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SURFACE LAYER PROPERTIES IN DRY TURNING OF C45 STEEL

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Abstract

In machining operations cooling and lubrication liquids perform significant technological functions such as reducing temperature of the cutting area and determine machined surface layer characteristics. However their negative ecological effects force the industrial and scientific community to find an alternative means of cooling and lubrication of the cutting zone. The article shows the results of performed experiments of the influence of cooling and lubrication methods on the machined surface layer roughness and bearing ratio after turning C45 steel. The experimental results indicate that in correct chosen cutting parameters, the elimination of cutting liquids does not have to decrease the machined surface quality and makes it possible to reduce ecological burdens imposed by wet machining processes.

Keywords: *cutting, cooling, lubrication; dry cutting; surface roughness*

1. Introduction

In machining operations cooling and lubrication liquids perform many important functions, mainly reducing temperature of the cutting tool point and work piece as well as removing chips from the machining area. More over liquids influence the tool life, dimension accuracy and machined surface quality. However the ecological awareness of machining processes motivated many scientific investigations, performed in order to determine the results of cutting liquids elimination and replace them with other cutting fluids [1,3,4,6]. The development in cutting tool materials and coatings made it possible to increase of the tool point toughness and resistance to high temperatures required in machining without cooling. Contemporary cutting tool materials enable dry cutting of different work piece materials both in the soft and hardened state [2,6]. Particularly important is the correct selection of tool's substrate and coating which in dry machining should give comparable tool life with that of wet cutting. The optimised cutting point geometry ought to reduce contact surface among tool, chip and work piece in order to minimize cutting friction, which is one of the main factors affecting the tool live and work piece temperature.

Elimination of cutting liquids from machining processes makes it possible to reduce costs associated with coolants purchase, exploitation and maintenance as well as with machining processes. Dry cutting is more environmental friendly and decreases health hazards induced by contact with cutting liquids. Practical applications however make sense when all tools engaged in the machining process can work dry, otherwise an intermittent flow of coolant can lead to numerous cracks and chippings on the cutting edge, which is made of material sensitive to high temperature shocks.

An important issue in dry machining is rapid chips removal from the cutting zone and machine tool. Slow chips disposal may cause a temperature increase of work piece material and machine tool elements, which in turn bring about deterioration of dimensional accuracy and surface layer properties.

The aim of presented investigations was to determine the influence of different cooling and lubrication methods of the cutting zone on chosen properties of surface layer after turning C45 steel.

2. Experimental procedure

Turning tests were carried out on a lathe TUD 50 with 6,7 kW main motor. Medium carbon steel C45 bars with separated segments of 35 mm length for each test were machined (fig. 1).

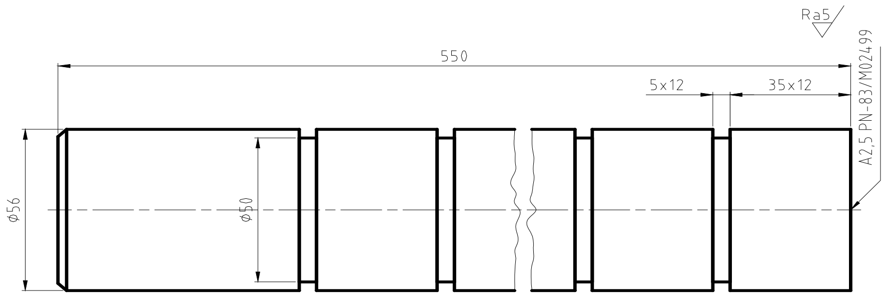

Fig 1. Workpiece specimen

The experiments were performed according to the static determined complete program [5]. The selected cutting parameters comprised three levels of cutting speed and feed rate and constant depth of cut a_p=1 mm (tab. 1).

