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BUILD UP EDGE PHENOMENON AND CHIP FORMS IN INCONEL 625 ALLOY LONGITUDINAL TURNING – CASE STUDY

ZJAWISKO NAROSTU ORAZ FORMY WIÓRÓW UZYSKANE PRZY TOCZENIU WZDŁUŻNYM STOPU INCONEL 625 – STUDIUM PRZYPADKU

Abstract

The paper presents the wear process of a carbide insert in Inconel 625 longitudinal turning as well as examples of chip forms. Inconel 625 alloy belongs to the difficult-to-cut material group and causes many problems in machining operations in industry. A major one concerns chip forms produced in turning operations and quick wear of the cutting edge. The conveyed research also revealed the Build Up Edge (BUE) phenomenon, which took place in conveyed tests. A few examples have been presented and analyzed.

Keywords: machining, turning, tool wear, BUE

Streszczenie

W artykule przedstawiono proces zużycia płytki z węglików spiekanych oraz postacie wiórów uzyskanych podczas toczenia wzdłużnego stopu Inconel 625. Inconel 625 należy do grupy materiałów trudnoskrawalnych i sprawia sporo problemów w obróbce skrawaniem. Dotyczą one głównie trudności w uzyskiwaniu korzystnej postaci wiórów i bardzo szybkie zużycie ostrza. Przeprowadzone badania ujawniły także zjawisko powstawania narostu na krawędzi skrawającej. Zaprezentowano i przeanalizowano kilka przykładów.

Słowa kluczowe: obróbka wiórowa, toczenie, zużycie ostrza, narost

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1. Introduction

When observing contemporary trends in machining, it can be noticed that the important thing is to pay attention to research concerning the variety of factors influencing the quality of processes. Such factors like the influence of cutting data on the surface roughness and cutting forces in machining extremely difficult-to-cut materials (e.g. sintered carbide) are the examples of such research activity [10, 11]. Additionally, cost effectiveness combined with cutting data selection process is a very important factor in any kind of machining [12].

One of the factors, which should be investigated, is chip form achieved in turning operations. The rake face of a carbide insert has a significant impact on this phenomenon.

The rake face of a modern insert is usually shaped in a chip breaker or chip former according to the terminology used by various manufacturers. Its task is to direct a chip towards the flank face of an insert or a raw surface of a workpiece. When a chip hits an obstacle, it breaks. The field of the chip breaker application is crucial for the final process of cutting data selection. This is particularly important when difficult-to-cut materials like HRSA (Heat Resistant Super Alloys) are machined. Chips are a waste product in every kind of machining and their unacceptable form (long and curly) can have a destructive impact on the quality of the machined surface. In the worst case, especially in automated manufacturing systems, they can cause catastrophic tool wear and even stop the production.

HRSA are generally resistant to temperature and corrosion. They can be divided into alloys based on nickel, cobalt and iron. In machining operation, these alloy components can cause quick wear of a tool, mainly due to chipping, deformation and work surface hardening [3]. The last one mentioned is the reason of depth-of-cut-line notching and can also compromise the fatigue strength and geometric accuracy of the part. Chips are usually difficult to control. High temperature in cutting zone and high cutting forces are also standard in machining operations. Low thermal conductivity of Inconel 625, (a representative of HRSA alloys), 9.8 W/(m · K), in contrary to steel C45 thermal conductivity, which is 50 W/(m · K), is the cause of very high temperature on the cutting edge, the main reason for fast tool wear process. These are important factors concerning tool life and chip forms.

Tool life depends on tool wear. The most popular are rake face tool wear (crater) and flank face tool wear. The latter is described by VB indicator in various form, the most popular and easy to measure is the average value of VB marked VB_B [5]. The interesting form of a tool wear is BUE (Build UP Edge). Theoretical background of BUE in turning is described in [4]. Generally, BUE consists of free particles of machined metal, which are not a part of a chip, but they are glued by the adhesion phenomenon to the cutting edge of a tool. BUE changes the geometry of a tool, especially a rage angle, leading to the changes of chip breaker geometry and deterioration of surface roughness.

