Experimental Relationship Between Tire's Structural Wave Propagation and Sound Radiation

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Experimental relationship between tire’s structural wave propagation and sound radiation

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Tire Noise

- Significance of Tire Noise

[ SPL inside Passenger Cabin ]

- Vibration Mode (Structure-borne)
- Cavity Noise

- Vibration
  - Structure-borne
  - Air-borne

- Pattern (Whine)
- Air Pumping (Sizzle)
- Horn Effect
Objectives and Contents

- Objectives
  - To identify structural wave propagation on tire surface and its sound radiation experimentally

- Contents
  - Structural vibration on tire surface
    - Experimental structural mobility distribution on tire surface
    - Structural wave propagation characteristics on tire surface
  - Sound radiation from a tire
    - Sound radiation measurement and calculation
    - Radiated sound power characteristics
  - Relationship between structural wave propagation characteristics and its sound radiation
Structural Vibration Measurement

- Structural vibration measurement on tire surface
  - Normal harmonic force was applied on the treadband center point of the slick tire (205/70R14 Tire).
  - Structural mobility was measured on whole tire surface. (except on wheel)
Structural Vibration Measurement

- Structural velocity (mobility) distribution

![Diagram showing velocity distribution at different frequencies](image-url)
Structural Wave Propagation

- Circumferential Wave Number Decomposition

- Structural velocity distribution in space domain

- Structural velocity distribution in wave number domain

- Treadband center line

- Ring mode (ring frequency)

- Flexural wave

- Longitudinal wave

- Cut-on freq of flexural wave mode

- \( m = 3 \)

- \( m = 5 \)

- \( m = 7 \)

- \( m = 1 \)

- \( \text{Frequency [Hz]} \)

- \( \text{Circumferential wave number [m}^{-1}\text{]} \)

- \( \text{Magnitude [dB]} \)
Structural Power Contribution

- **Structural input power**

\[ E = \rho_0 c S_b \langle \bar{V}_b^2 \rangle \]

- Structural vibrations below 300 Hz, transferred to the interior cabin, appears mainly on treadband.
- Sidewall’s contribution on structural power is higher in the mid-frequency region.
Nearfield SPL and intensity measurement and calculation

- Nearfield sound radiation resulting from a tire’s structural vibration was measured and calculated.
- Sound radiation was measured in the hemi-anechoic chamber.
- Radiated sound calculation using D-BEM was based on the structural mobilities obtained in the structural vibration measurement.
Nearfield Radiation Model

- Nearfield Sound Radiation Model
  - To validate BE calculation by comparing with measurement results
  - Nearfield SPL and intensity were measured and calculated in front of treadband centerline.
  - Nearfield radiated sound power was measured and calculated on half-box recovery surface.
Nearfield Sound Radiation

- Nearfield SPL distribution

- Generally calculation results are matching well with measurement results.
- SPL at the ring frequency, 570 Hz, is higher all over circumferential positions.
- Region close to contact patch area has high SPL level above 1000 Hz: **Horn effect characteristics.**
Nearfield Sound Radiation

- Nearfield intensity distribution

 Generally calculation results are matching well with measurement results.
- Flexural motion on treadband contributes to nearfield sound radiation below 400 Hz.
- Intensity at the ring frequency, 570 Hz, is higher all over circumferential locations.
Sound Radiation from a Tire

- Nearfield intensity distribution at 570 Hz

- Generally calculation results are matching well with measurement results.
- Sound radiation from whole tire surface dominates at the ring frequency.
Structural Vibration/Radiation Relationship

- Relationship between structural wave propagation and its radiation
  - Radiated power peaks don’t match with those of structural power.
  - Structural input power peaks appear at cut-on frequencies of flexural wave mode.
  - Radiated power peaks appear when structural wave has low wave number.
  - The peak at 570 Hz relates to ‘ring frequency’.
  - Structural vibration below the ring frequency does not contribute to sound radiation effectively.

- Diagram showing input and sound power vs. frequency with marked frequencies and components.
Summary and Conclusions

• The sound radiation resulting from the structural wave propagation was investigated.

• The relationship between structural wave propagation on the tire surface and its radiation was identified empirically.

• Most of a tire’s structural vibration does not contribute to sound radiation.

• Effective radiation was found at the frequencies where low wave number components of the longitudinal wave appear.

• The fast longitudinal wave propagating through the treadband contributes on sound radiation at the tire’s ring frequency.
Q & A

~ Thank you ~