Development of a fuel efficiency analysis tool that shortens the development period

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Summary

In recent years, not only society's environmental needs, but also the needs of vehicle manufacturers that are our customers for shorter development periods and reduced development costs have been continually increasing. The newly developed fuel efficiency analysis tool described here shortens the lead time from analysis to the determination of specifications. As a result, it makes it possible to achieve the targeted fuel efficiency and to reduce the number of fuel efficiency tests conducted, thus not only contributing to the environment, but also enabling an effective response to the needs of vehicle manufacturers. This article describes in detail the development of this fuel efficiency analysis tool.

1. Introduction

Demands for a reduction of CO_2 emissions as one of society's environmental needs have become increasingly more numerous in recent years. Transmission (TM) development activities have been helping to resolve this environmental need by discovering and proposing various measures for improving vehicle fuel economy.

At the same time, vehicle manufacturers that are our customers need shorter development periods and reduced development costs. It is also necessary to respond to their needs as well as to society's environmental needs.

A fuel efficiency analysis tool has been developed in this project as a measure for addressing these issues by shortening the development lead time from the analysis of fuel efficiency waveforms to the determination of the related specifications. As a result, the lead time for proposing specifications contributing to improving fuel economy has been shortened (Fig. 1). It has also contributed to cutting development costs by reducing the number of tests conducted. This article describes the details of the development of this fuel efficiency analysis tool.

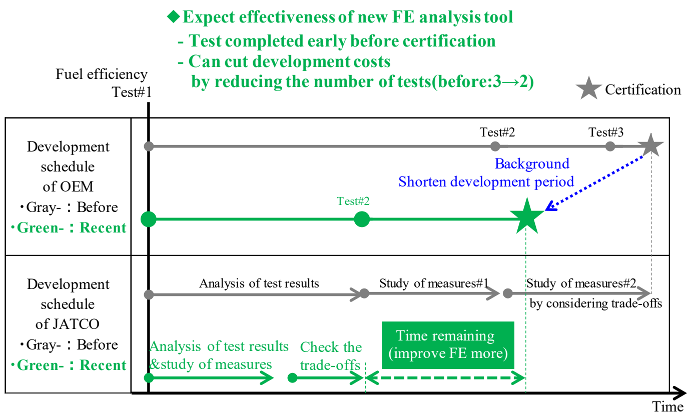

Fig. 1 Previous and recent development schedule

2. Issues and approaches to improvement

In proceeding with TM development work at JATCO, we have adopted the concept of the V-process, which is one systems engineering (SE) approach. The left side of the V-process consists of the design phase and right side is the testing phase for design validation. This V-process has the following issues.

- Design phase

Measures for building a TM so as to attain the required vehicle fuel efficiency are designed and studied. In this process, it is necessary to link the TM hardware specifications and software specifications.

1) In order to develop the design, the specifications

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of the selected vehicle, engine and TM must be coordinated in advance with the vehicle manufacturer.

2) It is necessary to ensure the accuracy of fuel efficiency simulations.

- Validation/calibration phase

In case the fuel efficiency improvement intended by the design is not achieved, the cause must be immediately and accurately analyzed so the results can be fed back to the design parameters.

1) Test waveforms are analyzed to see if there was any behavior other than the design intention or any differences between the test stand conditions and the assumed specifications at the time of design development. Nothing must be overlooked in the analysis, and the results are linked to a study of countermeasure specifications to be developed in a shorter lead time.

2) The TM calibration parameters that determine fuel efficiency performance have many trade-offs with the parameters for drivability, noise and vibration, and reliability. When calibration parameters are changed, countermeasure specifications must be presented that take into account such trade-offs (Fig. 2).

This project was focused on improvement of the validation/calibration phase. The studies conducted by the engineers in charge were sorted out; it was decided that the fuel efficiency analysis tool would automate an analysis of the measured fuel efficiency waveforms and an analysis of the contributions of the calibration parameters to fuel efficiency.

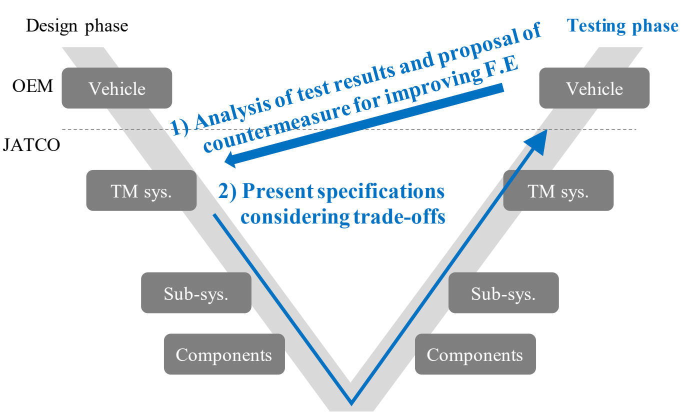

Fig. 2 Issues and V-process

3. Key points of improvement

3.1 Definition of functions needed by the fuel efficiency analysis tool

The fuel efficiency analysis tool has the following three purposes.

