Collaborative activity among Design, Experiment & CAE in the field of vehicle dynamics

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Taking the various and ever-changing trend of customers' demands into account, it is necessary to reduce the duration of vehicle development from concept to market. Meanwhile, in the field of vehicle dynamics, customers' voice indicates the requirement of high degree of profound performance. Naturally, design style should have been changed into objective oriented way. A well-validated full-vehicle modeling with the complicated force elements, such as tire, damper etc. will be consequently able to make the design style changed. This paper presents the outline of current design style here along with the description of potential future.

Keywords / Vehicle dynamics, Handling, Ride comfort, Suspension, Chassis, Kinematics, CAE, Elasto-Kinematics, ADAMS

1. INTRODUCTION

Facing up to the floating and diversified trends of customers' voice, shrinking the duration of the vehicle development will be asked for. And the high standard of expectation for vehicle dynamic performance naturally requires immediate re-engineering of design procedure. In this article, as one of the cut ends, the updated measurement technology to investigate into the subtle but important of qualified performance for customers, and the current state of the objective oriented design with CAE will be shown along with the future view.

2. V-CASCADE OF VEHICLE DEVELOPMENT

Considering the vehicle dynamic performance to have one aspect of an attractive profile of the product, in order to inspire with the vehicle concept for customers, our test pilots has driven prototypes for millions of miles to improve the characteristics of the new vehicle.

Carrying out our heritage efficiently, systematization of assessment topics to be coincident with the design issues has been achieved. By weaving the deployed QFD of every topic into the V-Cascade of vehicle development procedure shown in Fig. 1, the quality of the prototype has become obviously improved within a shorter period of development.

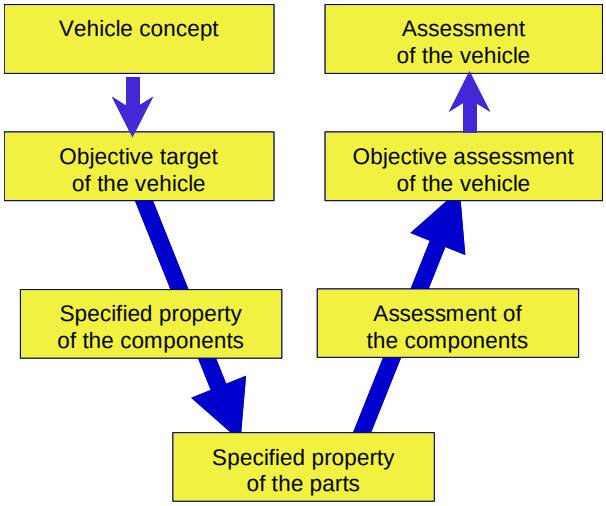

Fig .1 V-Cascade of vehicle development

3. DOUBLE TRUCKED DEVELOPMENT FLOW

The main role of the experiment section has been prioritized in the downstream of the design section, e.g. finding out the problems through subjective assessment, proposing the countermeasure through trial and error, and so on; previous CAE team has also been brought out to follow the experiment results of trouble shooting.

After the modernized CAE which covers the whole process during design and experiment phase has come into existence, several elements from experiment has rowed against the stream; quantitative analysis to improve the performance and measurement to validate the theory or to correlate the predictive accuracy of CAE. This natural revolution has gradually changed the sequential heavy traffic of “the experiment after the design with the prototype” into double-tracked traffic, that is, the internal cooperation shown in Fig.2.

