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Investigation of the Tool Wear Progression in Parting Technology

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Parting-off stands as a fundamental method of turning, involving the cutting of the workpiece. The tool is most frequently a replaceable insert secured in a clamping bed. A pivotal set of observable metrics that ascertain the efficacy of a tool and its appropriateness for machining a specific material under defined cutting conditions is its durability. These durability parameters need to be determined for all new tools to ensure optimal performance and application in various machining scenarios. The primary objective of this research was analysis of the wear experienced by replaceable cutting inserts within the realm of parting technology. There were three distinct variants of replaceable cutting inserts. These cutting inserts were applied in the parting process, consecutively machining two materials: bearing steel 100Cr6 and stainless steel 316L. The study not only encompasses the description of the cutting test procedure but also involves the meticulous execution of measurements and the subsequent analysis of the data procured from experimental activities. In the final phase of study, additional analyses are outlined to uncover the factors contributing to variations in certain obtained results. Those analyses, such as material or tool coatings analysis, provides more information about interplay between replaceable cutting inserts and the specific materials subjected to parting processes.

Keywords: Parting-off technology, Cutting insert, Tool wear, Durability, Tool coating

1 Introduction

Parting-off technology is one of the basic turning methods, but it involves several issues that must be addressed. One of them is the complex control and removal of chip from the cutting point, as the tool is surrounded by the workpiece throughout the machining process [1]. Parting-off tools are typically made as narrow as possible to conserve work material and minimize the magnitude of cutting forces. Taşgetiren has investigated the effect of cutting forces in a broaching tool on machining efficiency, or their effect on the tool itself and the material being machined. He used a model to show that the greatest stress value is generated by the cutting forces at the tool face and tip. As the coefficient of friction increases, the maximum stress value in the tool decreases and the wear has a more linear progression [2]. Zlamal et al. investigated the effects of dynamic loads on a mortising tool in relation to its geometry. The experiment shows that for each chip breaker, a proper combination with cutting conditions needs to be found [3].

The weakness of the parting-off and grooving tools is the generation of local heat in the narrow tool, which results in faster tool wear [4, 5, 6]. The tool width narrows in length from the width of the main blade [4]. The crimper is designed to provide controlled chip evacuation from the cutting area, further reducing the chip width, as its value otherwise corresponds to the width of the tool cutting edge [1]. Mahnama and Movahhedy through FEM simulation investigated the stability and chip formation during orthogonal cutting. The results proved, among other things, that the stability of the system during orthogonal cutting is mainly defined by the kerf width [7].
Chep et al. investigated the wear development of chamfering tools with different geometries. The experiment confirmed the recommendation that a chamfered edge chamfering tool is suitable for chamfering solid material [8]. Saffury tested the design of a new parting-off tool based on the vibrations generated when machining deeper grooves. This had a dynamic vibration damper, which enabled a chatter-free machining process to be achieved in the experiment under the same cutting conditions [9]. Haddag et al. analyzed the tribological behavior and wear development of the insertion inserts for roughing large-sized components intended for the nuclear industry. Using a numerical model with the finite element method, he was able to predict the shape and parameters of the chip. This model, which is based on a study of the tribological behaviour of the tool at the cutting point, has high applicability in the design of new tools [10].

As with all other machining methods, the cutting speed is an important parameter in parting-off technology. As the material is machined in the radial direction, the machined diameter changes. The value of the cutting speed thus decreases periodically towards the centre of the workpiece. On the workpiece axis, the cutting speed value is zero. The cutting conditions for the tool thus change considerably during the process, even if the cutting speed is set to a constant value throughout the parting-off process. The tool is thus subjected to cyclic loading. [1, 6] Machai et al. studied the effect of cutting speed and cooling methodology on the indentation processes of various beta-titanium alloys. The decrease in cutting forces in the cutting speed range of 40 to 140 m/min is caused by thermal softening of the material. As the cutting speed increases above 140 m/min, the cutting forces increase. In this study, it is confirmed that the increase in the weight of the tool holder, which was achieved by placing weights, means that the dynamic effects on the impaling tool are mitigated [11]. Research into the comprehensive assessment of wear and durability on coated tools often leads to the construction of Taylor's dependence. It has been verified that as with other types of turning operations, cutting speed is the most important cutting parameter affecting tool life. Next in order is feed rate and depth of cut. Durability can be defined as the time the cutting tool can machine accurately enough [12, 13, 14]. When machining tough materials, where long chip formation is typical, there is an increased likelihood of chip jamming at the cutting point and degrading the product and tool.

All austenitic steels are classified as harder to machine materials. This is due to the low yield strength, high ductility and higher toughness of these steels. When compared to carbon steel, the value of the impact work, which is used to evaluate the toughness itself, is 2.4 times greater for austenitic steel. On the basis of the above properties, austenitic steels are easier to harden. Better machinability can be achieved in most austenitic steels by heat treatment such as austenitizing annealing or soft annealing [15, 16].

In the case of parting-off technology, cooling is absolutely necessary, which is subject to increased demands. The use of cooling means increased tool life, improved chip formation or the possibility of using higher cutting conditions. When machining materials with lower thermal conductivity, which austenitic stainless steels undoubtedly are, the use of higher pressure cooling, directed as close as possible to the cutting point, is recommended. Otherwise, the heat can easily accumulate on the tool face and there may not be sufficient chip evacuation. When lower coolant pressures are used, there is also an increased risk of the coolant turning to vapour due to high temperatures. This will create a barrier that may prevent heat from being dissipated from the cut point. Ultimately, the formation of this barrier, due to which heat accumulates in the tool, can cause sudden destruction of the cutting edge of the cutting tool [17, 18, 19]. Wada was engaged in turning threads and grooves on Ti-6Al-4V material with high-pressure cooling. The high-pressure cooling resulted in better chip breakage. Compared to the conventional method, the use of the high-pressure version of the cutting fluid supply meant a slower increase in the wear of the grooving tool [20]. The data from TMC CR, s.r.o. proves that intelligent cooling is essential during grooving or parting-off operations. The specially developed cooling distribution system called ARNO – ACS cooling system, for which the company holds a patent, offers a controlled coolant flow, chip breaking and has a high cooling and lubricating effect. Combined with additive 3D printing technology, the use of this method is advantageous and opens up further possibilities for optimization. One of these is, for example, to reduce the width of the cutting tool. According to the manufacturer's data, a reduction of 1 millimetre in cutting edge width can save annual costs of up to 400,000 EUR, when considering a total of 20 machines operating for 220 working days [21, 22]. Vasilko et al. studied methods of extending tool life in high-speed steel tools, which include reducing residual stress in the cutting tool using alternating electromagnetic fields, electrospark hardening of the cutting part of the tool, and freezing of coated tools. Other methods, which are the same for sintered carbide tools, are geometry modifications associated with the reduction of applied cutting forces and PVD coating [6].

