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# RELIABILITY OF CONSTRUCTIONAL PRODUCTION LINE

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***Key words:*** *construction, constructional production line, reliability, reliability characteristics of constructional production line, reliability factors of constructional production line*
**doi:**10.5937/jaes0-28674

***Cite article:***
Bredikhin, V. V., & Bredikhina, N. [2020]. Reliability of constructional production line. *Journal of Applied Engineering Science*, 18(4) 586 - 590.

***Online aceess*** *of full paper is available at: www.engineeringscience.rs/browse-issues*

Original Scientific Paper

Istraživanja i projektovanja za privredu
Journal of Applied Engineering Science

doi:10.5937/jaes0-28674

Paper number:18(2020)4, 731, 586 - 590

# RELIABILITY OF CONSTRUCTIONAL PRODUCTION LINE

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*The article discusses the most important quantitative characteristics of the reliability of constructional production line. The reliability of constructional production line, in the general case, is understood as its property to maintain its parameters in permissible, predetermined limits. One of the main parameters of constructional production line is its intensity. In addition, intensity is one of the main indicators characterizing the efficiency of the production line. Generally speaking, efficiency serves as a measure of system productivity taking into account the external environment. Therefore, in a particular case, the reliability of constructional production line can be understood as the stability of its intensity.*

*Key words: construction, constructional production line, reliability, reliability characteristics of constructional production line, reliability factors of constructional production line*

## INTRODUCTION

The most important concepts are reliability and failure in reliability theory. In determining reliability, first, two sides of the issue are distinguished: quantitative and qualitative ones. Reliability, as a property of the system, is characterized by a qualitative definition. The quantitative characteristics of reliability measure the manifestation of this property.

The reliability of constructional production line should be practically determined in real operating conditions, taking into account the complex effects of external and internal factors related to climate patterns and geographic features, the real operating conditions of constructional production line and the conditions for providing the necessary resources [1] to [ 3].

It is common to distinguish between the reliability of systems and the reliability of the elements that make up the reliability theory [4], [5].

We call a system any complex constructional production line: specialized (for example, production lines for laying utility networks); object (for example, production lines for the construction of individual buildings); complex (for example, construction of a residential quarter, microdistrict, including the construction of buildings for various purposes, roads, utilities, electrical networks, landscaping, etc.) [6], [7]. Elementary constructional production line (for example, installation of a building) is called an element.

Naturally, the division of the constructional production line into systems and elements is a conditional number, but it is necessary for the process of studying its reliability [8] to [10].

The reliability of the constructional production line, in the general case, is understood as its property to maintain its parameters in permissible, predetermined limits [11]. Intensity is one of its main parameters. In addition, intensity is one of the main indicators characterizing the efficiency of production line. Efficiency, in the general case, serves as a measure of system productivity taking into account the external environment. Therefore, in the particular case, the reliability of the constructional production line can be understood as the stability of its intensity.

The failure of the constructional production line, in the general case, means the exit of its parameters beyond the permissible, predetermined limits. In particular, the functioning of production line with intensity less than a predetermined one (low intensity) can serve as a convenient determination of failure.

## CONCEPT OF SYSTEM RELIABILITY

The reliability of any system is a broad concept, and therefore can be quantified only using a number of criteria. In this case, “by the criterion of reliability” we mean the sign by which reliability is evaluated [12]. The quantitative content of the reliability criterion is called a characteristic or reliability parameter. The introduction of quantitative reliability characteristics is caused by the need, since only with their help it is possible [13], [14]:

- calculate production line reliability;
- formulate requirements for reliability of designed production line;
- compare the reliability of various elements of constructional production line;
- calculate the actual construction time taking into account the reliability of production line elements;
- outline ways to improve production line reliability;
- calculate the required amount of basic and reserve resources necessary for the construction to be carried out on schedule and with the best technical and economic indicators.

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## RELIABILITY CHARACTERISTICS OF CONSTRUCTIONAL PRODUCTION LINE

Consider the most important quantitative characteristics of reliability of constructional production line.

1. The probability of functioning of production line with a given intensity $R_i$ can be expressed by the probability that the actual intensity (*I*) of production line *i* will be no less than the projected $i_з$:

$$R_i = l - F(I < i_3) = P(I \geq i_3) = \int_{i_{\min}}^{i_{\max}} P(i)di \tag{1}$$

2. The probability of completing a certain amount of work in the estimated time period $R_t$. In this case, it is necessary to take into account the inverse relationship between the intensity *i* and the duration *t*:

$$i = \frac{q}{t} \tag{2}$$

where *q* is the amount of work. Then

$$R_t = F(t \leq t_3) = \int_{t_{\min}}^{t_3} P_t(t)dt \tag{3}$$

that is, the probability of completing work on time is equal to the probability that this period will not exceed the given ($t_з$).

