# Measurement and Data Analysis tool for efficient powertrain development

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## ABSTRACT

Real-world fleet testing is a critical process for new powertrain development. Over the course of development, enormous amount of data is recorded and needs to be analysed. Accurate analysis of such fleet testing data is essential for System, Software, and calibration robustness validation. Size of the data, elements of human error and difference in perception can affect analysis accuracy and timely completion – thus requiring high repeatability of analysis and process standardization. An automated analysis tool was developed in MATLAB /Simulink platform, which is capable of analyzing bulk measurement data of various types - data collection protocols, measurement software platforms, formats etc. The tool is customizable – it can be easily modified based on analysis requirement, target vehicle (development vehicle/Benchmark vehicle). It is also capable of online data analysis, where it can collect vehicle CAN data and other sensor signals using the same algorithm. Quick reconfirmation of observation can be done, thereby increasing the overall efficiency of development. The capability of the tool is explained with sample case of real world testing of automated manual transmission vehicles- where it was used to monitor powertrain and transmission robustness.

## INTRODUCTION

With increasing complexity of Powertrain and drive train control system, the importance of fleet testing or real world testing is paramount. Fleet testing provides crucial information about robustness of the hardware, control software and adaptation mechanism. In most cases, fleet or real world testing is done in parallel with actual control system development.

For example, in a case of an AMT vehicle powertrain, expected life of clutch and effectiveness of self-learning and adaptation algorithms related to clutch act as important information during vehicle development. Fleet testing provides valuable inputs and paints a real-picture about longevity of clutch and helped in identifying the effectiveness of clutch wear adaptation algorithm.

However, such information is usually not readily available in the controller memory. Only careful analysis of measurement data, collected across the lifetime/test duration, can provide us meaningful insights. This information helps in the development of the complete vehicle family - which uses the same or similar powertrain. Thus, accurate and timely analysis of fleet data can greatly enhance the powertrain and vehicle development efficiency.

## MAIN SECTION

AUTOMATED DATA ANALYSIS PLATFORMS (DEVELOPMENT AND FLEET) FOR EFFICIENCY IMPROVEMENT

<u>Diverse platforms used in data acquisition ( Kvaser / IPEtronik / ES720 / Vector GL series etc )</u> - In current powertrain development, we have multiple data acquisition platforms. Such real world DAQ platforms have multiple data-file formats and multiple data analysis interface. Although conscious efforts are made to create a common platform for fleet data acquisition, selection is usually done based on data acquisition protocols, vehicle ECU type and ease of usage or implementation and even availability of the tools at the time of test. Given the diversity of the file formats and analysis tools, test engineer has to develop skills in multiple platforms (steeper learning curves).

<u>Benchmark vehicles: different signal and data structure</u> - Depending on data acquisition style (continuous or trigger based), protocol and multiple other factors, the measurement files can be of various sizes.

A vehicle development cycle is accompanied by a high volume of measurement data. Big file sizes can give rise to multiple data management issues like storage space etc. In most cases, data ends up in storage device only - most of it is never used in development process. The root cause is usually attributed to

- High analysis time.
- Difficulty in analysis of files with big size in conventional visualization tool.
- Difficulty in conversion of big files to meaningful information for development.

- Basic analysis is also highly repetitive and cumbersome – increasing possibility of error.

Challenges in analysis methodology - Process repeatability/standardization - Even when data is analyzed manually, there is concern about repeatability and accuracy of analysis process. Multiple issues are foreseen with all human analysis of big files. With automated analysis, same data handling and analysis algorithm is used - which ensure repeatability of analysis. Also, automated analysis process can be easily documented. It is also possible to ensure traceability of information acquired from data.

## AUTOMATED DATA ANALYSIS TOOLS: REQUIREMENT AND IMPLEMENTATION

An analysis module was built keeping in mind the requirements to increase usage of bulk fleet data and make certain tests more viable as a result of swift data analysis.

Features (challenges overcome) -

- Diverse Platforms used in data acquisition - All data files are converted into a common data format for easy processing.
- Benchmark vehicles: Different signal and data structure - All signals are converted to common signal structure using adapter blocks.
- Processing Enormous size of data - Automated data analysis can be scheduled and can be controlled via scripts. Also, analysis files can be split using scripts. Merging of analysis files is also possible. Efficient use of PC memory – when required.
- Analysis methodology - Common analysis methodology is developed by expert. Guidelines are provided to the test engineer to use the script/analysis module. Only beginner-level MATLAB proficiency is required for analysis.
- Process repeatability/Standardization - With automated analysis, same data handling and analysis algorithm is used - which ensure repeatability of analysis (independent of test engineer).

The analysis module consists for four main modules.

The analysis module requires Measurement data to be fed as input in *.MAT format.

