Precise Alignment of Precision Forged Crankshafts in a Grinding Machine

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Abstract

Within the Collaborative Research Centre (CRC) 489 at the Leibniz Universitaet Hannover a new and innovative process chain for manufacturing of crankshafts is being investigated. A direct grinding of the burr-free and near-net-shaped precision forged and immediately heat treated crankshafts omits soft pre-machining and reheating. By this shortening of the process chain, the production cost can be significantly reduced. On the other hand, a precise alignment of these workpieces prior the grinding process is required to ensure an optimal processing of the seats. To distribute the available allowance on the bearing according to technologically useful criteria such as unbalance and allowance, the IFW in cooperation with the IMR are researching the active alignment of long components inside the grinding machine. In this paper, the approach of the measurement of a clamped crankshaft by an optical measuring device and its adjustment during the grinding process by an active tailstock is presented.

1 Introduction

Forged crankshafts have a higher load capacity and ductility compared to casted crankshafts. Due to their lighter weight and smaller dimensions, their application is moving to automotive engines [1]. Precision forged crankshafts are directly hardened after forging by an integrated heat treatment and then finalised by grinding only [2]. The process steps of deburring, cooling, soft pre-machining and reheating can be omitted. This new production process requires adapted subsequent process steps due to the characteristics of the new supply chain.

To clamp the workpiece during the grinding process, centre holes are required. The centre holes of near-net-shaped precision forged crankshafts are bored in the outer bearing seats centrically prior to the final grinding process. Hardness distortions and the allowance arrangement of all bearing seats are not being considered. On this account, the crankshaft axis does not coincide with the optimum machining axis. An in-process alignment regarding eccentric and tilt errors is necessary to allow a reject-free machining in spite of the low allowance.

The geometry and position of the clamped crankshaft can be measured by an optical inline measurement system (see Figure 1). Based on the measurement data an adjustment vector is calculated, which adjusts the eccentric and tilt error. In path controlled grinding, the degree of freedom (DOF) of the pendulum stroke of the grinding machine can be used to correct the eccentric error. A corresponding value can be assigned to the machine control. The tilt error of the crankshaft is corrected by a new active hydraulic tailstock (see Figure 1) by displacing the workpiece at one side as a function of the angular position of to the crankshaft.

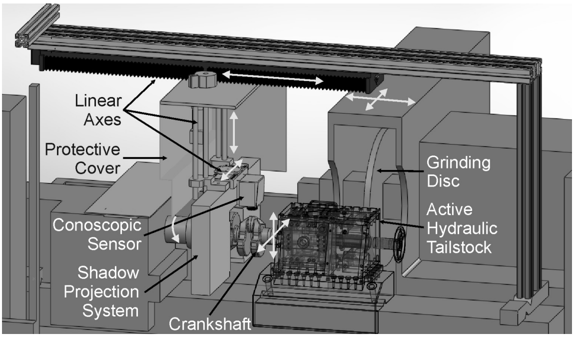

Figure 1: Schematic construction of the precise alignment system

2 The optical measurement system

For detection of positioning errors concerning to the machining axis, the position of the geometric elements of the crankshaft have to be measured. Therefore, an optical measurement system is integrated into a pin chasing grinding machine (see Figure 2). It currently consists of a shadow projection system, a conoscopic sensor and three linear axes. The shadow projection system detects the main and pin bearings and the conoscopic sensor measures the crank webs, while the crankshaft is rotating. Due to the fact that the sensors are one-dimensional, the sensors have to be moved by the linear axes to the measurement positions. A protective cover has been constructed to protect the measurement system against cooling lubricant and chips. An adjustment vector, which contains the correction of the eccentric and tilt error, can be provided to the actuating elements. A continuative approach is to approximate the unbalance of crankshafts only with the geometric data of the inline measurement system to combine the grinding process with the balancing of crankshafts. So the adjustment vector also contains the position corrections, which are needed to minimise the unbalance of the measured crankshaft during grinding of the bearings [3].

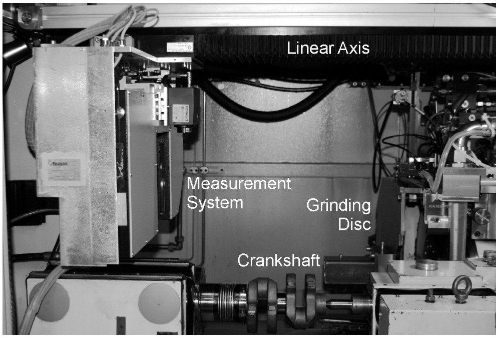

Figure 2: Inline measurement system for acquisition of geometric data of crankshafts

3 Active Hydraulic Tailstock

The active tailstock has to produce a counter-tilt during grinding. For this purpose, a dynamic drive of the tailstock center in two DOF as a function of angular position and angular speed is necessary. This shall be achieved by the use of two linear axes consisting of hydraulic screw-in short stroke actuators with a stroke of 4 mm [4].

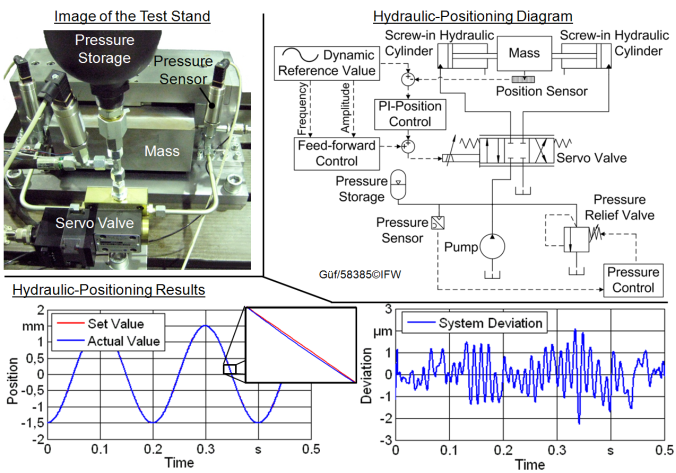

Figure 3: Layout and results of the hydraulic-positioning test stand

Hydraulic screw-in cylinders offer the advantage of a high power density. More important, they can be integrated into the structure. The dynamics of the hydraulic tailstock is currently designed to a rotational speed of the crankshaft up to 600 rpm with an accuracy of ± 2 µm. The hydraulic cylinders can apply a force of more the 8000 N. To verify the positioning behavior of the hydraulic system a single DOF test stand of one hydraulic axis has been built up. Figure 3 show an image of the test stand and the hydraulic-positioning diagram. An equivalent mass of 50 kg is positioned by a PI-position control. Based on a circular movement of the tailstock centre to generate a counter-tilt, a sine-wave has to be positioned in one axis. To enhance to the dynamic reference reaction a feed-forward control is added to the PI-controller. By the feed-forward control the reaction time of the hydraulic system can be compensated.
In the lower part of Figure 3 the positioning accuracy with a frequency of 5 Hz and amplitude of 1.5 mm is shown. The maximum deviation amounts 2 µm.

4 Conclusion and Acknowledgement

This paper describes a new approach of a positioning system, which can align long components during machining. Based on the data of the geometric elements of the crankshaft an adjustment vector can be calculated under different criteria. For this accomplishment an active tailstock is designed, which can realise an optimal machining position in combination with the pendulum stroke of the grinding machine.
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