Cutting inserts effect on heat generation in turning process

Vplyv druhu rezných doštičiek na generovanie teploty v procese sústruženia

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Abstract

The paper is focused on confirmation of an effect of cutting materials and cutting inserts geometry on cutting forces and temperature, quality and accuracy of machined surface in turning. The main part is devoted to description of advanced turning tools and cutting materials. The experimental part is focused on cutting forces and temperature measurement and machined surface quality in turning of steel grade 11 523 samples with one feed and depth of cut value and varying spindle speed. Measurements were performed with various types of indexable cutting inserts used. Measured values were evaluated in terms of the effect of different properties of cutting inserts and various spindle speed values.

Keywords: accuracy, cutting inserts, cutting forces, cutting materials, roughness, temperature, turning

Abstrakt

Článok je zameraný na preukázanie vplyvu rezných materiálov a geometrie rezných doštičiek na rezné sily a teplotu pri sústružení, kvalitu a presnosť obrobeného povrchu. Podstatná časť je venovaná opisu moderných sústružníckych nástrojov a rezných materiálov. Praktická časť je zameraná na meranie rezných síl, teploty rezania a kvality opracovaného povrchu pri sústružení vzorky materiálu ocele 11 523 pri konštantnej hodnote posuvu a hĺbky rezu a pri meniacich sa hodnotách otáčok vretena. Merania budú vykonávané pri použití vymeniteľných rezných doštičiek rôznych druhov. Namerané výsledky sa budú hodnotiť z hľadiska vplyvu rozdielnych vlastností rezných doštičiek a meniacich sa hodnôt otáčok vretena.

Kľúčové slová: drsnosť, presnosť, rezné materiály, rezné doštičky, rezné sily, sústruženie, teplota

Detailný abstrakt

Cieľom práce bolo sledovanie a hodnotenie zmien teploty medzi rezným nástrojom a obrobkom. zmien rezných síl pri sústružení vyvolaných odlišnými vlastnosťami jednotlivých použitých rezných doštičiek a zmien týchto charakteristík pri troch odlišných hodnotách otáčok vretena sústruhu.

Pozornosť sa sústredila na vplyv rezného materiálu a geometriu utvárača na teplotu pri sústružení. Aby bolo možné sledovať výlučne vplyv jedného faktoru, bolo potrebné zabezpečiť podmienky merania tak, aby boli odstránené ostatné faktory, ktoré by mohli vplývať na zmenu týchto veličín. Použili sme rezné doštičky rovnakého typu DNMG 150608, rôznych rezných materiálov s viacerými typmi utvárača. Pri hodnotení vplyvu rezného materiálu sme porovnávali iba tie doštičky, ktorých jediným odlišujúcim znakom bol práve rezný materiál. Rovnako sme postupovali aj pri hodnotení vplyvu geometrie utvárača rezných doštičiek. Sledovali sme, ako sa budú jednotlivé rezné doštičky správať pri rozdielnych otáčkach, preto naše merania prebiehali pri troch rôznych otáčkach, a to pri n_1 = 710 min^{-1}, n_2 = 1400 min^{-1} a n_3 = 2240 min^{-1}. Ostatné rezné podmienky (hĺbka rezu a_p = 1 mm a posuv f = 0.1 mm^{-1}) zostali konštantné. Ako vzorka materiálu bola použitá oceľ 11 523, ktorá patrí do skupiny P. Použité rezné doštičky sú určené pre obrábanie tejto skupiny materiálov.

Pri posudzovaní vplyvu rezného materiálu na teplotu bolo zistené, že doštičky s rovnakým typom utvárača a rozdielnymi druhmi rezného materiálu vykazujú rozdiely v nameraných hodnotách, z čoho usudzujeme, že rezný materiál vplýva na teplotu pri sústružení. K rovnakému záveru sme dospeli aj pri skúmaní vplyvu rôzneho druhu utvárača na teplotu, kedy boli pri doštičkách z rovnakého materiálu ale rôznymi druhmi utvárača namerané rozdielne hodnoty teploty.

