

Enhancement of Multi-Body Simulation Data Sharing

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ABSTRACT

Obtaining accurate input data from CAD (Computer Aided Design) geometry and reliable measurement data from suppliers is the main challenge of Multi-Body Simulation (MBS). Standards, processes and software were developed to enhance the process of creating an MBS model. A data extraction process from CAD was applied to extract only necessary data and combine the geometry information. Application of the Association for Standardization of Automation and Measuring Systems (ASAM) Open Data Services (ODS) format in conjunction with suppliers provided a common, reliable and transferable format. Key benefits are a time reduction for simulation feedback and independence from specific suppliers and MBS data structures.

1. Introduction

Safety requirements, environmental commitments, and the complexity of automotive vehicles are growing. However, development time, budgets, and manpower are typically limited. A key strategy in automotive development is to shorten development time, build fewer physical prototypes, and increase development in early stages. Digital manufacturing is a technology that every automotive maker has worked to develop during the past two decades. One of the improved digital methodologies is a numerical simulation called Computer Aided Engineering (CAE), which helps reduce product development cost and time while enhancing the safety, comfort, and durability of vehicles.

Finite Element Method (FEM) is one of the world's most widely used CAE solutions as implemented for crash simulation. FEM mainly originated from the need for solving small displacement elasticity and structural problems. In contrast, Multi-Body Simulation (MBS) was used in the early 1990s for large translational and rotational displacements, such as suspension stroke analysis (Fig. 1). More recently, MBS allows for predicting highly advanced phenomena such as elastic deformation⁽¹⁾ and rough road analysis⁽²⁾.

In spite of advances in this technology, MBS pre- and post-environments were still not well-organized. It was challenging to share input data between different solvers due to the small number of analysts and lack of a common data format. Moreover, to identify parameters, MBS requires actual measurement data from suppliers. For example, bushings require nonlinear, frequency-dependent, and displacement-dependent measurement data. Since there was no standardized measurement format for suppliers,

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each supplier had a different file and data format. Consequently, each CAE analyst had to gather the necessary input data and modify it to fit their own MBS input data. This led to redundant requests to design engineers and suppliers. Due to increased data requirements and reduced development time, the need to establish a common, shareable data format became necessary (Fig. 2).

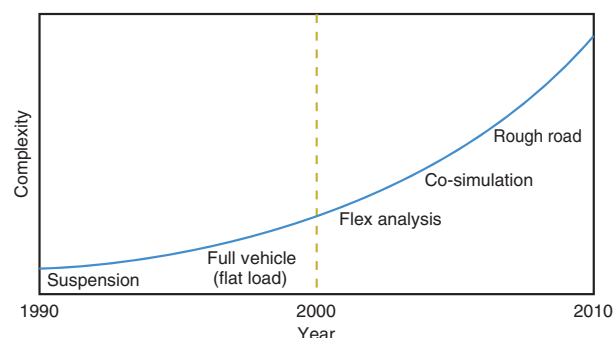


Fig. 1 Multi-body simulation technology

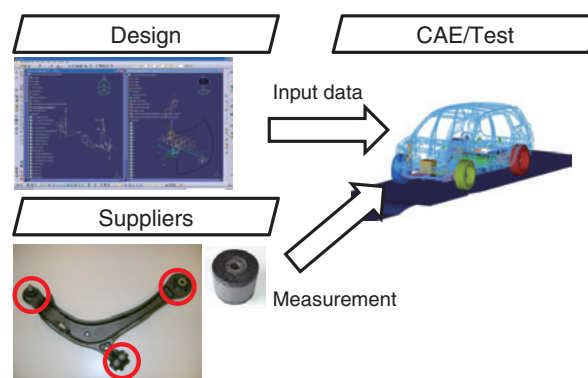


Fig. 2 Relation for Multi-body simulation input data

2. Construction of Multi-Body Simulation Data

MBS models are fundamentally constructed with geometric and non-geometric data (Fig. 3).

2.1. Geometric Data

Design engineers are responsible to confirm their own component designs and issue drawings for mass production. This is accomplished through component CAE and CAD applications during vehicle development. Design engineers can predict component characteristics by using component CAE at an early stage in development. Once design engineers evaluate their own concept after component performance is evaluated, CAD data is built and clearance with other components is confirmed. The purpose of component CAE is mainly static analysis such as suspension stroke. This static analysis is only dependent on the rough geometric information, but the full MBS model requires accurate mass, C.G. (Center of Gravity), and inertia. When a proper material with density is applied to the geometry, the MBS input data can be calculated. In addition to the shape of the parts, suspension/mount points and orientation information are required to satisfy the geometric data requirements of the MBS input model. All of this was accomplished by design engineers providing detailed CAD models.