Many problems concerning HRSA machining are described in details in application guides recommended by tool manufacturers, SANDVIK-Coromant, for example [1, 9]. It must be remembered that local operating features (machining system consisting of tool-machine tool-workpiece material) have significant influence on these recommendations [8]. For all the reasons described above, high temperature alloys deserve special machining techniques.

2. Research object

Inconel 625 was used as a work material [9]. It is a nickel-chromium-molybdenum based alloy widely used in aircraft engine constructions, chemical and shipbuilding industries.

As it was mentioned above, Inconel 625 belongs to super alloys (HRSA) so all problems concerning the machining of this group of alloys concern Inconel 625 machining.

In tests, ISCAR produced and recommended for HRSA turning, VCMT 160404 insert (Fig. 1) with SM type chip breaker geometry was used, grade IC 907 coated with TiAlN layer [2]. The insert was mounted to a tool holder SVJCR 2020K. Chip breaker recommended application area was a_p = 0.5–2.5 mm, f = 0.05–0.25 mm/rev. Fig. 2 shows a cutting edge of a new insert.

The cutting data used in tests are presented in Table 1. The value of feeds were determined by the feed system used in the lathe. Two values of feed were selected, the second approximately three times greater than the first one. Preliminary tests have demonstrated correct chip forms for a brand-new insert for each set of data [6].

The work piece used in tests (diameter Dc = 35 mm) was divided into 5 mm sections, so 15 tests took place. After turning each section, the insert wear was measured, the chip form was classified, the recordings of the turning process were analyzed and BUE removed.

Table 1

Cutting data used in tests

Chip breaker type	SM
Cutting speed, v_c [m/min]	65
Feed, f [mm/rev]	0.077, 0.211
Depth of cut, a_p [mm]	1.0

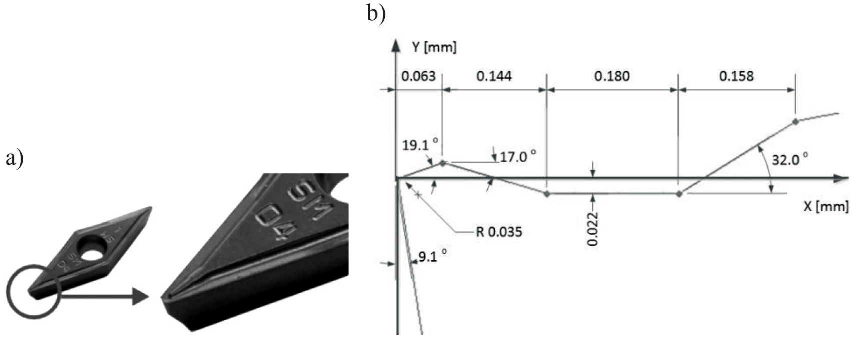


Fig. 1. Insert VCMT 160404-SM IC 90; a) general view, b) measured dimensions of chip breaker type SM [7]

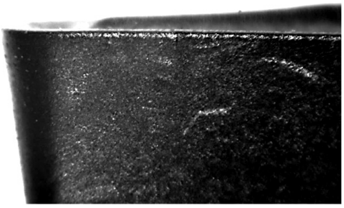


Fig. 2. The cutting edge of a new insert VCMT 160404-SM

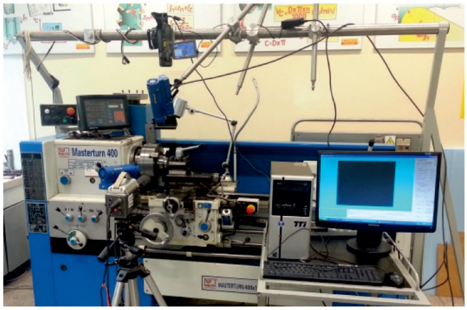


Fig. 3. Research stand for recording phenomena in the cutting zone in turning

The main components of research stand (Fig. 3) consisted of:

– Masterturn 400 lathe,
– high speed camera Phantom V5.2,
– spot illumination systems,
– 3-D Digital Kayence microscope,
– tool room microscope with MicroCamLab computer program.