Tab. 1. Cutting conditions

Test No	1	2	3	4	5	6	7	8	9	10	11	12
v_c m/min	76			120			190			237		
f mm/rev	0,08	0,27	0,47	0,08	0,27	0,47	0,08	0,27	0,47	0,08	0,27	0,47

Sintered carbide inserts SPUN 120308 (production of Pramet –Czech Republic) covered by PVD method with (TiAlSi)N coating were employed, fixed in a tool holder CSSPR 20 x 20mm. The following cutting point geometry was applied: $\gamma_0=5^0$, $\alpha_0=10^0$, $\chi_r=45^0$, $\lambda_s=0^0$, r_ε=0,8mm. Quoted inserts were recommended for machining of anticorrosive or heat resistance steels as well as soft steels machined with medium cutting speeds. The influence of the cutting tool wear on investigated factors was minimized by changing the cutting edge for each specimen.

The following cutting liquids were employed:

- E - 6% emulsion, on the basis of emulsifying oil ARTEsol with a flow volume 4 l/min,
- O - mineral oil ARTEkat Super VG-32 with a flow volume 4 l/min,
- S - without cutting fluid - dry cutting,
- P - dry cutting with compressed air 6 bar.

Emulsifying oil ARETEsol with 68% concentration of mineral oil and additives increasing lubricity in quantity of 6% was designed for turning, milling, drilling and other operations of machining steel, cast iron and nonferrous metals. When mixed with water it constituted milky emulsion with recommended concentration of 4-7%. The pH value of emulsion was 9.

Mineral oil ARTEkat Super VG-32 consists of highly refined mineral oil with lubricity increasing additives in concentration of 9-11 %, designed for turning, milling, drilling and other operations of machining steel, and cast iron.

Measurements of surface finish parameters: *Ra* and the profile bearing ratio were performed on a profilographometer Hommel-Tester T2000 with Tk300 sensor and the following parameters: evaluation length 4,8 mm, sampling length 0,8 mm. Tests were repeated 5 times and then the mean values determined.

3. Results and discussion

Experimental results indicated a substantial relationship between cutting conditions and geometrical properties of the surface layer. The influence of feed rate exceeded that of cutting speed, and at constant feed rates an increase of cutting speed caused a decrease of surface roughness parameter *Ra* or its value remained on the same level (fig. 2, 3).

At the feed rate of 0,08 mm/rev and in the used range of cutting speed, the biggest differences of *Ra* parameter appeared at v_c=120 m/min. The differences of *Ra* during turning with application of emulsions as well as with dry cutting were insignificant. A better surface finish was achieved when compressed air was engaged. The use of oil caused an increase of surface roughness. At the feed rate of 0,27 mm/rev and cutting speed of 76 m/min compressed air reduced values of surface roughness. At a speed range of 120 to 237 m/min and feed rate 0,27mm/rev the best surface finish was obtained using the ARTEkat Super VG-32 oil. The other methods of applying cutting fluids led to much the same results. A further increase of feed rate to 0,47mm/rev did not bring about significant differences in surface finish when cutting dry or with emulsion. The application of compressed air in these conditions produced an increase of surface roughness. On the contrary the application of non emulsifying oil brought the best results.

