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CHIP FORMATION AIDED BY HIGH PRESSURE CUTTING-TOOL LUBRICANT DURING TURNING

INTRODUCTION

The construction of a tool has important influence on the mechanism of cutting layer division, its transformation into a chip and on many phenomena assisting cutting process. It is thought that a chip is a waste and it has no utilitarian use. But in context of numerically controlled machine-tools (CNC) and machines with automatic tools' exchange, one, long chip is not the best solution. This long chip can cause the damage of a surface of a workpiece – it curves around a cutting tool. Also the switching of a tool can be difficult and a chip can be dangerous for a user [1, 2].

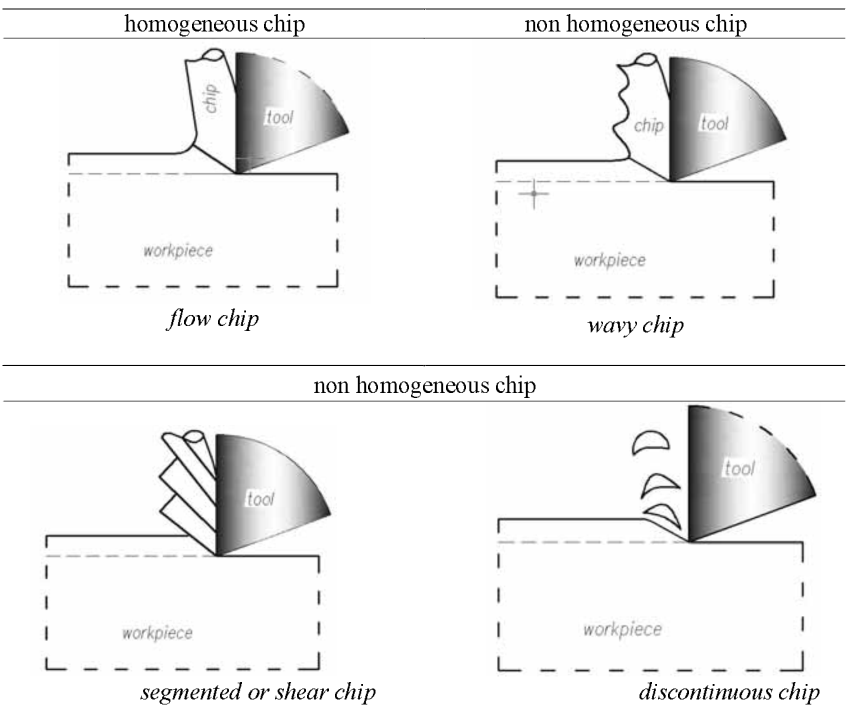

Fig. 1. Some of chip shapes in cutting

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The literature [2] proves that the knowledge of the shape of a chip is significant in view of work safety. What is more, the shape of a chip changes many times when cutting on CNC machines is constant and only the parameters, not a tool, are changed [1]. So, effective methods of the influence of a chip shape are demanded. Classic methods of chip disintegrating are impossible to implement in CNC machines [1-9]. In this case, correction of steering programs is necessary. The shape of a chip is also significant when we use HSC High Speed Cutting (v_c ↑) and HPC High Productive Cutting (v_f↑) [8-9]. Then, thick layers of a material are removed very quickly – even 80% to 90% of a semi-finished products when we consider matrixes – and the quantity of chips increase. Continuous chip takes a lot of space [2, 9]. This kind of a chip causes problems with its removing from cutting zone [15]. The mechanism of forming a chip and its impact on the process of cutting is the subject of research in many science centers around the world [1-15].

