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Response prediction techniques and case studies of a path blocking system based on Global Transmissibility Direct Transmissibility method

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ABSTRACT

In this paper, the prediction capabilities of the Global Transmissibility Direct Transmissibility (GTDT) method are further developed. Two path blocking techniques solely using the easily measured variables of the original system to predict the response of a path blocking system are generalized to finite element models of continuous systems. The proposed techniques are derived theoretically in a general form for the scenarios of setting the response of a subsystem to zero and of removing the link between two directly connected subsystems.

The objective of this paper is to verify the reliability of the proposed techniques by finite element simulations. Two typical cases, the structural vibration transmission case and the structure-borne sound case, in two different configurations are employed to illustrate the validity of proposed techniques. The points of attention for each case have been discussed, and conclusions are given. It is shown that for the two cases of blocking a subsystem the proposed techniques are able to predict the new response using measured variables of the original system, even though operational forces are unknown. For the structural vibration transmission case of removing a connector between two components, the proposed techniques are available only when the rotational component responses of the connector are very small. The proposed techniques offer relative path measures and provide an alternative way to deal with NVH problems. The work in this paper provides guidance and reference for the engineering application of the GTDT prediction techniques.

1. Introduction

In an engineering NVH problem, a common approach is the use of transfer path analysis (TPA) method to identify the NVH sources and calculate the contribution of each source to the problem. According to the analysis results, structure modifications then can be made in order to reach the desired goals. In the past three decades, a large number of TPA methods have been described in literature, all having their specific advantages and disadvantages.

Among TPA methods, one class aims at finding the contributions of various forces acting on the assembly to the target response, independently of their transmission paths [1]. Such strategies are referred to the classical TPA: the matrix-inverse

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and mount-stiffness methods [2], Operational path analysis with exogenous inputs (OPAX) [3] and Component-based TPA [4–6]. The Component-based TPA includes in situ TPA, blocked force approach, free velocity approach, hybrid interface approach and pseudo force method, which have been classified in [7]. Most research on these methods has been focused on improving the ways to obtain the operational forces acting on the assembly and reducing the time and effort involved. Besides, the Operational TPA [8–10] is also classified into this group, because it attempts to find the contribution of each transfer path to the target although it is decomposed in term of other subsystem responses, instead of forces.

Another class of TPA, aiming at quantifying and ranking the transmission paths, can be found by means of the Global Transmissibility Direct Transmissibility method (GTDT). The GTDT method, also called Advanced TPA, is a variant of TPA. In GTDT the response at a given subsystem is reconstructed from the direct transmissibility and responses at all other subsystems. GTDT offers an alternative for troubleshooting NVH problems in a very different way from other TPA methods since it cannot give explicit result of transfer path contributions in terms of operational forces, but characterizes the response transmission paths.

Since first proposed in 1981, GTDT has been reported in many literatures. For instance, it was applied to a finite simply supported beam [11] or a discrete mechanical system [12]. In the former reference, the main purpose is to expound the relationship between the so called global transmissibility and direct transmissibility, as well as the responses reconstruction process. In [12], the prediction capabilities of GTDT method in two path blocking situations (blocking a mass and blocking a link between two masses) were first discussed. Besides, an experimental validation of the direct transmissibility approach to classical TPA on a mechanical setup has been carried out in [13]. In [1,14], the GTDT method were applied to study the cabin noise of railways. Some other related topics can be found in [15–17], and they will not be discussed in this paper.

Generally speaking, the GTDT has the following features and advantages compared with other TPA methods:

- First, as mentioned above GTDT can characterize the response transmission paths, complementing the possibilities of other TPA methods by allowing the determination of the part of response due to neighboring subsystem responses.
- Second, GTDT calculates the target response using the direct transmissibility and other subsystem responses. It avoids the necessity to perform demounting tests and to measure, or indirectly determine the operational forces.
- Third, the direct transmissibility plays the role of a connectivity function, revealing the connection relation between two subsystems. A zero value means that the two subsystems are connected by a third subsystem, while a non-zero value corresponds to directly linked subsystems.
- Besides, GTDT offers much simpler sets of measurements, although it yields more intricate data post processing [12]. Other TPA methods do not necessarily involve more measurements but measurements are more complex.
- Last but not least, GTDT has the potential prediction capability. The prediction capability refers to predicting the response of a modified system (exactly speaking a path blocking system), rather than the original system. The force TPA also has prediction capability. Whether to apply one method or the other will depend on the possibility of acting on the forces entering the passive side of the mechanical system, or that of modifying the system itself.

Among these features, it is the authors' belief that a key advantage of this method is the potential prediction capability. Different from other TPA methods, GTDT prediction gives a relative path measure. This feature offers a possibility of directly assessing the effect of a structure modification on the target response. From that point, decisions can be taken to act directly on the selected components or connectors. The related work had been done for a discrete mechanical system in [12].

In this paper the prediction capabilities of the GTDT method are further developed. Two path blocking techniques are generalized to finite element models of continuous systems. The path blocking techniques solely use the easily measured variables of the original system to predict new system response. To verify the reliability of the proposed techniques, the structural vibration transmission and the structure-borne sound cases are studied using the proposed techniques in this paper.

Finally, it should be emphasized that the practicality of the method will not be discussed in this paper. In spite of this, the good practicality of the proposed techniques will be expected if a robust reliability is obtained. This is because the measurements involved in the proposed techniques pose no special difficulties, which has been validated by the controlled experimental tests in [13] and the engineering cases in [14]. Thus, no mention will be made of how measurements are to be made in practice as well as the statistical process involved. The finite element simulations provide all the relative data for analysis, avoiding random noise effects. The notation and terminology presented in the paper are designated to follow the ones used in related work of the GTDT method, and particularly the term subsystem is identified with a degree-of-freedom (DOF).

The following sections are organized as follows. First the basic theory of the GTDT will be reviewed in Section 2. In Section 3, two response prediction techniques are proposed and derived in a general form. The structural vibration transmission case and structure-borne sound case are presented in Sections 4 and 5 respectively. The proposed techniques will be applied on these two cases. A summary is given in Section 6.

2. The basic theory of GTDT

The basic theory of GTDT is briefly introduced in this section. More details can be found in [11–13].

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