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# AGAIN ABOUT OF THE TAYLORIAN RELATION

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## ABSRACT

*The Taylorian relation for the calculation of the values of the cutting speed is valid only on very small domain of the cutting speed. The obtained results give great errors on the large domain of the today used speeds from a few m/min to more thousand m/min. The manufacturing on CNC machine or the manufacturing on automatically production lines changes significant the use of the Taylorian relation and his influence on the factory overhead. The content of this work shows a new image of the very old relation of the metal cutting and new use condition.*

## 1. Introduction

The Taylorian relation express an analytically link between cutting speed *v* [m/min] and edge endurance *T* [min] of the cutting tool

$$v = C_v / T^m \qquad (1)$$

where $C_v$ and $m$ are determined from all conditions of the cutting (tool- and tool material, worked piece, lubricant and cooling medium etc.). The edge endurance *T* is the working time until the maximal accepted wear of the cutting edge.

The value of the wear, *VB*, depends in great measure from the cutting speed and has a

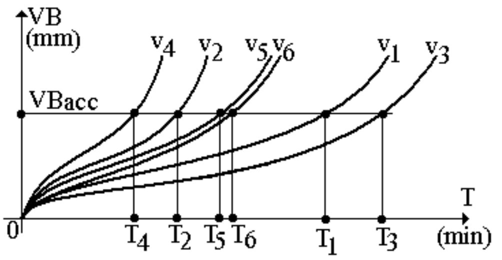


Fig. 1. The points $v_i, T_i$ with *VB* =constant

continuous increase in the time. If we fixe a maximal accepted wear value $VB_{acc}$, Fig. 1, the Points $v_i, T_i$ give the relation (1). But how much must be the accepted value of the wear *VB*, if this value can be or not can be optimised, these are in the moment only questions. In order to give a correct response, we need a few relations.

The cutting edge can be or can be not resharpened. It deals with resharpening reserve *Res*, fig. 2 and number of the resarpens $n_{rs}$.

For changeable edge is $n_{rs}$ =number of the

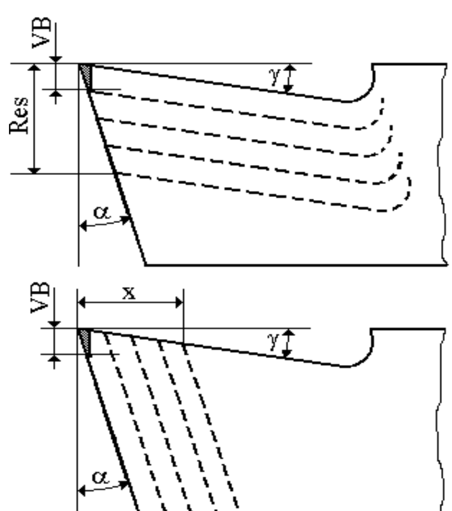


Fig. 2. The resharpening reserve

cutting corners. The economical edge endurance become from

$$T_{ec} = \frac{1-m}{m} \cdot \frac{C_t}{S_w} \qquad (2)$$

where *m*= the Taylorian exponent, $C_t$ the cost of the cutting tool on his endurance *T*, $S_w$ the salary of the worker (or the costs dependent from the working time) in money pro minute.

The cost $C_t$ contains the purchase of the tool $P_t$ divided trough the number of the resarpens $n_{rs}$ and the cost of the resarpening $C_{rs}$.

$$C_t = P_t / n_{rs} + C_{rs} \tag{3}$$

With the optimal durability $Tec$ we calculate the optimal cutting speed $v$ with (1) and $T = Tec$. The cost of the manufacturing $C_m$ is [2]

$$C_m = T_b \cdot S_w + \frac{P_t + n_{rs} \cdot C_{rs}}{N} \tag{4}$$

The working time for a piece $T_b$ is at turning

$$T_b = \frac{L \cdot \pi \cdot D}{1000 \cdot v \cdot s} \tag{5}$$

and the number of the worked pieces with entire cutting edge $N$

$$N = \frac{Res}{VB} \cdot \frac{T_{ec}}{T_b} \tag{6}$$

The cost of the manufacturing become

$$C_m = \frac{L \cdot \pi \cdot D}{1000 \cdot s} \cdot \left( \frac{S_w}{v} + \frac{VB \cdot P_t}{v \cdot T \cdot Res} + \frac{C_{rs}}{v \cdot T} \right) \tag{7}$$

In the relations (5)-(7) $s$ = the advance [$mm/rot$], $L$ = the length of the worked area [$mm$], $D$ = diameter of the piece [$mm$]. If the edge is not resharpened, become in (7) $C_{rs} = 0$ and $Res/VB = n_{rs}$ = number of the cutting corners.
Farther we consider the wear $VB$ as an unknown parameter and his value is to determine from the condition that the cost of the manufacturing become minimal, $\partial C_m / \partial v = 0; \partial C_m / \partial T = 0$, respectively

$$\begin{cases} S_w \cdot T + \frac{P_t}{Res} \cdot VB - \frac{P_t}{Res} \cdot v \cdot \frac{\partial VB}{\partial v} + C_{rs} = 0 \\ \frac{P_t}{Res} \cdot VB - \frac{P_t}{Res} \cdot T \cdot \frac{\partial VB}{\partial T} + C_{rs} = 0 \end{cases} \tag{8}$$

If $C_{rs} = 0$ or $C_{rs} \approx 0$ the last equation from (8) gives the relation:

$$\frac{\partial VB}{\partial T} = \frac{VB}{T} \tag{9}$$

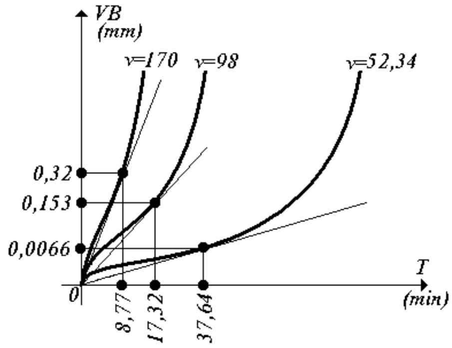


Fig. 3. Optimal wear at turning of steel 33MoC11–HB=229daN/mm$^2$, edge from P10 bedded with TiN

The relation (9) demonstrates that the wear can be not considered as a constant value. The optimal values of the wear become from (9) and are represented in fig. 3.