The comparison of the coatings is offered due to the experimental results, since the TiN coated A wafers differed from the B and C wafers by the type of coating. The TiAlN coating, which was used on the B inserts, has better properties than the TiN coating in all respects. Of all the coating types most commonly found on the market, TiAlN offers the best thermal insulation of the cutting tool, which results in the greatest amount of heat being dissipated through the chip. The temperature at which this coating begins to oxidize is 700 °C. Compared to TiN coating, this is a noticeably higher value when considering the operating temperatures to which the tool is exposed during the cutting process. The TiAlN coating also provides higher resistance to abrasion and diffusion. The results obtained and the differences in tool durability demonstrate the significant influence of the type of coating on the durability of the cutting tool [23, 24, 25]. Zhang et al. studied the effect of different substrate texture modifications on the adhesion and tribological properties of TiAlN coating fabricated by PVD method. By modifying the substrate surface using a laser, different textures were achieved before coating. Subsequently, coating tests of textured and untextured substrates were carried out on AISI 316 stainless steel.

The results confirmed that textured surface implies better adhesion properties of the final coating and due to this, the coated tools with textured substrate surface also possess higher wear resistance [26]. Wanigarathne et al. studied the wear of coated piercing tool in relation to cutting temperature. The study, in which cutting forces were measured simultaneously with the thermal field, indicated the occurrence of an accelerated wear band that occurs during the initial engagement of the piercing tool into the work material [27]. Through an experiment, Grzesik investigated the temperature evolution of coated inserts during turning. The experiment confirmed that if a workpiece material that has low thermal conductivity and low heat capacity enters the machining process with a tool whose coating also has low thermal conductivity, a thermal barrier will form. This barrier concentrates the heat in a thin layer on the tool surface and protects it from diffusion wear mechanism [28]. Kurt et al. used mathematical models to simulate the deformation and stresses of the indentation tool as a function of the cutting conditions. The study showed that the radial force (F_P) and the main cutting force (F_C) increased with increasing feed rate. On the other hand, the magnitudes of these forces slightly decrease with increasing value of cutting speed [1].

2 Experimental setup and material

For the experiment, parting-off tool for turning with catalogue designation L3-S2525MFL-24-80 was used.

The clamping v-groove is compatible with interchangeable inserts GL 2, 3, 4, 5, and 6, i.e. inserts with a width of 2 to 6 mm. The GL3-D300M02-PM:G8330 replaceable insert (hereafter referred to as insert A) served as the primary comparator in this experiment, against which the B and C inserts were compared. A view of the insert labeled B in the clamping bed is shown in Fig. 1. The substrate of insert A is WC-Co based, the coating is realized by a low temperature physical PVD coating method. The TiN coating, for which the golden colour is typical, ensures reliability and resistance to adverse conditions when machining most materials.

The first material to be machined was steel with the designation 100Cr6. It is a alloy structural steel with good machinability and hot formability. The Young's modulus of 100Cr6 is approximately 210 GPa. This steel also provides excellent wear resistance and has good thermal conductivity and low coefficient of thermal expansion. The yield strength value Re is equal to 410 MPa and the tensile strength Rm is 700 MPa [29]. To enhance machinibality, normalizing annealing was done. The second material was stainless steel 316L. This austenitic stainless steel is commonly used for structural parts that are in contact with water and moisture due to its high resistance to corrosion and acids. It is machinable, formable and weldable. This steel has lower hardness, but it provides excellent impact toughness. The Young's modulus of 316L steel is typically around 193 GPa. The yield strength is 270 MPa and the ultimate strength is 680 MPa [30]. The workpiece was quenched and low tempered to 242 HV. The chemical composition of both machined materials is shown in Tab. 1 and 2. All those information are from Standard, any additional analysis were not done. The by-product of the experiment was a 2 mm thick disc. More than 1,300 products were produced during the whole experiment. The cutting processes were carried out on a CNC turning centre SP 280 SY. The cutting conditions that were used for the experiment are shown in Tab. 3 and 4. These conditions were predefined for both machined materials.

Fig. 1 *Clamping of the replaceable insert*

Tab. 1 *Chemical composition of 100Cr6 [wg. %]*

C	Mn	Si	Cr	Ni	Cu	Ni+Cu	P	S
0.90-1.10	0.30-0.50	0.15-0.35	1.30-1.65	max 0.30	max 0.25	max 0.50	max 0.03	max 0.03

***Tab. 2**. Chemical composition of 316L [wg. %]*

C	Si	Mn	P	S	N	Cr	Mo	Ni
max 0.03	max 1.00	max 2.00	max 0.05	max 0.30	max 0.10	16.50 – 18.50	2.00-2.50	10.00-13.00

In case the experiment was related to the parting-off of solid material, it would be advantageous to reduce the feed value of 2 mm before the cut by up to 75%, or to stop approximately 0.5 mm before the axis of the part and let it fall off due to the gravitational force. This measure helps to reduce the stresses on the cutting edge [1, 2]. Since a 32 mm diameter hole was pre-drilled in the blank, the cutting conditions were constant throughout the experiment. The emphasis was on never parting-off a blank with a conical part of the inner hole. Otherwise, the tool is subjected to uneven stress and breakage occurs more easily [2].

***Tab. 3** Values of cutting conditions for machining 100Cr6 steel*

v_c [m.min^{-1}]	n [min^{-1}]	f [mm]
180	1081	0.12

***Tab. 4** Cutting condition values for machining 316L steel*

v_c [m.min^{-1}]	n [min^{-1}]	f [mm]
125	751	0.12

To evaluate the wear of the cutting tool, a direct method of optical measurement of individual wear values was chosen. After predetermined time periods, the cutting process was stopped and the replaceable insert was subjected to wear analysis under a microscope. At each measurement, images were recorded including a view of the main flank, the tool face and a view of the two minor flanks (see Fig. 2).