2.2. Non-Geometric Data

Most measurement data comes from suppliers for several components such as bushings, tires, and dampers. Chassis development demands several kinds of bushing data including orientation, displacement, frequency, preload condition and others. Suppliers may spend several weeks measuring this data. Previously, data requests to suppliers were inconsistent and the returned measurement data formats were unique for each one of the suppliers. Consequently, it took extra time to confirm the accuracy of the data and extract MBS numerical data.

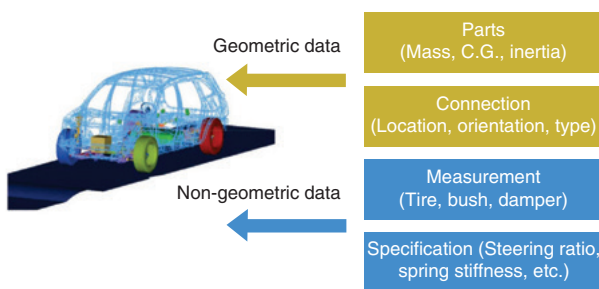


Fig. 3 Construction of MBS model

3. Extraction Process of Design Data

3.1. Master Work Sheet

A Master Work Sheet (Fig. 4) contains all the MBS input information and lists each sub-system on a separate spreadsheet. Being independent of a specific

CAE format, the Work Sheet is easy to understand and use and can be easily expanded to include other sub-systems.

Generally, the variety of suspension types is limited due to cost, performance, and manufacturing. Providing pre-defined templates for each suspension type enables a reduction in input workload. Through this research, design engineers defined the naming of the point and orientation; therefore, by using this naming rule and a predefined suspension type, each connection type can be automatically defined.

3.2. CAD Property / Naming Rule

To automate the process of geometric data extraction from the CAD data for use by MBS, the following three-part process is required:

- (1) Properties used for extraction
- (2) DPM/part construction
- (3) Naming rules of CAD hard point data

Property extraction from CAD requires standardization and correlation between test and design. The agreed upon properties include the part numbers and names that comply with the Honda Engineering Standards. In addition, material naming and mass values are required for determining the mass, C.G., and inertia values of the individual parts and MBS bodies.

The Digital Prototype Model (DPM) is used for the digital prototyping process before a prototype is actually built. The DPM construction further aids in automating data extraction. In order to guarantee accurate mass, C.G., and inertia values, each part should be constructed as a single body consisting of a single material. This method of part design should be used for all the vehicle parts required for simulation. Additionally, the construction and placement of the CAD hard point data file (Fig. 5) should also be standardized. It represents each critical control point, such as the bushing and ball joint centers of the suspension. This file's location was set to a specific area of the DPM to provide a consistent location for all users.

The CAD hard point data file should also follow a consistent construction format. This format is required for the automated extraction of the individual point locations. Additionally, the naming of these points was also standardized. This standardization was needed for the Master Work Sheet and involved design correlation to define the rules for point names and orientations. A sample of this standard is shown in Fig. 6.

Model Type	A	B	C	D	E	F	G	H	I	J	K	L
General Description	Front Suspension Assemblies											
Front Connections Assemblies	Front Connections Assemblies											
Engineer	AK											
Size	AK											
Front Suspension Connections	Front Suspension Connections											
Connection Name	Part No.	F - Section	Activate Connection	Mirror	Honda ID	Active Part	Active Node #	Passive Part	Passive Node #	Origin: P	PS	PY
STABILIZER	F04	X	X	NUT	STABILIZER_R	1011	1011	1011	1011	2011		
LOWER ARM	F04	X	X	NUT	LOWER_ARM_R	1012	1012	1012	1012	2012		
SHOCKER	F04	X	X	NUT	SHOCKER_R	1013	1013	1013	1013	2013		
STABILIZER	F04	X	X	NUT	STABILIZER_R	1014	1014	1014	1014	2014		
STABILIZER	F04	X	X	NUT	STABILIZER_R	1015	1015	1015	1015	2015		
TRAIL ROD	F04	X	X	NUT	TRAIL_ROD_R	1016	1016	1016	1016	2016		
TRAIL ROD	F04	X	X	NUT	TRAIL_ROD_R	1017	1017	1017	1017	2017		
CONNECTION PIVOT/UP	F04	X	X	NUT	CONNECTION_PIVOT/UP_R	1018	1018	1018	1018	2018		
SPRINGER	F04	X	X	NUT	SPRINGER_R	1019	1019	1019	1019	2019		
SPRINGER	F04	X	X	NUT	SPRINGER_R	1020	1020	1020	1020	2020		
WHEEL CUP	F04	X	X	NUT	WHEEL_CUP_R	1021	1021	1021	1021	2021		

