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Hydraulic expansion toolholders improve tool life, quality and productivity

Comparison of toolholding technology in high-performance cutting

Jürgen Fleischer, Volker Schulze, Frederik Zanger, Urs Leberle, Nikolay Boev, and Andreas Spohrer, Karlsruhe

A study conducted at the wbk Institute for Production Technology compared toolholding systems using hydraulic expansion technology and heat shrink technology.
The focus was on the important criteria of productivity and tool life in high-performance cutting.

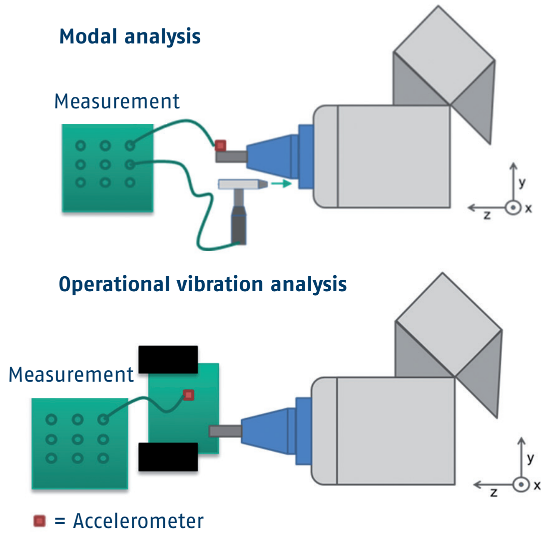

Figure 1
Modal analysis and operational vibration analysis.

The quality of a machined surface is affected to a large degree by machine vibrations resulting from the production process.
This "process-machine interaction" has been examined often [1], and, in most cases, the effect of the process forces on the machine vibrations have been analyzed and represented by means of stability charts [2]. As a result of simplified assumptions in the representation of the machine structure, the analyses conducted in the past generally neglected analysis of the effect of the toolholding systems. Due to the technical differences between different toolholding systems however, a significant influence on the process-machine interaction - and therefore on the quality of the machining result and the tool life - is to be expected, especially in the case of high-performance cutting. Hydraulic expansion technology (HE) uses the increased fluid pressure within the chuck and the resulting elastic deformation of the fixing material for the clamping of the tool. In heat shrink technology (HS), on the other hand, the thermal expansion during warming of the chuck is used, resulting in a press fit after cooling down the system. The goal of the study was to provide a systematic comparison of HE and HS technology with respect to the maximum achievable productivity and tool life in high-performance cutting. In addition, the vibration behavior of the two toolholding systems was examined in order to include the influence of the damping behavior of the two systems in the comparative analysis.

Comparison of productivity and tool life

To analyze the influence of the two toolholding systems on productivity and tool life, cutting tests were conducted with toolholders manufactured by Schunk. For the HS technology, a "Celsio SSF" (HSK-A63 or A100 ø12) was used, and, for the HE, a "Tendo SDF-E compact" (HSK-A63) or "Tendo SDF" (HSK-A 100 ø12) was used. For all tests an end mill of the type Walter "H4138217-12-0.5" or -1 was used. Different machining centers (MAG "NBH630", Heller "MC16" and Chiron "FZ15 S") were used to verify the results.
For the comparison of productivity, the maximum possible rate of metal removal was compared while maintaining equivalent surface quality. First, a reference workpiece of 16MnCr5 was defined, in which a half slot was cut in climb-cut milling and three full slots were cut with depths of 6 mm, 12 mm and 18 mm.
From preliminary tests it was known that HE technology provides better surface qualities than HS technology with the maximum permissible cutting parameters specified by the tool manufacturers. This made it possible to define the surface achieved with HE technology as a reference surface and to reduce the cutting speeds and feed rates with the use of HS technology until a surface roughness was achieved that was comparable with HE. The comparison of the respective achievable rate of metal removal allowed conclusions on the difference in productivity. All tests were statistically verified by repeating them three times on all machining centers.

The next step was a comparison of the two toolholding systems with respect to the achievable tool life in high-performance cutting. For this test, full slots with a depth of 12 mm were cut until the wear area width on the minor flank of the cutter had reached a value of 50 µm. The wear area width was measured and recorded with an optical microscope. The results were used to calculate and compare the total machined volume for the two toolholders.

Examination of the underlying damping behavior

The damping behavior of the two toolholding systems was measured and compared by means of modal and operational vibration analyses, as shown in **Figure 1.** In the modal analysis, the accelerations at the tool-engaging point were measured in all three planes and converted to a standardized acceleration-frequency response. The operational vibration analysis allowed sensoric measurement of the vibrations occurring during high-performance cutting and their analysis by means of fast Fourier transformation (FFT).