Wear was measured on the major and both minor flanks. The abbreviation VBb was used for the wear value of the major flank, while the abbreviation VBc and VB2 were used for the wear of the minor flanks. The values of the wear criterion, exceeding which meant the end of the tool life, can be seen in Tab. 5.

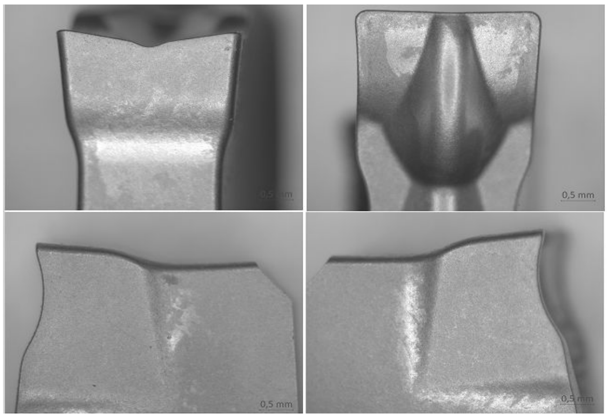


***Fig. 2** View of the major flank (top left), tool face (top right), minor flank (bottom left), minor flank 2 (bottom right)*

***Tab. 5** Wear criteria values*

Tool wear	**Marking**	**Criterion [mm]**
Wear of the major flank	VBb	0.2
Wear of the minor flank	VBc	0.4
Wear of the minor flank 2	VB2	0.4

3 Analysis of tool wear

The wear of the replaceable inserts was measured and checked after 3.1 minutes for 100Cr6 material, and the tools were subjected to wear analysis every 5.1 minutes when machining 316L material. When machining both materials, two inserts of the same type were always used (marking principle-A1, A2). The variance of the wear life of inserts of the same type was important and must not exceed 15%. If this happened, a replacement insert marked with index 3 (e.g. B3) was used.

3.1 Results on material 100Cr6

The experiment was started with the insert A1. The increase in its wear coincided with the theoretical assumption. At the fifth cutting cycle, its cutting edge was destroyed, so the final value of the durability was 13.4 minutes. The A2 insert showed a sharp increase in wear of the major flank (VBb=0.416 mm) during the fourth cutting cycle. The criterion value was therefore exceeded by more than 100%. Insert A2 reached a durability of 10.3 minutes, thus the durability variance was respected as its value was 13.1%. Insert B1 possessed a slower increase in its wear, the criterion for wear of the major flank was exceeded only after 27.9 minutes. On the other hand, for insert B2, the same criterion was exceeded after 9.3 minutes, i.e. after the third cutting cycle. Due to the high value of the variance of the durability of inserts B1 and B2, it was necessary to use a replaceable insert B3. The durability of the B3 insert was 21.7 minutes, the variance of the durability of the inserts B1 and B3 was again within 15%. The same scenario occurred in the machining of the 100Cr6 material for the inserts C and B. Insert C1 reached a lifetime of 16.5 minutes, but in the case of insert C2, the cutting edge of this cutting insert was destroyed during the third cutting cycle, which also led to the destruction of the clamping bed. The cutting insert C3 reached a durability of 15.5 minutes. The reason was that the value of the wear criterion VBb of the major flank was exceeded.

Graphs were made of the evolution of the individual wear criteria VBb, VBc and VB2 over time for all inserts used for machining the material (see Fig. 3).

In Fig. 4, the gradual increase of demage of insert A2 when machining 100Cr6 material is shown.

