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Research Article

EFFECT OF CHIP BREAKERS ON THE CUTTING FORCE DURING THE MACHINING OF STEEL C45

Jiří Kratochvíl[1], Jana Petrů[1], Marek Pagáč[1], Jozef Holubják[2], Jozef Mrazik[2]

[1] VŠB – Technical University of Ostrava, Faculty of Mechanical Engineering, 17. listopadu 15/2172, 708 33 Ostrava-Poruba, Czech Republic, e-mail: jiri.kratochvil@vsb.cz, jana.petru@vsb.cz., marek.pagac@vsb.cz

[2] University of Žilina, Faculty of Mechanical Engineering, Univerzitna 1, 010 26, Žilina, Slovakia, e-mail: dana.stancekova@fstroj.uniza.sk, jozef.holbjak@fstroj.uniza.sk, jozef.mrazik@fstroj.uniza.sk

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ABSTRACT

The paper deals with the dependence of cutting force on the breaker of an indexable cutting insert (ICI). The experiment monitored individual cutting force components for different insert breakers, cutting speeds and feed rates during machining. The cutting depth remained constant. The tool holder, material and coating of the indexable cutting insert was also identical.

Keywords: edge geometry, turning forces, breakers.

INTRODUCTION

The development of machine tools is constantly moving forward. Manufacturers are permanently seeking ways to improve them. Improvements can be achieved by better tool materials, better coatings or innovative tool geometry. Tool geometry affects both the properties of the final product as well as the force acting on the tool, its cutting power and durability. The paper deals with the measurement and comparison of these forces with respect to a change in the micro-geometry of indexable cutting inserts (ICIs) of the turning tool. Indexable cutting inserts have the same shape, the same tool holder, the same basic cintered carbide material and the same type of coating. Indexable cutting inserts only differ in the chip breaker. This paper provides a comparison of cutting forces at different cutting parameters, namely at different cutting speeds and feed rates. Cutting conditions were chosen as the intersection of the recommended values of cutting conditions of individual ICIs.

Conditions of the experiment

The experiment was conducted on lathe model NLX2500MC/700 produced by company DMG MORI. Force components were measured on a piezoelectric dinamometre (produced by Kistler) shown in Figure 1a. Figure 1b shows a dynamometer mounted on the machine. When measuring with a dynamometer, we essentially measure the response to machining forces (i.e. cutting resistances), which are identical to the cutting forces of the opposite direction. In Figure 1b), these cutting resistances are marked F_c', F_f' and F_p' [1, 2, 3].

For this experiment, we used a toolholder DCLNR 2525M-12 with a 95° lead angle (κ_r = 95°). Into this holder, we inserted Indexable Cutting Inserts (ICI) produced by ISCAR, with the base material of cemented carbide, type IC8250. The material machined during the experiment was steel C45 [4÷7].

Due to the dynamic behaviour of cutting force components, the experiment worked with mean values. These values were evaluated in the software Dyno Ware. This programme is also used to record the values of individual force components from the measuring system. The total cutting force is calculated in accordance with equation (1); for further use, it has been rounded to the nearest whole number.

