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Key Indicators of Quality and Reliability of Axial Tools

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Abstract: The practice of using drills shows that the use of a certain type of drills in technologies depends not only on the technological requirements (productivity, grade of the material being processed, accuracy of the holes, etc.), but also on the ratio of the costs of purchasing the tool, main and auxiliary devices and their operation. The reliability of any technical object (in this case, the technological operation of processing a hole) is determined by the number and type of failures that occur in the technological system (in this case, the actual number of failures along the entire technological chain when processing a given hole. Therefore, this article focuses on the “Failure-free operation” of the technological system.

Keywords: Indicator, tool, reliability, drill breakage, complex technical and economic indicator, quality tool.

INTRODUCTION

The wear and durability of the tool are closely related to its reliability. Each tool and each combination of cutting mode parameters has its own wear value, which determines the limit of economic durability. At the same time, the level of tool reliability is higher, the more stable the cutting process in a given operation [1-4]. The increase in the level of automation in modern technological processes of mechanical processing, as well as the tightening of requirements for the quality of manufactured products, have necessitated the formation of output technological parameters from the point of view of reliability. At the same time, a large share of all failures in operations of mechanical processing of materials, especially difficult-to-machine ones, falls on the tool. First of all, these are failures associated with the dimensional wear of the tool [5-9].

Fig. 1 shows a classification scheme for tool quality indicators proposed by S. B. Futoryan and V. V. Skibin. It is evident from the scheme that tool quality depends on a large number of factors, the determining ones being: tool design quality, source material quality and tool manufacturing quality (the degree to which the manufactured tool parameters correspond to the technical requirements for its manufacture, as stipulated by the relevant standards and provided by the manufacturer) [10, 11].

Cutting tool quality indicators are combined into three groups: parts processing quality indicators, parts processing productivity and tool reliability indicators. These groups of indicators are interrelated. For example, with an increase in productivity (cutting modes), tool reliability indicators usually decrease and often the quality of manufactured parts decreases [11-13].

METHODS

The relationship between the parameters of tool quality (under the condition of a given quality of part processing) is most fully expressed using a generalized complex technical and economic indicator expressed through the productivity of the tool taking into account its reliability and the costs of production (or acquisition) of the tool:

$$A = \frac{V_m}{C + (P_1 + P_2) \cdot K} \text{ , } V_m = t \cdot s \cdot V \cdot \Sigma T \text{ ,} \qquad (1)$$

where:

V_M - volume of material cut by a tool in a certain period of time, mm^3;

t, s, V - cutting depth, mm; feed, mm/rev; cutting speed, m/min;

C - cost of manufacturing or purchasing a tool;

P_1 - cost of resharpening (retooling) of the tool;

P_2 - cost of machine downtime associated with tool changeover);

K - number of periods of tool life before complete failure;

ΣT - average total tool life or durability.

Tool reliability is the ability to perform cutting operations while maintaining its performance indicators in the specified operation requirements for a certain period of time while maintaining the required quality of processing. According to currently accepted terminology, it is defined by failure-free operation, maintainability, durability, and storability [GOST 13377-67

Reliability. The property of a tool to maintain operability for a specified period of time without forced interruptions. It is necessary to distinguish between the concepts of tool failure and tool malfunction. Failure is a condition of a tool that consists of a violation of its operability during the cutting process, and malfunction is a condition of a tool when it does not meet at least one of the requirements of the technical documentation. Tool failures are divided into design failures, caused by errors in its design, and technological failures, caused by its improper manufacture and operation. The failure of a tool is determined by a partial or complete loss of its operability. Therefore, failures can be fixable, if the operability of the tool can be restored by resharpening the working surfaces, repairing the body or other parts, and irreparable. In the latter case, the tool is written off [14].

Recoverable failures may be wear, abrasion or micro-cutting, formation during processing of the quality of the part below the permissible level in terms of accuracy, surface roughness or physical and mechanical properties of the surface layer; occurrence during processing of increased cutting forces unacceptable for the machine, device or work piece; formation of chips dangerous for the worker; occurrence of vibrations of unacceptable intensity [15].

Irrecoverable failures are: cutting out of one of the cutting edges; breakage of the cutting plate or its separation from the tool body due to destruction of the solder or mechanical fastening; destruction of the tool body or its supporting part under the plate. Each type of tool has its own relative quantitative ratio of different types of failures, which also depends on the processing conditions. Table 1 shows the types of wear and failures of the tool typical for drills [2].

