Mold and Die Applications – Requirements on Milling Spindles

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Introduction

In the past, higher speed appeared by far to be the most significant requirement when high-strength materials had to be machined. Recently, accuracy (meaning tool center point repeatability) and reliability gain importance as well. Innovative spindle systems and/or spindle features for milling applications consider these additional requirements. Some will be presented below after the additional requirements have been explained in detail.

Accuracy

Today's manufacturing technology requires short non-productive times. Besides e.g. set up time and tool change time, the time to reach a constant temperature of the spindle (so called saturation time) offers a great potential to shorten the non-productive time.

Depending on spindle type, speed, spindle/drive configuration, machine frame, and its integration a spindle with a conventional cooling system needs between 15 to 30 minutes to reach a stable working temperature (figure 1). Due to the thermal expansion of the shaft and the housing the TCP might change due to that between 60 and 120 µm until the saturation state is reached.
Additionally, the spindle components heat up the tool and the tool holder. Consequently, any tool change will cause a deviation due to the temperature differential between the spindle and a cold tool coming from the magazine.

Reliability

The component of a system that sees the highest stresses generally determines the system's life. Besides may be the rotary joint, the bearings can be named as the most critical components of milling spindles. The tribological system bearing can be described by the surface of the contact partners, the lubricant used, the macro and micro geometry, and the

materials of the contact partners interacting physically or chemically. These reactions are significantly influenced by the bearing temperature (outer and inner ring temperature) and determine, assuming that no fatigue will occur, bearing life. Consequently, a key factor in order to achieve higher reliability is the bearing temperature.

Shaft Cooling System – a Fischer Solution for Higher Accuracy, Reliability, and Durability

Addressing the requirements accuracy, reliability, and durability, Fischer developed a shaft cooling system (figure 2) for its motor spindles. The complete shaft including rotor and bearing inner rings are cooled with water through a series of channels. This became possible by developing a special three-channel rotary joint that allows to supply the channels with water and offers the additional option of a regular rotary joint, i.e. sending coolant through the center of the shaft to the tool tip.

When major heat sources like the rotor and the bearings are cooled directly, tests[1] showed that up to 1kW additional losses can be removed from the shaft of the spindle. Consequently, the warm-up time of the test spindle was reduced by 80% (figure 4) and less heat would migrate into the machine. The temperature distribution of the spindle has been changed as displayed in figure 5. Compared to a conventional cooling system, at the tool interface a temperature reduction of 25°C was achieved. We can literally claim: The Fischer spindle does not heat up the tool (figure 5).

Additionally, tests with rigidly preloaded bearing systems have been very successful. Due to the reduction of the temperature differential between the inner and outer rings of the bearings speed factors up to 2 million $n \cdot d_m$ [mm/min] and higher were achieved. The opportunity of eliminating the often critical floating bearing system greatly enhances reliability. Generally the axial bearing displacement and the axial shaft growth are reduced, and also flexibly preloaded bearing systems are consequently less critical.

First tests show a very positive influence on bearing life. However, statistically proven data will be obtained in one or two years in various production trials.

[1] All tests have been performed with a Fischer MFW-1412/36, HSK-E50, n_{max}= 36'000 rpm, P_N = 15 kW, no loads applied.

A positive influence on bearing life can be assumed because an elasto-hydrodynamic lubrication film that is needed to separate bearing's contact partners can be built up earlier, at lower speed. Consequently, the number of wear conditions during operation are reduced which prolongs bearing life.

Conclusion

Accuracy and reliability gain further importance in today's machining industry. Innovative features like the Fischer shaft cooling system address the requirements that especially rise when it comes to the milling of high-strength materials.

By developing the shaft cooling system and offering this system as an option for a variety of spindles already, Fischer spindles outperform existing solutions in terms of thermal stability, life time, and reliability.

