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Issues to Consider in Determining the Torque Bearing Capacity of Sectional Clamp Assemblies

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Abstract

This work has as scope to theoretically determine and then experimentally check out the dependence between axial clamping force of threaded elements and the torque bearing capacity of the sectional clamp assembly.
In order to carry out tests a sectional clamping assembly is used a specialised stand for torque assemblies testing. Values of functional features analytically determined shall be compared to the results got on experimental way; a good concordance can be noticed between these respective values.

Key words: *assembly, sectional clamp assembly, torque bearing capacity.*

Introduction

The flexible clamp (collar clamp, bracket) achieves assembly by flexible tightening of an external member onto a shaft type internal member [1], [3], [4], [6]. The scope of utilisation of such assemblies is limited to low loads whenever frequent mounting-dismounting jobs are required or tightening needs adjusting or loosening of shaft section is not allowed.

These assemblies allow for interlinked parts to be mounted and adjusted into any angular or axial position over the length of a shaft section having constant diameter. To be noticed that unlike other types of detachable assemblies both mounting-dismounting and positioning of the shaft-clamp pair can be achieved very fast [4], [6].

The main design variants of clamping assemblies are shown in figure 1.

Operation of such assemblies is based on friction forces developing between the assembly elements as a result of typical forces acting onto mating surfaces.

Issues Concerning Calculus with Tightening Clamp Assemblies

The calculus scheme and components of a sectional tightening clamp assembly is shown in figure 2.

The clamp by means of which tightening of shaft 1 is achieved is composed of a sectional clamp 2 tightened with bolt 3 and nut 4.

