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EXPERIMENTAL STUDY ON TURNING WITH SELF-PROPELLED ROTARY CUTTING TOOL

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ABSTRACT
In metal cutting, self-propelled rotary tools in which the contact zone between tool and workpiece continuously changes have been used in recent years. The previous researchers used the self-propelled rotary cutting tools specially designed and manufactured for experimental study. This study presents an experimental investigation to evaluate the performance of a new designed and manufactured self-propelled rotary cutting tool. The experiments were realized by turning mild steel under different cutting parameters in order to determine the flank wear and the surface roughness. It has been seen that the new designed cutting tool has major advantage over stationary cutting tool providing longer tool life, but poor workpiece surface quality.

Keywords: *Self-Propelled Rotary Cutting Tool, Flank Wear, Surface Roughness*

INTRODUCTION
Metal cutting methods should be applied to provide fast and economically of desired machining quality. Cost effective machining can be provided by selecting process conditions and parameters accurately. Energy consumed in machining is mostly converted into heat. A lot of problems encountered during machining are due to heat generation and high temperatures. Resultant heat is a great influence on tool life and workpiece causing shorter tool life and poor accuracy and surface quality.

In metal cutting, there are various methods in order to reduce the heat generation effecting cutting tool life. The most common application is the use of cutting fluids. In recent years, the use of cutting fluids has been decreased due to detrimental effects of health and environment. It has begun on finding new methods instead of cutting fluids. One of these methods employs rotary cutting tool.

Cutting edge of tool is intended to be movable with respect to the workpiece. In order to avoid the increase of heat generation on the cutting edge of the cutting tool, circular cutting edge of tool must be rotated. Rotary cutting tool has a round insert that rotates continuously about its axis, as shown in Figure 1[1]. There are two types of rotary cutting tools, namely driven and self-propelled. The circular insert of a driven rotary cutting tool that rotating about its axis is driven by an independent external power. The insert of self-propelled rotary cutting tool is driven to rotate about its axis by chip formation.

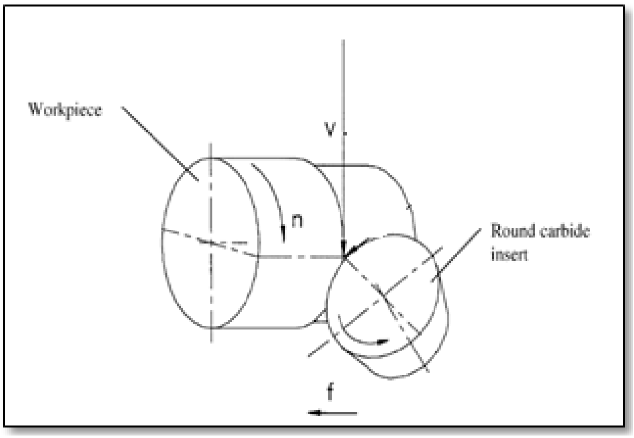

Figure 1. Schematic illustration of rotary cutting tool

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Tool wear reduces and cutting edge cools itself, because of a continuously rotated cutting edge is fed into the cutting zone during machining. Compared with the conventional stationary cutting tools, rotary cutting tool provides high cooling capability, prolonged tool life and better machined surface integrity. Rotary cutting tools have been used due to these benefits in metal cutting. Figure 2[2] shows a rotary cutting tool that developed and used for these purposes.

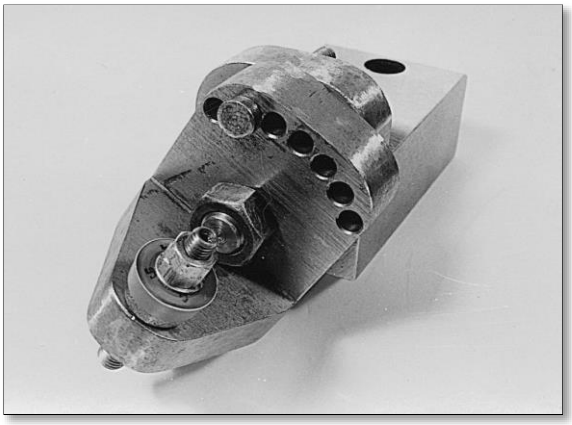


Figure 2. A rotary cutting tool

First fundamental principle of rotary cutting tools date back to 1865 by James Napier and although there were some studies improvement of rotary cutting tool, scientific works were started in 1952 by Shaw et al.[3]. They used driven rotary cutting tool in turning operation. The results shows a %30 reduction in total cutting power compared with a stationary cutting tool. Cutting temperature was decreased by approximately 200 °C compared to a stationary cutting tool. The studies on this issue was increased in the 2000s.and is still continuing. Today, turning and milling operations are performed using rotary cutting tools.