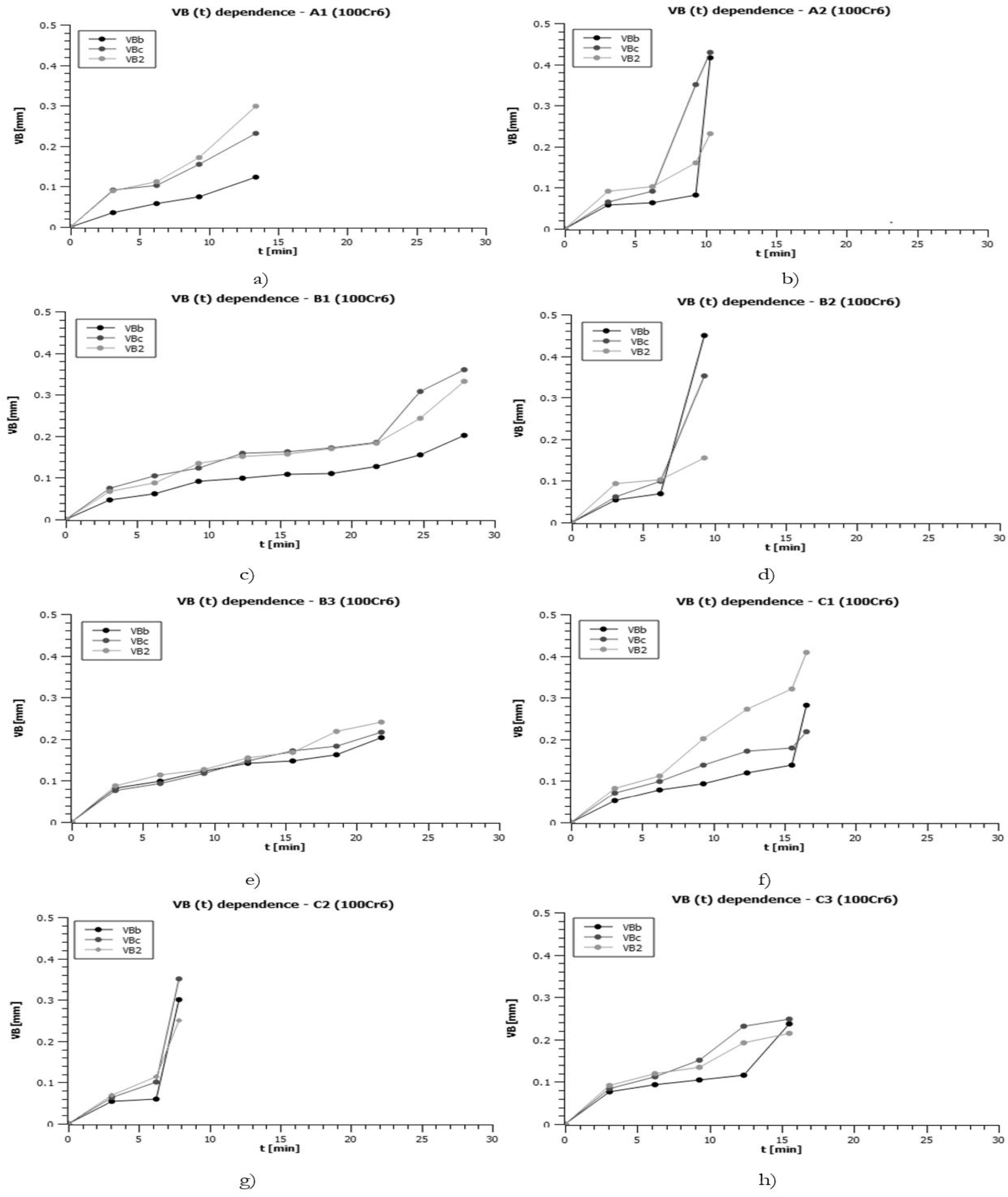


Fig. 3 *Evolution of tool wear when machining 100Cr6 (a) insert A1; (b) insert A2; (c) insert B1; (d) insert B2; (e) insert B3; (f) insert C1 (g) insert C2 (h) insert C3*

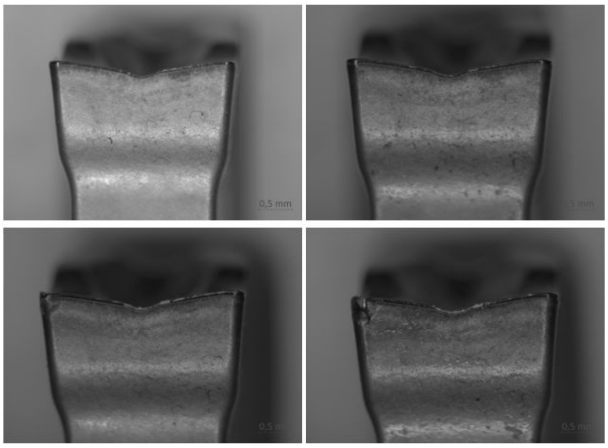


***Fig. 4** View of the tool wear of major flank (insert A2) after 3.1 minutes (top left), 6.2 minutes (top right), 9.3 minutes (bottom left), 10.3 minutes (bottom right)*

3.2 Results on material 316L

Replaceable inserts A showed the same behaviour when machining stainless steel, their wear pattern was almost identical. Both inserts reached a durability of 20.4 minutes. The reason for the end of their durability was exceeding the wear criterion VBb of the major flank. After the fifth cutting cycle, the wear of the major flank VBb on insert B1 reached the wear criterion value, which meant the removal of the insert from the experiment and termination of its durability, which was 25.5 minutes. Insert B2, whose reason for end of life was exceeding the wear criterion of the minor flank VB2, also reached a life of 25.5 minutes. Cutiing insert C1 reached a lifetime of 25.5 minutes, the wear criterion for the major flank VBb was exceeded and the wear criterion for the minor flank VB2 also reached a limiting value. The end of durability of insert C2 was not reached until after the sixth cutting cycle, i.e. after 30.6 minutes, when the VBb criterion was exceeded. The value of the variance of the durability of the C1 and C2 inserts was 9.1%, i.e. within the permissible interval. Graphs of the evolution of the individual wear criteria VBb, VBc and VB2 over time during machining of 316L material are shown in Fig. 5.

