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Development of engine vibration improvement design technology for 100% electrically driven hybrid vehicle

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In recent years, demands for the global environment have increased and in the field of the automobile industry, efforts are being made to reduce CO2 emissions by improving the thermal efficiency of internal combustion engines. On the other hand, as the thermal efficiency is improved, the cylinder pressure is rapidly burned, so the engine vibration tends to be worse. In a 100% electric hybrid powertrain that uses the internal combustion engine only for power generation, it is required to improve thermal efficiency as well as achieve high quietness from the point of view of marketability. Therefore, we tried to improve the sound volume and sound quality of engine noise during power generation.

There are two indicators that customers feel the sound is loud and annoying. The first is sound volume the second is sound quality. In this report, we focus not only on the reduction of engine vibration on the frequency axis that affects sound volume, but also on the time series engine vibration fluctuation that affects sound quality and clarified the mechanism that the dynamic behavior of the crankshaft and the difference in power plant transmission characteristics between cylinders affect engine vibration. As a result, we constructed a design technology for improving the sound volume and sound quality and introduced the result of validating it.

Using an actual engine simulation, we focused on the dynamic resonance phenomenon and the crank shaft journal load at the time of combustion in each cylinder and analyzed the mechanism. As a result, it was found that the #4 crank shaft journal load due to bending resonance at the crank Rr end is large which contributes to the sound quality. It turned out that it is a factor of the large vibration fluctuation. To reduce the #4 crankshaft journal load, we focused on the tilting rigidity of the rear end of the crankshaft. By lowering the tilting rigidity of the rear end of the crankshaft, the modal mass of the bending resonance mode of the crankshaft is reduced, and the node position of the resonance mode is reduced to the load of the #4 crankshaft main journal, which is the vibration input point of the power plant. Fig.1 shows the result of considering this mechanism using a simple physical model. The center of gravity position (node position) of an object composed of two objects with a certain mass can be expressed by equation (1). If the M1 is heavy, the center of gravity will move away from the #4 crankshaft main journal, and if the M1 is light, the center of gravity will move closer to the #4 crankshaft main journal. (Fig1)

$L1 = M2 \times L(M1 + M2) \ldots$ (1)

M1: mass of object 1 M2: mass of object 2
L: distance between center of gravity of object1 and object2
L1: distance between center of gravity of object1 and object composed of objects 1 and 2

Fig.2 shows the results of testing the specifications that optimized the tilting rigidity of the rear crankshaft, and verifying the effects using an actual prototype. The fluctuation component of the engine vibration on the time axis that affects sound quality, was reduced by 3dB as expected from the analysis. In addition, NVH request is defined by physical characteristics and designing while clarifying the OK area with functions, it is possible to drop to part specifications without going back.

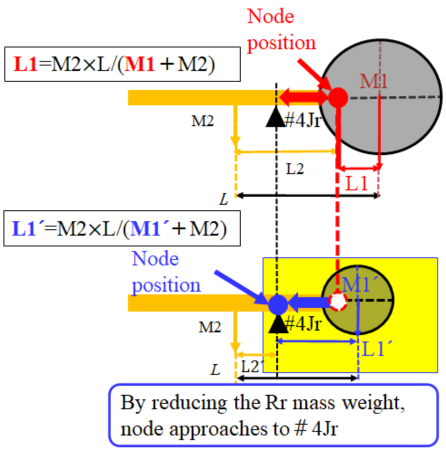

Fig.1 Improvement mechanism

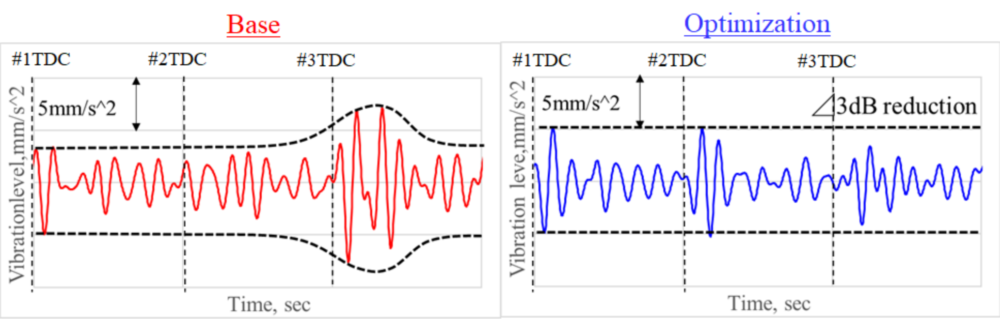

Fig.2 Improvement effect verification results