1) To eliminate any differences in analysis quality among employees.

2) To automatically visualize the analysis results for early determination of countermeasure specifications on the basis of effective coordination with the vehicle manufacturer.

3) To shorten processes that have previously been time-consuming.

The necessary functions for accomplishing these purposes were defined from the following perspectives

1) The process flow of the development activities at the work level of the engineers in charge was clarified (Fig. 3), and a study was made of the functions needed by the fuel efficiency analysis tool.

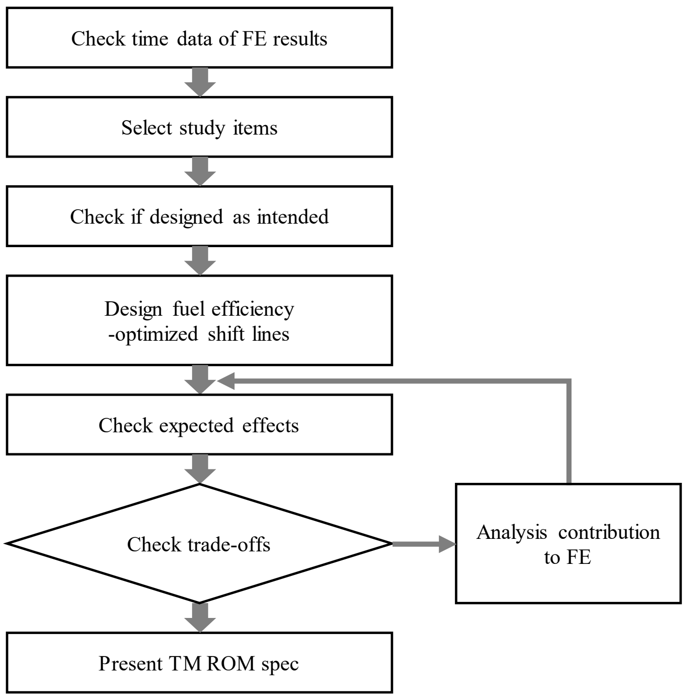

Fig. 3 Previous process flow

2) The TM factors influencing fuel efficiency were identified (Fig. 4) and the tool should be able to analyze quantitatively the items related to each influential factor.
3) Based on experience to date, the tool should be able to automatically generate the graphs and tables frequently used in coordinating with the vehicle manufacturer.

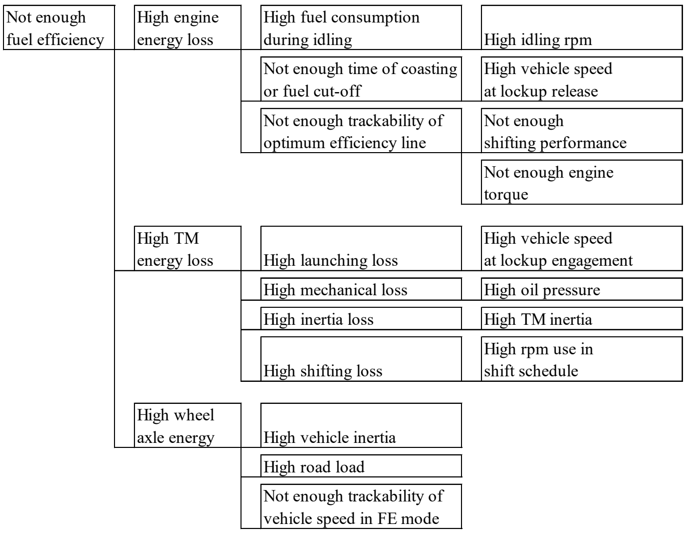

Fig. 4 Factors influencing fuel efficiency

The necessary functions were organized in terms of requirements, functions and logic (RFL), making it possible to complete the composition and structure of the fuel efficiency analysis tool to be developed (Table 1).