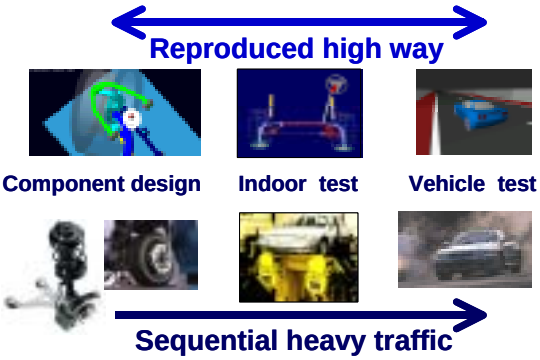

Fig.2 Double-tracked flow of vehicle development

4. OBJECTIVE TARGET OF THE VEHICLE

Pursuing the objective oriented design, to extract the vehicle concept, which has been and will be abstract and literal, into objective target will be one of the keys for qualified performance design of the vehicle. It is obvious that the perfect agreement between the subjective target which is elusive in itself and the objective target which should be crisp will be a matter to discuss with philosophers and cerebral scientists. But combining several objective values, overlooking them from the view point of the assessment situations and comparing to the ones of distributed map filled with other vehicles, some fragments of the subjective target will be elucidated. In addition to such kinds of arithmetic analysis, the scrupulous phenomena to fit to the customers’ demand have been continuously investigated in the way of the rule of virtue; replicate the situation which customers will encounter, distill the typical scene to assess, provide the ideal scenario for customers, reproduce the situation on test track and copy them out into the model of CAE.

A sample of the investigated scrupulous phenomenon of high speed straightability will be shown in Fig.3.

The agreement between experimental results according to ISO-13674-1 Weave test and the simulated results has been achieved through several contrivance of both experiment and CAE engineers. The maneuvering machine shown in Fig.4 has been introduced to reproduce the little steering angle in few degrees, and the ensemble averaging method in post processing has successfully separated the noise of road or wind from the slight signal.

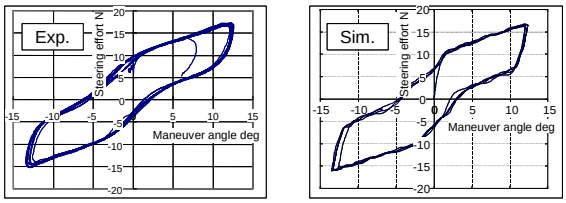

Fig.3 ISO-13674 Weave test and simulated result

Fig.4 Maneuvering machine

The steering model of 4-DOF shown in Fig.5 has been designed to include seven friction elements with stick-slip capability.

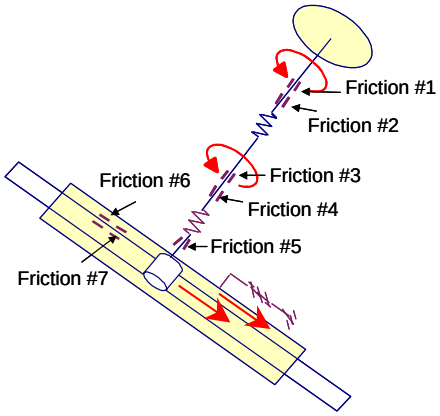

Fig.5 Steering model of 4-DOF

The series of these persistent activity for customers has been and will be the keys to open the doors by way of the labyrinth toward the qualified handling performance.

5. IMPROVEMENT IN DESIGNED QUALITY

Front-loading the development of vehicle dynamics design, the left part of the V-Cascade has become emphasized, such as, to deploy the performance of

components which will satisfy the objective target in vehicle, and to specify the property of parts which will materialize the allocated performance of each component. The activity to improve the designed quality has become more and more important.

For example, as shown in Fig.6, measuring the gravity center position and moment of inertia precisely has become necessary to arrive at the high accuracy in the prediction of vehicle dynamic performance.

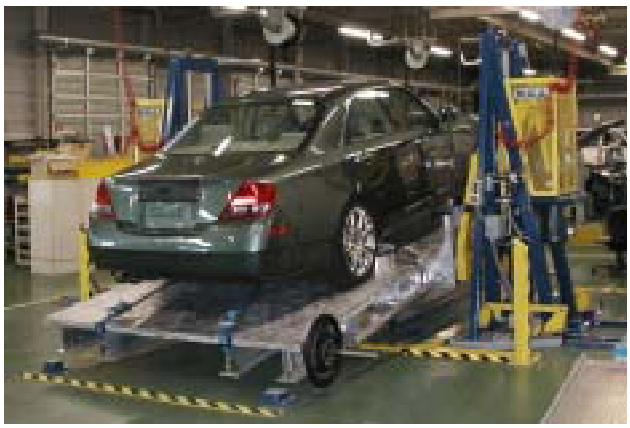

Fig.6 C.G.H. measurement facility

Another example will be shown in Fig.7. To identify the parameter of tire model on real road surface will be also necessary to arrive at the exactly alike situation between experiment and simulation in a pod.

