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RESEARCH OF THE INFLUENCE OF CLAMPING FORCES ON THE ROUNDNESS DEVIATIONS OF THE PIPES TURNED SURFACE

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Abstract

In practice, pipe products are often produced. The surfaces of these components are often turned. The three-jaw chuck is often used to clamp the components for turning. It is a universal clamping fixture. The main advantage of three-jaw chuck is its high flexibility. However, its disadvantage is the inappropriate influence of the clamping forces on the geometrical accuracy of the produced components. This article deals with research of the influence of clamping forces on the roundness of turned pipes. A universal three-jaw chuck was used. The chuck was tightened using a torque wrench. The applied tighten torques were determined by monitoring the commonly used torques for a manually tightened chuck. The article presents the results of experimental research.

Key words

Pipe, three-jaw chuck, clamping forces, tightening torques, roundness

INTRODUCTION

Clamping forces make workpieces elastically deformed if their stiffness in the direction of the clamping forces is low. The component surface is deformed at the contact point of the clamping element. If the surface is convex, more material than depth of cut is cut-off. The geometric shape obtained by machining is correct on the clamped workpiece.

The workpiece is deformed. Once the clamping forces are released, it will return to its original shape. After being disengaged, the workpiece is deformed, because it returns to its original shape.Such deviations are significant when clamping thin-walled bush, rings, tubes, and the like. Small clamping forces must be used for small workpieces stiffness and high precision required. When the internal surface is machined, the resultant thickness at the jaw-ring contact points would be minimal. Moreover, the machined internal surface would be more relaxed; so when the piece is released, the machined surface will deform much more than that of external surface that has not been modified. If we transfer the cylindrical shape to the original outer surface, the inner surface is deformed "mirroringly" to the clamping points. It is illustrated in Fig. 1. (1)

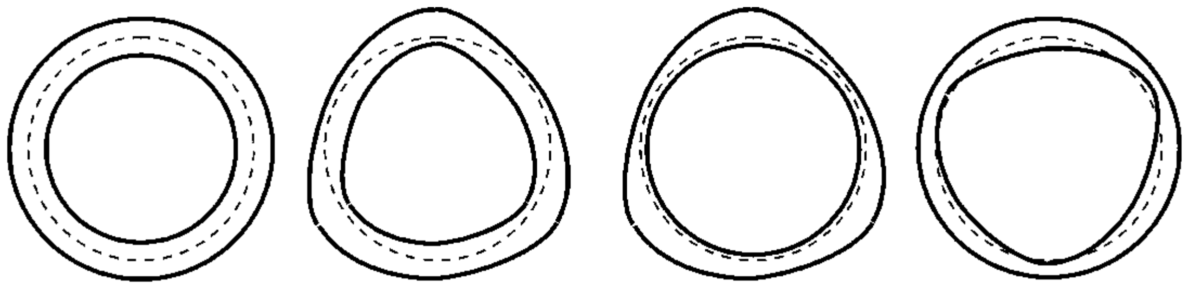

Fig. 1 *Ring shape evolution from the original to the final stage (1)*

The workpieces deformation can be avoided by using appropriate clamping. Instead of clamping in the three-jaw chuck, it is possible to clamp using a ring or using special chuck jaws. For example, there is a large contact area between the segment lathe chuck (Fig. 2 – a) and a component. In contrast, there is a small contact area between the common lathe chuck (Fig. 2 – b) and a component.

Fig. 2 *Segment (a) and common (b) lathe chuck (2)*

A number of papers have been published, which indicates that the subject of interest is still important. The method of geometrically adapted cutting to reduce machining irregularities has become public knowledge since it was first time discussed in 1970 by Peklinik (3). Also, Shawky et al. (4) showed that it was possible to minimize the minor wall thickness deviation by an adapted cutting in the same manner.

