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ASPECTS OF POWER CONSUMPTION IN ALLOY STEELS PROCESSING USING THREAD WHIRLING

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Abstract: The paper presents the results of the research conducted with the purpose of establishing the influences of the splintering process parameters with respect to the power consumption for the worm screw processing with whirling thread cutting devices. Experiments were carried out on specific steel used in the construction of the worm screw gear. Attempts have been made on various modules, processing carried out both climb and in reverse advance. Also, shown are the dependency relations between the power consumption of the motor and the parameters of the splintering process, which resulted from mathematical modeling of the experimental data.

Key words: power consumption, 19MoCr11, whirling thread cutting.

1. INTRODUCTION

Processing the screws can be done by several methods of cutting: turning on lathes, milling, threading using the vortex principle etc. In terms of productivity processing is the most efficient method of threading the whirlwind.

For processing of worm screws with the use of whirling thread cutting devices mounted on lathes, the primary movement that realizes the cutting is the rotation movement of the blades, produced by the device's motor.

The main rotation movement of the main spindle of the lathe becomes circular advancement motion, and this advancement movement becomes axial advancement movement (Fig. 1). As a consequence, the most important power consumption in the cutting process is the active power Pc, used by the motor of the whirling thread device.

Knowing the required processing power may be selected judicious driving power of the engine which performs the rotational movement of the screw head.

2. EXPERIMENTAL TRIALS

The experimental researches were conducted inside the TCM. Faculty of the "Gh. Asachi" Technical University of Iasi, on a lathe SNA 560x1000, on which a whirling thread cutting device, developed by the faculty, was mounted.

The revolution speed ns of the device's blades are provided by the revolution speed of the motor and the ratio of the wheels which transmit the motion from the motor to the body of the device, through a belt.

The primary diameter of the belt groove of the body of the device is D_{pd}=216mm. In order to obtain various revolution speeds of the splintering blades, multiple belt wheels were used for the motor axle, with the following primary diameters: D_{p1} = 188 mm; D_{p2}=162mm; D_{p3}=133mm; D_{p4}=92mm. Respectively, the revolution speeds of the main axle of the device become: n_{s1} = 1241 rot/min; n_{s2}=1070rot/min; n_{s3} = 878 rot/min; n_{s4} = 614rot/min.

For calculating the speed of the corresponding area of the tool which is processing the reference diameter, the following formula (Eq.1) is used:

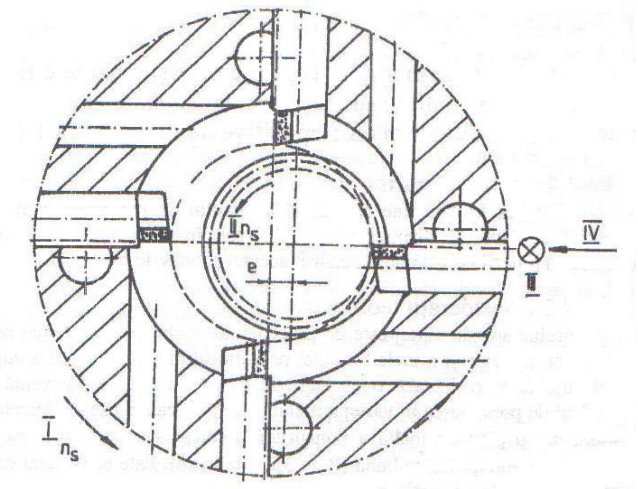

Fig. 1 Setup of the whirling thread processing

$$v_s = \frac{\pi \cdot \left(D_{vs} + 2{,}5 \cdot m_x\right) \cdot n_s}{1000} \text{ [m/min]} \qquad (1)$$

