Structural Response of a Reciprocating Compressor’s Discharge Tube Subjected to Model and Data Uncertainties

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The analysis of the dynamical responses of compressor components are typically evaluated by using mathematical-mechanical models, and many decisions are given based on numerical simulations. Such an investigation is usually performed in a deterministic framework that cannot consider the uncertainties of the numerical model. These uncertainties are present in a numerical investigation due to the variability of the model parameters, caused by the limitations of the manufacturing processes, as well as simplifications and/or lack of knowledge to describe complex physical processes accurately. In order to quantify the sensitivity of the model parameters and the epistemic uncertainties of a discharge tube’s structural numerical response—solved by the finite element method—two stochastic models are constructed, and their results are simultaneously analysed. The dynamical responses obtained from both stochastic models identify the robustness limits of the structural response when it is subjected to parameter uncertainties as well as model sensitivity by separating each contribution in the estimated dynamical structural response.

1. INTRODUCTION

In structural dynamics, a mathematical-mechanical model is constructed to quantify the physical responses of real structures. The first source of uncertainties during the modelling processes, called data or parameter uncertainties, is attributed to the variability of manufacturing processes. This sort of uncertainty affects model parameters like geometry, mechanical properties, and boundary conditions, among others. The second source of uncertainties, called model or epistemic uncertainties, is attributed mainly to assumed simplifications and/or the lack of knowledge to describe complex physical processes accurately. It is important to consider uncertainties during a modelling process as doing so can improve model predictability, especially at high frequencies at which small variations in system configuration can lead to very different structural responses.

The main purpose of this paper is to analyse a structural response of a discharge tube used in household compressors when subjected to data and model uncertainties. Figure 1 displays a scheme of a typical hermetic compressor used in household refrigerators. It is mainly composed of a compression mechanism, which generates high impulsive forces due to valve opening or closing, and a compressor housing, which is the most prominent source of noise in a household refrigerator. In order to decrease the vibration energy transmissibility from the compression mechanism to the housing, and consequently decrease the global compressor noise, the compression mechanism is suspended by springs. The spring stiffness values are selected to attain a mass-spring system with natural frequencies much lower than the operational frequencies of the compressor. The refrigerant fluid is conducted from the compression mechanism to the refrigeration system by means of the discharge tube. The tube serve as the main vibration energy path from the compression mechanism to the housing, and due its structural importance, it is designed with a particular geometry to decrease energy transmissibility from the former to the latter. However, due to its low dynamical stiffness, the first natural frequencies of the discharge tube are very close to the operational values. Thus any small variation in the structural configuration can lead to system resonance.

In order to investigate the sensitivity of a discharge tube finite element model’s sensitivity to data and model uncertainties, two stochastic models are constructed based on different formulations for random uncertainties modelling. The first one, called parametric probabilistic approach, allows the consideration of data uncertainties, modelling every uncertain parameter as a random variable. This is a very efficient tool to evaluate and due its structural importance, it is designed with a particular geometry to decrease energy transmissibility from the former to the latter. However, due to its low dynamical stiffness, the first natural frequencies of the discharge tube are very close to the operational values. Thus any small variation in the structural configuration can lead to system resonance.

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