Experimental Determination of the Loading Capacity of the Elastic Bracelet Assembly

I Geonea[1], N Dumitru[1], C Copilusi[1] and A Margine[1]

[1]University of Craiova, Faculty of Mechanics, e-mail: igeonea@yahoo.com

Abstract. In this paper we aim to experimentally determine the bearing capacity (the momentum) of the elastic bracelet assemblies. The moment of torsion transmitted by the assembly depends on the clamping force of the assembly and on the friction coefficient between the bushing mounted on the shaft and the hub of the assembly. An experimental stand is used which comprises a hub shaft assembly with a segmented elastic bracelet. The load bearing capacity of the elastic bracelet is determined depending on the strength of the screws. Experimental determination is made on three types of materials. For this purpose, on the shaft is assembled a bush made of different materials: aluminum, bronze, steel. In order to determine the capable assembly moment, strain gauge transducers are used to measure the elastic strains. The recording of the deformations is done by means of an efficient data acquisition system. The assembly characteristic is plotted, namely the dependence between the torque transmitted according to the tightening of the bolts, for three couples of materials.
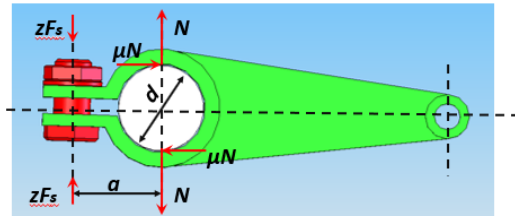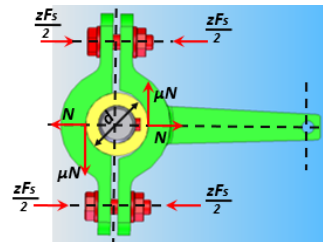
1. Introduction

The aspect of experimental tests of assemblies is the subject of numerous published articles. Thus, experimental researches are presented regarding the experimental determination of the bearing capacity of the cone clamping shaft assemblies [1], the experimental determination of the efficiency of the cylindrical gears [2], the experimental determination of the friction torque in the threaded assemblies [3] or the experimental determination of the friction torque in the bearings [4].

In this paper we aim to perform the experimental determination of the bearing capacity of the hub shaft assembly with elastic brace according to the clamping force of the clamping screws. The elastic bracelet, also called bracket or clamp, is part of the shaft-hub assemblies by tightening. The operation of these assemblies is based on the frictional forces occurring between the elements, resulting from the action of normal forces on the contact surfaces (figure 1 and figure 2). The normal force required to transmit the torque is achieved with the clamping screws. The magnitude of the friction forces depends on the value of the friction coefficient μ and it is influenced by a number of factors: the pair of materials, the macro and micro geometry of the surfaces in contact, the existence and nature of the lubricant, the existence of oxides, the existence of vibrations, etc.

Elastic brace assembly is used to lock circular shafts of cranks, bearings, transmission wheels, etc. when the load capacity is reduced or parts require frequent adjustment. These joints allow mounting and adjustment of the conjugated parts in any angular or axial position along the length of a constant diameter shaft section. The bracelet connections can be with cover (figure 2) or with the unilaterally cut hub (figure 1) when is called clamps. The contact surface of the joint parts may be smooth or roughed.

Figure 1. Elastic bracket from one part.

Figure 2. Elastic bracket from two parts.

The bearing capacity of the joint (the capable moment of transmission) in both constructive variants can be expressed in terms of the tightening torque in the bolts and the displacement law that is accepted for the contact stresses between the joint surfaces of the shaft and the hub.

Assuming that the contact stresses are evenly distributed over the contact surface, the momentum of the assembly is:

 - for elastic bracelet with cover [5]:

$$T = \frac{z \cdot \mu \cdot \pi \cdot d \cdot F_S}{2 \cdot k} \text{ [N·mm]} \tag{1}$$

 - for the elastic bracelet sectioned [5]:

$$T = \frac{z \cdot \mu \cdot (2 \cdot a + d) \cdot \pi \cdot F_S}{2 \cdot k} \text{ [N·mm]} \tag{2}$$

where: T - the momentum of the assembly, [N·mm]; z-number of elastic bracelet clamping screws; µ- the coefficient of friction between the shaft and the elastic brace; d- the diameter of the shaft on which the bracelet is mounted, in [mm]; k-safety coefficient of the assembly. Typically, $k = 1,2 ... 1,5$ and in shock operation $k = 2 ... 4$. F_s - the tightening force of the bolts, in [N] (see figure 2); a=145 mm, is the distance from the axis of the clamping screws to the assembly axis, in [mm];

