

Considerations about the influence of lubricant in different machining mechanical processes

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Abstract. There are numerous researches that highlight the fact that wear related processes of machine components are one of the main causes which leads to their destruction. The main reasons for wear are related to the initial state of contact surfaces described by mechanical and physical properties of their superficial layer. Thus friction surface's state depends on previous mechanical machining done on this surface especially the last one. This study presents a method which proposes and creates premises for a micro-geometry favorable to maintaining the lubricant on part surfaces for as long as possible dependent on different machining processes. Comparisons are made between values specific to the wear state of the considered part obtained by various machining by measuring material mass removed during functioning in similar working conditions.

1 Introduction

As part of this research test probes were manufactured having their outer surface resulted through cutting and superficial plastic deformation. Final machining operations on part surfaces were by turning, rectification, rolling, diamond polishing and vibration rolling. The last process was then divided into ball vibration rolling and ball vibration rolling with channels. For the machining of parts obtained through cold superficial plastic deformation a device was manufactured which had interchangeable deforming elements. Wear resistance estimation was carried out by means of a device which allowed friction moment measurement and the friction coefficient between the test probe and the machine shoe.

2 Investigation technique and instruments

The Machine Manufacturing Technology laboratory from the Gheorghe Asachi Technical University of Iasi holds a device, designed and developed inside the lab, for cold plastic deformation which allows rolling, vibrating rolling and polishing by means of diamond spherical tips [1]. Figure 1 shows the device working principle as figure 2 depicts a photography taken during experimental attempts. We are attaching the cold superficial plastic deformation device to the tool holder sledge of a SN400x1000 Romanian lathe. Pushing the deforming element onto the probe has been done by the arc based system (6).

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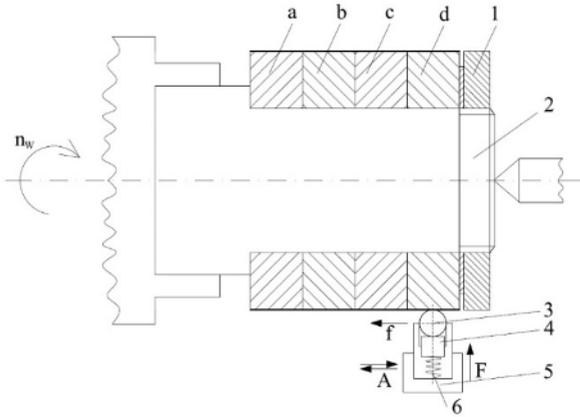


Fig. 1. The working principle of the used superficial plastic deformation device.

The device allows to inflict on the deforming element (3) oscillations (A) with amplitudes between 0 and 7 mm by means of a revolution variation device and a rod-crank type of tappet mechanism which allows oscillation frequency adjustment. The support (5) and the backing mechanism of the deforming element may be interchanged and replaced with other types; for example diamond tips. The revolution movement (n_w) of the mandrel support (2) makes the testing probes (a,b,c and d) revolve which overlaps with the feed of the lathe. The device

allows the adjustment of the pressing force with values between 20 and 1000N by adequately replacing the arc mechanism (6).

To appreciate the wear resistance of parts whose surfaces were machined by different processes the following criteria was taken into consideration [2]:

- Part dimensions decrease during functioning;
- Mass reduction of the two elements which make up the friction couple (the part and the machine shoe);
- Time or revolutions executed by the part until friction moment stabilization;
- Values and variations of the friction moment and the friction coefficient inside the friction couple during functioning.

To adequately study those values and parameters a device (figure 3) was designed and developed which adapts on to a fine mechanics designed lathe.

The studied friction couples have been formed from a cylindrical part which had its outer surface machined by means of cold superficial plastic deformation processes or by cutting and a machine shoe with its inner cylindrical surface machined by rectification [3].

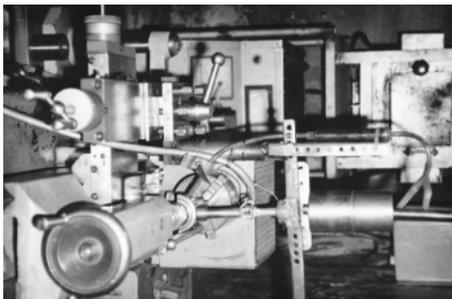


Fig. 2. Image taken during experimental attempts.

