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Investigation of a fine positioning method in lathes using an active clamping chuck

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Abstract

For an active compensation of workpiece clamping failures in lathes a novel fine positioning method using an active chuck is developed. The position of the workpiece is determined by two tactile displacement sensors. The chuck consists of integrated stepper motors which compensate eccentric displacement and tilting errors. The corrected position is fixed by frictional locking caused by the tensile force. All components required for this purpose are implemented in a lathe and examined in a turning process. The results proof a significant reduction of eccentric errors and the basic suitability of this method.

Lathe, fine positioning, clamping technology

1. Introduction

For contemporary industrial turning operations a precise positioning of the workpiece is mandatory to achieve demanding tolerances and avoid rejects. Particularly in case of complete machining reclamping of the workpiece is needed and requires a high correspondence between both clamping positions. Therefore, common clamping devices require a manual workpiece alignment. For a reduction of the resulting ancillary time and number of rejects, there is a need for automatic fine positioning of the workpiece after the clamping operation. In previous works a first-generation active clamping chuck with four degrees of freedom was investigated [1]. With the help of this piezo-actuated system a fine positioning in two translational degrees of freedom is realized to compensate eccentric displacement. Another two axes correct wobble errors. The realized operating ranges are ± 80 µm respectively ± 0.06° with an overall radial stiffness of 23.2 N/µm [2, 3].

To comply with the aim of adapting this principle to the requirements of industrial manufacturing processes the achieved operating ranges, stiffness and clamping forces must be increased significantly. Therefore, a second-generation fine positioning chuck was investigated with a modified construction, a different choice of actuators and a revised control principle [4]. Here, stepper motors with integrated spindle gears are chosen to actuate sliding surfaces with operating ranges of more than ± 250 µm respectively ± 0.25°. These actuators are driven by an open loop control. The corrected position has to be fixed by frictional locking afterwards. The main advantages of this method are a high stiffness and the capability to resist upcoming process forces. Experimental investigations demonstrate a radial stiffness of 120.1 N/µm, a maximum load transmission of more than 2 kN respectively 100 Nm and a sufficient positioning accuracy by using an external motor controller [4].

In the following, the overall system configuration is presented. This system enables an automation of the part centering procedure before the start of the machining process. In this paper, the second-generation system is prototypically implemented into a lathe and experimentally investigated by means of a turning process.

2. Fine positioning sequence

For this active chuck, the tensile force of the drawbar shaft serves two functions: it applies the nominal clamping force at the jaws and additionally delivers the normal force for the frictional locking so that the gliding surfaces (constructed as planar and ball joints) act as friction clutches. Hence, the hydraulic clamping cylinder of the lathe has to suspend its pressure temporarily to enable the positioning movements of the axes. Tension springs apply a relatively small force to hold the gravity forces but enable active movements by the actuators. Figure 1 illustrates the positioning sequence before the machining process.

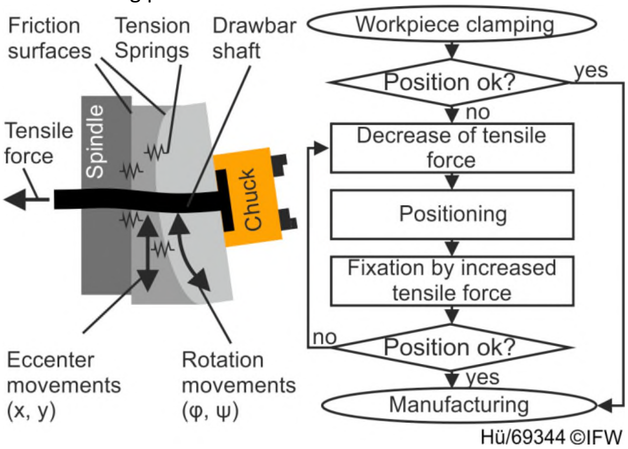

Figure 1. Principle structure and fine positioning sequence

3. External clamping position measurement system

The procedure depicted in figure 1 requires an external measurement system that detects the workpiece position, decides whether a correction is mandatory and calculates the setpoint values for the axes if necessary. With regard to the requirements of industrial manufacturing environments two tactile displacement sensors are chosen: one for measuring the axial and one for the radial direction (figure 2). Measurements at three positions between the clamping jaws offer the ability to determine its position in all degrees of freedom. The setpoints for the active chuck are then calculated to compensate the detected position failure. Afterwards, the setpoints are transmitted to the control electronics inside the rotating chuck via Bluetooth.

