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The quality of aerospace equipment production analysis

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Abstract. The dependability of the equipment is not determined by the dependability of its component parts. Modern equipment for aerospace systems is so difficult that often, when predicting reliability indicators, overestimated values of failure rates are obtained. Future reliability, maintainability and durability indicators depend not only on the element base and operating conditions, but also on many other factors, such as: developers' qualifications and experience in creating similar projects, availability of input control of purchased products and technical training of manufactured equipment and its components. Assessing the impact of these factors on the reliability of the equipment is a very difficult task in full, for solving which the expert method can be applied.

1. Introduction

The development of integrated circuits has led to a rapid increase in the complexity of electronic systems, including aerospace. The complexity of the equipment and its component parts greatly complicates the analysis of dependability and obtaining reliable indicators of the reliability of the product being developed [1-3].

The failure rate of a product is the conditional probability of a product failure, determined on the condition that the failure did not occur before the considered time point [4]. The failure rate is the ratio of the density of the distribution of time to failure to the probability of failure-free operation during time t :

$$\lambda(t) = \frac{f(t)}{p(t)}.$$

When evaluating dependability, the exponential distribution is used more often than others, since it is typical for products consisting of many elements. The increased failure rate in the initial period of operation is eliminated by the use of technical training. With an exponential distribution, $\lambda(t) = \text{const}$.

According to [5], the failure rate of an electronic device is estimated by the formula:

$$\Lambda = K_a \cdot \sum_{j=1}^m \sum_{i=1}^n \lambda_{eij},$$



where K_a - the quality factor of the production of electronic devices; λ_{eij} - operational intensity of failures of the i -th type of elements of the j -th group; n is the number of elements of the j -th group; m is the number of groups of elements.

The operational failure rate of an element depends on many factors [5]: operating conditions, electrical loads, the quality level of the element (acceptance), etc.

The coefficient of quality of production reflects the level of organization of production and the sophistication of the technical process. This coefficient takes into account the difference in the failure rate of the elements in the device, depending on the regulatory documentation that guided the design. According to current Russian standards, K_a can take only two values: 1 and 0.2. That is, the difference in the failure rates of devices manufactured according to the "Moroz-6" military standards complex and according to the position [6, 7] is about 5 times.

In fact, the quality of production of radio equipment is not so much connected with the requirements of regulatory documentation, as with objective factors, such as: employees and management of the manufacturer, a quality management system, technical equipment, etc.

2. Factors affecting quality

The authors of [8], analyzing the statistics of many manufacturers, suggested that the following factors may be the cause of failure and are decisive in assessing the production quality ratio:

- The quality of the components K_1 ;
- The design process K_2 ;
- Production process K_3 ;
- Control system K_4 ;
- Induced process K_5 ;
- Defect-free process K_6 ;
- Process of deterioration (aging) K_7 ;
- Failures during the period of extra running K_8 ;
- External influences K_9 ;
- Increase in failure rate K_{10} .

In [8], expert questions are presented that are necessary for estimating weights for each factor. The questions are very diverse and cover all areas for obtaining an objective assessment of the enterprise, taking into account both the degree of qualification of employees and the technical aspects of development. The quality factor of production can be expressed as:

$$K_a = K_1 \cdot K_8 \cdot K_9 + K_2 \cdot K_{10} + K_3 \cdot K_8 \cdot K_9 \cdot K_{10} + K_4 \cdot K_{10} + K_5 + K_7 \quad (1)$$

The influence of each of the causes of failure on the quality factor is shown in the diagram (figure 1). It is clearly seen that the largest contribution - about 59% - falls on the design, production and control systems, which is consistent with the actual situation.

