

Experimental Study on the Mechanism of Hot Judder in Automotive Disc Brakes

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In recent years, technological advances have made automobiles exceptionally quiet and highly safe. However, during braking from high speeds with disc brakes, severe vibrations known as Hot Judder may occur in the vehicle. Hot Judder is not simply a vibration issue; it is also a critical challenge from the viewpoints of component lifespan and safety. Therefore, there is a need to clarify its occurrence mechanism and develop preventative measures. The authors have modelled this phenomenon as a self-excited vibration caused by time delay and conducted theoretical analysis. Furthermore, vibration measurement results from basic experiments using a dynamometer confirmed good qualitative match with the theoretical analysis results. In this study, the analysis method used in our previous study was extended by applying a low-pass filter to the experimental data to improve the accuracy of evaluating the behavior of the target mode. The growth of hot spots was then analyzed. As a result, the vibration characteristics of the target mode could be evaluated more clearly, enabling a more detailed investigation of the hot judder phenomenon.

With recent advances in automotive technologies, vehicle quietness and safety have significantly improved. However, in automotive disc brakes, as the temperature of the rotor surface rises due to braking at high speeds or continuous braking on long downhill slopes, heat becomes cyclically concentrated, sometimes resulting in striped thermal patterns known as hot spot. This phenomenon causes severe vibration, known as hot judder, to occur in the vehicle. Hot judder is not simply a vibration problem; it can also be a factor leading to thermal cracking in the rotor. Therefore, from a safety perspective, there is an immediate need to clarify its mechanism of occurrence and to investigate preventive measures. In previous theoretical studies on hot spots and hot judder, the prevailing approach has been to treat the phenomenon as vibration caused by thermal buckling. Numerous experimental studies on hot judder have been reported, verifying the occurrence of the striped heat pattern. However, despite this phenomenon being related to vibration, there have been very few studies that have conducted experimental investigation from a vibrational viewpoint. The authors have instead approached this phenomenon as a vibrational phenomenon and have performed theoretical analyses treating it as self-excited vibration caused by a time delay in the deformation pattern associated with the rotor's thermal expansion. Furthermore, hot judder was reproduced through fundamental experiments using a dynamometer test rig, and continuous vibration measurements were performed during braking. The results of the vibration analysis revealed that hot spots repeatedly grow and decay, and that their number increases over time; these findings show good qualitative agreement with the theoretical analysis results. Furthermore, experiments were conducted using test rigs with different support stiffnesses, and continuous measurements of the vibration modes of the brake unit as a whole were performed. It was confirmed that hot judder occurs even under conditions where the support stiffness of the brake unit differs, and that different vibration modes occur within the same frequency band. It was also confirmed that hot judder occurs even under conditions where the braking hydraulic pressure is reduced. In this study, using braking test data obtained in previous research, an analysis using a newly applied low-pass filter was conducted to evaluate the behaviour of the target mode more accurately, confirming the growth of hot spots. The results showed that the vibration characteristics of the target mode could be evaluated more clearly, enabling a more detailed examination of the hot judder phenomenon.

Figure 1 shows the results of harmonic analysis of the brake torque fluctuations after applying the low-pass filter. Figure 2 shows the brake torque fluctuation waveform extracted using the spot number filter. The waveform shown is a representative example for the case of 10 hot spots. Figure 1 shows that the number of hot spots associated with the target hot judder mode at approximately 100 Hz increases as the rotational speed decreases. Figure 2 shows a detailed view of the growth process in the case of 10 hot spots. These results confirm that the analytical method combining the spot number filter and the low-pass filter is effective for evaluating and analyzing the hot judder phenomenon.

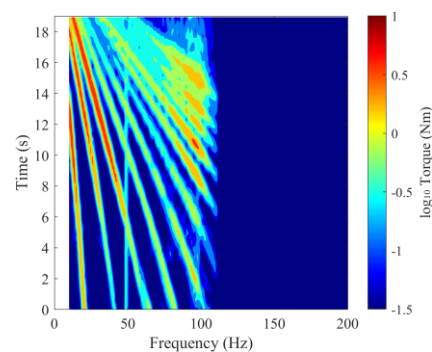


Fig.1 Harmonics Analysis Results with Low-Pass Filtering

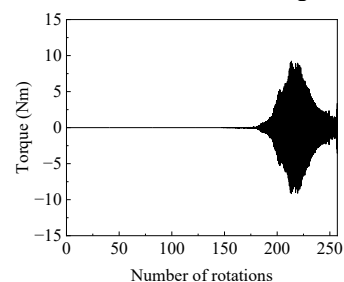


Fig.2 Low-Pass and Spot-Number Filtered Waveforms of Torque Fluctuation for 10 Hot Spots