There was no coolant used in machining tests in order to enable good quality chip photo acquisition. Additionally, coolant could affect chip forms. Acquisition parameters used for high speed camera were as follow: recording rate 1000 fps, resolution 1152 × 896 pixels.

3. Chip forms

Chips formed in machining were described and classified. Examples are presented in Tab. 2 and 3. Table 2 presents examples of chips for two tested feeds when the flank wear VB_B (e.g. average value of VB) was equal to 0.3 mm. All photos reveal correct chip forms. Chips were short and segmental. The second table (Tab. 3) exhibits chip photographs when unacceptable chips appeared.

Table 2

Chip forms achieved in Inconel 625 turning for VB_B = 0.3 mm [7]

	f = 0.077 mm/rev VB_B = 0.3 mm	f = 0.211 mm/rev VB_B = 0.3 mm
Correct chips, segmental, short helical, loose arc		

Table 3

Unacceptable chip forms achieved in Inconel 625 turning [7]

	f = 0.077 mm/rev VB_B > 0.45 mm	f = 0.211 mm/rev VB_B > 0.4 mm
Unacceptable long helical and tangled chips		

The flank wear indicator has different value for each feed. Chips were generally long, continuous and tangled. For the feed f = 0.077 mm/rev correct form of chips occurred up to VB_B = 0.45 mm. Respectively, for the feed f = 0.211 mm/rev, correct chips were present up to VB_B = 0.4 mm

4. Tool wear and BUE phenomenon analysis

Research revealed typical forms of insert wear, but abrasive wear on a flank face was dominant. The change of VB_B indicator value in consecutive tests, for two values of feed, is presented in Fig. 4.

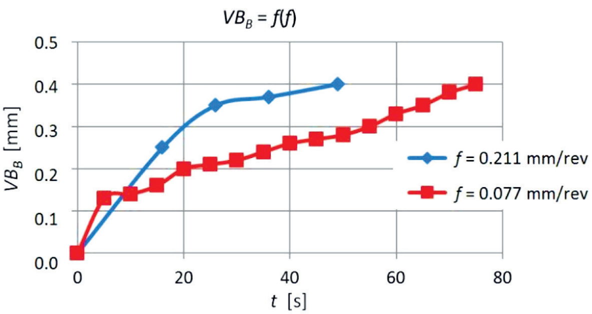


Fig. 4. Change of VB_B value in consecutive tests

The curve for f = 0.077 mm/rev shows almost a classic character of tool wear. If the value of feed increases, a tool wear curve is close to linear. When the time of cutting reached approximately $t \approx 100$ s, VB_B indicator exceeded 0.45 mm and then unacceptable form of chip was registered (Fig. 5).

b)

a)

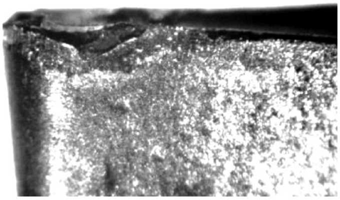


Fig. 5. Example of final stage insert wear: a) flank face wear photo, b) long tangled chips; $f = 0.077$ mm/rev, $v_c = 65$ m/min, $a_p = 1.0$ mm, $t \approx 100$ s [7]

Visual observation of the cutting edge of the wear insert showed many deformations, small grooves and crates caused mainly by abrasive wear. Since BUE (Build Up Edge) phenomenon was observed a few times during machining, adhesive wear must also have taken place.

