SUITABILITY OF VCGT AND VCMT CUTTING INSERTS TYPE FOR TURNING ALSI 304 STEEL

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The machined surface quality during turning is influenced by the type and geometry of cutting tool used and the selected technological machining parameters, as well as the presence of cutting fluid. The choice of the cutting insert type depends on the machined material and turning operation performed. The contribution compares two carbide-coated cutting inserts types, VCGT and VCMT, for turning AlSi 304 stainless steel. The comparison is performed with respecting the machined surface roughness when using variable cutting conditions. Simultaneously, the influence of the cutting fluid usage on the machined surface roughness is also investigated. Based on the results presented in the contribution, it is demonstrated that in the cutting conditions selected range in the production of a specific component, the values of the machined surface roughness after using VCMT cutting insert show better values. Simultaneously, it is found that in the cutting conditions selected range, the VCGT cutting inserts are prone to sudden brittle fractures, which limits their use in automated turning centers and systems.

KEYWORDS

Machining process, Turning, Cutting conditions, Cutting inserts, Surface roughness

1 INTRODUCTION

Machining processes are fundamental to the manufacturing sector, as they facilitate the production of high-precision components with excellent dimensional accuracy and surface quality [Mane 2025a]. Machining processes for components in industry have evolved rapidly in the last decade, thanks to new, powerful machines with high load capacities, the material used in their constructions and their increasingly advanced control systems. These technological developments allow machining of components with higher accuracy and better surface quality in a shorter time [Kundrak 2025, Vasilko 2021].

Turning is one of the most widely used and simultaneously one of the most important technologies in precision machining of steel components due to its high efficiency. If the surface texture characteristics allow it, grinding can be replaced by turning, since the exact same precision and surface quality can be achieved and additional finishing operations may not be necessary [Mathivanan 2021, Olejarova 2021, Molnar 2023]. Regarding the productivity and work efficiency, CNC lathes have become very popular and offer many advantages such as flexibility and high automation [Dua 2025].

Increasing productivity, quality, customer satisfaction and other current manufacturing trends present technical obstacles for manufactures such as surface integrity, high machining temperatures and last but not least, tool lifespan [Rajeswari 2024].

Tool lifespan is the time during which the tool cuts satisfactorily. Tool lifespan is very important in cutting processes, because considerable time and cost are lost when changing and re-setting the cutting tools. It is influenced by many factors, including tool material, tool shape and design, machining operation conditions, coolant types, and workpiece surface quality requirements [Abdeldjaouad 2022, Paengchit 2023]. Currently, indexable cutting inserts are used almost exclusively. The prevailing effort is to make the cutting insert, like other production tools, predictable in the machining process, both in terms of tool lifespan and in terms of machining results, resulting workpiece accuracy, and desired surface integrity [Naprstkova 2023].

In current manufacturing sector, companies are trying to implement a unified carbide cutting elements system that facilitates easy replacement of cutting components. The geometric, physical and chemical properties of cutting elements directly affect their capabilities and performance. These properties of each individual element play a key role in influencing its performance in contact with the workpiece and ambient conditions. In addition, each cutting material has an inherent tendency to cutting parameters modification, as well as abrasive and adhesive wear over time [Sramhauser 2024]. Coated indexable cutting inserts made of cemented carbides are currently a commonly used group of cutting tools in the assortment of manufacturing companies. One of the important factors influencing the machining process is the appropriate selection of the cutting tool depending on its properties, such as its own geometry, its change during the machining to the state of the cutting edge when changing tools, and the cutting material from which the tool is made and the surface treatment of the cutting edge. Incorrect tool selection or inappropriate tool use increases the company´s costs related to tools, which are still taken for granted today [Majerik 2021, Sramhauser 2022].

