Investigation of Washer Influence on Bolt Connections in Non-Ferrous and Non-Metal Constructions

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Abstract. Modern design of production and transport machines is currently characterised by a wide range of non-ferrous and non-metal materials. Typical reasons are demands on cost and weight. Further reasons are requirements on physical properties, e.g. thermal and electrical non-conductivity, the ability to dump vibrations and noise. For connecting machine parts from non-ferrous and non-metal materials, mechanical engineers usually use standard iron bolts and nuts that provide low costs and a wide range of goods. However, the functional reliability of bolt connection necessitates special attention and must reflect specific design principles. Operation difficulties often appear by the incorrect design process when diverse mechanical properties of connecting bolts and connected mechanical parts are not considered. In that case, joint diagrams of bolt connections are inappropriate and may lead to unreliable operation or machine failure. Therefore, the project aims to propose a design principle for reliable bolt connection of non-ferrous and non-metal mechanical parts based on joint diagram optimisation.

Keywords: Bolt Connection, Preload, Washer, Composite Materials.

1 Introduction

Reliability of bolt connections is highly demanded in the context of modern engineering design. Connected bodies are more often produced by non-ferrous, non-metal and composite materials. Requirements for current engineering design increases considering costs, energy consumption, ecology or weight of components. Therefore, traditional engineering materials are replaced in a wide range. While bolt connections in common steal constructions are reliable enough, there are a few issues to solve in modern materials. The root cause of reliability decrease is loss of preload, which provides strength and tightness of connection [1,2]. This phenomenon occurs as a consequence of the embedding process of connected bodies by thermal and vibrational conditions. The design of bolt connection in terms of load characteristics connected and connecting bodies is of great importance for the above reasons, primarily for preload securing of bolt connection in various operating conditions [3-5]. Thus, the paper focuses on several conditions that increase reliability.

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2 Methods

The load characteristics of common bolt connection (see Fig. 1) shows a steep deformation character depending on the preload of connecting bodies. The deformation of connecting bodies is relatively tiny against the deformation of connected bodies. This condition leads to significant preload loss after the embedding process of the bolt connection, as even a small deformation change generates a high decrease of load in the connection. By using a special-shaped washer under the bolt head, the degressive load characteristic of connecting bodies may be reached (see Fig. 2) [6]. And thus, minimalise the preload loss after the embedding process.

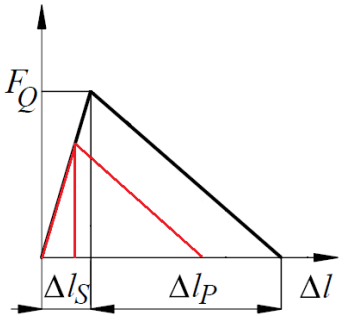

Fig. 1. Preload decrease in bolt connection without any washer.

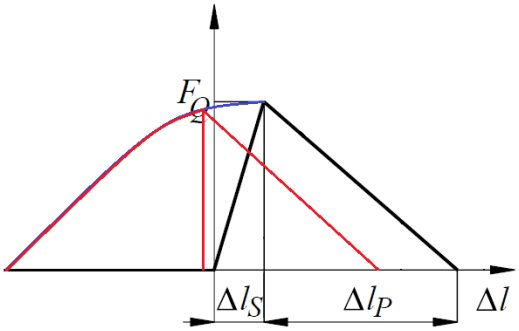

Fig. 2. Preload decrease in bolt connection with the special-shaped washer.

To investigate load characteristics of connecting bodies without using any washer and with using the special-shaped washer, the simplified 3D model was created, and deformations of connecting bodies via FEM analysis (Finite element method) were calculated.

In the FEM analysis (see Fig. 2 and 3), the bolt made of steel material was pulled in the axial direction by a remote displacement boundary condition that was placed on

the bolt's rotational axis. Connecting bodies were fixed to the rigid block by frictional connection.

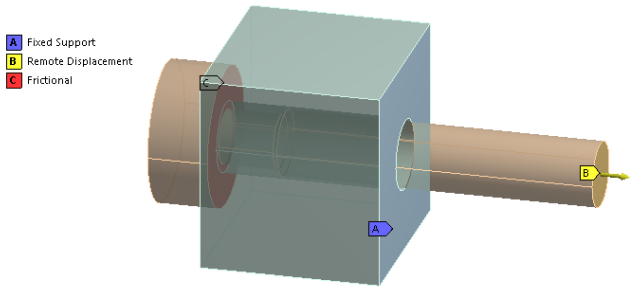

Fig. 3. Boundary conditions and contact connections – Bolt without any washer.

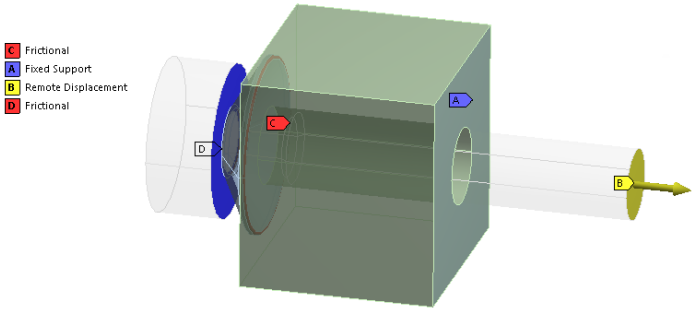

Fig. 4. Boundary conditions and contact connections – Bolt with the special-shaped washer.

