11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

PREDICTION OF RATTLE OCCURRENCE USING PROBABILISTIC APPROACH

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Key Words: *Modal Sensitivity Analysis, Frequency Response Function, Rattle index.*

In recent years, as the performance of automobiles has improved, customers also care about the unwanted noise such as rattle caused by vibration.[1] Until now, developers have tried to remove rattle noise by adding sponges or grinding. In order to solve this problem right the first time, efforts are being made to predict the rattle occurrence at the design stage using the CAE tools.

Typically, the rattle phenomenon occurs at the small gaps and/or preloaded interfaces when they are subjected to the excessive vibration.(see Fig. 1) Direct modeling of this phenomenon requires high degree of complexity including nonlinear dynamics with discrete contacts. As an alternative, linear frequency response function (FRF) analysis is adopted for the assembled structure for the sake of efficiency. The idea is that candidate points with the small gaps or preloaded locations are initially identified by performing static analysis of the structure. Then FRF analysis is conducted under the forced vibration to investigate points and frequencies with large amplitudes that exceed the initial thresholds, at which the rattle may occur most likely. Since the rattle is critical at the small gap or preloaded location, random variances of the parts geometry and material properties are of great concern for the practical application of the developed model.

In this study, an efficient approach to find out the probability distribution of FRF responses is developed to address this problem, in which the probabilistic analysis is conducted by employing the combined modal sensitivity and Monte-Carlo simulation of frequency responses.[2] Design sensitivity analysis technique is applied to obtain the first order approximation of eigen-pair. Monte-Carlo simulation is applied to generate random samples of eigen-pairs due to the variability of input parameters, which are used to obtain the frequency responses via modal superposition technique.(see Fig. 2) Rattle is regarded to occur

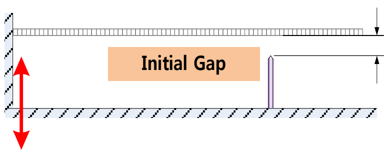

Figure 1. Rattle phenomenon

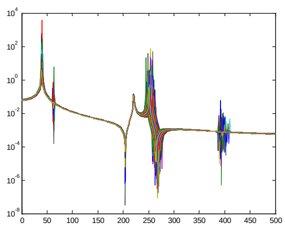

Figure 2. Frequency responses

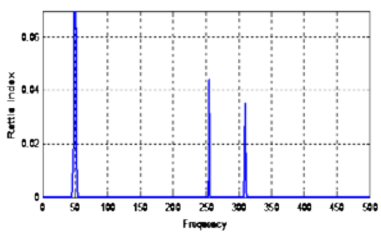

Figure 3. Rattle index

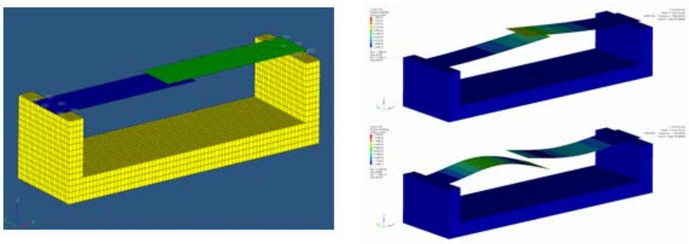

Figure 4. FRF analysis results of two beams

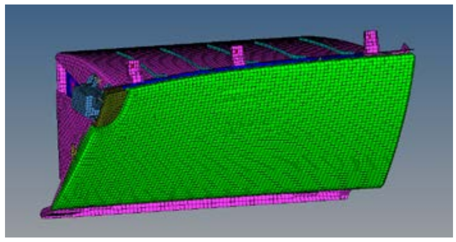

Figure 5. FEM model of glove box

at the gap when relative motion of two candidate points under forced vibration is bigger than the initial gap. Then, the FRF response of the two points is transformed to the time domain to obtain actual motion. To calculate the probability of rattle occurrence, rattle index is introduced.[3] Rattle index based on frequency response analysis indicates whether it occurs and how severe it is.(see Fig. 3) The advantage of the proposed method is the efficiency of computation as compared to the crude MC simulation, because it requires only a modal response analysis, followed by a small amount of additional computation. In order to carry out modal FRF and its sensitivity analysis, two options are considered and developed. One is to use commercial code NASTRAN because it has this analysis capability in its code. The other is to employ response surface method and carry out Monte-Carlo simulation in order to enable the solution while being independent of a particular code.

As a preliminary study, a simple problem with two cantilever beams(see Fig. 4) in close proximity is considered. Probabilistic FRF analysis is conducted under a given vibration with the thickness and material properties being random variables, from which the probability of rattle occurrence is evaluated. The results are validated by preparing a number of identical parts of the problem. The thickness and elastic constant are carefully measured for these models to estimate their probabilistic parameters. LMS shaker and accelerometer are used to measure the FRF responses and the rattle occurrence. The results are compared with the predicted ones.

Next, as a more practical application, rattle analysis of the automotive glove box(see Fig. 5) is carried out following the same procedure, and validated by a number of experiments.

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