METHODES OF IMPACT ON A SHAPE OF A CHIP

Most common methods of impact on a shape of a chip are those which base on separating a chip into regular or irregular pieces. The methods to obtain irregular pieces (which vary in length) are those techniques which base on proper cutting conditions: depth of cut (a_p), rate of feed (f), shape, geometry and construction of cutting tool's edge and chemical constitution of a workpiece. The methods, which allow for division of a chip into fixed-length segments are: toothed-roller burnishing of surface layer, burn-through of a chip by electrical impulses, stopping the feed, generating forced vibrations (to 200 Hz), usage of self-excited vibrations [10]. Some of these methods consume a lot of time and money and influence the shape and size of a workpiece negatively [10-15]. It is stated that the range of usage of that methods is limited (despite the stopping of feed during drilling and using proper geometry of cutting tool's edge), some of them also need implication of inefficient speed of cutting and feed which are often unacceptable in view of cutting process. What is more, most of the methods are unreliable. It is also proved by research that improper form of a chip can cause faster consumption of a cutting tool edge and its durability [1-15].

SIGNIFICANCE OF CUTTING FLUID IN PROCESS OF SHAPING A CHIP

It is scientifically proved that a chip can be a source of important information about phenomena which are present during cutting process [15]. Because of this, a chip is often used to monitor the process of cutting [1, 6]. In context of modern tool materials and parameters of cutting process, a chip absorbs maximal quantity of hest which is generated during cutting. Also a cutting lubricant absorbs part of this heat as a result of convection phenomena. Of course it is not necessary to use a lubricant during cutting process (Dry Machining) [6, 13]. Cutting process with the usage of cutting fluid can take place with normal, high or very high pressure. The method of implying of this fluid into the cutting zone have important impact on a chip shape. Gravitational implication of a fluid is replaced by implication by pressure (for example 1,5–2 MPa with tough materials). The stream of cutting fluid can be pointed at a chip which goes down the surface of working tool (figure 2a), on touching surface of a workpiece (figure 2b) or on the surface of advance between a chip and this surface (figure 2c) [2].

a) b) c)

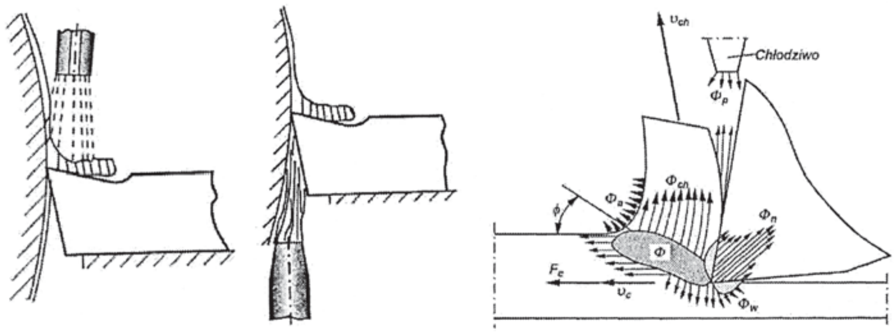


Fig. 2. Typical implementation of cutting-tool lubricant into the cutting zone: a) cutting fluid pointed at a chip which goes down the surface of working tool, b) on touching surface of a workpiece, c) on the surface of advance between a chip and this surface

Modern CNC cutting tools are more often equipped with high pressure fluid implication where the pressure equals 0.7÷10 MPa (cutting and turning centres like in Mazak Company – Integrex 200-IV ST, multi-task devices) and with very high pressure equal 10÷100 MPa (vertical turning lathes, for example Bertiez Co., Carnigi Co., D&G Technology Co., Toshulin Co., Phoenix Co.), multi-task cutting tools (for example WFL), etc. In real conditions, for the classical mode of implication of cutting-tool lubricant, the liquid influence only the minimal area of a tool edge.

a) b)

