Measurement of Screw Connection Parameters of Air Conditioning Systems

R. Jírová[1,*], L. Pešík[1]

[1] *Department of Design of Machine Parts and Mechanism, Faculty of Mechanical Engineering, Technical University of Liberec, Studentská 2, 461 17 Liberec, Czech Republic*

[*] *radka.jirova@tul.cz*

Abstract: In service, screw connections used in air conditioning systems require high reliability. Especially, a sealing function of the screw connection has to be appropriate to prevent coolant leaking. Therefore, the paper focuses on the measurement of screw connection parameters. The examined parameters related to the screw connection reliability were the friction coefficient in a thread of the screw connection and axial forces caused by the settlement process in screw connections.For this purpose, we designed a measurement device and analysed screw connections with different parameters.

Keywords: screw connection; force measurement; friction coefficient measurement; air conditioning system; sealing function.

1 Introduction

The reliability of screw connections of aluminium alloy bodies used in air conditioning systems depends on several factors. The principal factor is related to the friction in a thread of a screw and a connected body [1]. Two different materials are used for connection, steel and aluminium alloy. The coefficient of friction depends on a special surface layer on the screw thread, whereas thread lubrication is usually not performed during the assembling process. The lower coefficient of friction may cause a greater axial force at the prescribed tightening torque. Important is also a small variance of the friction coefficient values for the force ratios prediction in the screw connection. In addition to the friction coefficient that determines the magnitude of axial force in the connection, we need to ensure a constant magnitude of the force during the service and after a settlement of bodies. For this purpose, a disc spring in the form of a washer under the screw head was used in the screw connection of the air conditioning system [2, 3].

Both parameters, the friction coefficient and the constant force during the service of the connection, have to be carefully monitored during and after the installation [4]. This is the way to ensure sufficient reliability of the screw connection. For this purpose, we developed an original measurement device, which allows measuring both mentioned parameters.

2 Design of measurement device

The measurement device is based on a double reversing lever (Fig. 1).

2.1 Measurement of friction coefficient

Measurement of friction coefficient is ensured by the lever configuration, where at one end of the lever, the screw is tightened, and at the other end, the axial force in the screw is measured using a load cell.

By measuring the axial force and tightening torque, we found that thread lubrication is major for getting a higher value of axial force at the given value of tightening torque. In the measured case, we compared two different sliding surface layers on a screw thread.

The friction coefficient must be inspected before tightening of screw connection because it decides the reliability of the connection.

According to this measurement, we got statistical dispersion of axial forces at the given tightening torque.

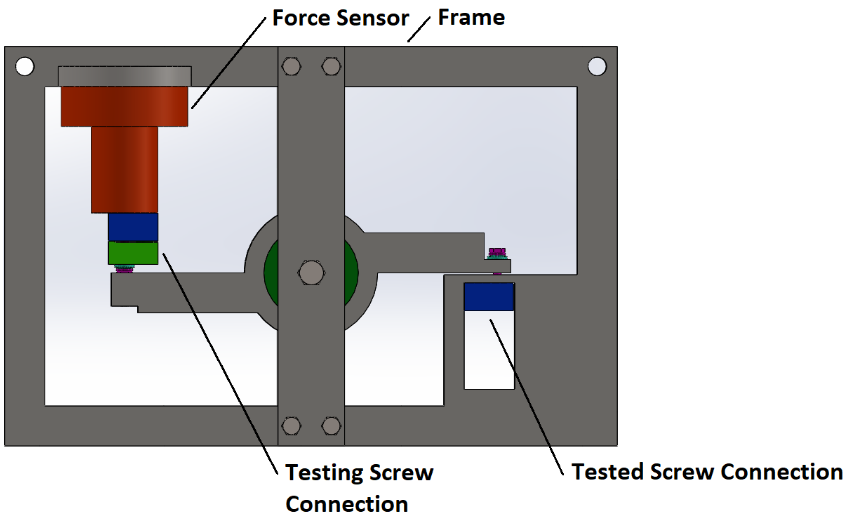

Fig. 1: Measurement device.

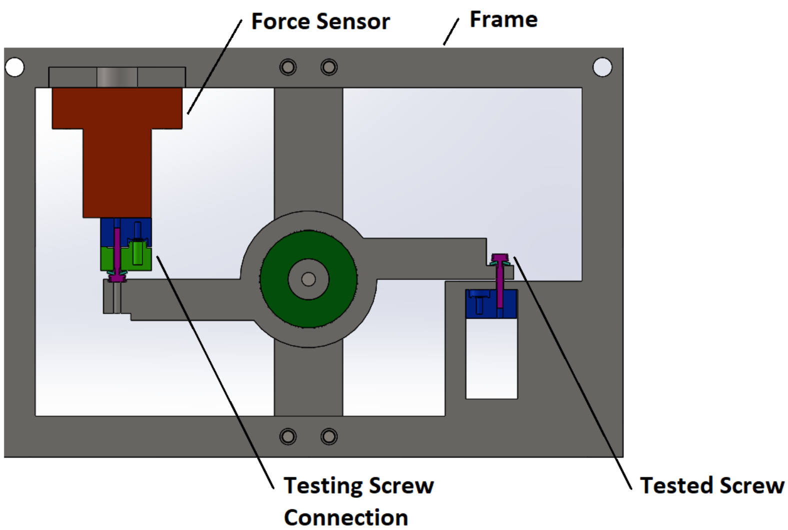

Fig. 2: Measurement of friction coefficient.