As demonstrated, the revolution speed of the main axle n_m becomes the revolution speed of the circular advancement motion. For this reason, it is necessary that the range of the revolution speeds of it to be modified. For this, an intermediate axle was constructed between the main motor of the lathe and the main axle of the gearbox. In this way, the revolution speed of the lathe's main axle was lower from a range of (16 ÷ 1600) rot/min to the range of (2.4 ÷ 242) rot/min. The revolution speeds used during the experiments were: 2.4 rot/min; 3 rot/min; 3.76 rot/min; 4.74 rot/min; 6 rot/min; 7.52 rot/min; 9.48 rot/min; 12 rot/min. The cutting total depth is given by the tooth height of the worm screw manufactured, which is calculated by the formula, (Eq.2):

$$h = 2.25 m_x \text{ [mm]} \tag{2}$$

Trials were done for 3 modules: $m_{x1} = 2$ mm; $m_{x2} = 3$ mm; $m_{x3} = 4$ mm, for which the total processing depths are: $a_{p1} = 4.5$ mm; $a_{p2} = 6.75$ mm; $a_{p3} = 9$ mm.

Another parameter that can be taken into consideration in the calculations, derived from the independent and constructive parameters, is the tooth f_z, given by the formula, (Eq.3):

$$f_z = \frac{\pi \cdot d_{a1} \cdot n_m}{n_s \cdot z_s \cdot \cos\gamma} \text{ [mm/tooth]} \tag{3}$$

in which:

d_{a1} – the head diameter of the worm screw spire;

n_s – the tool revolution speed;

z_s – the number of thinning blades;

γ - the angle of the slope of the worm screw's reference screw.

For a given worn screw, (d_{a1}, γ), a constant number z_s of thinning blades and a certain revolution speed of the blades, the tooth advancement f_z is directly proportional to the revolution speed of the tool n_m. Sometimes it is preferred to express the conditions of the splintering process through this parameter, because it shows the load of each blade during the process.

Experimental trials have been conducted on steel 19 MoCr 11 - STAS 791 - 88, with a hardness of 185 HB. The 19 Cr Mo 11 steel is one of the most used screws in the construction of worm gears.

Some of the working characteristics of the used whirling thread device are presented next:

-the motor used is type ASI 90 L - 24 - 4, with a nominal power of 1.5 kW, a nominal revolution speed of 1425 rot/min and an efficiency at nominal load of 76 %;

-the interior diameter of the main axle is 116 mm;

-the maximum inclination angle of the device's body in the rack is: 18°;

-the number of blades which can be mounted on the main axle is: 4.

The constructive parameters of the tool were established with respect to the characteristics of the worm screw manufactured. When the whirling thread processing accomplishes both the thinning and the finishing of the worm screw's flanks, the shape of the active part of the blade is identical to the hollow shape of the real worm screw.

In the case that, during the technological manufacturing process of the worm screw, the processing operation of the teeth with a whirling thread device is followed by another finishing operation (optionally after a thermal treatment), the shape of the whirling blades must ensure a finishing surplus a_f, considered in the normal section, in the medium screw of the hollow shape.

For ensuring the sharpening of all the blades of the whirling thread cutting device, with precision, a sharpening tool was constructed. This tool creates the following angles for the splintering part of the device:

- the placement angle of the side edges : 5°14';
- the placement angle of the front edge: 15°;
- the clearance angle for all 3 edges: 0°.

The sharpening of the splintering parts of the blades was done on a plan correction machine, type RP 250 A, using abrasive stones made of green silicon carbide and ceramic binder, type I 250 x 76,2 x 20 21 C 80/16 H 7 V 217, produced by S. C. ABROM S.A. Bârlad.

In order to study the influence of the advancement type used, processing trials were done, both in the advancement direction and opposite to it. For compensating the play from the lathe's gearbox in the case of threading in the direction of the advancement, a mechanism, capable of ensuring additional friction at the main axle level, bigger than the momentum created by the splintering forces, was used. In the case of threading in the opposite direction of the advancement, the splints are formed in rougher conditions, their thickness growing from zero to the maximum value, at a lower speed than in the case of threading in direction of the advancement.

The performed experiments have shown that the thermal energy produced by the splintering process, is mainly absorbed by the splints that detach during the process.