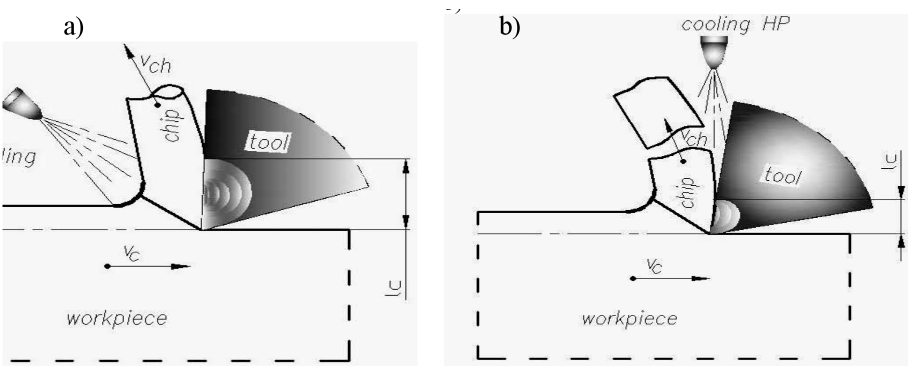


Fig. 3. The influence of a fluid on a length of chip and tool contact and the area of heat affect: a) classical implication of cutting-tool lubricant, b) high pressure implication between a chip and advancing zone

The usage of cutting fluids causes the reduction of temperature of the tool and the workpiece. The effects are: a product is more precise, the surface is more accurate, the blade is more durable, the friction, strength and power of cutting is lower, chips are removed more easily, the build-up is stopped, the workpiece and the cutting tool are protected against corrosion. The disadvantages are: pollution and high costs – of purchase, maintenance, vapors removal, filters, etc. What is more, legal regulations restrict the usage of cutting-tool lubricants [2, 6, 10].

TOOL SYSTEM TO WORK WITH HIGH PRESSURE CUTTING-TOOL LUBRICANT

The example of usage high pressure cutting fluid during turning is CoroTurn HP system with Coromant Capto C5-PCLNL-35060-12HP (figure 4). This system was designed by Sandvik Coromant and thanks to it we can use new technologies of cutting with a tool which is constructed in a way that the lubricant can flow by the holder, head or spindle and direct the lubricant precisely onto heat source. Here we should mention that it is not possible when we use traditional shank tools. The CoroTurn HP system was designed to increase the range of possibilities of cutting with high pressure lubricant. The lubricant is delivered by the tool to small, narrow and precise exhaust nozzles (d=1mm) and it is aimed at specified points in the plate of a cutting tool (figure 4b).

a) b) c)

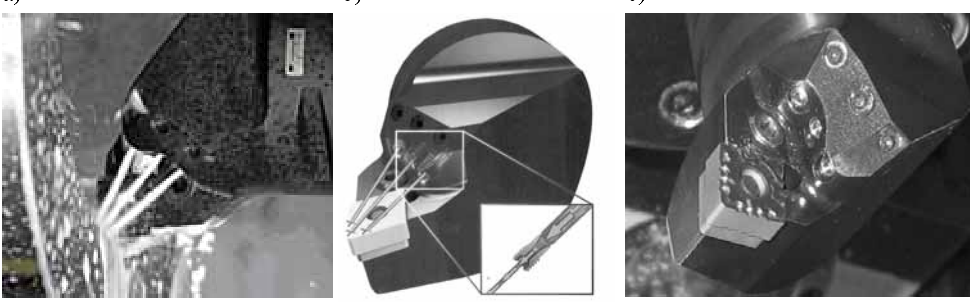


Fig. 4. CoroTurn HP system by Sandvik Coromant Co. [15]

The exhaust nozzles are placed near the edge of cutting plate (figure 4b). This placing allows the lubricant stream of lower pressure to be fastened and it not collides with the exchange of the plate. The stream of the lubricant is precisely directed (figure 5b) and it creates the ”extendible hydraulic wedge *p*” (figure 5a, b) which is created between the surface of advance and the bottom surface of a chip. This wedge assists in chip fracture by chip extension. The forces of wedge influence cause the lifting of a chip and its decohesion is faster. Also, the wedge provides intensive and efficient cooling in the area of chip – tool contact and fast removal of chips from the cutting zone.

