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Liquid covered micro-milling

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Abstract
Micro-milling tools made of cemented carbide suffer from fast tool wear and random tool breakage during the machining process. The cutting material cemented carbide is composed of a hard material phase made of tungsten carbide and a binder phase made of cobalt. An allotropical crystal lattice transformation of the binder phase at a temperature ϑ = 420 °C leads to increased tool wear. Commonly minimum quantity lubrication (MQL) is used as cooling lubricant technology in micro-milling. In this work a new liquid covered cooling lubricant (LCCL) technology and the commonly used MQL technology were compared regarding tool wear of cemented carbide tools for machining the steel STAVAX ESU. In the LCCL technology the cutting process is completely covered with cutting lubricant. It could be concluded that the new LCCL technology offers a high potential to reduce the tool wear in micro-milling of steel with cemented carbide micro-milling tools.

Keywords: micro-milling, steel, wear

1. Introduction

Precision components e.g. moulds, dies, or dental parts can be manufactured by micro-milling with high geometrical flexibility [1]. At state of the art micro-milling tools made of cemented carbide are commonly used in industry. Nevertheless, these tools suffer from fast tool wear and random tool breakage during the machining process [2, 3]. The cutting material cemented carbide is composed of a hard material phase made of tungsten carbide and a binder phase made of cobalt. An allotropical crystal lattice transformation of the binder phase at a temperature ϑ = 420 °C leads to increased tool wear. Commonly minimum quantity lubrication (MQL) is used as cooling lubricant technology in micro-milling. The cutting lubricants are often based on mineral oil with a great lubrication effect and a slight cooling effect. Nevertheless, water based cutting lubricants have a great potential to decrease the temperature ϑ in the cutting process. In this work a new liquid covered cooling lubricant (LCCL) technology and the commonly used MQL technology were compared regarding tool wear of cemented carbide tools for machining steel X40Cr13. In the LCCL technology the cutting process is completely covered with cutting lubricant.

2. Experimental setup

The investigations were carried out on a high-precision machine tool Wissner Gamma 303 High Performance from the company WISSNER GESELLSCHAFT FÜR MASCHINENBAU MBH, Göttingen, Germany, with ball bearing guideways and spindle. The cutting tests were done with different cooling lubricants and cooling lubricant technologies. Minimum quantity lubrication (MQL) technology is the most common cooling lubricant technology for micro-milling at the state of the art. For the MQL technology a common mineral oil based cutting lubricant Swisscut 6122 S from the company MOTOREX, Langenthal, Switzerland, and for LCCL technology the water based cutting lubricant W200SL of the company OPORTET GMBH, Duisburg, Germany, and the mineral oil based cutting lubricant Swisscut 6122 S were used. As process parameters a cutting speed v_c = 150 m/min, a feed per tooth f_t = 10 µm, a depth of cut a_p = 300 µm, and a width of cut a_e = 100 µm were used. For the experiments micro-milling tools made of cemented carbide with a diameter D = 1.0 mm with a corner radius r_ε = 100 µm from the company DIXI POLYTOOL GMBH, Birkenfeld, Germany, were used. Figure 1. illustrates the major flank face A_α and the Rake face A_γ of a new micro-milling tool.

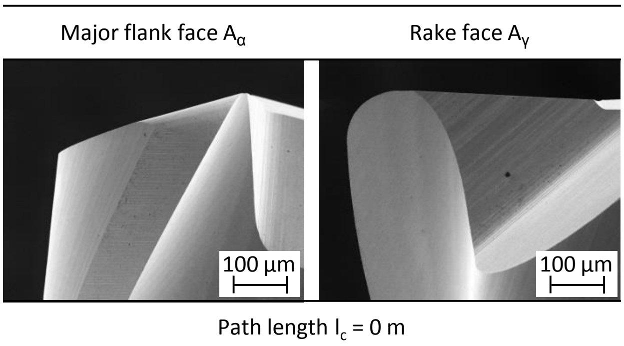


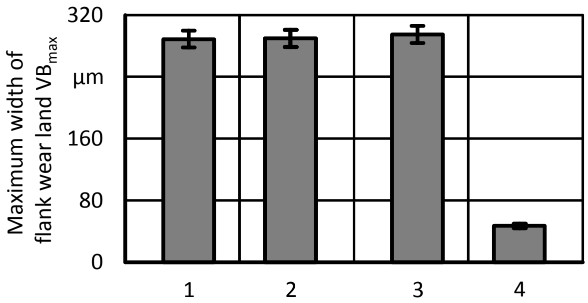
Figure 1. Micro-milling tool made of cemented carbide before cutting experiments

3. Machining results

The first cutting tests were carried out according to the state of the art with MQL technology and mineral oil based cooling lubricant Swisscut 6122 S. After a path length l_c = 8 m a maximum width of flank wear land VB_{max} = 289 µm could be observed. Using the new LCCL technology with the water based cutting lubricant W200SL the maximum width of flank wear land could not be reduced. A reduction of the cooling lubricant temperature ϑ_{cl} resulted in a slightly increased maximum width of flank wear land VB_{max}. Due to the use of the new LCCL technology with the mineral oil based cooling lubricant

Swisscut 6122 S the maximum width of flank wear land could be reduced by 83.7 % to VB_{max} = 47 µm.