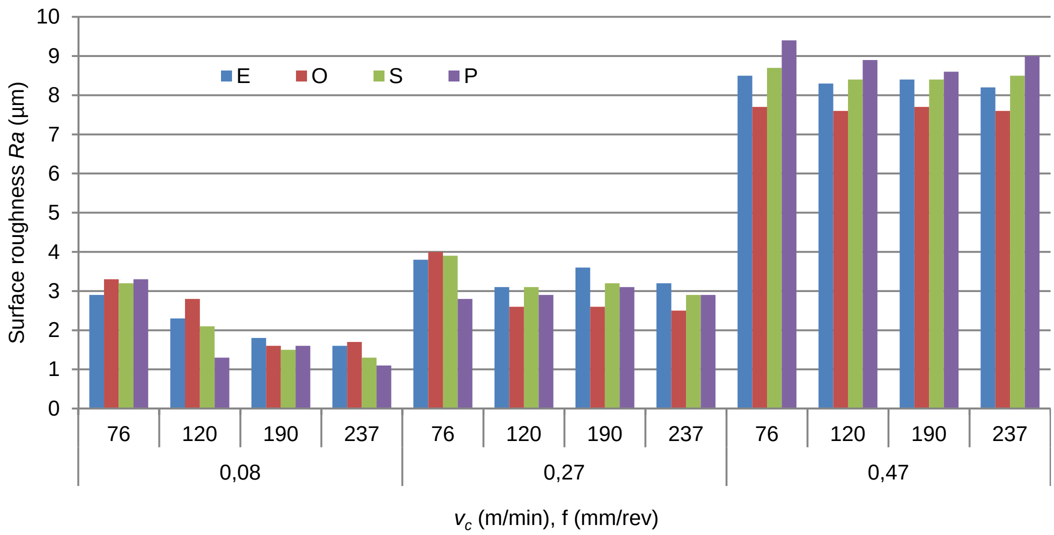

Fig. 2. Influence of cooling and lubrication conditions on surface roughness

The experiments showed that with the increase of speed, differences in surface roughness between dry cutting and with application of cutting liquids undergo diminishing tendency, especially when using small feed rates. An increasing pressure on the chip-tool point interface, at the higher speeds and feed rates, made the penetration of cutting liquids between rubbing surfaces of chip and tool point difficult or at least restricted at the same time reducing their lubricating effect and a positive influence on the surface finish. A higher cutting zone temperature in dry cutting facilitated the chip formation and separation and reduced material cutting resistance. The influence of the disturbing cutting process factors on the theoretical surface finish, ensuing from the geometric and kinematical reproduction of the tool point on the machined surface was also restricted [3,6].

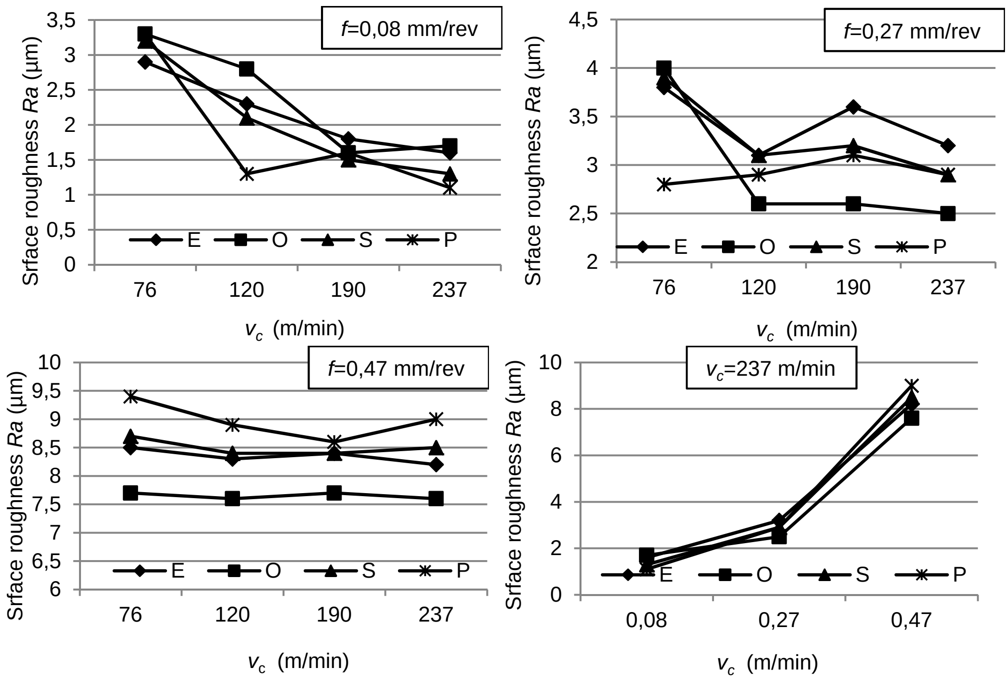

Fig. 3. Influence of cooling and lubrication on: surface roughness Ra

The increase of cutting speed at low feed rate made the influence of applied liquids on the quality of machined surfaces less significant, what could indicate on lack of reasons for their usage in finish turning of C45 steel. The reduction of surface roughness in the case of turning with the ARTEkat Super VG oil in increased feed rates could be due to the oil lubricating qualities and the used additives in its composition.

The positive impact of compressed air in the range of small speeds and feeds indicated on the existence of advantageous distribution of temperature in the cutting zone, which made the generated chips shorter and easier to transfer from the cutting area. The compressed air due to reduced cooling capacity did not induce such a temperature lowering effect in the tool-work piece interface as emulation or oil, which could facilitate the separation of chip from the machined material and increase of surface finish. Therefore at lower cutting speeds and feed rates it seems advisable to apply compressed air as a factor improving dry cutting process and chip disposal. The increase of speed and feed rate limited positive effect of compressed air on surface roughness.

