About hard turning of welded surface using tool with closed system of heat sink from replaceable plate

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***Abstract* — The special tool with the closed cooling system for replaceable hard-alloy plate on using thermoelectric Peltier modules is designed. Pilot studies of hard turning of 20X13 steel welded surface by a round plate of cubic boron nitride (by SECO) are conducted at increase in cutting speed from 100 to 300 m/min, revealing decrease in surface roughness by 22% for Ra and 26% for Rz, as well as in facet of plate cutting edge by 17%**

Keywords — Hard turning, Internal cooling, Cutting speed, Roughness, Wear

I. Introduction

Turning is accompanied by intense heat generation due to frictional interaction and deformation of the material being removed, as evidenced by the substantial heating of the chips, chisel and parts [1-5]. High temperature of the processed material adversely affects the quality of the processing, heating the tool leads to a decrease in the hardness of the cutting edge and its rapid blunting, which significantly reduces its life time [2]. The intensity of heat release depends on the properties of the processed and tool material, the geometry of the cutter and the cutting regimes. The greatest influence is exerted by the cutting speed, the smaller is the feed and depth of cutting [3].

The heat generated during turning is distributed between the chips, the cutter and the workpiece. The greatest share of heat (70% to 80%) is discharged into the shavings, the rest is divided between the cutter and the workpiece. According to [4-5], when the cutting speed of AISI 316L and AISI 1045 steels is increased from 10 to 80 m/min, the share of heat released into the tool is reduced from approx. 60% to 18%. With a further increase in speed, heat fluxes ratio does not change. In terms of machining quality, tool life and productivity, hard turning is most advantageously realized at a cutting speed of 50 m/min, when the heat dissipation rate is relatively small and the heat transfer to the tool is about 30%. According to SECO recommendations for the treatment of chromium steels with cubic boron nitride plates PCBN, the optimum cutting speed is 50 to 100 m/min.

To ensure the high quality of the machining and the durability of the cutter, when increasing the cutting speed, it is necessary to increase the fraction of the heat removed from the cutting zone into the tool. Since it is impossible to use external lubricant-cooling agent (LCA) with hard turning, and cooling the part is ineffective, the only and promising direction is the internal heat sink from the replaceable plate.

Approaches to the creation of a turning tool with internal cooling of replaceable carbide plate (RCP) are given in [6-8]. The idea is to supply the cooling liquid to the RCP base through channels made in the holder. In [6], an open-loop system is realized in which a liquid coolant is pumped. The system is easy to manufacture, however it requires a high-performance pumping equipment and is associated with a high flow rate of the cooling liquid. In [7, 8], a two-phase closed-loop system is presented, based on evaporation of the liquid refrigerant under the RCP. A closed-loop system provides more efficient cooling, however, because of the large dimensions of the capacitor, its use in production seems difficult.

A more efficient cooling system is presented in [9-10] to improve the performance of nanostructured smoothing. The open type system [9], based on high-pressure LCA pumping, increased the allowable processing speed of 20X13 steel (43 to 45 HRc) by 65%. The closed-circuit cooling system, using Peltier thermoelectric modules (TEM), demonstrated high efficiency in removing heat from the tool, providing an increase in the allowable smoothing speed by 2.2 times [11].

The purpose of this study is to find the dependency of treated surface roughness and tool stability on the internal heat sink from the RCP type PCBN when the welded material is hard turned using a closed cooling system with an increase in the cutting speed by 3 times with respect to the recommended one.

II. Methodology

To carry out the experimental studies, a lathe tool with an internal closed cooling system was created (Fig. 1). High heat dissipation rate was achieved due to a decrease in the temperature of the coolant in a closed loop, provided by a heat exchanger with an assembly of four Peltier TEMs. The cooling capacity of the TEM assembly was 400 W that ensured the coolant temperature to be maintained at 9°C with an increase in the turning speed up to 300 m/min.

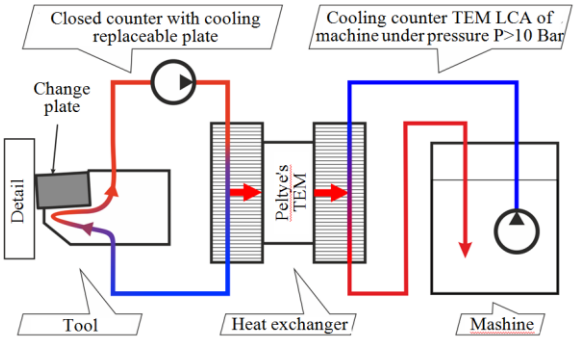

Fig. 1. *A closed system for liquid cooling of a replacement plate based on the Peltier thermoelectric module*

Experimental studies were carried out while turning the end of a disk sample made from 20X13 steel (in a delivery status) with a welded layer of 20X13 steel of 5 mm thickness. The hardness of the latter was in the range 45 to 48 HRC. The processing was performed on a turning lathe Okuma Multus B300 (Fig. 2).

