Development and Implementation of a Tool for Modeling Driveline Systems at Visteon

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ABSTRACT

In order to facilitate the modeling of vehicle drivelines in ADAMS, Visteon developed an ADAMS/View driveline tool with the aid of Mechanical Dynamics, Inc (MDI). Known as Visteon Axle & Driveline Simulation-Dynamics (VADSIM-DYNA) this tool is used to supply customers with driveline models for use in their full vehicle modeling as well as for predicting forces in the driveline. Of specific interest is a method for calculating the mesh point of a hypoid gear set using the geometry of the ring and pinion gears, and a custom force statement for calculation of the mesh point reactions at the center of gravity for both the pinion and ring gears. With the introduction of ADAMS/Driveline, Visteon has worked with MDI to implement VADSIM-DYNA into the base product. With the aid of VADSIM-DYNA the ability to provide customers with ADAMS models of driveline components and systems has been greatly enhanced. Through Visteon's experience, a process for building system models has been implemented that ensures that customer needs are met. This paper will discuss the development and implementation of VADSIM-DYNA.

INTRODUCTION

Suppliers are finding it necessary to dedicate more of their resources to Computer Aided Engineering (CAE) as Original Equipment Manufacturers (OEMs) place more of the engineering responsibility on their shoulders. In addition, suppliers are required to lower their prices, resulting in the need to streamline the process and reduce the resources needed for product development. While CAE helps to reduce cost through less time to market, need for fewer prototypes, etc, often the process that CAE uses can be time consuming and in some cases counter productive. Visteon Axle & Driveline realizes this and has developed and implemented both tools and a process to ensure that customers are provided with accurate, useable ADAMS models of driveline systems. This paper discusses the tools and process used by Visteon Axle and Driveline to design its systems and to help make our customers successful.

THE BEGINNING

In 1995, Visteon management realized the value of using virtual prototyping in the axle/driveline design process. A plan was created to develop a tool that would simulate an axle/driveline system. This tool was to be developed such that only a casual knowledge of Mechanical Simulation System (MSS) would be required by engineers to produce useable results. In addition, the basic steps for using the tool were spelled out at this time. The steps defined are as follows:

1) Assemble an axle system virtual prototype by selecting from a library of components, subsystems, systems, and test environments.
2) Complete predefined performance tests of the axle design.
3) Output standard test results in tabular, graphical, and/or plotted format.

These steps were accomplished through the creation of fully parametric modules that build the critical components and assemblies of the axle/driveline system. These modules are incorporated into ADAMS/View as a customized set of macros and menus, which are shown in Figure 1. However, it was deemed to be impractical to develop the entire package at once, so the project was broken up into a number of phases, each of which would add an important building block to the overall tool. Also, as each block reached completion, it was validated against available data and tests to ensure that it properly captured the performance of each system being modeled.

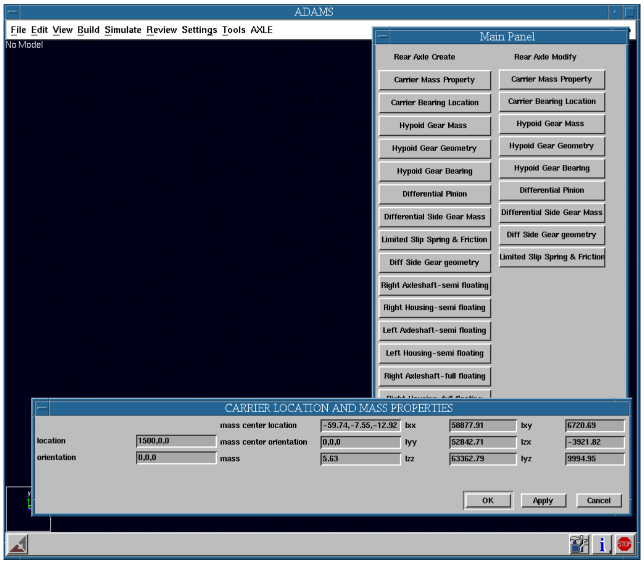


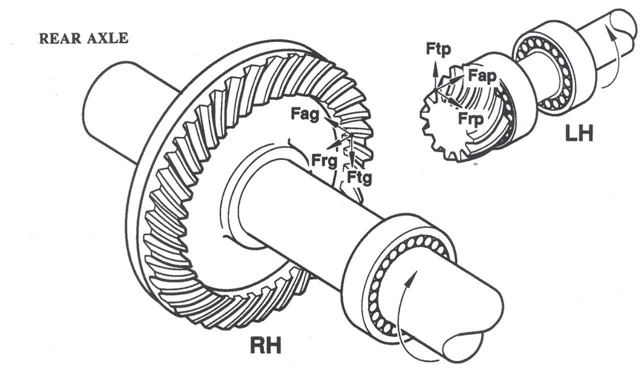
Figure 1

THE HYPOID GEAR SET

In Phase I of the project, a hypoid gear set module was created. This module allows the user to evaluate hypoid gear design performance alone, or as part of the axle system. Since evaluation of the contact forces of a hypoid gear system is a complex dynamic problem, Visteon decided to develop a module that contained forces, rather than the simple kinematic constraints available in the standard ADAMS package. In developing the equations necessary for these forces, a number of assumptions were made:

