DESIGN OF QUICK-STOP DEVICE EASY AND SAFE TO OPERATE FOR CHIP FORMATION STUDY ON TURNING

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Abstract. *The aim of this work is to present a new Quick-Stop Device (QSD) for turning operation, which is simple to operate and totally secure. Design considerations are described. Orthogonal cutting tests with a conventional tool holder, diferents levels of undeformed chip thickness and different grooved chip-breaker geometries were performed to test the device. The cross sections of chip root samples obtained in different cutting conditions were analyzed in micro scale. Photomicrographs showed that the device has been successfully. Finally,* some metallurgical aspects of *chip formation process when applied grooved chip-breaker inserts were discussed. The build-up layer observed when machining with grooved chip-breaker insert have not a constant thickness like is observed on build-up layer formed when machining with flat faced insert.*

Keywords*: quick-stop device, chip formation, chip root, orthogonal cutting, chip-breaker*

1. INTRODUCTION

The basis for a better understanding of all machining process can be achieved with the scientific study on chip formation process. This study has allowed significant advances on machining process and has contributed to the cutting tool improvement in respect to its surfaces, cutting edges, angles, as well as, new and effective tool materials allowing the machining of a wide range of material types (Machado *et. al.*, 2009).

According to Kishawy e Wilcox (2003), understanding the chip formation mechanism is essential to achieve a better insight of the machining process fundamentals. Trent (2000) assure that the main economic and practical problems concerned with rate of metal removal and tool performance can be understood only by studying the behavior of the work material as it is formed into the chip and moves over the tool.

The materials subjected to the machining process differs of each other in metallurgical aspects, i.e., they show differences on plastic deformation , fracture and on the ability to resist the applied stresses. In the cutting process, the high temperatures generated on the primary and secondary shear zones can cause some microstructural changes and phase transformation in the machined chips.

To do the study of such phenomena, on cutting region, it is necessary stop the process suddenly, in a way to obtain the chip root, i.e., to obtain the chip in formation process united to the workpiece submited to machining, to a later analysis. For this purpose are used quick-stop devices (QSDs) which have the objective of separate the tool from the workpiece with a velocity higher than the cutting velocity.

Chern (2005), listed certain desirable features and functions of the performance of a QSD from the literature. (1) The time taken during the tool-workpiece separation process should be as small as possible. (2) Geometrical and metallurgical changes in the chip and the workpiece surface arisen from the action of the device should be limited to a minimum. (3) Disturbance, such as vibration, that may occur in the cutting process by the action of the device should be minimal. (4) The device should work as a tool post that possesses good characteristics, both statically and dynamically. (5) The device should be safe and easy to use, and be adaptable to commercial machine tools without complex modification. (6) Resetting time of the device in between applications should be very short. (7) The device should be reliable and give reproducible results, and can be manufactured inexpensively.

Some QSDs projects are available on the literature. Jaspers (1999), Lucas e Weingaertner (2004), Chern (2005) and Reis *et al.* (2006), are examples of works on chip root analysis using different QSD types.

The conventional QSDs generally uses explosive charges and shear pins, being its operation complicated and dangerous. Therefore, this work have the purpose to present a new QSD for turning process simple to operate and secure. Considerations about the project are described. Orthogonal cutting tests were performed with different undeformed chip thickness levels (in orthogonal cutting, undeformed chip thickness h is equal to feed f) and different grooved chip-breaker geometries. The chip roots samples obtained in different cutting conditions were analyzed and the results are presented and discussed.

1.1. Chip formation dynamics aspects with grooved chip breaker inserts

Figure 1 shows the grooved chip-breaker geometric parameters which consist of the rake land length (*l*), the land angle (γ_1), the rake angle (γ_0), the groove width (*w*), the groove depth (*H*) and the groove backwall height (*h*).

