Approach For Determining The Quantity Of Single Flute End Mill Cuters For High-Speed Milling, Planned Out For Recovering

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Abstract

High-speed milling at quasi-dry maschining of aluminum sheets, composite panels and HPL boards runs under intensive cutting conditions characterized by velocities ranging V_c = 550-700m/min and working minute feed’s reaching $f=45.10^3$mm/min. Performed by single flute end mill cutters – fig.1 on three-coordinate machining centers. Technical use of equipment of this type requires continuous monitoring of the geometric parameters of carbide tip and introduction of weightings in the control software to compensate tool wear. In multi-machine processing emphasis is transferred from the fastness of the tools to the strict monitoring of the synthesis parameter intensity flow of failures, a central feature of the tool infallibility of production systems [1,2,6].

The article proposed algorithm to determine the amount of end mill cutters planned out for recovering in plants for these high-speed steel (with or without inflicted multilayer coating) or by changing the carbide tip in cutting tools.

Keywords: Mean time between failures (technical resource T_H) , single flute mill cutters, high-speed milling, intensity flow of failures, intensity flow of recapping.

1. Introduction

Supposedly probability of the failure *F(t)* (violation of the cutting properties) and the probability of infallibility *R(t)* are random determined and permanent values (1),(2). Differential number of possible solutions for each of them - f(t).dt expressed by probability density in integral form, which maximum threshold levels are correlated with the period of technical use of the tools to reach their mean time between failures – MTBF (T_H) [1,7–9,11].

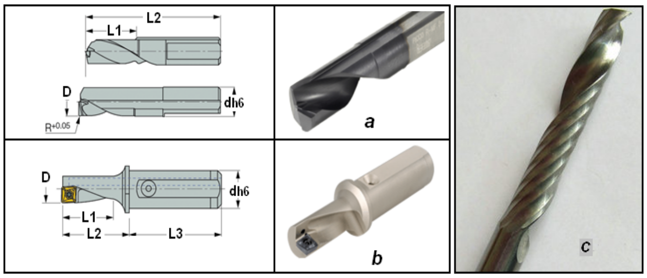

Fig. 1 Single flute end mill cutters [4]:
a) a rigid carbide tip, b) with carbide replaceable tip, c) tools of high speed steel

$$F(t) = \int_0^{T_H} f(t).dt \qquad (1)$$

$$R(t) = \int_0^{T_H} f(t).dt \qquad (2)$$

Therefore, probability of the failure *F(t)* is the reciprocal of the probability of infallibility *R(t) – fig.2.*

$$R(t) = 1 - F(t) \qquad (3)$$

After substitution according (3) of the Basic Low of the Reliability (4) [6,10]:

$$R(t) = \exp\left[-\int_0^{T_H} \omega(t).dt\right] \qquad (4)$$

where:

- $\omega(t)$ - the intensity flow of failures.

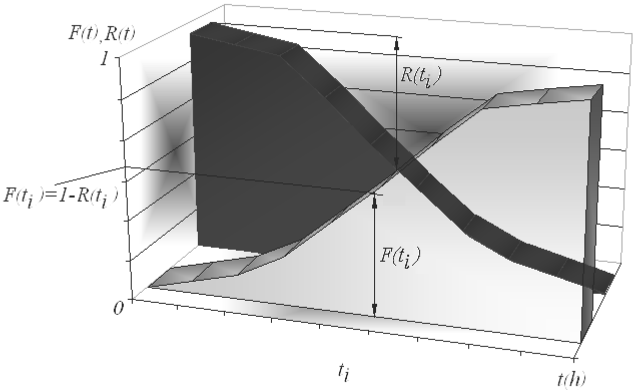

Fig. 2 Graph of probability of the failure *F(t)* correlated with the probability of infallibility *R(t)* of single flute end mill cutters

Dependence (2) extract form:

$$F(t)=1-\exp\left[-\int_{0}^{T_H}\omega(t).dt\right] \qquad (5)$$

2. Expose

Let accept that the technical use of tools systems is accompanied by the presence of failures and recoveries (recapping), by resharpening of tools in plants. For refusing to accept the case operational period of time in which single flute mill cutters goes from operational capability in non-operational capability [3,6]. Limiting factor in this case is the value of the critical wear.

In this whole process is especially topical prediction of quantity tools is need of resharpening or replacement of the cutting tip. It should be determined by apriori statistics of failures and recapping, which are generally time are non-linear and collected in industrial plants or research laboratories, based on accelerated conducted (with intense cutting conditions) or classical active or passive experimental research.

The intensity flow of failures - $\omega(\Delta t)$ and the intensity flow of recapping - $\mu(\Delta t)$ in the observed interval of time Δt, be determined by the following formula [1,6]:

$$\mu(\Delta t)=\frac{\sum_{i=1}^{N}K_{Bi}(\Delta t)}{N_{AC}(\Delta t).\sum_{i=1}^{N}\tau_{Bi}(\Delta t)}\ ,\ \mu(\Delta t)\le\omega(\Delta t), \qquad (6)$$

where:

- $N_{AC}(\Delta t)$ - number of operated tools systems of the same type in the reference interval (Δt),
- $K_{Bi}(\Delta t)$ - number of recapping in the i-th tools systems at the reference interval (Δt),
- (Δt) - reference apriori interval,
- $\tau_{Bi}(\Delta t)$ – time for recapping in the i-th tools systems at the reference interval.

