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Simulation Life Cycle Management as Tool to Enhance Product Development and its Decision-Making Process for Powertrain Applications

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Abstract: Product development is becoming more complex. It involves not only system simulation requirements, but also the need to manage and share huge amounts of engineering information that is housed throughout the world. It quickly becomes complex when getting into detailed system simulation for powertrain applications such as sealing products.

Computer Aided Engineering (CAE) has played a major role in development, design, and performance optimization for those applications for a long time. Due to the complexity of the current simulation environment and the need to expand simulation to the whole engineering process, including manufacturing, new analytical tools are required to support development, virtual testing, and decision-making. The sheer complexity requires a new approach to the engineering process. The PLM (Product Life Cycle Management) as we know it will look completely different in the future. We believe that in a simulation-driven engineering business, SLM (Simulation Life Cycle Management) plays a central role.

In this paper we use the processes for cylinder head gaskets (CHG) and material data input management as examples of how SIMULIA SLM provides us with more consistency, accuracy and faster turnaround times through easier, coordinated information flow and access. Using 3D-Live capabilities enables us to provide an easy-to-use environment to make simulation information available to non-CAE users, like engineering management, to support decision-making.

Keywords: SIMULIA SLM, CAE, Sealing, Powertrain, PLM, Virtual Testing, 3D-Live, Engineering Process, CHG, Data Management, HPC

1. Introduction

1.1. Product Development and its Complexity in the Overall Context of Engineering

Product development is a complex thing. Regardless of the type of product, the major steps in product development are:

- Initial idea
- Drawing / concept
- Prototype
- Testing / validation
- Turn over to manufacturing.

Whether the product is automotive, pharmaceutical, industrial, or something else, behind each of the above mentioned steps lay different tasks with additional tasks needed to move between the different steps. In addition to having those steps in common, they all require that data / information between the different tasks be communicated and stored. In this paper we want to focus on engineering products for powertrain applications, with focus on sealing applications. In particular, we will mention the cylinder head gasket (CHG) and how Simulation Life Cycle Management (SLM) can be applied. Figure 1 shows an overview of sealing products for powertrain applications.

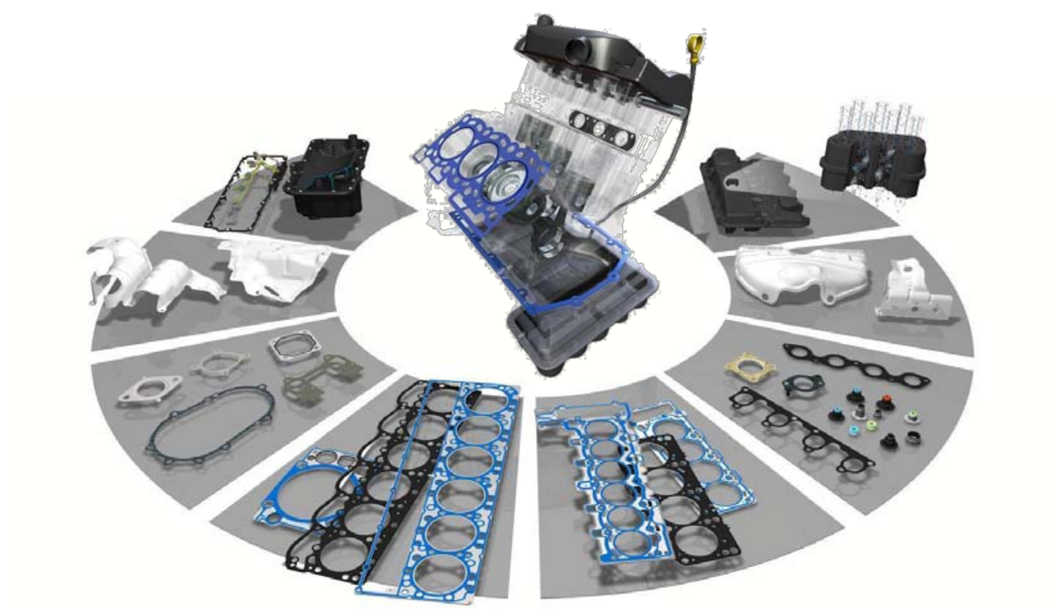

Figure 1: Sealing Products for Powertrain Applications

Over the years, the complexity in product development of CHG has increased drastically. What started out as "something" simply having sufficient sealing function placed between the cylinder head and cylinder block to guarantee the engine function, has become a component having a huge influence not only on engine performance, but also emissions, fuel and oil consumption, NVH, and more. In addition, regulatory requirements have become more stringent, which makes sign-off more complicated as well.

While the complexity in CHG development was increasing over the years, a new detailed support structure that was highly engineered and specialized became essential. Many new testing capabilities were developed in order to be able to test and validate the product before providing it to the customer. Some of those tests are:

- Bench tests, such as:
  - Sealability
  - Fatigue
  - Metallurgical examinations
  - Material resistance to the different fluids in a powertrain environment
  - Load / deformation behavior
  - Powertrain component distortion
- Dynamometer testing
- Field testing.