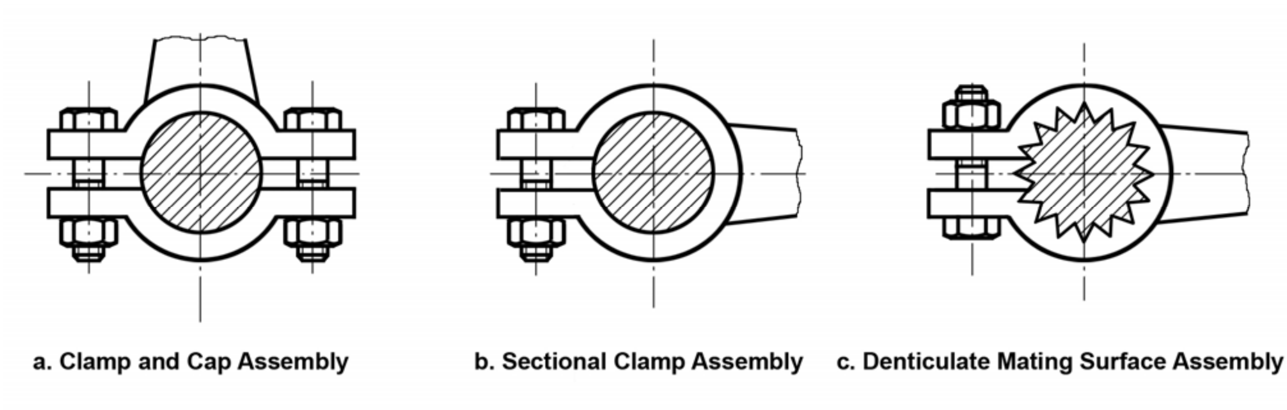

Fig. 1. Clamping Assemblies; main shape cases of shaft-clamp pair

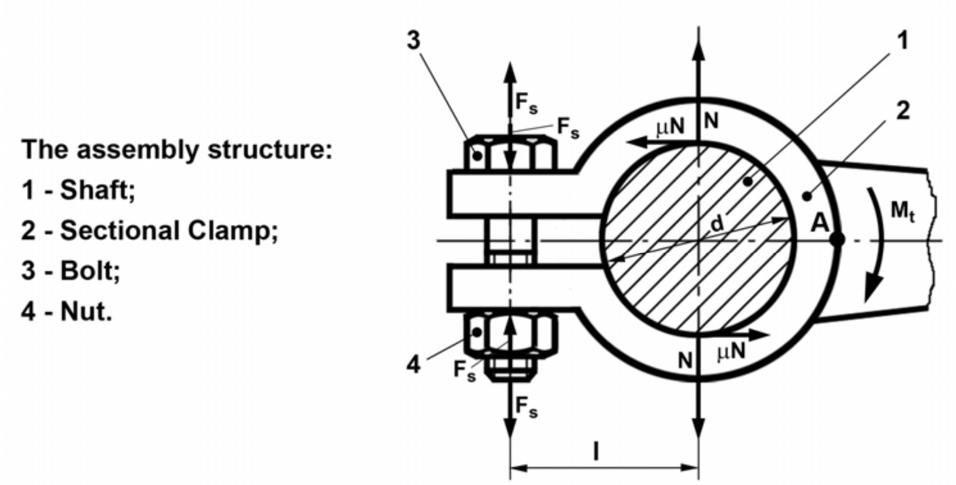

Fig. 2. Diagram of sectional tightening clamp assembly; calculus scheme and components

Should the torque M_t act on the shaft in order to allow for it to be transmitted to clamp 2; axial tightening force F_s needs being developed in bolt 3 then the thrust force of the clamp pushing on the shaft results out of the functional requirement that the assembly should transmit the torque by friction [2], [4]:

$$M_f = \mu_c \cdot N \cdot d = c_s \cdot M_t \,, \tag{1}$$

where c_s is the safety coefficient, while μ_c is the friction coefficient onto the component cylinder mating surface resulting in as follows:

$$N = \frac{c_s \cdot M_t}{\mu_c \cdot d} \,. \tag{1'}$$

Force F_s developed in threaded assembly can be determined by writing down the equilibrium condition of the clamp under the form of force torques against A point – taken as conventional a hinge one:

$$F_s \cdot \left(l + \frac{d}{2}\right) = N \cdot \frac{d}{2} \quad , \tag{2}$$

out of which we get:

$$F_s = \frac{N \cdot d}{2l + d} \,. \qquad (2')$$

If considering the both equation (1′) and (2′), the final relation for the axial load will be:

$$F_s = \frac{c_s \cdot M_t}{\mu_c \cdot (2l + d)} \,. \qquad (2'')$$

Experimental System and Instrumentation Used

The system of testing sectional tightening clamp assemblies is composed of the following parts:

- Sectional clamping assembly (fig. 3);
- Special stand for assembly twisting tests;
- Instrumentation (dynamometer, torque wrench, slide calliper rule, etc.).

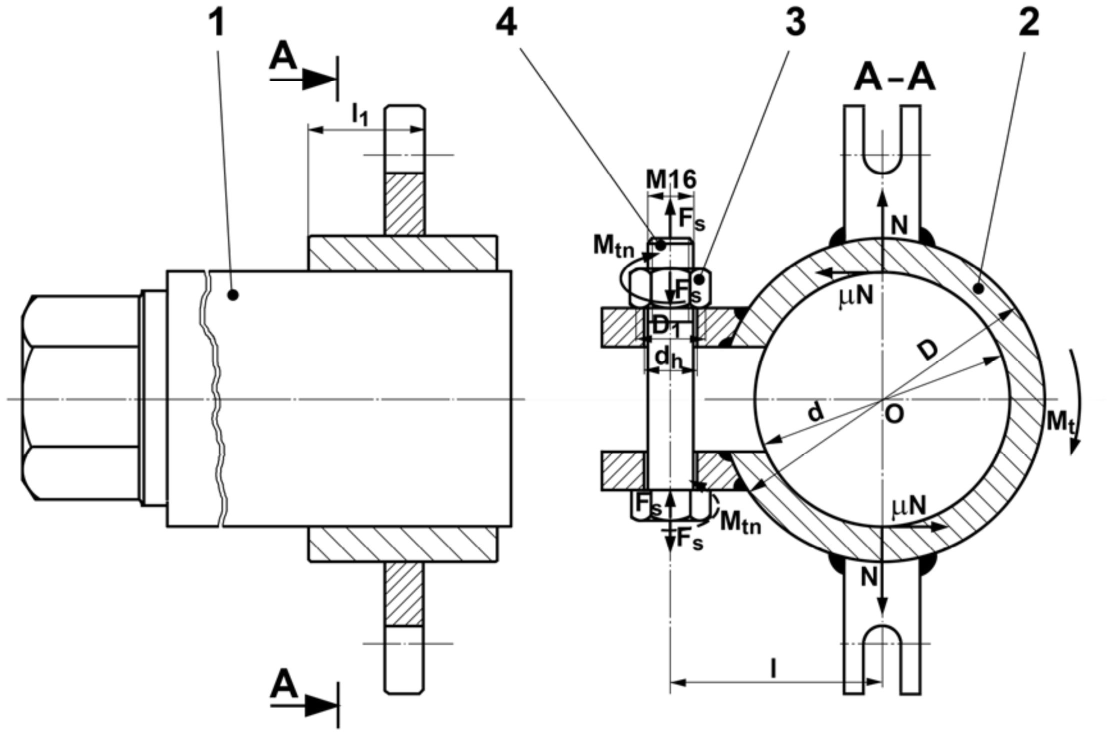

Fig. 3. The sectional clamping assembly detailed structure used for the torque bearing capacity tests