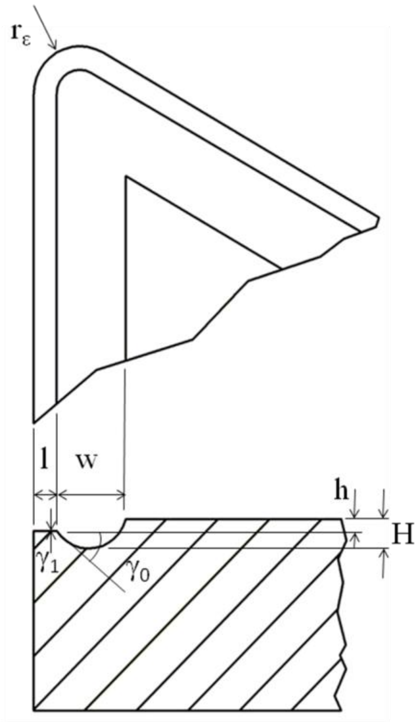

Figure 1. Grooved chip-breaker parameters

According to Jawahir (1988) the chip back-flow (known as chip streaming) is possible only when the tool restricted contact length (*l*) is less than the tool-chip natural contact length (l_n) as can be seen on Fig. 2. The grooved chip-breaker tools works with restricted contact mechanism, having limited tool face lands allowing the chip to flow back into the groove.

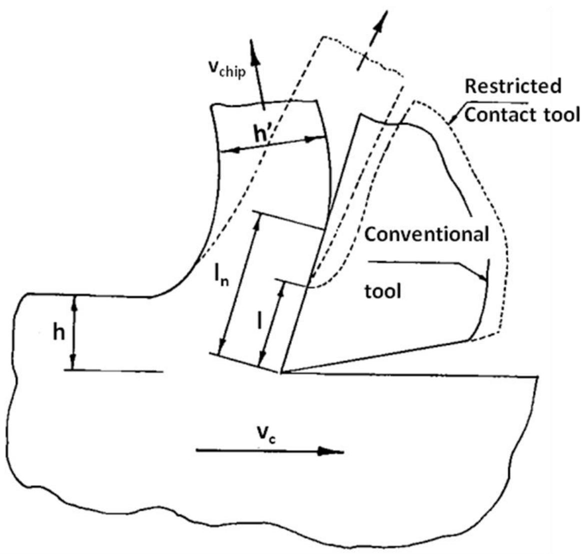

Figure 2. cutting model for conventional flat-faced and restricted contact tools (Jawahir, 1988)

The chip back-flow angle (ψ_i) is very important because it is the angle at which the chip enters the groove (see Fig. 3). It is known to be a function of the ratio of feed to land length (*f/l*), rake angle and land angles. The relationship showed in Eq. 1 was proposed by CHOI and LEE (2001).

$$\psi_i = \gamma_0 - (\gamma_0 - \gamma_1)\exp(-k(h/l)) \quad (1)$$

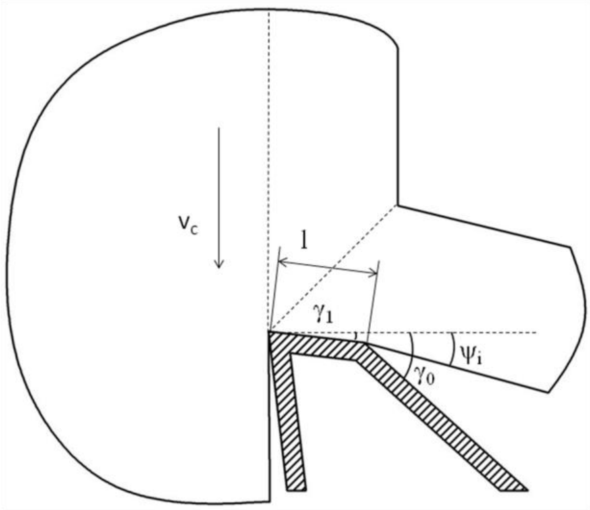

Figure 3. Chip back-flow angle (adapted from CHOI and LEE, 2001)

2. QUICK-STOP DEVICE PROJECT

Figure 4 shows details of the QSD projected. The device components were made by medium carbon steel which balances ductility and strength and has good wear resistance. The device was made by components to facilitate its production process. The main QSD components are the primary (1) and secondary (2) bases; the trigger (3); the tool holder (5) and the insert (6); the spring (7) and its base (4); and the lever (8). The device is fixed in the machine tool in a conventional way by fixing the secondary bases (9).

