Reduction of Tire Radiated Noise by Pattern Design Considering Tread Deformation during Rolling

Hiroshi Fujii [1)] Fumihiko Kosaka [2)]

1) Yokohama Rubber, Co. , Ltd.
2-1 Oiwake, Hiratsuka City, Kanagawa Prefecture, 254-8601, Japan (E-mail: hiroshi.fujii@y-yokohama.com)
2) Dassault Systemes K.K.
Kanden Fudosan Fushimi Bldg. 12F, 1-8-16 Sakae, Naka-ku, Nagoya-shi, Aichi, 460-0008, Japan (E-mail: fumihiko.kosaka@3ds.com)

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To address the stringent requirements of the exterior noise regulation (R51-03), this study introduces a novel tire pattern design method aimed at reducing tire-radiated noise at the source. Conventional methods, such as reducing the main groove volume to suppress resonance, often compromise essential performances like drainage and wear resistance. Therefore, we focused on the dynamic geometric deformation of the tire tread during rolling to develop a solution that avoids such trade-offs.

First, rolling simulations were conducted, and band-pass filtering was applied to the time-series data of the tire surface coordinates. This process successfully visualized a standing wave-like, steady geometric deformation on the tread ribs occurring near the contact patch. We discovered that this wave-like deformation dictates the dynamic behavior of the lug grooves: the grooves open when passing through the convex parts of the wave and close at the concave parts. Because this deformation is governed by the geometric flattening of the tire against the road surface, its wavelength (λ) can be defined by the rolling speed (v) divided by the center frequency (f_c).

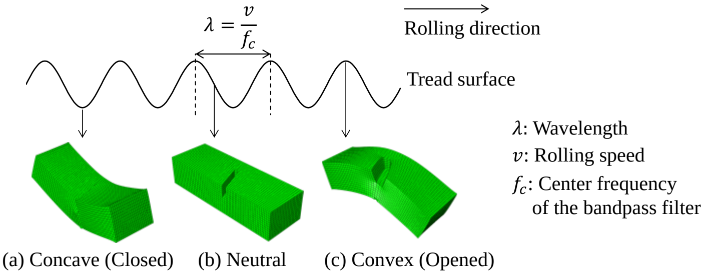

Fig.1 Schematic of the lug groove opening/closing mechanism caused by tread deformation

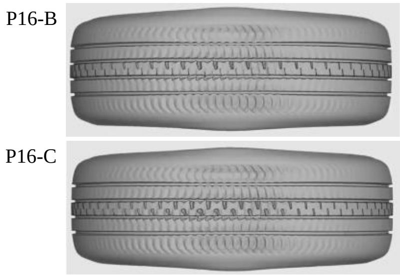

Fig.2 Dynamic deformation behavior of the tire at 957 Hz

Based on this mechanism, we hypothesized that the radiated noise, which is heavily amplified by the horn effect around 1000 Hz, could be suppressed by intentionally dispersing the opening and closing phases of the lug grooves along the tire circumference. By aligning the target frequency with the pitch frequency, the optimal lug groove interval (L) was theoretically derived as $L = P/2n$ (where P is the pitch length and n is the harmonic order). Notably, this optimal interval is independent of the vehicle speed, ensuring robust noise reduction across different driving conditions.

Vibro-acoustic simulations using single-pitch models demonstrated significant noise reduction when the lug grooves were arranged in an anti-phase configuration. Furthermore, when applied to a practical pitch-variation model (235/60R18), the optimized arrangement achieved a peak reduction of 6.6 dB at 50 km/h and 6.9 dB at 65 km/h. Finally, deploying this methodology to a production tire pattern resulted in a 1.5 dB reduction in the overall sound power level. This simulated improvement was successfully validated through physical bench testing of hand-carved prototype tires. The results confirm that this geometry-based approach is a highly effective, size-independent method for reducing tire-radiated noise.

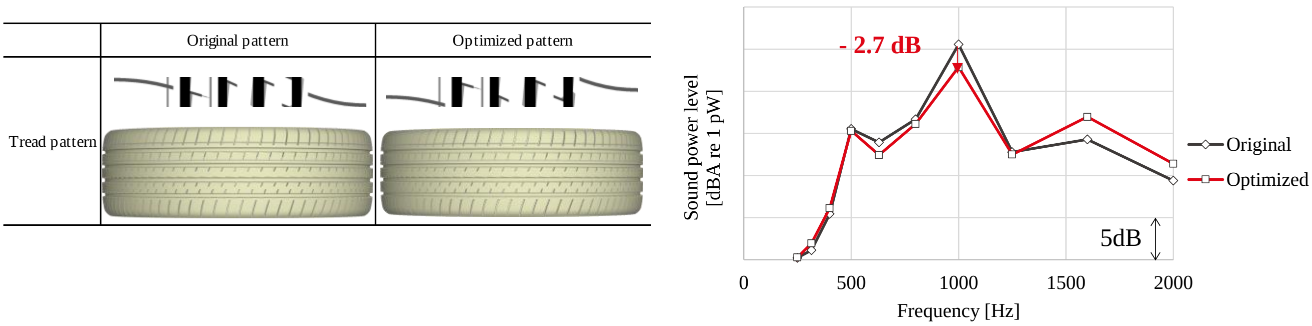

Fig.3 Comparison of sound power level between original and optimized patterns (Simulation)