The sectional clamping assembly is composed of shaft 1 having an end finished with a cylinder surface and the other end with a portion having hexagonal outline required to mount it into the twisting test device, the tightening sectional clamp 2 (made into welded design form) and the connection assembly of two threaded parts – nut 3 and bolt 4.

The axial tightening force F_s is reached by screwing nut 3 by means of the torque wrench. The torque applied is read on the scale of the torque wrench (controlled torque).

For purpose of analytical calculus the friction feature needs being known for friction surfaces; for part assembling surfaces – achieved by fine turning – the following intervals may be considered for the values of friction coefficients:

- For the thread friction surfaces:
  μ = 0.10...0.15; the chosen value was μ = 0.12
- For the nut positioning surface:

μ_r = 0.10...0.12; the chosen value was μ_r = 0.11

- For shaft-clamp mating cylinder surface:
  μ_c = 0.05...0.10; the chosen value was μ_c = 0.08.

Determining the Axial Tightening Force and the Ultimate Torque of the Assembly

By tightening the nut 3 by means of the torque wrench into the threaded rod, an initial tightening force develops ($F_o = F_s$) that stretches the screw type part (4) and compresses the flange type part (clamp 2).

Depending on the value of the torque applied with the torque wrench, M_{tn}, the expression can be reached of the initial tightening force:

$$F_o = \frac{M_{tn}}{\frac{d_2}{2} \cdot \mathrm{tg}\,(\alpha_m + \varphi') + \frac{1}{3} \cdot \mu_r \cdot D_r} = k_1 \cdot M_{tn} = F_s\,, \qquad (3)$$

where d_2 is the medium diameter of the thread, α_m is thread spire inclination and φ' is the reported friction angle to be determined with relation:

$$\mathrm{tg}\,\varphi' = \frac{\mu}{\cos\frac{\beta}{2}}\,, \qquad (4)$$

while the expression of factor k_1 [mm^{-1}] becomes obvious in the relation (3).

Using M16 threaded components (hexagonal bolt 4 an nut 3), there are following geometrical elements to be involved: d_b = 16 mm; d_1 = 13.835 mm; d_2 = 14.701 mm; p = 2 mm; $\alpha_m{}^{\circ}={}^{\circ}2.4796$; φ' = 7.8889; d = 65 mm; l = 55 mm.

Relation (2) is applied and results in the expression of typical response, N:

$$N = \frac{2l + d}{d} \cdot F_s = k_2 \cdot F_s\,, \qquad (5)$$

where the constant is written down:

$$k_2 = \frac{2l + d}{d}\ . \qquad (6)$$

The ultimate torque of the assembly may be determined with relation:

$$M_{tc} = \mu_c \cdot N \cdot d = k_3 \cdot N\,, \qquad (7)$$

where factor k_3, obvious in relation (6), is expressed into [mm].

Experiments to Determine the Assembly Ultimate Torque

Experimental identification of the ultimate torque of the selected clamping assembly is achieved on a special design stand on which also other types of detachable assembly types can be tested (threaded, cone-shaped, taper ring assemblies, [5]).

The torque pre-loading the assembly is applied by means of a motion screw acting on a lever of length R. Axial force developed in the motion screw is monitored by means of a dynamometer resulting in as follows:

$$M_{tm(exp)} = F \cdot R \cdot \eta_r \, . \qquad (8)$$

In relation (8), η_r stands for the mechanical efficiency of the whole system of levers composing the twisting test stand; this can be considered at the usual level of:

$$\eta_r = 0{,}90\ldots0{,}97.$$

To determine the bearing capacity of selected clamping assemblies the following working stages are needed:

- Tighten the nut of the assembly by applying a torque whose value is read with the torque wrench. Depending on the value of the applied torque the initial tightening force $F_o = F_s$ is determined – by applying relation (3), the typical response, N – relation (5) and the ultimate torque of the assembly, M_{tc} – relation (7).
- The clamping assembly is mounted on the stand and stressed to torsion while reading with the dynamometer the value of the force (F) developed in the motion screw corresponding to the wheel of the shaft 1 versus the sectional clamp 2; this way it results in the size of the assembly ultimate torque by using relation (8).
- The ultimate torque determined analytically, M_{tc}, is compared with the one deducted experimentally $M_{tm(exp)}$, thus deducing the degree of closeness of the results thus got.
- The experimental test is repeated several times for other increasing values of the nut screwing moment.