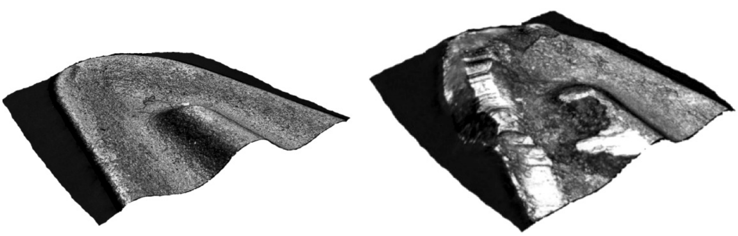


Fig. 6. 3-D view of a new insert rake face and after time of cutting $t \approx 100$ s, $f = 0.077$ mm/rev, $v_c = 65$ m/min, $a_p = 1.0$ mm

Fig. 6 presents views of the rake face of the worn insert. An extensive wear of a backwall of a chip – groove is noticeable. This is probably the cause of unacceptable chip forms in this stage of machining. A chip was not directed towards an obstacle (a flank face of an insert or raw surface of a workpiece) to be broken.

As it was mentioned above, in a few tests for cutting data $f = 0.077$ mm/rev, $v_c = 65$ m/min, $a_p = 1.0$ mm BUE phenomenon took place. This caused temporary direct change of chip form from correct to unacceptable.

Table 4 presents the test number (out of 15) in which this phenomenon was observed, along with the appearance of the cutting edge, the chip form achieved in particular test as well as VB_B value. Characteristic grooves are visible on the flank face. It is caused by abrasive interaction between cutting edge and the workpiece machined surface. Fig. 7 shows the basic dimensions of BUE which allow to define changes in cutting wedge geometry, while Table 5 presents dimensions of BUE in particular tests.

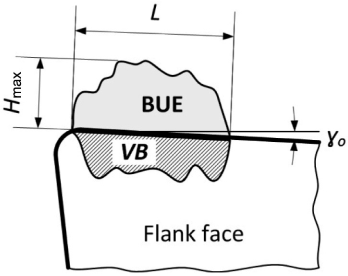
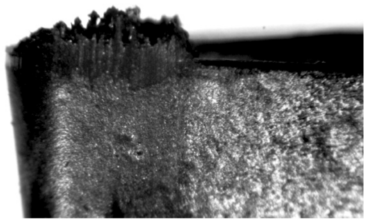
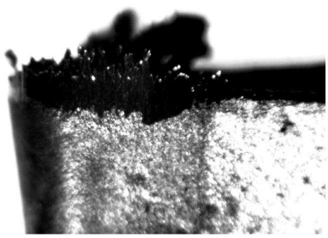
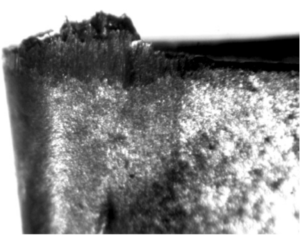


Fig. 7. Basic dimensions of BUE

Table 4

BUE phenomenon and chip form in selected tests

Test number	Flank face and cutting edge	Corresponding chip form	VB_B
3			$VB_B = 0.16$ mm
4			$VB_B = 0.2$ mm
5			$VB_B = 0.21$ mm

