A REVIEW OF MULTIBODY DYNAMIC SIMULATION IN MECHANICAL PRODUCT DEVELOPMENT

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ABSTRACT

This paper deals with multibody dynamic simulation of mechanical systems in the product development process. The approach is to make the process of multibody dynamic simulation more efficient by structuring of simulation models and the method for usage in product development. Clarification of the multibody dynamic simulation methodology has been made in the performed work. The engineering process used to be based nearly exclusively on the experience and intuition of a company's best technical people. But today more and more products are developed in a virtual environment in which a large number – often many thousands – of design alternatives are simulated and evaluated as software prototypes A proposal for performing the multibody dynamics methodology in a distributed and modular way in the product development process is given together with a prototype implementation. The prototype system facilitates the idea of distributing analysis possibilities from simulation experts to engineers, hereby increasing the simulation usage in product development. The purpose is to arrive at a simulation driven design rather than a simulation verified design.

Keywords: Multibody Dynamic Analysis, Product Development, Simulation Process.

I INTRODUCTION

In order to achieve the successful development of products, companies must strive for an understanding of the own company processes, methods and tools used when developing the products.[1] When this fundamental understanding is achieved it is possible to restructure and enhance the different company tasks and perform world-class product development.[2] Product manufacturers often struggle to understand true system performance until very late in the design process. Mechanical, electrical, and other subsystems are validated against their specific requirements within the systems engineering process, but full-system testing and validation comes late, leading to rework and design changes that are riskier and more costly than those made early on. The last decade's rapid development and implementation of computer-based tools have had great impact on the product development processes. Especially, the area of Computer Aided Design (CAD).[3] has changed the best practice of how to develop products. Here, development of computers, productivity and design tools as well as special tools like analysis and simulation software has created a number of new engineering disciplines. Among the tools for design of mechanical systems, computer aided simulation techniques for complex mechanical dynamic systems, multibody dynamics have a large potential in product development. This potential is only partly used today due to, for example, modeling and simulation complexity.[4] In order to make it possible for a design engineer, and not only for a specialist in dynamics, to use multibody dynamic (MBS) simulation methods for development of dynamic systems, the complexity of the procedure for using them must be reduced. This paper deals with simulation of multibody dynamic systems in the product development process. The aim of the work is twofold; to perform advanced dynamic simulations in order to predict the dynamic behavior of the studied systems and at the same time to clarify the methodology and task process of advanced MBS analysis in product development. Clarification of the multibody dynamic simulation Methodology has been made in the performed work. A proposal for performing the multibody dynamics methodology in a distributed and modular way in the product Development process is given together with a prototype implementation. The prototype system facilitates the idea of distributing analysis possibilities from simulation experts to engineers, hereby increasing the usage of simulation in product development. The purpose is to arrive at a simulation driven design rather than a simulation verified design.[5] Product manufacturers often struggle to understand true system performance until very late in the design process. Mechanical, electrical, and other subsystems are validated against their specific requirements within the systems engineering process, but full-system testing and validation comes late, leading to rework and design changes that are riskier and more costly than those made early on. [6]

II KNOWLADGE DOMAINS

During the paper work, some different knowledge domains are introduced. In this chapter an introduction to the main knowledge domains are given.

2.1 Product Development

Product development has been defined by Ulrich & Eppinger as

"*The set of activities beginning with the perception of a market opportunity and ending in the production, sale and delivery of a product"*

In a company, the different phases the product passes during the development are typically described as the product development process. This product development process (PDP) is often specific for the company since the manufactured product highly describes the process. However, at a low level of detail, the process is similar independent of company. There are a variety of methodologies for understanding and enhancing the efficiency of the product development process. These theories mainly consist of literature and studies establishing a view of how to perform good product development and how to structure the company processes. The development tasks should also be carried out in parallel rather than sequential. These overlapping activities are one of the key factors to the increasing information flow between different processes in the development [7][8]. Simultaneous engineering has been defined by Winner, R. I. Penell. [9] as:

