1. Introduction

Recently, automobile manufacturers have been introducing development processes such as model based development MBD in order to develop a wide variety of powertrains efficiently. Likewise, efficient development by suppliers is important to satisfy customers’ needs. This digest introduces an instance of front-loading development by which a 25% reduction in the development period was achieved.

The newly developed intake manifold is currently being assembled into a 3.5L V6 engine for the North America market. Although the magnesium alloy has been used as the conventional material, it has been replaced by resin for further light weight and low cost. Fig. 1 shows the product structure.

![Fig. 1 Structure of intake manifold](image)

2. Front-Loading Development

The term allowed in this development was about 1 year from the start of design to completion of engine performance tests. In order to not extend the schedule by repeating tests or significantly change the design, all participants in development both in North America and in Japan considered prevention measures in the early stages of development. Fig. 2 shows the development target and activities to meet the schedule.

Design of air flow paths that impact engine performance are usually verified using flow rate analysis by computational fluid dynamics (CFD). It was verified that the new design did not affect the flow rate to any significant extent by conducting analysis with a CFD model that incorporated the die mold construction from simultaneous design.

Manufacturing variation that is difficult to predict with CFD was classified with minimum, medium and maximum by flow rate tests, and it was confirmed with bench tests conducted in advance that there were no problems in engine performance due to manufacturing variation (See Fig. 3). In order that the flow rate tests could be conducted as scheduled, an improvement in replicability of the tests and a reduction in test time were achieved by improving

![Fig. 2 Development target and front-loading activities](image)
the equipment, the jigs and the flow rate calculation method.

The improvement of quality at an early stage in the development was achieved by optimizing gates, cooling and conditions of the die mold by injection molding computer-aided engineering (CAE) (See Fig. 4).

Also, a non-contact coordinate measuring machine (CMM) was applied for reducing time by rationalization. As a result, it was possible to easily determine the overall airflow path affecting engine performance, and thus make an early judgment. Fig. 5 shows the measurement results, which correlate well with the results of the injection molding CAE shown in Fig. 4.

From results of the first engine performance test, it was confirmed that 99.7% of the target had been achieved, and it was possible to promptly define design changes to meet the target from analysis of the non-contact CMM data. Additionally, as a result of reproducing engine output and predicting improvements for the same with 1D simulation, we were able to complete development within a short term. Fig. 6 shows the development steps. Repetitive prototyping and analysis is necessary in the conventional development, but it was possible to reduce the time and eliminate prototyping by virtual verification of engine performance with the processes described in this digest.

As a result of this study, a 25% reduction of the development term was achieved by virtue of the front-loading considered in the early stages and virtual verification using 1D-simulation, and we were able to complete the development as scheduled (See Fig. 7).

For the improvement of development efficiency, the technology using 1D-simulation and a non-contact CMM will be further improved, thus accelerating rational development in order to provide excellent products.

3. Summary

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### Front-Loading Development of Resin Intake Manifold for V6 Engines

**Conventional**
- Design
- Production → Test → Analyze → Pre-test → Die Modify → Test

**Front-Loading**
- Design → Production → Test → Die Modify → Test → 25% → Virtual Verification

<table>
<thead>
<tr>
<th>Reducing Item</th>
<th>Simulation</th>
<th>Measurement</th>
<th>Flow/Bench Test</th>
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**Fig. 7** Effects of front-loading development

### Author

T. KOMATSU

During the development covered in this digest, I appreciated the fact that participants both in North America and in Japan shared the target at an early stage. I believe that this development was promoted speedily by the excellent ability, ideas and the cooperation of the participants, with also 24-hour development of through utilization of the time difference. (KOMATSU)