Fig. 4 Master work sheet format

Using required properties, a standardized structure, and naming rules allows for automation capability that leads to an increase in simulation efficiency.

3.3. CAD Extraction Process

Once the Master Work Sheet, CAD geometry, and CAD hard point data are prepared, necessary design data can be retrieved with a CAD Extraction tool (Fig. 7).

This tool can read both CAD and spreadsheet data. When the CAD point and orientation names are matched with the spreadsheet data, the point information of CAD can be mapped to the spreadsheet. By using this process, large amounts of data can be extracted without errors. This operation is very simple in that the exact same CAD parts can be shown on the CAD extraction tool (Fig. 8). After completing every part assignment, the spreadsheet file can be exported.

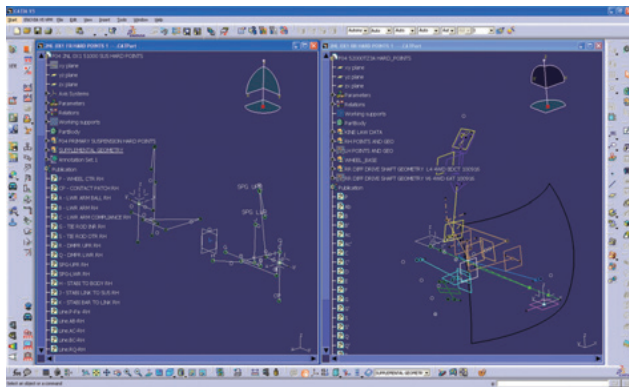


Fig. 5 Sample of CAD hard point data file

Front suspension example

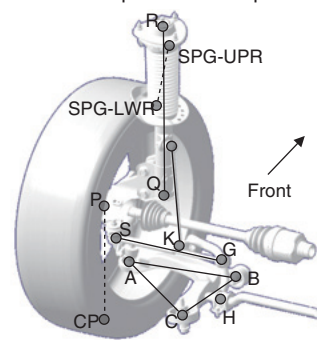


Fig. 6 Sample of suspension naming rule

WHEEL CENTER	P
	CP
LOWER ARM	A (b, c)
	B
	C*
TIE ROD	G
	S
DAMPER	R
	Q
SPRING	SPG-UPR
	SPG-LWR
STABILIZER	H
	J
	K

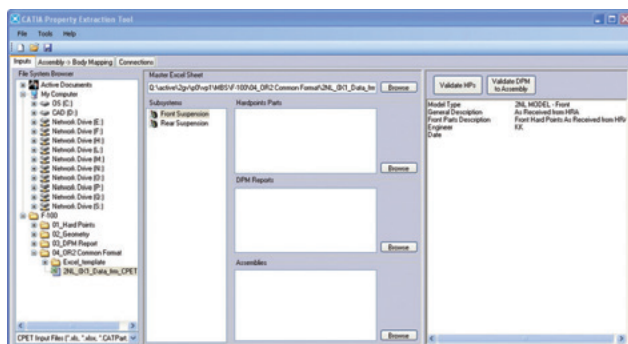


Fig. 7 CAD extraction tool (GUI)

Previously, the extraction process (Fig. 9) was performed manually by multiple CAE analysts. Each analyst spent about a week to gather the MBD input data from several design engineers. Through this new extraction process, these tasks can be completed in one day by one analyst. This allows the CAE specialists to focus their time on analysis rather than model building.