For creating the load characteristics of both cases, the deformation of connecting bodies and reaction forces of remote displacement conditions were calculated.

3 Results and Discussion

The figures (see Fig. 5 and Fig. 6) show deformation without using any washer and with using the special-shaped washer.

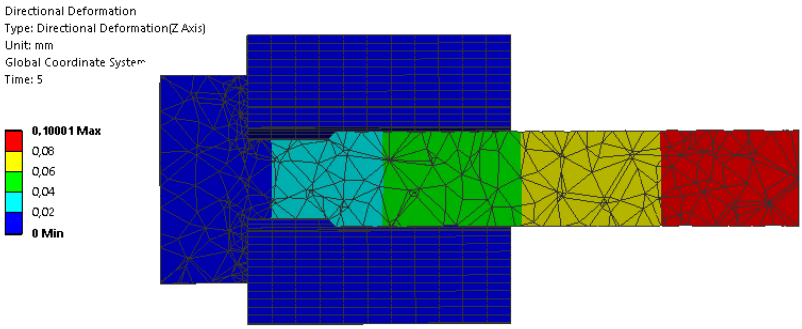

Fig. 5. Deformation in Z-axis – Without any washer.

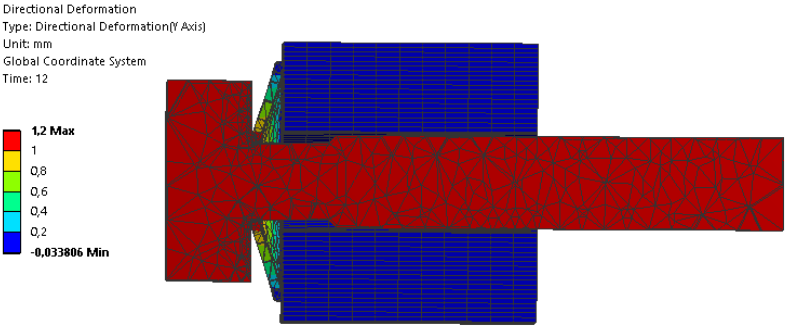

Fig. 6. Deformation in Z-axis – With the special-shaped washer.

Table 1 summarises the results of reaction forces in the case without using any washer and with using the special-shaped washer.

Table 1. Reaction forces of remote displacement boundary conditions.

Bolt without any washer		Bolt with the special-shaped washer	
Displacement [mm]	Force [N]	Displacement [mm]	Force [N]
0.00	0.00	0.00	0.00
0.02	2596.00	0.10	2010.00
0.04	5189.80	0.20	3864.50
0.06	7781.50	0.30	5551.20
0.08	10371.00	0.40	7046.10
0.10	12959.00	0.50	8387.80
		0.60	9531.30
		0.70	10524.00
		0.80	11326.00
		0.90	11983.00

1.00	12459.00
1.10	12774.00
1.20	12883.00

The data in Table 1 were used for charting the load characteristics without using any washer and with using the special-shaped washer (see Fig. 7).

From the graph in Fig. 7, the great importance of stiffness decrement of connecting bodies might be observed by using the special-shaped washer placed under the bolt head. While the stiffness of the bolt without using any washer is significant, by using the washer in the shape of, e.g. a disc spring, the stiffness decreases markedly. The load characteristics of bolt connection that uses the washer of disc spring shape reports degressive characteristics of connecting bodies stiffness. In the case of the embedding process of connected bodies, the bolt connection preload drops minimally.

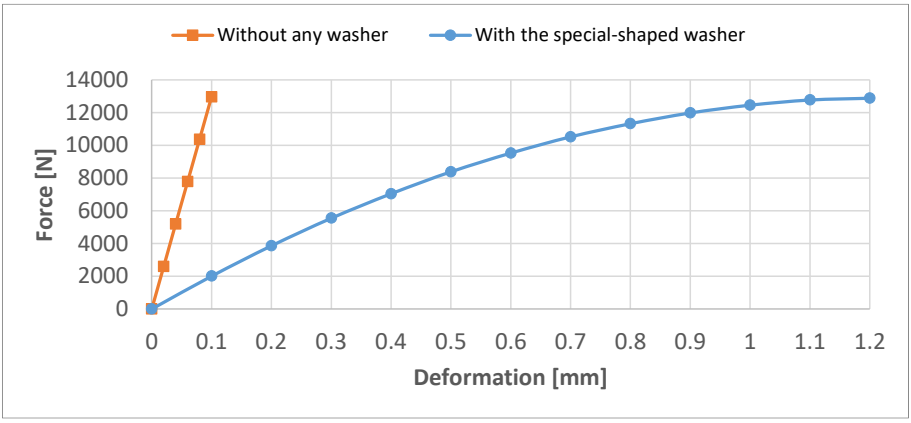

Fig. 7. Comparison of load characteristics – Without any washer and with the special-shaped washer.

4 Conclusions

The paper focused on the problematics of preload loss due to the embedding process of connected bodies in constructions of non-ferrous or non-metal material. In the solved case, the preload loss is tightly related to the steep load characteristics of connecting bodies that are usually made of standard steel materials. To minimise preload loss, the special-shaped washer under the bolt head may be used for reaching the degressive load characteristic of connecting bodies. Then, the deformation change after the embedding process generates a small decrease of preload in the connection.

Acknowledgements

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