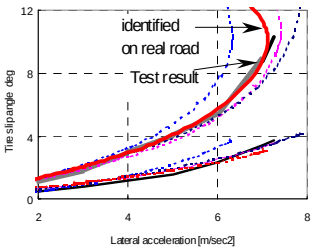

Fig.7 Identification of tire model on real road surface

Integrating FEM model into Multi Body Simulation shown in Fig.8, the predicted accuracy has made a scientific breakthrough which has filled the role to accelerate these activities.

Concerning the body structure design, the earlier the better to solve the configured problems combined with other components. Previous style of “sequential heavy traffic” has sometimes missed a proper timing to feedback. In the past, the information on body structure design has been apart from the information on the load in vehicle, and vice versa. Reproducing the assessment situation in vehicle by ADAMS/Nissan, the separated collaboration between vehicle dynamics designers and body structure designers has been focused in the limelight.

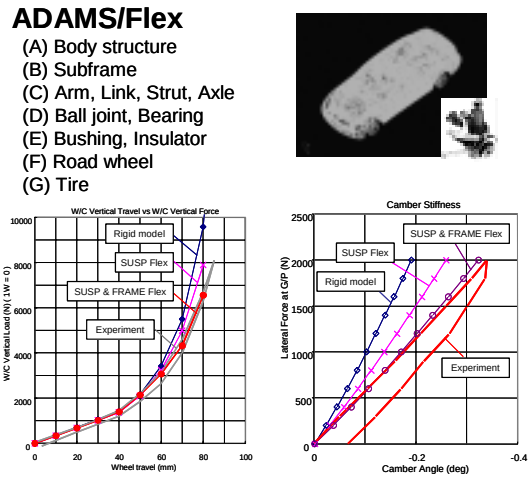

Fig.8 FEM integrated into MBS (ADAMS/Flex)

The force from suspension in time domain will be loaded to the body structure, and the deformation of body structure will be assessed by TEK/Body method (Technique based upon Experience and Knowledge) which consist of the analyzed experience of subjective assessment. This activity has evidently reduced the change of the design in body structure during the later phase of vehicle development.

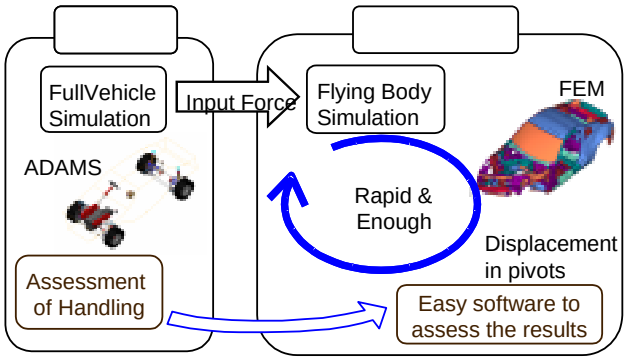

Fig.9 TEK/Body method

On the other hand, the confirmation of the achieved performance in body structure shown in Fig.10 will be also necessary.

Fig.10 Bench test of body structure

Applying the flexible ring tire model accompanied with the precisely replicated road surface, the envelope effect in tire will be correctly reproduced and the predictable range in frequency domain will be enhanced. The agreement between the experiment result and the simulated result from F-Tire overriding a cleat on drum test is shown in Fig.11. The agreement during overriding a diagonal cleat is also shown in Fig.12 (Red : F-Tire).