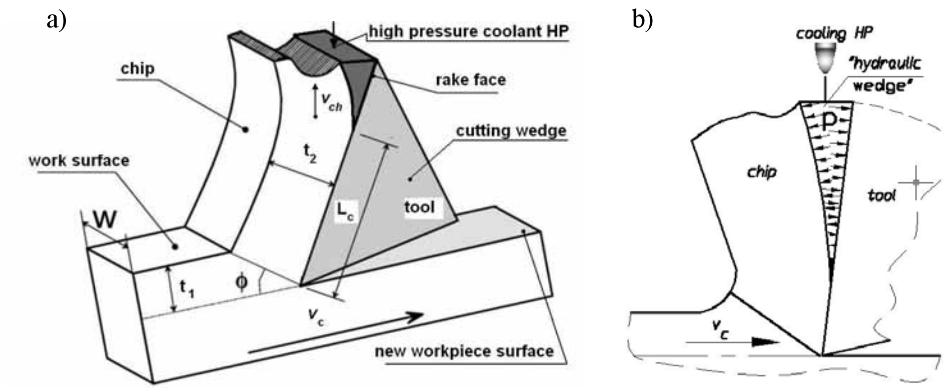


Fig. 5. "Hydraulic wedge" of cutting-tool lubricant which assist in process of chip fracture

The research [15] show that overcoming of difficulties connected with improper shape of a chip can bring economic advantages. The lowering of volume which is taken by the chips disintegrated during the cutting process leads to shortening the time needed to remove them. The volume of disintegrated chips equals even 80% of one long chip. Some sources [10] say that the time needed to remove disintegrated chips of specified volume is 2-4 times shorter than removal of the long ones of the same volume.

CoroTurn HP can be used on every cutting-tool equipped with high pressure lubricant implement system. The system can be also used when we consider tools which have Coromant Capto clamping. Coromant Capto junction allows coolant delivery through the head or spindle. CoroTurn HP with Coromant Capto is used mostly on multi-task cutting-tools, vertical lathes (VLT) and turning centres and it provides optimal chip removal and safety which is necessary in self-acting production.

Thanks to lowering the temperature in cutting zone, speeding of cutting is possible. That results in shortening the time of cutting. Also productivity increases in comparison to conventional methods of lubricant implementation. For rough cutting of tough materials, speed increase can equals 20–50%.

RESTRICTIONS OF HP USAGE

The methods of high pressure cutting fluid implementation, between the surface of advance and a chip, have some restrictions. These restrictions come from the necessity of using the tools of specified construction, mainly the tool holder. These tools need precise exhaust nozzles associated with tool posts witch allow the presence of high pressure and its correct directing. Additional requirement for cutting-tools is productivity of pumps which allow to obtain and maintain of these pressures. High pressure of cutting-tool lubricant as the assistance factor of disintegration of a chip causes the splashing of this fluid. So, the construction of the cutting-tool have to be compact, hermetic and restricted. Another restriction is also the sensitivity of sintered carbides on thermal shocks (cutting plate fractures) and cutting of some materials like for example magnesium alloy (presence of water can cause self-ignition), bronze, plastic and cast iron (the soil of a cutting-tool). Also ecological issues, industrial safety and utilization of fluids may be another restrictions.

METHODOLOGY AND RANGE OF EXPERIMENTAL RESEARCH

The goal of these research was to evaluate the quality of the influence of high pressure of cutting-tool lubricant on a shape of a chip. The research were carried out on the example of turning process on the turning centre of Mazak Company – Integrex 200 IV ST (figure 6). This turning center is optionally equipped with high pressure fluid implementation system. The subject of the research was the shape of a chip created in changeable conditions during cutting various constructional materials. The specimens were made in shape of stepped cylinder of specific geometry.

a) b)

