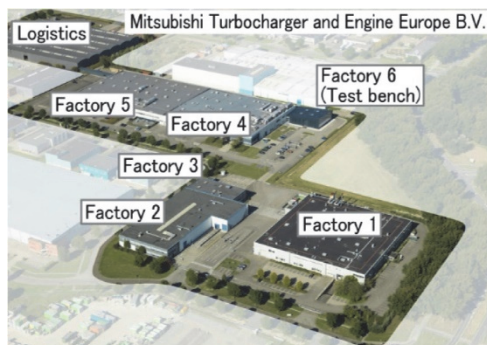


Function of Mitsubishi Turbocharger and Engine Europe as Turbocharger Development Center



Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.
Turbocharger Division

Mitsubishi Turbocharger and Engine Europe B.V. (hereinafter referred to as MTEE), a wholly-owned subsidiary of Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. (hereinafter referred to as MHIET), has been established in Europe as a development, design and manufacturing base for turbochargers for the European market. Among the MHIET group companies, MTEE is positioned as the second development base following MHIET.

1. Introduction

Customers of the MHIET Group, namely automotive companies, are increasingly adopting development processes that emphasize pre-verification, such as Model Based Systems Engineering (MBSE) and Model Based Development (MBD), in order for short-term development of increasingly complex vehicle systems. In these development processes, evaluating functionality and performance of subsystems and their components in the verification phase prior to fabricating the prototype, so as to avoid design rework after fabricating the prototype, is important. For components such as turbochargers, providing highly accurate performance data in the verification phase and designs that satisfy the requirements of higher-level systems (e.g. functionality and durability under operating conditions) is required.

In response to the conditions of short-term development, MHIET is continuously improving turbocharger development processes.

2. Responding to shorter-term engine development

In response to the needs of our customer for short-term development, MHIET established a development process that incorporates a systems engineering method (**Figure 1**). During the design verification phase of the development process, in other words the components or component assemblies, on the left side of the V-shaped process, each functional unit is analyzed and evaluated. On the right side of the V-shaped process is the verification phase of the actual component. Component tests of the smallest functional units are conducted to verify that the requirements for each function are satisfied. Furthermore, turbocharger stand-alone tests and on-engine-bench tests are carried out to verify reliability of the product.

In order to further enhance the reliability of the established development process, it is important to construct and improve the accuracy of the analysis model used on the left side of the V-shaped process. Efforts to incorporate feedback from the verification results of each actual component on the right side of the V-shaped process into the analytical model are also promoted.

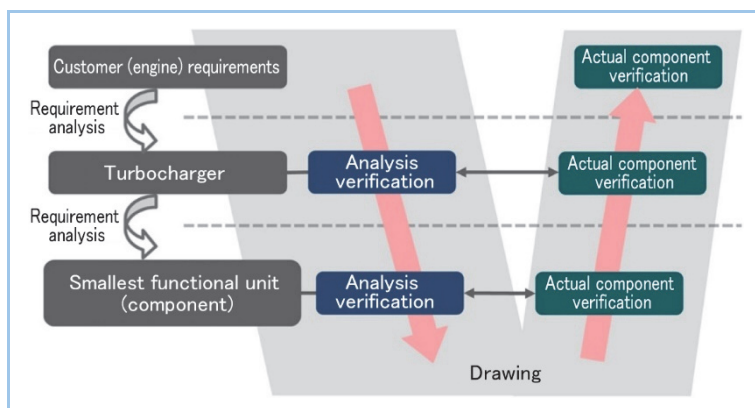


Figure 1 Development process using systems engineering

3. Development function of MTEE

MTEE has also applied the same development process when conducting analysis evaluations during the design verification phase and various tests are carried out during the evaluation phase of each actual component.

Generally, verification that the specifications of the turbocharger turbine and compressor satisfy the required engine characteristics is carried out in the design verification phase of a turbocharger. Next, the design is developed to satisfy the customer's installation and control requirements. In the industry, using a one-dimensional engine simulator called GT-Power to evaluate the characteristics of turbochargers is standard. MTEE also uses this simulator to verify whether the specifications recommended to the customer can satisfy the required engine characteristics in advance. Some stationary flow paths designed according to customer's layout requirements have additional bends and bypass flow paths. To account for these effects, flow analysis of the flow path section is carried out and performance characteristics of the turbine and compressor, including flow rate, pressure ratio, and efficiency, are calibrated to improve accuracy (Figure 2).