"a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements"

2.2 Computer-Aided Simulations

The techniques for modeling and simulation are becoming mature, the industry is getting more eager to implement them. A beneficiary factor here is the implementation of three-dimensional (3D) CAD models into the design stages of product development creating a virtual prototype base for further computational simulations. Presently, CAD is not particularly effective in the initial synthesis of design or in the redesign portion of the design loop [10]; however, it is very useful in providing more efficient ways to help the designer revise the design. A simple sequence of new design commands can cause a wide range of changes throughout the design if the 3D model is parameterized correctly. The rapid development and implementation of new tools allow CAD to be used in a greater part of the development chain. CAD systems are usually not well integrated with current simulation techniques although the simulation techniques are well developed. However, integrated analysis is possible where CAD models can be used for creating Finite Element Models (FEM) for structural analysis, dynamic models for simulation of behavior via MBS or for performing Computational Fluid Dynamics (CFD) simulation.[11][12]

2.3 System Dynamics Ofmulti Body

A *multibody system* (MBS) is a system that consists of solid bodies, or *links*, that are connected to each other by *joints* that restrict their relative motion. The study of MBS is the analysis of how mechanism systems move under the influence of forces, also known as *forward* dynamics. A study of the inverse problem, i.e. what forces are necessary to make the mechanical system move in a specific manner is known as *Inverse* dynamics. This is particularly important in some branches of robotics where precise motion control is needed. When dealing with MBS there is a need for understanding of both the theory behind it as well as the actual methods and tools for analyzing complex mechanical systems. [6]

2.4 Product Structuring

The area of product structuring when developing products is also of interest today. This since industry has to arrive at a product design that has been systematically optimized in order to meet customer needs and still satisfy a large market variety.

This applies to products for mass customization but also to products with lower volumes. One proposed method for dealing with the above issues is to use a modular approach in the development of the products. This since the modular approach with building blocks, modules, claims to give reduced lead-time, improved quality, high flexibility as well as retaining low costs. By using work made in this area and apply it to the area of simulation, modeling benefits can be achieved since simulation models can be reused. Comprehensive work in this area is performed by. Business and technical aspects in product modularization are topics discussed by Blacken felt. Structuring products into modules with the help of the Modular Function Deployment, MFD, method is described by Erickson. Sellgren introduces a modular methodology to product data management, CAD and finite element modeling.[13][14][15][16]

2.5 Application Area

The work performed during the development of this paper spans over different product applications. Efforts in simulation have been made within pantograph dynamics, hydraulic rotators, combustion engines, variable valve techniques, automotive dynamics and automotive vehicle suspension dynamics, according to examples in Figure 1.

Figure.1.MBS simulation model of vehicle suspension and CAD model of hydraulic rotator.

The area for these applications is however all within vehicle system dynamics. To enlighten the reader of the application example used in a major part of the appended papers. [17]

III MULTI BODY DYNAMICS IN THE PRODUCT DEVELOPMENT PROCESS

Traditionally, mainly large companies with special analysis departments have used simulation in their development of products. These simulation verified products are typically of very high technical level. Due to the rapid development of digital computers, and since the techniques for modeling and simulation are becoming mature, a broader spectra of industrial companies are eager to use and implement.

3.1 Development Ofmechanical System

The development of a product is often an iterative process, both the whole process as well as underlying sub-processes. There are different aspects on MBS simulation when developing a product regarding if it is a new mechanical system, *original design*, or if it is a redesign of an existing product, *continuous design*.

3.2 Simmulation Process In Product Development

A possible iterative product development process is shown in Figure 2. The figure shows some generic phases in the development of an original or redesigned product. Although there is a start and an end in the figure it is to be seen as a snapshot of an iterative and continuously evolving development process where the product support phase acts as input for the development of a new or redesigned product. The smaller upper and lower arrows indicate some possible generic simulation processes during the development of a product. These simulation processes could be Computational Fluid Dynamics (CFD), for establishing a view of the air resistance of a car body, Finite Element Method (FEM), for calculation of deformation zones of a car, or MBS analysis for evaluating ride comfort in a vehicle, among others.