In the literature; about of tool wear, workpiece surface roughness, cutting force, temperature distribution, high-speed machining, chip flow were studied using rotary cutting tool. Chen and Hoshi [4] studied turning of SiC Whisker-Reinforced aluminium composite using self-propelled rotary cutting tools. They designed and manufactured a rotary cutting tool and they reported that rotary cutting tool life is 53 times more than stationary cutting tools and the machined surface roughness by the rotary cutting tool is much lower than by the square insert due to the large edge curvature. Ezugwu et al. [5] researched principles of rotary cutting and factors influencing rotary cutting tool wear, surface integrity, cutting force and they compared the results with stationary cutting tools. Joshi et al. [2] investigated the tool wear in machining of Al/SiC_p composites with the designed and manufactured a rotary cutting tool. They developed a model by achieving tool wear of different cutting parameters and defended to use of rotary cutting tools. Lei and Liu [6] developed a new driven rotary cutting tool and high speed machined titanium alloy Ti-6Al-4V. They indicated that rotary cutting tool give more tool life by 30 times compared to stationary cutting tool. Kishawy and Wilcox [7] studied tool wear and chip formation during hard turning with self-propelled rotary cutting tools and they reported that self-propelled tools showed good resistance to tool wear compared with stationary cutting tools under the same cutting conditions. Ezugwu et al. [8] investigated wear evaluation using self-propelled rotary cutting tool in machining of titanium alloy IMI 318 and rotary cutting tool exhibited superior wear resistance to conventional stationary cutting tools. Kishawy et al. [9] studied on tool performance and machined surface quality during the machining of aerospace alloys using self-propelled rotary cutting tools and they obtained optimum and safe cutting conditions. Kishawy et al. [10] set a model of tool wear using genetic algorithms during hard turning with self-propelled rotary cutting tools and they reported results of measured and model are compatible with one another. Kato et al. [11] investigated on driven rotary cutting tool for finish turning of carburized hardened steel and they obtained that rotary cutting tool provide good wear resistance and better finished surface quality. Kıyak and Altan [12] studied the effects of cutting parameters on surface of machined part during the turning of mild steel using rotary cutting tool.

In this experimental study, turning of AISI 1040 mild steel was performed by the manufactured self-propelled rotary cutting tool. The effects of cutting speed and feed on tool flank wear and workpiece surface roughness were investigated. The previous researchers were used small depth of cut about (0.05-0.6) mm in previous studies made with rotary cutting tools. This study was carried out in larger depth of cut (0.75 mm).

EXPERIMENTAL PROCEDURE

In this study, the effects of cutting speed and feed on tool wear and surface roughness were investigated with self-propelled rotary cutting tool in turning. For this purpose, a new self-propelled rotary cutting tool was designed and manufactured (Figure 3).

Figure 3. Self-propelled rotary cutting tool

In the experiments cutting speed is selected 105 m/min, 145 m/min, 192 m/min; feed is selected 0.12 mm/rev and 0.14 mm/rev; depth of cut is selected 0.75 mm. Inclination angle (Ɛ) of self-propelled rotary cutting tool is 20° and rake angle is -5°. The insert used in this experiment is rounded tip, RCMX3209M0, in ISO Standard having diameter of 32 mm, clearance angle of 7°. Also, a triangle tip insert used, TNMA 160408 KR3025, in ISO Standard, rake angle of -5°. Cutting inserts used in experiments are given in Figure 4.

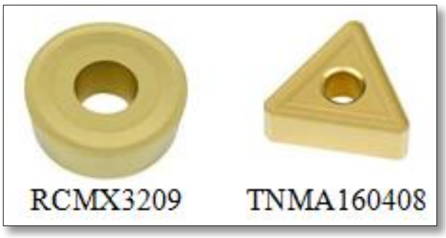


Figure 4. Cutting tools used in experiments

The workpiece material is AISI 1040 mild steel with a diameter of 70 mm. The chemical composition of the material is given in Table 1.