- There is continuous gear tooth contact, which always occurs at the same point on the tooth profile.
- The tooth contact is frictionless.
- The mass and inertia properties of the two gears are known.
- The gears are constrained using bearing sets.
- Slide and backlash phenomena between the gears is not included.

The basis used for the formulation of the hypoid gear set equations was an internal paper written by Santosh Neriya, Ph.D., who is a current member of the Visteon Axle & Driveline Systems CAE section. Dr. Neriya's paper defined equations for the hypoid gear forces at the mesh point for both drive and coast conditions, front and rear axle Global Coordinate System (GCS) for mesh point definition, mesh point coordinates in GCS, direction cosines of the hypoid gear forces at the mesh point in GCS for both drive and coast conditions, and force equilibrium in the GCS for both drive and coast conditions [1]. Figure 2 shows a typical hypoid gear set



and the corresponding forces at the mesh point.

Figure 2

The module created allows the user to input a standard set of hypoid gear set parameters, gear set parametric geometry, material properties, and input torque on the hypoid pinion gear. The module then builds the hypoid gear set and outputs information such as the mesh point location and action/reaction forces at the pinion/ring gear center of gravity, mesh point, and bearings. These resulting outputs were then compared to analyses and calculations performed by Dr. Neriya for verification.

DIFFERENTIAL GEAR SET

Another aspect of the driveline modeling tool's first phase is the differential gear set. These are also modeled using idealized contact and gear interaction forces developed within Visteon. As with the hypoid gear force, input parameters include predetermined gear set parameters, parametric geometry of the gears, and material properties. In addition, the differential case and pinion shaft geometry are included in the input parameters. Figure 3 is an example of a typical differential gear set created using VADSIM-DYNA.

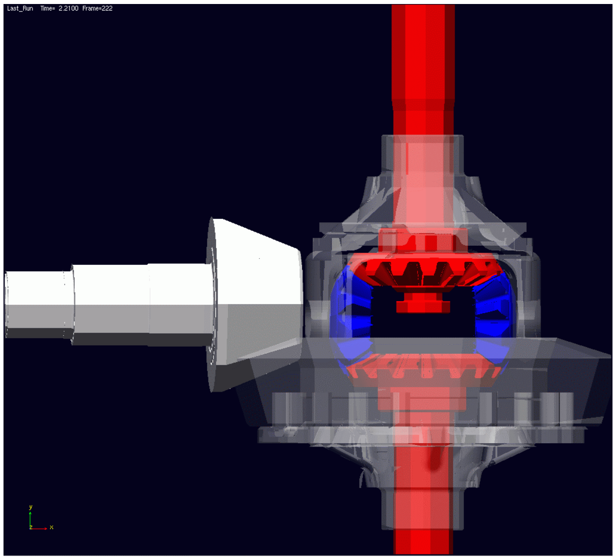


Figure 3

LIVE REAR AXLES

With the completion of the hypoid gear, and differential gear sets, a base was created upon which entire axle systems could be built. In Phase II of the project, modules to build full and semi-float axles, and prop shafts were added to the tool. These two modules, along with the hypoid and differential gear set modules, were made available to the user under a common menu system in ADAMS/View. See Figure 4 for an example of a live rear axle built using VADSIM-DYNA.

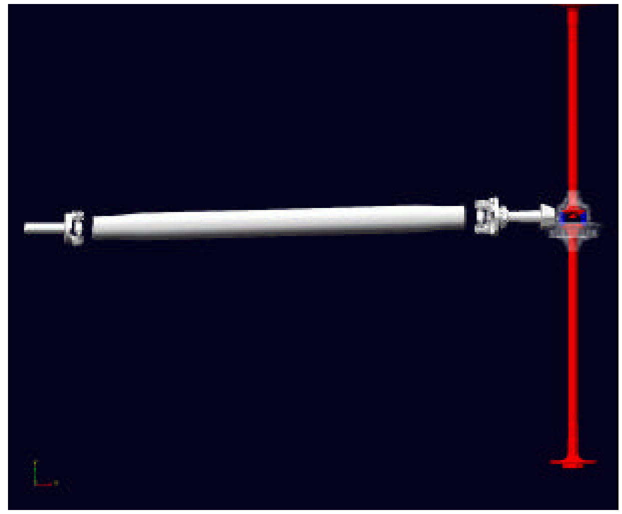


Figure 4

Included as part of the live axle was the ability to create flexible axle shafts and housing tubes. These elements were created using ADAMS/BEAM statements. The interface panel that creates the BEAM elements allows the user to specify a number of different diameter changes along the length of the shaft or tube.

