

A Fundamental Study on the Geometry of Intake Manifolds for Multi-Cylinder Engines with a Single Throttle System

-Evaluation of Intake Air Distribution Characteristics Using Transient Flow Analysis-

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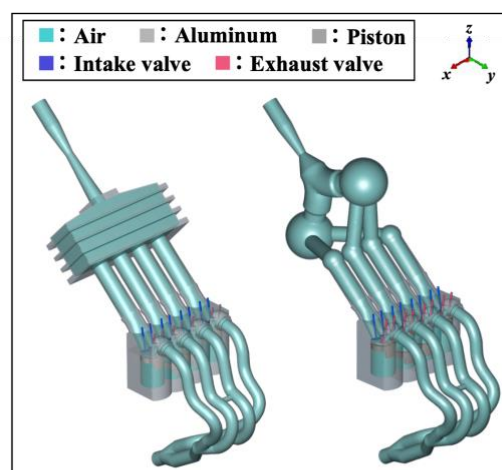
In this study, we conduct a fundamental evaluation of the inter-cylinder air flow distribution characteristics in a multi-cylinder engine with a single throttle system through transient fluid analysis that accounts for piston motion and the opening and closing of intake and exhaust valves, with the aim of clarifying the factors influencing these characteristics. To this end, we propose a multi-stage branched intake manifold-which divides the flow path downstream of the single throttle into two stages-as an alternative to the conventional surge tank-type manifold. The multiple split model aims to limit the range within which multiple cylinders influence one another via a common space by gradually branching the flow path from the throttle to each cylinder, thereby reducing inter-cylinder intake interference caused by the sequence of the intake strokes.

We compared a single split model, in which the flow paths converge without branching, with the proposed multiple split model. The results confirmed that the multiple split model exhibits smaller differences in air distribution among cylinders compared to the single split model, and demonstrated that differences in intake air among cylinders arise due to the intake configuration.

To perform the CFD analysis, we used the 3D CAD software Autodesk Fusion 360 to create a CAD model extending from the air intake to the exhaust outlet, incorporating an intake model and a simplified engine model, and then performed the CFD analysis using Autodesk CFD 2026. The engine model was created based on measurements of the 599 cc, 4-cylinder engine installed in the SUZUKI MOTOR CORPORATION GSX-R600 used in this study. Fig. 1(a) shows the single split branching model, and Fig. 1(b) shows the multiple split model. This analysis was performed over 3,600 deg., corresponding to five cycles at 10-deg. intervals of the engine's crank angle, with the evaluation focusing on the range from 2,160 deg. to 3,600 deg., covering cycles 3 through 5. A transient analysis was conducted at an engine speed of 5,000 rpm.

In addition, to evaluate the uniformity of the distribution of incoming air among the cylinders, the mass flow rate $\dot{m}$ [g/s] is measured along the intake valve face, and the mass of incoming air m [g] is calculated by integrating over time relative to the crank angle; this value is then expressed as the coefficient of variation CV[%].

Fig. 2 shows a graph depicting the CV for the two intake models. As shown in Fig. 2, the CV for the single split model is 9.3%, while that for the multiple split model is 7.4%; these results indicate that the multiple split model exhibits smaller variations in airflow distribution among cylinders compared to the single split model. Since the single split branching model draws intake air from a common source for all four cylinders, it is presumed to be more susceptible to the effects of the intake strokes of other cylinders compared to the multiple split model. On the other hand, the multiple split model takes ignition sequence into account and is configured to branch the intake air to cylinders 1 and 4, and cylinders 2 and 3, respectively, so that their intake periods do not overlap. Consequently, it is less susceptible to the effects of other cylinders during the intake stroke, and intake interference may be suppressed.



(a) Single split model (b) Multiple split model
Fig. 1 Model diagram within the analysis

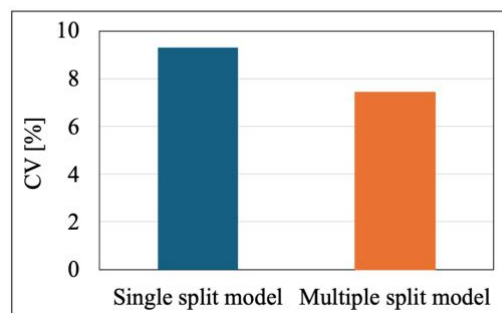


Fig. 2 Relationship diagram of the coefficient of variation for each model at 5,000 rpm