*International Journal of Automotive Technology*, Vol. 24, No. 2, pp. 527−539 (2023)
DOI 10.1007/s12239−023−0044−3

pISSN 1229−9138/ eISSN 1976−3832

# EFFECT OF TURBINE UPSTREAM GEOMETRY ON PULSATING FLOW AND TURBOCHARGED SI-ENGINE PERFORMANCE

Jeyoung Kim[1,2], Meng Soon Chiong[2] and Srithar Rajoo[2]*

[1]University of Vaasa, School of Technology and Innovations, Wolffintie 34, FI-65200 Vaasa, Finland
[2]UTM-LoCARtic, IVeSE, Universiti Teknologi Malaysia, Johor 81310, Malaysia

*(Received 14 March 2022; Revised 7 September 2022; Accepted 26 September 2022)*

**ABSTRACT**−The pulsating exhaust flow propagates through the exhaust line upon opening of exhaust valves while carrying a high amount of energy (high pressure and temperature). The amount of energy delivered to the turbine could be affected by turbine upstream geometry along with the propagation. Therefore, in this study, the impact of the turbine upstream geometry (diameter, length of exhaust runner, and exhaust manifold volume) on pulsating flow and engine & turbocharger has been investigated using 1D engine simulation packages, AVL-BOOST. A validated 1-liter 3-cylinder SI-engine model was utilized as a base engine model. The simulation captured how different geometry influences the pulsating pressure profile and the impact on system-level performance and behavior. The current research highlighted that the exhaust manifold volume is strongly associated with exhaust resistance, scavenging, pulsation, knocking, and fuel economy. By minimizing unnecessary volume in the exhaust manifold, it presents high potentials to improve low-speed torque (~15 %), fuel consumption (~2.4 %), brake thermal efficiency (~1.4 %), scavenging and knock resistance against the baseline model.

**KEY WORDS** : 1D engine simulation, Pulsating exhaust flow, Exhaust geometry, Exhaust resistance, Boosting system, Low-speed torque

## NOMENCLATURE

| | |
|---|---|
| 1D | : one dimensional |
| ACT | : active control turbine |
| AR | : aspect ratio |
| BDC | : bottom dead center |
| BEV | : battery electric vehicle |
| BMEP | : break mean effective pressure, bar |
| BSFC | : break specific fuel consumption, g/kwh |
| c | : specific heat capacity, kg/kgK |
| CAD | : crank angle degree |
| D | : diameter of exhaust runner, m |
| ECU | : engine control unit |
| EVC | : exhaust valve closing |
| EVO | : exhaust valve opening |
| FCV | : fuel cell vehicles |
| h | : specific enthalpy, J/kg |
| ICE | : internal combustion engine |
| IVC | : intake valve closing |
| k | : specific heat ratio |
| L | : length of exhaust runner, m |
| MAP | : manifold absolute pressure, kPa |
| MBT | : max brake torque, BTDC |
| MFP | : mass flow parameter, $kg\sqrt{K}/sbar$ |
| $\dot{m}$ | : mass flow rate, kg/s |
| N | : turbocharger rotational speed, RPM |
| NA | : naturally aspirated |
| OEM | : original equipment manufacturer |
| P | : pressure, bar |
| P | : power, kW |
| PMEP | : pumping mean effective pressure, bar |
| PR | : pressure ratio |
| T | : temperature, K |
| TC | : turbocharged |
| u | : mean gas velocity, m/s |
| V | : volume of exhaust manifold, $m^3$ |
| VCR | : variable compression ratio |
| VGT | : variable geometry turbine |
| WG | : waste gate |
| WLTC | : world harmonized light-duty vehicles test cycles |
| $\eta$ | : efficiency |

## SUBSCRIPTS

| | |
|---|---|
| 0 | : reference condition or baseline |
| B | : engine brake thermal |
| Bst | : boost |
| D | : displacement |
| exhaust | : exhaust |
| in | : inlet |
| isen | : isentropic |
| m | : mechanical |
| out | : outlet |
| p | : pressure |
| T | : turbine |

**Corresponding author*. e-mail: srithar@utm.my