

SECTION 8.

GENERAL MECHANICS AND MECHANICAL ENGINEERING

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SOME ISSUES IN ASSESSING THE RELIABILITY OF HONING MACHINES

Abstract. *Honing machines are essential in precision machining, ensuring high surface quality and dimensional accuracy of internal cylindrical surfaces. The diversity of honed parts has led to the development of vertical and horizontal honing machines, each suited to specific workpiece dimensions. This article examines the classification, technical requirements, and operational parameters of honing machines, with particular attention to diamond honing technology. Special emphasis is placed on machine reliability, including probabilistic models for failure analysis and performance evaluation. The study highlights the importance of proper machine selection, automation of auxiliary processes, and the application of scientific reliability management methods. Mathematical expressions describing failure probability, reliability function, and failure intensity are presented to support analytical assessment. Ultimately, improving the reliability and efficiency of honing machines contributes significantly to enhanced productivity and reduced operational costs in modern manufacturing systems.*

Introduction. The wide variety of shapes and sizes of honed parts leads to the emergence of various machines, which can be divided into two main groups: vertical honing machines and horizontal honing machines. Parts with a length of 100–200 mm are generally processed on vertical honing machines, while longer parts are processed on horizontal honing machines. Machines intended for diamond honing are subject to higher requirements in terms of rigidity, vibration resistance, and accuracy. To fully utilize the advantages of diamond honing stones over abrasive ones, machines should, as far as possible, ensure automation of all auxiliary processes [1-13].

Main Part. When selecting machines for diamond honing, it is first necessary to correlate the dimensional parameters of specific parts and their production

program with the main technical characteristics of the machine, ensuring that such parameters as the diameter of the machined hole and the stroke length of the spindle head correspond to the dimensions of the part. The spindle speed and the speed of the reciprocating motion of the head must ensure compliance with the modes recommended for diamond honing of materials with specific physical and mechanical properties. Therefore, in each case, it is necessary to determine the feasibility of modernizing the machine in order to achieve the highest technical and economic performance of diamond honing [14-27].

The designs of certain models of serial machines have been improved to provide controlled radial feed of the stones, monitoring of cutting power, and compensation for stone wear. Many machine models can be supplied in single- and double-spindle configurations. On double-spindle machines, finishing honing can be carried out simultaneously on two parts, or rough and finishing operations can be performed separately [28-35].

Thus, having certain data, it is possible to perform reliability calculations of honing machines. It should be noted that such calculations for honing machines of types 3M82, 3M83, etc., are carried out for the first time.

The solution to the reliability problems of metal-cutting machines should be divided into two stages. At the first stage, changes in machine quality indicators over time should be considered, and at the second stage, scientific methods of reliability control should be studied. Naturally, each stage is characterized by specific complexity, such as the study of failures, their systematization, determination of main quantitative parameters, use or development of calculation methods, determination of the optimal reliability level, and methods for ensuring it [36-54].

The optimal level of reliability of honing machines is established during their design and manufacturing. However, developers and manufacturers cannot ensure and maintain the main characteristics of honing machines for a long time. Therefore, scientific methods of reliability management must be applied [55-77].

Assume that a honing machine starts operating at time $t = 0$, and a failure occurs at a random time τ . Suppose that no failure occurs in the interval from 0 to t , i.e., $\tau > t$. Then the probability of failure-free operation of the honing machine up to time t is expressed as [2]:

$$P(t) = P(\tau > t). \quad (1)$$

According to [78-91], if during testing or operation of n machines, $N(t)$ machines have not failed by time t , the statistical estimate of the probability of failure-free operation up to time t is approximately:

$$p(t) \approx \frac{N(t)}{n}. \quad (2)$$

As t increases, the probability $P(t)$ decreases, with $P(0) = 1$ and $P(\infty) = 0$.

The probability of failure of a honing machine up to time t is denoted by $Q(t)$, where τ is the time of failure and t is an arbitrary fixed moment:

$$Q(t) = P(\tau < t). \quad (3)$$

Then:

$$Q(t) \approx \frac{n - N(t)}{n}. \quad (4)$$

Failure and failure-free operation of a honing machine up to time t are opposite events. Therefore:

$$Q(t) = 1 - P(t). \quad (5)$$

The derivative $q(t)$ of the function $Q(t)$ is called the probability density function of time to failure:

$$q(t) = Q'(t). \quad (6)$$

Then:

$$q(t) = -P'(t). \quad (7)$$

The failure rate of honing machines is defined as:

$$-\frac{p'(t)}{p(t)} = \frac{q(t)}{p(t)}. \quad (8)$$

Denoting this ratio by $\lambda(t)$, we obtain:

$$\lambda(t) = -\frac{p'(t)}{p(t)} = \frac{q(t)}{p(t)}. \quad (9)$$

Considering that:

$$\begin{aligned} Q(t, t + \Delta t) &\approx \frac{p'(t)}{p(t)} \cdot \Delta t \text{ и} \\ Q(t, t + \Delta t) &\approx \lambda(t) \Delta t. \end{aligned} \quad (10)$$

If $\Delta t = 1$, then:

$$\lambda(t) \approx Q(t, t + 1) \quad (11)$$

Since Δt is sufficiently small, from (9) we obtain:

$$\lambda(t) \approx -\frac{p(t) - N(t + \Delta t)}{\Delta t N(t)}. \quad (12)$$

From relations (2) and (12), we get:

$$\lambda(t) \approx -\frac{N(t) - N(t + \Delta t)}{\Delta t N(t)}. \quad (13)$$

According to (3), we introduce the relationship between the probability of failure-free operation up to time t and the failure rate $\lambda(t)$. For this purpose, we integrate expression (9):

$$\lambda(t)dt = -\frac{dp(t)}{p(t)}; \quad (14)$$

$$\int_0^t \lambda(t)dt = -\int_0^t \frac{dp(t)}{p(t)}; \quad (15)$$

$$\ln p(t) = -\int_0^t \lambda(t)dt; \quad (16)$$

$$p(t) = e^{-\int_0^t \lambda(t)dt} \quad (17)$$

Considering that $p(t, t + \Delta t) = \frac{p(t, t + \Delta t)}{p(t)}$ and using relation (17), we obtain the formula for determining the probability of failure-free operation of a honing machine in the interval $(t, t + \Delta t)$:

$$p(t, t + \Delta t) = e^{-\int_0^{t+\Delta t} \lambda(t)dt} \quad (18)$$

Conclusion. Thus, based on the given relationships and calculations, it is possible to determine the reliability indicators of honing machines and evaluate their probability of failure-free operation over time. These analytical expressions make it possible to assess the failure rate and reliability level, which are essential for improving the technical and economic efficiency of honing processes and ensuring

optimal machine performance.

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