Brinksmeier (5) states that the inner machining in a 3-jaw-chuck causes a triangular shaped out-of-roundness. By clamping on a segment chuck, the formed deviation of the inside is inversely transferred to the outside. The segment jaws cause a triangular deformation of the outside in the opposite direction. As the wall thickness is decreased by the inner machining, the clamping force must be lowered for the outer machining to allow an annihilation of both. A disadvantage of this clamping sequence is that the wall thickness deviation becomes maximal. In contrast to that, an angular shift of 60° between the internal and external clamping minimizes the wall thickness deviations, but leads to the maximal out-of-roundness.

Grote (6) recommends the use of hard jaws for outer clamping and segment jaws for inner clamping. The segment jaws have to imply a triangular deformation of the ring which, in clamped state, annihilates the deformation caused by inner machining. The use of a mandrel enables the production of rings with a constant wall thickness.

By Beekhuis (7), if clamping forces are kept constant, the elastic deformation of a ring increases due to the clamping forces with decreasing rings' stiffness.

Görög (8) and Maračeková (9,10,11,12) deal with experimental research, too. Some publications also deal with the mathematical solution to this problem. For example, Estrems (1,2,13) presented a model to estimate the total deformation of turned rings.

MATERIAL AND METHODOLOGY OF EXPERIMENT

Thick-walled pipes were selected for experimental research. The machined workpiece was made of steel S355J2H (STN 41 1503). The chemical composition of the material is shown in Tab. 1.

Table 1: Chemical composition of steel S355J2H (% by mass, maximum)

C	Si	Mn	P	S
0.22	0.55	1.60	0.035	0.035

Mechanical properties of the steel S355J2H are: yield point Re = 335 to 355 MPa, resistance to tensile stress Rm = 490 to 630 MPa, elongation A = 20 to 22 %. The dimensions of the used thick-walled pipes are shown in Tab. 2.

Table 2: Dimensions of the thick-walled pipes (mm)

Dimension of pipe	Outer diameter	Inside diameter	Wall thickness	Length
∅ 89x16	∅ 89±1	∅ 57±1	16	60±0.1
∅ 70x17.5	∅ 70±1	∅ 35±2	17.5	
∅ 70x10.5	∅ 70±1	∅ 49±1	10.5	

The thick-walled pipes were chucked into the three-jaw chuck by turning. The torque wrench was used for tightening the chuck. Tightening was always performed at one tightening point. Clamping was similar to that of a key wrench attached to the chuck. The tightening torques were chosen by monitoring the tightening torque during manual tightening of the chuck - 100, 130 and 160 N.m.

Turning was performed by the SUI 500 COMBI lathe. The pipes were turned from the inside. The SANDVIK S25T-PCLNR 12 boring tool was used for turning with the cutting insert KORLOY CNMG 120408-HM NC 3020. The cutting insert material NC 3020 corresponds to P15 to P30 class cemented carbide. It is a coated cemented carbide (MT-TiCN + Al2O3 + TiN) designed for medium steel machining. First, unevenness of the surface was aligned to ensure the same depth of cut. The pipes were subsequently turned by the recommended cutting conditions:

- Cutting speed: $v_c = 180$ m.min^{-1},
- Depth of cut: $a_p = 1$ mm,
- Feed: f = 0.2 mm.

The position of all the pipes clamping was the same as during turning. Fig. 3 presents chucking of the pipes and simultaneously the planes in which the roundness and cylindricity of the pipes was measured.

