

Vibration	Development of Adaptability to Vehicles of Torque Rod Incorporating Active Control Using Inertia Mass	Transportation Machines
Control		

Object Machine	Torque rod as an engine-mount system part. A torque rod is a part to connect the engine and the vehicle body, consisting of two bushes and rods, which supports a driving reaction force of a pendulum type engine mount system (Fig.1).	
Observed Phenomena	<p>In accordance with the demand in recent years to enhance the fuel economy performance of automobiles, the downsizing technology (DST) accompanying cylinder reduction is being developed that uses an in-line four-cylinder engine as an alternative for a V type six-cylinder engine. If an in-line four-cylinder engine is used to deliver an engine torque equal to that of a V type six-cylinder engine, a torque per one cylinder increases, so that the engine originated exciting force becomes larger due to torque fluctuations, thus the sound vibration performance will be a problem (Fig.2). Up until now, an electric active control mount E-ACM (Fig.3 (B)) has been employed together with a cross mount system as a countermeasure to achieve, by an in-line four-cylinder engine, a sound vibration performance comparative to a V type six cylinders engine. But this method requires an additional mass, though the mass reduction is indispensability.</p> <p>This problem was compromised by using a simpler pendulum mount system. This technology was developed to provide a measure to achieve DST and weigh reduction (Fig.3 (C)). However, if a high torque engine is maintained in the pendulum mount system, noises during acceleration will be problematic.</p>	
Cause Estimation	<p>When the driving reaction force exceeds a supportable area, the bush of a torque rod receives a compression (or tension), leading to increase in the dynamic spring constant (Fig.4). Thus, engine vibrations are liable to be transferred to the vehicle body, and noises during acceleration will be a problem. By setting an upper torque rod on the strut side unfavorable for the vehicle transfer sensibility, contribution to the vibration transfer will be highest (Fig.5).</p>	
Analysis and Data Processing	<p>In the conventional torque rod design, it is a common practice to stiffen one insulator out of two, and to set the resonance before and after the torque rod higher, so as to reduce transfer. Setting high the resonance before and after the torque rod will be favorable to the muffled sound area up to 200Hz (secondary exciting force of a four-cylinder engine). On the other hand, as an engine vibration transfer will increase in the acceleration noise area of 250Hz to 800Hz, it was considered that, if the transfer system in this frequency region was improved, a sound vibration performance comparable to a V type six-cylinder engine might be attained (Fig.6).</p> <p>In place of an upper torque rod having a higher contribution to acceleration noises, an active torque rod (ATR) technique was applied as a countermeasure. With this ATR, the resonance before and after the torque rod was set at 200Hz or lower, together with utilization of the anti-vibration area in the acceleration noise area, the engine vibration transfer was decreased (Fig.6). However, setting the resonance before and after the torque rod at 200Hz or lower deteriorates the muffled sound, so that an active technique was adopted to this area as a countermeasure.</p>	
Countermeasures and Results	<p>Providing the torque rod with an acceleration sensor to detect forward/backward vibrations and also by controlling an integrated magnetic type of inertial mass actuator by acceleration feedback, the resonance was damped to reduce the gain (Fig.7). Here, the actuator coil was used as an integrator, and by applying an acceleration control voltage to the actuator, the speed phase was delayed by 90°, thus generating a control force proportional to the speed (Fig.8). By assembling an ATR into an actual vehicle, sound pressures were measured at the driver's ear position in the vehicle interior.</p> <p>Results of vehicle verification of acceleration noises are shown (Fig.9). Consequently, by the anti-vibration effect of ATR, the engine mount system mass, that has realized a performance level equal to or better in comparison with vehicles of competitors of V type six cylinder engines, has achieved a weight reduction by 40% compared to the conventional technology.</p>	
Lesson	<p>ATR has enlarged an application area of the pendulum mount system to the driving torque, thereby realizing the weight reduction of vehicles. And, in addition to the active mount (E-ACM) that has so far been applied to the main mount, the active technique (ATR) has been made available to torque rods. Thus, the engine mount system compatible with fuel economy</p>	

References

performance and sound vibration performance has found a wide field of application.

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Keywords

Control, engine mount system, active control, torque rod, acceleration noise, vibration control area