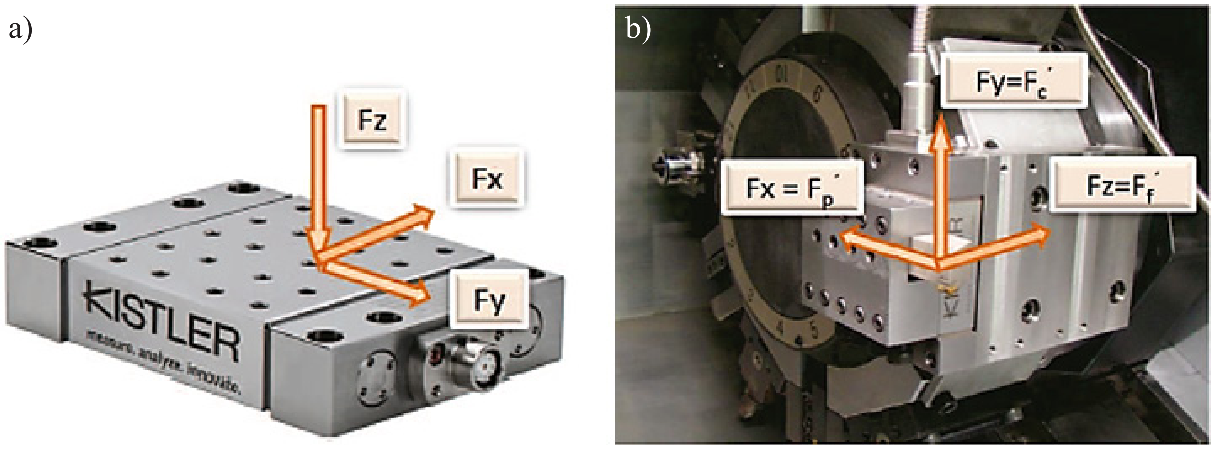

Fig. 1. (a) dynamometer and measured forces, (b) breakdown of the measured forces on the machine

$$F = \sqrt{F_c^2 + F_f^2 + F_p^2} \tag{1}$$

F - resulting cutting force (N),
F_c - cutting force component (N),
F_p - passive force component (N),
F_f - feed force component (N).

To present micro-geometry of ICI inserts, contours were marked in the plane parallel to the feed direction and at a distance of 2 mm from the ICI tip. This value was chosen with regard to the cutting depth used. The contours were measured using a contourgraph by Mahr and generated in MarWin 5.00-12 SP1. The contours of individual breakers are shown in Figures 2 to 5 and described below.

ICI CNMG 120408-M3P

ICI CNMG 120408-M3P, see Figure 2: a double-sided 80° rhombic inserts, for medium machining conditions on steel. Low cutting forces due to positive rake, provide smooth cutting [8].

Recommended cutting conditions [8]:
a_p = 0.5÷5.5 [mm],
f = 0.15÷0.5 [mm],
v_c = 140÷320 [m/min].

ICI CNMG 120408-PP

ICI CNMG 120,408-PP, see Figure 3: Double-sided 80° rhombic inserts with a positive rake angle and sharp, positive-radial edge. Used for machining very ductile materials such as alumin-

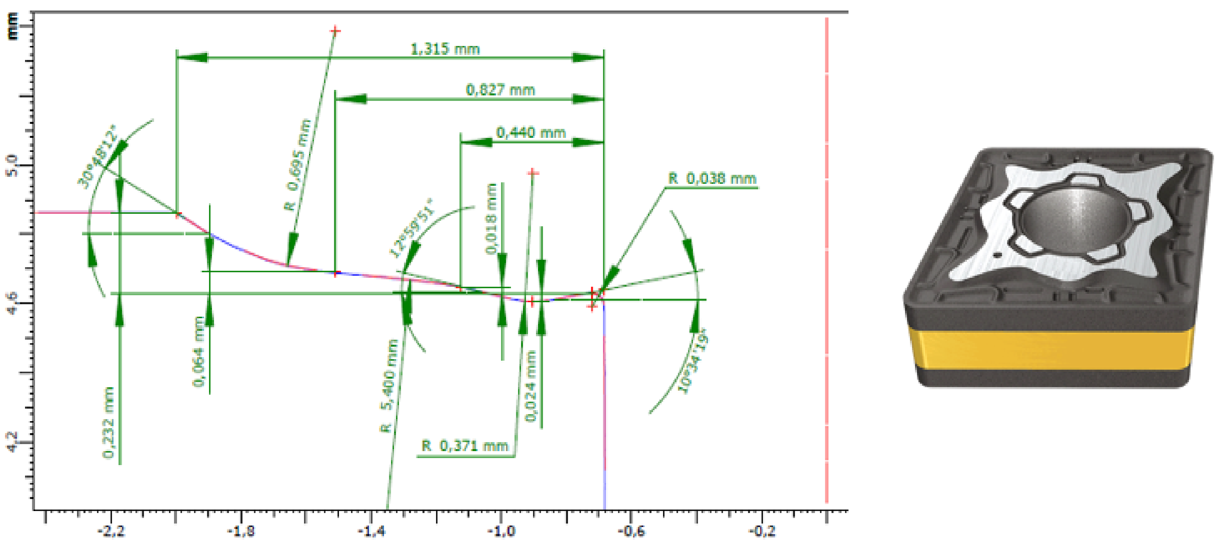

Fig. 2. Contour of ICI breakers CNMG 120408-M3P and CNMG 120408-M3P [8]