The investigations did not reveal any significant impact of applied cutting fluids on the surface roughness profile shape (fig. 4) and the bearing ratio (fig. 5, 6). The digressive-progressive shape of the surface bearing ratio curves indicated small values of core roughness depth and reduced peak height. The reduced valley depth values exceeded the peak height, which pointed out to a good load bearing capacity, wear ability and oil retaining capability of the machined surfaces.

An increase of the cutting speed did not only reduce the surface roughness but also contributed to the improvement of the surface bearing ratio (fig. 5). With an increase of feed rate a negative change in the profile bearing ratio occurred which caused a reduction of surface bearing ratio (fig. 6). The lower feed rate contributed to an increase in the bearing ratio especially after turning with compressed air. The shape of the profile bearing ratio curves after turning with emulsion and oil were similar depending on the applied feed rate.

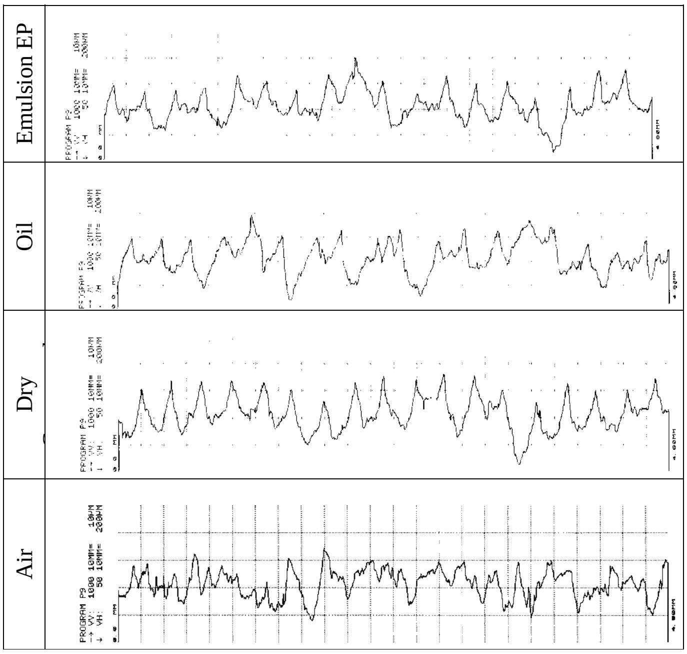

Fig. 4. Profilogram of surface roughness: Vc=76 m/min, f=0,27 mm/rev

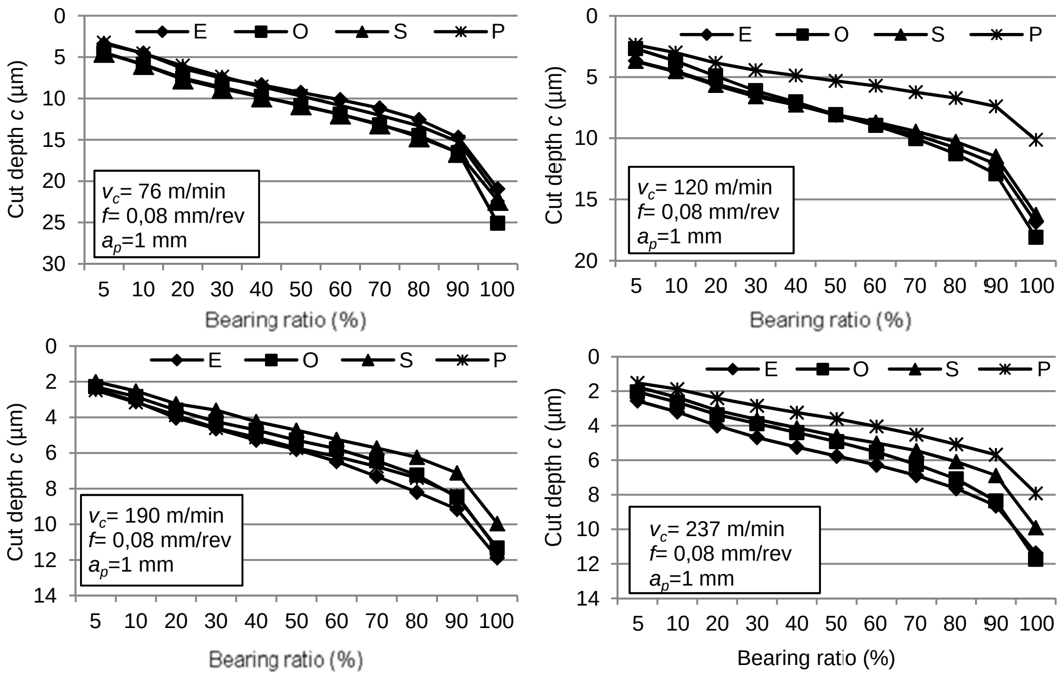

Fig. 5. Influence of cooling, lubrication and cutting speed on surface bearing ratio