Table 1 Requirements and functional methods

Requirement	Function1	Function2
No change in analysis quality among employees	Compare design intent and test results	Check the intention of shift schedule
		Check the intention of lockup engagement
		Check the intention of sub-gear schedule
	Energy analysis in test results	Analysis of engine energy loss
		Analysis of transmission energy loss
		Analysis of transmission output energy
	Compare with F.E optimized shift schedule	
Decide the specifications for early contermeasures	Analysis of contribution to FE	Check the frequency of time use in test
		Check the frequency of energy use in test
Shorten the time of studying test results	Arrangement of study specifications	Select specifications of vehicle and TM
		Import control constant from ROM file
	Arrangement of test results	Automatically convert to proper format
		Match the time of test results
		Match the name of label
	Accumulate analysis results for experience	Save analysis results

3.2 Creation of fuel efficiency analysis tool

The tool was designed to shorten the lead time from fuel efficiency waveform analysis to the proposal of specifications for improvement by enabling anyone to study the processes from analysis to specification proposal without overlooking anything. Moreover, all of the necessary functions were incorporated into one tool (Fig. 5).

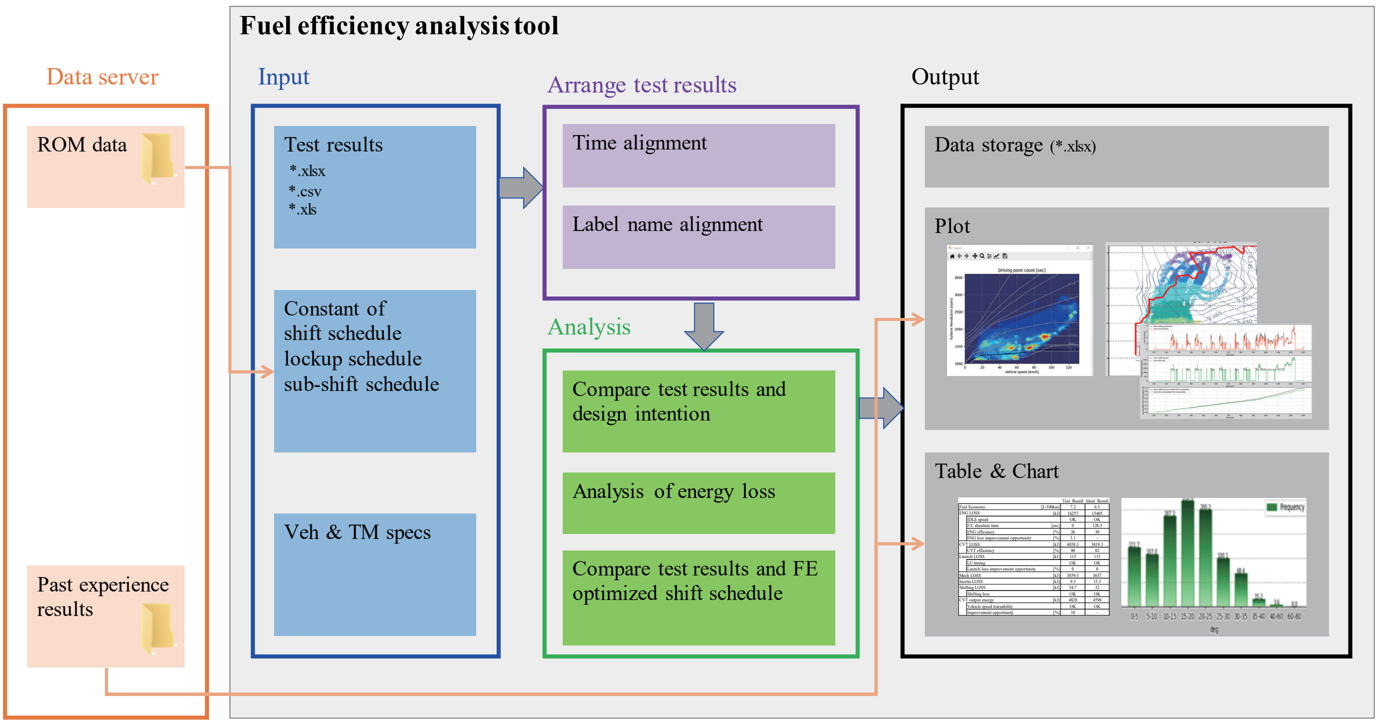

Fig. 5 Flowchart of inputs & outputs

- Shortening lead time
  1) By simply inputting the waveform, the tool can automatically search for the zero-point marking the start of fuel efficiency measurement (Fig. 6).
  2) Linking the tool to the data server has shortened the time for importing the TM ROM specifications and the time for confirming actual market trends.