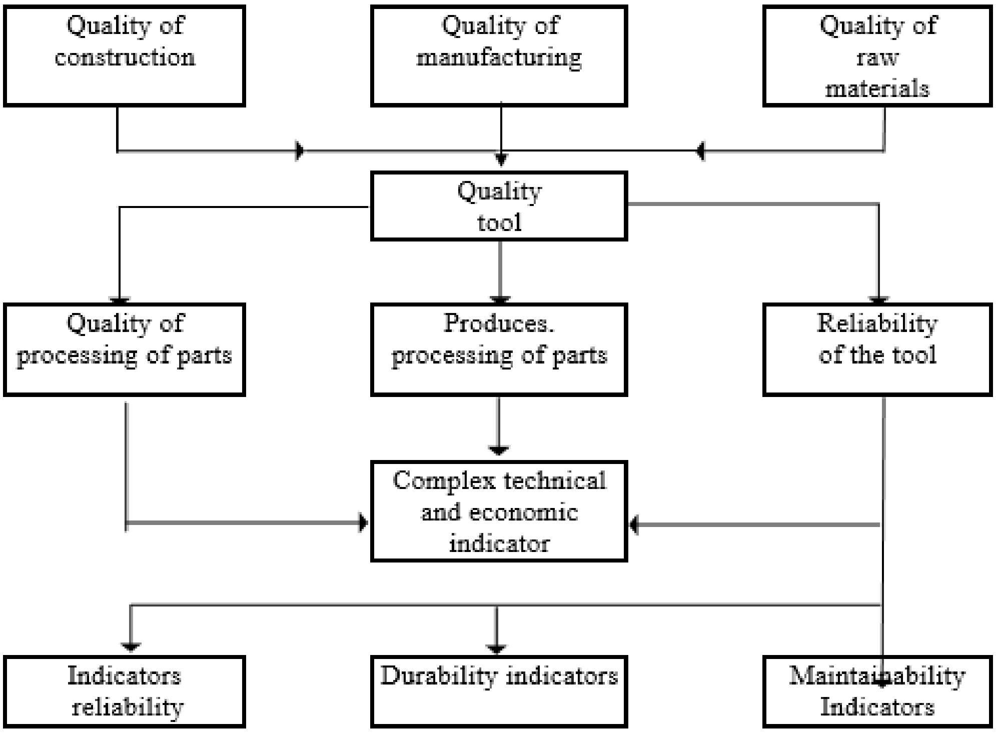

Fig. 1. Classification of quality indicators of tools [1]

The failure-free operation time of a tool is expressed by the operating time τ_i before any complete failure, the total operating time $\Sigma\tau_i$ before complete irreparable failure, or the number of regrinds k_i before complete irreparable failure. In mass production, it is more convenient to define these characteristics by the number of parts processed by a given tool (in drilling - the number of drilled holes), before any failure $z_д$ and $\Sigma z_д$ before irreparable failure.

Table 1

Nature of refusal	Possible reasons	Способы предупреждения и устранения
1	2	3
1. Chipping of cutting blades	1. High cutting speed 2. Incorrect cooling mode (quantity and composition of coolant 3. Presence of solid inclusions	1. Reduce cutting speed 2. Increase the amount of coolant; change its composition 3. Cut off hard inclusions or replace the workpiece
2. Dulling of cutting blades	1. Long-term operation with a drill with a worn bridge 2. Over-feed 3. Incorrect sharpening 4. Drill spinning in the chuck 5. Poor fit of the conical surfaces of the drill shank and the adapter sleeve	1. Sharpen the drill 2. Reduce the feed 3. Sharpen the drill correctly 4. Secure the drill carefully 5. Replace the cone sleeve
3.Rapid wear of cutting blades	1. High cutting speed	1. Reduce cutting speed
4. Damage to the edges Ribbons	1. The drill bushing is larger than the drill bit.	1. Replace the bushing

5. Drill breakage	1. Severe blunting of the drill 2. Large spindle play 3. Overload of the drill 4. Spiral flute clogged with chips 5. Low speed at high feed 6. Insufficient clearance angle of the drill 7. Voids, cavities and heterogeneity of the work piece	1. Do not let the drill become blunt. 2. Adjust the spindle 3. Set the correct operating mode 4. Remove the drill from the holes more often, clean it from chips 5. Increase the speed or decrease the feed 6. Reinsert the drill, increase the back angle 7. Replace the work piece
6. Foot breakage shank	1. Presence of dirt and burrs in the adapter sleeve 2. Poor fit of the shank in the tapered adapter sleeve	1. Clean and dry wipe the adapter sleeve and drill shank 2. Repair the adapter sleeve or replace it with a new one

The failure-free operation of a tool is determined by the probability of its failure-free operation P(τ), average durability or mean time without failure T, the time of operation with probability p or guaranteed durability Tp and indirect probabilistic characteristics - the density of the distribution of durability (the probability density of failures) f(τ) and the failure rate.[3]

The probability of failure-free operation P(τ) characterizes the probability that in a given time interval τ the failure of the tool will not occur. The failure rate λ(τ) is determined by the probability of failure per unit of time after a given moment of processing, provided that the failure has not occurred before this moment.

