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A Study on Predicting Backpressure in Mufflers with Exhaust Variable Valves

Shim, Yun Jeong[1)] Jo, Jae Yeon[1)] Mo, Yong Woo[1)] Koo, Jeong Su[2)] Shin, Jin Man [2)]

1) Hyundai Motor Group, Research & Development Division, Mid-Large Sized Vehicle Chassy Engineering Designe Team 6
150, Hyundaiyeonguso-ro, Namyang-eup, Hwaseong-si, Gyeonggi-do, 18280, Korea (E-mail:yj.s@hyundai.com)
2)SJG Sejong, 82, Hyoja-ro, Buk-gu, Ulsan, Korea

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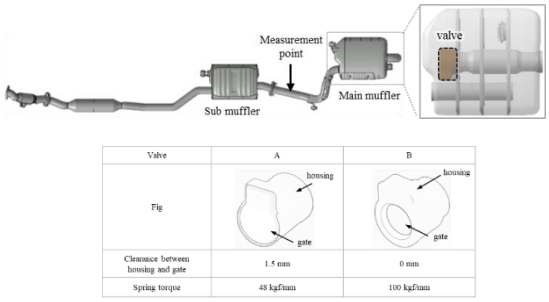
As exhaust emission regulations continue to strengthen in the automotive industry, the complexity of catalytic systems has increased, leading to higher backpressure in exhaust systems. While increased backpressure results in reduced engine output, simultaneously achieving noise reduction and backpressure reduction presents conflicting performance requirements. To address this challenge, variable valve systems have been introduced in the exhaust line. However, the nonlinear characteristics of variable valves that change with operating conditions make it difficult to quantitatively predict backpressure performance.

This study presents an integrated methodology that quantifies the nonlinear characteristics of exhaust variable valves through experimental evaluation and enhances prediction accuracy by incorporating these characteristics into analytical models.

First, an airflow rig evaluation method using a flow resistance device (FRD) was developed as a practical alternative to engine bench testing, enabling simulation of ICE and HEV operating conditions.

Second, an experimental-based methodology was proposed to extract 1-D simulation parameters of variable valves by converting measured valve opening angle–flow characteristics into equivalent opening area and pipe diameter, thereby improving modeling accuracy of nonlinear valve behavior.

Third, the extracted parameters were applied to a 1-D analysis tool (GT-POWER), and the predicted backpressure results showed strong agreement with airflow rig evaluations, validating the proposed approach.



Valve	A	B
Fig	housing, gate	housing, gate
Clearance between housing and gate	1.5 mm	0 mm
Spring torque	48 kgf/mm	100 kgf/mm

Fig.1 Exhaust system configuration and variable valve specifications

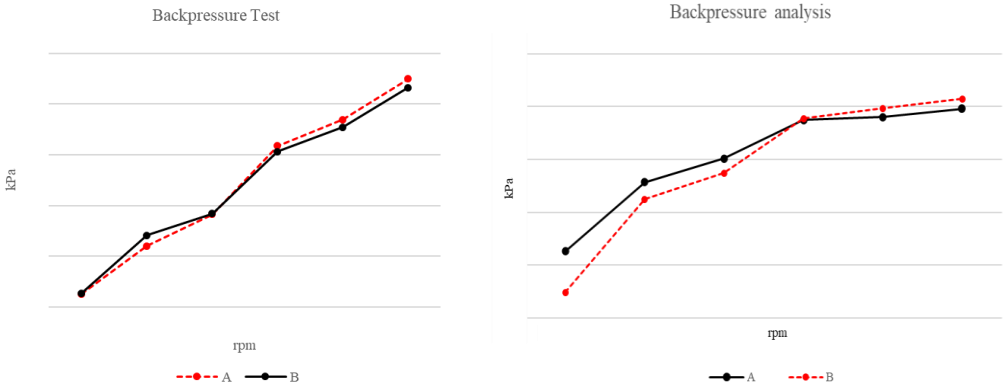


Fig. 2. Comparison between airflow rig test and 1-D analysis results

Fourth, thermal aging effects on variable valve spring torque were analyzed, confirming that torque degradation under real driving conditions can significantly affect backpressure performance and should be considered in durability evaluation.

The core contribution of this study lies in integrating experimental characterization with analytical modeling to accurately predict exhaust system backpressure in early development stages, thereby improving design efficiency and reducing iterative evaluation cycles.