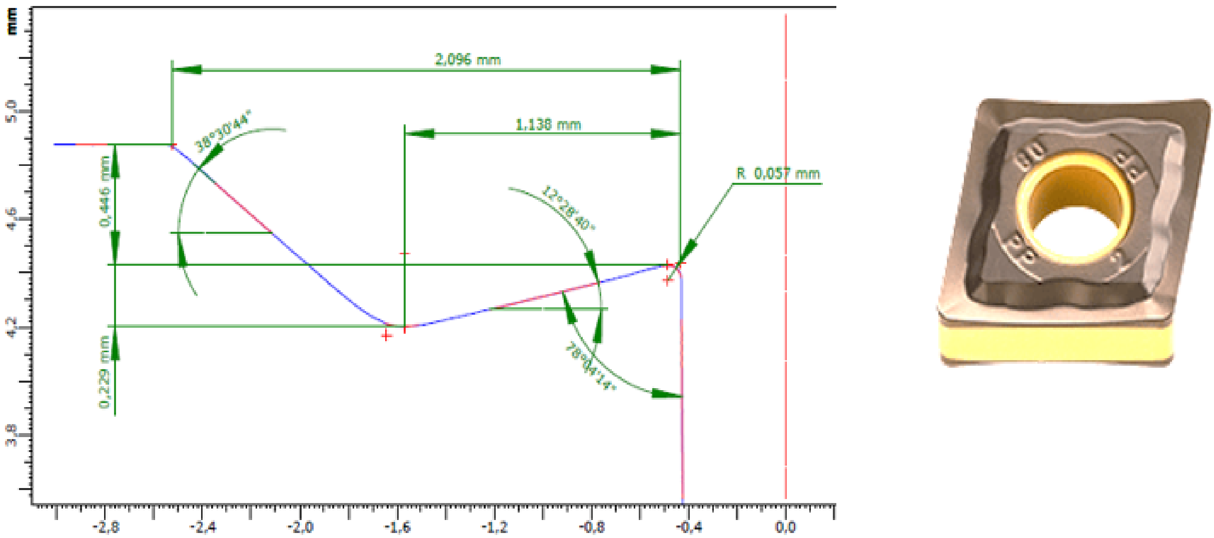

Fig. 3. Contour of ICI breaker CNMG 120408-PP and ICI CNMG 120408-PP [9]

ium alloys, soft, low carbon steel, stainless steel, and high temperature alloys [9].

Recommended cutting conditions [9]:
a_p = 1÷4 [mm],
f = 0.14÷0.3 [mm],
v_c = 140÷320 [m/min].

ICI CNMM 120408-R3P

ICI CNMM 120408-R3P, see Figure 4: a double-sided 80 ° rhomboid inserts, for rough turning applications of steel [10].

Recommended cutting conditions [10]:
a_p = 0.7÷7.5 [mm],
f = 0.2÷0.55 [mm],
v_c = 140÷320 [m/min].

ICI CNMM 120408-M4PW

ICI CNMM 120408-M4PW, see figure 5: The insert has a very positive radial, helical cutting edge and a positive rake angle, which reduces the cutting forces. A wiper corner design produces a high surface finish even at high feed rates. Used for heavy machining applications [11].

Recommended conditions [11]:
a_p = 1.5÷5 [mm],
f = 0.24÷0.59 [mm],
v_c=140÷320 [m/min].