Introduction

Materials machining is a production process in which a semi-finished product gets a specified shape and dimensions by surface material removal. The most common method is cutting when mutual interaction of tool and workpiece results in material removal in the form of chips. Based on long-time cutting material development, the creation of an absolutely new cutting material cannot be expected (Belák and Drlička, 2001). The research of prominent tool and cutting materials producers is therefore oriented primarily to existing materials improvement, their optimal use specification and exact definition of application area (Drlička and Matúš, 2011). Another research effort is oriented to cutting material development for dry or near dry machining (Kročko et al., 1999; Tomáš et al., 2002).

The cutting part of tool is subjected to high thermal and mechanical load, friction, vibrations and sudden thermal and mechanical impacts in the cutting process. The measurement and study of material behaviour in these conditions is therefore an integral part of cutting materials research and development (Žitňanský and Drlička, 2009).

Steel machine parts, which are a product of cutting operation, have to be protected against corrosion. Adhesion of the anticorrosion coating is mainly affected by surface roughness Ra. Modern trends of anticorrosion protection consists of galvanizing, zinc dipping or duplex system. (Votava, 2012; Votava, 2013a) On the contrary, when renovating machine parts by hot metalizing method the roughness values Ra can have a bigger difference. Anchoring system is namely formed by partly-fused basic material and melted additional material. (Votava et al., 2012)

Thermal effects in metal cutting can be significantly influenced by cutting fluid use and application (Drlička et al., 2005; Kročko et al., 2012). Cutting fluid properties can be tested in the machining process, but the aim is to find appropriate laboratory testing methods for cutting fluid performance evaluation (Drlička and Žarnovský, 2011).

Materials and Methods

The experimental work was focused on observation of cutting material and chip breaker effect on temperature in turning. To observe single factor effect, the measurement conditions have to be set in a way removing all other varying factors causing potentially these conditions change. The same cutting inserts type was used, DNMG 150608, and different cutting materials and chip breaker types. The cutting inserts of different cutting material were compared in evaluation of cutting material effect. The other objective was to find the inserts behaviour at various cutting speeds; therefore, the measurements were performed at three different cutting speeds:

n_1 = 710 min^{-1},

n_2 = 1400 min^{-1},

n_3 = 2240 min^{-1}.

Other conditions were held constant:

- depth of cut a_p = 1 mm,
- feed rate f = 0.1 mm.

Sample material steel grade 11 523 belongs to the machinability group P. The cutting inserts used in experiments are designed for machining of this material type.

Sample characteristics

Samples used in experiment were of the same shape, dimensions and material.

Table 1 Chemical composition of material – steel 11 523

C [%]	Si [%]	Mn [%]	P [%]	S [%]	N [%]
0.2	0.55	1.6	0.04	0.04	0.009

Mechanical properties

Yield strength: R_e = 345 MPa
Tensile strength: R_m = 490÷630 MPa

Applications

Structural fine-grain steel for bridges and other welded structures, bended profiles, welded pipe structures and parts of machines, cars, motorcycles and bicycles, for parts of heat power appliances and pressure vessels.

Used sample dimensions are depicted in Figure 1. The sample was clamped in 3-jaws chuck. To prevent vibrations, the sample was supported by tailstock. The central hole had to be drilled.