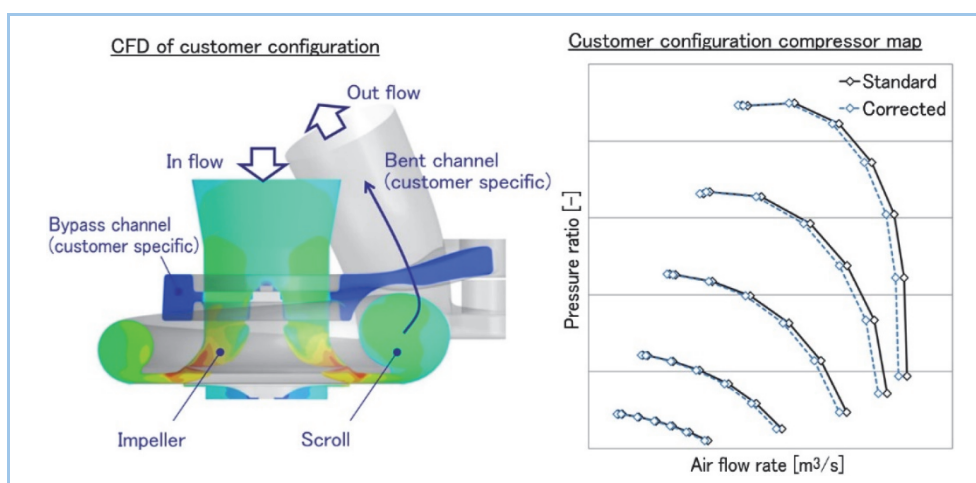


Figure 2 Calibration of compressor characteristics using flow analysis

MTEE conducts not only component tests and turbocharger hot gas stand tests, but also engine bench tests which serve as a higher-level test system. Various evaluation tests are conducted using engines provided by the customer during development of the turbocharger, and the results are used to improve the accuracy of the component test conditions and analytical models, in order to increase the reliability of the turbocharger. As an example of this approach, the thermal boundary conditions of the conjugate heat transfer model were optimized based on actual turbine housing temperature measurements obtained during the engine bench tests, as shown in Figure 3.

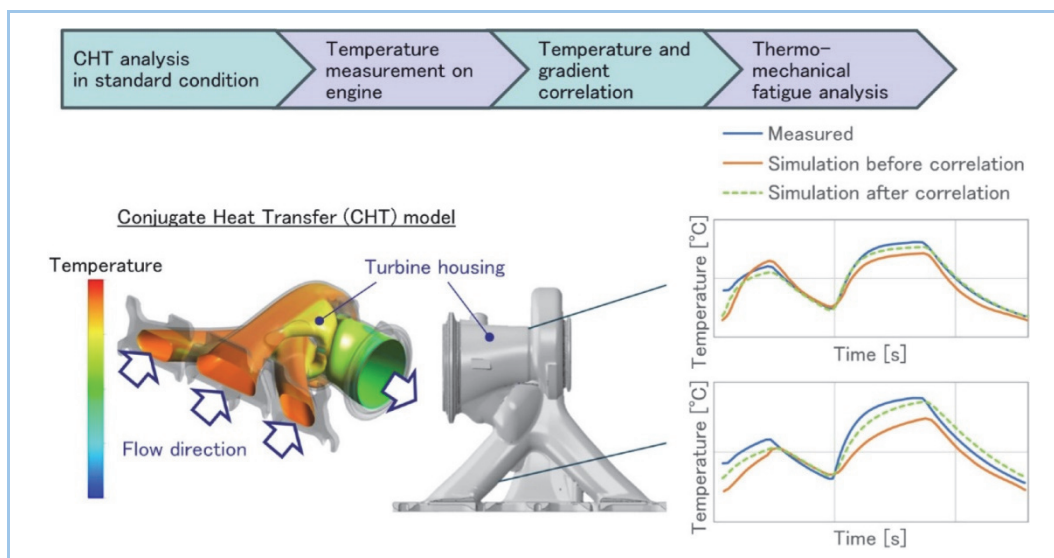


Figure 3 Example of improving the analysis model using engine tests

4. Function of MTEE in development of new products

New products are mainly developed by Mitsubishi Heavy Industries, Ltd. Research & Innovation Center and MHIET, while MTEE conducts engine bench tests on new products, utilizing its abundant experience in engine bench testing and its knowledge of the latest turbocharged engine controls. In particular, by applying its remote monitoring system, MTEE can conduct endurance tests 24/7 and complete the tests in a short period of time (Figure 4). For this reason, MTEE has been in charge of the durability evaluation of many new products, including variable geometry turbochargers for gasoline engines.

In expectation of future shifts toward electrification, MTEE has also introduced test facilities that can conduct evaluation tests for electric compressors and expanders for fuel cells, and has conducted various evaluation tests including elemental tests and performance tests at the request of Mitsubishi Heavy Industries, Ltd. Research & Innovation Center and MHIET.

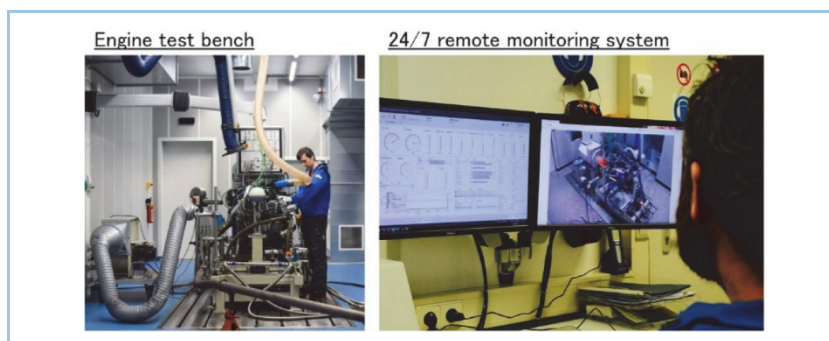


Figure 4 Example of improving the analysis model using engine tests

5. Future prospects

The development process used by automotive companies continues to evolve day by day, and requirements for pre-verification and actual component verification for turbochargers and other components have become stricter. In order to meet these increasingly challenging requirements, MTEE will continue to improve the development process and increase customer satisfaction.