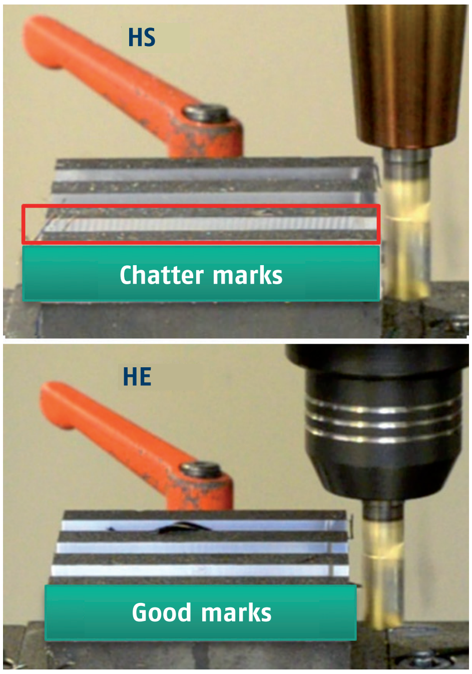

Figure 2

Machining center after high-performance cutting with a heat shrink (HS) toolholder and a hydraulic expansion (HE) toolholder.

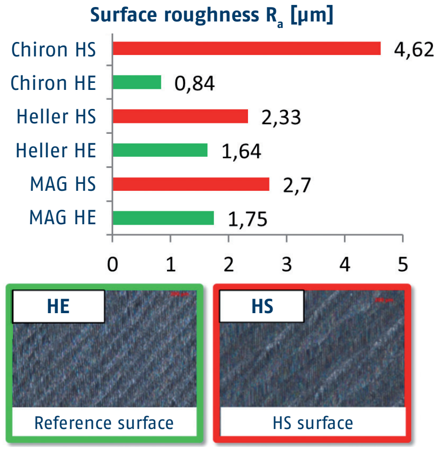

Figure 3

R_a values and microscopic image on the climb side of the 12 mm full slots.

Results of the tests

The cutting tests showed significant differences in the machining process and the results of the process. Especially striking with the use of HS technology was a loud and high-frequency whistling tone (f = 3,300 – 3,700 Hz) and the significantly lower noise emission with the use of HE technology by comparison. A striking machining result was the overall poorer surface quality with the use of HS technology, which was even more prominent in the form of chatter marks in the case of deep slots. **Figure 2** shows an exemplary machining result after high-performance cutting with HS and HE technology. An exemplary result from the tests is shown in **Figure 3**, in which the maximum permissible cutting parameter specified by the tool manufacturer for cutting full slots with a depth of 12 mm was used. HS technology resulted in significantly poorer surface qualities in comparison with HE technology. For the other three slots as well, the surface quality was generally poorer with the use of HS technology on all three machining centers. The only exception were the half slots with a depth of 12 mm cut on the Chiron, in which the heat shrink technology provided somewhat better results.
Furthermore, Figure 3 shows the microscopic recordings of the surfaces after the reference tests, in which it can be seen that the better quality was produced with HE technology.

Influences on the surface roughness

The results of the tests made it possible to describe the effect of the feed rate and cutting speed on the surface roughness by means of suitable regression functions. These functions were used to define the optimal combination of feed rate and cutting speed for HS technology to achieve a comparable surface quality to that achieved with HE, as well as to verify additional validation tests.
Figure 4 shows the results achieved on the Heller MC16 machining center by plotting the comparable R_a values over the rate of metal removal. An average 10% increase in productivity is possible with the use of hydraulic expansion technology on both the Heller MC16 and the MAG NBH630.

Tool life

Over the course of the study the maximum achievable tool life was examined with the use of the two toolholding systems.
Figure 5 shows the comparison of the respective tool life. It is clear that the tool life was increased by up to 300% with the use of HE as compared with HS technology.