Table 1 shows mean values of the individual force components as well as the calculated values of the resultant cutting force for the part of the

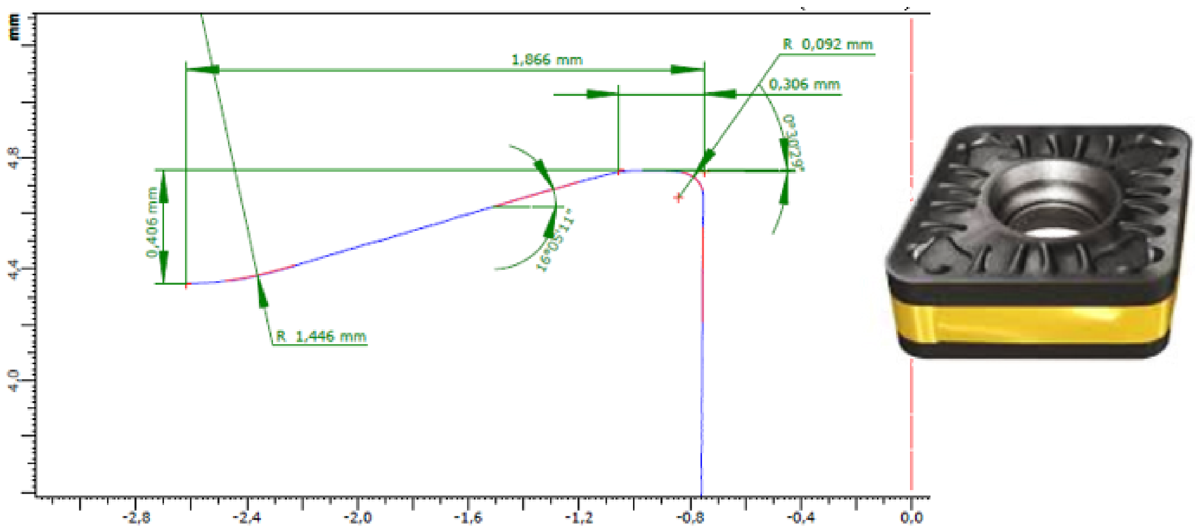

Fig. 4. Contour of ICI breaker CNMM 120408-R3P and CNMM 120408-R3P [10]

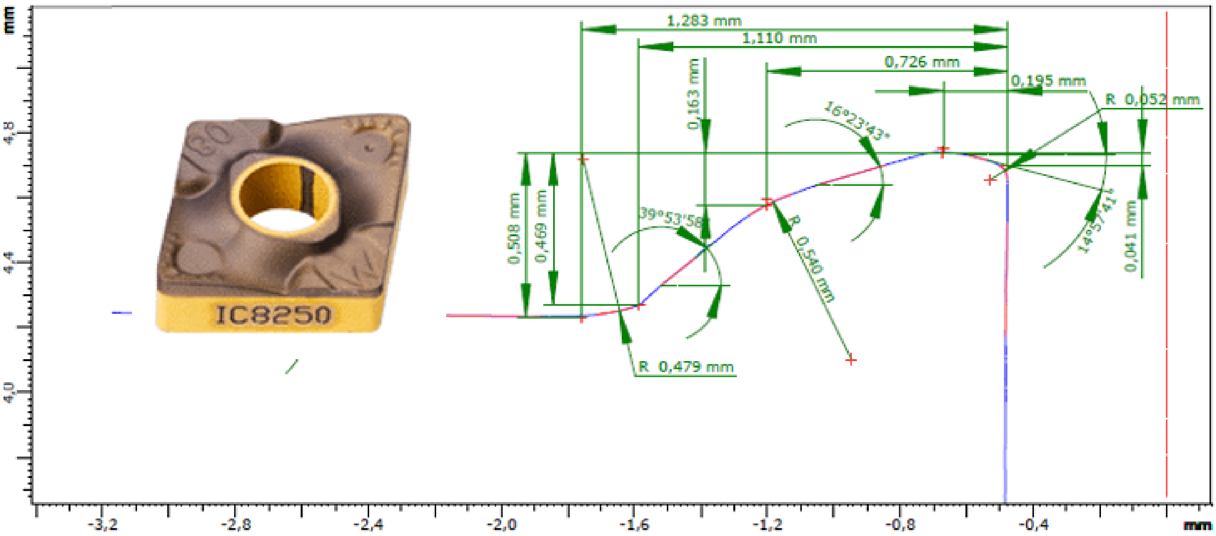

Fig. 5. Contour of ICI breaker CNMM 120408-M4PW and CNMM 120408-M4PW [11]