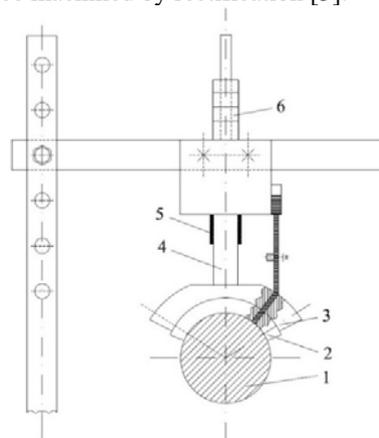


Fig. 3. The working principle of the device that estimates wear resistance of outer cylindrical parts.

Between friction couple's elements there is a relative motion obtained when the part revolves as the machine shoe stays fixed. Figure 3 presents a sketch of the designed device which has the interchangeable machine shoe (2) fixed on the shoe holder part (3). Inside the shoe holder part we have drilled a hole for the lubricant to be injected in the friction area between the part and the machine's shoe.

The shoes were made out of wear resistant materials such as the X210Cr12 steel which complies with the EN ISO 4957 standard. The shoe holder part is being fixed with the rod (4) on top of which dependent to its axis are mounted in a semi-deck format two 2359/TH 120-20 type of tensometric transmitters (5) having a resistance of $R = 128\Omega \pm 0.2\%$ and a constant of $2.39 \pm 3\%$.

By means of rod (4) the system has been loaded with the weights (6). The friction moment produced between the part (1) and the machine shoe (2) is being transformed into a bending moment at rod's (4) level and is being sensed by the transmitters.

The obtained information is then overtaken and recorded by a tensometric bridge. The lubrication system's adjustment is made through H2O oil flow control which complies with the STAS 9691-74 standard. An image taken during functioning is presented in figure 4.

The designed device allows the measurement of the following parameters:

- The friction moment between the part and the machine shoe;
- The friction coefficient and the friction force between the part and the machine shoe.

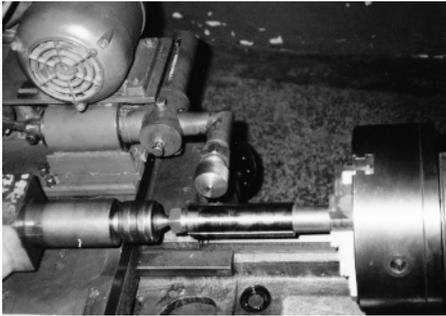


Fig. 4. Image taken during experiments.

The friction moment is given by [4]:

$$M_f = r \cdot F_f \quad [Nm] \quad (1)$$

Where r represents the radius of outer cylindrical test probe used in the experiment and F_f is the friction force between the two elements.

This force is expressed as [5]:

$$F_f = \mu \cdot N_a \quad [N] \quad (2)$$

Where μ represents the friction coefficient between the part and the machine shoe and N_a is the force of normal pressing on the part's surface imposed by the friction shoe.

This force is determined as a product between the mass of the weights mounted on the vertical rod (4) and the gravitational acceleration g .

It results that by measuring the moment we can compute the friction coefficient as [4]:

$$\mu = \frac{M_f}{(m \cdot g)} \cdot \frac{1}{r} \quad (3)$$

Where g represents the gravitational acceleration and m the mass of the parts used as weights.

After experiments we can establish:

- Friction moment values and the values of the friction coefficient;
- The time needed for the grinding type of wear by drawing out the correlation graphical representations between the friction moment and the functioning time;
- The optimum type of micro-geometry in friction conditions;
- Comparison of different technological processes from the point of view of wear resistance of the machined parts;
- The optimum type of micro-geometry that is more suitable for energy dissipation which translates into lower values recorded for the friction moments.

3 Experimental results and interpretation

The experimental research has been focused on the comparison of friction moments between a part obtained by means of various machining and the machine’s shoe made out of X210Cr12 steel which complies with the SR EN ISO 4957 standard depending on the pressing pressure between the part and the machine shoe and the oiling regime.

Test probes from ST60 steel have been manufactured having a 60 mm diameter and a widening of 22 mm machined through various processes up to 1 μm for the Ra roughness parameter for surface quality. A revolution speed of 800 rot/min has been used and lubricant up to 12 – 14 drops per minute for one set of experiments and no oiling at all for another set of experiments.

The pressing force was of 550 N for a pressure of $p = \frac{550}{\pi \cdot 2.2 \cdot 6} = 13.26 \text{ N / cm}^2$. The friction moment was periodically measured. By analyzing the experimental data we can observe the friction moment is greater for the scenario which does not uses lubricant between the part and the machine shoe. The friction forces are greater for the cutting machined parts.

Table 1. Friction moments between the part and the machine shoe with lubricant.