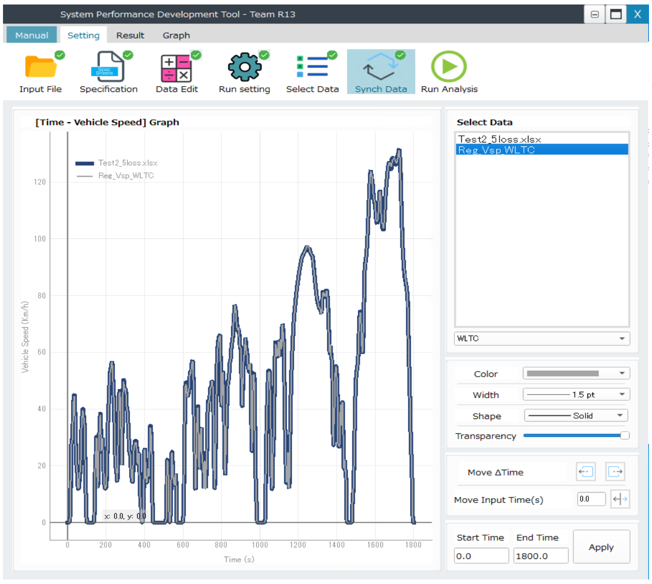

Fig. 6 Function to match the time of test results

- Every employee's analysis quality is equal to or better than before.
  1) A user interface was developed for the tool that enables anyone to conduct a fuel efficiency analysis with just simple operations.

The newly developed tool makes it possible to analyze fuel efficiency with just one user interface and simple operations for inputting specifications (Fig. 7).

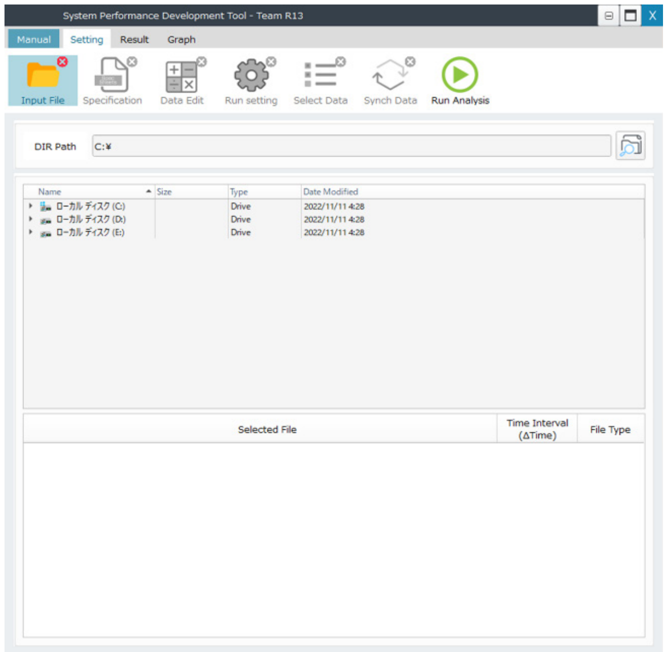

Fig. 7 Main interface display of new fuel efficiency analysis tool

3.3 Function for automatic analysis of TM factors influencing fuel efficiency

The TM factors influencing fuel efficiency can be broadly categorized as follows:

(1) Mechanical loss
(2) Shifting loss
(3) Launch loss
(4) Inertia loss

The influence of these four factors is quantitatively calculated from the measured fuel efficiency waveform and comparisons are made with the design plan values and general trends. On that basis, it must be possible to identify the factors contributing to non-attainment of the fuel efficiency target. In case the unattained factors do not have the targeted values, it is necessary to be able to identify the causes involved.

The fuel efficiency analysis tool incorporates the following four measures for accomplishing these tasks.

1) It can calculate the loss from the four factors influencing fuel efficiency as a result of inputting the fuel efficiency waveform.
2) It automatically calculates the shift lines and lockup clutch engagement values imported from the TM ROM and is equipped with a function that can compare the measured values and the intended design values.
3) It imports previous results from the data server and can compare the losses of the four factors influencing fuel efficiency obtained from the fuel efficiency waveform with the general trends.
4) If the losses deviate from the design plan values, the tool incorporates a function for analyzing the factors involved (Table 2). Examples here include the shift lines and engagement region of the lockup clutch

Table 2 Results of energy loss analysis

		Test result	Ideal result
Fuel efficiency	[L/100km]	7.2	6.5
Engine loss	[kJ]	16257	15405
Idle speed		OK	OK
Fuel cut-off duration time	[sec]	0	128.3
Engine efficiency	[%]	26	30
Engine loss improvement opportunity	[%]	3.1	-
CVT loss	[kJ]	4038.3	3819.3
CVT efficiency	[%]	80	82
Launch loss	[kJ]	115	115
Lockup timing		OK	OK
Launch loss improvement opportunity	[%]	0	0
Mech loss	[kJ]	3859.3	3657
Inertia loss	[kJ]	9.3	15.3
Shifting loss	[kJ]	54.7	32
Shifting loss		OK	OK
CVT output energy	[kJ]	4828	4598
Vehicle speed traceability		OK	OK
Improvement opportunity	[%]	10	-

The tool is capable of comprehensively analyzing the TM factors influencing fuel efficiency automatically. Accordingly, anyone can identify the factors contributing to the non-attainment of the fuel efficiency target in a shorter period of time without overlooking anything.