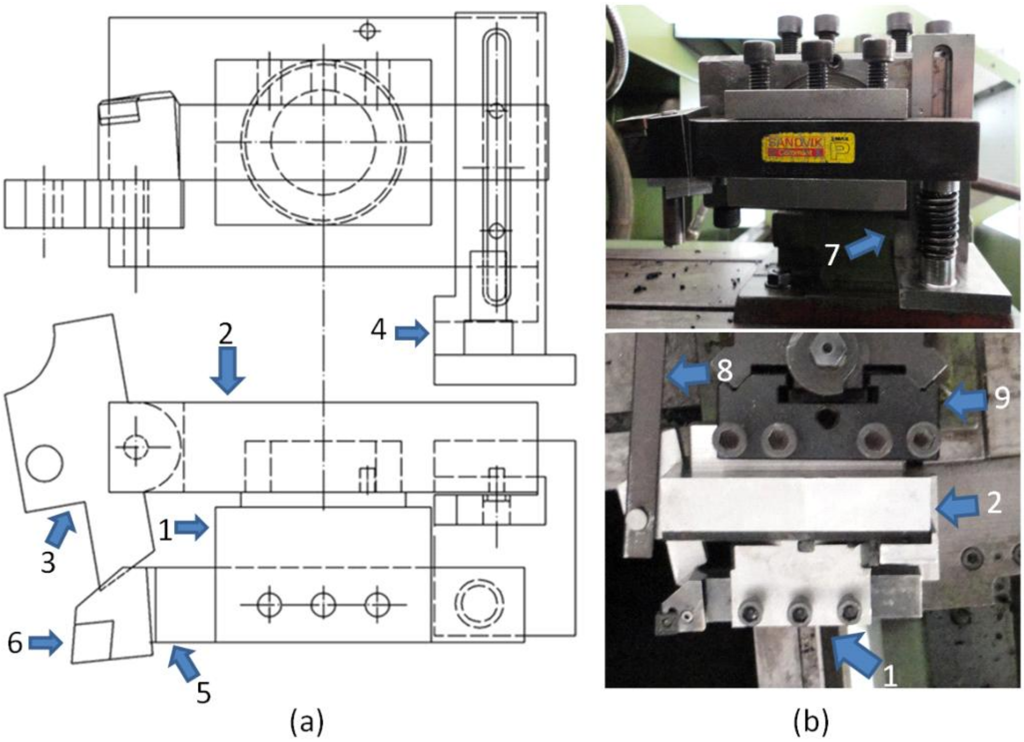

Figure 4. QSD (a) schematic view; (b) device mounted on machine tool

The device is activated by a compressed spring situated at the tool holder bottom. Under the tool holder front, the trigger support to the cutting action. The primary base, which contains the tool holder and insert fixed in a conventional way, is articulated on the secondary base by a bearing. When the trigger is activated, the spring force exerted on the tool holder bottom make it spin with the primary base removing the cutting tool from the cutting action. QSD photos before (a) and after (b) triggering are shown in Fig. 5.