Austenitic stainless steels are more difficult to machine than other steels due to their high tensile strength, high ductility, high hardening rate, low thermal conductivity, and high tendency to for edge growth (BUE). Austenitic stainless steel AlSi 304 is an alloy with strategic properties such as good corrosion resistance, good formability and non-magnetic properties. All these properties qualify this type of steel as a good choice for many applications in various fields such as the marine industry, the chemical and petroleum industries, the food industry, and nuclear power engineering [Boucherit 2021, Zhang 2022]. High-speed machining of stainless steel has long been a subject of research. Due to its properties (low thermal conductivity and tendency to hardening), AlSi 304 steel is difficult to machine. One of the most stringent indicators of the efficiency and effectiveness of machining process is the tool lifespan and the machined surface quality [Chinchanikar 2023].

Surface roughness (Ra) is a popular quality indicator and in most cases a technical requirement for mechanical components. Achieving the correct surface quality is crucial for the functionality of the component. As is known, surface roughness in actual machining is affected by a number of factors including cutting parameters, tool variables and workpiece variables. Cutting parameters include cutting speed, feed and depth of a cut. Tool variables include tool material, apex radius, face angle, cutting edge, tool vibration, tool overhang, tool apex angle, etc. Workpiece variables include material hardness and mechanical properties. Taking into consideration all the parameters that determine surface roughness for a specific manufacturing process is extremely challenging. It is quite difficult to select cutting parameters for a turning operation to achieve a good surface finish [Molnar 2022, Zhujani 2025]. Therefore, optimization of machining parameters is a continuous technical activity aimed at reducing production costs while achieving the desired quality of the result [Mane 2025b].

The primary objective of the submitted contribution is to assess the suitability of using VCGT and VCMT type indexable cutting inserts in machining AlSi 304 steel by turning. The machined surface roughness Ra is chosen as a qualitative indicator in the evaluation of suitability. The machined surface roughness Ra was evaluated for both variants of the cutting inserts under variable conditions. Based on the results obtained from experiments, recommendations for the use of assessed indexable cutting inserts in automated turning centers are drawn at the end of the contribution.

2 DESCRIPTION OF EXPERIMENTAL PROCEDURE

The evaluation of the suitability of using indexable cutting inserts was performed during the production of components according to Fig. 1. The component is made of AlSi 304 (1.4301) steel. The semi-finished product is a round bar KR Ø24.

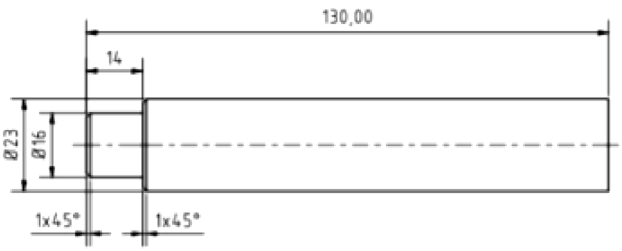

Figure 1. The shape of a component manufactured by turning

The component was machined using VCGT and VCMT indexable cutting inserts. The VCGT insert, exact designation VCGT 110304FN-ASF AM7020 is a carbide-coated insert designed for machining stainless steels, titanium and hard steels. It is characterized by high thermal stability, resistance to high temperatures and flank wear. It has reliable run time and excellent chip control. The VCMT insert, exact designation VCMT 110304EN-PMT1 AM5120 is a carbide-coated insert designed for rough machining of stainless steels and heat-resistant alloys. It is characterized by high resistance to flank wear, excellent heat resistance, reliable run time and chip control Both inserts are product of ARNO Werkzeuge. As part of the consultation regarding production technology when implementing a new project, they were recommended by TMC CR, s.r.o. The evaluated indexable cutting inserts and their characteristic dimensions are shown in Fig. 2.

The characteristic dimensions of the indexable cutting inserts according to Fig. 2 are stated in Table 1. The cutting inserts were clamped on a right-hand lathe toolholder with the designation SVJCR 2020 K11, produced by ARNO Werkzeuge.