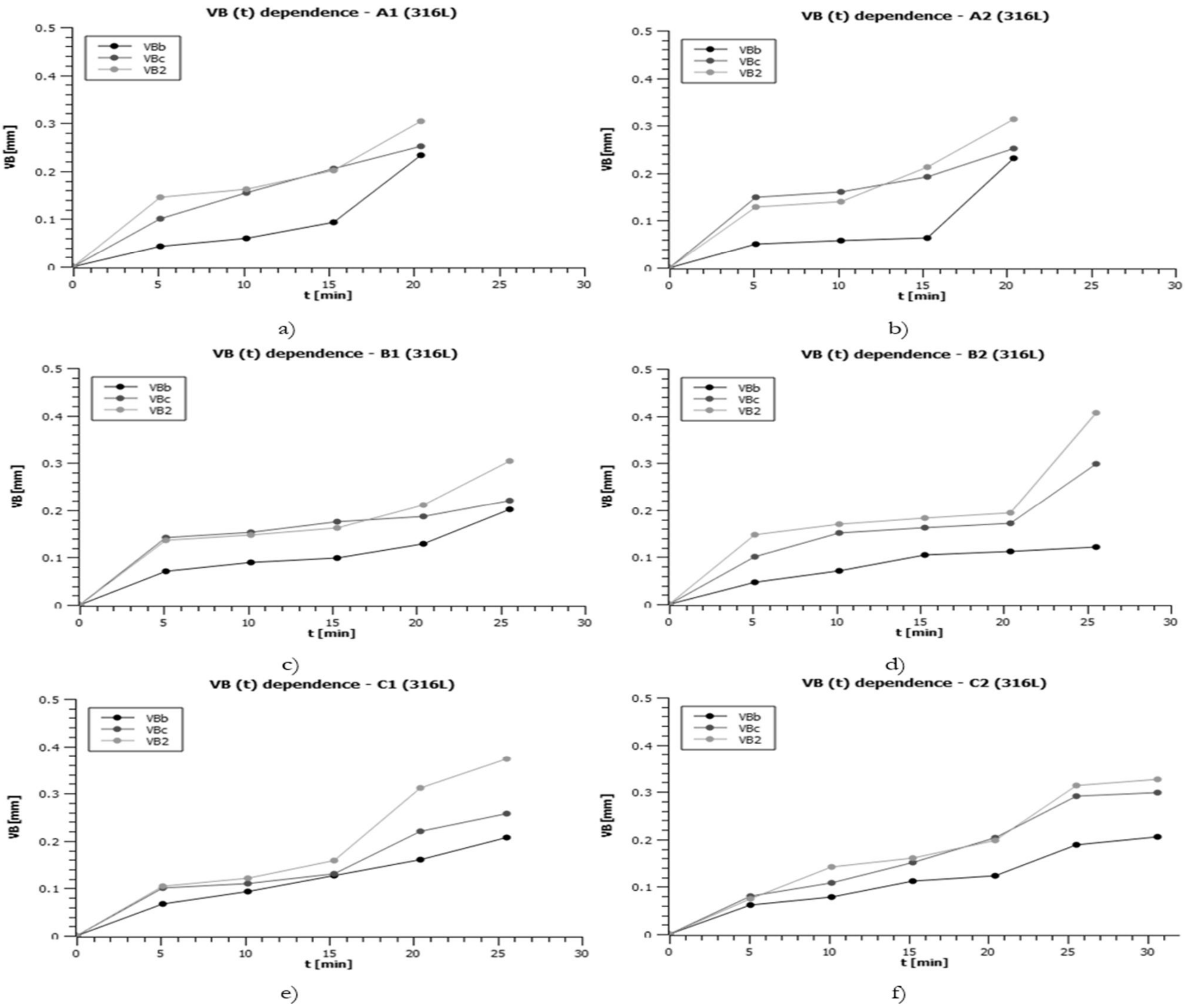


***Fig. 5** Evolution of tool wear when machining 316L (a) insert A1; (b) insert A2; (c) insert B1; (d) insert B2; (e) insert C1; (f) insert C2*

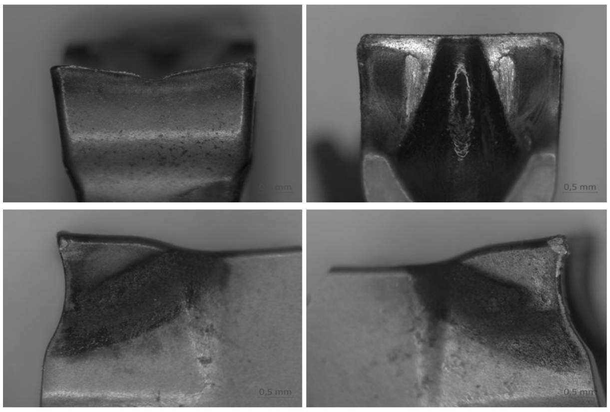


Fig. 6 *View of the tool wear after 20.4 minutes of major flank (top left), tool face (top right), minor flank (bottom left), minor flank 2 (bottom right)*

In Fig. 6, the demage of all analyzed sections of insert A2 when machining 316L material is shown.

3.3 Analysis of tool surface deviations (comparison of new and worn tool surfaces)

Scans of the surfaces of the new and worn inserts used for the experiment were taken using an Alicona InfiniteFocus G4. The scan data was processed in GOM Inspect to produce colour maps showing the surface variations of the new and worn inserts (see Fig. 7). The new insert is a reference surface, so the deviatioins shown in figures belong to the worn insert. Thanks to these photographs, it is possible to observe where the loss of tool material occurred or where the adhesive wear of the tool appeared.

