

Technique for Predicting Powertrain Self-Excited Vibration at Vehicle Start-Up

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ABSTRACT

A clutch FEM model was created to quantitatively understand the operation and dynamic friction characteristics of the facing materials. And a simulation model for dynamic behavior analysis of the torque transmission characteristics from a transmission that incorporates drivetrain damping characteristics to the vehicle body was constructed. The data of the actual vehicle was also measured when vibration occurs and loss torque is generated by friction in the drivetrain, and damping characteristics were determined from the measurement values. In order to confirm the usefulness of this method, the construction of a clutch that suppresses self-excited vibration was examined by simulation and the reduction of vibration in an actual vehicle was confirmed.

CITATION: Hoshi, T., "Technique for Predicting Powertrain Self-Excited Vibration at Vehicle Start-Up," *SAE Int. J. Engines* 8(4):2015, doi:10.4271/2015-01-1674.

INTRODUCTION

The vibration that is an issue in the drivetrain includes forced vibration and self-excited vibration. The frequency of forced vibration varies depending on the speed of rotation, and the frequency of self-excited vibration depends on the eigenvalue of the drivetrain and remains fixed. In the case of forced vibration, the shape and precision of component parts often provide ways of examining the causes of vibration and measures against it. In the case of self-excited vibration, the amplitude of the vibration tends to continue increasing as long as slippage occurs in the clutch. Many of the factors involved in quantification of the slope of the dynamic frictional characteristics of the clutch and the damping characteristics of the drivetrain are unknown. In the current state of technology for simulating vehicle vibration, the clutch is most often represented by a single coefficient of friction, so that the technology is not yet at the point of allowing for investigation of vibration countermeasures by means of clutch structure at the design stage. Consequently, countermeasures against self-excited vibration to date have been taken from the perspective of limiting the deterioration of facing materials or oil, which affects friction characteristics to a considerable extent (1),(2). For this paper, therefore, attention was focused on the dynamic frictional characteristics of the clutch facing materials and methods for their use. The clutch was created as a finite element method (FEM) model, and technology for dynamic behavior analysis capable of simulation torque transmission characteristics during self-excited vibration by means of a plant model that includes the damping characteristics of the drivetrain was developed. This clarified the mechanism by which the torque transmission characteristics of the drivetrain are determined and enable quantitative prediction of self-excited vibration.

VIBRATION ANALYSIS

Figure 1 shows the main section of the transmission used for analysis. It has a wet-type starting clutch placed above the driven pulley shaft, and it enables the vehicle to move smoothly from a standing start by controlling the pressure in a hydraulic circuit placed within the rotating shaft.

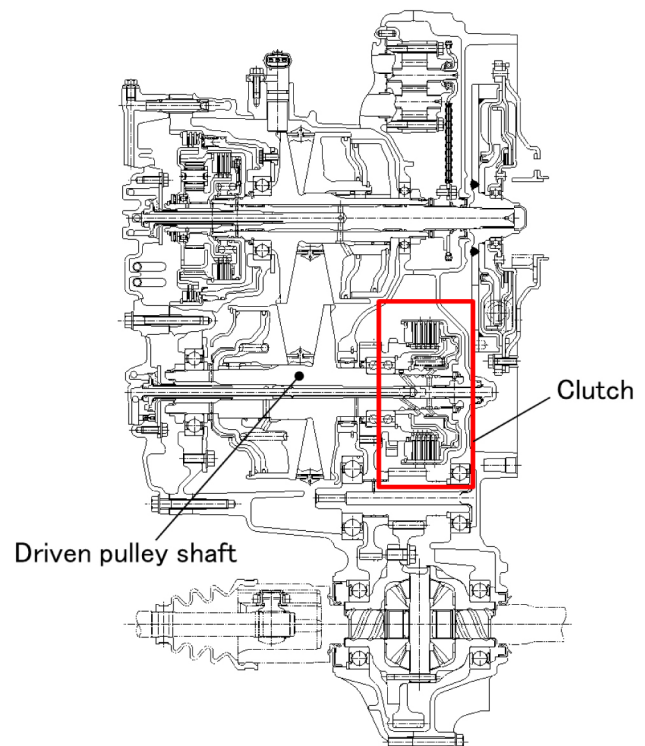


Figure 1. Main section of CVT transmission



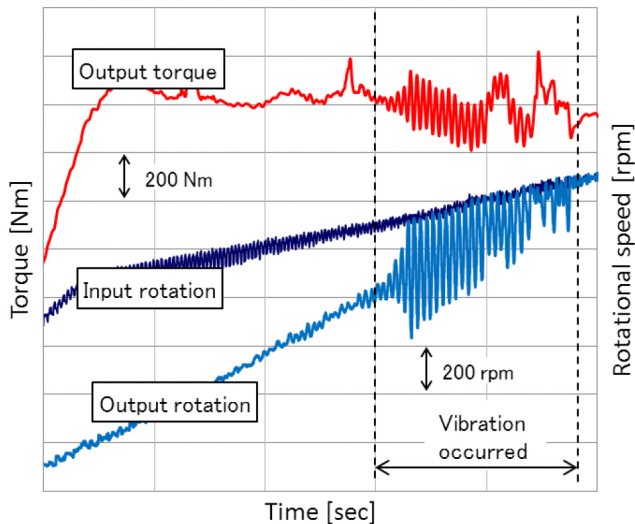


Figure 2. Self-excited vibration measurement results

Figure 2 shows the results for reproduction of vibration in an actual vehicle by the use of oil that has no friction modifiers added to it. The output speed during acceleration from a standing start was subjected to frequency analysis by fast Fourier transform (FFT), and the results indicated that in addition to a forced vibration with a frequency that rises in proportion to the speed of rotation, there was also a self-excited vibration with a frequency that reached a fixed peak independent of the speed of rotation in the range where vibration occurred in the clutch (Figure 3).