2. Experimental setup

An experimental test bench is made to determine the load capacity of the assembly. The actuation is by turning the crank 1 which drives the worm and worm gear 2-3 mounted in the casing 6 that is attached to the base 7. The worm wheel 3 is provided with the nut 4 acting on the force bolt 5. This cannot be rotated thanks to the stop 8, and will perform a translation motion. This movement is transmitted via pin 9 to the transducer 10 which, by means of the bolt 11, acts on the arm of the elastic bracket 12. The brace cover 20 is fastened to the body 12 by means of two screws 13. The bolts are tightened by means of the nuts 14 via the transducers 15 and the special washers 16.

The shaft on which the assembly is fastened is constituted by the bush 18 (there are four identical bushings of various materials) which are mounted by means of the parallel wedge 17 on the fixed shaft 19.

The clamping forces of the bolts 13 are measured by means of the force transducers formed by the bush 15 and the washers 16. On the outer surface of the sleeves 15 there are applied two strain gauge transducers (TERs) disposed in a half bridge configuration and connected to an acquisition system.

With the aid of the transducer 10, on which two other strain gauge (arranged in a half Wheatstone bridge) are applied, and the force acting on the arm of the brace is measured. This force acting at a distance of 154.5 mm from the center of the assembly creates an active moment, opposed to the moment of friction forces that develop on the bracelet-tree contact surfaces.

To determine the possible moment of assembly, is proceed as follows:

a) one of the bushings 18 is mounted on the fixed shaft 19;

b) installing the elastic brace without tightening the nuts 14 until the clearance between the parts is cancelled;

c) the transducer 10 is mounted with bolts 9 and 11;

d) zero balancing the electronic equipment;

e) tighten the bolts 13 taking care that the forces developing in them are equal (since the calibration diagrams of the two transducers are practically identical, it will be observed that the indications of the electronic equipment are the same); the indicated values are entered in the result table;

f) rotate evenly the crank 1 so that the screw 5 moves to the left (figure 3), thus tensioning the transducer 10. When the moment created by the force in the transducer equals the moment of the friction forces in the assembly, the slip occurs and the indication of the electronic device no longer grows. That value will be recorded as being appropriate to the capable moment;

g) Unload the transducer 10 by turning the crank in the reverse direction and unscrew the bolts 13. Change the tightening force of the screws and resume the experience.
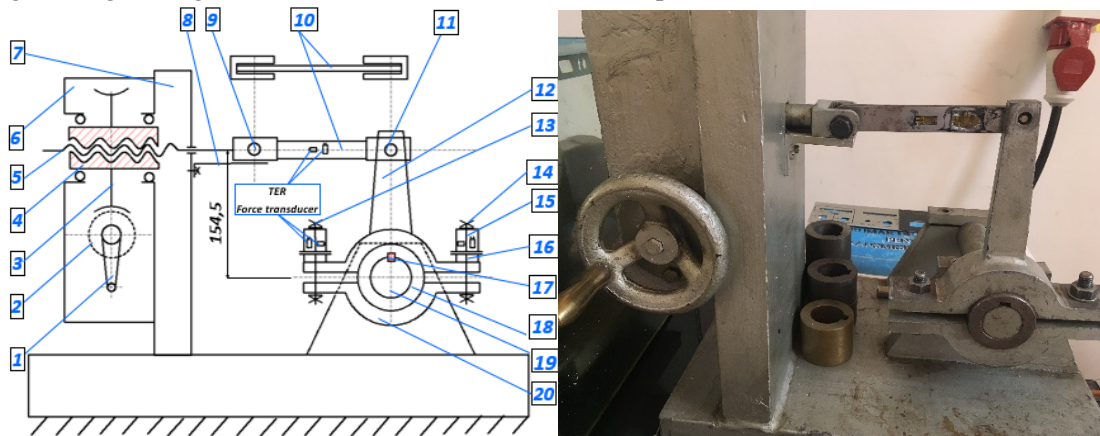

Figure 3. The experimental setup.

The load on bolts 13 will be limited to maximum 1900 N, that means $\varepsilon_1^i = \varepsilon_2^i = \max\ 400\,\mu m\,/\,m$.

The experimental moment is calculated with the equation (3) [6]:

$$T_e = 154{,}5 \cdot F_3\ [\text{N·mm}] \tag{3}$$

The equation (1) determines the theoretically capable torque depending on the tightening forces in the screws.