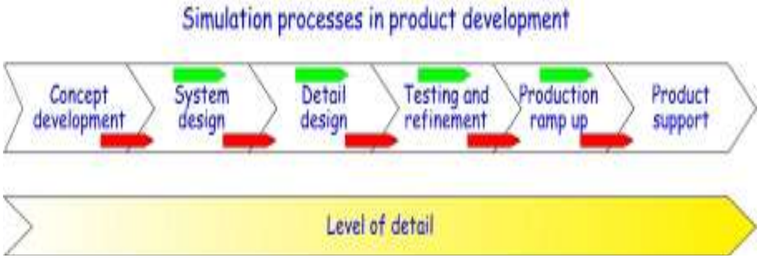

Figure.2. Simulation processes in product development. Upper and lower arrows represent generic simulation processes.

3.3 Multi Body Dynamics Simm Ulation Methedology

During the lifecycle of a product the same questions arise several times, see the MBS methodology in Figure 3, where a typical methodology for multibody dynamic analysis is extracted from the development process. In the early stages fast modeling and comparative analyses are crucial in order to evaluate different concepts. The accessible information is often insufficient and unstructured a the time frame for decisions limited. At later stages the product is defined with higher level of detail, and accurate analyses are increasingly important. In these phases, better information. is often available in form of experimental data from prototype testing and better product knowledge. This makes it possible to verify the developed simulation models. After this verification, the simulation model can be used to predict, if used in a correct way, the behavior in other situations than the experimentally tested ones.

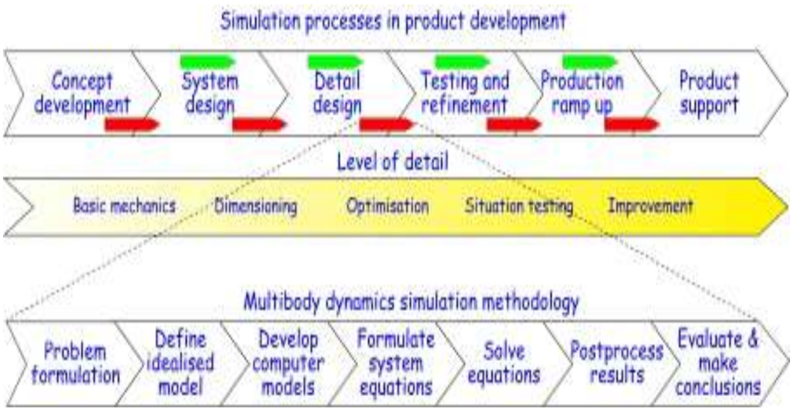

Figure.3.Multibody dynamic simulation in different parts of the development process.

3.4 Mbs Process Reflection

The above-described MBS process has its origin in literature combined with findings from the MBS modeling performed in the thesis work. It can work as a guide for planning and performing MBS simulation in product development. The steps of equation generation and solving in the MBS process are often computerized while the other steps still require human effort. Naturally, this process is applied differently depending on company and personnel situation. Documentation when performing the steps above is important, both in terms of creating the opportunity to reproduce the specific results of each step and in terms of having the process documented if redesign is necessary.

3.5 Moduler Multi Body Dynamics Modeling Approach

Generally, simulation departments have simulation experts that build, simulate and analyses results of a given task received from, for example, the design department. In this way the special domain knowledge of the design department is lost since they do not perform simulations themselves. If the tools were handled in such a way that the simulation department developed a parameterized simulation model of, for example a pantograph suspension, and the suspension department designers were given this model, then they could combine their domain specific knowledge with the simulated behavior and develop a good product. This approach would make parallel development of subsystem models, or simulation modules, possible. If the different developed subsystems then were integrated into a common simulation environment where total system simulation was performed it would be possible for the subsystem designer to see the impact of his development to the total system behavior without having the knowledge to build the total system. Simulation models developed when working with pantograph/catenary systems might look like Figure 4.