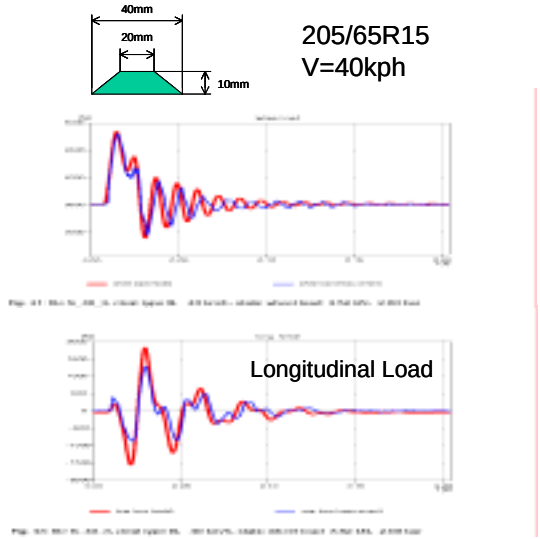

Fig.11 Reproduced envelope effect by F-Tire

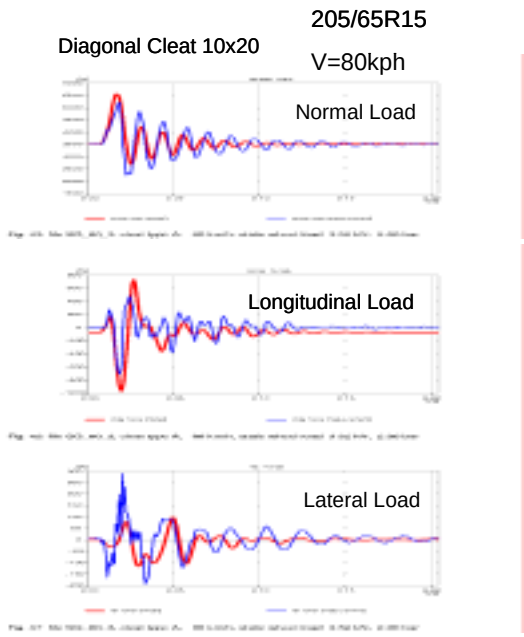

Fig.12 Overriding diagonal cleat with F-Tire

Prediction of EDM (Empirical Dynamic Model) traces the time history of measured data as shown in Fig.13. Combined with F-Tire, the feasibility of EDM including non-linear property will indicate sufficient reproduction of damping after overriding an obstacle or load from the continuous uneven road e.g. pebble stone road or horse dropping road and so on.

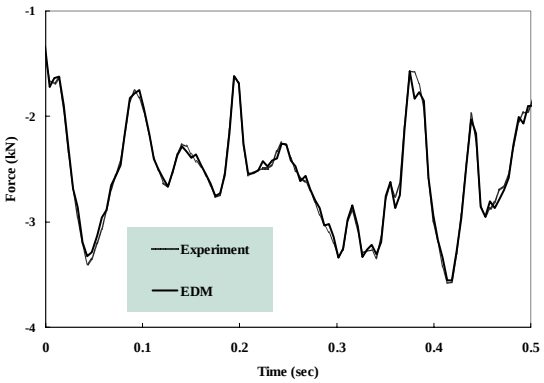

Fig.13 Precise reproduction of non-linear damper

6. NEW FINDING FROM THE ACTUAL ENTITY

The objective oriented design has made a remarkable progress in vehicle dynamics design and stimulated the new approach and new finding from the experiment.

For example, investigating into the dynamic property of real entities, objective assessment has become available to comprehend the unknowns in subjective assessment.

The superior vehicle-A and the inferior vehicle-B in subjective assessment of high speed straightability will not be able to be illustrated by the previous guidelines of suspension characteristics e.g. induced steer, steering stiffness nor tire cornering force & moment which are measured in static condition. Actually, the steering stiffness in vehicle-A and vehicle-B are almost same as shown in Fig.14.