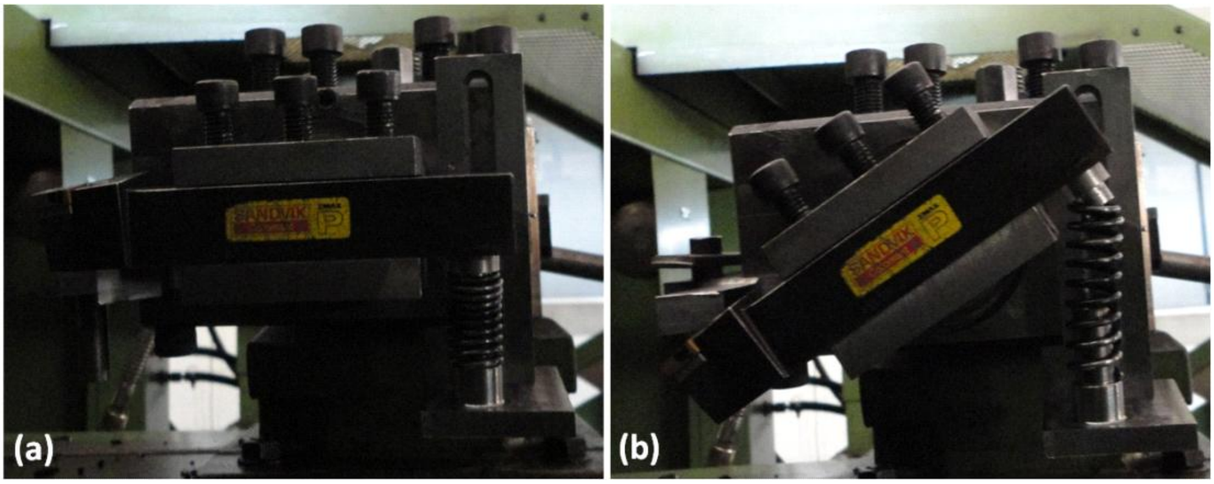

Figure 5. (a) QSD before triggering; (b) after triggering

3. EXPERIMENTAL WORK AND EQUIPMENTS

3.1. Equipments and tools

Orthogonal cutting tests were carried out on a *Romi Centur 35 II* lathe with CNC *Mach 4.* All the tests were performed using the QSD to obtain chip root samples. An tool holder with ISO code PCLNR-2525K12 from *Sandvik-Coromant.* was utilized. The tool holder has a major cutting edge angle χ_R equal to 95º, rake angle γ_0 and cutting edge inclination angle λ_s both equal to -6º. However, the major cutting edge angle χ_R was adjusted to 90º like is required in orthogonal cutting (Fig 6). Besides, to prevent flank contact with the machined surface on cutting tool leaving, the tool clearance angle α_0 was increased to 12,5º which had consequently changed the rake angle.

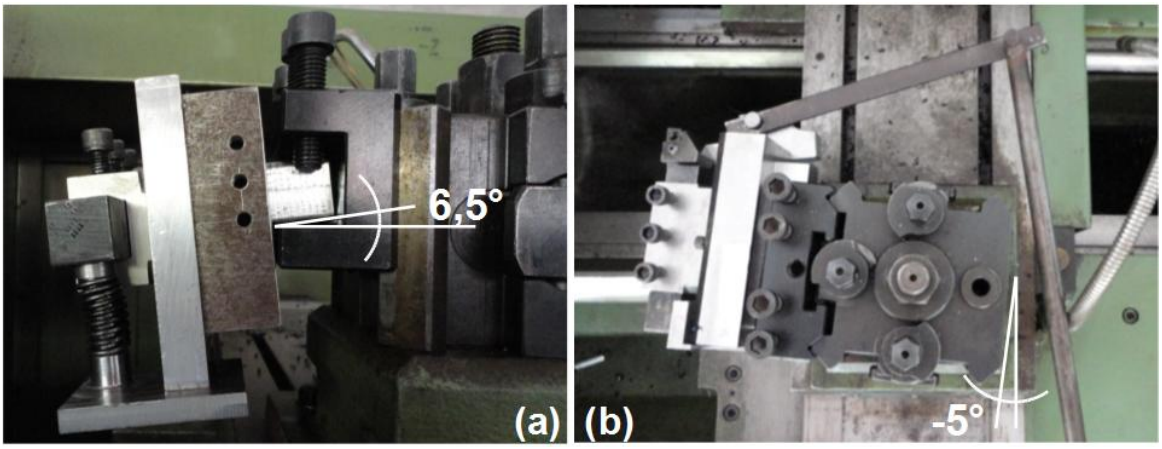

Figure 6. (a) Clearance angle α_0; and (b) major cutting edge angle χ_R adjustment.

Coated carbide inserts from *Sandvik-coromant* with ISO code CNMG 120408 (with chip-breaker) e CNMA 120408 (without chip-breaker) were utilized. The chip-breaker geometries are shown in Fig. 7. The land angle and the rake angles of the chip-breaker profiles were modified due to the increase on tool holder rake angle, such as shown in Fig. 6(a). The corrected values are exposed in Tab. 1.