Vibration analysis

Figure 6 shows the results of the operational vibration analysis in the manufacture of full slots with a depth of 18 mm on the machining center Heller MC16. While only very weak excitation over the entire frequency band was detected with the use of HE technology, very strong excitations occur especially in the frequency range above 2,800 Hz with the use of HS technology. In this frequency range, the high-frequency whistling tone also occurs during the cutting process.
In the analysis of the acceleration frequency processes shown in **Figure 7** it can be seen that generally lower acceleration amplitudes occur with the use of HE technology at frequencies above 1,700 Hz. Starting at about 2,500 Hz, damping of the HE system is up to four times better. In the lower frequency range both toolholding systems display similar damping behavior with slight advantages for the HS system.
The results achieved in the experimental tests show that HE technology in comparison with HS technology generally offers better damping properties. The result of this is that the machined component surfaces are better

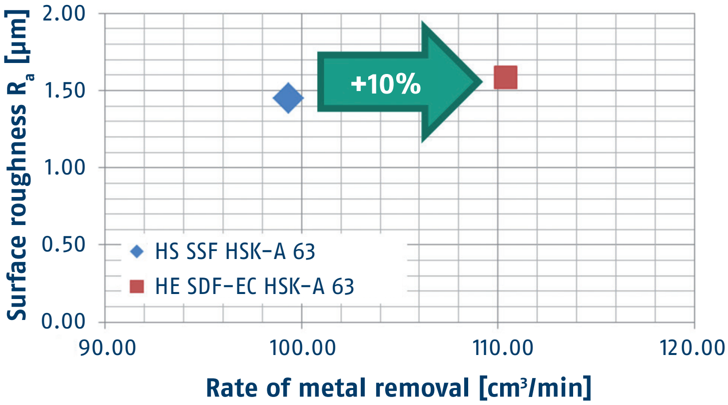

Figure 4

Comparison of productivity in machining on the "Heller MC16" for the manufacture of 12 mm full slots.

and the tool life is longer. The better damping properties are especially obvious in the high frequency range in the form of significantly lower noise emission during high-performance cutting with HE technology.

Summary

A study compared toolholding systems using HE and HS technology. In cutting tests it was shown that the use of HE technology allows higher cutting speeds and feed rates while achieving the same surface quality, which is accompanied by an increase in productivity in comparison with HS technology. In addition, the use of HE technology under the same cutting conditions increases the tool life significantly.

The results were then supplemented with modal and operational vibration analyses. In these analyses, the vibration properties of both toolholding systems were compared quantitatively, in which, in general, better damping behavior was found when using the HE technology.

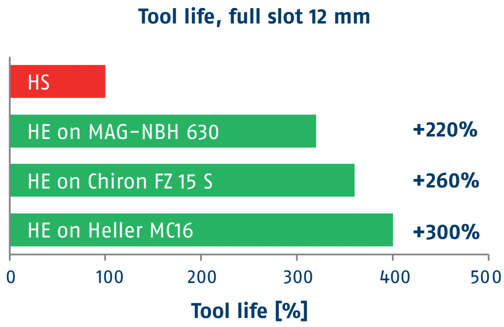

Figure 5

Comparison of the maximum achievable tool life (results for the 12 mm full slots).

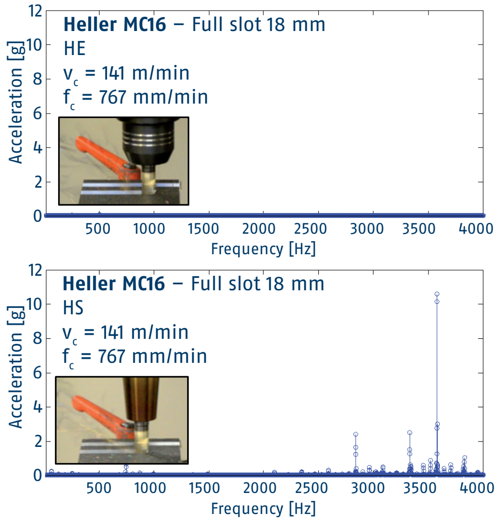

Figure 6

Excited operational vibrations with HE (top) and HS (bottom).

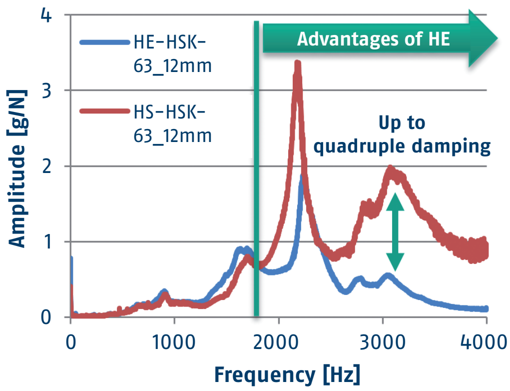

Figure 7

Acceleration frequency responses at the tool-engaging point on the Heller MC16.

Authors

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