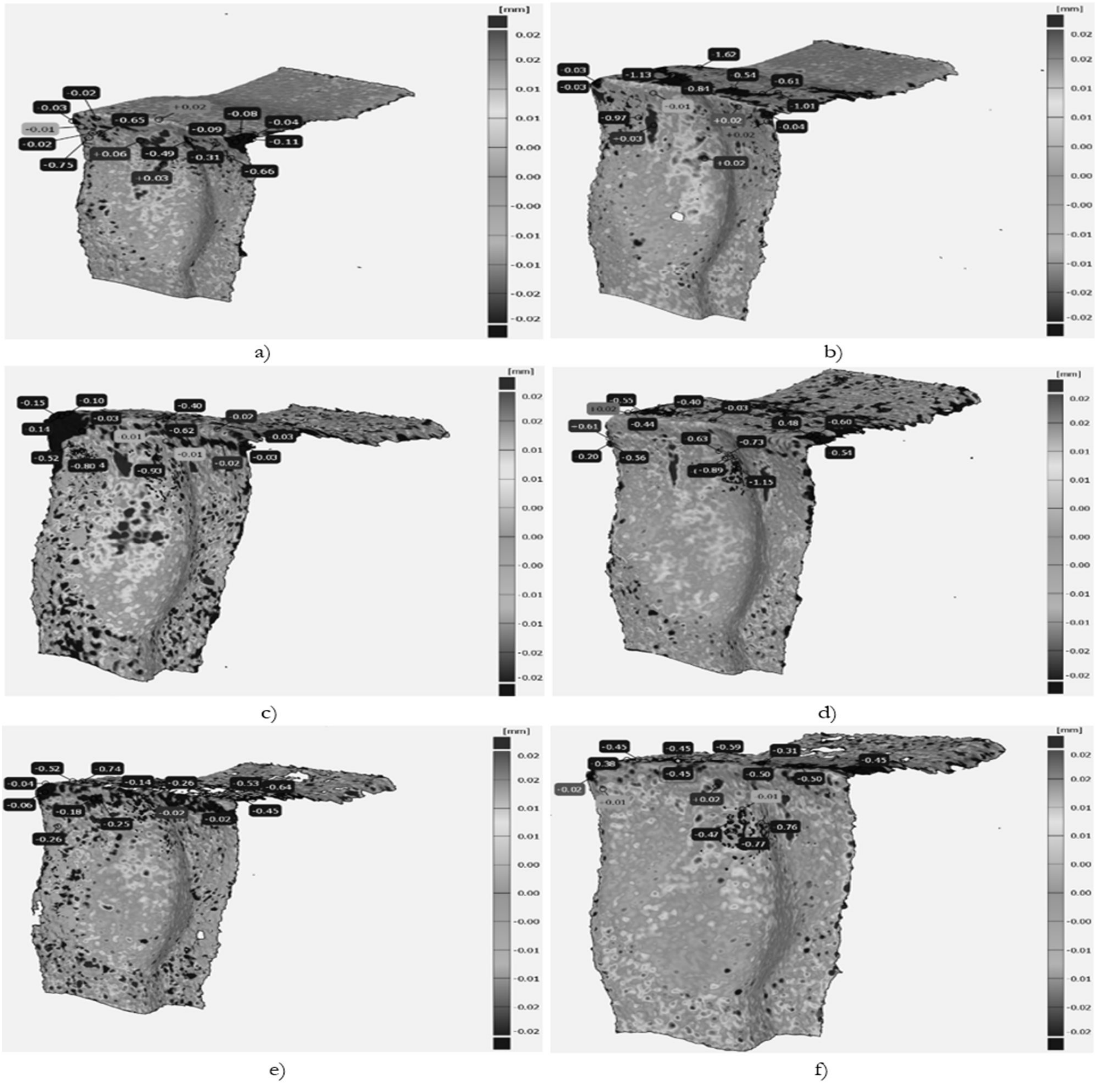


Fig. 7 *Tool wear (a) insert A1 - mat. 100Cr6; (b) insert B1 - mat. 100Cr6; (c) insert C1 - mat. 100Cr6; (d) insert A1 - mat. 316L; (e) insert B1 - mat. 316L; (f) insert C1 - mat. 316L*

3.4 Conclusion

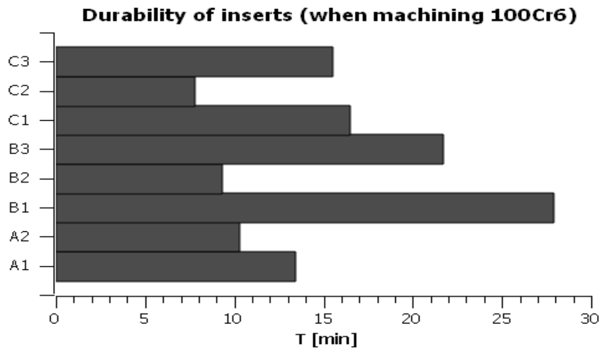


Fig. 8 *Durability values of inserts tested on 100Cr6 material*

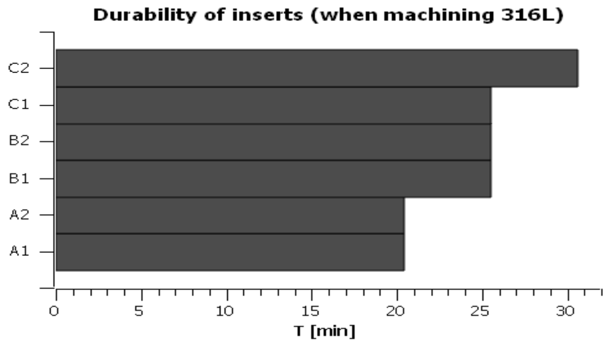


Fig. 9 *Durability values of inserts tested on 316L material*

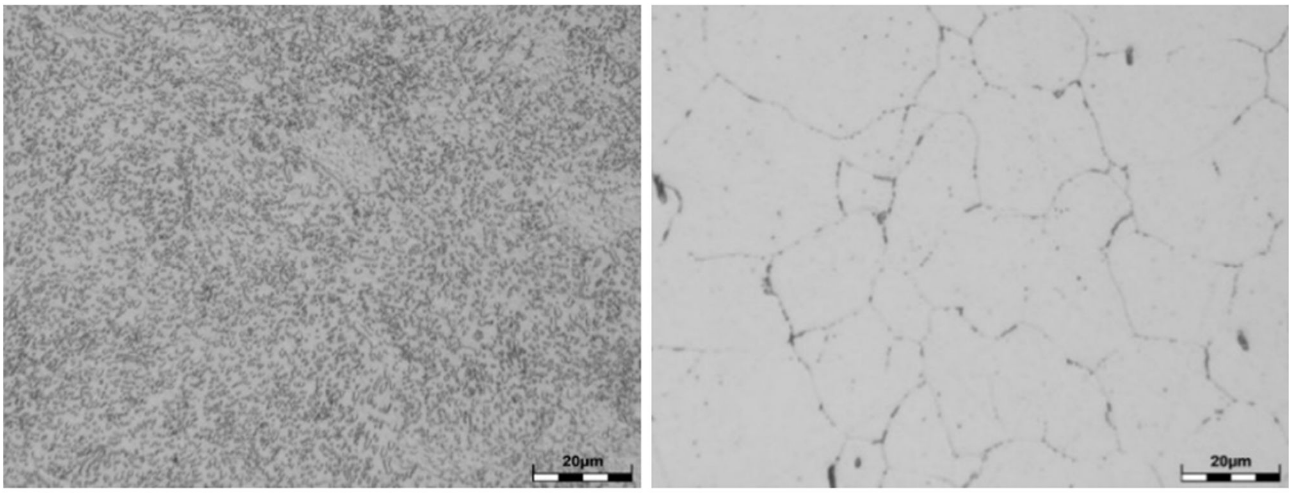
Prior to the experiment, it was anticipated that machining stainless steel would be more problematic compared to 100Cr6 material. From the data obtained in the experiment, it is clearly evident that this assumption was incorrect. There was no unexpected destruction of the cutting edge of the cutting tool when machining stainless steel. Furthermore, the insert durability values are highly variable when machining 100Cr6 compared to the durability values of the inserts machined with 316L (see Fig. 8 and 9). This fact was the main reason why the machined materials and tools used for the experiment were subjected to further investigation.

4 Analysis of machined materials

Both machined materials were analysed. For each material, a sample was cut from the blank, which was then modified to meet the requirements to perform the necessary analyses. A portion of the sample with a maximum size of 20x20 mm is pressed into a fixture prior to examination, which facilitates handling of the material during analysis as it is undesirable to touch the surface of the specimen. The surface of the specimen is ground after pressing into the preparation in order to achieve as smooth a surface as possible.