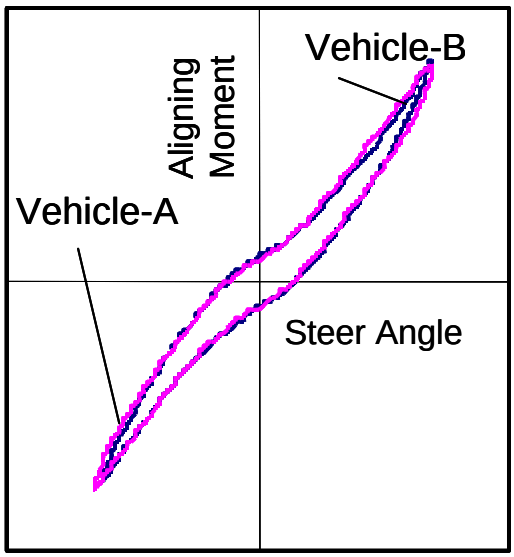

Fig.14 Steering stiffness in vehicle-A and vehicle-B

Taking the dynamic characteristics measured by dynamic K&C test facility shown in Fig.15 into account, the white mist which has laid over the bridge from the subjective to the objective has been cleared off.

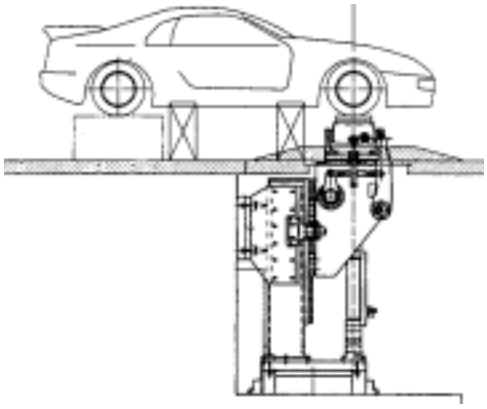

Fig.15 Dynamic K&C test facility

The difference in these two vehicles has been appeared by applying dynamic force & moment in tire contact patch. Thus the transmissible gain of steering effort for tire force & moment in frequency domain has been revealed to be distinct. Higher the frequency, lower the steering effort in vehicle-A shown in Fig.16.Assuming that too solid response in steering effort due to the unevenness of the road surface will be no use to drive straight on center, the high mark in vehicle-A will be simply explained.

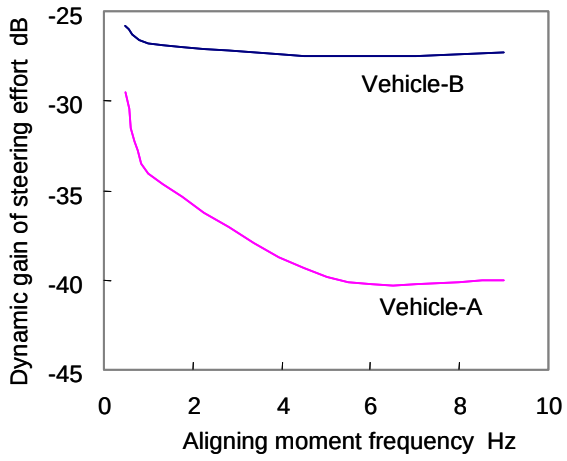

Fig.16 Difference in vehicle-A and vehicle-B

7. CONCLUSION

The collaborative activities among Design, Experiment and CAE, which encourage to enjoy the complexity in the actual entity, has inevitably not only led us to the improved efficiency in development, but also pointed the technical passion in each engineer into the same direction toward the customers' satisfaction.

The new findings from the experiment to make an approach to the subjective assessment will drive the new CAE technology to investigate clearly into the virtual but artificially real world. New experimental facility will be the spiral step to become aware of the existence of another new finding which will be, to say, never ending improvement in vehicle.

Upcoming CAE equipped with new technology e.g. EDM, F-Tire etc. will play an important role to spiral up never ending improvement.

On the other hand, the activities of industry-university cooperation in sorts of consortiums among Europeans' will be more and more valuable to develop and share the high technology which will meet to the expected one.

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