Table 1. Chemical composition of the workpiece

%C	%Si	%Mn	%P<	%S<
0.37-0.44	0.10-0.34	0.60-0.90	0.040	0.050

Rake angle (γ) of tool holder is -5°. The cutting parameters used in experiments are given in Table 2.

Machining time in all experiments was carried out in 300 seconds for tool wear. The cutting tool flank wear was measured every 60 seconds. SOIF model optical microscope and having 1.0 µm precision OSM model ocular micrometer was used for flank wear measurements.

Measurement of surface roughness was carried out using a Mitutoyo Surftest SJ-210 surface roughness measurement instrument. Since it is considerably large as compared to the usual tool nose radius (0.8 mm), the cut-off length for surface roughness measurement was chosen to be 2.5 mm. At least 4 measurements of surface roughness were taken per experimental run and the average value of measurements is used as response variable.

Table 2. Cutting parameters

RCMX insert inclination angle(°)	20		
RCMX insert rake angle(°)	-5		
Depth of cut(mm)	0.75		
Feed (mm/rev)	0.12		0.14
Cutting speed(m/min)	105	145	192

In figures 5-6, experimental setup arranged on the lathe was shown.

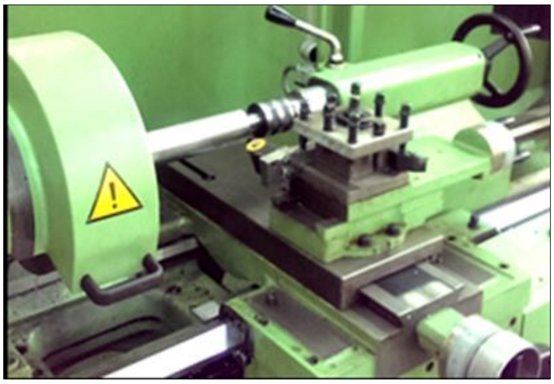


Figure 5. Experimental setup

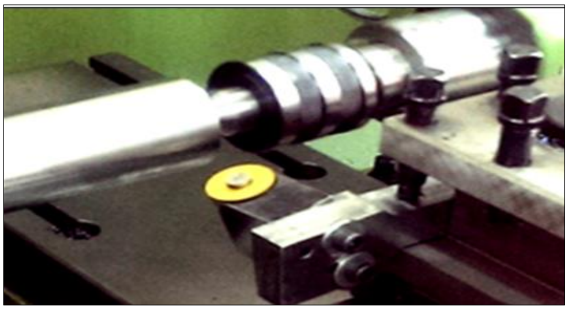


Figure 6. Detailed experimental setup

RESULTS AND DISCUSSION

Cutting Speed and Tool Flank Wear

In Figure 7, effects of cutting speeds (105 m/min-145 m/min-192 m/min) and feed (0.12mm/rev) on tool wear using rotary cutting tool were given. In this experiment group, the effect of on the wear of changing of cutting speed was determined. Machining time in all experiments was carried out in 300 seconds for tool flank wear and the cutting tool flank wear was measured every 60 seconds using optical microscope and ocular micrometer. The cutting insert used in experiments is TiN coated, ISO standard having diameter of 32mm RCMX 3209M0 type.

In figure 8, self-propelled rotary cutting tool having rake angle of -5°, inclination angle of 20° and stationary insert (TNMA 160408) were compared at cutting speed of 105 m/min and feed of 0.12 mm/rev. Tool flank wear difference between the rotary cutting tool and stationary cutting tool were defined as 10-fold in Kishawy's study[7]. Moreover, the workpiece material was AISI 4340 steel and cutting tool was coated and uncoated used at cutting speed of 100 m/min, 130 m/min, 270 m/min and feed of 0.2 mm/rev. Kishawy selected small depth of cut (0.1 mm-0.2 mm).