Part characteristics	N · mm											
	0	12	24	36	48	60	72	84	96	108	120	132
The number of part revolutions expressed in thousands	0	12	24	36	48	60	72	84	96	108	120	132
Ra = 1.69 μm (turning)	275	289	300	325	340	355	360	375	390	400	405	410
Ra = 0.82 μm (rectification)	250	268	283	310	329	346	355	370	385	400	410	410
F = 350N, f = 0.059 mm/rot, Ra = 0.65 μm (ball rolling)	140	180	215	245	270	295	315	330	340	347	350	350
f = 0.059, Ra = 0.1 μm (ball vibration rolling)	120	155	185	210	230	245	260	270	276	280	281	281
(ball vibration rolling with channels)	90	120	145	170	190	205	215	217	220	220	220	220

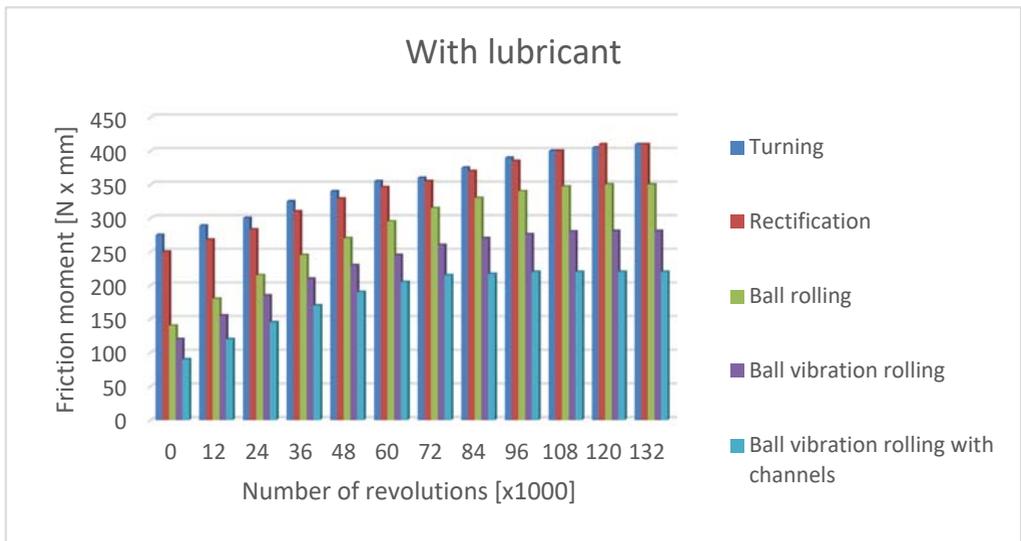


Fig. 5. Friction moments variations dependent on different machining types using lubricant.

The explanation points out the modifications of superficial plastic deformation surface characteristics. We can see that the parts machined by vibration rolling have a much smaller friction moment than the ones machined by other cold superficial plastic deformation processes. That is because we are achieving a much more pronounced hardening at vibration rolling obtaining a complete new topology as opposed to rolling or diamond based polishing. Rounding radiuses for the micro-irregularities in case of vibration rolling present greater values and have a much more obvious regular disposition which result in the so called “elementary cells of regular micro-relief”. In the case of the micro-relief with a pressed channels system a significant role is attributed to the channels and their behavior as true “oiling pockets” in which the oil is maintained and/or transported in the friction zone.

Table 2. Friction moments between the part and the machine shoe without lubricant.

Part characteristics	$N \cdot mm$											
	0	12	24	36	48	60	72	84	96	108	120	132
The number of part revolutions expressed in thousands												
$Ra = 1.69\mu m$ (turning)	330	370	400	425	450	470	490	505	515	525	530	535
$Ra = 0.82\mu m$ (rectification)	300	340	370	400	425	445	460	475	485	495	500	504
$F = 350N, f = 0.059 mm/rot, Ra = 0.65\mu m$ (ball rolling)	180	175	210	240	265	285	300	315	330	340	355	355
$f = 0.059, Ra = 0.1\mu m$ (ball vibration rolling)	150	180	210	230	246	261	273	280	287	292	295	295
(ball vibration rolling with channels)	125	150	172	195	206	220	226	229	235	235	235	235