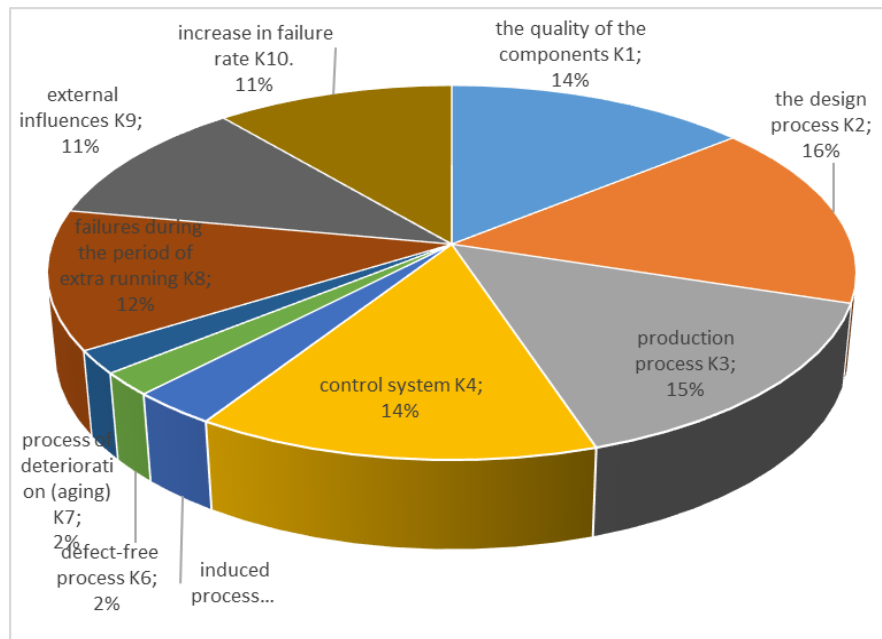


Figure 1. Diagram of the influence of the causes of failure on the value of the quality factor of production.

The numerical values of the factors influencing the quality factor of production are calculated using the following mathematical models. For factors K1-K7:

$$K_i = \alpha_i (-\ln(R_i))^{\frac{1}{\beta_i}},$$

where α_i and β_i are constants corresponding to each of the factors; R_i - is defined as:

$$R_i = \frac{\sum_{j=1}^{n_i} G_{ij} W_{ij}}{\sum_{j=1}^{n_i} W_{ij}},$$

where G_{ij} is the level of the j -th item of the i -th reason for failure. This level is rated between 0.0 and 1.0 (from worst to best). W_{ij} is the weight value of the j -th item of the i -th failure reason, n_i is the ordinal number of the criterion level associated with the i -th failure reason.

Table 1 shows the values of the constants α_i and β_i and their default values, for the case when it is not possible to estimate the causes of possible failures.

Table 1. Factors parameters.

Factor designation	The name of the factor	α	β	Default factor value
K1	Quality of parts	0,30	1,62	0,243
K2	Design process	0,12	1,29	0,094
K3	Manufacturing process	0,21	0,96	0,142
K4	Control system	0,06	0,64	0,036
K5	Induced process	0,18	1,58	0,141
K6	Defect free process	0,29	1,92	0,237
K7	Deterioration process	0,13	1,68	0,106

Factor K8 - failures during the period of running:

$$K8 = \frac{t^{-0.62}}{1.77} (1 - S),$$

where t is the time in years; S is the ratio of the number of detected failures to the total number of hidden defects in the product.

External influences factor K9:

$$K9 = \frac{0.855 \times (0.8(1 - e^{(-0.065(\Delta T + 0.6)^6)}) + 0.2(1 - e^{(-0.046G^{1.71})}))}{0.205},$$

where ΔT is the temperature change between operating modes, ° C; G - the value of random vibration during operation of the product.

The factor of increasing failure rate K10:

$$K10 = \frac{1.12(t + 2)^{-\delta}}{2^{-\delta}},$$

where δ is a growth constant, which is equal to R_i for this process.

3. Practical use

Consider the use of model (1) for real production. Suppose there is equipment developed by the provisions of [6, 7]. The necessary initial data for the calculation of factors K8, K9, K10 are:

- Operation time, $t = 43800$ hours (5 years);
- The ratio of the number of detected defects to the total number of hidden, $S = 0.6$;
- Temperature difference between operating modes $\Delta T = 5$ ° C;
- The value of random vibration during operation $G = 5.77$ g.

The values of the factors are given in table 2.

Table 2. Assessment of factors for equipment manufactured according to [6, 7].

Factor designation	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
Estimated value	0.127	0.048	0.045	4.657E-03	0	0.097	0	0,083	3,839	0.32

The calculated value of the production quality factor will be $K_a = 0.159$.

The error between the value specified in [5] and the calculated one is 20%.

4. Conclusion

The quality of equipment production depends on many factors. The reason for future refusal may be both technical and administrative.

Analysis of the quality of production equipment - is the task of the quality management system of the enterprise [9]. However, one should not ignore its obvious connection with dependability.

Provisions [6, 7] allow you to create highly reliable aerospace equipment by complying with a set of requirements (quality level of components, 100 percent input control, technical training, testing of prototypes for reliability), which allows to reduce the failure rate 5 times in assessing reliability. The expert technique [8], also based on statistical data, allows analyzing possible causes of failures and

identifying the “weak points” of production organization at the enterprise, numerically substantiating what consequences this will have for the reliability of newly developed equipment.

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