Table 1. Experimental values at different f and constant v_c = 300 m/min and a_p = 2 mm

f [mm]	CNMG 120408-M3P				CNMG 120408-PP				CNMM 120408-R3P				CNMM 120408-M4PW			
	F_p [N]	F_c [N]	F_f [N]	F [N]	F_p [N]	F_c [N]	F_f [N]	F [N]	F_p [N]	F_c [N]	F_f [N]	F [N]	F_p [N]	F_c [N]	F_f [N]	F [N]
0.25	288	1108	764	1376	186	1143	789	1401	385	1218	914	1571	368	1129	802	1433
0.35	437	1444	949	1782	248	1504	1044	1848	550	1510	1156	1980	449	1447	984	1807
0.5	619	932	1285	1704	393	743	1435	1663	789	677	1525	1846	671	1004	1326	1793

experiment where the cutting speed was v_c = 300 m.min^{-1}, cutting depth a_p = 2 mm and there was a change in the feed rate f (mm).

After calculating the resulting force (the green column according to equation 1 in Table 1), a chart was created to compare the different ICI breakers at given conditions (see Figure 6).

The graph clearly shows that the ICI exposed to the highest load was ICI with breaker CNMM 120408-R3P for all selected feed values. Conversely, the breaker CNMG 120408-M3P is exposed to the smallest force load at feed values f = 0.2 and 0.35 mm. Only at feed f = 0.5 mm, the breaker CNMM 120408-M4PW was exposed to the lowest load.

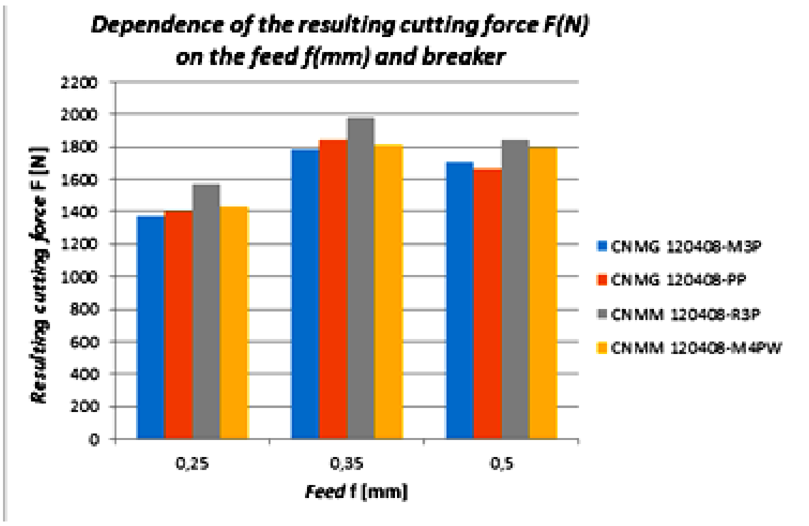

Fig. 6. Dependence of the resulting cutting force on the feed and breaker for v_c = 300 m.min^{-1} and a_p = 2 mm

Table 2. Experimental values at different v_c and constant f = 0.25 mm and a_p = 2 mm

	CNMG 120408-M3P				CNMG 120408-PP				CNMM 120408-R3P				CNMM 120408-M4PW			
v_c [m.min^{-1}]	F_p [N]	F_c [N]	F_f [N]	F [N]	F_p [N]	F_c [N]	F_f [N]	F [N]	F_p [N]	F_c [N]	F_f [N]	F [N]	F_p [N]	F_c [N]	F_f [N]	F [N]
150	269	1125	779	1395	196	1191	853	1478	350	1206	905	1548	346	1187	855	1503
250	353	1061	729	1335	198	1168	820	1441	362	1205	897	1545	362	1124	799	1426
300	288	1108	764	1376	186	1143	789	1401	385	1218	914	1571	368	1129	802	1433

The resulting force between the highest and lowest value of cutting force is ΔF = 195 N at feed rate f = 0.25 mm. At f = 0.25, the difference is ΔF = 198 N and at f = 0.5, the difference is ΔF = 183 N. This difference may result in a longer life of the ICI, when smaller force presses the abrasive particles against the edge, and even the temperature could be lower at the cutting point.

