ECCOMAS Thematic Conference on Multibody Dynamics
June 29 - July 2, 2015, Barcelona, Catalonia, Spain

A semi-analytic/flexible bearing module combining multibody and parametric model order reduction

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Abstract

Over the last decades, the design of modern high performance and light weight mechanical systems led to an increasing interest in accurately predicting the dynamic behaviour, the vibration and the noise radiation levels in an early design stage by means of virtual modelling. Since roller bearings are an essential component in numerous machinery applications and represent an important force transfer path, they are often a determining component for the vibration levels and lifetime conditions in machines.

The use of analytical bearing models like, for instance, [1] and [2] in Flexible Multibody (FMB) models offers an effective means to include accurate bearing stiffness representations during system-level analysis. These kinds of approaches can take into account effects like centrifugal loads and gyroscopic effects, and are usually based on the Hertzian contact theory. In some applications, however, the influence of the supporting structure's flexibility and their interface can be decisive for the bearing's behaviour as it affects the load distribution over the rolling elements [3]. Consequently, bearing models representing sufficiently accurate stiffness and deformations on the interfaces to other bodies are essential in a FMB model to capture correctly the system's dynamic behaviour.

This contribution proposes to combine analytic solutions with the Finite Element (FE) method to deal with above mentioned ring and supporting structure's flexibility. The approach separates the bulk deformation and the nonlinear local deflections at the contact zone in a similar fashion as performed by Wensing [4] for bearings, or Anderson and Vedmar [5] for gears. The main advantages of these semi-analytic strategies lie in the accurate contact description that combines the non-linear effects present at the contacting interface with a standard FE formulation in those regions in which nonlinear effects are not prominent. Moreover, coarser FE meshes can be used as they should only accurately represent the more global bulk deformation. The latter, however, might cause convergence problems and unphysical oscillations when contact algorithms are applied as the C^0 continuity of the FE meshes results in more abrupt changes in the element surface normal. For dynamic contact simulations, C^2 continuity is called for to yield continuous accelerations at the inter-element boundaries. Contact smoothing, using B-splines surfaces, has been adopted to alleviate issues of non-smoothness.

Model Order Reduction (MOR) [6] schemes are used to keep computational effort affordable at the expense of a minimal loss of accuracy. The FE model which describes the global bulk deformation caused by the rolling element contact forces is reduced by projecting it onto a suitable low-dimensional subspace, spanned by a set of (global) deformation patterns. The influence of the supporting structure's stiffness and their interface are automatically considered in the reduced order model. The deformation patterns are adjusted such that they only represent the bulk deformation of the rings and supporting structure. One particularly challenging problem is the efficient treatment of time-varying multiple-input/multiple-output (MIMO) behaviour. The application of traditional MOR techniques such as Component Mode Synthesis (CMS) [7] leads to a considerable reduction, but suffers from this strong input/output correlation. Recent developments in the field of parametric MOR (pMOR) have led to a new method [8, 9] that deals with the particular but frequent case of moving loading or boundary locations. A parametric relationship which describes the location of externally applied loads on a linear hexahedron mesh has been described to form a continuously time-varying reduction space. A mode tracking technique is inherently incorporated in this method by interpolating among the correct modes. This work elaborates on the simulation of an indirect dynamic bearing force measurement setup using the pMOR strategy in order to demonstrate the capabilities of the proposed semi-analytic bearing model. Preliminary results of the efficiently reduced order bearing model with flexible rings will be shown.

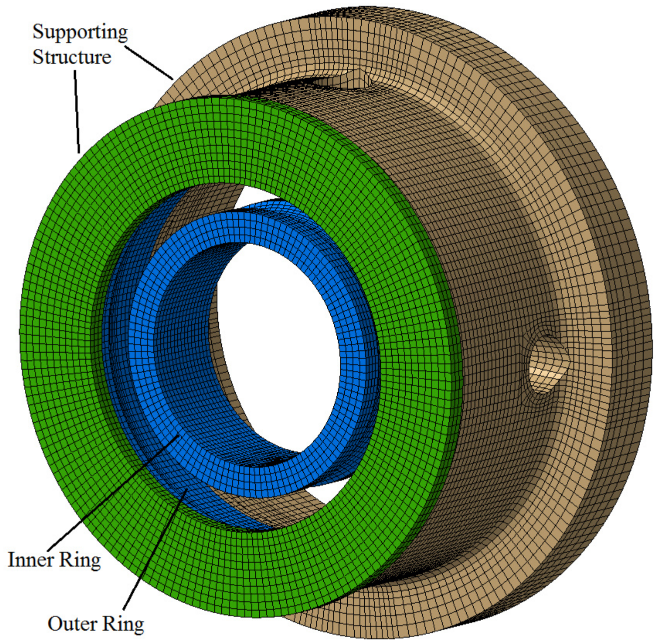

Figure 1: Finite element mesh of the bearing rings with supporting structure for the computation of the bulk contribution.

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