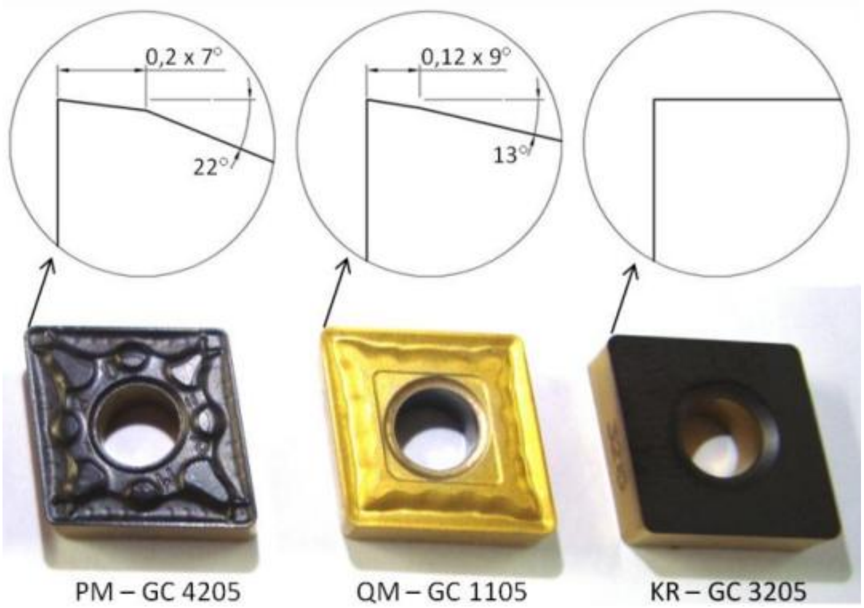

Figure 7. Chip-breaker geometries utilized on tests

Table 1. Insert angles values corrected

Inserto	γ_1^*	γ_0
PM	-5,5°	9,5°
QM	-2,5°	0,5°
KR	-	-12,5°

* land surface angle

3.2. Cutting conditions and experimental parameters

The cutting velocity (v_c) was 104m/min and the cutting depth (a_p) was 2mm for all tests. The undeformed chip thickness (h is equal to f) values are shown in Tab. 2. Considering all chip breaker type and all undeformed chip thickness values combinations, were performed a total of 9 tests.

Table 2. Cutting conditions varied on tests

	Unidade		Levels	
Chip-breaker type	-	PM	QM	KR
Undeformed chip thickness(h)	mm/rot	0,16	0,24	0,32

3.2. Workpiece configurations

Work material AISI 1045 steel was utilized on tests. Nine tubular workpieces were prepared to guarantee the round cutting edge portion out of the cutting, as is required on orthogonal cutting. The wall thickness, which is exactly equal the cutting depth, is 2.0mm The workpiece measurements are shown in Fig. 8.

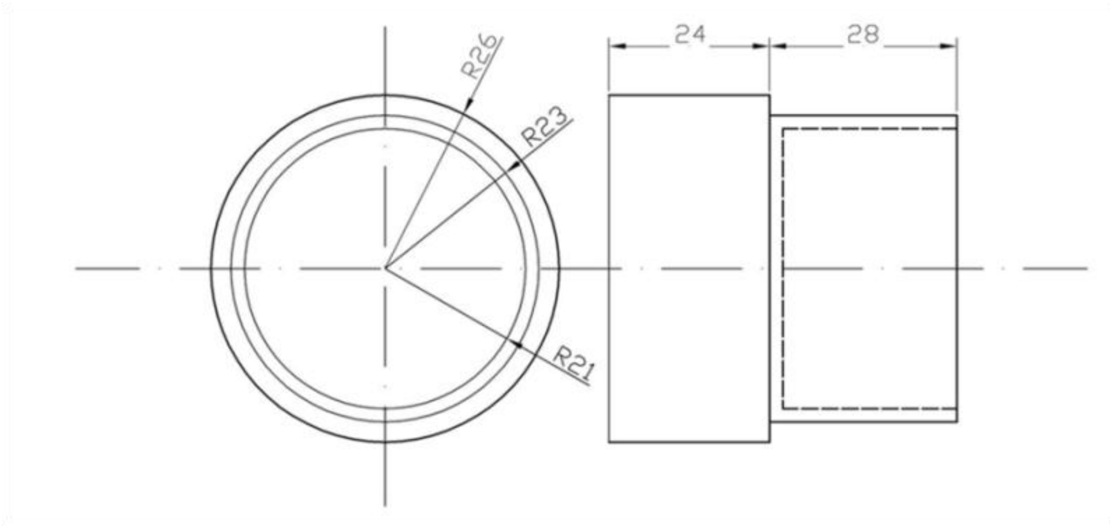

Figure 8. Workpiece configurations and measurements (mm)

After each successful test with QSD, the chip root was sectioned, molded into plastic resin, sandpapered, polished and subsequently examinated under optical microscope. Then some metallurgical aspects were exposed and discussed.