3.4 Automatic visualization of frequently used graphs

In order to quickly plan countermeasure specifications based on the analyzed results, it is necessary to determine specifications that take into account trade-offs resulting from specification changes. For that purpose, the related departments must coordinate with the vehicle manufacturer. The tool is equipped with a function for visualizing frequently changed parameters in order to coordinate them preferentially in the validation/calibration phase.

- Shift calibration
  1) The tool can plot contour graphs showing the proportion of fuel efficiency mode driving and the fuel consumption rate on the shift schedule lines (Fig. 8).

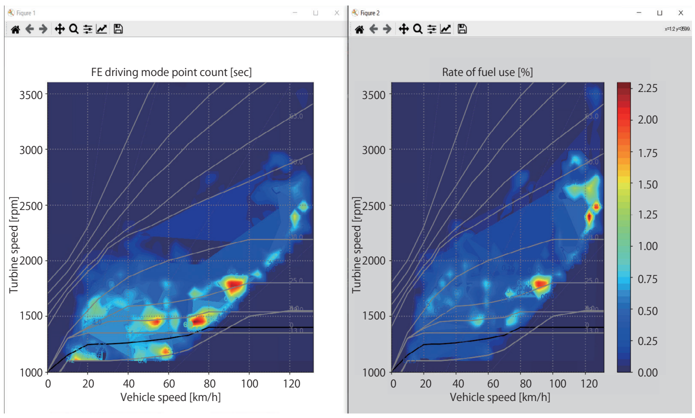

Fig. 8 Contours of proportion of FE driving mode and fuel use in shift schedule

  2) The tool is equipped with a function for superimposing the predicted design speed and actual speed on a time chart and highlighting the places that deviate from the design prediction (Fig. 9).
  3) The tool can superimpose the ideal speed for fuel efficiency and the measured speed on a time chart and highlight the places where the measured values deviate from the ideal values. Moreover, it can automatically calculate how much improvement in fuel efficiency can be expected by approaching the ideal values (Fig. 10).

