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Out-of-Round Turning of Polygon Couplings

Out-of-round turning is an efficient alternative to profile milling and grinding for polygon couplings that could replace traditional spline and shrink-fit connections in automotive transmissions.

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Vehicle manufacturers have invested billions of dollars over recent years to develop the cleanest cars, vans and trucks in history. Among other advances, more sophisticated valve trains, turbocharging, transmissions with more gears, and optimized controls have driven emissions from new vehicles to an all-time low. However, many incremental technologies remain sitting on automotive engineering shelves, ready to be deployed.

One example cited by Reiner Jörg, head engineer of machine tool builder Weisser's R&D department in southern Germany, is polygon couplings or polygon shaft-hub connections that could replace splines and shrink-fit connections.

"Polygon couplings are nothing new," he says. "Designed to eliminate common failure problems associated with splines and keyed shaft attachments, the general polygon system is a proven superior method for making demanding mechanical connections that are stronger, more precise and have a substantially longer service life, because effective load distribution virtually eliminates point contact, minimizing stress fatigue and distortion. The polygon has a greater capacity for torque than any other shaft attachment. The force transmission and load ratings

Polygon shafts are designed to eliminate common failure problems associated with splines and keyed shaft attachments. The polygon has a greater capacity for torque than any other shaft attachment. The force transmission and load ratings are optimized and a shorter shaft connection can often be used to save space.

Weisser's Hyperspeed Oval Turning (HOT) "out-of-round" machining unit enables hard and soft machining of reciprocating pistons for combustion engines made of aluminum and steel, hardened camshafts, polygonal profiles or shapes, and automotive fuel pumps, among other applications.

are optimized and a shorter shaft connection can often be used to save valuable space. Less accelerated mass in a smaller space (such as gearboxes) contributes to the aforementioned fuel efficiency."

Nevertheless, he says car manufacturers have yet to adopt polygon couplings for their transmissions. One reason is that the parts are difficult to machine. However, Weisser's out-of-round turning technology could change that by enabling manufacturers to turn finished polygonal shapes in one setup on one machine. Such capability can make out-of-round turning a more efficient alternative to the profile milling and grinding processes typically used to produce traditional automotive shaft-hub connections.

Since its introduction in 1993, out-of-round turning has been used for hard and soft machining of reciprocating pistons for combustion engines made of aluminum and steel, hardened camshafts, polygonal profiles or shapes, and automotive fuel pumps. Now, Weisser is working on several projects with original equipment manufacturers (OEMs) to demonstrate how wider adoption of this process could make it feasible to replace traditional shaft-hub connections with polygon couplings.

30 Gs Nominal Acceleration

Weisser's Hyperspeed Oval Turning (HOT) out-of-round machining system is a separate unit that integrates with the company's Vertor vertical turning machine. Oval or out-of-round shapes are produced by the interaction of the workpiece spindle axis with the diameter-generating feed axis of the tool.

The tool's cutting edge moves in the same direction of the X axis and perpendicular to the workpiece spindle axis. The cutting edge can be positioned variably in this notional (polygon cross-sectional) plane to produce radial and frontal contours or hemispherical out-of-roundness.

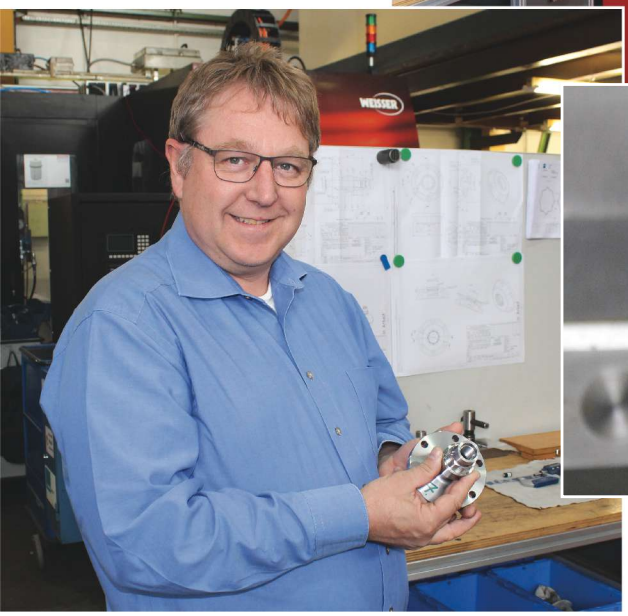
Weisser uses linear drives rather than ballscrews to accelerate the oval turning units.

The power of the highly dynamic drive is partly required for the acceleration of the mass and partly required as the force acting on the tool cutting edge during machining. The cutting tool can be accelerated in a radial oscillating movement by as much as 130 Gs. This level of acceleration is so extreme, even for the latest Siemens and Bosch Rexroth CNCs, that most applications involve accelerations of only 30 to 90 Gs (which equates to six to seven times the acceleration of an aircraft's ejection seat).