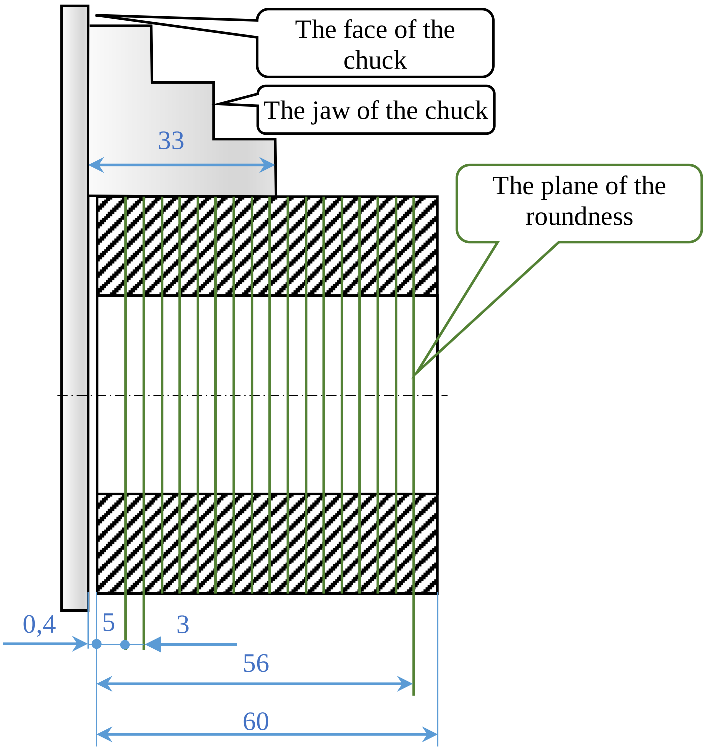

Fig. 3 *Chucking of the pipe and planes during the roundness measurement*

The machined pipes were measured on the Rondcom 60A roundness machine. The first roundness was measured 5 mm from the face of the pipe which was turned at the face of the chuck. Roundness was measured in 18 sections in increments of 3 mm, as can be seen in Fig. 3. As many as 3600 points were measured in each section.

Roundness was evaluated by the MZC Minimum Zone Circle method. In this method, two circles are used as reference for measuring the roundness error. One circle is drawn outside the roundness profile just as to enclose the whole of it and the other circle is drawn inside the roundness profile so that it just inscribes the profile. The roundness error here is the difference between the radiuses of the two circles. This method is shown in Fig 4 (14).

Out of the 18 measured roundnesses, cylindricity was evaluated, too (18*3600=64800 points).

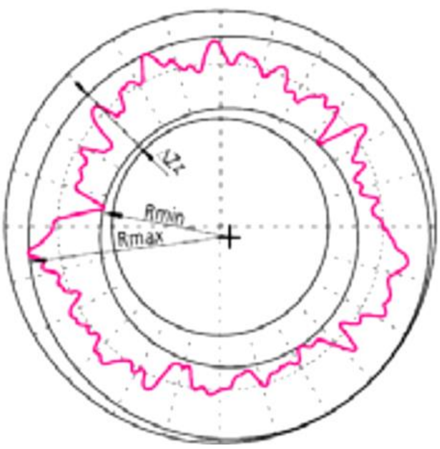

Fig. 4 *The Minimum Zone Circle (MZC) method (14)*

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ATTAINED RESULTS

Two samples were taken from each pipe size. They were machined and measured in the same way. The arithmetic mean was taken from the measured values. Figs. 5, 6 and 7 present the results of the average roundness on the machined pipes which were tightened in the chuck at a torque of 100, 130 and 160 N.m.

