

# Control of geometric characteristics of surface micro-relief in metal turning using nanodiamond powders

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**Abstract.** The study analyzes the impact of different technological agents on the surface purity during metal turning. New technological lubricants consisting of organic compounds are studied. In the agents nanodiamond powder is used to intensify the metal turning processes. The agent is fed into the sample's turning zone while affecting the purity of the surface. The impact of the agent on the surface layer quality in the processing of heat-resistant steels and alloys is investigated. The optimal composition of the agent is revealed when turning one or another material. The tests established the positive effect of the agent on the quality of the treated surface and other parameters of the turning processes of various metals and alloys.

## 1. Introduction

Technological advances in the most important branches of modern mechanical engineering are associated with more and broader application corrosion-proof, heat-resistant and another hardly processed steels and alloys [1-2]. This puts forward the task of developing, investigating and introducing highly efficient formation processes using the latest advances in physics, chemistry and related sciences.

It is known that with the increase in heat resistance in the treatment of hard-to-process materials cutting rates are sharply reduced [3-4]. Cutting rate can be reduced up to 20 times and more [5], [6]. This results in a sharp increase in part processing time and a decrease in processing productivity [7].

One of the most important productivity-enhancing reserves and improving cutting technology is the use of efficient lubricating-cooling and protective process agents [8].

Lubricating-cooling liquids, gases and solid lubricants are generally recognized means of increasing the efficiency of cutting and machining operations [9]. Their application also contributes to improvement of accuracy of parts, improvement of cleanliness and quality of treated surfaces [10].

The right agent generally tends to have a favorable and versatile effect on friction, wear and other factors in finishing and polishing the metals [11-12].

Influence of lubricating-cooling process agents (LCPA) with nanodiamond powder on the surface quality during turning is investigated in this work. As some studies show this topic is ambiguous and requires comprehensive study for various steels and alloys [13-14].

## 2. Methods and materials

The testing results of LCPA technological properties are greatly influenced by the choice of elements of cutting modes. Mostly it's cutting rate.

The main series of tests should be carried out at the cutting rate which provides the average durability of the tool when working with the reference LCPA corresponding to the minimum cost of cutting processing. To obtain more informed conclusions the cutting rate in tests is changed by 1.2-1.4 times, both in the direction of increase and in the direction of reducing rate.

The cutting supply and depth are assigned in accordance with the testing objectives.

Assessing the technological effectiveness of LCPA in cutting it is necessary to proceed from the main indicators determining the cost-effectiveness of the operation and the quality of the treated surface. These indicators include the wear of the tool. It determines the technological durability, the treated surface roughness and, as a result, affects the cost-effectiveness of cutting treatment.

Of particular importance is the choice of parameters that not only provide the end result in a particular technological operation but also allow for a more comprehensive assessment of LCPA ability and their action mechanisms. The choice of estimates is decided by using LCPA evaluation system.

Assessing the impact of LCPA on the treated surface roughness is one of the most important elements of the evaluation system. It does not cause much difficulty in implementation. It is only necessary to take measures to suppress the direct influence of the instrument geometry and the section of cut on the relief of the treated surface. This effect may override the effect of LCPA on the height of microroughness on cutting surfaces and eventually on the treated surface. Uneven wear of the top and auxiliary cutting edge due in large part to the agent chemical activity is directly related to the roughness of the treated surface and the dimensional wear, i.e. determines the technological tool durability.

LCPA composition is given in table 1.

**Table 1.** LCPA compositions.

Component	LCPA content numbers and component content							
	1	2	3	4	5	6	7	8
Nanodiamond powder		0.1	2	-	0.2	0.6	1	-
Potassium chromate	Dry cutting	-	-	0.028	0.025	0.03	-	-
Trietanolamine		2	2	0.25	0.2	0.3	-	-
Sodium nitrate		-	-	0.07	0.06	0.08	-	-
Fatty acid potassium salt		-	-	0.015	0.01	0.02	-	-
Glycerin		-	-	0.8	0.7	0.9	-	-
Water		97.9	96	98.837	98.805	98.37	99	100