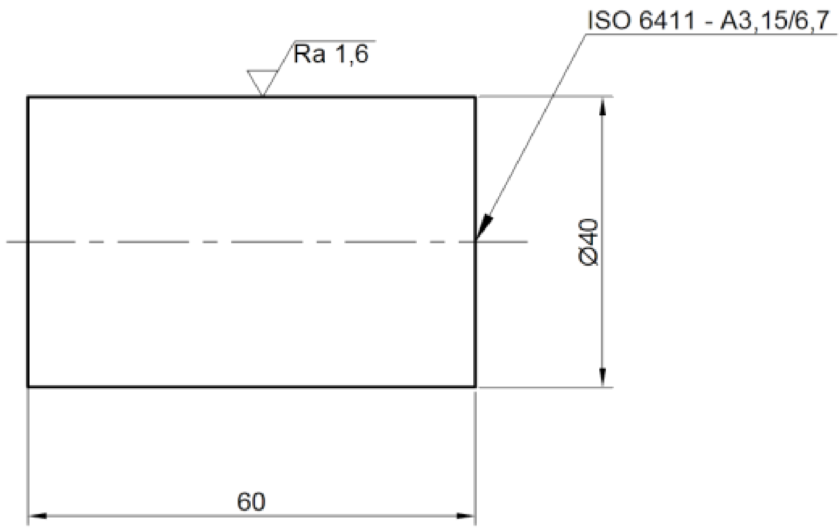


Figure 1 Testing sample drawing

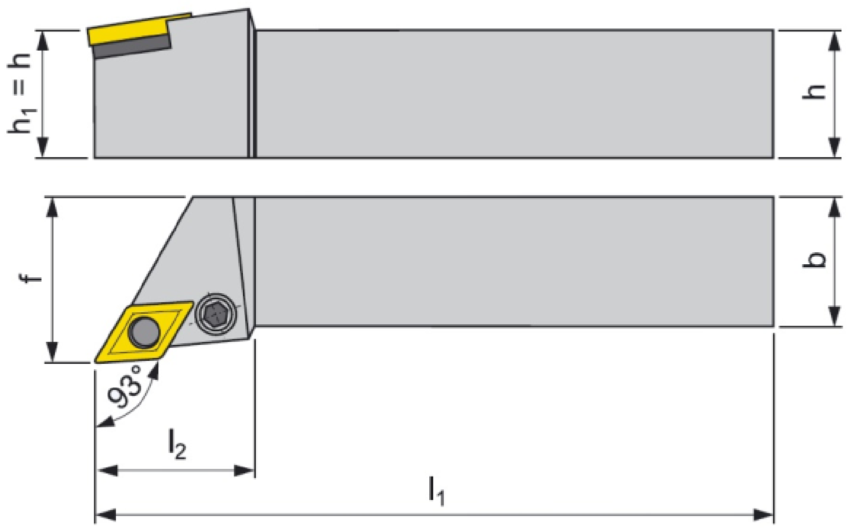


Figure 2 Turning knife PDJNR for external turning (Pramet, 2013)

Characteristics of used tool holder

The tool holder (Figure 2) PDHNR 2525 M15 of the company Pramet Slovakia, spol. s r.o. was used for external turning.

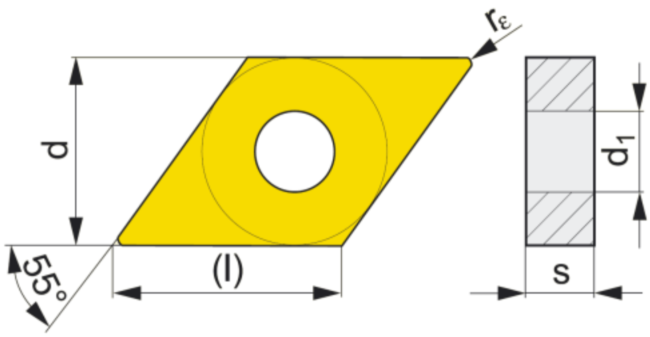
Tool holder dimensions:

$h = h_1$ = 25 mm
b = 25 mm
f = 32 mm
l_1 = 150 mm
l_{2max} = 40 mm
rake angle γ_0 = -6°
side rake angle λ_s = -6°
weight w = 0.68 kg

Characteristics of cutting inserts used

Shape and dimensions

In cutting temperature measurement, the cutting inserts DNMG 150608 of the company Pramet Tools, s.r.o were used.



l = 15.5 mm d = 12.7 mm d_1 = 5.16 mm s = 6.35 mm r_ε = 0.8 mm

Figure 3 Dimensions of indexable cutting insert DNMG 150608 (Pramet, 2013)

Results

Temperature measurement

Temperature measurement was performed using a tool-work thermocouple method. Nine cutting insert types were used in measurement. Measurements at 3 different spindle speeds were performed with each insert, n_1 = 710 min^{-1}, n_2 = 1400 min^{-1}, n_3 = 2240 min^{-1}. The depth of cut and feed were left unchanged with measurement on the same material sample. Measured voltage output in mV was transformed using a calibration chart to average values of temperature (in °C) in cutting insert and workpiece contact. Computed values are recorded in tables and presented in the plot of temperature dependency on cutting insert type for 3 cutting speeds.

