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Centre displacement device for eccentric turning of large workpieces

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Abstract

Large cylindrical inhomogeneous workpieces are commonly mounted on lathes using four-jaw independent chuck. Adjusting the rotation centre of the workpiece is done manually and is thus prone to human error. Flexible workpiece rotation centre adjusting is especially prone to errors because contact with the workpiece is changed every time the rotation centre is adjusted.

A device for centre displacement adjusting was developed. The main principle is that with the new device, the rotation centre of the workpiece can be adjusted without changing the contact with the workpiece. The device is mounted on the lathe spindle by replacing the chuck. The working principle of the device is that the rotating centre of the workpiece is adjusted by changing the angular displacement between two eccentric members in the device. Rotation of the eccentric members is locked with a spring force produced by a steel membrane. The membrane is operated with hydraulic pressure so that pressurization unlocks the rotation of the eccentric members and vice versa. The test device is equipped with a 315 mm standard three-jaw chuck and is designed to withstand 2500 Nm of maximum throughput torque.

The device was validated using a static torque load measurement. According to the conducted tests, the device is capable of operating with at least 2800 Nm of throughput torque. The maximum eccentricity is 20 mm and the hydraulic pressure needed to operate the membrane is 250 bar. The device increases the accuracy of the machining process and moreover reduces the risk of accidents.

Turning, workpiece holding, eccentric

1. Introduction

Centering of large inhomogeneous workpieces and eccentric turning processes commonly utilizes four-jaw independent chucks. Adjusting the position of the workpiece and clamping it with high accuracy require expertise and the mounting of large flexible workpieces has low repeatability using conventional methods. This study develops a device for adjusting the rotation centre of a workpiece in relation to the rotation centre of the lathe in a precise, repeatable, and safe way.

A four-jaw independent chuck is the most common device used to adjust the centre of rotation of workpieces in turning. Very few alternative devices have been developed. The state-of-the-art review uncovered two devices intended for eccentric turning in lathes, developed and patented in the 1940s and 1960s [1-2]. Both devices are intended for small-diameter workpieces and utilize uniaxial eccentricity adjustment, which allows adjustment of the rotation centre in only a single axis. Biaxial eccentricity adjustment is advantageous with inhomogeneous workpieces, as the magnitude and direction of the eccentricity can be individually adjusted in relation to the workpiece's section profile. Biaxial turning profile adjustment can also be performed, for example, with a computer-controlled tool holder system. Several systems with similar purpose have been published earlier [3-5].

2. Methods

The structure of the developed device is shown in Figure 1. The frame and the membrane unit are bolted together, which forms the body for the device and a cavity between the components. The combination of the frame and membrane unit is located inside the 1st eccentric member, and furthermore, the 2nd eccentric member is located topmost. The pull stud is threaded to the center of the membrane unit and the three-jaw chuck is mounted on the 2nd eccentric member.

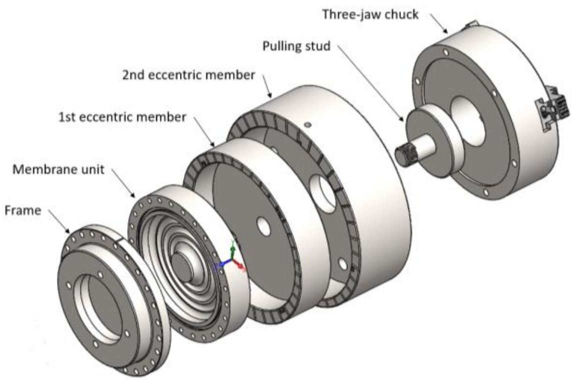

Figure 1. *Exploded view of the centre displacement device*

The center axis of the internal bore of the eccentric members has 10 mm eccentricity in relation to the external surface. By changing the angular displacement between the body and the eccentric members, the displacement between the center lines of the three-jaw chuck and the lathe spindle can be adjusted without steps and biaxially. Angular displacement is adjusted with a specially made pin wrench from the rear surfaces of the eccentric members.

The cavity formed by the frame and the membrane unit is used as a hydraulic membrane actuator. A pull stud, connected to the center of the membrane, is used to lock the rotation of the eccentric members. The locking of the rotation is achieved by friction between the contact surfaces of the membrane unit and the eccentric members. The surfaces are coated with a friction-increasing material used in clutches. Pressurization of the cavity deforms the membrane and introduces axial clearance between the eccentric members, allowing rotation of the members. In contrast, depressurization of the cavity locks the rotation by compressing the components axially with the spring force of the membrane.

2.1. Investigated device

The investigated test device was designed to be used with a standard three-jaw chuck with diameter 315 mm, whereas the outer diameter of the device is 400 mm. Figure 2 presents the realized prototype mounted on a lathe spindle.

Figure 2. *Centre displacement device mounted to the lathe.*

The target throughput torque for the device was set to 2500 Nm, according to the average maximum throughput torque of lathes with the corresponding chuck size. The structure between the body of the device and the eccentric members corresponds to a disc clutch, so furthermore the structure of the membrane was scaled according to the needed compression force between clutch elements. The design parameters of the device are presented in Table 1.

Table 1. *Design parameters of the centre displacement device.*

Chuck size	315 mm
Device outer diameter	400 mm
Max eccentricity	20 mm
Operating pressure	250 bar
Max throughput torque	2500 Nm

2.2. Measurement setup

The measuring process consisted of a test which proofs the maximum throughput torque of the device. The device was mounted directly on the lathe spindle and spindle rotation was prohibited with separate feature supporting the device to lathe guideways. A long beam was mounted on the chuck of the device and an accurately known mass was placed on the end of the beam.

Internal slipping of the clutch surfaces in the device under static torque load was measured. The measurement was conducted using dial gauges by measuring the difference in the location of the chuck before and after the loading cycle. Figure 3 presents the maximum throughput torque measuring process where the maximum applied torque was 2800 Nm.

3. Results

The realized test device met the design targets according to the performed tests. The chuck displacement after maximum throughput torque test was lower than 0.01 mm, which means that the clutch surfaces did not slip notably.

Unlocking the rotation of the device was successfully performed with 250 bar hydraulic pressure applied to the chamber. The eccentric members were rotated manually with a pin wrench with similar ease before and after the maximum throughput torque test.

Figure 3. *Maximum static throughput torque was measured by using a beam and an accurately known mass. The figure presents the unloaded situation where the mass is hanging from an overhead crane.*

4. Discussion

The centre displacement device is efficient equipment for machining tasks where accurate eccentric workpiece mounting is required. Eccentricity adjustment without changing the contact with the workpiece is advantageous especially with flexible workpieces, because of its higher repeatability.

The realized test device achieved the set goals and performed the operational tests as expected. The maximum throughput torque is the most important limiting operational factor with the device and according to the conducted tests, the device produces enough throughput torque capacity for most use cases. Even though the device performed well under a static torque load, the maximum throughput torque could not be obtained due to the torque limitation of the lathe used in the test setup. Therefore, further studies should investigate the performance of the device under dynamic loading conditions.

The centre displacement device can be combined with a computerized measuring setup which measures the roundness and, with tubular work pieces, the wall thickness variation of the workpiece and defines the needed centre displacement according to the desired end product properties, be it minimized unbalance, maximized bending stiffness or minimized dynamic deformation. The system gives direct adjusting values to be applied by the centre displacement device. The computerized measuring system increases the profitability of the system significantly and so it is a highly recommended add-in with the centre displacement device.

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