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RELIABILITY ANALYSIS OF THE CERAMIC CUTTING TOOLS DURING TURNING

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Abstract
In this paper are given exapmles of reliability of the ceramic cutting tools, wich are determined on the basis chosen of theoretical distribution, which in the best way approximates experimental data on the base of comparative analysis. For both exapmles normal theoretical distribution or normal model of reliability of failure of ceramic cutting tools for turning is chosen, which are accepted on the basis of non-parameter tests.

Keywords: *reliability, technical system, metalworking, turning, cutting tool*

1. INTRODUCTION

The reliability of a machining system, e.g. a lathe with numerical control (NC), consists of the reliability of subsystems (figure 1): machine tools, cutting tools and auxiliary accessories, which are connected in a series or in an order, i.e. successively. In contrast to machining systems, the connection between individual components in technological and production systems may be in addition to the connection in series, parallel, combined or mixed, etc.

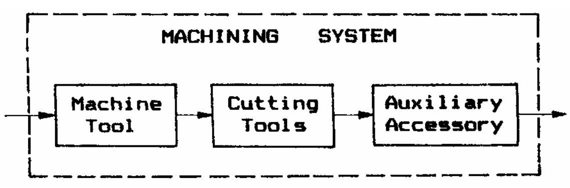

Figure 1: *Serial connection of the machining system reliability*

Nowadays the studying of reliability of modern technological and machining systems: NC, CNC, DNC, FMS, RMS, IMS and so on - both the whole systems and their components - is certainly interesting.

In paper [7], is given an example of analysis of one production system, i.e. production line, with mixed connection (combination of series and parallel connections).

By the application of statistical methods, following the breaking down of components of technological and machining systems in the phase of real exploitation, it is possible to determine the theoretical distribution, which is best for the approximation of experimental data. In the course of this we meet mostly the following theoretical distribution: equal, linear, exponential, hyper-exponential, normal, logarithmic normal, Weibull′s, Rayleigh′s, gamma, Erlang's and Gumball′s or extreme (minimum or maximum) value of type I. The choice of theoretical distribution is checked through non parameter tests: Pearson, Romanovski, Kolmogorov, Kolmogorov-Smirnoff and Misses.

2. CAUSE OF EMERSION AND CRITERIA OF CUTTING TOOLS FAILURE

The failures of cutting tools can happen at:
- cutting parts of the tool,

- elements for bending and breaking of shavings;
- parts for mechanic fixation and clamping of indexable inserts of soldered joints and
- tool housing i.e. tool holders or tools bearer and so on.

However, it should be noted that the failures prevail at cutting parts of the tool.

Under the cutting tool failures are considered the acts which have as a consequence the loosing of working capability. Besides, the cutting tool failures can be:

- the failures with the possibility of renewing cutting tools working capacity which can be realized by sharpening the cutting parts of high-speed steel, by soldering of the tool cutting parts, by regeneration and coating indexable hard metal inserts, introducing a new cutting blade or other parts of the tool by means of repairing tool holder or other parts of the tool and similar
- the failures without the possibility of renewing cutting tools working capacity i.e. failures, which cause the necessity of cutting tools writing-off.

Failure of cutting tools might be caused by various influences [2]:

- increased intensity of cutting tools wear
- gain of alowed wear intensity value or period of constancy of the tools.
- destruction of cutting parts of the tools in form of tearing, breaking of cutting parts of the tools
- plastic deformations of cutting parts of the tools (especially top of the cutting pin)
- methodical sharpening and reparation of tools parts
- deterioration of technology parameters

By observing the changes of some parameters in the process of cutting it comes to so called curved wearing of the tools in definite cycle of time. Presence of more parameters of cutting pin wearing indicates to a conclusion that the process of wearing can be shown with more curved wearing wich can by the state of position VB,t and for be very different. In the figure 2 is given graphical preview of interaction intensity wear VB and reliability R(t) tools for life time cycle in case when the tool is being simultaneously worn out on the both sides.

At the rough machining operations, the criterion for cutting tool failures is usually determined on the base of maximal life of the tool, according to the conditions of rational production and on the base of increased value of the cutting force or cutting temperature and so on.

At the final machining operations, at which should be obtained the proper quality of the machining surface and the definite measure exactness, the cutting tool failure criterion is defined by the amount of the wear parameters until which is possible the wearing process without exceeding the allowed quality limits of machining, by the roughness parameters, by the piece of work exactness, measure tolerances and so on.