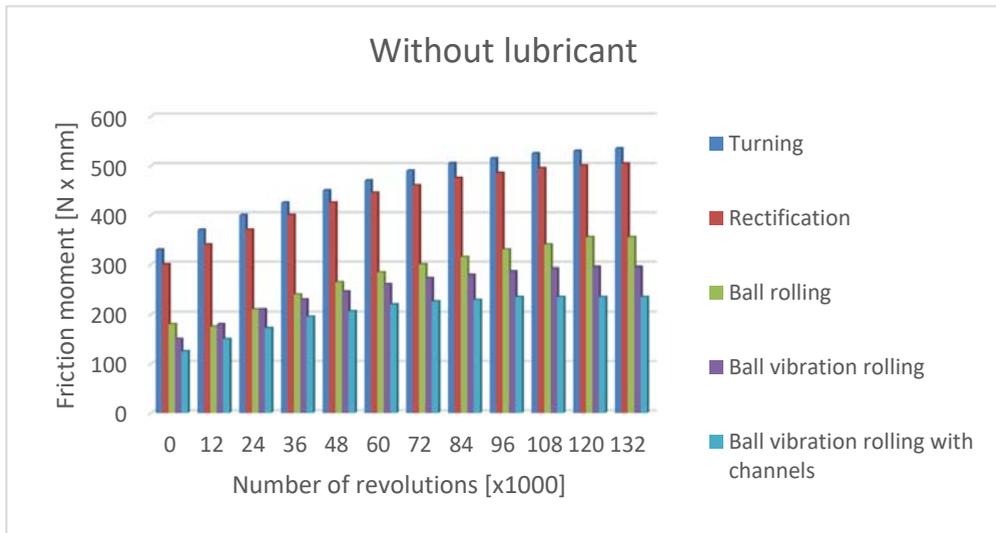


Fig. 6. Friction moments variations dependent on different machining types without lubricant.

A comparison between the two cases was carried out in order to highlight the main differences that occur in terms of friction moments related values. For all cases, as expected the use of lubricant decreases the friction process that occurs between the part and the machine shoe. Higher values are recorded for turning and rectification as the rolling processes

do manage to record about half of those values. As well as the number of revolutions are getting bigger the friction moments are significant larger as result.

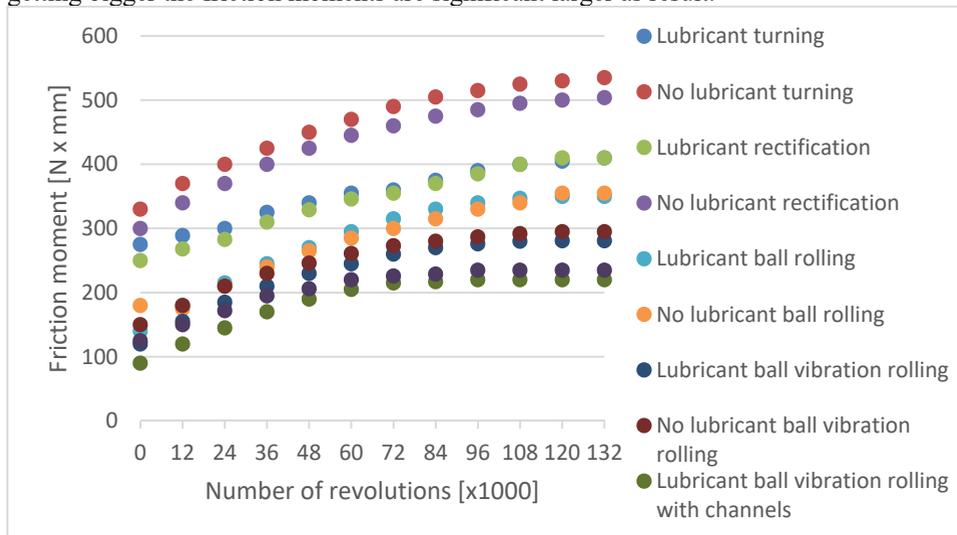


Fig. 7. Comparison between friction moments variations dependent on different machining types with versus without lubricant.

4 Conclusions

In all cases we can observe that that using lubricant produces better results in terms of friction moments between the part and the machine shoe. The best results are obtained for the ball vibration rolling with channels. The channels dissipate the energy produced as moments of friction in a very timely and accurate manner. The results obtained for this particular process do overlap all other ones even if no lubricant are used highlighting the importance of energy dissipation by means of channels.

In a brief presentation based on the sustained experiments and results in case of vibration rolling we are noticing:

- A double increase of wear resistance for the cold superficial plastic deformation machined parts and especially for the vibration rolled ones; the case of the friction couples;
- A decrease of the friction moment and that of the friction coefficient for the vibration rolling obtained parts;
- A decrease of the grinding time up to two times for the superficial deformed parts and especially at those subjected to vibration rolling.

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