Additional indicators of tool reliability are the average failure rate a(τ), which determines the average number of tool failures per unit of time taken for the moment in time under consideration, and the average time of failure-free operation τ_0. For statistical evaluation of these characteristics, tests or observations of the operation of a sample of n tools under specified conditions are carried out. In this case, the durability of each of them is determined: τ_1, τ_2, τ_3,..., τ_n. The durability can be assessed using the following formulas [5]:

$$T = \frac{1}{n}\sum_{i=1}^{N_0}\tau_i \ , \quad P_{(\tau)} = \frac{N_0 - m(\tau)}{N_0} \ , \quad \lambda_{(\tau)} = \frac{2\Delta m(\tau)}{(N_i - N_{i+1})\Delta\tau} \ ,$$

$$f(\tau) = a(\tau) = \frac{\Delta m(\tau)}{N_0 \Delta\tau} \ , \qquad \tau_0 = \sum_{i=1}^{N_0}\frac{\tau_i}{N_0} \ , \qquad (2)$$

Where:

N_o - number of instruments at the beginning of the tests;

N_i, N_{i+1} -the number of working instruments at the beginning and end of the interval Δτ, respectively;

m(τ) - number of failures during time τ;

Δm(τ) - the number of failures in the time interval from (τ - Δτ/2) до (τ + Δτ/2).

RESULTS AND DISCUSSIONS

The dependence P(τ) is called the reliability curve or the decay curve; it can be used to find T(p) — the failure-free operation time of a tool with probability p, i.e. the time during which, on average, (1-p)100% of the tools will fail. To assess the reliability of a newly received batch of tools, it is advisable to test or observe the operation of the tools in this batch to obtain the distribution of times to failures of all types of interest (for example, until wear $\tau_{иi}$ and until failure τ_{pi} of the tool). Then it is possible to separately assess the wear resistance and strength of the tool. The values of T, P(τ), f(τ), λ(τ) and τ_0 can be different for a new tool, after the first resharpening, after the second resharpening, etc. At the same time, with a sufficiently large amount of data, it is advisable to construct these dependences separately for each period of operation — until the first failure, from the first to the second, from the second to the third, etc.

Due to the growing requirements for the stability of the cutting tool, the dispersion indicators of the tool life are of great importance. The dispersion of the tool life can be estimated by its mean square deviation or relative dispersion indicator - the coefficient of variation of the life. An indirect indicator of the stability of the cutting properties of the tool can also be the value of its guaranteed life Tp.

For the analysis of the quality of the tool and the causes of failures, the function describing the probability of failure in a very short period of time, provided that there were no failures before this moment, is also of interest. This function is called the failure rate and has the form:

$$\lambda(t) = \frac{f(t)}{1 - F(t)} \text{ ,} \qquad (3)$$

Where:

ŕ(t) – distribution density;

F(t) – long term failsafe distribution function.

Statistically, the failure rate is defined as the ratio of the number Δm of instruments that fail per unit of time to the number $m_и(t)$ of instruments that are operational at time t:

$$\lambda(t) = \frac{f(t)}{1 - F(t)} = \frac{\Delta m / N\Delta t}{[N - m(t)]/N} = \frac{\Delta m}{m_u(t)\Delta t}, \qquad (4)$$

Where:

$m_u(t) = N - m(t)$, N - total number of instruments in the sample.

The failure rate function can be used in cases where the running-in period and the period of accelerated wear at the end of the operating time are of great importance for the tool life. Then the failure rate will be high at the beginning and end of the operation, and relatively low in the middle section of stable operation. In this case, it is possible to optimize the reliability during the operating period by initial running-in to eliminate early failures and replacing the tool at the onset of the period of accelerated wear. For a reliable statistical assessment of the failure rate, it is necessary to have a large group of tests or observations, since λ(t)Δt is actually a particularity and is subject to large random variations, especially towards the end of the tests.

CONCLUSIONS

The task of determining the value of the economic durability of the $T_Э$ is complicated by the fact that the existing standards do not take into account the inevitable dispersion of the operational characteristics of the tool (its actual durability). This leads to the need to adjust the calculated cutting modes based on operational tests for reliability.

Thus, the definition of cutting modes by the traditional method is carried out in the following sequence: first, the cutting depth is set (for drilling in solid material $t=D_{otv}/2$), then the feed and, lastly, the cutting speed. The feed is assigned the maximum permissible, taking into account the restrictions from the conditions: drill strength - $s_1 = C_3 \cdot D^x$, the greatest force allowed by the feed drive mechanism of the machine - ($s_2=(P_{Oдoн} / C_2 \cdot D_{X2})^{1/y2}$), the greatest feed allowed by the strength of the main movement mechanism of the machine - $s_3=(M_{KPmax} / C_1 \cdot d^{x1})^{1/y1}$, where the parameters Ci, Xi, Yi are determined according to the cutting mode standards, and $P_{Oдoн}$ and M_{KPmax} - from the passport of the machine used. In case of increased requirements for the roughness of the hole surface or reduced rigidity of the work piece, the feed is also determined from the conditions of surface roughness restrictions (s_4) and (s_5) in accordance with the recommendations of the cutting mode standards and reference literature The maximum permissible feed is determined as: $s= min\{s_1, s_2, s_3, s_4, s_5\}$.To determine the cutting speed, the value of the period of economic stability $T_Э$ is specified (from previous experience, reference literature, or as mentioned above by economic calculations), then the value of the cutting speed $V_Э$ is determined, corresponding to the specified values of s and Te. The obtained values s, $V_Э$ are checked for permissible cutting power according to the machine passport data, adjusted with the machine passport data.

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