Results determined analytically and based on the achieved experiment shall be put down in table 1.

Table 1. Values of features that have been analytically and experimentally determined

No	M_{tp}, [Nm]	μ	μ_c	μ_r	α_m, [°]	φ', [°]	d, [mm]	k_1, [mm^{-1}]	F_o (F_s), [N]	k_2	N, [kN]	k_3, [mm]	M_{tc}, [Nm]	R, [m]	F, [N]	M_{tm}, [Nm]
1	40								16276		43.82		228		F_1	M_{tm1}
2	60	0.12	0.08	0.11	2.48	7.89	65	0.4	24414	2.69	65.73	5.2	342	0.2	F_2	M_{tm2}
3	80								32552		87.64		456		F_3	M_{tm3}

For an optimum relevance of comparing the ultimate torques determined by calculus and found out experimentally (M_{tc} and $M_{tm(exp)}$) – trials are recommended to be repeated another 2 or 4 times. This way for three subsequent trials experimental values of ultimate torques shall be found in a relation as follows:

$$M^{(i)}_{tm(exp)} = \frac{M^{(i)}_{tm(exp),1} + M^{(i)}_{tm(exp),2} + M^{(i)}_{tm(exp),3}}{3} \qquad (9)$$

The block diagram of analytical calculus procedures and experimental determinations is summarized in figure 4. After completion of analytical calculus procedures and stand testing of the assembly the results of such shall be graphically processed. A suggestive comparison of calculated values with the ones experimentally found is shown in the diagram/schedule in figure 4.

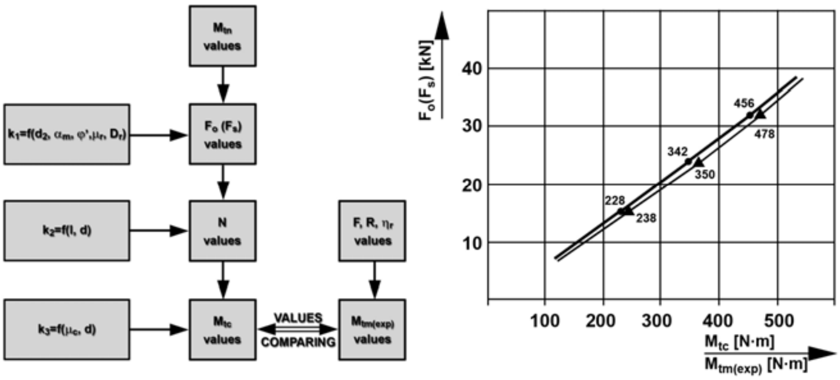

Fig. 4. The block diagram of analytical calculus procedures and diagram of experimental determinations

Conclusion

The comparison analysis of ultimate torques of sectional clamp assembly resulted in the following significant conclusions:

- As foreseen variation of the ultimate torque is linear versus the tightening force developed in threaded elements;
- The same linear variation is also noticed in ultimate torques found out experimentally;
- Against calculated values of ultimate torque experimentally found values are relative close to the former and sensibly higher;
- Differences recorded between calculated and experimental values may be accounted for by: errors in reading of the nut screwing moment, errors in reading force on dynamometer and differences between values of actual friction coefficients versus the ones estimated (selected) for calculation purpose.

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Aspecte privind determinarea capacității portante a asamblărilor cu brățară de strângere secționată

Rezumat

Lucrarea prezintă cercetări privind determinarea capacității portante a asamblărilor cu brățară de strângere secționată. În cadrul lucrării sunt prezentate procedurile de calcul analitic privind dependența dintre forța axială de strângere şi momentul de torsiune capabil. Rezultatele stabilite prin calcul sunt verificate experimental, folosind modelul şi standul specializat pentru încercări la torsiune