MODELLING NONLINEAR PRELOADED MULTI-BOLTED SYSTEMS ON THE OPERATIONAL STATE

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1. Introduction

Multi-bolted connections can be characterized by the following three main features: the nonlinearity of the joint, two states of loading and deformation, as well as the presence of the structure allowing to treat the joint as a system.

The nonlinearity of multi-bolted connections arises from the fact that they are usually composed of many bodies being in a contact. The source of this nonlinearity are all of contact connections existing between joined elements, as well as gaskets often used as additional intermediate elements in this type of connections [1].

Multi-bolted connections before their maintenance are most often preloaded. Thus, in modelling and calculations of multi-bolted connections both the assembly state (when the joint is mounted) and the operational state (when the preloaded joint is loaded by an external force) should be taken into account.

Papers on modelling and calculations of multi-bolted connections are generally associated with conventional types of joints, such as: beam-to-column connections [2], double lap connections [3] and flange connections [4]. In all of these publications, a systemic approach to modelling, calculation and analyzing multi-bolted connections is not taken into account.

In this paper a model of the multi-bolted connection treated as a system consisting of components is presented, which can be considered, modelled and calculated as separate subsystems using methods adequate to their properties. The aim of the paper is to show the way of modelling such multi-bolted systems with regard to their nonlinearity and the occurrence of the above-mentioned two states of loading and deformation.

2. Structure of the multi-bolted system

The structure of the multi-bolted system model results from the concept described in [5]. The model is built with four subsystems shown in Figure 1.

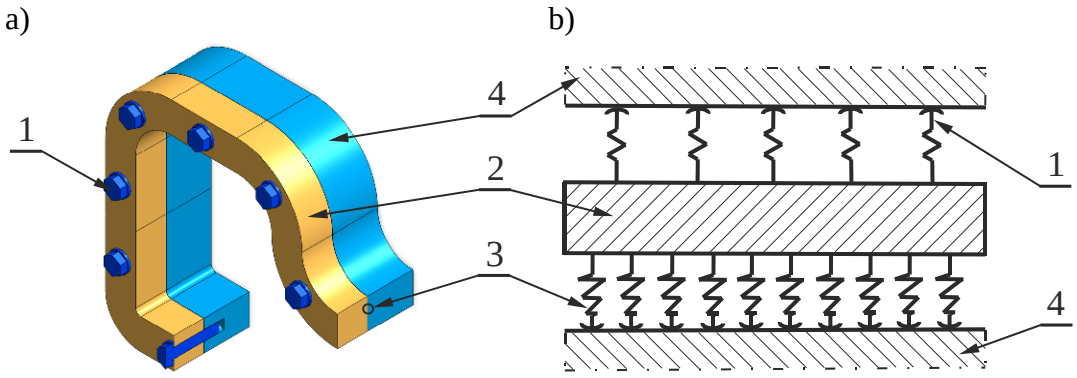

Fig. 1. Multi-bolted system: a) scheme, b) division into subsystems (1 – subsystem **B**, a set of the bolts, 2 – subsystem **F**, the flexible flange element, 3 – subsystem **C**, the conventional contact layer, 4 – subsystem **S**, the flexible support).

The set of equations of equilibrium of such a multi-bolted system can be written in the form:

$$\begin{bmatrix} \boldsymbol{K}_{BB} & \boldsymbol{K}_{BF} & \boldsymbol{0} & \boldsymbol{K}_{BS} \\ \boldsymbol{K}_{FB} & \boldsymbol{K}_{FF} & \boldsymbol{K}_{FC} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{K}_{CF} & \boldsymbol{K}_{CC} & \boldsymbol{K}_{CS} \\ \boldsymbol{K}_{SB} & \boldsymbol{0} & \boldsymbol{K}_{SC} & \boldsymbol{K}_{SS} \end{bmatrix} \cdot \begin{bmatrix} \boldsymbol{q}_B \\ \boldsymbol{q}_F \\ \boldsymbol{q}_C \\ \boldsymbol{q}_S \end{bmatrix} = \begin{bmatrix} \boldsymbol{p}_B \\ \boldsymbol{p}_F \\ \boldsymbol{p}_C \\ \boldsymbol{p}_S \end{bmatrix} \tag{1}$$

where: $\boldsymbol{K}_{BB}$, $\boldsymbol{K}_{FF}$, $\boldsymbol{K}_{CC}$, $\boldsymbol{K}_{SS}$ – stiffness matrices of separate subsystems, $\boldsymbol{K}_{BF}$, $\boldsymbol{K}_{FB}$, $\boldsymbol{K}_{BS}$, $\boldsymbol{K}_{SB}$, $\boldsymbol{K}_{FC}$, $\boldsymbol{K}_{CF}$, $\boldsymbol{K}_{CS}$, $\boldsymbol{K}_{SC}$ – matrices of elastic couplings among subsystems, $\boldsymbol{q}_i$ – displacements vector of the i-th subsystem, $\boldsymbol{p}_i$ – loads vector of the i-th subsystem (i – symbol of the subsystem, $i \in \{B, F, C, S\}$).

3. Results of calculations and conclusions

Sample calculations are performed for a selected asymmetrical multi-bolted system shown in Figure 2a. The thickness of joined flanges is equal to 20 mm. The connection is fastened by means of seven M10 bolts with the preload F_m equal to 20 kN. The preloaded multi-bolted connection is subjected by external normal force F_e equal to 30 kN and applied in the manner shown in Figure 2a. Distribution of operational bolt forces F_{ei} referenced to the preload F_m is illustrated in Figure 2b.

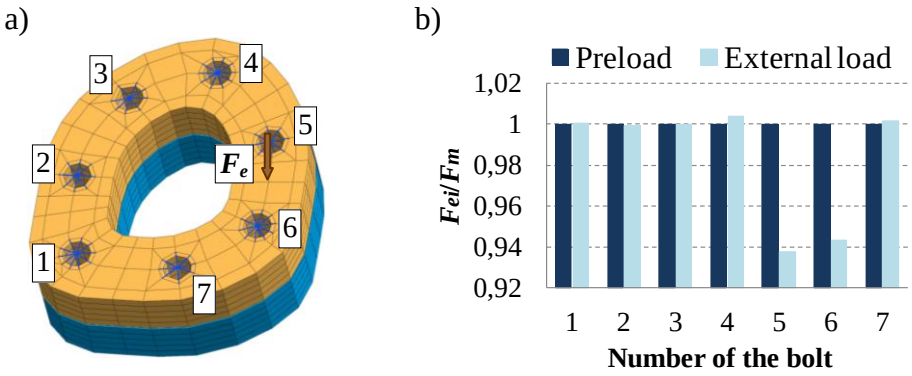

Fig. 2. Example of calculations: a) FEM-based model of the multi-bolted system, b) bolt force values in the multi-bolted connection loaded externally.

The paper presents a general systemic approach to modelling and calculations of arbitrary multi-bolted systems. It can be implemented in both the assembly and operational state of the connection.

References

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