2.2 Measurement of axial force

By mounting the screw connection, also the embedding of connected bodies must be included to its reliability. For measuring the change of the axial force in the assembled screw connection caused by the settlement of bodies, the axial force is created at one end of the lever using an auxiliary screw connection, which is arranged in series with the load cell at the other end of the lever.

The measurement device is a relatively flexible construction in that the screw connection with simulated preload is mounted. In real conditions, the screw is preloaded by tightening torque, and connected bodies are pressed between the head of the screw and the body with thread. In the measured case, connected bodies are pressed similarly, but axial force appears through the measurement device.

For getting the preload loss due to embedding of connected bodies, the stiffness of the measurement device k_p and the stiffness of bodies pressing the connected bodies k_s must be known.

By the preload F_Q in the screw connection, according to Fig. 3, the deformation of connected bodies Δl_p and the deformation of the measurement device Δl_s appears. We may get a system stiffness k_{ps} through the measurement of overall deformation Δl_{ps}.

$$k_{ps} = \frac{F_Q}{\Delta l_{ps}} = \frac{F_Q}{\Delta l_p + \Delta l_s} \tag{1}$$

The overall stiffness is defined as

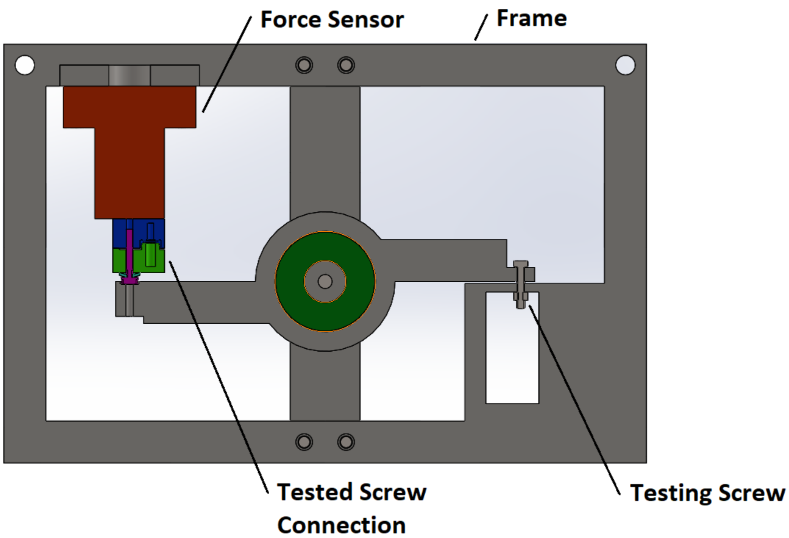

Fig. 3: Measurement of axial force.

$$\frac{1}{k_{ps}} = \frac{1}{k_p} + \frac{1}{k_s} \tag{2}$$

where stiffness k_p is

$$k_p = \frac{F_Q}{\Delta l_p} \tag{3}$$

and stiffness k_s

$$k_s = \frac{F_Q}{\Delta l_s} \tag{4}$$

Then, we used a strut with known stiffness k_r, which is higher by orders than stiffnesses k_p and k_s. Then the overall system stiffness changes to

$$\frac{1}{k_{rs}} = \frac{1}{k_r} + \frac{1}{k_s} \tag{5}$$

Through Eq. 5, we may get the stiffness of the measurement device k_s. Whereas

$$k_{rs} \cong k_s \tag{6}$$

Then, through Eq. 2, we may get the stiffness of bodies pressing the connected bodies k_s.

After mounting the screw connection with known stiffness k_b, the preload loss due to the embedding process is described in Fig. 4.

We may note that

$$\operatorname{tg} \alpha_p = k_p \tag{7}$$

and

$$\operatorname{tg} \alpha_b = k_b \tag{8}$$

We observed that lower screw stiffness generates lower preload loss due to the embedding of connected bodies.

