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PARTIAL INTERFACE MODES IN COMPONENT MODE SYNTHESIS

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ABSTRACT

Component mode synthesis (CMS) methods consist in performing the dynamic analysis of structures by decomposing the structure into substructures and by projecting the motion equation of the substructures on a projection basis to obtain the reduced systems of the substructures before performing the substructure coupling to obtain the reduced coupled system of the whole structure.

For the classical CMS methods, the substructure projection basis is composed of, on the one hand, the rigid and flexible normal modes of the substructure with fixed, free, hybrid or loaded boundary conditions at the substructure interface, and on the other hand, the Ritz vectors obtained from the static deformation modes of the substructure, such as the constraint modes, the attachment modes, the residual attachment modes etc.

A particularity of the classical CMS methods is that the unknowns in the reduced coupled system include all the physical displacements at the interface between the substructures. In some cases, especially when three-dimensional structures are concerned, the size of the reduced coupled system are still important since there can be many thousands degrees of freedom (DOF) at the interface, for example between the blades and the disk or between the disk sectors in turbomachinery blade-disk systems.

In order to reduce the number of the interface coordinates, the CMS methods using the interface modes has first been developed for the fixed interface CMS method [2,1] and then extended to the free and hybrid interface CMS methods [4,5,6]. In these methods, the static modes are replaced by the interface modes, also called the eigen modes of the Poincaré-Steklov operator, which are the first few normal modes of the whole structure after performing Guyan's static condensation [3] to the interface between the substructures. The interface displacements associated with the static modes in the classical CMS methods are replaced by a few generalized coordinates associated with the interface modes, producing reduced coupled systems with very small sizes. One of the drawbacks of these methods is precisely that all of the interface displacements are eliminated from the reduced coupled system, while the presence of some physical interface coordinates is sometimes necessary, either because these coordinates can provide quick and useful information, or because we want to intervenne directly on these coordinates, for example in problems involving local non-linearities such as friction or free-play.

The aim of this work is to propose the new CMS methods using the partial interface modes in order to fix this drawback. These methods are the generalization of the classical CMS methods and the methods

using the interface modes, since they allow at the same time the reduction of the number of the interface coordinates and the conservation of some physical displacements at the substructure interface. To this aim, the originality of the new CMS methods is that, instead of computing the interface modes, the latter are approximated by applying a second level CMS method to Guyan's reduced system whose DOF are partitionned into two sets containing respectively the interface coordinates to be eliminated and to be kept in the final reduced system, the first set being considered as the interior DOF and the second set as the interface DOF in the second level CMS method. The partial interface modes are defined as a first few normal modes of Guyan's reduced system in which some of the kept interface DOF can be fixed, depending on which CMS method, that is with fixed, free or hybrid interface, is applied to Guyan's reduced system. They are completed with the static modes of the latter. The static modes of the classical methods or the interface modes of the methods using the interface modes are then replaced by the partial interface modes and the static modes of Guyan's reduced system in the projection basis.

Several new CMS methods using the partial interface modes, with various types of interface (fixed, free and hybrid) and with 3 interface nodes kept in the final reduced system, are applied to a bladed disk with cyclic symmetry in both tuned and mistuned cases (Figure 1a). They are compared with the classical CMS methods and the methods using the interface modes, and also with the reference results obtained by performing the computations on the whole structure. In the tuned case, only one reference sector is modelized (Figure 1b) since the cyclic symmetry properties are used in the CMS methods as well as for the reference results. In both tuned and mistuned cases, the results provided by all the CMS methods are in very good concordance the reference results (Figure 2). However, the advantage of the new CMS methods is that although the size of the reduced system is about 5 times smaller compared to the classical methods, the results are still very good, and they are also better than those of the CMS methods using the interface modes, with a few additionnal physical coordinates in the reduced system.

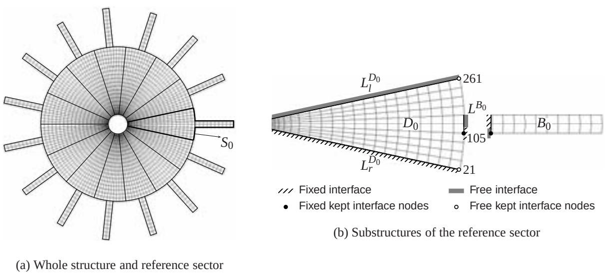

Fig. 1: Mesh of the bladed disk and substructures of the reference sector

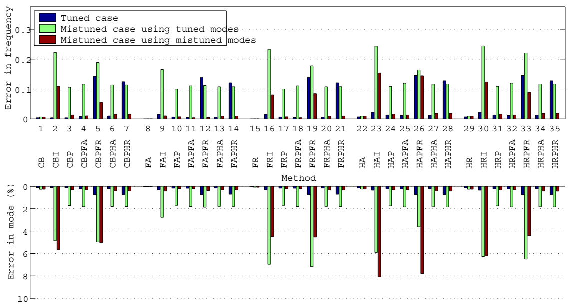

Fig. 2: Percent errors in structure frequencies and modes obtained with CMS methods

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