

Probabilistic approach for rattle simulation of automotive interior parts

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In the recent period, squeak and rattle (S&R) in the automotive interior parts has become a primary source of undesired noise due to the relative improvement of noise and vibration quality of the other parts. Current practice is limited to the find and fix approach on the prototype vehicle such as taping or grinding, which may lead to increased lead time or greater warranty costs. In order to avoid this, recent efforts are directed to the development of CAE tool that predicts S&R at the design stage. Typically, the S&R phenomena occurs at the small gaps and/or preloaded interfaces when they are subjected to the excessive vibration. Direct modeling of this requires high degree of complexity including nonlinear dynamics with discrete contacts. As an alternative, recent development is devoted to the efficient method detecting the S&R points based on the linear frequency response function (FRF) analysis of the assembled structure. 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 of relative motion that exceed the initial thresholds, which are considered as hot spots where S&R are most likely to occur. Since the S&R 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 order to account for this, it is necessary to find out the probability distribution of the initial thresholds and FRF responses.

In this study, an efficient approach is developed to address this problem, in which the probabilistic analysis is conducted by making the first order approximation of the FRF response. Design sensitivity analysis technique is applied for this, which significantly reduces computational cost in contrast to the ordinary finite difference method. Commercial code NASTRAN is employed for the modal FRF and design sensitivity analysis with the solution SOL 111 and SOL 200 respectively. As a result, the probability distributions of the FRF response and initial thresholds are obtained, from which the probabilistic assessment of the S&R occurrence can be made. For the illustration of the method, two simple problems are examined to account for the gap and preloaded condition respectively using the two crossed cantilever beams made of polymer with one being in close proximity and the other being in forced contact. 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 but slightly different models. The thickness and elastic constant are carefully measured for these models to estimate their probabilistic parameters. For each model, initial thresholds for the gap and preloads are measured. Then shaker and accelerometer are used to measure the FRF responses and the rattle occurrence. The results are compared with the predicted ones.