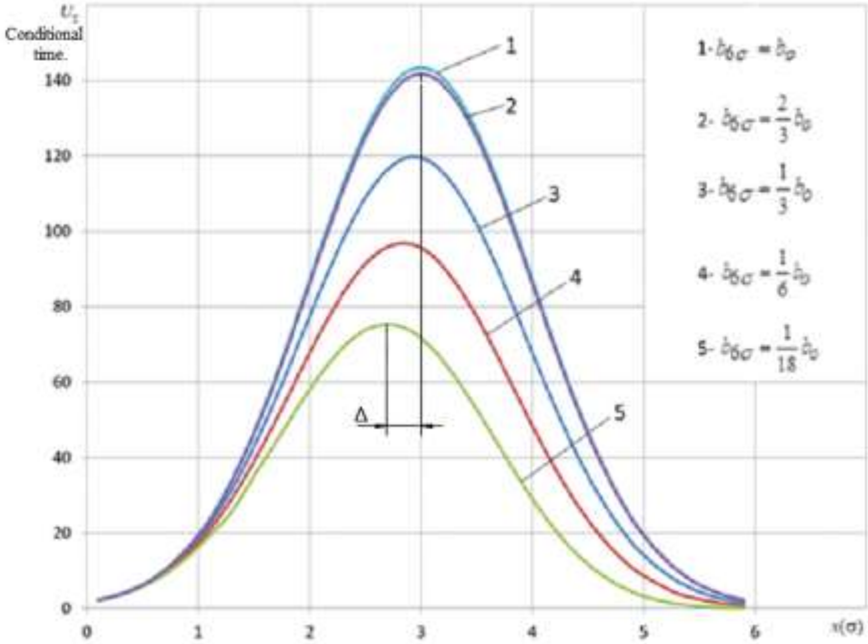

Fig. 2. Dependence of the total service life of products on the quality parameter

$$U_{\sum i} = b_i \cdot m_i = b_i \cdot F_i \cdot n \tag{4}$$

Where m_i - the number of products with quality parameters that are within the selected interval,

b_i - the average life of these products,

F_i - the shaded area in Fig. 2., equal to the probability of occurrence of products with quality parameters in the range of the selected interval,

i - ordinal (desired) number of an interval (group).

Taking into account the adopted laws of change b_i (straight) and m_i (Gaussian law), we determine their values:

$$b_i = b_o - k \cdot x_{ia} = b_o - k(x_i + 0{,}5p) \tag{5}$$

$$F_i = \int_{-\infty}^{x_i+p} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-3\sigma)^2}{2\sigma^2}} dx - \int_{-\infty}^{x_i} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-3\sigma)^2}{2\sigma^2}} dx \tag{6}$$

Taking (5) and (6) into (4) into account, we obtain:

$$U_{\sum i} = [b_0 - (x_i + 0{,}5p)] \cdot n \cdot \frac{1}{\sigma\sqrt{2\pi}} \left(\int_{-\infty}^{x_i+p} e^{-\frac{(x-3\sigma)^2}{2\sigma^2}} dx - \int_{-\infty}^{x_i} e^{-\frac{(x-3\sigma)^2}{2\sigma^2}} dx \right) \tag{7}$$

The last formula allows us to determine the overall service life of all products that have a manufacturing quality parameter in the range $[x_i;(x_i + p)]$. Thus, the use of the last formula for the entire product set in the range of $[(-3\sigma), 3\sigma]$ will allow us to determine the functional relationship between the service life of all products and their manufacturing quality. Since the task of the work is to determine the dependence $U_\sum = f(x)$, which is generalized and does not depend on the number of products, in expression (7) n can be replaced with the probability of the occurrence of all products. Then:

$$U_{\sum i} = [b_0 - k(x_i + 0{,}5p)] \cdot \frac{1}{\sigma\sqrt{2\pi}} \left(\int_{-\infty}^{x_i+p} e^{-\frac{(x-3\sigma)^2}{2\sigma^2}} dx - \int_{-\infty}^{x_i} e^{-\frac{(x-3\sigma)^2}{2\sigma^2}} dx \right) \quad (8)$$

Here, $x_{(i+1)} = (x_i + p)$ and the number of intervals (groups) is equal to $\frac{6\sigma}{p}$. When, $i = 1$,

$x_{i=1} = 0$; when $i = \frac{6\sigma}{p}$, $x_{6\sigma/p} = (6\sigma - p)$.

For the construction of the empirical distribution curve $U_{\sum} = f(x)$, the values of $U_{\sum i}$ for each group $(1 \le i \le 6\sigma / P)$. are determined. At the same time, the generally accepted methodology for constructing empirical scattering curves is used. The value of the interval (step) was adopted
$P = 0{,}2\sigma$, the number of intervals $i = 30$. Analysis of the dependence (8) shows that the parameter of the curve $U_{\sum} = f(x)$ depends on the coefficient *k*, which determines the slope of the straight line (2) (Fig.1)
For the full evaluation of the curve, we took characteristic values for the coefficient *k*. To do this, the maximum service life b_o of the product with the best manufacturing quality was adopted (the value of b_0 is conventionally assumed to be equal to 1800 days). Designated characteristic values of service life for products with the lowest manufacturing quality, corresponding. The equation of service life of products is used in the form

$$b_{6\sigma} = b_o - k \cdot 6\sigma$$

And the values of coefficient k are determined.

$$k = \frac{b_o - b_{6\sigma}}{6\sigma}$$

Then:

1) with $b_{6\sigma} = b_o$; $k = 0$; . . . . . 5) at $b_{6\sigma} = \frac{1}{18} b_o$; $k = \frac{17 b_0}{108 \cdot \sigma}$;

Where $b_{6\sigma}$ is the service life of the product with the quality parameter 6σ.

$U_{\sum i}$ was evaluated for each group and empirical dependencies $U_{\sum} = f(x)$ were built for all options using the Excel program (Figure 2). In reality, options 1 and 6 are purely theoretical.
It should be noted that in this case, there is a multiplication of some part of the Simpson scattering law by the law of Gaussian scattering.
As expected, at $k = 0$ the scattering of the total service life of all species in aggregate obeys the normal law (curve 1, figure 2). By increasing coefficient *κ* the centers of products' service life grouping are shifted (Δ) towards its maximum value, the symmetry of the empirical distribution curves of scattering is distorted (curve 2-5, Fig. 2). Moreover, the larger the coefficient *k*, the greater the shift of the scattering curve and its grouping center.
The study shows that with an increase of coefficient *κ* the deviation of scattering curve parameter is increased from the parameters of initial normal law and families of scattering curves (3-5) are formed in the form shown in Fig. 2. Thus, it becomes necessary to study in detail such scattering curves.

IV. CONCLUSION

- Functional dependence of the total service life of a batch of products in aggregate on the manufacturing quality parameter limiting it has been proposed.
- The proposed dependence allows to predict the service life of a batch of products in engineering in aggregate, to evaluate and compare the activity of manufacturers' enterprises.

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