- Input data handling – For bridging the differences between measurement data source and analysis module [Measurement data from different vehicles]. This helps keep the analysis module common.
- Triggers – Identification of events in the measurement data and triggering the calculation module
- Calculators – Calculation of event-based information for analysis purpose. Eg. Gearshift (event) – Clutch opening time (calculator)
- Storage – Retaining calculated information in memory and store them for further analysis in logical usable formats.

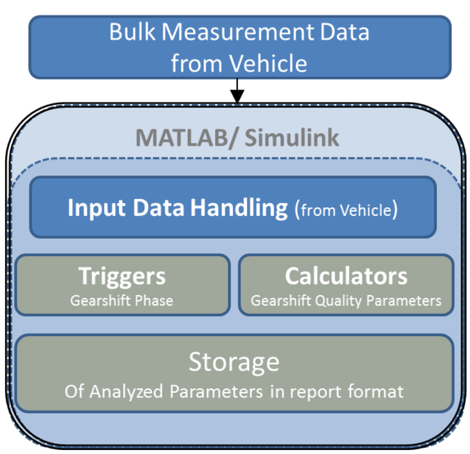


Fig.1 – Analysis tool structure

Benefits -

- Easy incorporation of data analysis algorithms
- Easy Management of Multiple vehicle platform by modification of input handling block / adapter block
- Can be used on, both, In-house vehicles and Benchmark vehicles

## ADDITIONAL CAPABILITY: ONLINE DRIVABILITY ANALYSIS TOOL

This module adds additional functionality of logging and processing measurement data real-time. It is targeted towards short-term tests for quick validation of calibration changes and quick analysis in general. Additionally, measurement data can be re-used for additional offline analysis when required.

Challenges - Real-time synchronization of the Analysis tool was a challenge and achieved through the addition of a module 'Real-Time Sync'

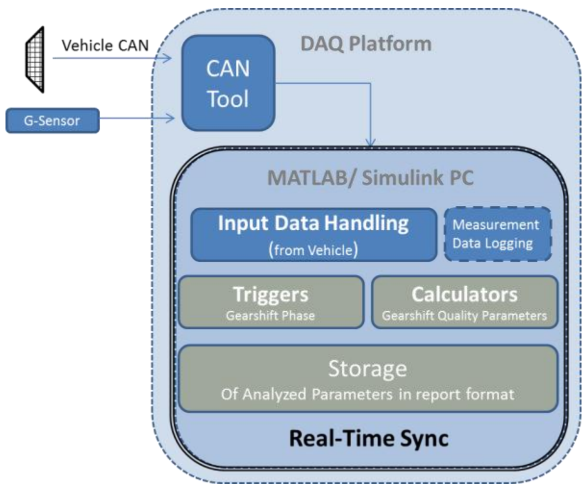


Fig.2 – Current Platform for Online tool usage

## FURTHER ADVANTAGES OF AUTOMATED ANALYSIS

Incorporating complexity and detail in analysis becomes easier and repeating the complexity becomes an easier task.

Data-analysis algorithm modeling – Detailing the aspects of manual analysis into the analysis model through influence on modeling intent and calculating intent.

Knowledge modeling – Calculating and objectively defining aspects of design/calibration philosophy, detecting driver abuse, influence of a type of calibration on driving patterns etc. Eg. Use of upshift with released AP (off-up) to shift earlier.

Simulink Platform - Code commonization with In-house tool – Main part of analysis module is re-used for different data sources using adaptor blocks. With the addition of new analysis processes / calculation logic, the same is updated across all vehicle-types, since the code is common.

## SAMPLE STUDY OF MANUAL VS AUTOMATED ANALYSIS

Case-study of AMT Gearshift quality analysis – In general, gearshift quality analysis involves the calculation of the time duration of the different phases like clutch opening, gear change, clutch closing (for eg. T1, T2, T3 respectively) etc. and the accompanying change of acceleration feeling during the process of gear-shifting. A sample study of time required for manual vs automated analysis showed savings in the region of 70 to 90% in the time required for analysis.

| Analysis Steps | Manual | Automated |
|---|---|---|
| Data Conversion | - | 0.5 T |
| Data Analysis | 5-10 T | 0.2 T |
| Report | 1-2 T | 0.2 T |
| Total | 7-20 T | < T |

T - total time of measured data in fleet test logging file

Table 1 – Indication of time required for bulk data analysis (for sample of fleet test data)

The above study focused only on basic repetitive analysis parameters and was done with 3-4 nos. individuals of varying experience in analysis and reporting. Analysis requiring mathematical operations like integration to be performed on certain parameters at certain conditions was not considered due to the complexity involved in manual analysis. With increasing complexity of analysis, automated analysis makes life easier for the test engineer.