According to the manufacturer's recommended conditions, it is clear that the inserts which can be used for larger cutting depths were subjected to greater cutting force than inserts intended for smaller cutting depths. Here, we can see the effect of micro-geometry, especially a negative breaker facet. The larger the facet, the greater the cutting force, but also greater rigidity of the cutting edge for greater material removal.

Table 2 shows mean values of the individual force components as well as the calculated values of the resulting cutting force for the part of the experiment where feed f = 0.2 mm, cutting depth a_p = 2 mm and where changes occurred in the cutting speed v_c (m.min^{-1}).

After calculating the resultant force (the green column according to equation 1 in Table 2), a chart was created to compare the different ICI breakers at given conditions (see Figure 7).

The graph clearly shows that the ICI exposed to the highest load was again the ICI with breaker CNMM 120408-R3P for all selected cutting speeds v_c (m.min^{-1}). The breaker CNMG 120408-M3P is in this case the best for all cutting speeds v_c (m.min^{-1}).

The difference between the highest and the lowest cutting force is ΔF = 153 N at a cutting speed v_c = 150 m.min^{-1}, and ΔF = 210 N at a cutting speed v_c = 250 m.min^{-1}. At a cutting speed v_c = 300 m.min^{-1} the difference ΔF = 195 N. Identically to the different feed rates, also here it was confirmed that the inserts which can be used for larger cutting depths were subjected to greater cutting force than inserts intended for smaller cutting depths.

CONCLUSION

The paper compares forces acting on four types of chip breakers, using the same shape, material and coating of indexable cutting inserts (ICIs). The experiment was divided into two parts. The first part focused on comparing the forces acting on ICIs at different feed rates. The second part focuses on the experiment at different cutting speeds.

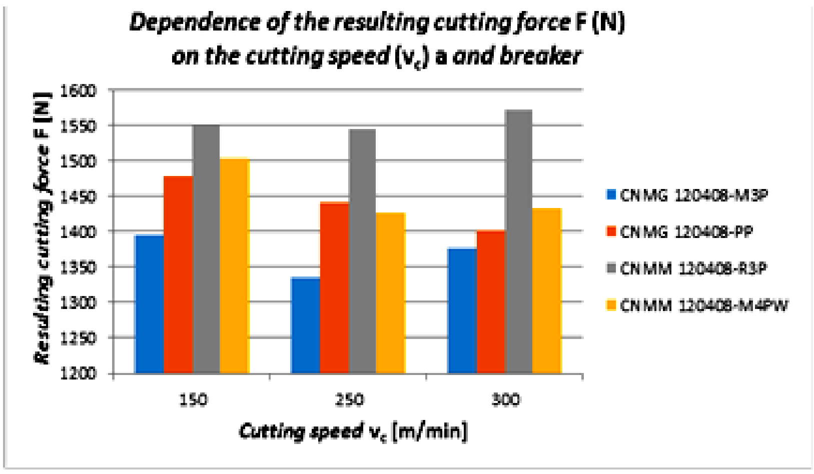

Fig. 7. Dependence of the resulting cutting force on the cutting speed and breaker for f = 0.25 mm and a_p = 2mm

The results of the experiment clearly show the effect of geometry on cutting force. In most of the tests, the lowest force was acting on the ICI breaker CNMG 120408-M3P, while the breaker CNMM 120408-R3P was exposed to the highest force in all experiments.

The evaluation of the experiment also showed that it will be necessary to extend the experiment to include ICI testing at different cutting depths, where better results could be shown for ICIs with a greater recommended cutting depth (where a larger breaker facet would not pose a problem), which corresponds to the breaker CNMM 120408-R3P.

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