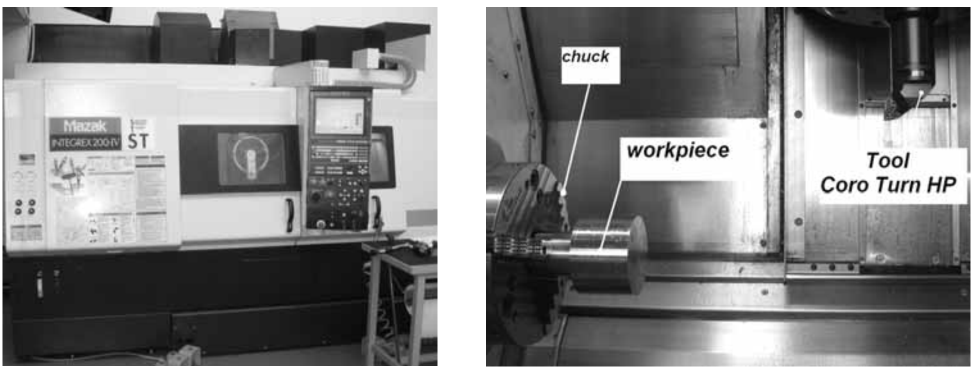


Fig. 6. Working station: a) turning centre CNC Mazak Integrex 200 IV ST; b) cutting zone – general view

Research materials were: titanium alloy Ti6A14V (hardness 30HRC), aluminium alloy AlSi5 (hardness 100 HB), stainless steel 316L (hardness 230HB), low-carbon steel C15 (hardness 130 HB). The process of cutting was carried out in stages for specific cutting conditions (a_p= 0,15; = 0,2; = 0,25 mm; f= 0,1; = 0,2; = 0,3 mm/rev., v_c = 60, 180, 300 m/min). Two types of cutting were tested: with classic fluid implementation (normal pressure) and with fluid stream compessed to 0,7MPa.

Three streams of cutting-tool lubricant were implemented into the cutting zone – between a chip and a surface of cutting blade advance. These streams were implemented in the directed way (figure 4b). There were many tests when the chips were gathered – during normal and high pressure of cutting fluid. The final results are presented below (table 1-4).

Table 1. The results of the cutting fluid influence on chip shape – TITANIUM ALLOY Ti6A14V

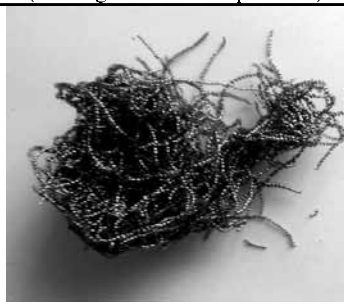
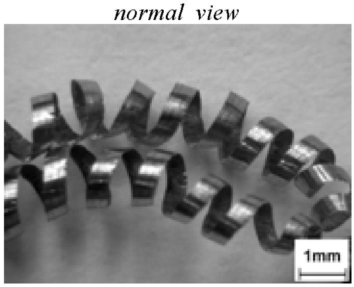
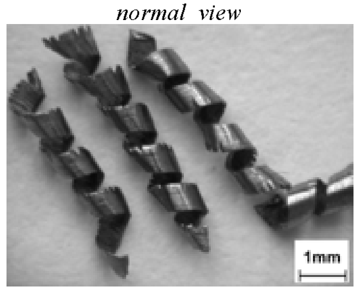
Material of workpiece	Chip (cooling with normal pressure)	Chip (cooling with high pressure – 0.7 MPa)
TITANIUM ALLOY Ti6A14V, Hardness: 30HRC, Cutting parameters : v_c = *60 m/min* *f = 0,1 mm/rev* a_p = *0,25 mm* Tool: *CoroTurn HP C5-PCLNL-35060-12HP Cutting plate CNGP 12 04 08 H13 A*	 *normal view*  *zoom*	 *normal view*  *zoom*

Table 2. The results of the cutting fluid influence on chip shape – ALUMINIUM ALLOY AlSi5