Figures

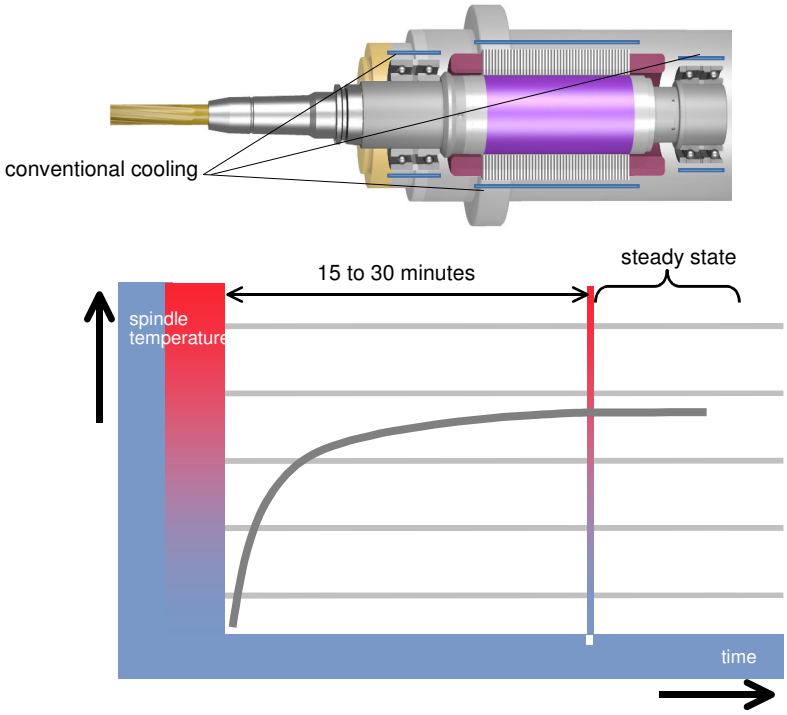

Figure 1: Temperature behavior of a spindle during the warm-up procedure.

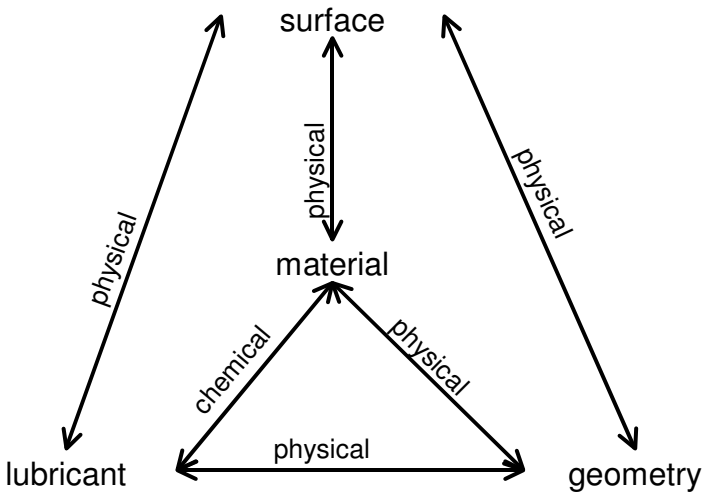

Figure 2: Tribological stress on the bearing systems [1].

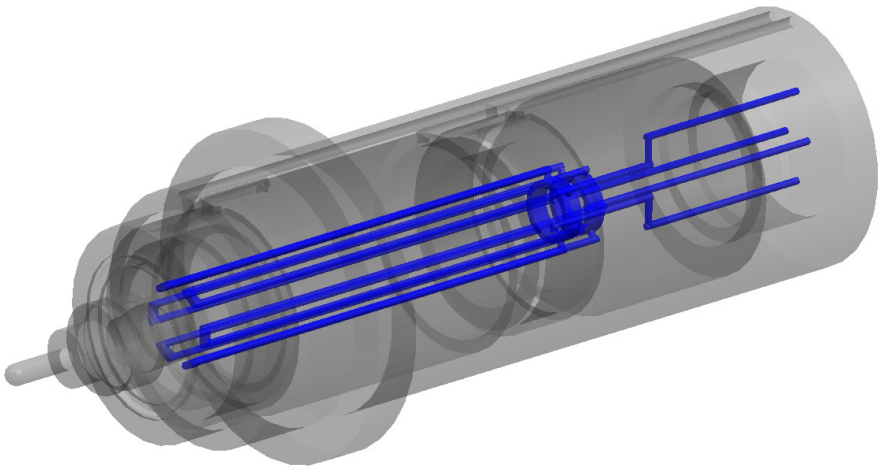

Figure 3: Fischer shaft cooling system.

