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A New Measurement Method of Piston Friction Force

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To improve engine fuel economy, a floating-liner measurement technique was developed, which quantifies piston friction force under fired engine operating conditions over a wide speed range. However, conventional floating-liner apparatuses are often limited at high engine speeds by vibration-induced noise and by drift caused by combustion-heat-induced thermal stress in the liner/support structure. Accordingly, this study aims to improve the repeatability of friction-loss measurement results in the high-speed operating region.

To suppress vibration, the liner assembly was supported from both sides via force sensors (double-sided support), which increases the effective stiffness of the support structure and thereby improves the speed capability. However, double-sided support can make force-sensor preload sensitive to thermal stress, resulting in measurement drift. To mitigate this drift, a cooled double-liner structure was introduced to isolate combustion-heat-induced deformation and to stabilize the sensor-mount temperature (Fig. 1).

At higher engine speeds, vibration of the support structure becomes non-negligible. Therefore, accelerations were measured on both the liner and the support, and the inertial-force correction used the difference between these accelerations (Fig. 2). The measurement signals were recorded at 200 kHz and processed with a 5 kHz low-pass filter, and the cycle-resolved friction force was obtained from an ensemble average over 200 cycles. Compared with the conventional liner-only correction, the proposed dual-acceleration correction reduced residual noise in the friction-force waveform. Repeatability was evaluated using friction mean effective pressure (FMEP) from repeated measurements at each speed; the repeatability metric (3σ of FMEP) remained below 0.5 kPa across 1000–4000 r/min, achieving highly repeatable measurement up to 4000 r/min (Fig. 3).

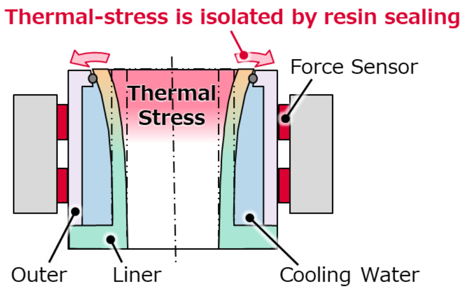

Fig. 1 Double-liner structure for thermal-stress isolation

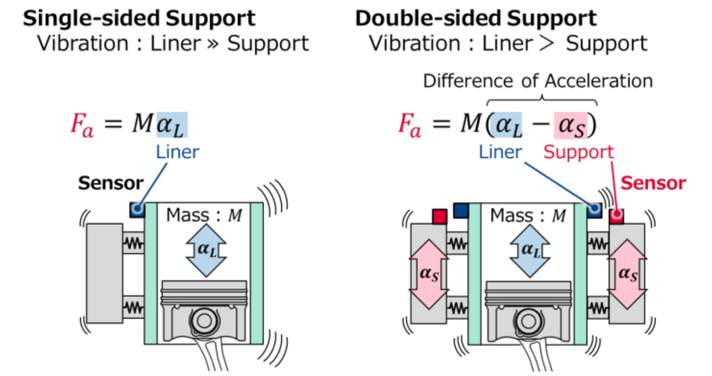

Fig. 2 Vibration-noise cancellation using liner and support accelerations

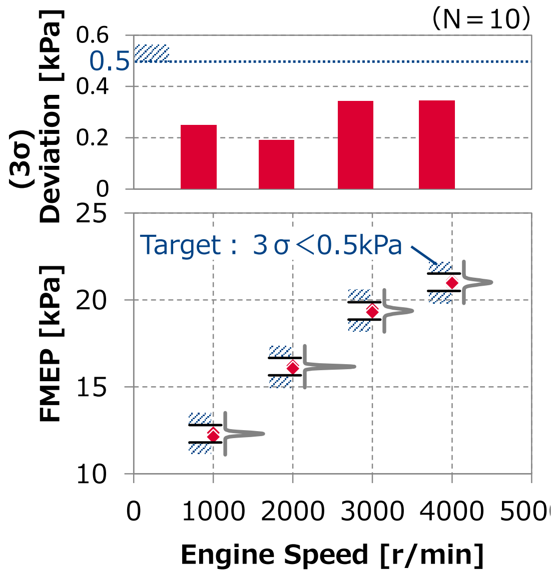

Fig. 3 Repeatability of FMEP at 1000–4000 r/min

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