Due to the rotation of the blades and of the fact that they splinter for less than a quarter of the time of a complete rotation, the temperature of the blades remains at low values. The thermal energy transmitted to the processed piece is also low, due to the fact that at normal processing (speeds lower than 200 m/min and tooth advancements between 0,1 and 0.2 mm/tooth), the speed of the heat propagation in the piece is less than the speed of the longitudinal motion of the blades. The temperature of the piece in the work area increases considerably only at low values of the tooth advancement and high splintering speeds.

2.1. The influence of the splintering process parameters and of the worm screw's geometrical parameters on the power consumption during worm screw processing with whirling thread cutting devices

The active power consumption P_c was measured with a monophased wattmeter with the constant k_p=20W/div, considering the triphasic motor system has symmetrical load. If the indication of the wattmeter is P_A [W], the active power consumed is, Eq.4 [1]:

$$P_c = 3\,P_A\ [W] \qquad (4)$$

To estimate the mechanical power consumed by the whirling thread device, the starting point is the nominal parameters of the motor, used to determine the available power P_u, (Eq.5), produced by the motor, which in turn is equal to the consumed mechanical power.

$$P_u = \eta_m \cdot P_c = \eta_m \cdot 3\,P_A\ [W] \qquad (5)$$

In which: η_m – the efficiency of the motor with respect to the available power [2].

The efficiency of the motor is a quantity which depends on the actual consumed power. Starting from the actual values of the efficiency, given by the manufacturing company for different ratios of the nominal power, a formula can be determined depicting the dependency between the efficiency and the consumed power. Knowing the consumed power for a certain processing, using the aforementioned formula, the actual efficiency can be determined and then, through equation (5), the available mechanical power transmitted to the device.

The values of the consumed power, at different splintering processes and different constructive parameters of the worm screws are available in table 1.

The variation of the power consumption at various tool working speeds and tooth advancement are shown in figure 2 and figure 3.

At the graphical representation of the dependencies of the power in relation to the parameters of the splintering process, only the samples for which the processing was done in one sweep were considered.

Using a processing program for multidimensional arrays [3, 4, 5], the mathematical dependency relations were determined for the power consumption with respect to the axial module, the speed of the tool and the tooth advancement. For the processing of the material 19MoCr11, in the direction of the tooth advancement, the dependency is, (Eq. 6):

$$P_c = 0.21758 \cdot 1.376^{m_x} \cdot 1.008788^{v_s} \cdot 14.6958^{f_z} \qquad (6)$$

For the processing of the material 19 MoCr 11, in the opposite direction of the tooth advancement, the dependency formula is, (Eq. 7):

$$P_c = 0.24517 \cdot 1.2161^{m_x} \cdot 1.0099^{v_s} \cdot 20.649^{f_z} \qquad (7)$$

Table 1. The values of the power consumption, for processing material 19 MoCr 11

No. Prob.	D_{vs} [mm]	m_x [mm]	q	n_s [rot/min]	v_s [m/min]	n_m [rot/min]	f_z [mm/tooth]	γ [°]	Advancement type	Pc [kW]	No.of passings
1	36	2	12	1070	129	6	0.12	4.76	ca	1.86	1
2	36	2	12	1070	129	3.76	0.08	4.76	ca	1.8	1
3	36	2	12	878	106	4.74	0.12	4.76	ca	1.38	1
4	36	2	12	878	106	3	0.07	4.76	ca	1.26	1
5	36	2	12	1070	129	6	0.12	4.76	sa	1.74	1
6	36	2	12	1070	129	3.76	0.08	4.76	sa	1.62	1
7	36	2	12	614	74	4.76	0.17	4.76	sa	1.2	1
8	36	2	12	614	74	3	0.11	4.76	sa	1.08	1
9	49	3	11	878	145.5	3	0.1	5.19	ca	2.34	1
10	49	3	11	878	145.5	4.74	0.17	5.19	ca	3.18	1
11	49	3	11	614	102	2.4	0.12	5.19	ca	1.8	1
12	49	3	11	614	102	3	0.15	5.19	ca	1.92	1
13	49	3	11	614	102	2.4	0.12	5.19	sa	1.92	1