4. RESULTS AND DISCUSSION

Figure 9 shows a chip root attached to the workpiece after the quick-stop test. Photomicrographs of chip roots obtained at different feeds and different chip-breakers are shown in Fig. 10.

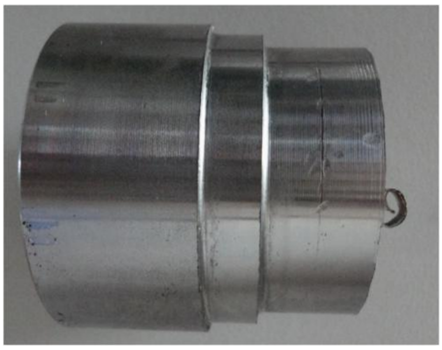

Figure 9. Chip root attached to the workpiece

In all tests build-up edge presence were not identified. This happened due the cutting velocity value used which is bigger than that in which this phenomenon may occur. In the tests with KR insert (see Fig. 10), the chip roots formed had negative rake angle due this insert rake angle value (see Tab. 1). With this insert the chip thickness remained constant along chip root length.

With the insert PM, which has the most positive rake angle value (see Tab. 1), can be observed high chip streaming degree i.e., the degree of chip flowing into the groove. Therefore, tests with PM chip-breaker were observed higher chip back-flow angle than with KR.

With QM, which has the smallest land length (*l*), the chip streaming degree was too accentuated due the ratio between feed (*f*) and land length (*l*). The bigger is the ratio *f/l* bigger is the chip-back flow angle.

The chip thicknesses obtained on tests made with chip breaker inserts are not constant along the chip length. It occurs mainly due the chip breaker which curves the chip mechanically, changing the chip formation dynamics and, consequently, the chip characteristics when compared with cutting process without chip-breaker presence.

