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EXPERIMENTAL STAND FOR THE STUDY OF THE CONSTRUCTIVE–FUNCTIONAL CHARACTERISTICS OF SELF–CENTERING MANDRELS WITH BILATERAL CHUCK COLLETS WITH DIRECT CONE

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Abstract: The paper presents an experimental stand with the help of which the constructive–functional characteristics of the self–centering mandrels with bilateral chuck collets with direct cone, used to center and tighten the cylindrical parts for cutting processing, can be studied. The device is equipped with mechanical systems for the application of an axial force and a torque, thus simulating the force and the cutting moment. Two systems, consisting of compression force transducers, connected to the DigiForce 9307 data acquisition system, are used to measure the applied forces. With the help of the stand, two dependencies can be determined experimentally, namely: between the axial force at which the part slides axially in the collet and the clamping force of the part in the mandrel, as well as the tangential force at which the piece rotates in the chuck collet and the clamping force. At the same time, the sliding frictional coefficients in axial and tangential directions can be determined.
Keywords: fixture design, collets, clamping force, experimental equipment

1. CHUCK COLLETS: CONSTRUCTION AND CALCULATION

Self–centering mandrels with bilateral chuck collets with direct cone are used for the orientation and fixing of parts on machined external surfaces, for turning, semi–finishing and finishing operations, achieving an accuracy of 0.05 ... 0.1 mm [1].

The design and calculation dimensions of the bilateral chuck collets with direct cone used in the construction of the mandrels are shown in Table 1 and Figure 1.

Table 1. The sizing of the bilateral chuck collets with direct cone [2]

Parameter	Calculation relations
d	imposed value
α angle	$\alpha=29^0$ or $\alpha=30^0$ – constructive recommended value
t_1	t_1 – constructive adopted value (t_1=4…6 mm)
D	$D = d + 2 \cdot t_1$
l	$l = 1{,}67 \cdot \sqrt[4]{D^3}$
b	$b = 0{,}6 \cdot \sqrt[3]{D}$
R	$R = (0{,}2 \ldots 0{,}4) \cdot D$
b_1	$b_1 = 2 \cdot b$
L	$L = 2 \cdot \frac{3{,}3 \cdot D}{\sqrt[6]{D}}$
t	$t = 0{,}37 \cdot \sqrt{D}$
R_1	$R_1 = t$
l_1	$l_1 = L - 1{,}5 \cdot l$
n	n – number of notches, constructive adopted value, depending on the diameter of the part; d < 30 mm, n=3; d = 30…80 mm, n=4; d > 80 mm, n=6.

The main calculation relations necessary for the design of the mechanisms with chuck collets refer to the calculation of the actuation force F_a depending on the total clamping force F and to the stroke of chuck collet c_a depending on the radial stroke of a jaw c_f.

The calculation relations for F_a were deduced from the equilibrium equations of the chuck collet, required by the forces F_a, F, the friction forces F_{f1}, F_{f2} – between the different elements of the mechanism – forces F_b – needed to deform the chuck collets from free state to contact with centering surfaces – and the normal reactions N of sleeves or rigid cones [1].

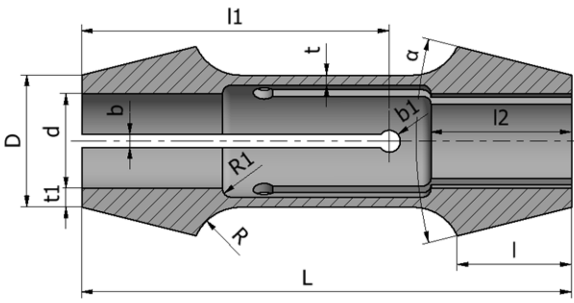

Figure 1. The main dimensions of the bilateral chuck collets with direct cone

According to figure 2, the maximum clamping force F is determined as follows:

$$F_a = T_2 - T_1 + 2F_{f2},$$

$$F_a = \left(\frac{F}{2} + F_b\right) tg(\alpha + \varphi_1) - \left(\frac{F}{2} + F_b\right) tg(\alpha - \varphi_1) + \mu_2 F, \quad F = \frac{2F_a - 2F_b \cdot \left(tg(\alpha + \varphi_1) - tg(\alpha - \varphi_1)\right)}{tg(\alpha + \varphi_1) - tg(\alpha - \varphi_1) + 2\mu_2},$$

where:

F_b – the force needed to deform the chuck collet to the contact with the semi–finished product, N;