No. Prob.	D_{vs} [mm]	m_x [mm]	q	n_s [rot/min]	v_s [m/min]	n_m [rot/min]	f_z [mm/tooth]	γ [°]	Advancement type	Pc [kW]	No.of passings
14	49	3	11	614	102	3	0.15	5.19	sa	2.1	1
15	49	3	11	878	145.5	3	0.1	5.19	sa	2.52	1
16	49	3	11	878	145.5	4.74	0.17	5.19	sa	3.3	1
17	67	4	11	878	198	2.4	0.11	5.19	ca	2.46	2
18	67	4	11	878	198	3	0.14	5.19	ca	2.94	2
19	67	4	11	878	198	3.76	0.18	5.19	ca	3.58	2
20	67	4	11	614	139	2.4	0.16	5.19	ca	2.46	2
21	67	4	11	878	198	2.4	0.11	5.19	sa	2.58	2
22	67	4	11	878	198	3	0.14	5.19	sa	3	2
23	67	4	11	878	198	3.76	0.18	5.19	sa	3.66	2
24	67	4	11	614	139	2.4	0.16	5.19	sa	2.58	2

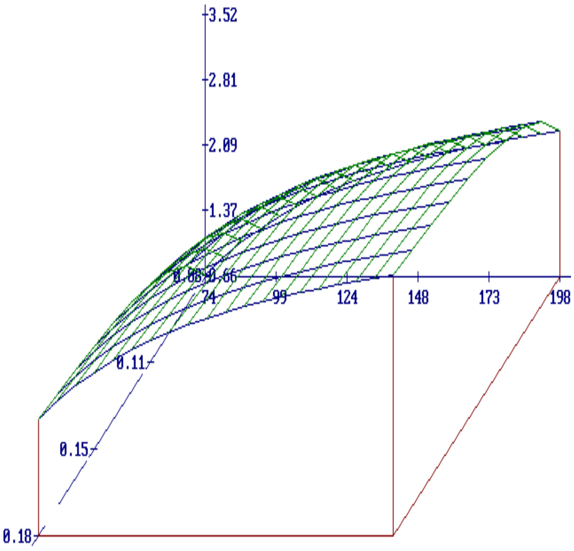

Fig. 2 The variation of the active power consumption at tool working speeds and tooth advancement, of $m_x = 2$, for processing material 19 MoCr 11, in direction of the tooth advancement

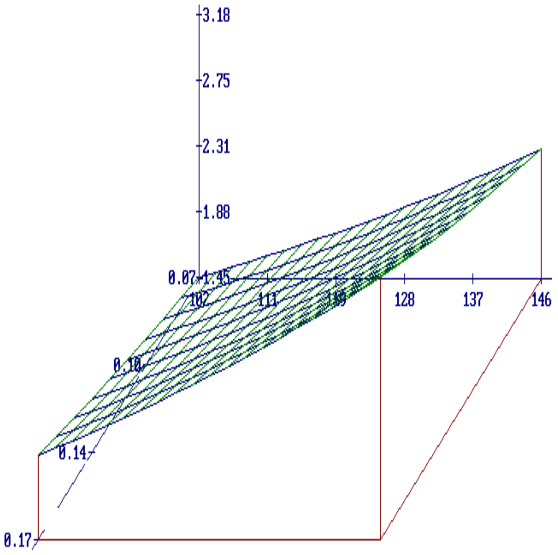

Fig. 3 The variation of the active power consumption at tool working speeds and tooth advancement of $m_x = 3$, for processing material 19 MoCr 11, in opposite direction of the tooth advancement

3. CONCLUSIONS

By increasing the splintering speed per tooth, the power consumption increases. The same phenomena can be seen at the increase of the tooth advancement. The power consumed for processing in the direction of the tooth advancement is lower than the one necessary for the processing in the opposite direction. When processing module snails with greater than 3 is necessary that the removal depth of cut to make at least two passes, as power consumption rises considerably.

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