STUDY OF THE DISTRIBUTION OF NORMAL CONTACT PRESSURE BETWEEN ELEMENTS JOINED IN A MULTI-BOLTED SYSTEM UNDER OPERATIONAL LOADS

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1. Introduction

In a multi-bolted connection treated as a system [1], it is possible to distinguish, among others, the contact layer at the interface of the joined elements. This contact layer can be replaced with both nonlinear and linear elastic foundation models.

Assuming that the load of the joined elements acts on the direction perpendicular to the surface of their contact, the contact layer can be modelled using the Winkler model [2]. Then contact phenomena between the joined elements can be sufficiently modelled using the normal characteristics of the connection. Such characteristics can be represented with a good approximation by an exponential function [3, 4]. However, the contact layer at the interface of the elements joined in the multi-bolted connection is usually operated after the preload, when the normal characteristics of the connection from nonlinear become close to linear. Therefore, in addition to the application of nonlinear contact characteristics, it is also appropriate in this case to use linearised courses of these characteristics.

In the paper a multi-bolted system model with the Winkler type contact layer between the joined elements is presented, on the basis of which it is possible to include for each element of the contact layer (for each nonlinear or linear spring, depending on the model) normal mechanical characteristics, for example obtained from experimental tests. The aim of the paper is to study the distribution of normal contact pressure between the elements joined in a multi-bolted system under operational loads for selected models of this system.

2. Structure of the system

The structure of the multi-bolted system is based on the model of four subsystems shown schematically in Figure 1.

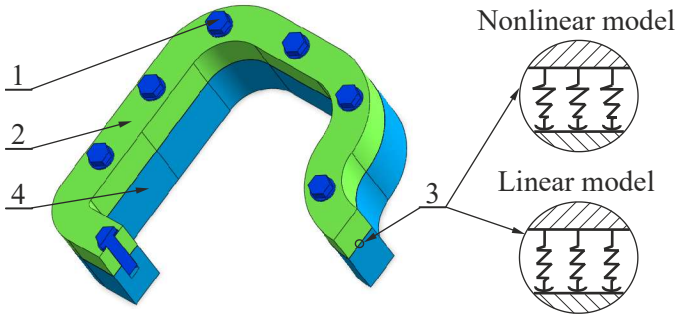

Figure 1: Multi-bolted system (1 – subsystem **B**, a set of the bolts, 2 – subsystem **F**, the flexible flange element, 3 – subsystem **C**, the contact layer, 4 – subsystem **S**, the flexible support).

The set of equations of equilibrium of such a multi-bolted system can be written in the following matrix notation

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

where: $\boldsymbol{K}_{BB}$, $\boldsymbol{K}_{FF}$, $\boldsymbol{K}_{CC}$, $\boldsymbol{K}_{SS}$ – stiffness matrices of individual 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 between separated 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

Sample calculations were performed for a selected asymmetrical multi-bolted system shown in Figure 2a. The thickness of the 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 set of bolts is built from the spider bolt models. The preloaded multi-bolted system is subjected to an external normal force F_e equal to 30 kN and applied in the manner shown in Figure 2a. The location of nodes adopted to describe the normal contact pressure distribution is depicted in Figure 2b. The distribution of normal contact pressure at the interface of the elements joined in the multi-bolted system loaded externally by the force F_e is illustrated in Figure 2c.

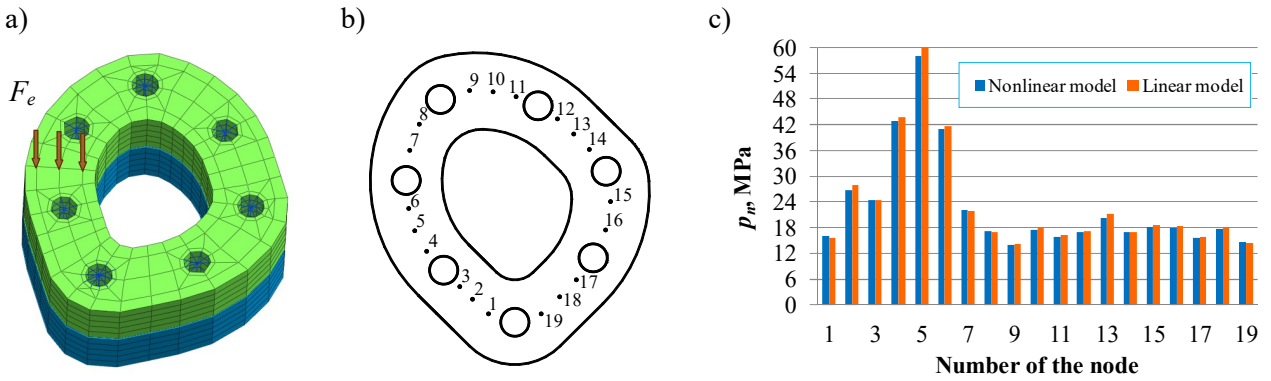

Figure 2: Example of calculations: a) FEM-based model of the multi-bolted system, b) nodes adopted to describe the normal contact pressure distribution, c) distribution of normal contact pressure at the interface of the elements joined in the multi-bolted system loaded externally.

4. Conclusions

In the paper a general systemic approach to modelling and calculations of arbitrary multi-bolted systems is presented. It can be implemented in the operational state of the system adopted for various bolt models.

References

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