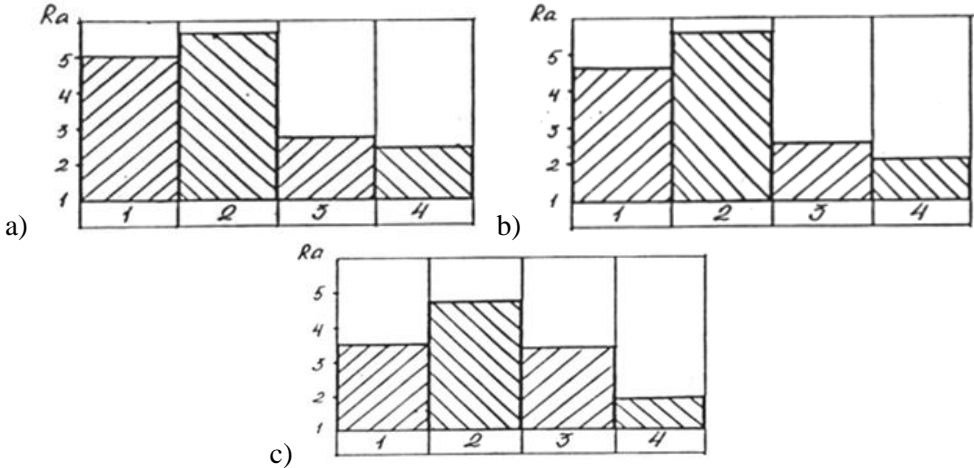
In order to determine the effectiveness of LCPA on the quality of the treated surface, the surface roughness was determined. The effect of LCPA on the purity of the treated surface was investigated with longitudinal turning of alloys on nickel-based N07750 and NiCr20TiAl as well as steel with special properties 34NiCrMoV14-5. The studies were carried out by turning pass-through cutters with five-sided throwaway solid alloy inserts of HG30 brand for nickel steels and HS123 for steel with special properties.

The "Kalibr" profilograph-profilometer was used to control surface roughness. It allows estimating the surface roughness by the parameter of arithmetic average deviation  $R_a$  by the device or by recording in increased scale of the microroughness profile  $R_z$ .

## 3. Results

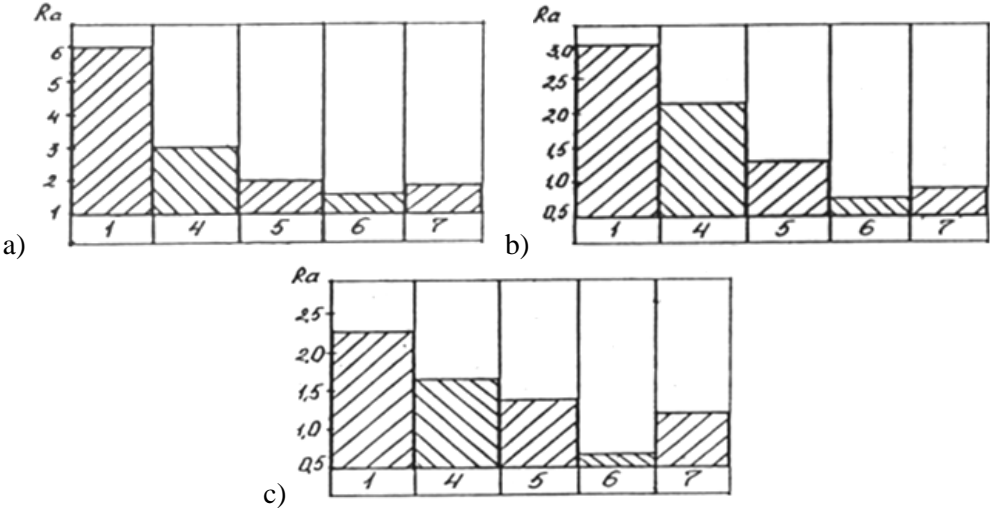
Studies showed that the roughness of the treated surface is influenced by both the change in cutting rate and the agents used. At N07750 dry turning the purity of the surface increases (figure 1) as the cutting rate increases. The use of water as LCPA contributes to the intensive formation of growth,

frequent disruptions from the front surface along with particles of the cutting tool material and, as a result, the deterioration of surface roughness in the entire range of cutting rates. The use of LCPA 3 and 4 significantly reduces the size of roughness in this range of cutting rates. For example, figure 1 shows that when using LCPA No. 3 the purity of the treated surface in the entire cutting rate range increases, as it does for LCPA No. 4.



**Figure 1.** Effect of cutting rate and lubricants on roughness ( $\mu\text{m}$ ) of the treated surface when turning alloy N07750 at rate: a)  $v = 18$  m/min; b)  $v = 25$  m/min; c)  $v = 40$  m/min.