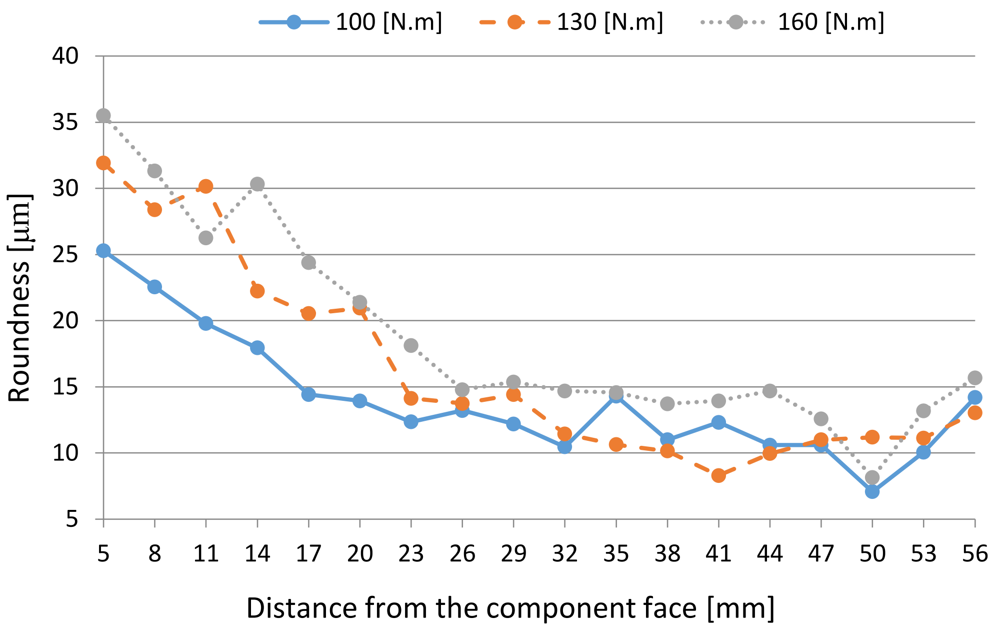

Fig. 5 *Roundness of the pipe ∅89x16*

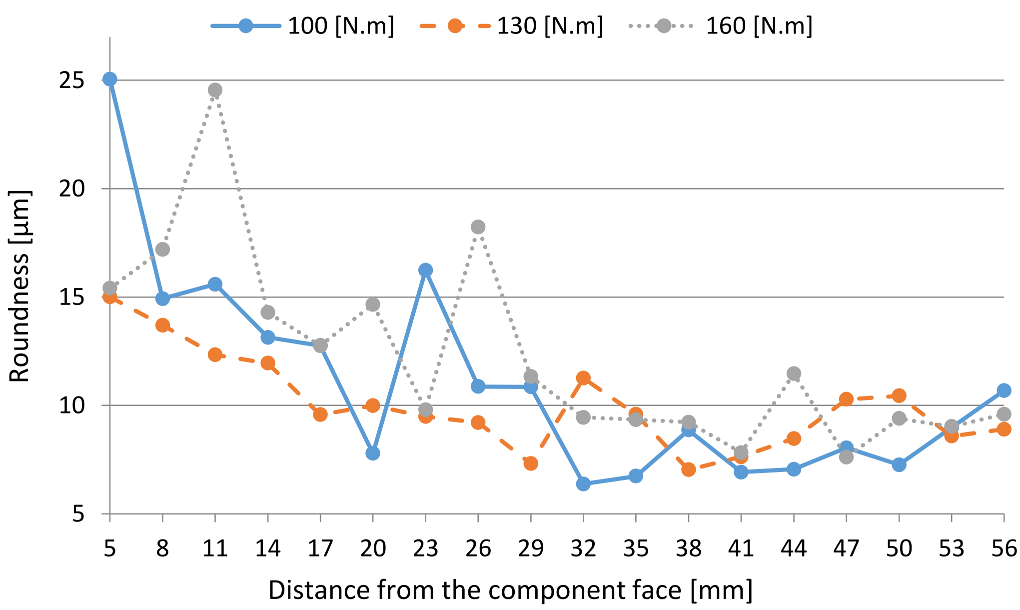

Fig. 6 *Roundness of the pipe ∅70x17.5*

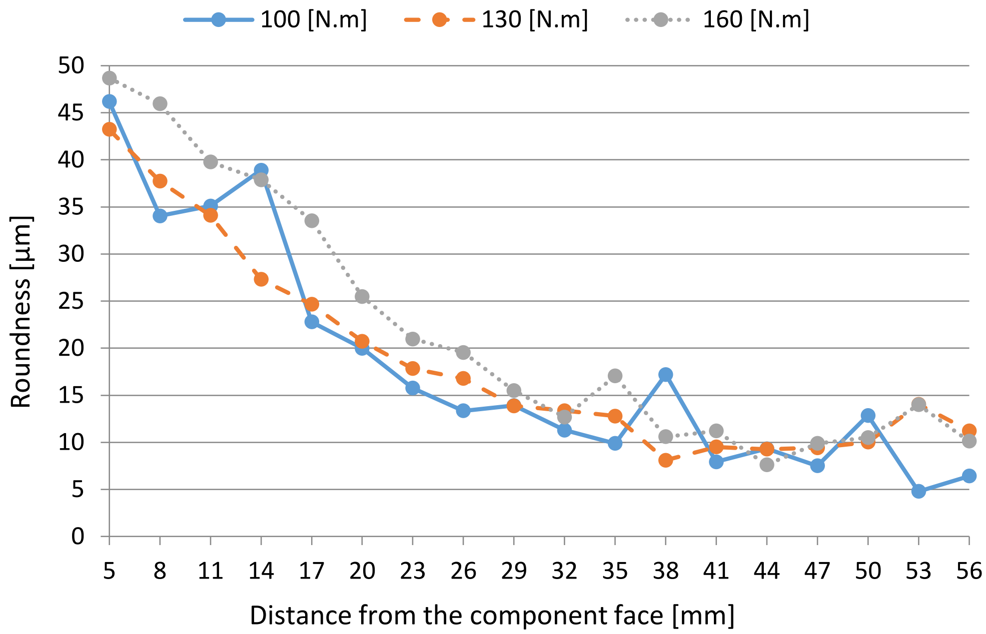

Fig. 7 *Roundness of the pipe ∅70x10.5*

Cylindricity results are presented in Figs. 8. In Fig. 9, there is a graphical representation of the pipe cylindricity Ø 70x10.5 which was tightened at 100 N.m torque. The third harmonic component is the most dominant in this graphical representation. It was caused by deformation during the chucking into the three-jaw chuck.