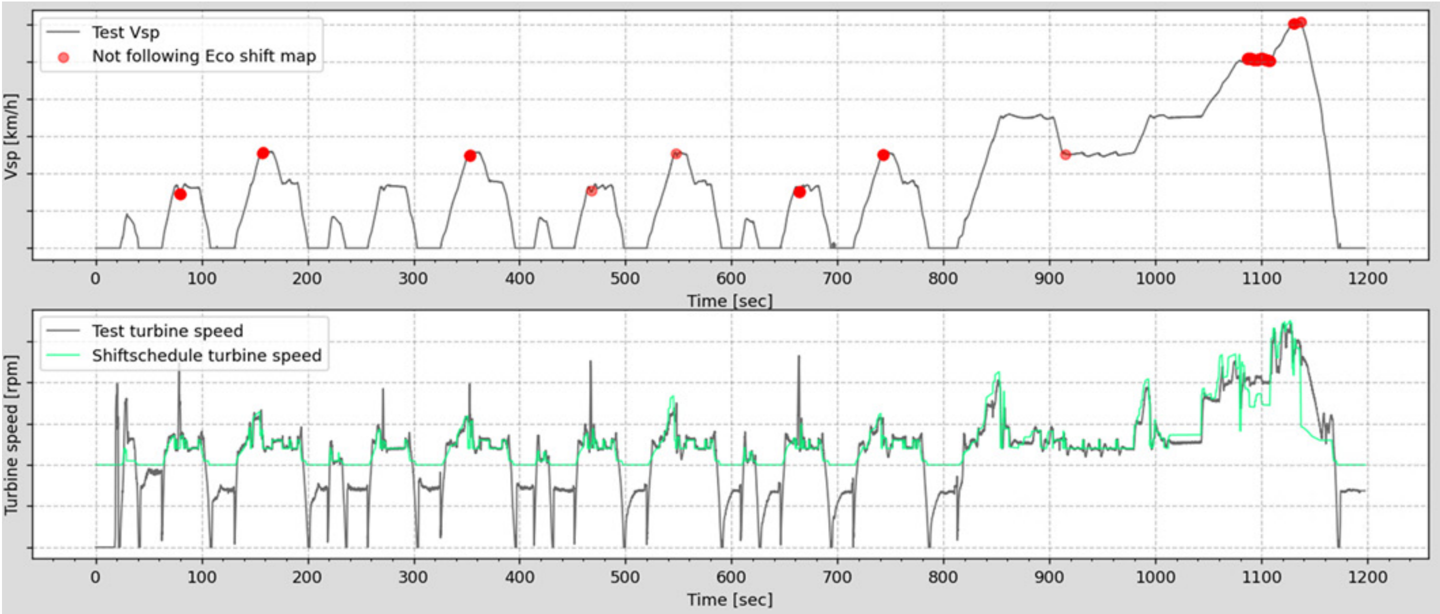

Fig. 9 Function to check the intention of shift schedule

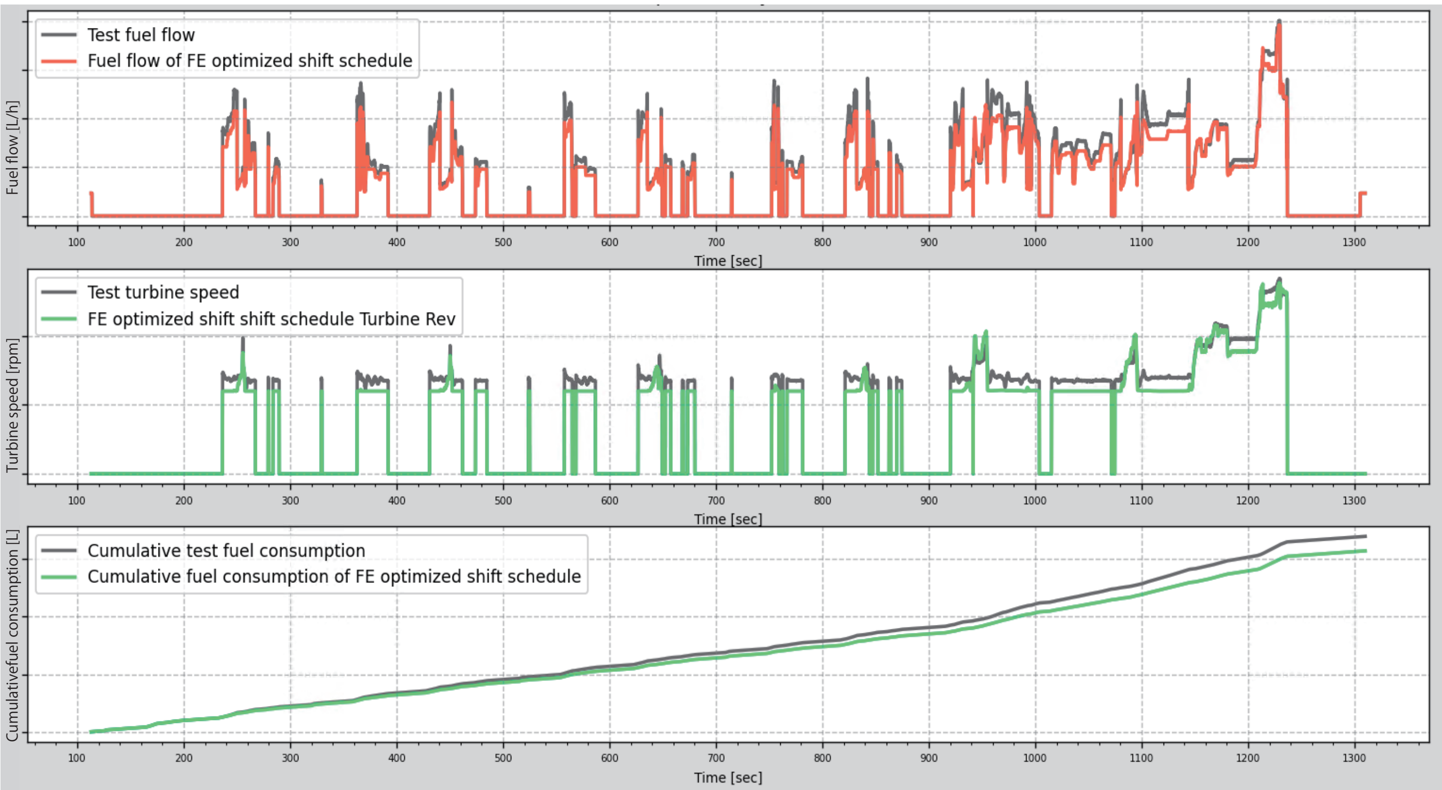

Fig. 10 Function to compare test results and FE optimized shift schedule

- Lockup calibration
  1) The tool is equipped with a function for superimposing the designed lockup clutch engagement region and the measured region on a time chart and highlighting the places where the lockup behavior deviates from the design intention (Fig. 11).

