Measurement Device for Experimental Investigation of Bolted Joint Diagram in Applications with Non-Metallic Materials

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Abstract: The present design of industrial machines is currently constructed with a wide range of non-ferrous and non-metal materials. The connection of machine parts of materials with non-standard strength properties provides specific demands to bolt connections concerning securing the proper preload. To ensure sufficient preload, specially shaped washers can be used. In the design process, the stiffness of a particular shape of the washer must be tested. Therefore, the article describes an innovative measurement device that enables testing washers for connections of various non-ferrous and non-metal materials. The laboratory testing process is shown in the specific example of the washer used in industrial practice.

Keywords: Bolted joint diagram; Stiffness measurement; Washer

1 Introduction

The reliability of bolted connections is currently very important in modern machine design. The connected components are more often produced of non-ferrous and non-metallic materials or composites. The demands on modern machine design regarding economic efficiency, energy consumption, weight, etc., are increasing, and traditional materials are being replaced with a wide range of applications [1,2]. While bolted connections in conventional steel structures are reliable enough, the situation in the case of modern materials is entirely different. The main reason for the reduction in reliability is the loss of the preload, which ensures the strength and tightness of the connection. This phenomenon occurs due to the seating of connected components or thermal or vibration conditions that are more problematic in the case of non-ferrous and non-metallic materials [3-8]. For these reasons, the design of the bolted connection itself regarding the bolted joint diagram of connecting and connected components is of great importance.

This problem can be solved by using a special washer that ensures sufficient preload in the bolted connection even after the seating of connected components or under thermal or vibration conditions [9,10]. In order to verify the designed shapes of washers, a special measurement device was proposed for testing the force and deformation conditions in bolted connections with non-ferrous and non-metallic materials. The article describes the special measurement device and shows its function through an example from an industrial practice.

2 Measurement Device

In order to verify the proposed washer shape, the special measurement device was designed. Using the measurement device and by analysing the measured force and deformations of the washer, the graph of stiffness characteristics of the washer testing specimen can be obtained.

The washer testing specimen can be loaded and unloaded through the pressure base plate using a pressure bolt with trapezoidal thread. The pressure base plate is guided in the measurement device by linear rolling systems fixed to the frame of the device (Fig. 1).

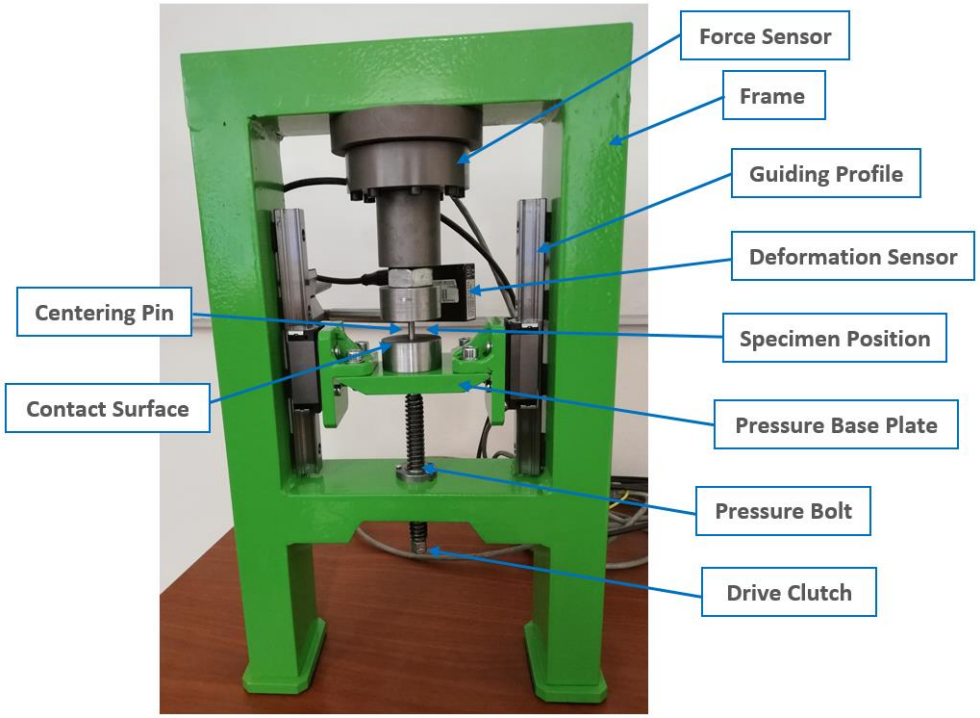

Fig. 1 Measurement device.

The measurement device disposes of changeable contact surfaces for placing the washer testing specimen. The changeable contact surfaces can be made from various non-ferrous and non-metallic materials, including composites. Changeable survaces, as well as, washer testing specimens are centred to the axis of the pressure bolt through centering pin with hardened surface.