For bilateral chuck collets,

$$F_b = 2\lambda \cdot \frac{D^3 \cdot t \cdot J_{max}}{l^3}, \text{ N.}$$

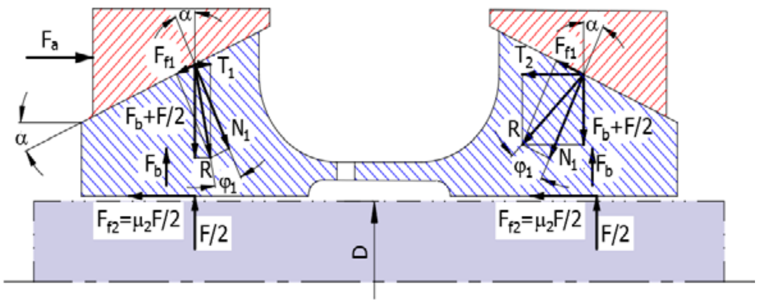

Figure 2. Clamping force calculation scheme

λ – coefficient, λ = 588 for collets with 3 blades; λ = 196 for collets with 4 blades;

D –inner diameter of chuck collet, mm; t – the thickness of a blade, mm;

l – the distance from the point of application of force F_b to the point of embedding;

J_{max} – the maximum diametrical clearance between the intended collet and the workpiece, J_{max}=0,2 mm;

α – half–angle of the cone, α =15°; φ_1 –the friction angle between the chuck collet and the sleeve,

μ_2 – the coefficient of friction between the chuck collet and the part;

c_a – the stroke of the chuck collet;

$$c_a = \frac{c_f}{tg\alpha} = \frac{t_D + J_{min}}{2 \cdot tg\alpha} = \frac{t_D + 0{,}1...0{,}2\,mm}{2 \cdot tg\alpha}$$

c_f – the radial stroke of a jaw; t_D – tolerance to diameter D; J_{min} – the minimum clearance required for easy installation and removal of the part, J_{min}=0,1…0,2 mm.

The maximum cutting moment that can act on the semi–finished product without rotating it on the collet is:

$$M_{asch} = \frac{1}{k} \cdot F \cdot \frac{D}{2} \cdot \mu_{2t},$$

where: k – safety coefficient; k=1,5 for finishing turning, semi–finishing and grinding ;

D – inner diameter of the chuck collet, mm; μ_{2t} – coefficient of friction, in tangential direction, between the chuck collet and the outer surface of the semi–finished product $\mu_{2t} = 0{,}05...0{,}1$.

The maximum axial cutting force, F_{asch} is:

$$F_{asch} = \frac{1}{k} \cdot F \cdot \mu_{2a}, \text{ N}$$

where: μ_{2a} – coefficient of friction, in axial direction, between chuck collet and the inner surface of the semi–finished product, $\mu_{2a} = 0{,}1...0{,}2$.

2. CONSTRUCTION OF MANDRELS WITH BILATERAL CHUCK COLLET WITH DIRECT CONE

Figure 3 presents the construction of a mandrel with bilateral chuck collet with direct cone. The chuck collet 4 is deformed due to conical collet 3 and the inner conical surface machined in the part 5. The part 5 moves along the mandrel axis due to the threaded joint. When screwing part 5, the deformation of the chuck collet jaws occurs, resulting in the orientation and fixing of the workpiece. On the mandrel body 1, the screw 6 opposes the rotation of the chuck collet in the mandrel body, and the plug 2 serves to axially support the part. When unscrewed, the jaws of the collet return to their original position by the elasticity of the connecting slats between the active parts of collet.

3. CONSTRUCTION OF THE EXPERIMENTAL STAND

For the study of the functional characteristics of self–centering mandrels with bilateral chuck collets with direct cone, an experimental stand is proposed whose general scheme – 3D modeled in Autodesk Inventor [3, 4] – is presented in figure 4.

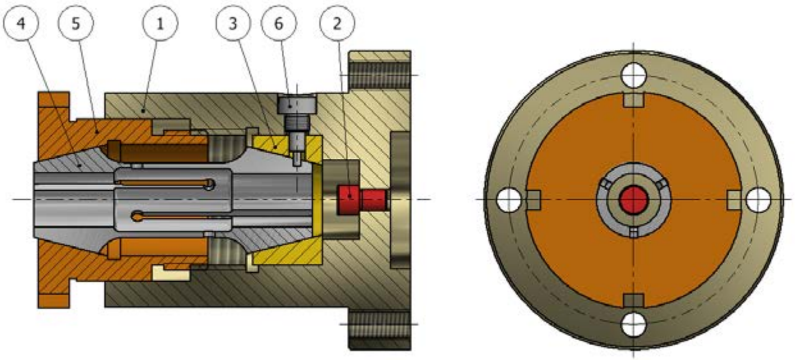

Figure 3. Mandrel with bilateral chuck collet with direct cone, manually operated

It consists of a self–centering chuck 1, whose components can be identified in figure 3, mounted with the help of cylindrical head screws and hexagonal slot M12 on the vertical plate 2. Plates 3 and 2 make up the base plate of the stand, which are also assembled with the help of cylindrical head screws and hexagonal slot.