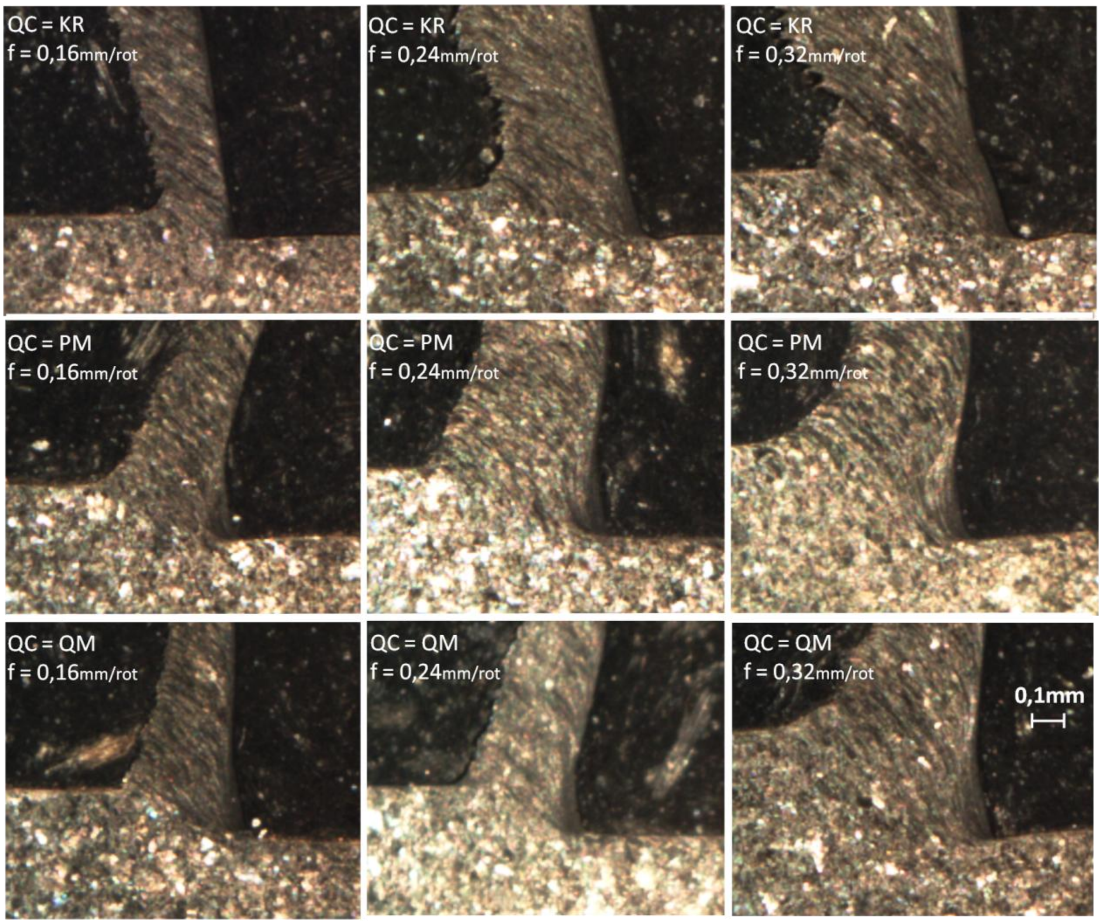

Figure 10. Chip root photomicrographs

Figure 11 shows a photomicrograph with the primary shear plane direction representation (AB). This direction is assumed as a primary shear plane simplification. This direction separates the deformed of the undeformed region. The crystals deformation direction is different from the shear plane due the friction on the chip-tool interface, which produces a bending moment on chip lamella.

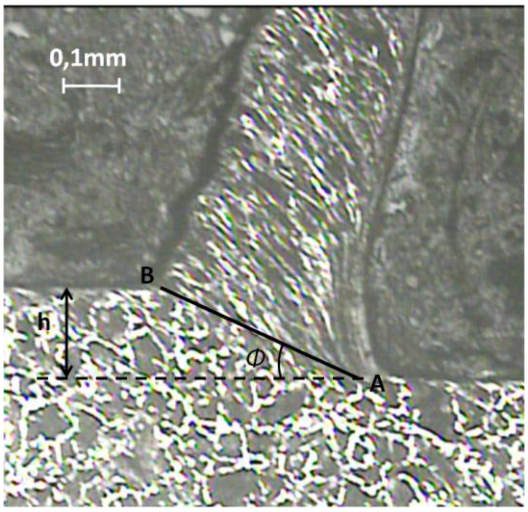

Figure 11. Shear plane direction representation – AB (QM insert; f= 0,24mm/rot)

Figure 12 also shows the presence of a deformed area of the chip which is caused by high shear and friction rates developed in the secondary shear zone. This deformed area is referred as build-up layer (BUL), which should not be confused with the build-up edge. When machining without chip-breaker presence, BUL have a constant thickness along its length (Fig. 12(b)). However, on tests using grooved chip-breaker insert, was observed that the BUE have not a constant thickness which decreases as the chip lose contact with the chip-breaker land surface (Fig. 12(a)). Then, it could be inferred that the BUL formatted in machining with grooved chip-breaker presence have not a constant thickness due the chip streaming mechanism of chip-breaker insert.