## 2. Another relations like Taylorian type

Practically research of the author [4] has given enough data in order to model more relation. The wear can be modelled with the relation

$$VB = \sum_{i=1}^{n} a_i \cdot T^{b_i} \cdot v^{c_i} \tag{10}$$

If $n$ is greater, the precision of the equation becomes greater. The figure 4 shows the graphics of the relation $VB = 4.47 \cdot 10^{-5} \cdot T^{0.2} \cdot v^{1.6} + 1.024 \cdot 10^{-19} \cdot T^4 \cdot v^{6.3}$ [$mm$] on the domain $T \in [0, 10]$, $v \in [80, 174]$. The equation (10) can be used mostly in order to demonstrate another relations.
If $VB$ is constant and $n$=1 we have

$$a_1 \cdot T^{b_1} \cdot v^{c_1} = K \Rightarrow v = \frac{(K/a_1)^{1/c_1}}{T^{b_1/c_1}} \tag{11}$$

respectively the Taylorian relation. For $VB$=0.7 we have $v = 418/T^{0.125}$, a very usual relation but the precision of (10) is very low for $n=1$. If (9) is considered we have

$$\sum_{i=1}^{n} a_i \cdot T^{b_i - 1} \cdot v^{c_i} = \sum_{i=1}^{n} a_i \cdot b_i \cdot T^{b_i - 1} \cdot v^{c_i} \tag{12}$$

For $n$=1 we have $b_1 = 1$, $VB = a_1 \cdot T \cdot v^{c_1}$ respectively a linear increase of the wear in time, an incorrect fact. This demonstrates that in (10) $n > 1$.

If the manufacturing is without labour on automatically production lines, in (8) $L_A = 0$, $P_{ns} = 0$ or $P_{ns} \approx 0$. The optimal wear is in the points, which verify the relations

$$\begin{cases} \dfrac{\partial VB}{\partial v} = \dfrac{VB}{v}; \quad \dfrac{\partial VB}{\partial T} = \dfrac{VB}{T} \end{cases} \tag{13}$$

These points have a special property, downer demonstrated. We derive the function *VB*

$$dVB = \frac{\partial VB}{\partial T} dT + \frac{\partial VB}{\partial v} dv \tag{14}$$

and, from (13) and (14) we have

$$dVB = VB \cdot \left( \frac{dT}{T} + \frac{dv}{v} \right) \Rightarrow \frac{dVB}{VB} = \frac{dT}{T} + \frac{dv}{v} \Rightarrow$$
$$\Rightarrow \ln(VB) = \ln(T) + \ln(v) + \ln(k)$$

or

$$v \cdot T = VB/k \tag{15}$$

respectively the coordinates *v* and *T* must verify (15). We consider (10) and obtain

$$\sum_{i=1}^{n} a_i \cdot T^{b_i - 1} \cdot v^{c_i - 1} = k \tag{16}$$

If $n$=1, from (16) we obtain the Taylorian relation (1) but the increase of *VB* in time is not more linear and the relation is better.

## 3. Conclusion

The Taylorian relation can be used like (1) if the practical determined values of *T* and *v* are determined like in the fig. 3.

We obtain a series of the values $VB_i, T_i, v_i$ and, under a usually interpolation, we have two different relations: a Taylorian relation like (1) but with greater precision and another relation like

$$VB = C_{VB} / T^{w} \tag{17}$$

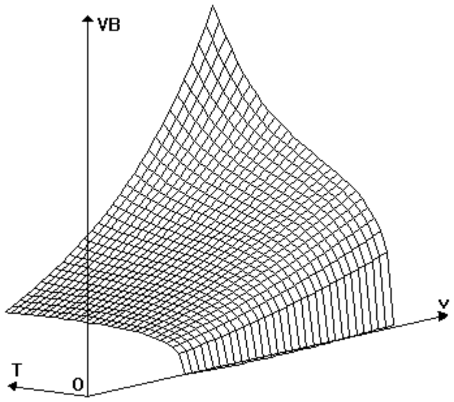


Fig 4. The wear *VB* as function of v and T

The cost given from (7) becomes

$$C_m = \frac{L \cdot \pi \cdot D}{1000 \cdot s} \cdot \left( \frac{S_w \cdot T^m}{C_v} + \frac{C_{VB} \cdot P_t \cdot T^{m-1-w}}{C_v \cdot Rez} + \frac{C_{rs} \cdot T^{m-1}}{C_v} \right) \tag{18}$$

The minimal cost is under the condition $\partial C_m / \partial T = 0$, respectively

$$m \cdot L_A \cdot T + \frac{C_{VB} \cdot P_t}{Rez} \cdot (m - 1 - w) \cdot T^{-w} + C_{rs} \cdot (m - 1) = 0 \tag{19}$$

The solving of the (19) is only on numerically way possible and gives the optimal edge endurance *T*. For unresharpened edges the relations are easier. The relations from Taylorian type (1) and (17) determined from the points like fig. 3 give, together with the solution of (19), the best possible working conditions at lower costs.

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