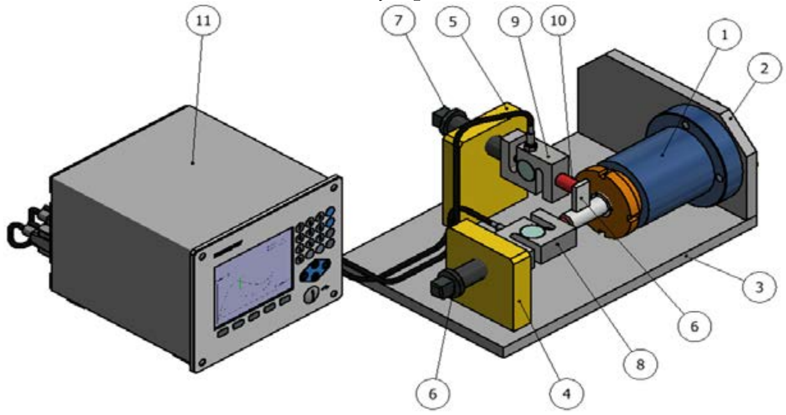

Figure 4. The general scheme of experimental stand

Because with the help of the experimental stand it is wanted to study the constructive–functional characteristics of the mandrels with bilateral chuck collets with direct cone, systems for applying an axial force and a twisting moment were provided, thus simulating the force and the cutting moment. These systems consist of the support plates 4 and 5 and the screws 6 and 7. The support plate 4, together with the screw 6, ensures the application of an axial force whose direction coincides with the axis of the chuck. The support plate 5 and the screw 7 allow a twisting moment to be applied to the workpiece.

For the measurement of the applied forces, two systems can be used, consisting of trading compression forces 8 and 9, connecting to the DigiForce 9307 data acquisition system, noted with 11 in the figure. With 10 we noted the pressing elements, which make the connection between the force transducers 11 and the cylindrical mandrel type workpiece.

4. EXPERIMENTAL PROCEDURE

Insert part 6 in the mandrel 1 and apply, with a torque wrench, a known torque moment to the actuator (pos. 5 in figure 3), thus achieving the orientation and tightening of the part. An axial force is then applied to the part 6 with the screw 6, measurable with the force transducer 8, identifying on the acquisition system screen the value for which the part slides axially along the chuck axis, because the value of the axial force remains constant (or starts slightly to decrease) even if we continue to operate the screw 6.

To subject the workpiece tightened to the self – centering chuck to a moment of rotation, actuate the screw 7. The value of the moment at which the part starts to rotate in the chuck, around its axis, is determined by calculation, multiplying the value of the force measured with the transducer 9 and read on the screen of the acquisition system by its arm (35 mm). The device also allows the determination of the sliding friction coefficients between the chuck collet and the part.

Thus, for determining the coefficient of sliding friction in the axial direction μ_{2a}, a part is fixed in the mandrel and an axial force is being applied, a frictional force F_{fx} will appear between the jaws of the collet and the semi–finished product, which will oppose the axial movement of the part and whose expression has the form:

$$F_{fx} = \mu_{2a} \cdot F$$

From the condition of equilibrium at the limit:

$$F_{fx} = F_a \text{ or } F_a = \mu_{2a} \cdot F,$$

The value of the axial friction coefficient μ_{2a} between collet and the part can be obtained:

$$\mu_{2a} = \frac{F_a}{F}.$$

Similarly, by applying a tangential force, F_t, to the part, at a distance L = 35 mm from the axis of the part, this moment of rotation is opposed by a moment of frictional force between the part and the chuck collet. From the equation of equilibrium of the active moment M_t and friction moment M_f:

$$M_t = M_f \text{ or } F_t \cdot L = \mu_{2t} \cdot F \cdot \frac{D}{2},$$

the value of the sliding friction coefficient in the tangential direction can be determined:

$$\mu_{2t} = \frac{2 \cdot F_t \cdot L}{D \cdot F}.$$

5. CONCLUSIONS

The wide use of the orientation–fixing mechanisms provided with chuck collets within the machine building industry imposes the need for their constructive and functional study [3,5–8,10] in order to use them in optimal and favorable conditions, a situation that involves the development of stands to study them in laboratory conditions [4,9].

The stand designed for this paperwork meets this need, thus allowing dependence relationships between energetic parameters at cutting (axial force, tangential force) and the clamping force of a self–centered mandrel with bilateral chuck collet with direct cone mechanism. These dependences can be useful in the stages of technological design of cutting processes that use such mechanisms for the orientation–fixing of semi–finished products. Furthermore, with the help of this stand, by using the procedure described in the experimental procedure, the coefficients of sliding friction on axial and tangential directions can be determined.

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