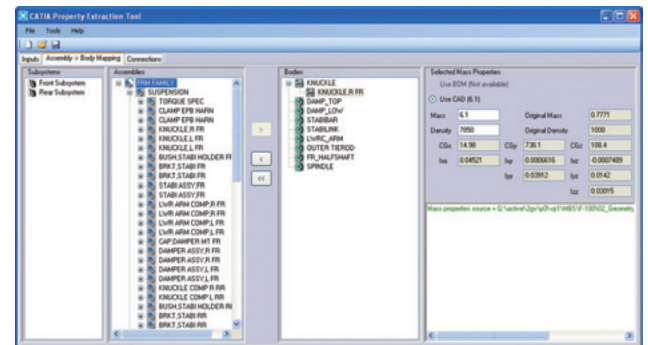


Fig. 8 CAD extraction tool (GUI)

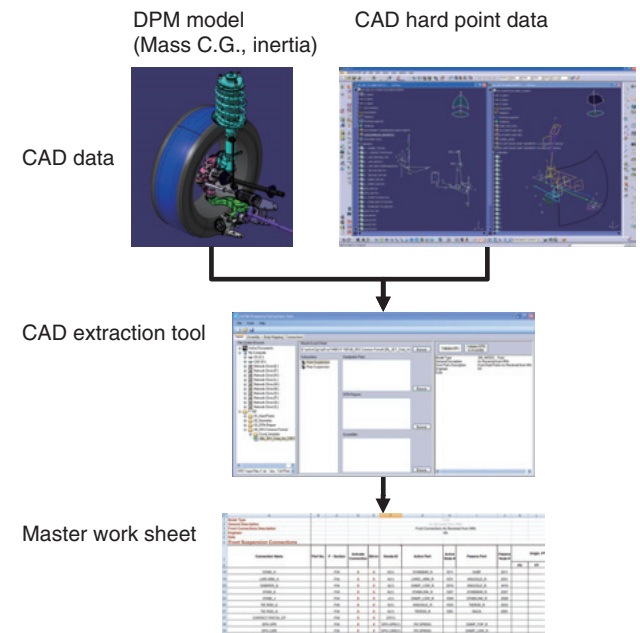


Fig. 9 CAD extraction process

4. Supplier Data Sharing

As MBS models are applied to address increasingly complex vehicle dynamics problems, a higher degree of fidelity is required. This increased fidelity is achieved by increasing the details and accuracy of the component characteristic data that is used to represent the vehicle and construct the model. For instance, tire models have been researched and developed for decades and have increased in the ability to accurately represent the tire-road surface dynamics for an ever greater range of loading events.

Similarly, it has been shown that an improved representation of the non-linear, dynamic characteristics

of chassis bushings and mounts can provide improved MBS model accuracy. This is especially true in the areas of ride and NVH⁽³⁾. However, just like a single, computationally-intensive tire model is not always the best solution for a particular dynamics concern, the same can be said for bushing models. NVH prediction requires a component representation that is based on very small input displacements or forces. This small input is due to the nature of visco-elastic rubber behavior and is highly dependent on displacement and frequency of excitation⁽⁴⁾. Conversely, durability-related prediction requires characterization of the same parts over a much greater load range and the stiffness and damping characteristics are typically not as frequency dependent. Thus, for a single component, many different characterization tests in multiple degrees of freedom may be required. Maintaining a catalog of bushing data presents an opportunity for increasing efficiency not only for MBS but also at an enterprise level by decreasing the number of redundant tests requested of the suppliers and by making the measurement data more widely available and accessible.

4.1. Standardized Tests and Metadata

The first step was to create a data template that captures the broadest array of possible test specifications with the smallest number of specified parameters (e.g., static, dynamic: min/max load, Hz, preload, etc.) (Fig. 10). This information should be clearly and easily communicated to suppliers in a package that maintains a record of the test component(s) and both the requested and actual test procedures. This template also helps to establish a minimal set of metadata to be captured and reported with every set of test results. The metadata aids in interpreting the data by having a record of the conditions under which the part data was recorded.

4.2. Standardized Workbook

The next step of this project was to create a template for exchanging the actual measurement

data between the OEM and suppliers (Fig. 11). This template is an extension of the Master Work Sheet and is extended to include the raw measurement data as well as functions for error-trapping and basic data confirmation, such as key reference data, plotting, rate calculations, and others.

Fig. 11 Detailed specifications in request sheet

5. Bushing Application Data Model

The ISO-22720 standards defined by ASAM-ODS describe the structure and rules for a relational data model for measurement data. ASAM was founded in December 1998 as an initiative of the German Car manufacturers Audi, BMW, Daimler, Porsche, and Volkswagen and is now in use at OEMs and suppliers globally. This standard was considered ideal for this project because it is hardware-, software-, and vendor-independent, and is supported by many of the largest and most common analysis software vendors. With the bushing test data templates matured and in frequent use by suppliers, the next step was to create a bushing-specific ADM.