The results of the cutting tests concerning the maximum width of flank wear land VB_{max} are shown in figure 2.



1 MQL – Swisscut 6122 S
2 LCCL – Oportet W200 SL
3 LCCL – Oportet W200 SL Ice
4 LCCL – Swisscut 6122 S

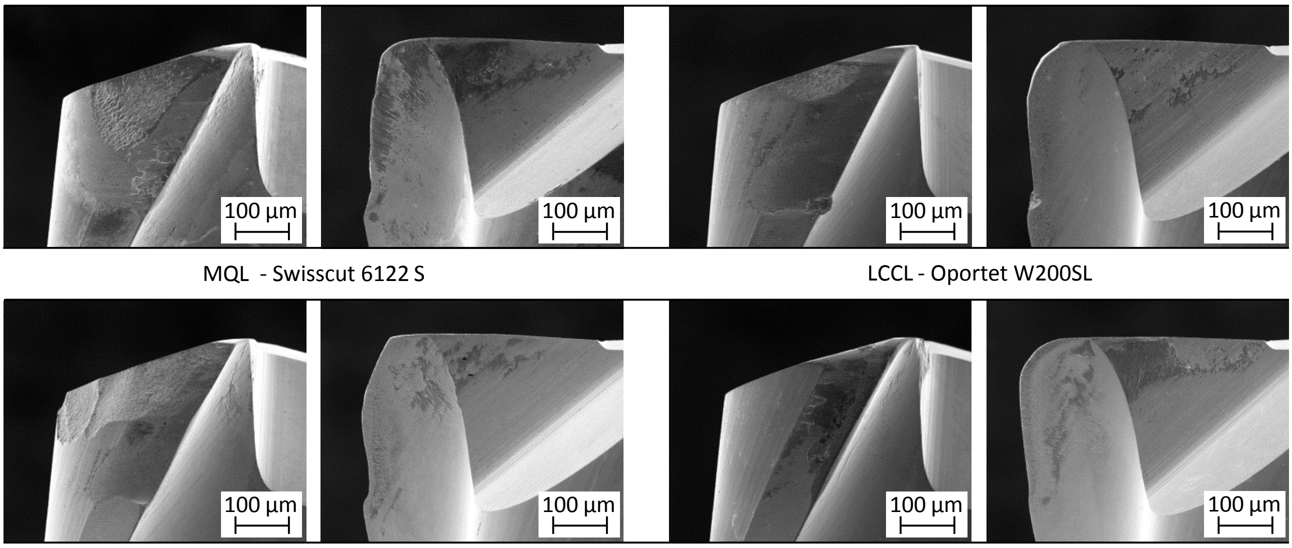
Figure 2. Results of the cutting tests concerning the maximum width of flank wear land VB_{max} after a path length l_c = 8 m

Figure 3. illustrates the scanning electron microscope (SEM) images of used tools after a path length l_c = 8 m. Using MQL technology with the mineral oil based cooling lubricant Swisscut 6122 S a strong change of the macro geometry occurs as a result of the wear. A reduction of the diameter D, the tool length l_t, the major tool cutting edge angle κ_r, and the minor tool cutting edge angle κ'_r are obviously. These phenomena lead to changed cutting conditions and geometrical inaccuracy during the cutting process. Furthermore, adhesive wear on the major flank face A_α, partial tool breakage, as well as remaining workpiece material on the rake face A_γ are visible. The application of the LCCL technology with W200SL as cooling lubricant results in a reduction of remaining workpiece material on the rake face A_γ of the micro-milling tools. Due to the use of the cutting lubricant W200SL with ice an increased partial tool breakage could be observed. Using the LCCL technology with the cooling lubricant Swisscut 6122 S the macro geometry of the micro-milling tools remains as manufactured with just a slight reduction of the diameter D.

As a consequence of the cutting results it can be assumed that the reduced friction between the workpiece and the tool has a greater impact on the tool wear than the pure reduction of the cutting temperature ϑ_c with water based cooling lubricant.

Process:	**Process parameter:**	**Tool:**	**Workpiece material:**
Micro-milling	v_c = 150 m/min f_t = 10 µm a_p = 300 µm a_e = 100 µm	Cemented carbide uncoated Two flute end mill D = 1 mm	Steel X40Cr13

Major flank face A_α | Rake face A_γ | Major flank face A_α | Rake face A_γ



LCCL - Oportet W200SL Ice | LCCL - Swisscut 6122 S

Figure 3. Results of the cutting tests

4. Conclusion

As a result of this ongoing research it could be concluded that the new LCCL technology offers a high potential to reduce the tool wear in micro-milling of steel with cemented carbide micro-milling tools. With respect to the elaborated results the maximum width of flank wear land could be reduced by 83.7 % using the new LCCL technology and Swisscut 6122 S as cutting lubricant for cutting steel with cemented carbide micro-milling tools. As a consequence a remarkable improvement of the precision in micro-milling of steel components can be achieved.

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