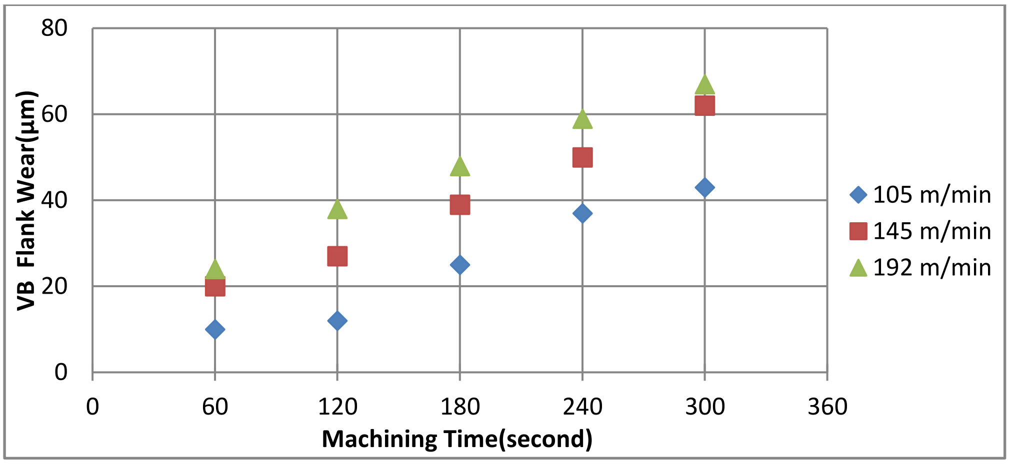


Figure 7. Flank wear of rotary cutting tool at different cutting speed (f=0.12 mm/rev)

In this study, difference of cutting tool flank wear between the self-propelled rotary cutting tool and stationary tool was determined 2.6-fold. Self-propelled rotary cutting tool provided more than 2.6 times tool life.

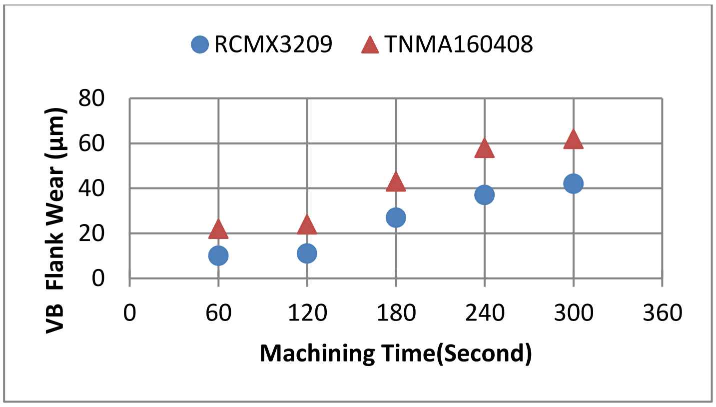


Figure 8. Comparison of flank wear between self-propelled rotary cutting tool (RCMX3209) and stationary cutting tool (TNMA160408) (V=105 m/min, f=0.12 mm/rev, a=0.75 mm)

The comparisons of self-propelled rotary cutting tool and stationary cutting tool are presented in Figure 9 and Figure 10, respectively at cutting speed 145 m/min and 192 m/min, feed 0.12 mm/rev, depth of cut 0.75 mm. It is obvious that self-propelled rotary cutting tool exhibits superior wear resistance compared with stationary cutting tool.

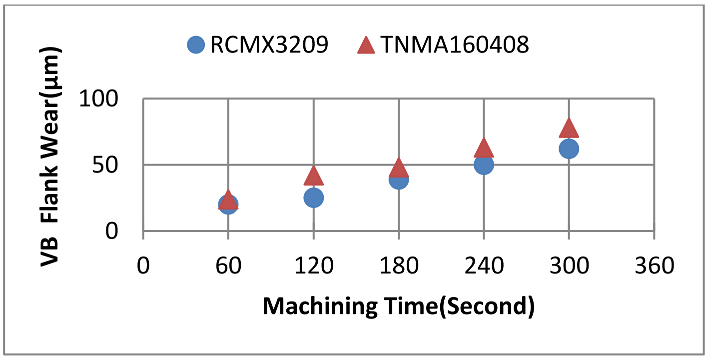


Figure 9. Comparison of flank wear between self-propelled rotary cutting tool (RCMX3209) and stationary cutting tool (TNMA160408) (V=145 m/min, f=0.12 mm/rev, a=0.75 mm)