The preliminary turning was performed with a Sandvik WNMG 080408-SM plate at a cutting speed of 80 m/min and a feed rate of 0.06 mm/rev. Surface roughness after turning Ra=0.45 ... 0.5 µm, Rz=2.7 ... 3.15 µm.

Final hard turning of the annular sections was performed by a round plate SECO RNMM190400S-10020 of 19 mm diameter made of cubic boron nitride CBN500. The depth of cut was assigned t = 0.15 mm, feedrate f = 0.15 mm/rev. Cutting speed was set to 100, 200, 250 and 300 m/min for different tracks.

During the processing, RCP front surface temperature was measured using a thermal imager Testo 875. The roughness of the treated annular sections was measured by the contact method using "Caliber" gauge model 170623. The arithmetic average value of a roughness for ten measurements was taken as a result.

Fig. 2. *Cutter with closed cooling system for replacement plate on the lathe Okuma Multus B300: 1 - Holder with RCP; 2 - Cooling system; 3 - Thermal imager; 4 - Workpiece*

III. Experimental Results

Both in the case of turning without a heat sink, and with a cooling system, the dependence of the RCP temperature on the cutting speed is the same (Fig. 4). When the speed rises from 100 to 250 m/min, the temperature increases linearly. However, an increase in speed from 250 to 300 m/min leads to a significant decrease in the RCP temperature. The maximum and minimum temperature of the RCP in processing without a heat sink reached 263°C and 69°C respectively. Use of the cooling system reduces the maximum and minimum temperatures, respectively by 12% to 235°C and by 32% to 47°C. A significant temperature drop at a speed of 300m/min can be explained with friction reduction at this speed range.

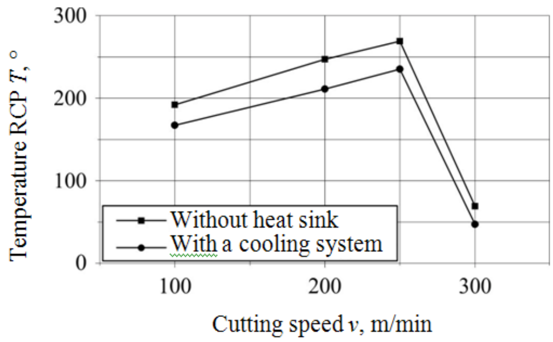

Fig. 3. *RCP temperature dependency on cutting speed*

Dependency of surface roughness changes after turning (Fig. 4) shows a good correlation with RCP temperature. RCP Cooling decreases the surface roughness, which is especially noticeable when turning at a speed of 300 m/min. The roughness Ra is reduced by 22% from 0.23 µm to 0.18 µm and Rz by 26% from 1.43 µm to 1.06 µm.

The use of a cooling system also reduces the wear of the RCP. At an optimum speed of 300 m/min, the width of the chamfer of the cutting edge wear is reduced by 17% from 2.3 mm to 1.9 mm (Fig. 5).

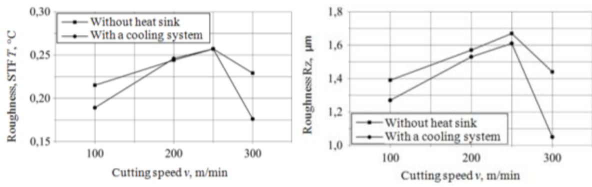

Fig. 4. *Dependency of the roughness Ra and Rz on the cutting speed*

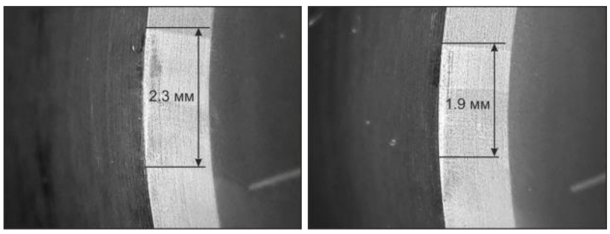

Fig. 5. *Chamfer of a wear of the CBN500 plate after turning at a speed of 300m/min without a heat sink and with a cooling system*

IV. Conclusion

The research proved that the use of a closed cooling system contributes, both to decrease in the roughness of the treated surface, and to an increase in the RCP resistance. It is established that the most favorable hard turning of the welded layer of 20X13 steel takes place at a speed of 300 m/min. The use of a cooling system at the optimum speed leads to a 22% reduction in the roughness Ra from 0.23 to 0.18 μm and Rz by 26% from 1.43 μm to 1.06 μm compared to the treatment without a heat sink. The chamfering width of the cutting edge of the RCP is reduced by 17%. Thus, the use of a closed cooling system is an effective method of improving the turning quality and RCP life time.

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