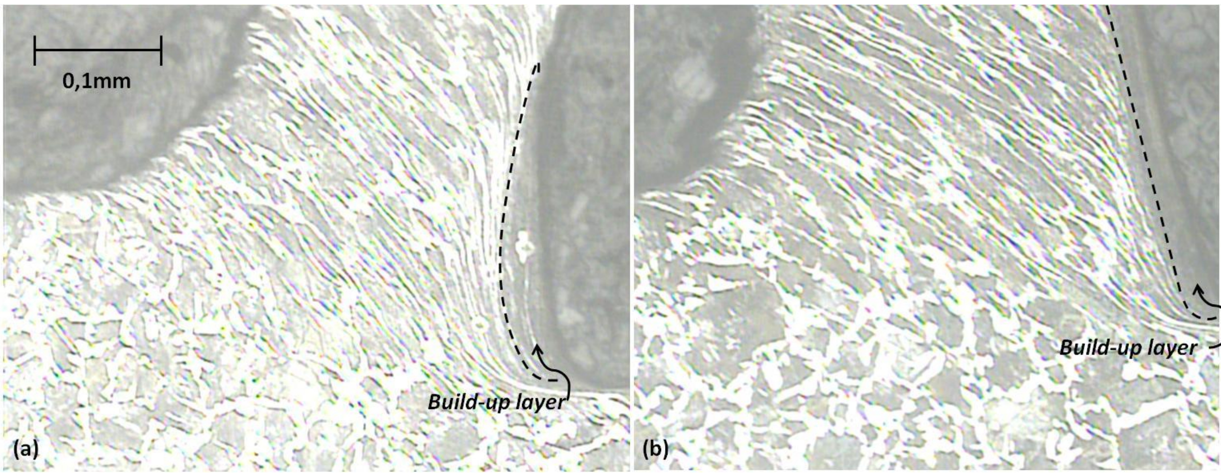

Figure 12. Build-up layer . (a) PM insert, f =0,16mm/rot; (b) KR insert, f =0,24mm/rot

In the chip roots obtained with KR insert, the undeformed chip thickness *h* measured values on the photomicrographs were lower than the programmed values. It happened due tool deflection when it was removed from the cutting action by the QSD action. The rake angle negative value (γ_0) used due the clearance angle adjustment (see Fig. 6(a)), may have generated high cutting forces, which led these deviations. With chip-breaker presence, it does not happened due the positive values of rake angles on groove entrance.

The restricted tool-chip contact mechanism observed when machining with chip-breaker inserts cause chip thickness compression ratio decreasing. Machining with chip breaker changes the chip formation characteristics on chip root region. Therefore, the shear angle models considered for machining with conventional flat-faced inserts should not be applied in the chip-breaker case, due the geometric parameters of inserts containing this feature (see Fig. 13).

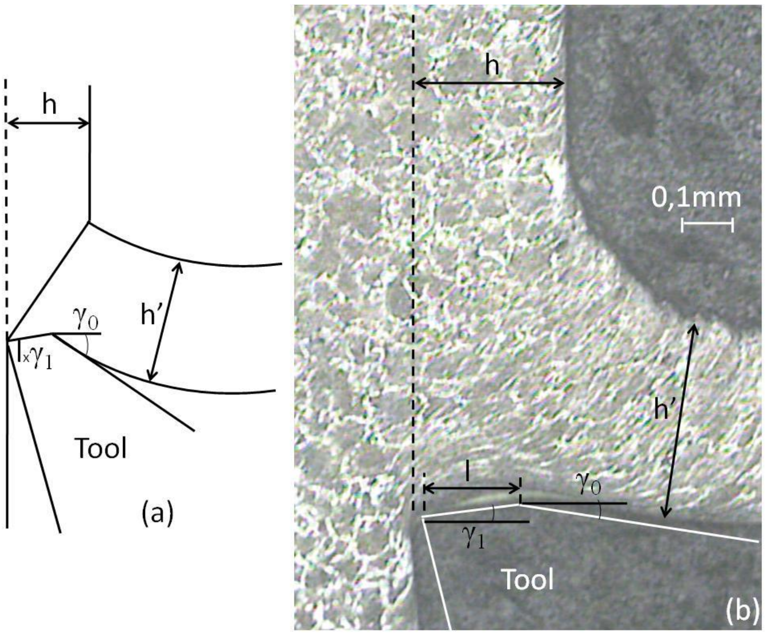

Figure 13. Chip root obtained with a grooved chip-breaker insert. (a) schematic representation; (b) photomicrograph (PM insert; f = 0,32)

5. CONCLUSIONS

The quick-stop device developed for chip formation study without employing any explosive charges or breaking any shear pins had stable operation. However it is necessary to test the device with a smaller adjustment of the clearance angle or with another tool holder which contains a smaller rake angle.

It was noticed that the build-up layer formed, when machining with grooved chip-breaker, have not a constant thickness due the chip streaming mechanism of the grooved chip-breaker insert.

Through the chip roots analysis it can be inferred that machining with chip-breaker showed significant differences on chip formation when compared with machining with flat-faced inserts. Consequently, the models to calculate the shear angle for flat-faced inserts (tools) are not valid for chip-breaker inserts.

5. ACKNOWLEDGEMENTS

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