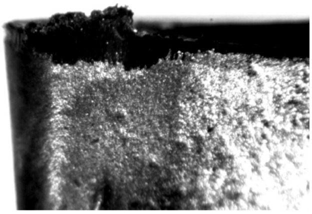
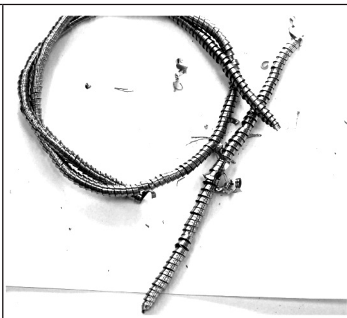
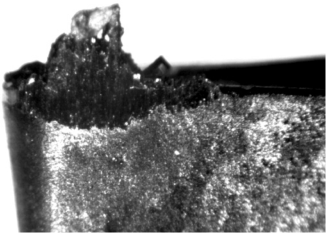
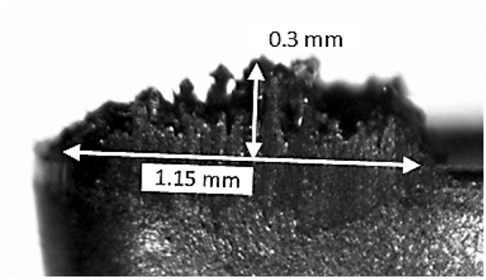
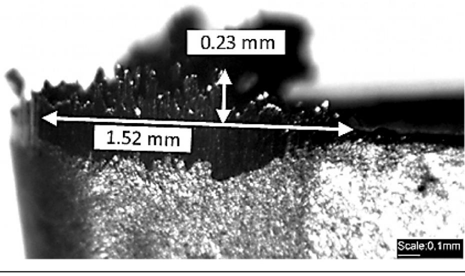
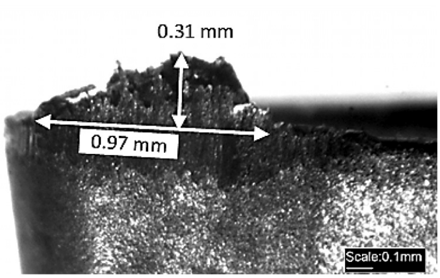
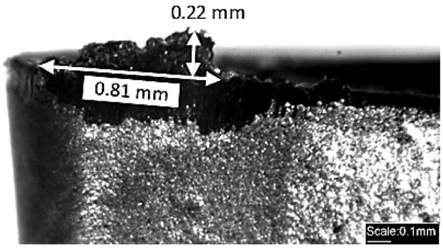
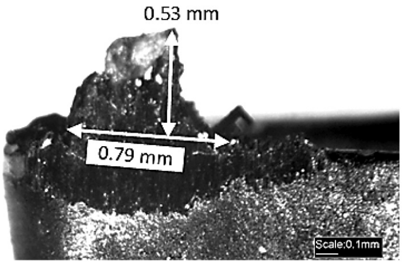
<table>
<tr><td>7</td><td></td><td></td><td>$VB_B = 0.24$ mm</td></tr>
<tr><td>13</td><td></td><td></td><td>$VB_B = 0.35$ mm</td></tr>
</table>

Table 5

BUE dimensions in selected tests

<table>
<tr><th>Test number</th><th>Photographs of BUE phenomenon</th><th>BUE dimentions (H_{max}, L)</th></tr>
<tr><td>3</td><td>
</td><td>$H_{max} = 0.3$ mm
$L = 1.15$ mm</td></tr>
<tr><td>4</td><td>
</td><td>$H_{max} = 0.23$ mm
$L = 1.52$ mm</td></tr>
</table>

5		H_{max} = 0.31 mm L = 0.97 mm
7		H_{max} = 0.22 mm L = 0.81 mm
13		H_{max} = 0.53 mm L = 0.79 mm

5. Conclusions

The investigation of the tests led to the conclusion that the BUE phenomenon occurred more often than not in the first stages of tool wear. Especially up to VB_B = 0.26 mm. It created unacceptable chip form. After removing BUE, a return to the beneficial chip form took place. So it is obvious that the tested set of cutting data was disadvantageous; the technologist could be misled assigning the disadvantageous form of chips to excessive tool wear. The remedy would probably concern the increase of cutting speed, but that could have disadvantageous influence on tool life. Another way would be to use a different grade of carbide insert recommended by a tool manufacturer (verifying tests would be necessary in this case) or feed change (for the feed f = 0.211 mm/rev this phenomenon did not appeared). The change of feed leads to a different roughness of the machined surface – in this case – deteriorates it.

Generally, flank wear of VCMT 160404 – SM insert had no significant influence on chip forms for stable, correctly selected cutting data. For the majority of tool wear time, chip forms were correct or acceptable. Loose arc or bounded arc chips were dominant up to significant tool wear when long, continuous chips of various kinds appeared. The primary cause of unacceptable chip creation was the wear of the chip groove backwall (Fig. 6).

Short tool life in the tests was caused by the fact that machining was performed without coolant. Industrial practice shows that coolant with almost 17% of oil is convenient in the case of Inconel alloys machining.

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