When NiCr20TiAl alloy turns with increasing rate the surface purity improves (figure 2). Here LCPA No. 6 shows itself positively. Moreover, the use of LCPA is more significantly manifested at low cutting rates. The effect of LCPA on the size of the surface microrelief in the entire range of cutting rates is similar. Less effective is LCPA No. 4, the most effective No. 6. Moreover, with the increase in cutting rate their action changes slightly which is clearly seen from figure 2.

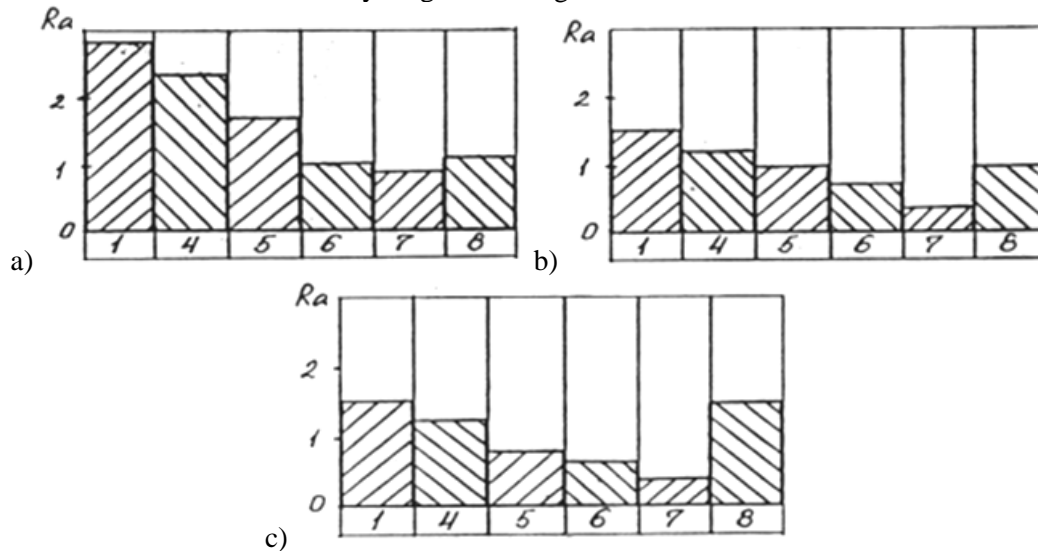


**Figure 2.** Effect of cutting rate and lubricants on roughness ( $\mu\text{m}$ ) of the treated surface at NiCr20TiAl alloy turning at speed: a)  $v = 25$  m/min; b)  $v = 40$  m/min; c)  $v = 55$  m/min.

The action of LCPA 5, 6, and 7 is particularly similar. All these agents include active additives which have anti-wear and antioxidant properties. They contribute to the formation of metal sulphide films on friction surfaces which helps to reduce the phenomenon of setting the contact surfaces of

the tool and the part leading to torn surfaces. Furthermore, no build-up was observed using these agents which also contributes to a higher surface purity.

Effect of cutting rate and LCPA applied to the roughness of the treated steel surface 34NiCrMoV14-5 is characterized by diagrams on figure 3.



**Figure 3.** Effect of cutting speed and lubricants on roughness ( $\mu\text{m}$ ) of the treated surface at 34NiCrMoV14-5 alloy turning at speed: a)  $v = 102$  m/min; b)  $v = 190$  m/min; c)  $v = 250$  m/min.

The increase in cutting rate is accompanied by the decrease in surface roughness (figure 3). Further increase in cutting rate does not reduce roughness. Introduction to the cutting zone LCPA helps to reduce the size of rough edges and the purity of the treated surface. As the chart shows, LCPA affect the reduction of roughness in different ways. The least effective were LCPA No. 4 on all the steps of the study range of cutting rates. The most effective were LCPA No. 7, LCPA No. 6 were close to the previous one. The chart also shows that with the increase in cutting rate the efficiency of LCPA decreases, the purity of the surface does not change, and the use of LCPA No. 8 gives even an increase in the height of the microrelief when turning at the last stage of cutting speed.

#### 4. Conclusion

Steels N07750, NiCr20TiAl and 34NiCrMoV14-5 were tested by turning with different lubricating-cooling process agents. It has been found that as the cutting rate increases the micro-relief decreases and the surface purity improves. The use of water as a process agent contributes to the formation of a build-up and worsens the purity of the treated surface. Compositions No. 6 and 7 containing nanodiamond powder are recognized as the best technological agents. Active process agents introduced into cutting zone containing nanodiamond powder and improving cutting conditions help to improve the quality of treated surface, reduce the size of the microrelief of the treated surface.

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