For each pair of materials, the graph of the torque variation is plotted on Excel, depending on the tightening force of the bolts (experimental and theoretical).

The figure 4 shows the experimental recording of force F_3, which acts in the end of the brace, corresponding to the clamping force F_s of 900 N. The recording is made for the steel and bronze used as pair of materials of the assembly. Note that the force increases to a certain value until slippage occurs. The value of the measured force multiplied by the distance a, gives us the momentum of the assembly.
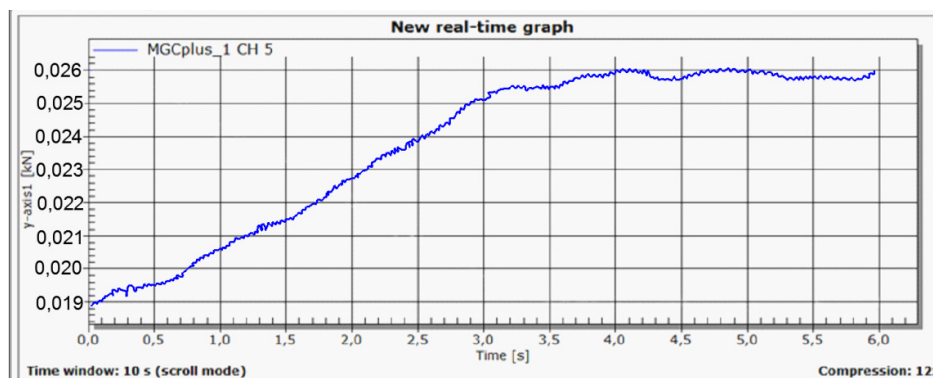

Figure 4. The experimental results.

The graph in figure 4 is obtained for the clamping force of 230 N. In order to determine the dependence of figure 5 is performed progressive tightening of the bolts with force F_s, for which the assembly capable torque is measured. It is noted that the torque transmitted by the assembly increases as the clamping force of the screws increases. Dependence is obtained for the couple of steel and bronze materials.
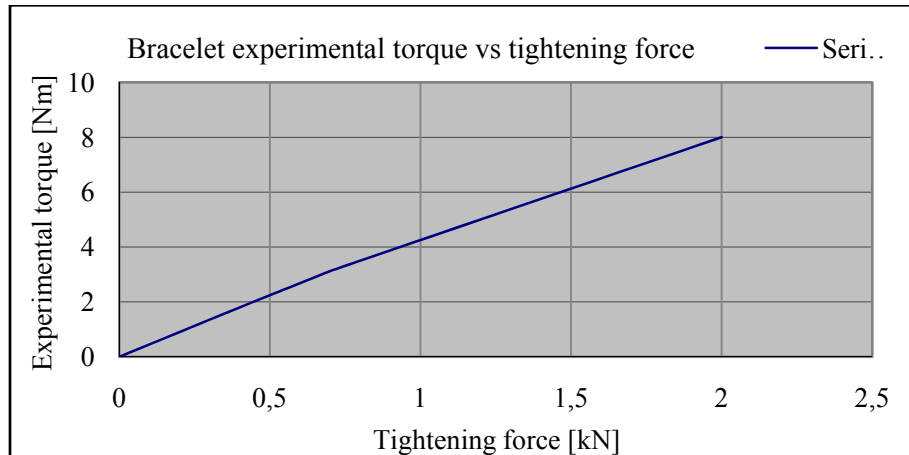

Figure 5. The experimental results.

3. Bracelet structural analysis

To perform the structural analysis of the elastic bracket assembly, we performed the simulation of the experimental stand in SolidWorks. The design of the experimental bench is shown in figure 6.
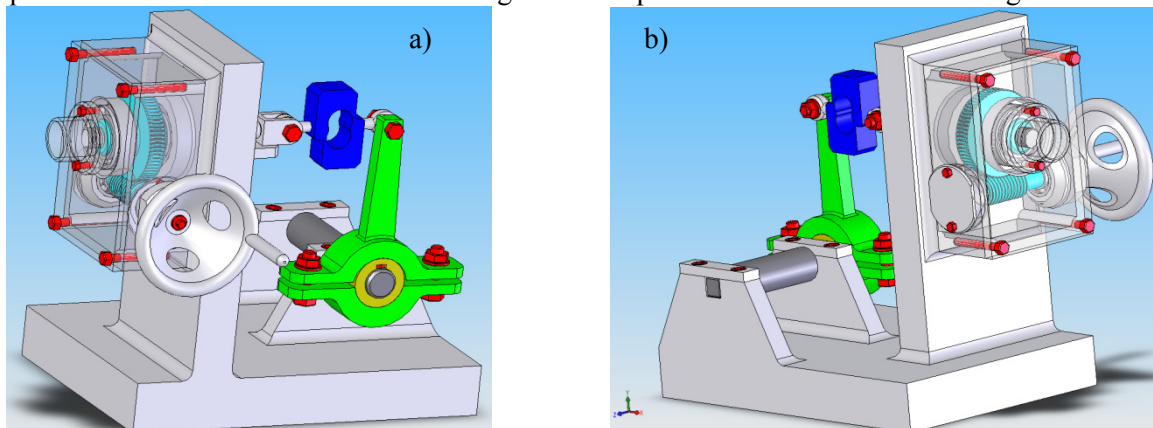