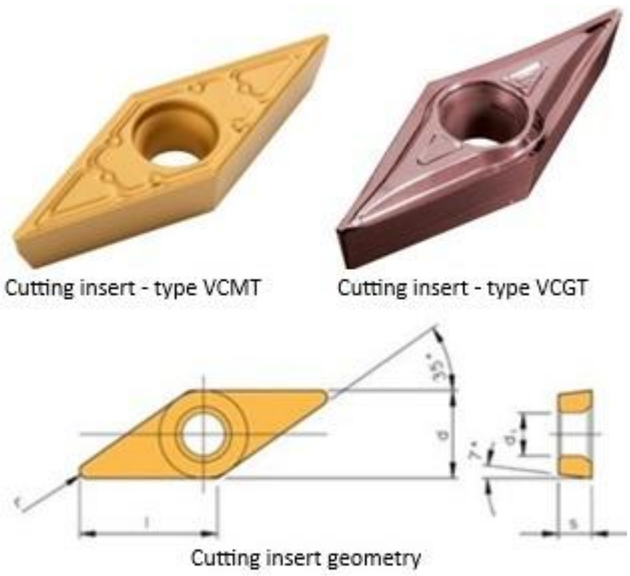

Figure 2. The evaluated cutting inserts

The cutting insert is clamped in the holder using the ISO S system, which uses screw clamping.

Table 1. Geometric parameters of cutting inserts

Parameter	VCGT	VCMT
r, mm	0.4	0.4
l, mm	11.1	11.1
s, mm	23.18	23.18
d, mm	16.35	16.35
d_1, mm	2.9	2.8

The production of the components was performed on a Masturn MT 550i CNC lathe from Kovosvit MAS Machine Tools a.s., equipped with a Heidenhain Manual plus 620 control system.

The suitability of the VCGT and VCMT inserts was assessed with regard to the achieved machined surface roughness Ra, when machining with variable cutting conditions. The cutting conditions in column "A" represents the cutting conditions recommended by the vendor, the cutting conditions in column "B" are the conditions determined by the calculation.

Table 2. Selected cutting conditions

Parameter	A	B
Cutting depth P, mm	0.5	0.5
Cutting speed S, m/min	120.0	177.0
Feed F, mm/ot	0.2	0.16

In the production of components, a cutting fluid based on an emulsion of mineral oil and water of the Blasocut 20 was used. To assess the suitability of thee selected cutting inserts, the production of components under the cutting conditions according to Table 2 was performed with and without the use of cutting fluid.

The machined surface roughness Ra was measured using the Mitutoyo Surftest SJ-410 device. The evaluation of the machined surface roughness on the components was performed twice, on mutually opposite sides of the component, i.e., when rotated by 180°. The machined surface roughness was measured in the are 10 mm from the cut-off point, as shown in fig. 3. The measurement was performed in the area highlighted in red.

The selection of this area was conditioned by the elimination of phenomena that worsen the surface roughness. First of all, it is the components displacement during its free unloading, when the roughness increases with the increasing distance from the spindle to the free end. Simultaneously, the possible imperfect chip removal in the spindle area was also considered.

Figure 3. Machined surface roughness Ra measurement area

The conditions under which the machined surface roughness Ra was determined are stated in Table 3.

Table 3. Roughness evaluation parameters

Parameter	Value
Standard	ISO 1997
Profile	R
Parameter	3
Filter	GAUSS
λc	0.25 mm
λs	2.5 µm
N	5
Pre/Post	On
Delete waves	Off
Profile compensation	Off
Medium Profile	Off

3 RESULTS AND DISCUSSION

In each series, ten pieces of components under cutting conditions according to Table 2 were manufactured, with and without the use of cutting fluid. The indexable cutting insert was replaced by a new one after the end of the production of each series, so that results were not distorted by the repeated use of one insert. The following tables show the values of the machined surface roughness of the individual studied components.

Table 4 shows the measured values of the machined surface roughness Ra for indexable cutting inserts of the VCMT type under cutting conditions according to Table2, column A, with the use of cutting fluid.