Quality of Analysis -

Fig.3 below give us an idea of the difference in values obtained through manual and automated analysis. The example shows shift times of different segments of a gearshift obtained by the two methods. The graphs on the left (top and bottom) show absolute and percentage difference in times of diffferent segments and the graphs on the right (top and bottom) show absolute and percentage difference in total gearshift time. The absolute difference in case of individual segments is as high as 25% and the difference in case of the total time reduces to 2%. The presence of sequential segments causes error due to manual calculation in one segment to be reflected in another. This is visible in the low total error. The repeatability of manual analysis becomes a huge cause for concern.

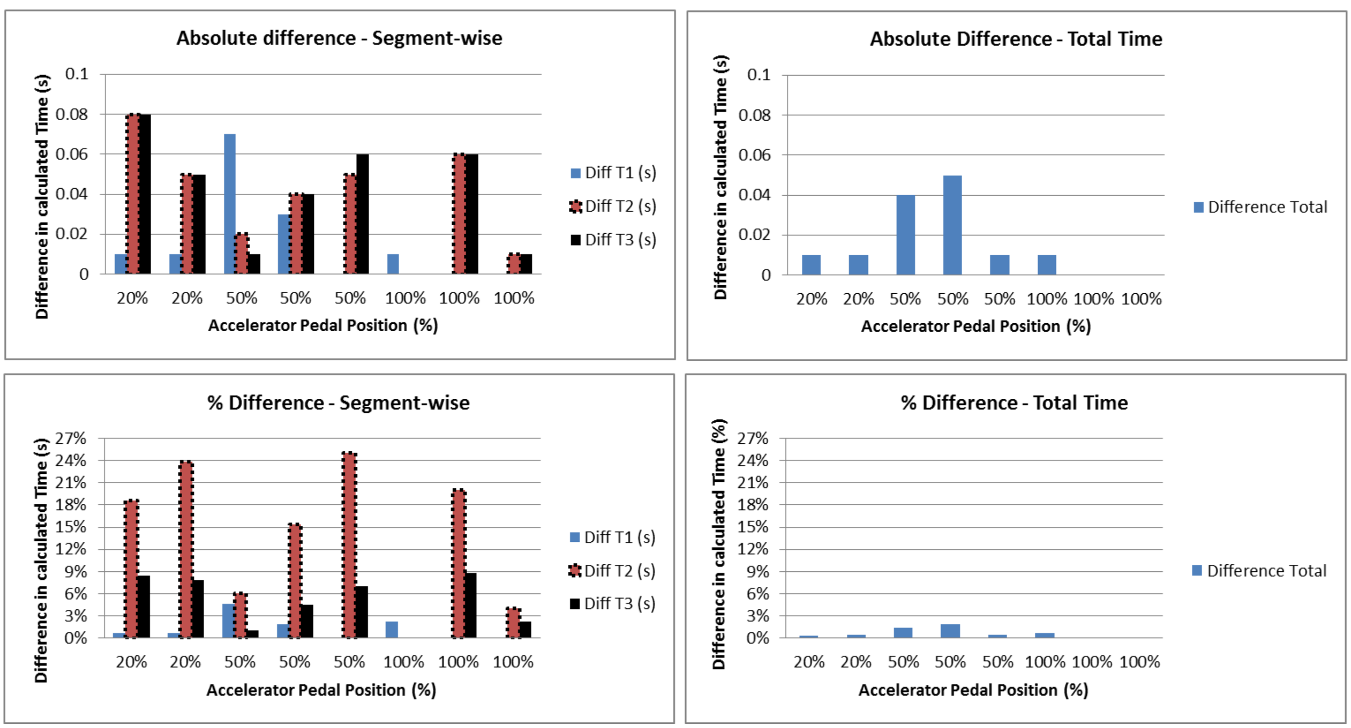


Fig.3 – Comparison of Manual vs Automated Analysis – Manual Errors

## CONCLUSION

The advantages of using automated analysis are innumerable and helps reduce development / re-calibration time significantly.

1. Analysis of bulk measurement data from regular long-term testing
2. Quick analysis of Short-term validation testing
3. Custom calculations based on calibration philosophy → Vehicle type, customer/market type, benchmark etc.
4. Highly complex analysis algorithms can be easily incorporated and re-used.

However, it is recommended to use automation only in repetitive and established processes only, where repetitive work can be automated. There is no substitute for experienced engineer's judgment on the actual vehicle. This tool is only a means to ease the burden of a test engineer in understanding and interpreting data to better judgment of a given situation.

## REFERENCES


1. MATLAB Help menu.
2. Mathworks Central


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## ADDITIONAL SOURCES

Here are any additional sources. This is an optional section.

## DEFINITIONS, ACRONYMS, ABBREVIATIONS

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## APPENDIX

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