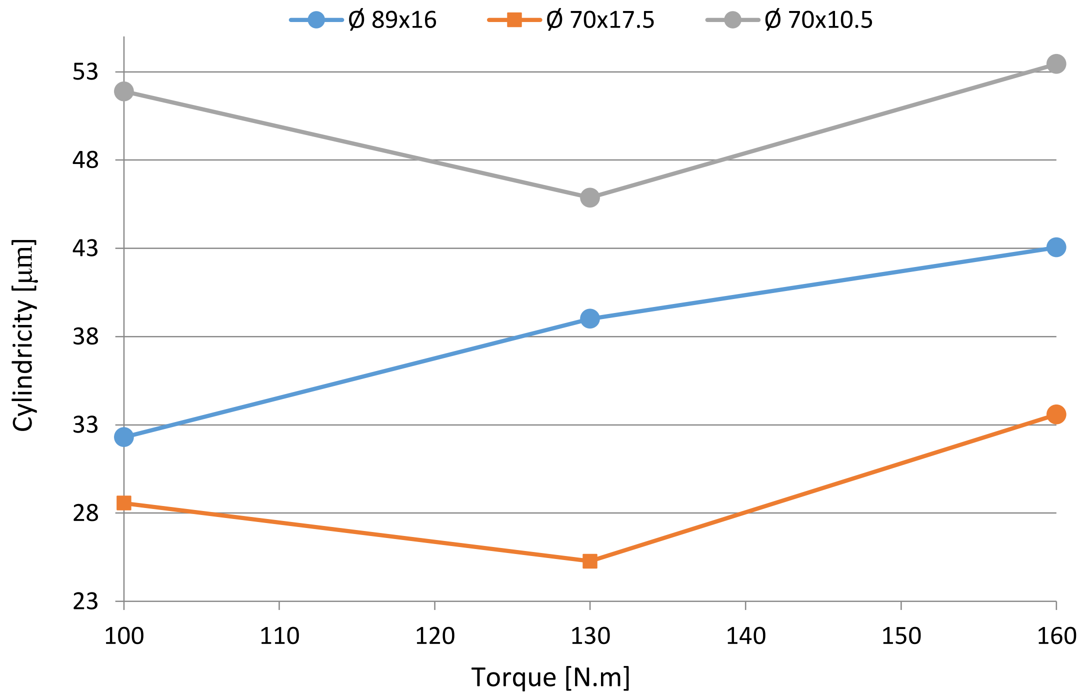

Fig. 8 *Cylindricity of the pipes*

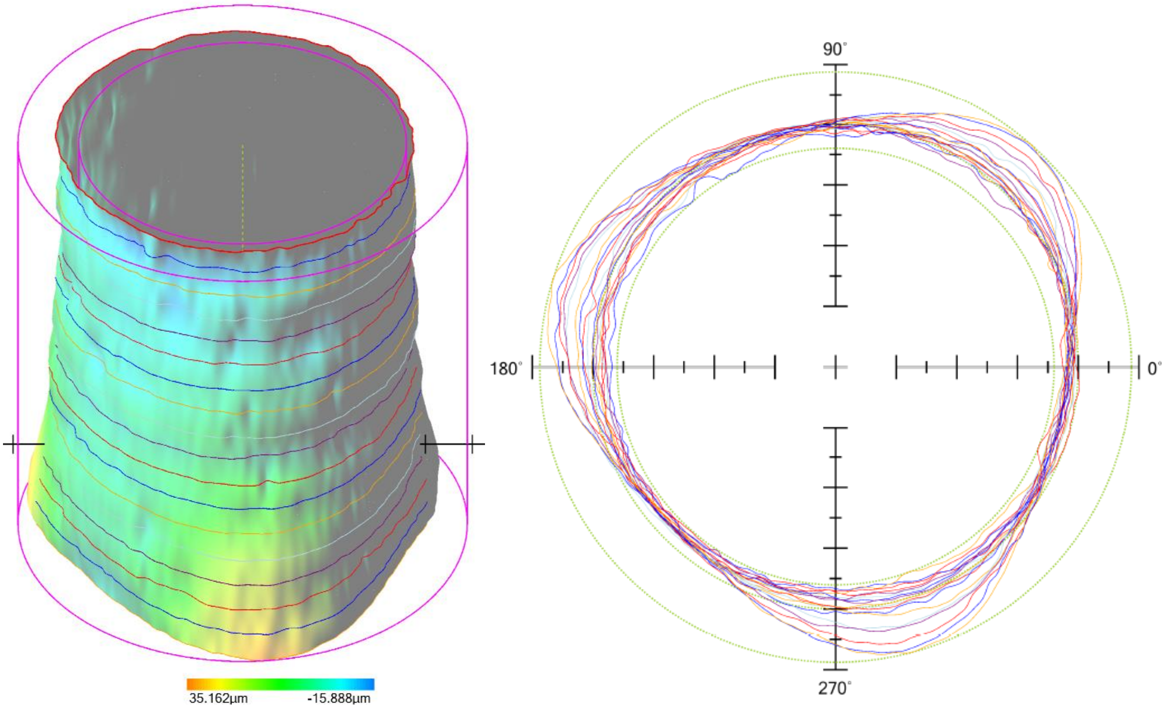

Fig. 9 *Graphical representation of the pipe cylindricity Ø 70x10.5*

CONCLUSION

The following statements can be made on the basis of the measured values:

- Circle values are the highest at the front of the component, that it is clamped in the chuck.
- The round profile is of a “triangular” shape – the third harmonic component is dominant
- If the distance from the front of the component increases, the roundness decreases.
- Roundness decreases only on the clamped part of the component - there is a deformation effect of the clamping.
- Roundness varies on the free part of the component - due to accidental effects of machining
- Roundness depends on the wall thickness of the pipe – the smaller the wall of thickness, the higher the roundness.
- Roundness depends on the clamping forces (tightening torque) – the higher the clamping forces (tightening torque), the higher the roundness
- Cylindricity increased slowly due to the influence of the clamping forces (tightening torque)

Acknowledgement

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