Table 4. Roughness Ra for VCMT, P=0.5 mm, S=120m/min, F=0.2mm/rpm, using cutting fluid

	Ra, µm	
Sample	position 0°	position 180°
1.	1.827	1.673
2.	1.590	1.479
3.	1.162	1.500
4.	1.500	1.443
5.	1.589	1.615
6.	1.387	1.490
7.	1.409	1.484
8.	1.059	1.483
9.	1.664	1.374
10.	1.438	1.481
Average	**1.463**	**1.502**
Overall average	**1.482**	

Table 5 shows the measured values of the machined surface roughness Ra for indexable cutting inserts of the VCMT type under cutting conditions according to Table 2, column A, no cutting fluid used.

Table 5. Roughness Ra for VCMT, P=0.5 mm, S=120 m/min, F=0.2 mm/rpm, no cutting fluid used

	Ra, µm	
Sample	position 0°	position 180°
1.	1.735	2.212
2.	1.799	1.800
3.	1.825	1.769
4.	1.743	1.662
5.	1.946	1.936
6.	1.840	1.812
7.	1.788	1.790
8.	1.694	1.565
9.	1.613	1.682
10.	1.593	1.669
Average	**1.758**	**1.790**
Overall average	**1.774**	

Table 6 shows the measured values of the machined surface roughness Ra for indexable cutting inserts of the VCMT type under cutting conditions according to Table 2, column B, using cutting fluid.

Table 6. Roughness Ra for VCMT, P=0.5 mm, S=177 m/min, F=0.16 mm/rpm, using cutting fluid

	Ra, µm	
Sample	position 0°	position 180°
1.	0.866	0.852
2.	0.711	0.755
3.	0.810	0.783
4.	0.629	0.754
5.	0.854	0.827
6.	0.802	0.829
7.	0.777	0.751
8.	0.764	0.826
9.	0.833	0.794
10.	0.766	0.756
Average	**0.781**	**0.793**
Overall average	**0.787**	

Table 7 shows the measure values of the machined surface roughness Ra for indexable cutting inserts of the VCMT type under cutting conditions according to Table 2, column B, no cutting fluid used.

Table 8 shows the measured values of the machined surface roughness Ra for indexable cutting inserts of the VCGT type under cutting conditions according to Table 2, column A, using cutting fluid.

Table 9 shows the measured values of the machined surface roughness Ra for indexable cutting inserts of the VCGT type under cutting conditions according to Table 2, column A, no cutting fluid used.

Table 10 shows the measured values of the machined surface roughness Ra for indexable cutting inserts of the VCGT type under cutting conditions according to Table 2, column B, using cutting fluid.

Table 7. Roughness Ra for VCMT, P=0.5 mm, S=177 m/min, F=0.16 mm/rpm, no cutting fluid used

	Ra, µm	
Sample	position 0°	position 180°
1.	1.040	1.053
2.	1.009	0.976
3.	0.996	0.959
4.	0.968	0.922
5.	0.914	1.044
6.	0.951	0.973
7.	0.987	0.962
8.	1.000	1.000
9.	1.066	1.015
10.	1.006	1.024
Average	**0.993**	**0.993**
Overall average	**0.993**	

Table 8. Roughness Ra for VCGT, P=0.5 mm, S=120m/min, F=0.2mm/rpm, using cutting fluid

	Ra, µm	
Sample	position 0°	position 180°
1.	0.519	0.386
2.	1.319	1.406
3.	1.200	1.382
4.	1.434	1.717
5.	1.519	1.652
6.	1.548	1.167
7.	1.543	1.503
8.	1.199	1.320
9.	1.259	0.766
10.	1.177	1.215
Average	**1.271**	**1.251**
Overall average	**1.261**	

Table 9. Roughness Ra for VCGT, P=0.5 mm, S=120m/min, F=0.2mm/rpm, no cutting fluid used

	Ra, µm	
Sample	position 0°	position 180°
1.	2.036	0.905
2.	0.769	1.330
3.	1.274	1.394
4.	1.280	1.383
5.	1.429	1.220
6.	brittle fracture on cutting insert	
7.	production discontinued	
8.	test terminated	
9.	----------	----------
10.	----------	----------
Average	**1.358**	**1.246**
Overall average0	**1.302**	