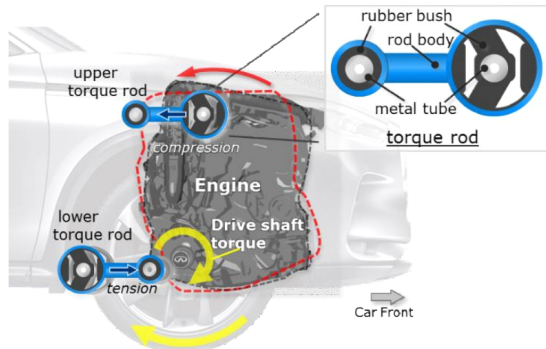


Fig.1 Function of torque rod

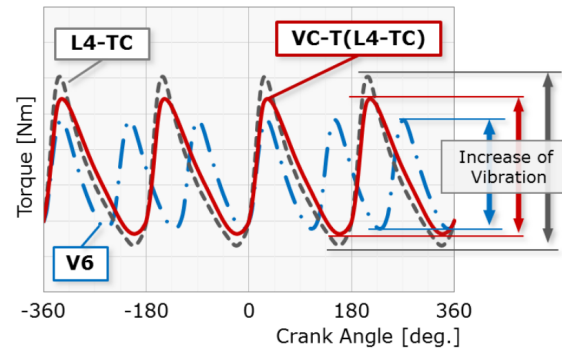


Fig.2 Cylinder reduction downsizing torque fluctuation

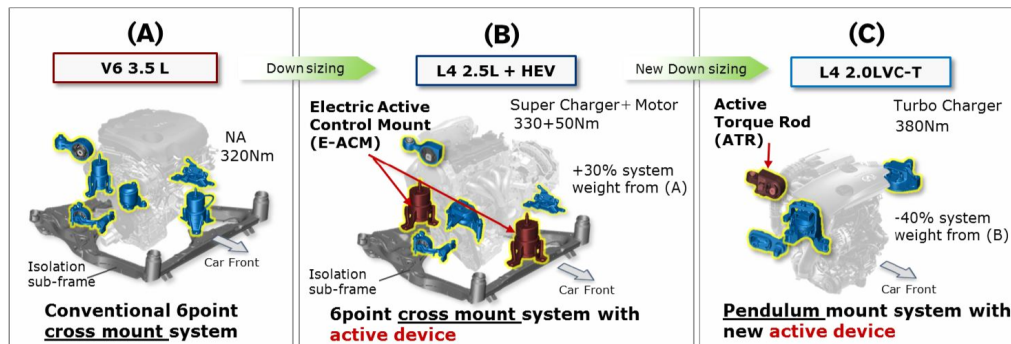


Fig.3 Downsizing Engine and Engine mounting system technology

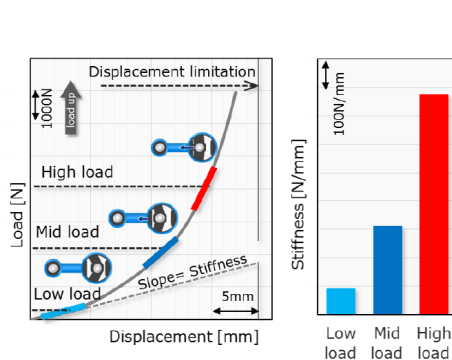


Fig.4 Load deflection and bush stiffness

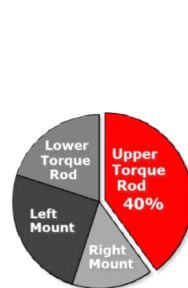


Fig.5 Vibration Input Contribution

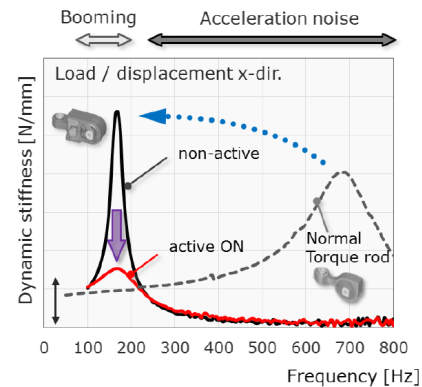


Fig.6 Test result of ATR and normal torque rod

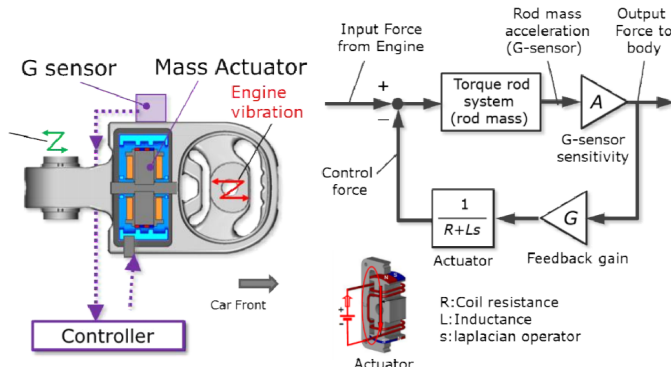


Fig.7 ATR system

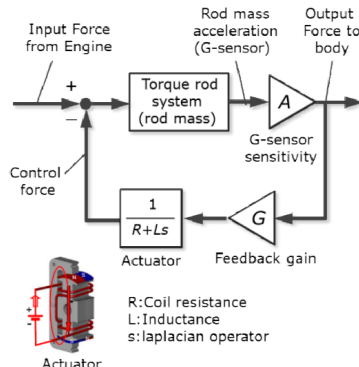


Fig.8 Control block diagram

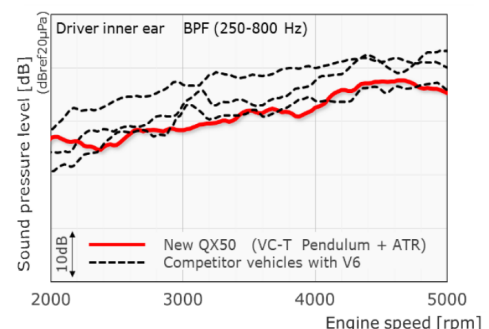


Fig.9 Acceleration noise