3. When designing the production line term for intensity ($t_0$), it is important to know its mathematical expectation (*M*):

$$i_0 = M(i) = \int_{i_{\min}}^{i_{\max}} iP(i)di \tag{4}$$

Statistically, the average production line intensity *i* is determined by the formula:

$$\bar{i} = \frac{i_1 m_1 + i_2 m_2 + \ldots + i_j m_j + \ldots + i_n m_n}{n} = \frac{\sum_{i=l}^{n} i_i m_i}{n} = \sum_{j=l}^{n} i_j P_l \tag{5}$$

Where *i*- observed intensity values; $m_i$- frequency of production line functioning with *i-th* intensity; *n* is the number of observations; *Pj* is the probability of functioning of production lines with the *i-th* intensity.

For large *n*, according to the Chebyshev theorem [15]:

$$i \approx M(i) = i_0 \tag{6}$$

4. The dispersion of production line rate $D_i$ is calculated as follows:

$$D_i = M(i - i_0)^2 = \int_{i_{\min}}^{i_{\max}} (i - i_0)^3 P(i)di \tag{7}$$

5. Similarly, the variance of the duration of a given amount of work $D_t$ is determined by the formula:

$$D_t = M(t - t_0)^2 = \int_{t_{\min}}^{t_{\max}} (t - t_0)^3 P(t)dt \tag{8}$$

The main characteristics do not exhaust the concept of reliability of constructional production line sufficiently. The probabilistic nature of both the intensity and the timing of construction is due to the influence of a large number of disturbing factors, which are most manifested in the form of various downtimes of constructional production line. As a result of this, we give the criteria necessary to assess the effect of obvious downtime on reliability to characterize the reliability of production line fully.

6. The mathematical expectation of forced downtime duration of production line is determined by the formula:

$$x_0 = M(x) = \int_{x_{\min}}^{x_{\max}} xP(x)dx \tag{9}$$

Accordingly, statistically [16]:

$$\bar{x} = \frac{x_1 m_1 + x_2 m_2 + \ldots + x_j m_j + \ldots + x_n m_n}{n} = \frac{\sum_{i=l}^{n} x_i m_i}{n} = \sum_{j=l}^{n} x_j P_l \tag{10}$$

7. The variance of forced downtime duration of production line is defined as:

$$D(x) = M(x - x_0)^2 = \int_{x_{\min}}^{x_{\max}} (x - x_0)^2 P(x)dx \tag{11}$$

8. The next criterion is the probability of line failure, generally speaking, can be expressed in terms of probability of production line downtime. However, the relationship between the value of downtime and the value of intensity, as one of the main characteristics of production line reliability, is not functional due to the destabilizing effect of many hidden factors, the influence of which can only be determined statistically.Therefore, in the general case, each value of the amount of production line downtime may correspond not to one but several values of its intensity. This means that a production line failure will occur in the general case when some critical downtime value is reached, which should be determined statistically. The concept of critical gap will be described in detail below. Given the above, the probability of production line failure $Q_x$ can be defined as the probability that the downtime reaches critical:

$$Q_x = P(x \geq x_{kP}) = \int_{x}^{x_{\max}} P(x)dx \tag{12}$$

9. According to the probability addition theorem for opposite events [16], the probability of failure-free operation of production line $R_x$ is calculated by the formula:

$$R_x = l - Q_x = l - P(x \geq x_{kP}) = F(x < x_{kP}) = \int_{0}^{x_{kP}} P(x)dx \tag{13}$$

10. The average uptime of production line can be determined from the following expression:

$$t_0^{aut} = t_t - t_0^{cr} \tag{14}$$

11. Where $t_0^{aut}$ is the average uptime; $t_t$ is the total operating time of production line; $t_0^{cr}$ is the average idle time, the value of which exceeds a critical value.

Reliability can also be characterized by the following factors:

1. The production line readiness coefficient *Kr*, that is, the ratio of the production line uptime to the total time of its operation, including the time of failures, is determined by the formula:

$$Kr = \frac{t_0^{aut}}{t_t} = \frac{t_0^{aut}}{t_0^{aut} + t_0^{cr}} \tag{15}$$

2. The forced downtime coefficient *Kd* is the ratio of critical downtime to the sum of downtime and uptime:

$$Kd = \frac{t_0}{t_t} = \frac{t_0}{t_0^{aut} + t_0^{cr}} \tag{16}$$

3. The coefficient of relative flow efficiency $K^{rfe}$ is equal to:

$$K^{rfe} = \frac{i}{i_s} \tag{17}$$

where *i* is the average actual flow rate; $i_s$ is the specified (calculated) intensity.