Table 10. Roughness Ra for VCGT, P=0.5 mm, S=177 m/min, F=0.16 mm/rpm, using cutting fluid

	Ra, µm	
Sample	position 0°	position 180°
1.	1.043	1.063
2.	1.084	1.031
3.	1.091	1.136
4.	1.326	0.984
5.	brittle fracture on cutting insert	
6.	production discontinued	
7.	test terminated	
8.	----------	----------
9.	----------	----------
10.	----------	----------
Average	**1.136**	**1.054**
Overall average	**1.095**	

Table 11 shows the measured values of the machined surface roughness Ra for indexable cutting inserts of the VCGT type under cutting conditions according to Table 2, column B, no cutting fluid used.

Table 11. Roughness Ra for VCGT, P=0.5 mm, S=177 m/min, F=0.16 mm/rpm, no cutting fluid used

	Ra, µm	
Sample	position 0°	Position 180°
1.	1.035	1.078
2.	1.058	1.039
3.	1.071	1.086
4.	0.805	0.961
5.	1.197	1.073
6.	0.993	1.029
7.	1.033	1.015
8.	0.951	1.012
9.	1.002	1.093
10.	1.157	1.014
Average	**1.030**	**1.040**
Overall average	**1.035**	

Based on the results presented in Table 4 to Table 11, a graph comparing the individual average machined surface roughness depending on the type of indexable cutting insert and variable cutting conditions was constructed from the average values of the machined surface roughness in the monitored section, shown in Fig. 4.

The graph in Fig. 4 shows that the VCMT type cutting insert, with the cutting conditions recommended by the vendor, when used with and without cutting fluid, showed the highest average surface roughness among the samples examined in both cases. This fact may indicate that the application of this insert under the given cutting conditions, regardless of whether it is used with or without cutting fluid, can lead to a rougher surface of the components. However, observation of the cutting inserts after turning showed that these inserts demonstrated a very good resistance to damage. This fact indicates that despite the higher surface roughness, these inserts can be effective and durable in practice. As for the cutting fluid, it seems that it does not have a significant effect on the surface roughness and deformation of the cutting insert under these specific conditions.

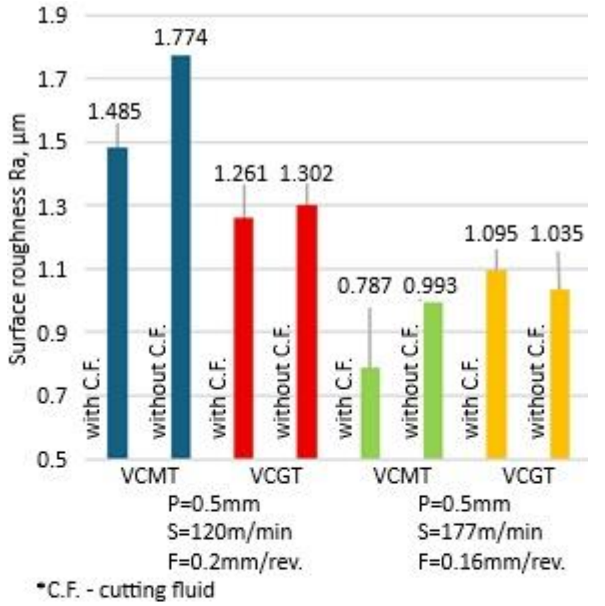

Figure 4. Comparison of the average machined surface roughness for individual variants of working conditions

The VCMT type of cutting insert with calculated cutting conditions, used both with and without the cutting fluid, showed the lowest average surface roughness among the samples examined in the overall study. This result suggests that the application of calculated cutting conditions can lead to smoother components surfaces, regardless of whether the cutting fluid is used or not. However, after examining the inserts, slight deformation was noted at the tip of the cutting inserts, as shown in Fig. 5. Under these specific conditions, the effect of cutting fluid has only a minimal impact on the surface roughness, with slight consideration given to the deformation of the cutting inserts.