Probability of unrecoverable failures F_f observed in time interval is determined by:

$$F_f(\Delta t)=F(\Delta t).R_f(\Delta t) \qquad (7)$$

where:

- $F(\Delta t)$ - probability of failure in reference interval (Δt),

$$F(\Delta t)=1-\exp[-\omega(\Delta t).\Delta t] \qquad (8)$$

- $R_f(\Delta t)$ - probability of non-recovery in reference interval (Δt),

$$P_{HB}(\Delta t)=1-\exp[-\mu(\Delta t).\Delta t] \qquad (9)$$

By $\omega(\Delta t).\Delta t<<1,\ \mu(\Delta t).\Delta t<<1$ [$\Delta t\approx4800$min for tools system] from (7) following:

$$F_f(\Delta t)\cong\omega(\Delta t).\mu(\Delta t).(\Delta t)^2 \qquad (10)$$

Perform the approximation of $\omega(\Delta t)$ and $\mu(\Delta t)$ and by continuous functions of time *t* over the same interval (Δt), represented by a polynomial (7) and (10) of [1,5,6,8,9]:

$$\mu(\Delta t)=p_0+p_1t+p_2t^2+\ldots, \qquad (11)$$

where:

- $p_0,p_1,p_2,\ldots$ - coefficients determined on specific points of the function of $\mu(\Delta t)$ for a priori time $t_i(i=0,1,2,3,..)$, by methodology [1,5].

From formulas (6) and (7) follows:

$$F_f(\Delta t)=(\Delta t)^2.\left[s_0+s_1.\Delta t+s_2.(\Delta t)^2+\ldots\right] \qquad (12)$$

where:

$$\left.\begin{array}{l} s_0=\omega_0.p_0,\\ s_1=\omega_0.p_1+a_1.p_0,\\ s_2=a_2.p_0+a_1.p_1+\omega_0.p_2,\\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \end{array}\right|$$

If a priori interval collection of statistics on tools system is (Δt), it hereditary behavior of the probability of non-recoverable failures observed in time – $t^*=t_i+\Delta t$, which can not be removed, is determined by extrapolation polynomial of Lagrange:

$$F_f(t^*)\cong(\Delta t)^2.\left[s_0+s_1.(\Delta t+t^*)+s_2.(\Delta t+t^*)^2+\ldots\right] \qquad (13)$$

The projected amount of tools system to be resharpening - K_{rH} in end of posterior interval (Δt), after timing t_i will be determined by:

$$K_{rH}=N_{AC}(\Delta t).F_f(\Delta t)\cong N_{AC}(\Delta t).(\Delta t)^2.\left[s_0+2s_1.\Delta t+4s_2.(\Delta t)^2+\ldots+n.s_m(\Delta t)^m\right] \qquad (14)$$

where:

- n - final n-th member of the Lagrange polynomial,
- m - exponent of the final n-th member.

The resulting algorithm (16) allows for a posteriori determining the quantity of tools system to be resharpening or replacing the carbide tip.

The accuracy of the prediction can be increased by using a polynomial of higher degree.

The displayed theoretical model (16) adequately describes the empirical distribution whose contribution is achieved in reliability research clearly set input and confounding factors, the evaluation of the failure is perceived forecast for the whole batch tools.

Fig. 3 reflect in graphic form data from comparative experimental research, taking into account the intensity flow of recapping *μ(Δt)*.

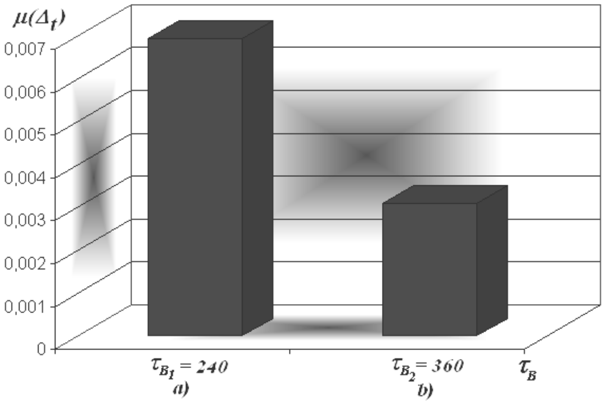

Fig.3 Intensity flow of recapping - *μ(Δt)*:
a) tools from high-speed steel; b) cutting tools with carbide tip

They are conducted in conditions of quasi-dry masching with single flute mill cutters, high-speed milling, levels of indicators, according to equation (6):

- Tools - Chart 1 from high-speed steel without inflicted multilayer coating, Chart 2 cutting tools with carbide tip,

- $N_{AC}(\Delta t)$ = 12 tools with diameter D=8mm in the reference interval *(Δt)*,

- $K_{i1}(\Delta t)$ = 20 - number of recapping in the i-th tools systems at the reference interval *(Δt)*- for tools from high-speed steel,

- $K_{i2}(\Delta t)$ = 13,33 - number of recapping in the i-th tools systems at the reference interval *(Δt)*- for cutting tools with carbide tip,

- *(Δt)* = 4800min - research a priori time interval,

- τ_{B1} = 240 min - recovery time of the i - th tools system in the range of *(Δt)*, for tools from high-speed steel,

- τ_{B2} = 360 min - recovery time of the i - th tools system in the range of *(Δt)*, cutting tools with carbide tip.

The levels of the cutting conditions in both cases are maintained constant and does not affect results.

Obviously the use of tools with carbide tip reduces the intensity failures with 55.47%. The effect in real terms significantly multiplies, taking into account the possibility of intense the cutting conditions with up to 45% compared to the tools from high-speed steel.

3. Conclusions

The proposed algorithm for preventive mathematical modeling of the amount of single flute mill cutters for high-speed milling, recoverable formed the basis of subsequent numerical optimization research [3,7]. On the exposed tools category, the optimum application of multivariable single parameter iterative optimization with factor scan or in some cases multi-parameter optimization multifactorial modeling elements of the cutting conditions and tool geometry, according to requirements for low cost, high performance and maximum durability.

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