Using the above criteria and coefficients, it is possible to characterize the reliability of constructional production line sufficiently fully or any structure. At the same time, it should be noted that, given the complexity of determining the statistical characteristics of complex constructional production lines (specialized, objective, complex), it is most expedient to determine the indicated reliability characteristics for private production lines, and to evaluate the quality of functioning of complex production lines by their efficiency, taking into account the reliability of private production lines.

The coefficient of system efficiency conservationcan serve as a general indicator of reliability of both elementary (private) and complex systems or the coefficient of its relative efficiency [17] can serve as an indicator of constructional production line.

It should be noted that the main method to increase the reliability of constructional production line as a whole should be to increase the reliability of private production lines.

## FACTORS AFFECTING THE RELIABILITY OF CONSTRUCTIONAL PRODUCTION LINE

Among the many factors affecting the reliability of constructional production line, and, ultimately, its efficiency, two main groups can be distinguished: deterministic factors and random factors. Reliability theory is studying the influence of precisely random factors on the activity of systems. The influence of deterministic factors is not difficult to consider when designing production line. The influence of a combination of random factors is probabilistic in nature and it is actually much more difficult to take it into account.

It is impossible to assess the influence of each of the many random factors separately, because they are not only random in nature, but also arise in random combinations and at random times. The approach to the study of random factors should undoubtedly be statistical in the construction industry. This means that based on statistical data, the cumulative effect on the efficiency of constructional production line of various random factors is revealed, the main ones are identified and the proportion of the influence of each of them is estimated. The impact of these factors on the reliability and efficiency of constructional production line is manifested both explicitly and in hidden form. Under the influence of these factors, the production line parameters may go beyond the established limits, i.e., the production line will fail.

To the greatest extent, the influence of random factors on the reliability of production line is manifested in the form of various irregularities in the construction industry — the loss of working time, which is usually divided into explicit and hidden [18], [19]. Hidden losses of working time are difficult to identify and account for, however, data from special studies show that these losses are often very significant. Explicit losses of time are divided into intra-shift and shift ones. Hidden downtime, as a rule, is only intra-shift. Loss of time means downtime and unnecessary work.

Currently, a significant part of construction processes is mechanized. As an example, consider the characteristic causes of downtime for mechanized processes. We denote the intra-shift time losses of machines for various reasons, the data of which can be obtained from photographs of the time of machine use, through $x_1$, $x_2$,... $x_9$.Then downtime $x_1$ - due to lack of materials at the site; $x_2$ - due to lack of electricity or fuel; $x_3$ - due to absence of work front; $x_4$ - due to lack of technical documentation and instructions from technical personnel; $x_5$ - due to malfunctions of machines and mechanisms; $x_6$ - due to lack of transport carrying out the supply of materials to the construction site; $x_7$ - due to violations of labor discipline; $x_8$ - due to adverse weather conditions; $x_9$ - due to loss of time for other reasons.

## CONCLUSIONS

In order to develop scientifically based measures aimed at mitigating the destabilizing effect of various factors on the quality of functioning of constructional production line, it is necessary to analyze these factors from the point of view of their controllability [20]. In other words, in order to increase the reliability of constructional production line, it is necessary not only to identify the main factors among the factors affecting the reliability, but also to divide these factors into groups (based on the possibility of impact on them in order to eliminate their influence completely or partially).

Obviously, some of the factors can be attributed to the group of fully controllable ones — these are determinate factors. In fact, such determinate factors as: the volume of work on erected structures and structures; uniformity of the erected structures; methods of production; the level of accepted specialization and division of labor of workers; the number and qualifications of workers; the number of construction machines and necessary equipment can be considered completely controllable, since their effect on the reliability of constructional production line can be taken into account in advance, and even during the operation of production line, if necessary, you can, for example, change the number of employees, the number cars, etc. [21], [22].

At the same time, the influence of factors $x_1$, $x_2$, ...,$x_9$ on the reliability of production line appears randomly and at random times. By the nature of occurrence and duration, the resulting downtime can be considered random variables. This does not mean, however, that some of them (factors $x_1$- $x_7$) cannot be influenced in order to reduce their influence to a minimum. It is possible to control these factors during the construction process, but, given the probabilistic nature of their occurrence, it is difficult to be sure of their complete elimination.

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*Paper submitted: 02.10.2020.*
*Paper accepted: 02.11.2020.*