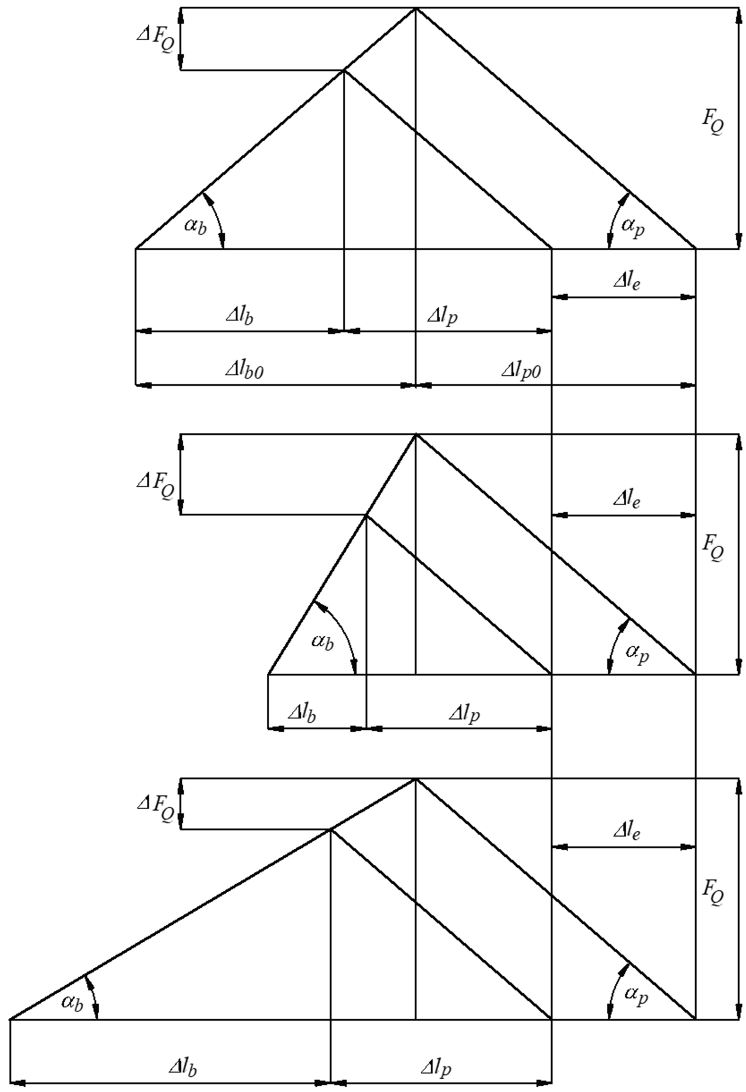

Fig. 4: Influence of screw stiffness on the preload loss due to embedding process.

3 Results

3.1 Friction coefficient

The friction coefficient influences the preload value of the screw connection. Two types of sliding surface layers of the screw were tested, Type A (Tab. 1) and Type B (Tab. 2), by the tightening torque of 12 kN. Then, the variation of preload was observed.

Tab. 1: Preload of screw connection – sliding surface layer Type A.

Specimen	1	2	3	4	5	6	7	8	9	10
Force [kN]	6.4	7.7	7.0	6.4	6.5	7.3	7.1	7.5	6.3	8.6

Tab. 2: Preload of screw connection – sliding surface layer Type B.

Specimen	1	2	3	4	5	6	7	8	9	10
Force [kN]	10.4	10.8	10.0	10.7	12.0	9.7	11.6	9.5	10.6	12.4

Results show that the sliding surface layer Type A of the screw reports higher friction than Type B layer. In the first case, we got the preload ca. 7.0 kN. In the second case, we reached nearly 11.0 kN.

Fig. 5: Diagram of screw connection – after mounting.

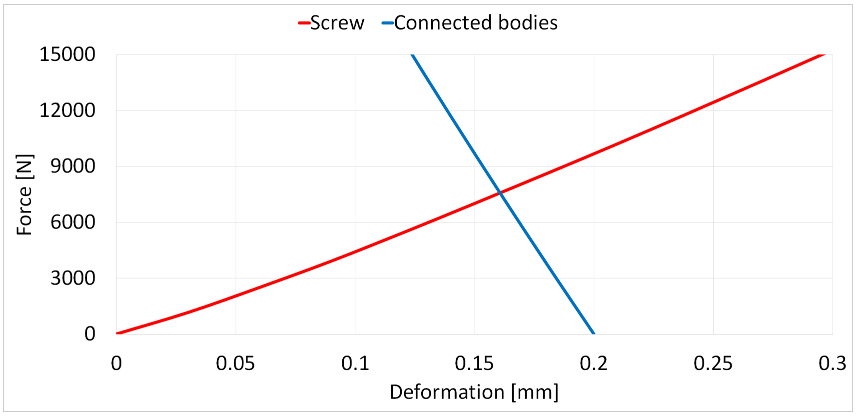

Fig. 6: Diagram of screw connection – after embedding process.

3.2 Axial force

By measuring axial force and deformation, we got diagrams of screw connection after mounting (Fig. 5) and after the embedding process (Fig. 6). In diagrams, the preload value is represented by an intersection of a screw line (red) and a connected bodies line (blue).

The initial condition of preload was 12 kN after mounting. Duo to embedding process, the preload decreased at 60% of the initial value.

4 Conclusion

The paper showed two possibilities of measurement of screw connection parameters in practice. Measurement results of the friction coefficient and the axial force in the screw connection are significant for the reliability and the quality of screw connections in air conditioning systems.

Regarding friction, the proper lubrication or sliding surface layer of thread is needed for sufficient axial force. Regarding the minimal preload loss due to the embedding of connected bodies, the low stiffness of the screw is demanded that may be reached by using the disc spring with degressive force-deformation characteristics as a washer under the screw head.

Acknowledgement

This work was supported by the Student Grant Competition of the Technical University of Liberec under project No. SGS-2019-5036.

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