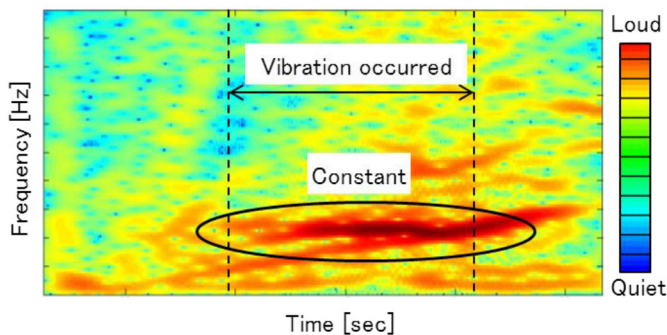


Figure 3. Frequency analysis of vibration at starting acceleration

Verification was also conducted of torque transmission characteristics from the torque measured on an actual vehicle and the rotational difference in the clutch. This showed a negative slope in the range of rotational difference where vibration occurred, suggesting that torque transmission characteristics with a negative slope with respect to rotational difference were contributing to the vibration (Figure 4).

Next, the distribution of surface temperature and surface pressure was investigated in order to determine the state of friction surfaces when vibration occurs in an actual vehicle. In order to measure the temperature of friction surfaces in the course of clutch engagement, thermocouples were embedded in the plates (Figure 5).

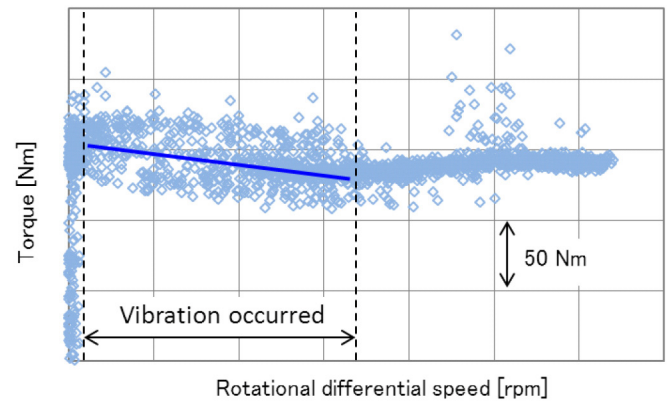


Figure 4. Torque transmission characteristics

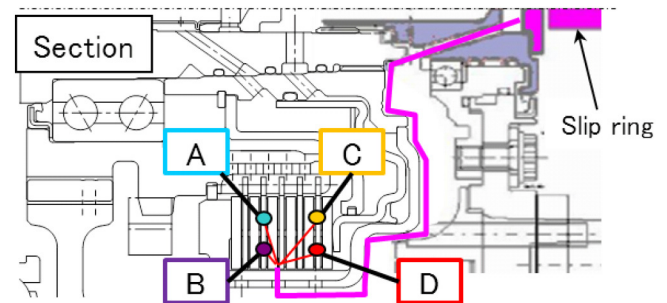


Figure 5. Measurement points

The rates of plate temperature increase were different at points A and C on the inside diameter and points B and D on the outside diameter, suggesting that temperature is distributed in a radial direction (Figure 6).

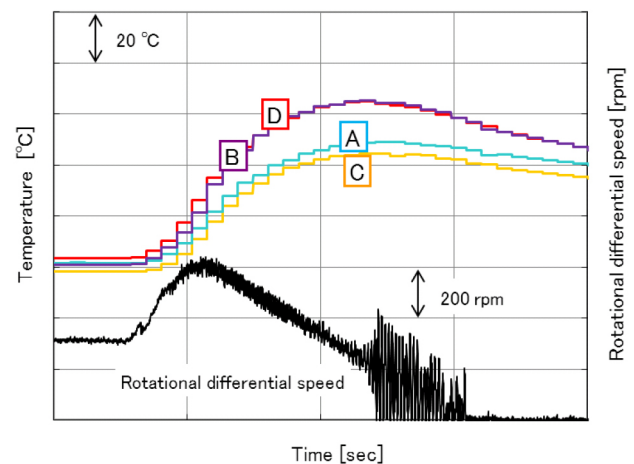


Figure 6. Plate temperature measurement results

ANALYSIS BY SIMULATION

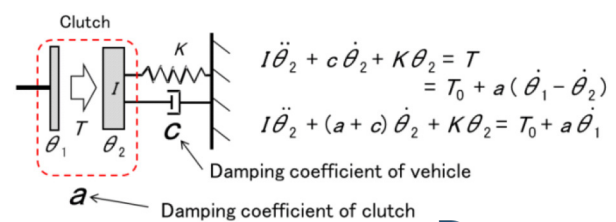


Figure 7. Self-excited vibration equation

