Mechatronic Chuck with 4 Degrees of Freedom Precision Positioning

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Abstract

The precision of machine tools has continuously advanced due to the integration of optimized sensor and actuator systems. Nevertheless, the clamping of workpieces especially in turning chucks is usually effected by solely mechanic solutions. This offers the possibility of a significant increase of clamping– and positioning accuracy by application of mechatronical approach.

This paper presents such a novel chuck concept. By the integration of mechatronic elements, the workpiece can be aligned in four degrees of freedom after being clamped in the machine tool. The aim of the mechatronic chuck is to increase the clamp repeat accuracy, to reduce the allowance of a part and to shorten the cutting time. The possibility of the alignment of big gears by such chuck systems (as needed for example in wind power plants) is presented.

1 Introduction and purpose

The mechatronic chuck with 4 degrees of freedom is designed for precise alignment of precision-forged gear shafts previous to a hard turning process. In a precision forging process the gear shaft will be forged near-net-shape. Before the following process steps, a reference geometry has to be built in a turning process. Because of the low allowance the crank shaft has to be aligned precisely to assure that a machining of all functional surfaces is possible. By precision forging in combination with the precision positioning chuck it is possible to shorten the process chain for the production of gear shafts and thus save costs.

Figure 1 shows the assembly of the mechatronic chuck in a sectional view. Eight piezoelectric actuators, four in one level, allow a precise positioning of gear shafts in four degrees of freedom. The lower actuator level enables a positioning of the workpiece in xy-direction by tilting the core. The tilting of the core will be transformed into a tranlational movement by flexure hinges and enables a movement of the pivot of the workpiece for eccentric error compensation. The stroke of the piezoelectric actuators is doubled by leverage. A tilt of the workpiece can be compensated by the upper actuator level. By tilting a swash plate, the actuators enable an adjustment of the tilt of the pivot in φψ-direction. Further information concerning the design of the mechatronic chuck is published in [1] and [2].

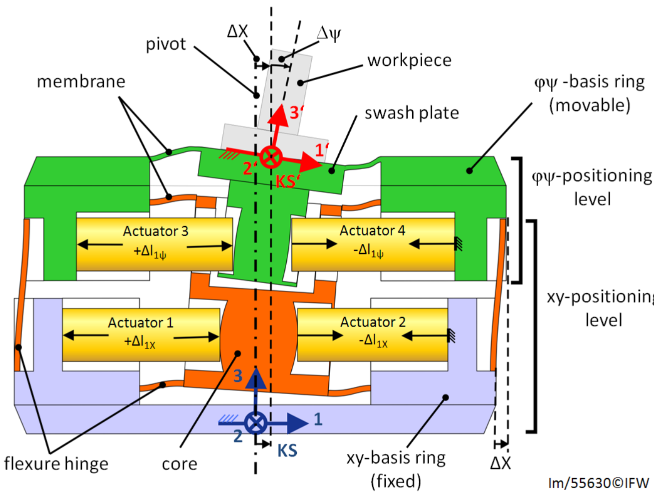

Figure 1: Schematic assembly of the mechatronic chuck

2 Experimental verification

For verification a prototype of the mechatronic chuck has been built and integrated into a turning machine. The control of the piezoelectric actuators is implemented by means of an integrated micro-controller. The power supply is realized wireless by magnetic induction. The micro-controller communicates wireless via Bluetooth with a computer for data transmission and control [3].

In Figure 2 the prototype is shown in the turning machine. To verify the precision of positioning, two optical sensors were also implemented into the machine in cooperation with the Institute of Measurement and Automatic Control [4]. One sensor measures a first section of the workpiece position near the clamping and the other sensor measures a second section at the end of the workpiece.

The verification showed a maximum adjustment of an eccentric error of ±83 µm with a positioning accuracy of less than 0.1 µm and an adjustment of the tilt of ± 0.06 ° with an accuracy of less than 0.15×10^{-3} °.
Beyond the precision of positioning, the radial stiffness of the mechatronic chuck has been determined in experimental verifications to 23.2 N/µm with active position control at the clamping system. The first eigenfrequency of the mechatronic chuck was identified at 267 Hz.

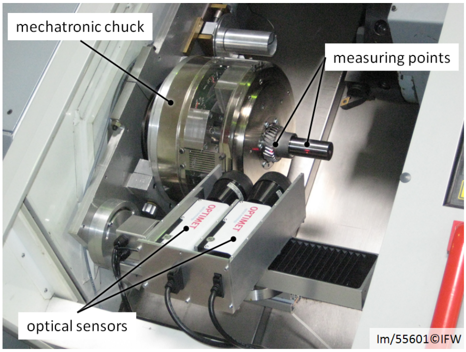

Figure 2: Prototype of the mechatronic chuck in a turning machine

The functionality has also been verified in machining experiments up to 2000 rpm using aluminum and steel shaft. Surfaces of a high quality can be machined in a chatter free turning process. Hard machining was verified using CBN cutting inserts.

3 Transferability to Wind Turbines

Tooth breakouts of gears in wind turbines are a common issue and often lead to failure [5]. The reason for tooth breakout can be an under-dimensioning of the gears, but another reason can be the precision of the gears. The pitch cycle diameter has to be concentric to the bearing diameter. Otherwise, the teeth are loaded unequal and an overload occurs. By precise positioning of the gears with the mechatronic chuck before turning the bearing face, eccentric errors will be avoided. With an accordant scalability the assembly of the mechatronic chuck can be integrated into the clamping system of a turntable of a gear grinding machine. Research activities concerning this matter are envisaged.

4 Conclusion and Outlook

A mechatronic chuck with 4 degrees of freedom precision positioning has been designed. By precise alignment of gear shafts with the mechatronic chuck the repeat accuracy increases, the allowance and thereto the cutting time can be reduced. In combination with precision forging and the precision positioning chuck it is possible to shorten the process chain clearly for the production of gear shafts and save thus costs. A prototype has been build up. The precision of positioning has been verified. A chatter free turning process is possible. With an accordant scalability of the mechatronic chuck the results can be transferred to the production of gears and gear shafts for wind turbines to increase the precision and reduce the failure rate.

5 Acknowledgement

The authors would like to thank the German Research Foundation (DFG) for their support and the funding of the associated project "SFB 489". The presented results refer to the sub-project A5.

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