A GTM Series K force sensor with a nominal force of 10 kN and a Micro-Epsilon optoNCDT1402 laser deformation sensor with a range of 20 mm was employed at the measurement device. The parameters of the measurement device are summarised in Table 1.

Table 1. The parameters of measurement device.

Maximum Tightening Torque [Nm]	Maximum Axial Force [kN]	Maximum Lift [mm]	Alignment [mm]	Deformation Measurement Sensitivity [mm]
40	10	100	0.5	0.01

3 Example from Industrial Practice

The measurement device was tested on the practical example of the washer in the shape of a disc spring. The washer is used in the bolted connection of batteries cooling system in electric cars. In the cooling system, the coolant distribution is made of aluminium alloy.

Fig. 2 shows the cooling system assembly that is mounted by the bolt with the special washer. The cooling system assembly is realised with washers provided by two producers, Brugola OEB Industriale S.p.A. (Brugola) and Fontana Gruppo (Fontana).

The dimensions of washer testing specimens are shown in Fig. 3. The washer is designed for bolted connection with bolts of M6 size.

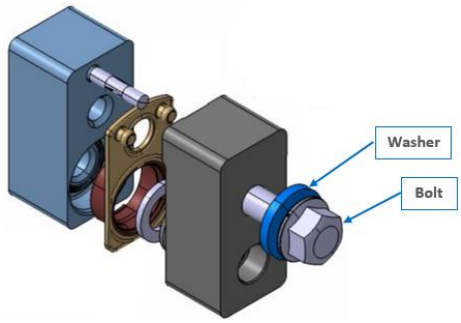

Fig. 2 Assembly of cooling system.

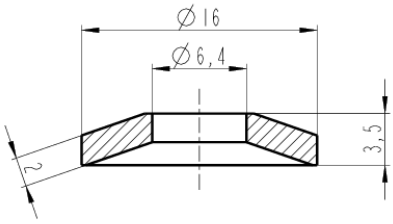

Fig. 3 Dimensions of washer testing specimens.

The testing process of the washers of both producers was processed through the measurement device with a measurement unit Dewesoft Sirius R2DB and software Dewesoft X. Sampling frequency of measurement was set to 100Hz.

Fig. 4 shows the results of the measured axial force and deformation of each washer. Differences in results of stiffness Brugola and Fontana washers are related to their production process. Output stiffness is dependent particularly on the accuracy of dimensions and material properties, especially the heat treatment process of spring steal.

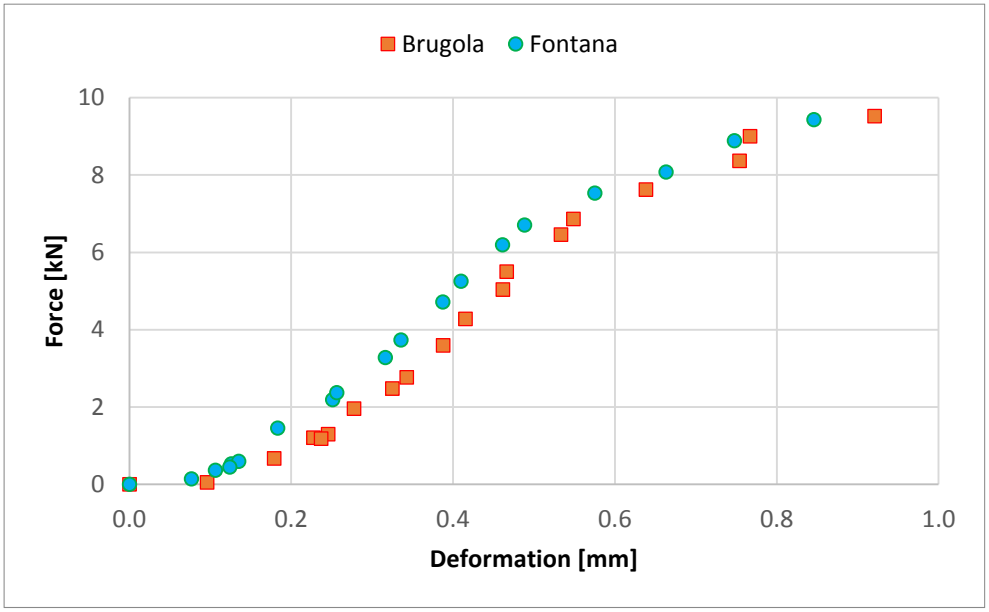

Fig. 4 Washer stiffness.

Conclusions

The article described the innovative measurement device that enables testing and evaluating the stiffness of specially shaped washers for bolted connections used in the construction of non-ferrous and non-metal materials. The measurement device uses the force sensor to detect the axial force and the laser position sensor to measure the axial deformation of the washer. The obtained data can be next composed to the graph of washer stiffness as the dependence of the axial force on the deformation.

Acknowledgements

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