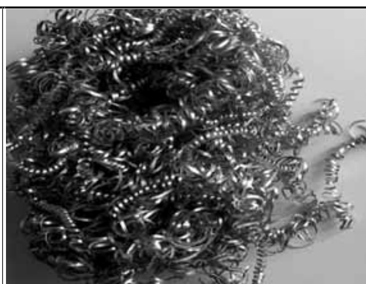
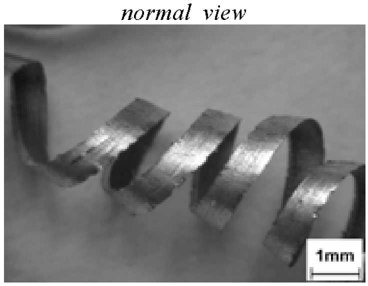
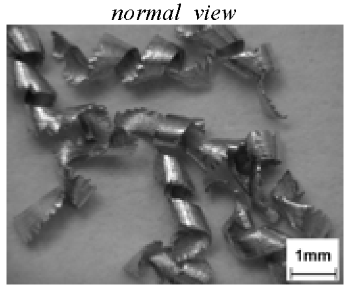
ALUMINIUM ALLOY AlSi5, Hardness: 100HB, Cutting parameters: v_c = *300 m/min* *f = 0,1 mm/rev* a_p = *0,2 5mm* Tool: *CoroTurn HP C5-PCLNL-35060-12HP Cutting plate CNGP 12 04 08 H13 A*	 *normal view*  *zoom*	 *normal view*  *zoom*

Table 3. The results of the cutting fluid influence on chip shape – STAINLESS STEEL 316L

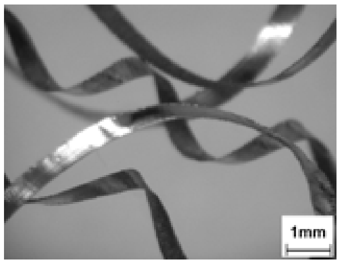
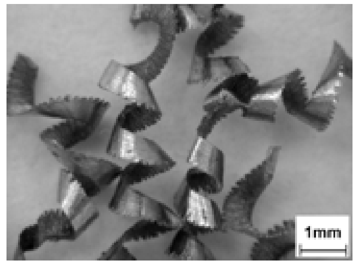
STAINLESS STEEL 316L, Hardness: 230HB, Cutting parameters: v_c = *180 m/min* f = *0,1 mm/rev* a_p = *0,25 mm* Tool: *CoroTurn HP C5-PCLNL-35060-12HP Cutting plate CNMG 12 04 08 – MM 2025*	 *normal view*	 *normal view*
	 *zoom*	 *zoom*

Table 4. The results of the cutting fluid influence on chip shape – LOW-CARBON STEEL C15

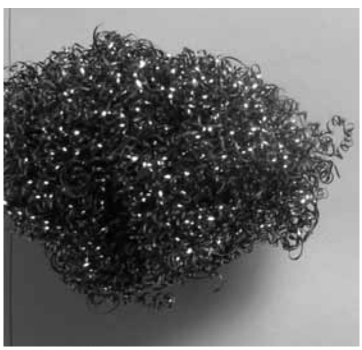
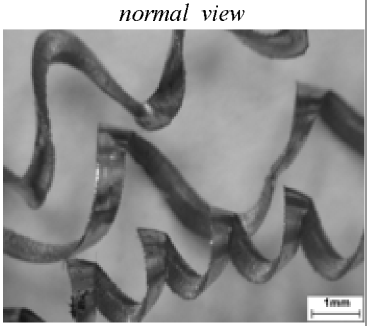
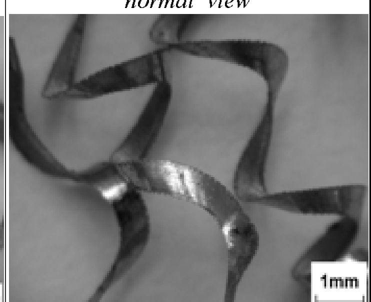
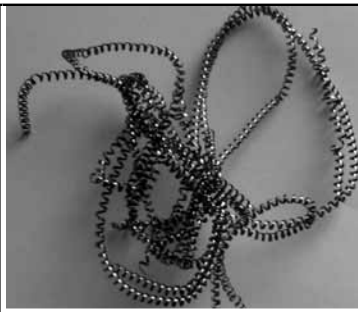
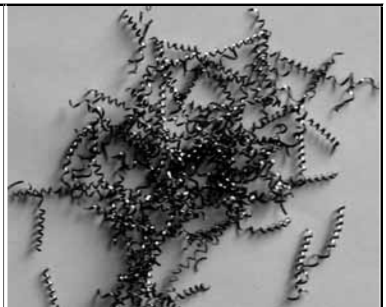
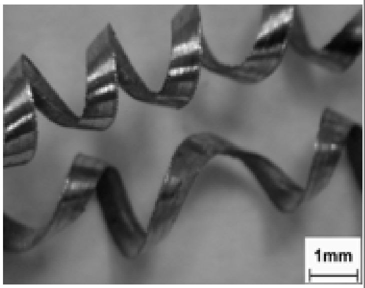
LOW-CARBON STEEL C15, Hardness: 130HB, Cutting parameters: v_c=*300 m/min* f = *0,1 mm/rev* a_p = *0,25 mm* Tool: *CoroTurn HP C5-PCLNL-35060-12HP Cutting plate CNMG 12 04 08 PF 4225*	 *normal view*	 *normal view*
	 *zoom*	 *zoom*