By automatically visualizing frequently used graphs, the tool makes it possible to distinguish regions having a large impact on fuel efficiency and regions of high priority. In addition, in regions where the measured behavior deviates from the design intention, it can narrow down the places requiring a detailed factor analysis, thus enabling studies to be conducted efficiently.

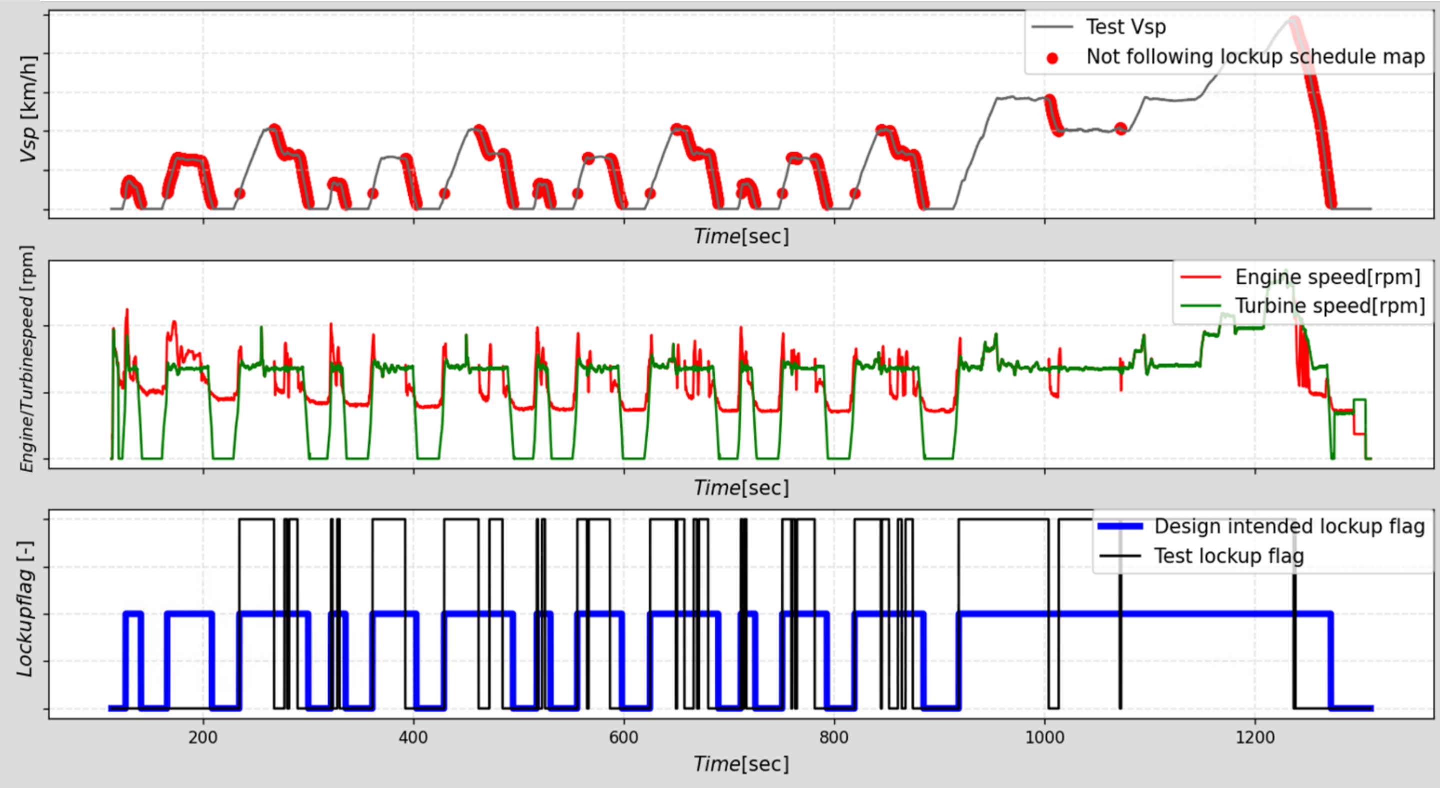

Fig. 11 Function to check the intention of lockup engagement

4. Conclusion

The use of the newly developed fuel efficiency analysis tool has improved the lead time efficiency of work processes by 60%, thereby reducing the time required for waveform analysis and examination of improvement measures (Fig. 12). In addition, using this tool has made it possible to achieve the targeted fuel efficiency in a short period of time. It has reduced the number of tests needed to attain the targeted fuel efficiency, enabling the remaining time until fuel efficiency certification to be used effectively for discovering further measures for improving fuel efficiency. Moreover, when a trade-off occurs in the development process, the tool makes it possible to quickly confirm if there is any resultant impact on fuel efficiency, thus enabling smooth adjustment of specifications toward the attainment of fuel efficiency certification.