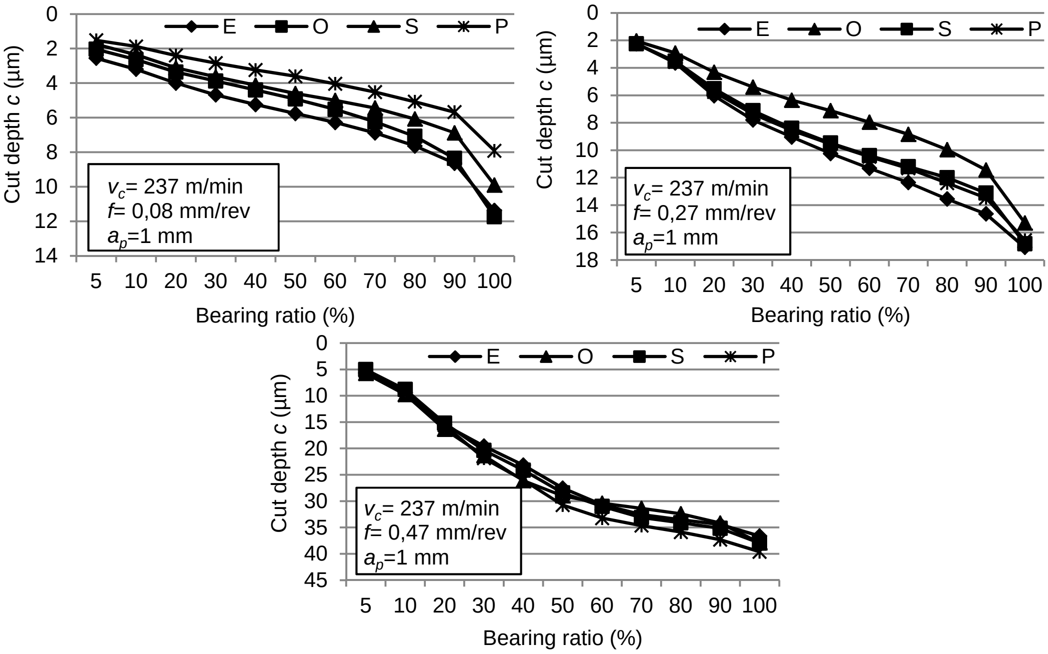

Fig. 6. Influence of cooling, lubrication and feed rate on surface bearing ratio

4. Conclusions

The experiments confirmed a significant influence of cutting parameters on geometric characteristics of a machined surface. The largest influence is exerted by feed rate, and with constant feed rate, the increase of cutting speed caused a reduction of surface roughness and bearing ratio or they remain on near the same level.

Differences between particular surface roughness values depending on cutting fluids were not significant, especially in the range of small cutting feed rates. It is possible to obtain in dry turning of C45 steel comparable surface geometrical characteristics to that of wet machining.

The application of compressed air in the range of low cutting speeds and feed rates influenced favourably geometrical surface parameters in dry turning and can support cutting process and chip disposal.

The applied methods of cooling and lubrication did not show a significant influence on the shape and bearing ratio of surface roughness profile. With the increase of feed rate the bearing ratio underwent negative changes.

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