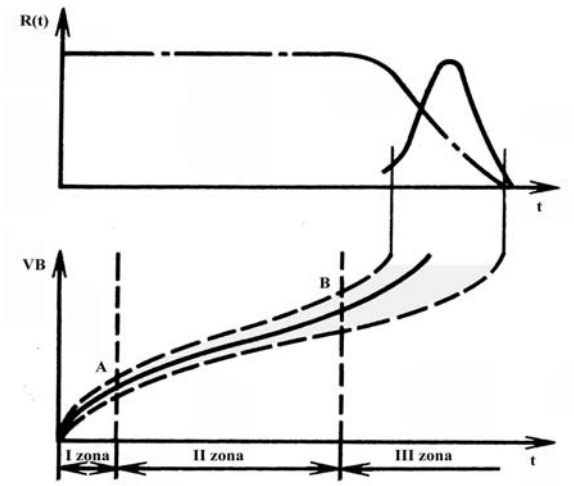

Figure 2: *Graphical preview of interaction intensity wear and reliability tools for life time cycle*

3. RELIABILITY ANALYSIS OF CUTTING TOOLS

Security of demanded reliability of cutting tools represent continual process wich comprises and withal depends from the folowing phases: construction, manufacturing or production and serviceability of cutting tools [2].

According to literature data as a function of cutting tools distribution, Weilbulls distribution is most frequently used [1-3,4,6]. In first papers wich are related to realiability of cutting tools normal distribution was used. In some paper there are also exponential, log-normal, gama and Poason’s and Gumbel’s distribution of miminam and maximal values of type [1-3,4,6].

Due to the vareous factors, all of these distributions can be seen in classic cutting tools made of alatnih i brzoreznih i liemljenih plocica. With these cutting tools failure might happen sudenly, that is, they do not depend on how much was the cutting tool worn and in what condition it was.

Nowdays, more and more usage have cutting tools with mechanical fixing of cutting inserts (MFCI) or also multicutting indexable inserts (MCII), wich repressed other sorts of cutting tools , especialy in areas of turning, plane, puncturing and milling. According to many researches MCII in the process of finishing acts stable, so the values of faliure of cutting tools approximately simmetrical disposed around the midvalue and can be approximated with normal theoretical distribution.

3.1. Example of the reliability analysis of multi-bladed indexable inserts made of mixed ceramic during turning

For determination of reliability of cutting tools there had been considered the operation of the finished turning of steel C.4721 (according to JUS standard) or 20CrMo5 (according to DIN standard) or 18CD4(S) (according to AFNOR standard), which is hardened to the hardness of 56-60 HRC [1-3,5]. Machine for turning has been universal lathe D-480. Cutting tools has been tool holder CCLNR 2525M 16 and the multi-bladed indexable inserts CNGN 160812T02020 made of mixed ceramic SH1 from the firm SPK-Feldmuhle. Nose radius has been r=1,2 [mm]. Elements of cutting regime has been: cutting depth a=0,5 [mm], number of passes i=1, speed of rotation n=280 [rev/min], i.e. cutting speed v=68,61-95 [m/min] and feed s=0,16 [mm/rev] and main machining time t_m=0,66964 [min]. Process has been realised without cooling and lubrication.

The experiment has been realized in the production conditions of the Industry "14. October" in Krusevac, with the sample size n=27. The time of work without failures of cutting tools made of mixed ceramic *t* has been measured in [min] and has run from 12,0536 [min] to 19,4196 [min]. The results of the failures observation of cutting tools made of mixed ceramic are grouped in six equal intervals of so-called group intervals, as it is done in table 1 [1].

Table 1. The results of the observation of failures of multi-bladed indexable inserts made of mixed ceramic for turning of hardened steel 20 CrMo5

i	Group intervals	Δn	f(t)	N(t)	F(t)	n(t)	R(t)
1.	12.00-13.25	2	0,074	2	0,074	25	0,925
2.	13.25-14.50	5	0,185	7	0,259	20	0,740
3.	14.50-15.75	8	0,296	15	0,555	12	0,444
4.	15.75-17.00	6	0,222	21	0,777	6	0,222
5.	17.00-18.25	4	0,148	25	0,925	2	0,074
6.	18.25-19.50	2	0,074	27	1,000	0	0,000