Figure 6. The experimental bench in SolidWorks.

The simplified model of the experimental bench is imported into the ANSYS finite element analysis program. Elements of component elements are defined, contact between elements is defined by the bonded type. The detailing of the contact between the components is shown in figure 7.
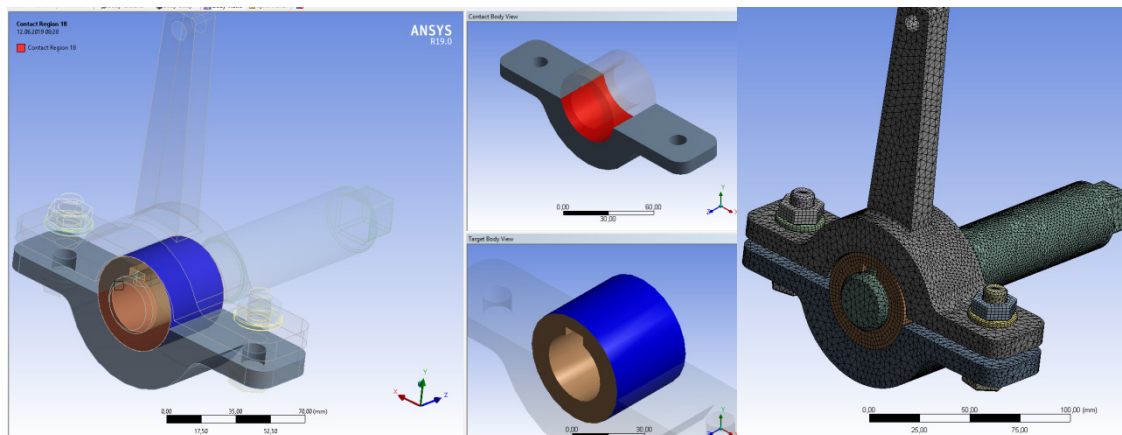
Figure 7. The contact details and mesh in ANSYS.

To perform the structural verification of the elastic bracket, a force of 2000 N is defined in the free end of the brace. As a fixed support is defined the assembly shaft.

The results of the finite element analysis, namely the distribution of the equivalent stresses and the distribution of the elastic strain, are shown in figure 8 and figure 9. The maximum elastic strain of the bracelet assembly is 0.00108 and the total deformation is 0.522 mm. The maximum amount of equivalent stress is 212 MPa.
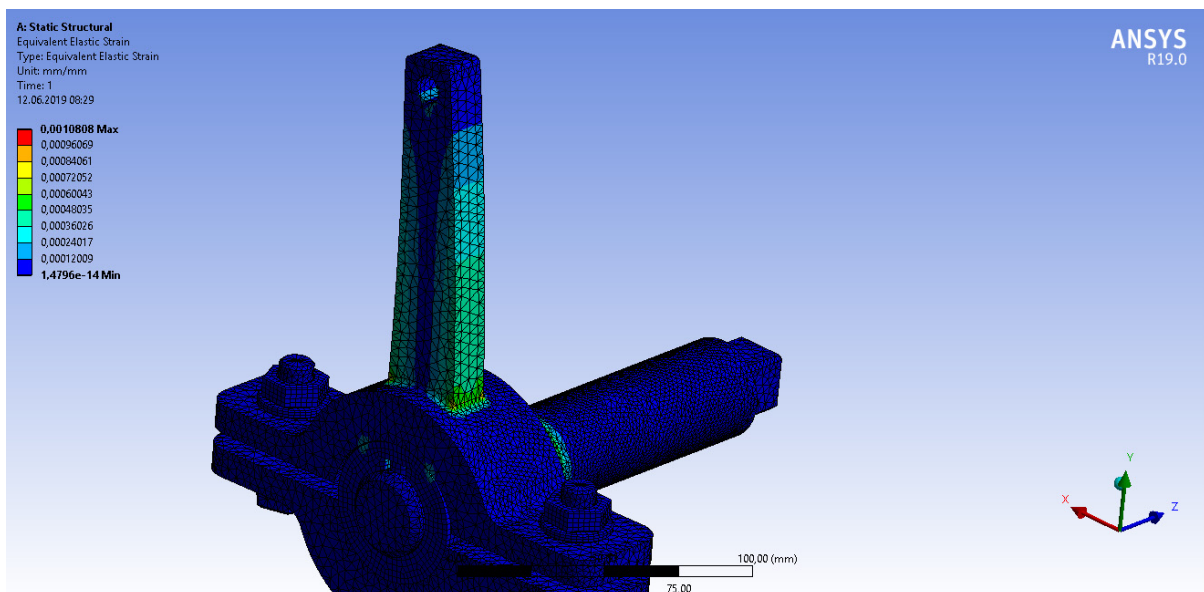