4.1 Analysis of microstructure

The analysis that was carried out for both machined materials was the observation of the microstructure. The instrument used was an Olympus DSX 100 opto-digital metallographic microscope. In Fig. 10(a), i.e. the microstructure image of the 100Cr6 material, the homogenous structure with globular pearlite can be observed. Fig. 10(b) represents the microstructure of austenitic stainless steel 316L. In this structure, which corresponds to austenitic, an increased number of inclusions can be seen. These inclusions are sulphidic and therefore do not have a negative effect on machinability, rather the opposite.



a) b)

Fig. 10 *(a) Microstructure of 100Cr6 material (b) Microstructure of 316L material*

4.2 Analysis of microhardness

Microhardness measurement is one of the most accurate methods of determining the hardness of the material under test. Microhardness differs from hardness in the load that the indenter is forced into the material under test. In the analysis described in this chapter, a load of 0.5 kg (5 N) was used. The microhardness is determined from several punctures examined with a light microscope.

The microhardness analysis on the 100Cr6 material revealed the presence of a hardened layer at a total depth of 2 mm below the surface (see Fig. 11). The average microhardness value was 198 HV, after conversion to Rockwell scale it was 91 HRB. The average microhardness value of the 316L specimen was 200 HV (92 HRB). There were no areas showing signs of hardening in this material.

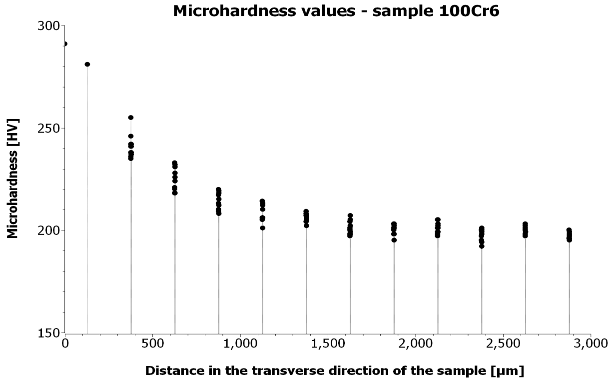


Fig. 11 *Graph of microhardness values (sample 100Cr6)*

4.3 Conclusion

Although the variance of the measured values reached 15% in some cases, this is a permissible range in microhardness analysis. The variance of the microhardness results for 316L was mainly influenced by the increased presence of inclusions in the structure, which negatively affect the accuracy of the measurements. The finding of a hardened layer in 100Cr6 indicates that this defect may have been a major contributor to the variable durability of the cutting tools in question. Further microhardness analyses would need to be carried out at other locations in the blank in order to be conclusive.

5 Analysis of tool coatings

The replaceable inserts used in the experiment were subjected to an adhesion analysis of their coating. The Daimler-Benz adhesion test is linked to the Rockwell hardness test. After this test, the hardness value is not the determining parameter, but the surrounding area of the impression is examined. A comparison table is used for the evaluation (see Fig. 12). The occurrence of cracks around the impression is common, even at high concentrations. However, if the substrate of the insert is exposed, this indicates inappropriate coating behaviour and the analysis result is unsatisfactory (group HF3 and worse). The value of the preload used was 100 N, the full load was 600 N. The experiment was performed on a ZHR 4150AK hardness tester. Based on the electron microscope images (see Fig. 13), the coatings of the inserts A, B and C were classified into the appropriate HF group. The coatings of A and C were classified as HF4, while the coating of B belonged to HF5.

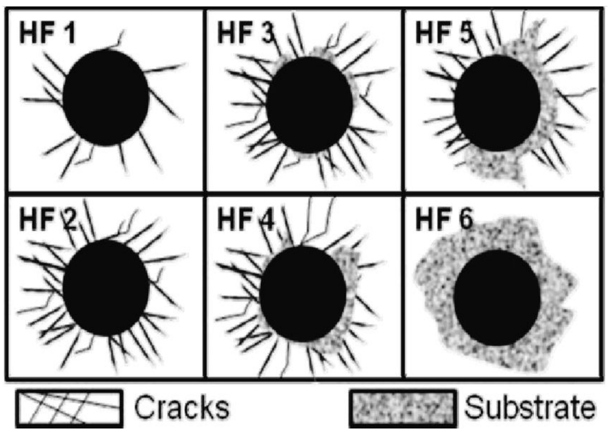
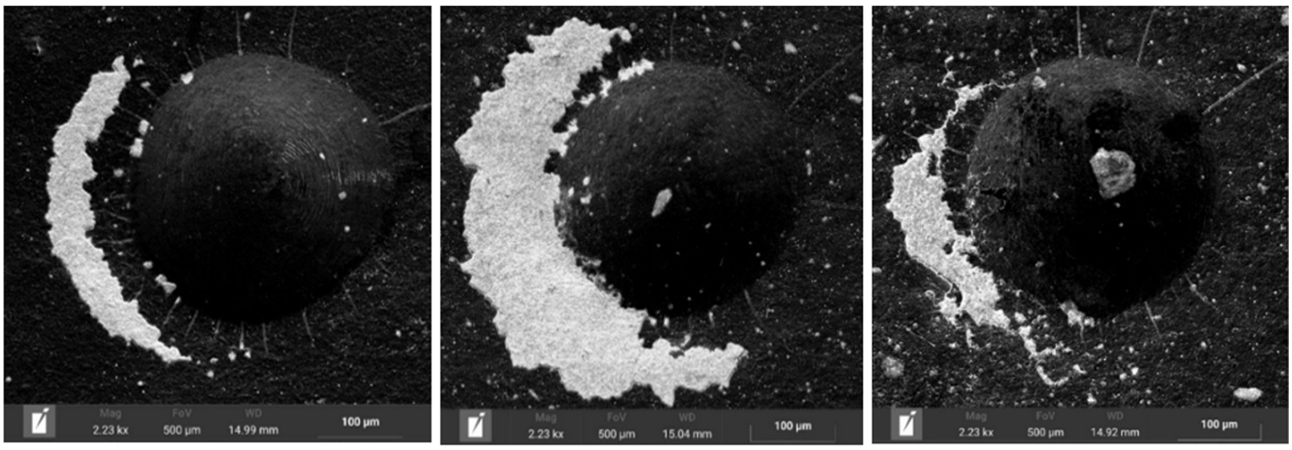


Fig. 12 *Impression samples for evaluation*



a) b) c)

Fig. 13 *(a) Appearance of the impression of insert A (b) insert B (c) insert C*

This method of coating quality assessment is dependent on several influences that negatively affect its results. One of the most significant is the coating thickness, which can be variable depending on the coating method used. The wafer coatings were made by the PVD coating method. This method, which is incidentally highly susceptible to impurities present on the substrate surface prior to coating, is also associated with the so-called shadowing effect. In the PVD method, which takes place under vacuum, it is necessary to move the tool, which can result in uneven coating thickness.