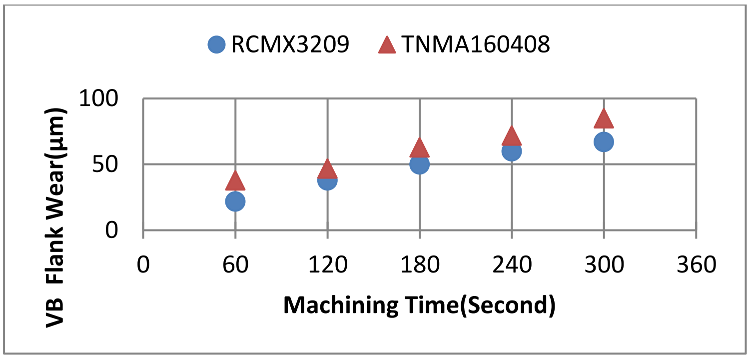
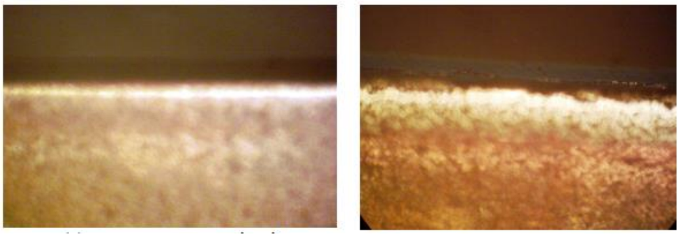


Figure 10. Comparison of flank wear between self-propelled rotary cutting tool (RCMX3209) and stationary cutting tool (TNMA160408) (V=192 m/min, f=0.12 mm/rev, a=0.75 mm)

The wear ratio of stationary cutting tool to rotary cutting tool increases with the increase of machining time. The cause of this increase is heat generation of stationary cutting tool when machining time increase.

Wear measurements photographed with OGATECH OG5110 model digital camera after the measurements. Figure 11 shows worn insert after machining 60sec. and 300sec. at cutting speed of 145 m/min and feed of 0.12 mm/rev with self-propelled rotary cutting tool.



a) Tool wear after 60 sec b) Tool wear after 300 sec

Figure 11. Flank wear of self-propelled rotary cutting tool at cutting speed of 145 m/min, feed of 0.12mm/rev

Feed and Tool Flank Wear

Flank wear was given in Figure 12 at constant cutting speed of 145 m/min, feed 0.12 and 0.14 mm/rev with self-propelled rotary cutting tool. It is observed that flank wear increased with increasing feed.

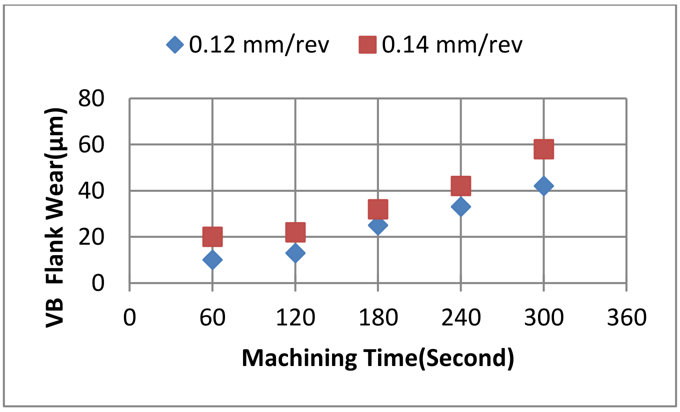


Figure 12. Effects of feed on flank wear with self-propelled rotary cutting tool (V=105 m/min, f=0.12 mm/rev-0.14 mm/rev, a=0.75 mm)

Cutting Speed, Feed and Surface Roughness

In Figure 13, effects of cutting speeds (105 m/min-145 m/min-192 m/min) and feeds (0.12-0.14 mm/rev) on mean surface roughness using rotary cutting tool were given. Surface roughness decreased with increasing cutting speed. And surface roughness increased with rise of feed in the same cutting speed.

Effects of cutting parameters on surface roughness with stationary cutting tool shown in Figure 14. Surface roughness increased when cutting speed increases at feed of 0.12 mm/rev. But at feed of 0.14 mm/rev, surface roughness increased first, then decreased with rise of cutting speed. It is observed that surface roughness increased when feed rise.