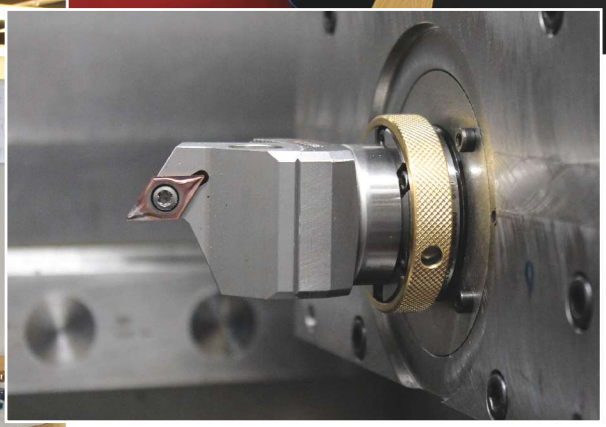
"For a given out-of-roundness, the maximum

“The general polygon system is a proven superior method for making demanding mechanical connections that are stronger, more precise and have a substantially longer service life.” – Reiner Jörg

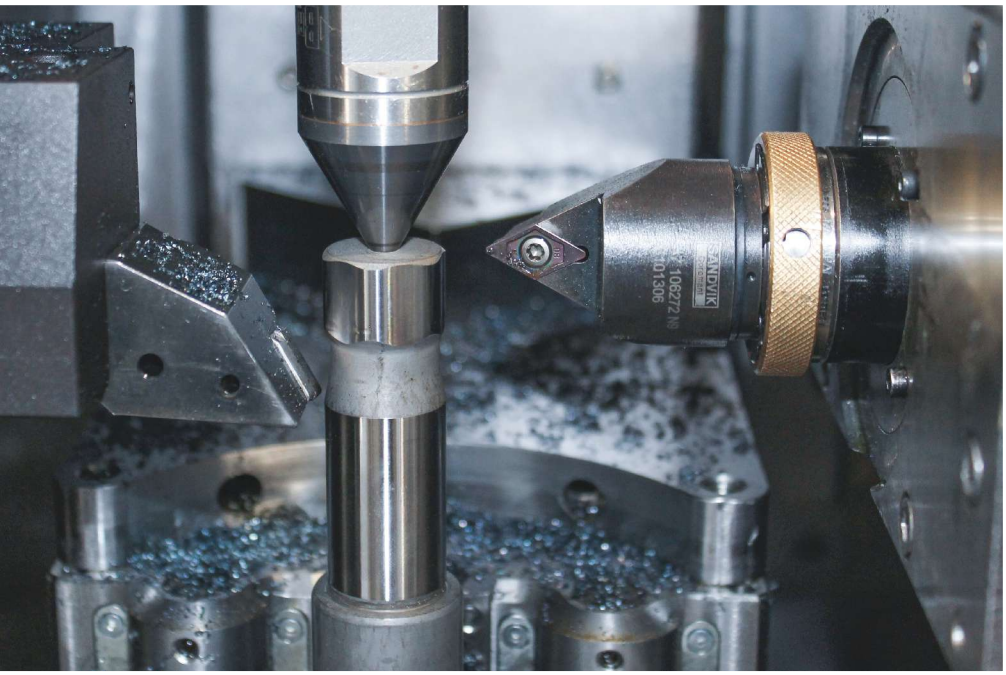
The HOT system is integrated in the Weisser vertical turning machine Vertor C in a separate unit. The interaction of the workpiece spindle axis with the diameter-generating feed axis of the tool produces oval or out-of-round shapes.



Reiner Jörg, head engineer of machine tool builder Weisser’s R&D department in southern Germany, explains how customers in the automotive industry can benefit from Weisser’s dynamic out-of-round turning.



The movement of the tool’s cutting edge is in the direction of the X axis and, therefore, perpendicular to the workpiece spindle axis. The cutting edge can be positioned variably in this notional plane so that radial and frontal contours or hemispherical out-of-roundness can be produced.



Weisser demonstrated HOT out-of-round turning technology at AMB 2018, Germany's metalworking show.

allowable rpm of the workpiece is related to the maximum acceleration of the tool bit, as produced by the oscillating drive. A nominal acceleration of 30 Gs facilitates the highest accuracy and the generation of a first-class surface finish," Mr. Jörg says.

Impulse Neutralization Ensures Precision

Despite the high nominal acceleration, special shock-absorbing properties ensure precision by limiting the force exerted on the machine base structure. "Our system compensates acceleration forces by turning acceleration work into kinetic energy, so machine vibrations are eliminated and high-surface qualities achieved,"Mr. Jörg says. Due to the integrated cutting force compensation, the net cutting forces (passive forces) can be almost entirely neutralized."

One of Weisser's customers manufactures polygonal cams in less than a minute in one setup and four turning passes, including face machining and chamfering operations. At 1,500 rpm, the out-of-round turning unit generates a feed rate of 0.1 mm per rotation and a cutting depth of 0.8 to 2 mm. The parts are finished with an accuracy of 10 microns.

Another customer that has gone a step further than many international competitors has already integrated a polygon coupling into a newly developed gearbox, using Weisser's HOT technology. "The customer replaced the spline shaft with a polygon shaft in the seventh gear, which reduced the shaft length from 20 to 12 mm since the polygon has a greater capacity for torque than any other shaft attachment, so a shorter shaft connection can be used and valuable space saved," Mr. Jörg explains. All in all, 6 mm of space savings helped optimize the transmission ratio of the first gear, which encountered fatigue problems with the original design.

Pushing its HOT technology for polygon shaft-hub connections, Weisser has sold around 100 machines with an integrated out-of-round turning unit so far. It is now offering its Vertor C vertical turning machine with an automatic tool changer to enable even more flexible machining. According to Mr. Jörg, the achievable accuracy is currently limited by the capacity of the CNC. "If you run your machine at 1,800 rpm and want to machine your part with a resolution of one degree with our out-of-round turning unit, the controller has to handle 9,180 signals per second. We are talking about a resolution in the area of nanoseconds. That's the limiting factor; but we are working on further limiting these system boundaries to machine at a micron tolerance level."

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