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# Reduction of Engine Shake Base on Energy Transmissibility Control

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Performance evaluation indexes for automobiles include ride comfort, steering stability, and collision safety, and vehicle development that optimizes these multiple performances at the same time is required. However, so-called "rework" still occurs today, and design development without rework is expected by optimizing multi-performance at an early stage of design.

Based on this expectation, the authors are working on high-efficiency design without reworking by optimizing multi-performance in the early stages of design and creating new value in the process. As part of this effort, we have constructed a model focusing on the transfer characteristics of vibration energy and obtained low-vibration design guidelines for the conceptual design of automobile road noise (multi-input, broadband vibration noise). Statistical Energy Analysis (SEA) was used to study the energy transmissibility (Coupling Loss Factor) between structural elements represented by a mathematical formula (model not considered in terms of form). This CLF formulation can be applied to systems with many modes, and although it is effective for low-frequency problems where modes are conspicuous, it is not sufficient. Therefore, in order to solve the vibration problem in the low-frequency range, we focused on the CLF between the two-degree-of-freedom vibration system, which is shown as the basis of SEA, and analyzed the behavior between the yaw response and the roll response during vehicle motion.

Therefore, in this research, using the CLF (energy transmissibility) between two-degree-of-freedom vibration systems, we discuss how existing method to reduce engine shake can be interpreted from the perspective of energy transfer, and how it can be applied to design. In this paper, we focus on two typical techniques for reducing engine shake, namely, the combination of engine bouncing and pitching and the use of a hydraulic engine mount.

The energy transmissibility, which express the ease of transmission of energy between mass points, are expressed below using each item in Fig.1.

$$\eta_{12} = \frac{1}{\omega}\frac{\kappa_{12}^2(\Delta_1+\Delta_2)}{(\Omega_1^2-\Omega_2^2)^2+(\Delta_1+\Delta_2)(\Omega_1^2\Delta_2+\Omega_2^2\Delta_1)} \tag{1}$$

where $\Omega$ and $\Delta$ are the uncoupled natural angular frequency and damping characteristics of the mass point , and $\kappa_{12}$ are the coupling characteristics between the mass points, and are expressed as follows.

$$\Omega_i = \sqrt{\frac{k_i+k_c}{m_i}}\ (i=1,2)\ ,\Delta_i = \frac{c_i}{m_i}\ (i=1,2)\ ,\kappa_{12} = \frac{k_c}{\sqrt{m_1 m_2}} \tag{2}$$

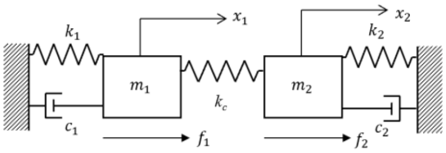
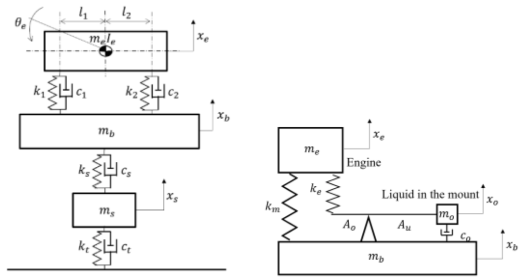


Fig.1 Two degree of freedom model

In this report, we apply the Eq.(1) to Fig. 2(a) and (b) and reconsider the existing papers from the energy perspective.

The model of energy transmissibility focuses on the energy transfer between mass points (elements) of the target system, and as shown in Fig.3, it represents the elements (blocks) that store energy and the paths (lines) between the elements. It becomes an energy block diagram. This diagram provides a bird's-eye view of the entire target, and for example, the addition of a "new element (function) that stores energy" indicated by #new in the diagram, and the dotted line indicating elements #4 and #7 It can be said that it is easy to lead to the creation of new ideas such as the addition of a new transmission route (Additional path).

Applying the above to Fig.2 (a) and (b), we can interpret them as follows. In other words, in order to suppress engine bouncing, engine pitching was added in Fig.2(a), and a hydraulic engine mount was added in Fig.2(b).




(a) Engine two mode model (b) Hydraulic mount model

Fig.2 Engine shake models

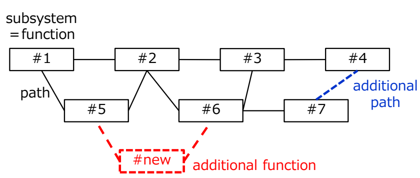



Fig.3 An example of energy-brock diagram