6 Analysis of machined surface

The roughness of the machined surface was examined for the products made in the experiment. The Ra value and the Rz value were measured. The Ra value indicates the mean arithmetic deviation of the profile, which is one of the most common data in the evaluation of the surface roughness. The disadvantage of the Ra value is that, due to averaging, it does not sufficiently account for extreme measured values. In this respect, a better value is Rz, i.e. the greatest height of the profile, which indicates the sum of the greatest height and depth of the profile under examination.

After each cutting cycle, 10 samples were taken at random and the required values were measured with the roughness tester. A TR-100 roughness tester with a diamond tip was used for the measurements.

The measurement of the roughness of the machined surface is one of the indirect methods for the analysis of cutting tool wear. The basic assumption of this method is that the quality of the machined surface deteriorates as the cutting edge of the cutting tool wears. As with all indirect methods, the results are only approximate, so the machined surface analysis was performed only as an afterthought and the direct micrometric method was used as the starting point in the experiment.

The time evolution of Ra and Rz values were determined. The basic assumption of this method, that the roughness value of the machined surface increases with the gradual degradation of the cutting tool, was most consistent with the surfaces machined with inserts marked C on 316L material. The roughness values measured on samples machined with inserts marked A and B were more variable.

7 Analysis of the economic benefits

The results of the experiment showed which cutting tool, or which replaceable insert, was most suitable for machining a particular material. The economic aspect of the whole thing was chosen for illustration, which is important for the customer. More precisely, it was a comparison of the cost per cutting edge for the production of 1 piece of product. The cost of the cutting edge was determined on the basis of the known price of the insert A, taking into account the final number of products made with the tool.

The price of the cutting insert with the A marking is 30.8 euros. For 100Cr6, an average of 146 products were produced using inserts A. Inserts B were able to produce an average of 304 products before the end of their service life, and inserts C 196 products. For 316L stainless steel, an average of 159 products were produced using inserts A. 200 and 220 products were produced using inserts B and C, respectively, before the end of their tool life.

This higher production rate means a reduction in cost per cutting edge when using B and C inserts compared to A inserts. The cost per cutting edge to parting-off 1 piece of 100Cr6 product was €0.21 using A inserts.

This cost was 0.1 euro when using B inserts and 0.16 euro when using C inserts. For 316L machining, the cost per cutting edge for the parting-off of one product was 0.19 euros using inserts A, 0.15 euros for inserts B and 0.14 euros for inserts C. Thus, the highest savings per piece produced were achieved with B inserts when machining 100Cr6 steel. This saving was more than 50% compared to the cost per cutting edge when using inserts A (see Fig. 14).

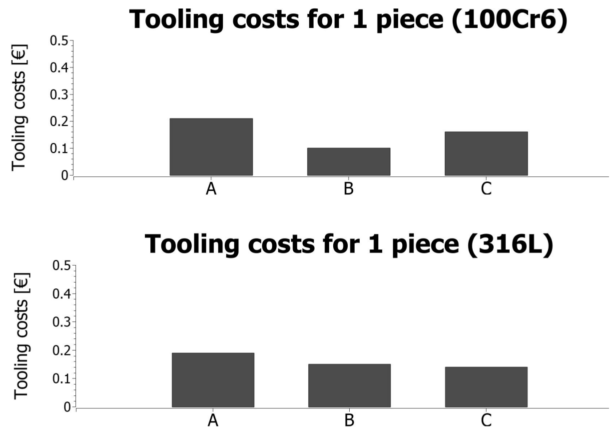


Fig. 14 *Tooling costs to produce 1 piece of product*

The costs discussed can be influenced by changing the cutting conditions, mainly by changing the cutting speed and feed rate. By adjusting them, the effect of reducing the total cost of producing a single component can be achieved. Tooling costs are typically represented by 3 to 5 % of the total cost. Based on Sandvik Coromant's statistical data, the increase in tool life achieved by reducing cutting speed and feed rates is only a 1% reduction in the total cost of producing a part. It is much more profitable to increase the cutting conditions. Sandvik Coromant states that increasing the value of cutting speed or feed rate can result in up to a 15% reduction in total cost [4]. This abysmal difference between the two options is because of achieving higher tool life will also increase the time required to produce the part. Thus, the only cost saved is the cost of the tool and its replacement. Other costs, which make up a much larger percentage of the total cost, such as wages and operating costs, increase.

8 Conclusions

An experiment carried out to explain the process of testing new tools and determine the machining behaviour of those newly developer cutting inserts proved that they are of sufficient quality and in many respects have better properties than those of the existing product range. The main difference between the cutting edges after the development process, i.e. those marked B and C in the experiment, is the different coating composition and surface finish of the tool. The coating of the inserts marked A (TiN) was compared in the experiment with the coating of the inserts marked B and C, i.e. with extra coatings containing Al.

By comparing the results of the experimental testing, the following conclusions were reached:

- When machining 100Cr6, B inserts achieved an average life of 20.2 minutes, an increase of almost 70% compared to A inserts, which achieved an average durability of 11.9 minutes.
- C inserts achieved an average durability of 16.0 minutes when machining 100Cr6 material, an increase of 34.5 % compared to A inserts.
- When 316L material was parting-off, the average durability values of inserts B and C were 25.5 minutes, an increase in durability of 25% compared to inserts A.

Comparing the results, it is evident that the aluminium coating used on inserts B and C positively affected the resulting tool life of these tools. The difference in tool life was in the tens of percentages compared to inserts A and TiN coating.

From the results of the analyses carried out, it can be concluded that the new blades, which for the purposes of this experiment were marked B and C, are suitable for machining both materials under the correct cutting conditions. When introduced to the market, the new replaceable cutting inserts will offer a very interesting value for potential customers. With their increased wear resistance, which was significantly higher than that of the existing product line, the use of these inserts will be one of the opportunities to achieve the lower overall costs discussed in the previous chapter.

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