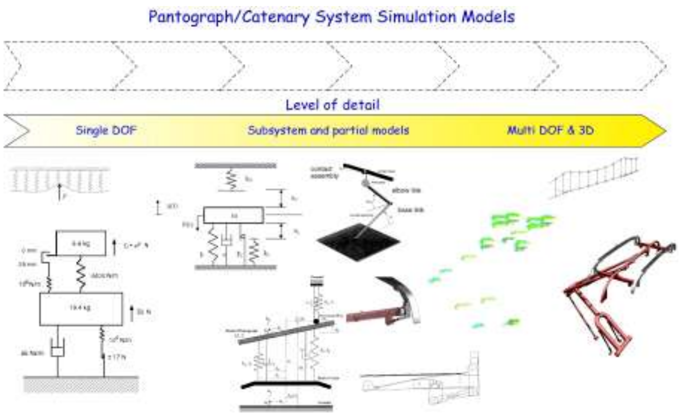

Figure.4. Simulation models developed for pantograph/catenary system.

3.6 Prototype System

Based on the proposed modular MBS approach and the need of integration of multi domain simulation, a prototype system where the presented ideas are implemented has been developed. The idea is that the system shall facilitate ideas regarding how to use the MBS methodology in product development. The application is within vehicle dynamics, a front suspension, and the possibility for an engineer, and not only a simulation expert, to perform MBS analysis is created.

In the work a collaborative MBS simulation environment is proposed and developed. Based on the belief that events can be correctly understood only if observed in their natural environment, ethnographic methods have been used in order to understand and describe the engineering analysis work practice that the tool is supposed to support. The simulation packages ADAMS and MATLAB are used together with database and web technologies, according to Figure 5. [6][18][19].

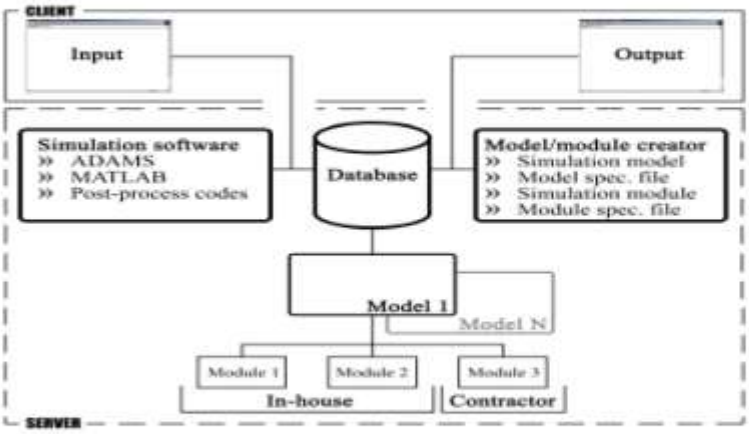

Figure.5. Software tool integration in prototype system

IV CONCLUTION

This work describes simulation of multibody dynamic systems in the product development process. The papers presented describe how computer tools are used in product development and how multibody dynamic analysis can be applied to applications within vehicle dynamics. The approach has been .to identify the process of multibody dynamics simulation and make it more efficient by structuring of the simulation, simulation models and their usage. Previous work has concentrated on developing faster calculation methods and more specialized simulation software. Efforts have been made to clarify how computer tools and multibody dynamic analysis methods are used in product development in industry today. The different stages of the MBS process are discussed and insight into non-linear analysis is given. Insight into the knowledge domains of product development and multibody

Dynamic is given together with an introduction to the area of distributed simulation and modularization techniques. The performed work is to be seen as cross-functional work in order to bring different domains together for the sake of a better total product development.

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