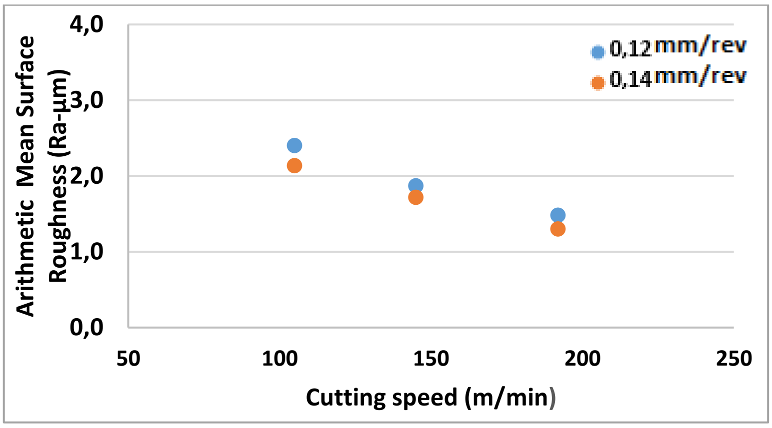


Figure 13. Effects of cutting speed and feed on surface roughness with self-propelled rotary cutting tool

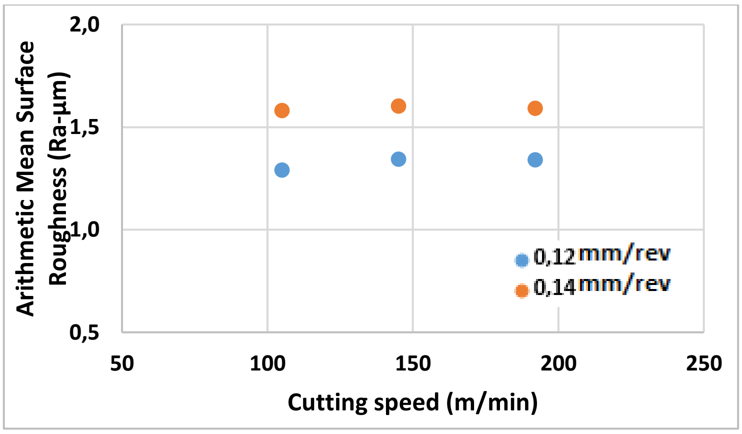


Figure 14. Effects of cutting speed and feed on surface roughness with stationary cutting tool

CONCLUSION

New studies and technologies are developed to increase tool life and to maintain quality machined surface. One of these is the use of rotary cutting tool in machining. In this study, it was aimed to investigate the effects of cutting parameters on tool wear and surface roughness in turning with self-propelled rotary cutting tool. Tool wear and surface roughness values were measured by changing cutting speeds and feeds. Experiments were performed with constant rake angle of -5° and constant inclination angle of 20°. The results obtained are summarized as follows:

- A new generation of self-propelled rotary cutting tool was first designed and manufactured. Experiments show that it is suitable for machining.
- It was seen that flank wear increased with increment of cutting speed and feed in self-propelled rotary cutting tool.
- Self-propelled rotary cutting tool showed good wear resistance compared to stationary cutting tool under the same cutting conditions. 2.6 times less flank wear were obtained with self-propelled rotary cutting tool compared to stationary cutting tool.
- When machining time increased, stationary cutting tool flank wear was more than self-propelled

rotary cutting tool. When machining time is applied to more than 300 seconds, self-propelled rotary cutting tool will provide wear resistance more than 2.6-fold.

- It was seen that surface roughness decreased with rise of cutting speed and surface roughness increased rise of feed. It was observed that rotational motion of the tool relates to cutting speed that increased, rotational motion of the tool raised. So, surface integrity is good at higher cutting speeds.
- Previous researchers mainly studied small depth of cut with rotary cutting tools. This study was performed larger depth of cut, 0.75 mm and it was observed that depth of cut can be increased by changing constructive structure of self-propelled rotary cutting tool.

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NOMENCLATURE

V cutting speed (m/min)
f feed (mm/rev)
n revolution (rev/min)
a depth of cut (mm)
γ rake angle (°)
ε inclination angle (°)

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