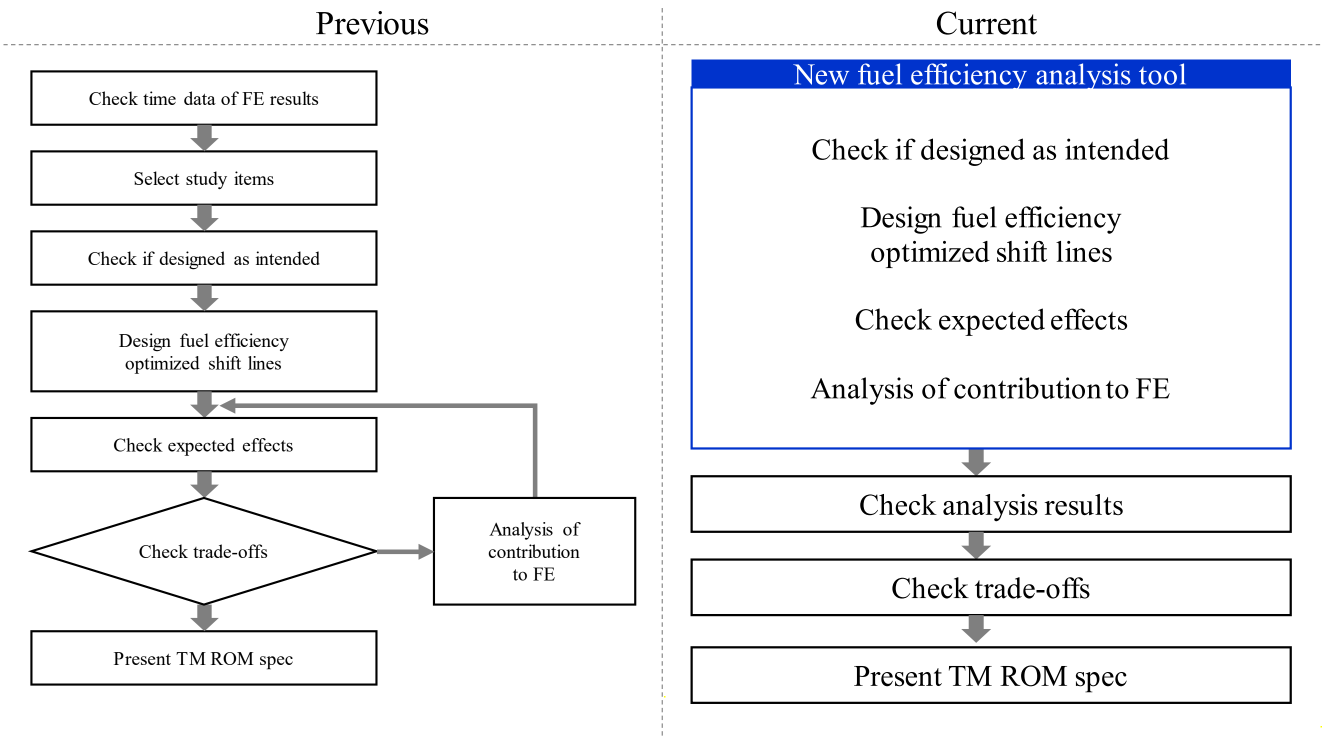

Fig. 12 Previous and current process flow

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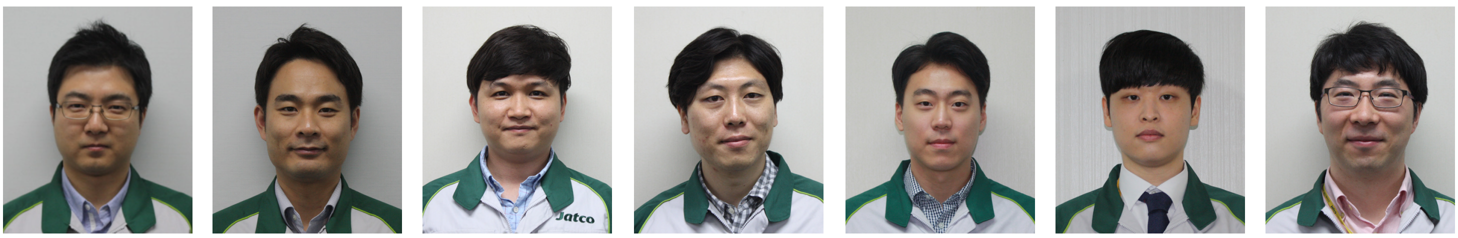

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