Flexible multibody modeling of a racing motorcycle cranktrain: model reduction issues

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ABSTRACT

This paper discusses the development of a multibody model of a Ducati L-twin engine cranktrain, aimed at accurately evaluating the loads acting on the main components in the system, thus allowing an improved structural design. The model comprises a single throw crankshaft carrying a flywheel and two pinions, and coupled with two connecting rods and related pistons.

The high rotational speed of the engine at issue makes it necessary to model the main system components as flexible, in order to capture elastodynamic effects which might have a major impact on the estimated loads. Starting from a Finite Element description of such components, a classical Component Mode Synthesis technique is employed to reduce the model order: after the definition of interface degrees of freedom (DOFs), with subsequent partitioning of mass and stiffness matrices, a Craig-Bampton mode set is formed, made up of constraint modes and fixed-interface normal modes. Commonly all normal modes having frequencies below an arbitrarily chosen cutoff value are included in the mode set. In this work the selection procedure is performed in accordance with a modal ordering scheme based on the Effective Interface Mass measure of dynamic importance, originally developed for pure structural dynamics analysis. The effectiveness of the selected modal base is judged by comparing full and reduced representation frequency responses over the frequency range of interest, and by using some standard modal correlation criteria.

The model assembly phase is carried out using a commercial multibody software platform. The flexible multibody model is enriched by introducing non-ideal joints at the main interface locations. In particular, angular contact ball bearings are modeled according to a 5-DOF nonlinear scheme in order to properly account for the main bearing dynamics. In addition, an impedance-based hydrodynamic bearing model is implemented providing an enhanced load prediction at the big end locations. Nonlinear dynamic simulations are eventually performed, and results are presented supporting the effectiveness of the proposed model reduction methodology.

Keywords: engine cranktrain, flexible multibody modelling, model reduction, effective interface mass

1 INTRODUCTION

Modern powertrain design is facing increasingly strict requirements in terms of emissions, fuel consumption, noise and vibration levels. In recent years, this trend is extending towards the motorcycle industry, in which competitive design focused on achieving high power-to-weight ratios calls for optimized engine components. This in turn requires the adoption of a multi-disciplinary approach early in the conception phase, and the use of advanced simulation tools which might help the analyst in gaining a deeper insight into the physical phenomena associated with the engine operation. Concerning powertrain dynamics, modern analysis techniques involve the adoption of multibody simulation tools, which allow an accurate prediction of loads acting on the engine components, thus leading to an optimal structural design.

Several approaches are described in literature dealing with multibody modelling of i.c. engine powertrains. Some papers deal with the construction of fully coupled cranktrain models through the use of commercial multibody dynamics codes, which provide a general modelling platform for mechanical systems,