5.1. Basis for Application Data Model

The purpose of this template is to set the basis for the development of a bushing-specific Application Data Model (ADM) that is used to form the basis of the database and Web interface to be used to exchange data with suppliers. Once the data is stored in the ADM, which is a customized version derived from the ASAM Open Data Services (ODS) base model, the data can be exchanged directly with the ODS database or exported into XML text files according to the ATF-XML standard.

5.2. Data Converter

Within ASAM ODS, there is defined a base model with a set of defined based elements and a set of base relations between them. An application model was developed specifically for bushings and specifies which elements and relations from the base model are actually in use (Fig. 12). The actual measured data is stored in data elements and related to test parameter elements (e.g., preload, duration, rate, etc.) as described in the Test Request Sheet. The Data Converter uses the application model to map the Excel data to an ODS ATFX file or ODS database.

The biggest challenge is to create the ADM and the

Fig. 10 Simple request form

applications necessary to interpret and verify the data in the spreadsheets. After these steps are achieved, it is much easier to store the data into an ATF/XML file or directly upload it to an ASAM database.

Figure 13 shows the overall bush data sharing flow. This process was created through discussion and understanding between suppliers, design engineers, and Information Technology (IT) engineers.

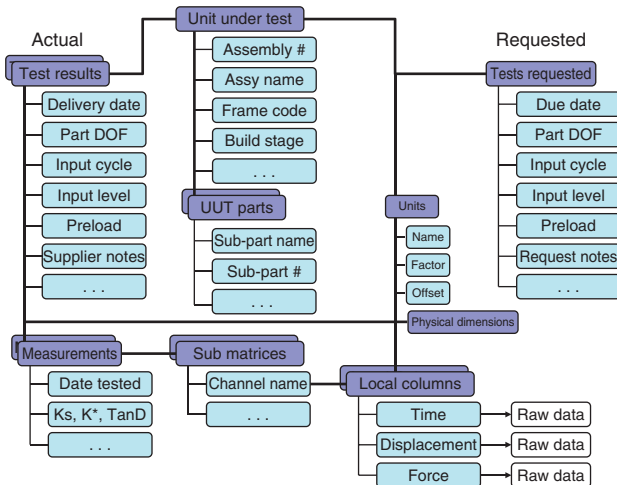


Fig. 12 Bushing application data model

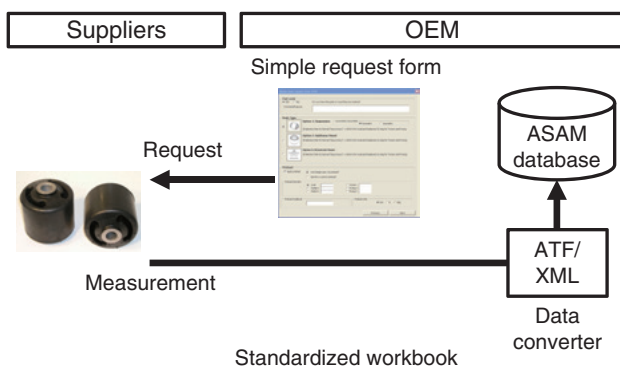


Fig. 13 Bush request flow

6. Case Study

The process described in this paper was tested with a suspension subsystem. The new rules and tools reduced data gathering time from one week to one day. Three suppliers who supported the direction towards standardization were introduced to the test data standard format. In total, the time to request, receive, and review the data was reduced.

7. Conclusion

Through this research, an effective MBS data sharing process was developed. The key items can be summarized as follows:

- (1) Standardized CAD properties and measurement data are important in reducing the MBS feedback time by allowing for automated data extraction and MBS model creation.
- (2) A flexible and extendable data format for non-

geometric data is necessary to accommodate future CAE methods.

- (3) While the initial trial and benefits were limited to suspension, it is clear that extending this process to the other parts and systems will further enhance the simulation-design development loop.

Finally, through this research, there were opportunities to meet with other OEMs to discuss their systems and methodologies related to MBS. This provided a better understanding of the different strategies and systems implemented across a range of OEMs' CAE maturity and scale.

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