Table 5. The results of the cutting fluid influence on chip shape – LOW-CARBON STEEL C15

LOW-CARBON STEEL C15, Hardness 130HB, Cutting parameters: v_c *= 300 m/min* *f = 0,2 mm/rev* a_p *= 0,2 mm* Tool: *CoroTurn HP* *C5-PCLNL-35060-12HP* *Cutting plate* *CNMG 12 04 08 PF 4225*	 *normal view*	 *normal view*
	 *zoom*	 *zoom*

Analysing the table we can state that the stream of compressed cutting-tool lubricant of pressure 0,7MPa implemented into the cutting zone (between a chip and a surface of a tool) influence the shape of a chip significantly. High pressure of the fluid caused significant disintegration of a chip in case of aluminium and titanium alloy and also during the cutting of stainless steel. The results of preliminary research showed that in case of low-carbon steel, the degree of shortening the chip is lower. Nevertheless, in all cases the results were predicted before – long, spiral chip was exchanged by a short, removable one. Detailed evaluation of a degree of chip disintegration and its presentation (considering quantity) will be the next goal of research for the authors of this study. Preliminary results show clearly that also the surface of a product after cutting improved (lower parameters of roughness R_a and R_z). In later studies the authors are going to present the observed quantity differences.

What is more, different conditions and materials will be analysed. Also the optimalization of fluid pressure influence on a shape of a chip will be the subject of research. To achieve it, the influence of different pressures of the fluid and the mechanism of chip formation will be studied.

CONCLUSION

Following the current prognoses and corporations' evaluation, turning operations will soon be carried out without a coolant or with its high pressure. The pressure which is normal nowadays will be out-of-date. And for that reason, the trend in cutting process will be aimed at increasing the pressure to more than 0,7 MPa. The advantage of implementation of the method of chip fracture by the compressed stream of fluid is the improvement of productivity of a tool blade or its durability.

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Summary

The subject of this work is to show the significance of the shape of a chip during automated cutting process. Selected ways of the influence on a chip shape are going to be shown. The main point is the assistance of chip fracture by a compressed stream of cutting-tool lubricant. This mechanism is shown on the example of tool system CoroTurn HP. The results of preliminary researches are presented graphically.

KSZTAŁTOWANIE WIÓRA PODCZAS TOCZENIA WSPOMAGANE WYSOKIM CIŚNIENIEM CIECZY OBRÓBKOWEJ

Streszczenie

W pracy poruszono znaczenie postaci i kształtu wióra podczas obróbki w zautomatyzowanym – elastycznym systemie wytwarzania. Przedstawiono wybrane sposoby oddziaływania na postać wióra. Szczególny nacisk położono na wspomaganie procesu łamania wióra sprężonym strumieniem płynu obróbkowego. Na przykładzie systemu narzędziowego CoroTurn HP omówiono budowę i sposób mechanizm łamania wióra strumieniem sprężonej cieczy obróbkowej. Wyniki wstępnych badań rozpoznawczych przedstawiono w postaci graficznej