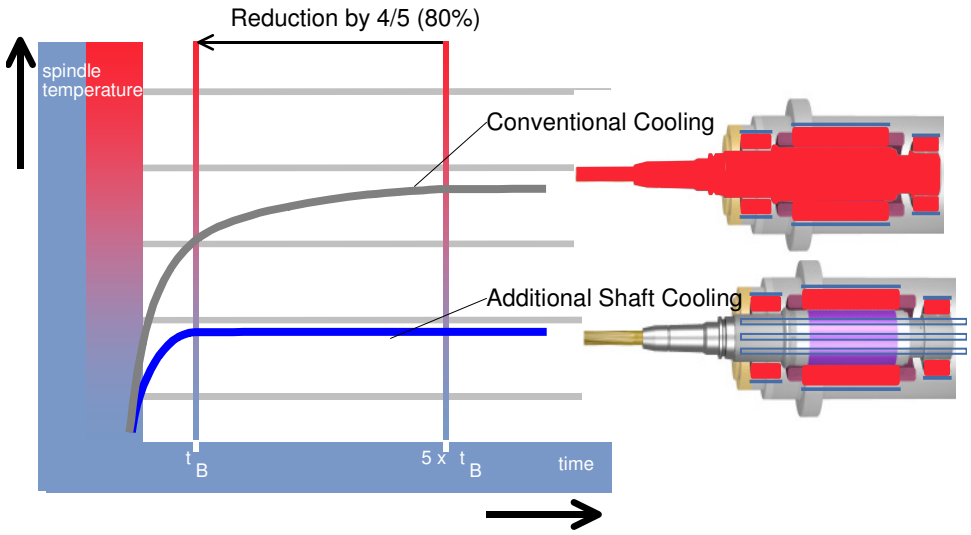

Figure 4: Reduction of run-in time.

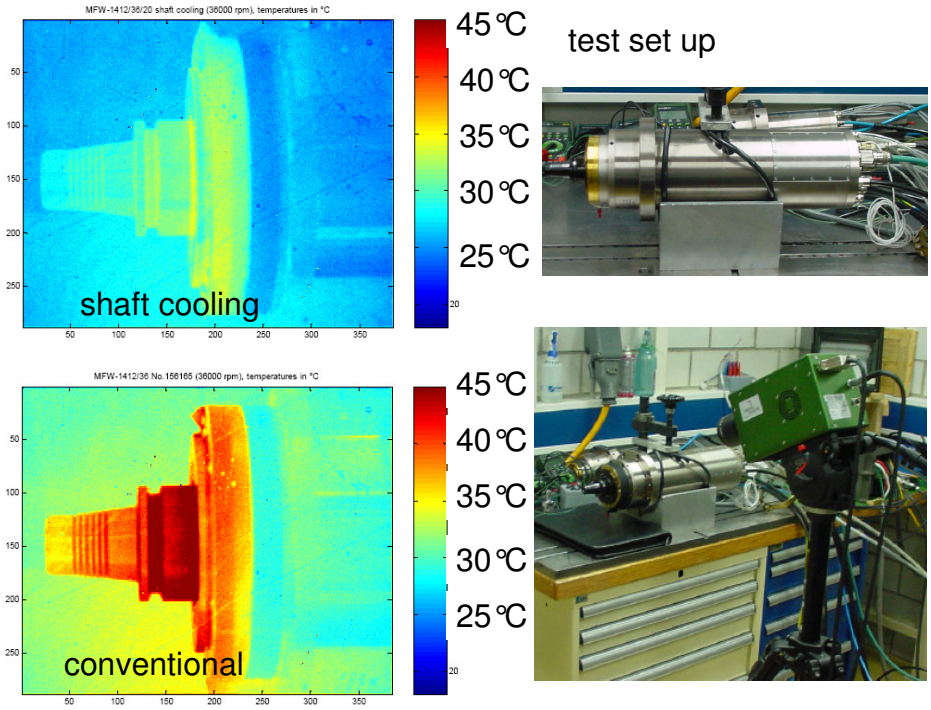

Figure 5: Influence of the shaft cooling on the spindle temperature distribution.

References

[1] Bayer, O.: Modern Spindle Bearing Concepts, 3rd International Conference on Metal Cutting and High Speed Machining, Metz, France, June 27th to 29th, 2001