The prop shaft module allows the user to create one, two, and three piece prop shafts. In this phase of the project, the prop shaft tubes were modeled as rigid parts. The universal joints are modeled to allow both the phasing of the joints, and the ability to add friction in the joint bearing sets. The rigid tubes could be replaced with a flexible FEA representation if the user chose. The method of using flexibility was validated with test data.

At this time, a number of other enhancements were made to the tool. The enhancements are as follows:

- The hypoid gear set was modified to allow the user to input parameters for the transmitted error induced by the gear teeth.
- Flexible axle shafts and a CV joint were added to the tool to facilitate limited modeling of independent suspensions.
- Interface templates were added to automatically combine axle models with full vehicle models.
- A modify menu was created so the engineer could change parameters in the model through the interface.

SUPPLYING MODELS TO CUSTOMERS

At this time, Visteon began supplying models of driveline systems to customers. With each model delivered, new lessons were learned in areas such as:

- What the customer wants.
- What the customer needs.
- What time frame the model can be delivered.

Using the knowledge gained in building these early models, Visteon has made adjustments to the level of modeling available to the customer and what constitutes a deliverable model. Furthermore, the program design team is included in the process to ensure the CAE analyst has the necessary information to build the model. As each new model is built, it is cataloged into a database along with the pertinent information on mass, inertia, and position. This allows other analysts to obtain baseline data for a particular platform in order to quickly and efficiently build additional design iterations of the same vehicle platform. Figure 5 is an example of a full vehicle model delivered to a customer.

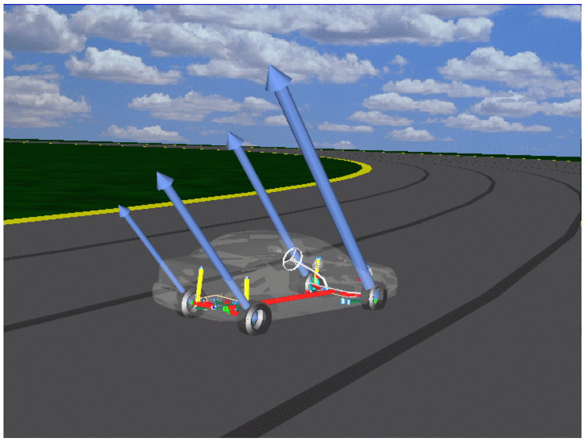


Figure 5

ADAMS/DRIVELINE

With the knowledge gained from providing the initial models to customers, a plan was made to migrate the existing tool into the ADAMS/Pre environment. However, with the decision by MDI to create ADAMS/Driveline, Visteon decided a better alternative would be to embed VADSIM-DYNA into a Visteon specific version of the ADAMS/Driveline tool. Since ADAMS/Driveline is an ADAMS/Car based tool, Visteon has also added a capability to easily export models built with VADSIM-DYNA into a format that is easily used by customers without the ADAMS/Car software. The updating of VADSIM-DYNA to ADAMS/Driveline has been completed and a number of models have been successfully supplied to customers. Figure 6 shows some typical results given to a customer.

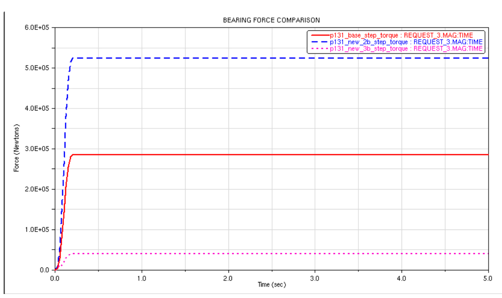


Figure 6

CONCLUSIONS

With its customers placing more of the design and analysis responsibility on its shoulders, Visteon has embarked on a path to accomplish those tasks. In doing so, a method that incorporates best practice modeling techniques, and ensures that each model is created in an efficient and consistent manner. This method is comprised of a modeling tool, VADSIM-DYNA, and a procedure for using the tool. Both the tool and modeling procedure are evolving as the modeling technology improves, and experience reveals better methods of meeting the customers' needs.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Dr. Santosh Neriya for his work developing the equations for calculation of the hypoid gear forces and mesh point. We would also like to thank MDI for their help creating the custom interface. Last but not least, a special thanks goes out to our customers who helped us through the trials and tribulations of proving out VADSIM-DYNA.

REFERENCES

[1] Neriya, S., et al, "Static Hypoid Gear Mesh Forces for the Front and Rear Axles: Magnitude, Direction, Location, and Equilibrium," Proprietary internal Visteon technical paper.