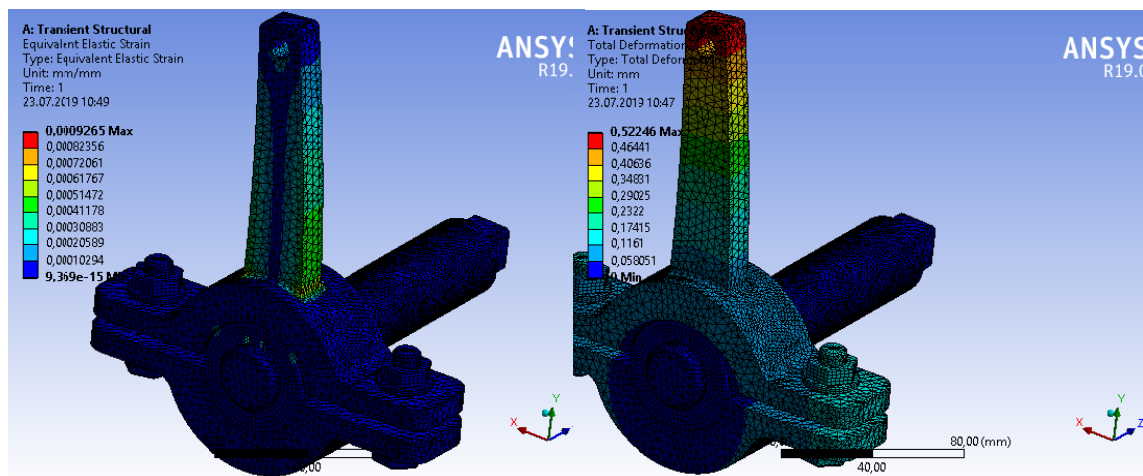**Figure 8.** The equivalent elastic strain distribution in ANSYS.

Figure 9. The equivalent von Mises stress and total deformation in ANSYS.

4. Conclusion
Elastic bracelets are used in the field of agricultural machinery. The carrying torque capacity of the assembly depends on the tightening force of the screws and by the material pair between the shaft and the hub. For the couple of steel-bronze materials, the load bearing capacity of the assembly is shown. Dependence is a linear one. Also stress analysis of the assembly is performed in ANSYS.

5. References
[1]   Geonea I, Dumitru N, Copilusi C, Otat O and Tutunea D 2018 Theoretical and experimental analysis for the load capacity of the cone tightening assemblies *Proc. in Automotive Eng.* **1** 437-445
[2]   Dumitru N, Dragut E, Craciunoiu N and Geonea I 2018 Experimental bench for spur gears efficiency measurement *Mech. and Mach. Sci.* **57** pp 477-485
[3]   Geonea I, Dumitru N, Margine A and Copilusi C 2018 Experimental investigations concerning friction from threaded assemblies *App. Mech. and Mat.* **880** pp 33-38
[4]   Geonea I, Dumitru N and Dumitru I 2017 Experimental and theoretical study of friction torque from radial ball bearings *IOP Conf. Ser.: Mater. Sci. Eng.* **252** 012048
[5]   Mott R L and Tang J 1999 *Machine Elements in Mechanical Design* (London: Prentice-Hall) pp 17-150
[6]   Catrina G, Margine A, Ungureanu C and Dumitru N 2009 *Machine Parts* vol 3 (Craiova: Universitaria) p 122