Eliminating interface degrees-of-freedom in substructuring

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Abstract

Substructuring methods have been used in finite element modeling of large or complex structures by partitioning the entire structure into several smaller or less complex substructures. The FE model of each substructure is reduced individually via a component mode reduction technique and then assembled together with the remaining reduced substructures to obtain a reduced model for the entire system. In the standard substructuring methods that have been developed in the past decades the interface degrees-of-freedom (DoF), or a transformation of them, remain in the reduced model [1–3]. Although in some problems it might be necessary to keep such DoF in the reduced model, in general the size of the model could be reduced even further if the interface DoF are reduced as well. Despite the works done on the truncation of the interface DoF [4–6], to the best knowledge of the authors, none has addressed the possibility of eliminating such DoF.

In this paper a different method of substructuring is presented which enables the elimination of the interface DoF [7, 8]. The proposed method employs a new way of partitioning the structure that is different than what is normally used in the standard substructuring methods. In this method the partitioning is done in such a way that the adjacent substructures overlap in two layers of nodes, as shown in Fig. 1–a. Therefore the interface degrees of freedom of each substructure become a subset of the free DoF of the other substructure(s). The inclusion of the interface DoF as a subset of the free DoF can potentially be used to eliminate the interface DoF.

Eliminating the interface DoF can greatly reduce the DoF of a condensed model incorporating substructuring. For example, subtracting can be used to isolate the contact region in a condensed FE tire model. Such isolation allows a more efficient mode selection to capture the deformation in the contact region. However, using a standard subtracting method requires defining several interface nodes which remain in the condensed tire model. On the other hand, using the new method one can eliminate these nodes achieving a much smaller condensed tire model. Table 1 summarizes two condensed FE tire models which incorporate substructuring. The total number of DoF of the model which uses the new method is only a fraction of that of the model which uses a standard method.

This paper addresses the case where a structure is composed of two substructures. It is shown that under certain conditions it is possible to eliminate the interface DoF from the reduced model. The present authors in another presentation [7] have shown the applicability of this method on a simple structure. In this paper the new method is applied to more examples and its advantages and disadvantages are discussed.

Table 1: Substructuring in a condensed FE tire model.

Method	# of modes from substructure 1	# of modes from substructure 2	# of interface nodes	Total DoF
Standard method	10	20	100	10 + 20 + 3*100
New method	10	20	NA	10 + 20

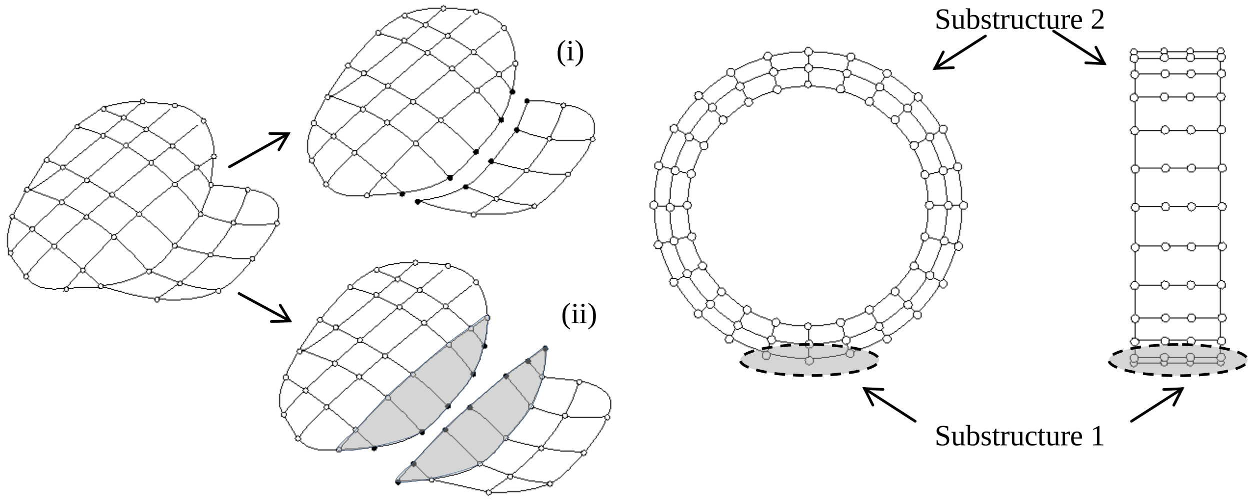

Figure 1: (a) The partitioning of a structure into two substructures; (i) the conventional way, and (ii) the proposed method; the overlapped region is shown in grey. (b) Substructuring in a FE tire model to isolate the contact region (substructure 1).

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