On the base of comparative analysis [1-3,5] of the theoretical distribution: normal, logarithmic normal, Weibull′s and Gumball′s distribution for grouped experimental data (table 1) the chosen one is normal distribution (figure 3), and its reliability functions is as follows [1]:

$$R(t) = 0,5 - \Phi\left(\frac{t - 15,0383}{1,7337}\right) \qquad (1)$$

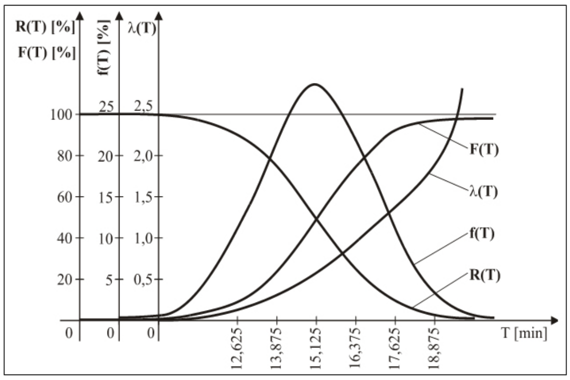

Figure 3: *Graphic review of basic theoretical indicators of normal model of reliability of multi-bladed indexable inserts made of mixed ceramic for turning of hardened steel 20 CrMo5*

3.2. Example of the reliability analysis of multi-bladed indexable inserts made of nitride ceramic during turning

For determination of reliability of cutting tools there had been considered the operation of the external finished turning of steel 20X (according to GOST standard), which is hardened to the hardness of 50-52 HRC [5]. Machine for turning has been lathe 16K20. Cutting tools has been multi-bladed indexable inserts SNGN 1204082020 made of nitride ceramic PKC 22 derivation with granular grinding tools 7/5 from the ″Stankin″ Moscow. Nose radius has been r=0,8 [mm]. Elements of cutting regime has

been: cutting depth a=0,25 [mm], number of passes i=1, cutting speed v=87 [m/min] and feed s=0,07 [mm/rev]. Process has been realised without cooling and lubrication.
The experiment has been realized in the Insitute "Stankin" in Moscow, with the sample size n=30. Wearing of tools during work without failures of cutting tools made of nitride ceramic *VB* has been measured in [mm] and has run from 0,3 [mm] to 0,42 [mm]. The results of the failures observation of cutting tools made of nitride ceramic are grouped in six equal intervals of so-called group intervals, as it is done in table 2 [5].

Table 2: The results of the observation of failures of multi-bladed indexable inserts made of nitride ceramic for turning of hardened steel 20X

i	Group intervals	Δn	f(VB)	N(VB)	F(VB)	n(VB)	R(VB)
1.	0.30-0.32	2	0,067	2	0,067	28	0,933
2.	0.32-0.34	4	0,133	6	0,200	24	0,800
3.	0.34-0.36	5	0,167	11	0,367	19	0,633
4.	0.36-0.38	10	0,333	21	0,700	9	0,300
5.	0.38-0.40	6	0,200	27	0,900	3	0,100
6.	0.40-0.42	3	0,100	30	1,000	0	0,000

On the base of comparative analysis [1-3,5] of the theoretical distribution: normal, logarithmic normal, Weibull's and Gumball's distribution for grouped experimental data (table 2) the chosen one is normal distribution (figure 4), and its reliability functions is as follows [5]:

$$R(VB) = 0,5 - \Phi\left(\frac{VB - 0,3653}{0,0272}\right) \qquad (2)$$

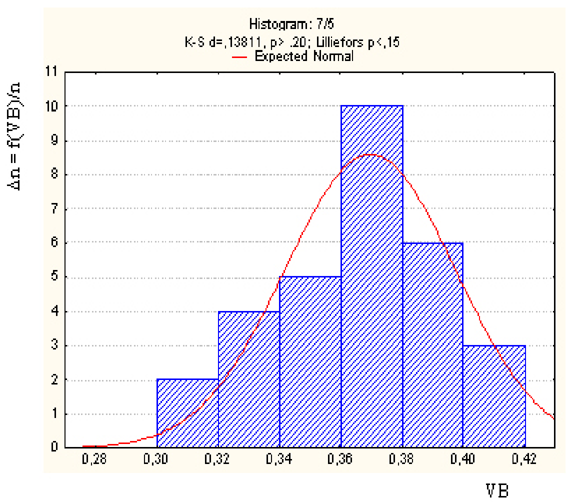

Figure 4: *Graphic review of basic failure frequency function of normal model of reliability of multi-bladed indexable inserts made of nitride ceramic for turning of hardened steel 20X*

4. CONCLUSIONS

The reviewed methodology of the reliability determination of the cutting tools on the basis of the comparative analysis of the different theoretical distribution is a general character and can be applied to the reliability analysis of both different components and complex systems.
Theoretical normal model reliability represents the experimental data very well during both examples of the observation of work without failure of ceramic cutting tools for turning.

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