Table 2 Calibration chart

T [°C]	60	65	70	85	115	185
U [mV]	1	1.1	1.2	1.5	2.1	3.5

Temperature measurement results

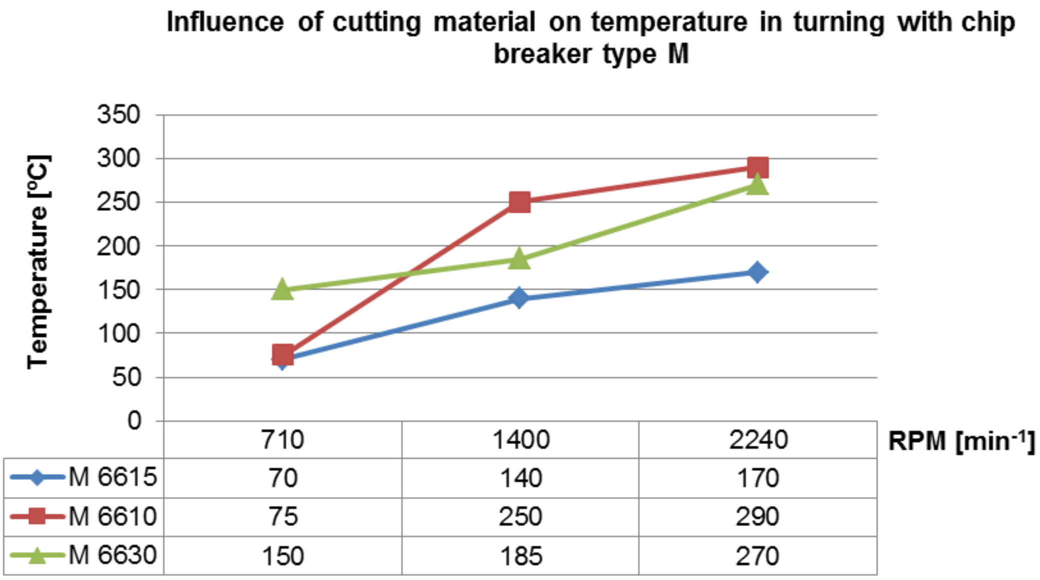


Figure 4 Effect of cutting material on temperature in turning

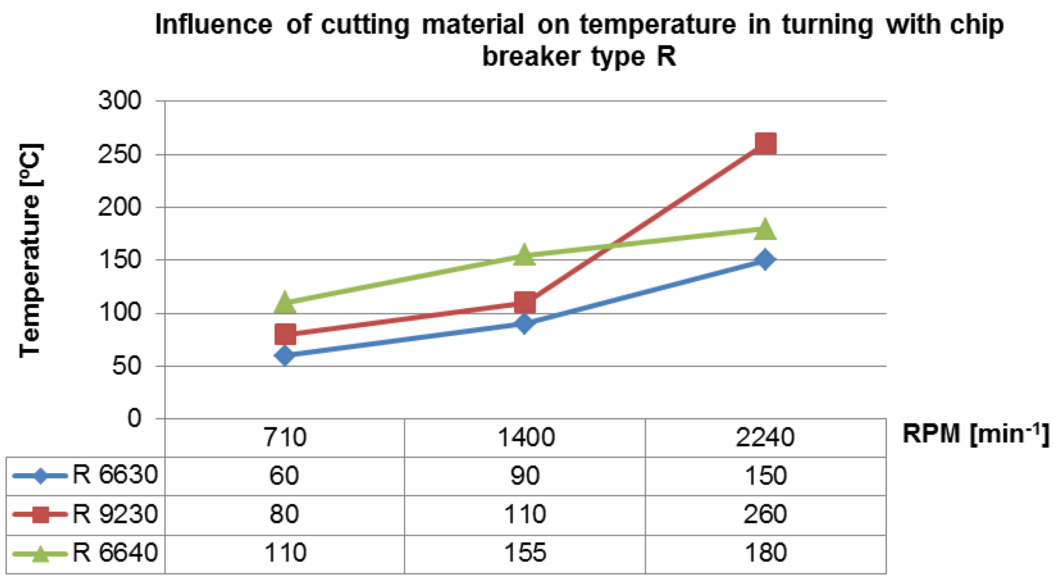
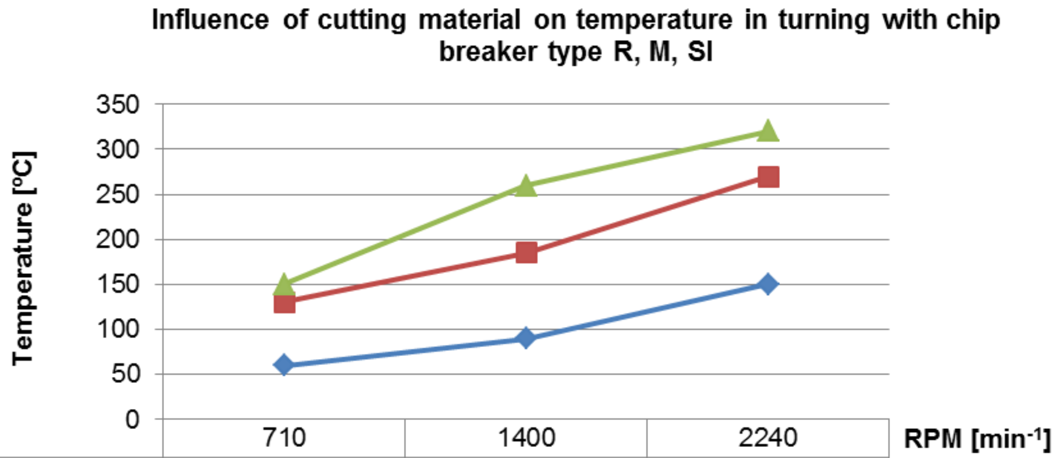


Figure 5 Effect of cutting material on temperature in turning

Chip breaker type effect on temperature in turning

Chip breaker has to be the only differing feature of cutting inserts compared when evaluating the chip breaker type effect on temperature in turning. Three cutting inserts of the same cutting material 6630 with different chip breakers of type R, M and SI were used in experiments.



	710	1400	2240
R 6630	60	90	150
M 6630	130	185	270
SI 6630	150	260	320

Figure 6 Chip breaker type effect on temperature in turning

Conclusions

Radius of cutting tips has a crucial effect on roughness of a machined surface. In order to lower roughness *Ra*, the radius r_ε has to be increased and at the same time parameters of cutting speeds depending on diameter of a workpiece has to be kept. (Votava, 2013b)

Cutting temperature measurement showed that the cutting speed rise results in cutting temperature increase. With the cutting insert of material 6630 with the type R chip breaker, the temperature generated was the lowest at all the three cutting speeds, the values being t_{n1} = 60 °C, t_{n2} = 90 °C and t_{n3} = 150 °C, and only moderately increased with the speed. The second lowest measured temperatures were observed in case of the cutting insert of material 6615 and the chip breaker type M, namely t_{n1} = 70 °C, t_{n2} = 140°C and t_{n3} = 170 °C. A significant growth of cutting temperature is apparent when spindle speed is set to n_2. The cutting material 6615 is characterised by the manufacturer as the most versatile in its class, with the chip breaker type R designed for semi-roughing and roughing turning.

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