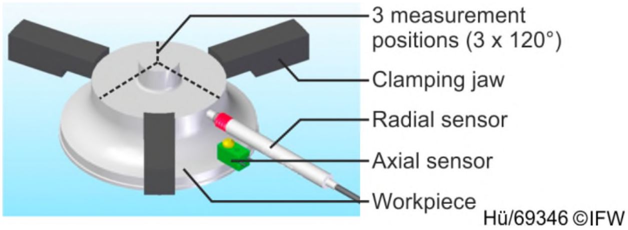

Figure 2. Sensor configuration

For investigations of the repeat accuracy of the whole measurement system the sensors are mounted on the tool turret inside the test lathe Gildemeister CTX420 (figure 3). The overall accuracy consists of the measurement accuracy of the sensors and the positioning accuracies of the involved X-Axis and tool turret rotation axis. Table 1 lists the results of the analysis. The repeat accuracies of both sensors are only slightly larger than 1 µm when moving the X-axis. Even in case of additionally using the tool turret rotation they remain below 3 µm. With respect to the permitted manufacturing tolerances of 20 µm in radius it can be noted that this measurement system is suitable for the application according to figure 1.

Table 1 Measurement repeat accuracy of the sensor system

	Measurement repeat accuracy	
	Without tool turret rotation	**With** tool turret rotation
Radial sensor	1.19 µm	2.27 µm
Axial sensor	1.17 µm	2.80 µm

4. Investigations in a manufacturing process

For the experimental validation of the entire system including the active clamping chuck, the measurement system, the sequence control and the wireless data transfer the experimental setup on a lathe Gildemeister CTX 420 (figure 3) was also used. Since the required temporary suspension of the tensile force is not feasible on the standard lathe, the safety- and non-return valves inside the clamping cylinder were demounted. Thus it is possible to manually adjust the tensile force by manipulating the pressure control valves.

When increasing the force after positioning an unacceptable radial displacement of up to 120 µm occurs at the end effector. This effect is due to a self centering of the ball joint of the active chuck. As a result the ball joint was demounted and replaced by an adapter. Afterwards the experiments were carried out for an eccentric positioning system with two degrees of freedom.

Two cylindrical turning operations were executed on each aluminium alloy test workpiece (figure 3) at 780 rpm: one before and one after the positioning step according to the sequence shown in figure 1. To induce initial positioning failures laminations were manually inducted between one clamping jaw and the workpiece. The eccentricities of both resulting surfaces were finally measured by a coordinate measuring machine in order to provide benchmarks for the evaluation of the positioning process.

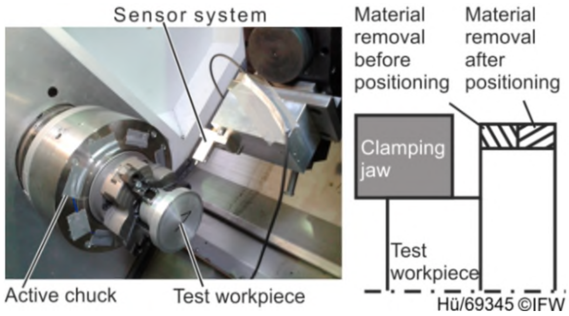

Figure 3. Experimental setup (left) and test workpiece (right)

Table 2 lists the results of a test with a single positioning step and a test with an iterative adjustment. Here, the position was corrected three times in a row before increasing the tensile force. Though the initial position failures are significantly decreased in both cases, the residual eccentrics of up to 32.2 µm respectively 24.9 µm are not tolerable for a precise manufacturing. The reason for this is the inability of the open loop control implemented on the integrated circuit board to handle irregular effects like friction and reverse clearance.

Table 2 Results of the final positioning processes

	Eccentricity **before** positioning	Eccentricity **after** positioning
Single positioning step	235.8 µm	32.2 µm
Multiple positioning steps	160.1 µm	24.9 µm

5. Summary and conclusion

A novel fine positioning method for lathes using an active clamping chuck is presented with regard to industrial requirements. Although the principle suitability of this method is proven, an implementation that takes safety regulations into account requires further development work concerning the clamping cylinder. It must be able to temporary decrease the tensile force without compromising security during the manufacturing operation.

The workpiece measurement can be realised by tactile sensors being attached to the tool turret with an overall repeat accuracy of less than 3 µm and thus requires no further improvements. Tests in a lathe proof a significant reduction of eccentric clamping failures from 235.8 µm to 32.2 µm. To reduce these remaining errors an implementation of a close control loop is promising since a threefold positioning repetition improves the eccentricity to 24.9 µm.

Acknowledgement

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