A comparison of VCMT inserts using vendor-recommended cutting conditions and calculated conditions shows a clear difference in surface roughness. Better surface roughness results were achieved using the calculated cutting conditions.

The VCGT type of cutting insert, used with the recommended cutting conditions, was examined both with and without cutting fluid use. When turning without cutting fluid, the insert suddenly broke and the test was terminated. This phenomenon reflects poor wear resistance.

The VCGT type of insert, used with the calculated cutting conditions, manifested good surface roughness on the samples examined, both with and without cutting fluid use. The insert without cutting fluid manifested growth on its tip (see Fig. 5). When manufacturing components using cutting fluid, the insert suddenly broke and the test was terminated. This phenomenon confirms the above statement that in the selected range of cutting conditions, the VCGT type of insert show lower wear resistance.

Comparing the VCGT type of inserts with different vendor-recommended cutting conditions and the conditions determined by calculation, there is little difference in surface roughness. Better result in surface roughness was achieved when using the cutting conditions determined by calculation.

Overall, we can say that within the range of selected cutting conditions, the machined surface roughness reaches a smaller dispersion of values when using the VCGT ty of cutting inserts. Although VCMT type of cutting inserts achieved a higher dispersion of surface roughness values, they are not prone to random brittle fractures, which is a problem that affects the VCGT type of cutting inserts. For this reason, it is more advantageous to select a more reliable cutting insert.

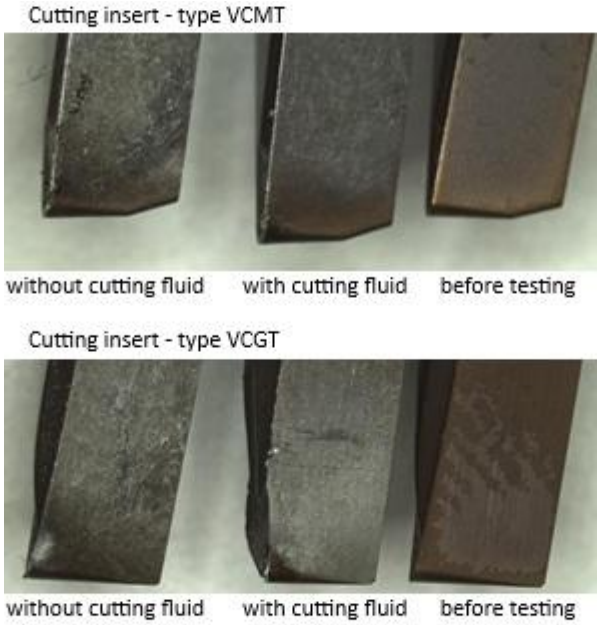

Figure 5. Comparison of cutting inserts for **conditions** P=0.5 mm, S=177 m/min, F=0.16 mm/rpm

The overall surface roughness shows better results when using the cutting conditions determined by calculation. This result confirms the fact that the feed size F has a significant impact on the resulting machined surface roughness, when a lower feed value shows lower values of machined surface roughness. [Boucherit 2021, Paengchit 2023].

4 CONCLUSIONS

The contribution addresses the suitability of using VCGT and VCMT type of indexable cutting inserts in machining of AISi304 austenitic stainless steels. As manifested by the experiments, in the selected range of cutting conditions, taking the machined surface roughness Ra as an evaluation parameter, lower Ra values are achieved when using the VCMT ty of cutting insert. During the experiments, it was found that the VCGT type of cutting inserts is susceptible to sudden brittle fractures in the selected range of cutting conditions, which limits their use in automated turning centers and systems.

The presented results will serve as a platform for further research in the field of machining of austenitic stainless steels and improving the quality properties of the machined surface. At the same time, they expand the knowledge base in the field of metalworking, which is part of technically oriented subjects taught at all levels of education.

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