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Bolted joints for very large bearings—numerical model development

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Abstract

The conventional theory of bolted joints does not take the complexity of external loads into account, neither its related joint stiffness nor the contact non-linearities. This article deals with a 2D numerical model allowing fast and precise calculation of the fastening bolts for very large diameter bearings subjected to an overturning moment. The originality of the modelling lies in the use of a particular finite element that behaves like a ring, except in the axial direction. Its axial stiffness is the local stiffness that governs the behaviour of the bolted assembly. The model was tuned upon 3D finite elements simulations and provides excellent results for several types of bearings.

Keywords: Bolted joints; Numerical model; Slewing bearings; Finite elements analysis

1. Introduction

Providing fast and accurate results is one of the challenges of practical engineering mainly during the early stages of the design process. The manufacturers of different mechanical systems involving bolted joints need suitable calculation models that allow integrated solutions. Numerous models approximate the parts and bolt stiffness using cones, spheres, equivalent cylinders or other analytical models [1–4]. According to the conventional theory, which was originally developed for loads that are centred or

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slightly off-centre, the stiffness of the member is constant. However, finite elements simulations as well as experimental results show strong non-linearities due to the changing contact area [5–7] with the external load. Stiffness non-linearities were studied by Grosse [8] and Guillot [9] and they propose a non-linear model but only for plate-like configurations.

Another weakness of the conventional theory lies in the way the so-called load factor is calculated. The load factor tries to measure the amount of the external force which is transmitted to the bolt. The location where external forces are applied on the member governs the load factor and the way the member stiffness is distributed. Zhang [10] developed a new analytic model of bolted joints and takes into consideration the stiffness reduction associated with the residual force on the assembly, compression deformation caused by external force and dimensions changing due to member rotation. This model has its limitation and is not applicable to bolted assemblies when the members are of different geometry or when the external forces are not symmetric about the member interface.

The specific model we are proposing for large bearings can serve as base for a generic model of circular flanges which can take into account the different non-linearities as well as different configurations or geometries by appropriate stiffness distribution.

2. The slewing bearings

The model this article proposes is suitable for specific bolted joints for large diameter bearings. These large bearings (up to 13 m (43 ft)) also called "slewing bearings", are used for cranes, radar dishes, tunnel-boring machines, etc. The two bearing rings are clamped to the main frame by preloaded high strength bolts. One or both rings are provided with gear teeth to enable the swing drive to operate. The connection is like a thick and narrow cylindrical flange on a very rigid frame fastened with a large number of bolts.

Another particularity of the system is the important and variable overturning moment. The bearings are subjected to radial and axial loads of same importance. The three types of bearings under study, ball bearings, crossed-roller bearings and three-row roller bearings, are presented in Fig. 1.

Due to the complexity of structure and the particularity of bolted joint loading, neither traditional models nor non-linear models are appropriate.

Thus we have developed a new model that takes into account simultaneously the bending stiffness in the axial direction with shell elements and in radial direction with tube-like elements. Furthermore, the

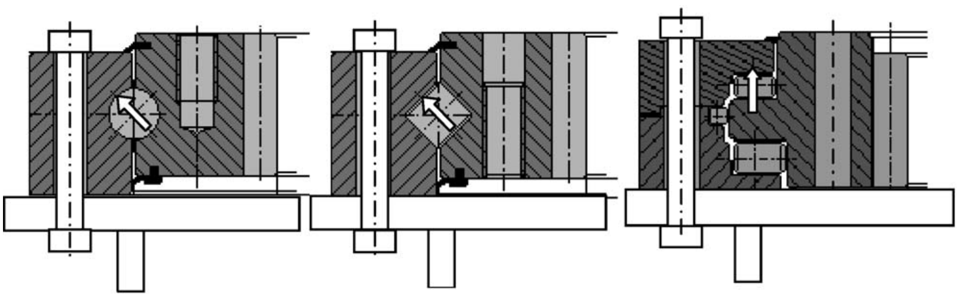

Fig. 1. Slewing bearings.