The increase in testing that became required in order to develop a CHG resulted in an increase in the time it took to go from initial idea to final product. At the same time, costs were increasing at an alarming pace. Even though the introduction of more sophisticated bench testing allowed design screening of CHG before dyno testing, to some extent it was not unheard of that there were 10, 20, or even more design iterations during a CHG development. At that point, this after-the-fact development approach was more than ripe for improvement. This was the time when Computer Aided Engineering (CAE) started to find its way into CHG development. Only this technology allows optimization of the CHG before an actual prototype is cut. This is the only way to reduce development time and costs while guaranteeing high performance and quality of the product.

In addition to advanced testing requirements, stronger requirements regarding emission, NVH, and fuel consumption required new technology in exhaust and after-treatment systems as well as injection and control systems. These additional components not only act or function on their own, but also influence and interact with each other. At this point, a simple component-based approach in product development of sealing products started to be insufficient. What was needed in order to satisfy the development needs is a system approach. Figure 2 is an example of how different sealing applications of a powertrain can be put together into a system. This shows not only that the development went into much more detail, but also exponentially increased the amount of data that was generated.

In recent years, additional levels of complexity in product development were introduced with the extreme globalization of our industry:

- The requirement to be present and support our customers in all regions of the world the same way
- The need to be even faster in time-to-market by utilizing a 24x7 approach
- An even larger pressure on keeping costs under control in this complex environment forcing utilization of lower cost alternatives in different regions of the world.

All of the above factors require tremendous effort in effective data management, communication, and decision-making in order to make product development successful.

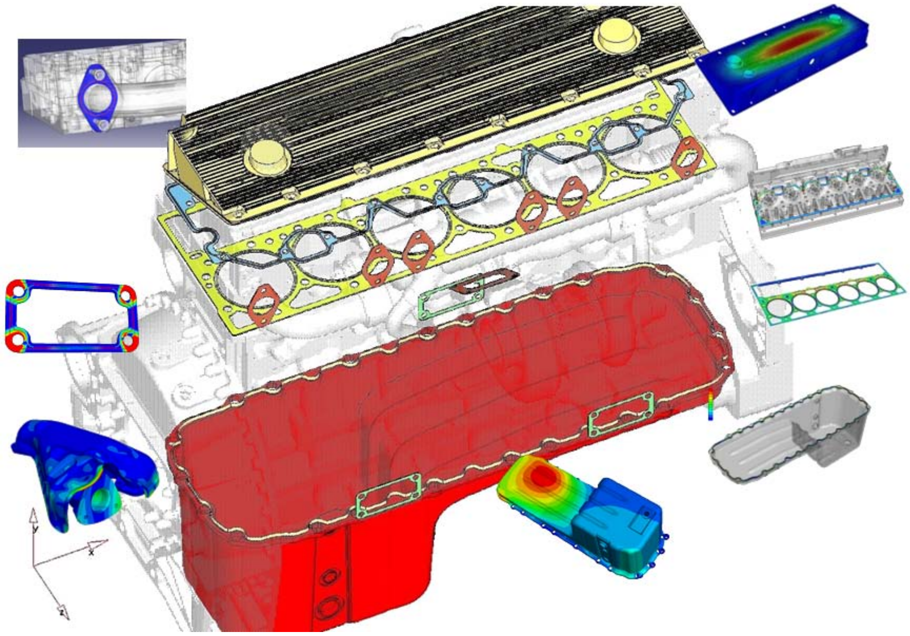

Figure 2: Example of a Sealing System for Powertrain Applications

1.2. Role of CAE in Product Engineering

CAE plays an important role in product engineering now more than ever. With shorter development cycles and time-to-market, CAE is and will be a major contributor to the success of a company. With most companies having “First Time Right” design initiatives, CAE has gone from a “nice-to-have” feature to an essential tool in the product development process. Cost reduction initiatives to cut down on prototype and testing costs have also helped to boost CAE as an essential tool for product development.

With the advances in the computer industry and CAE solver technologies, engineers have been able to conquer more advanced problems in shorter time with a focus more toward system simulation and how one component affects another component. This is all the more important in powertrain analysis due to the presence of thermal and mechanical stresses, components packaged together more closely, as well as a variety of materials being used to reduce weight. Typically for cylinder head gasket analyses, only the cylinder head and block models have been used to analyze the sealing pressure on the gasket. In recent times, more components such as valve seats, injectors, exhaust and intake manifolds, and turbochargers have been included to give a more comprehensive understanding of the system. As the packaging requirements and weight reduction are becoming more and more critical, the effect of heat shields on the thermal stresses has to be considered also. Figure 3 illustrates a rough overview of the CAE approach for multi-layer steel (MLS) CHG covering the main stages from manufacturing to system simulation to correlation and validation.

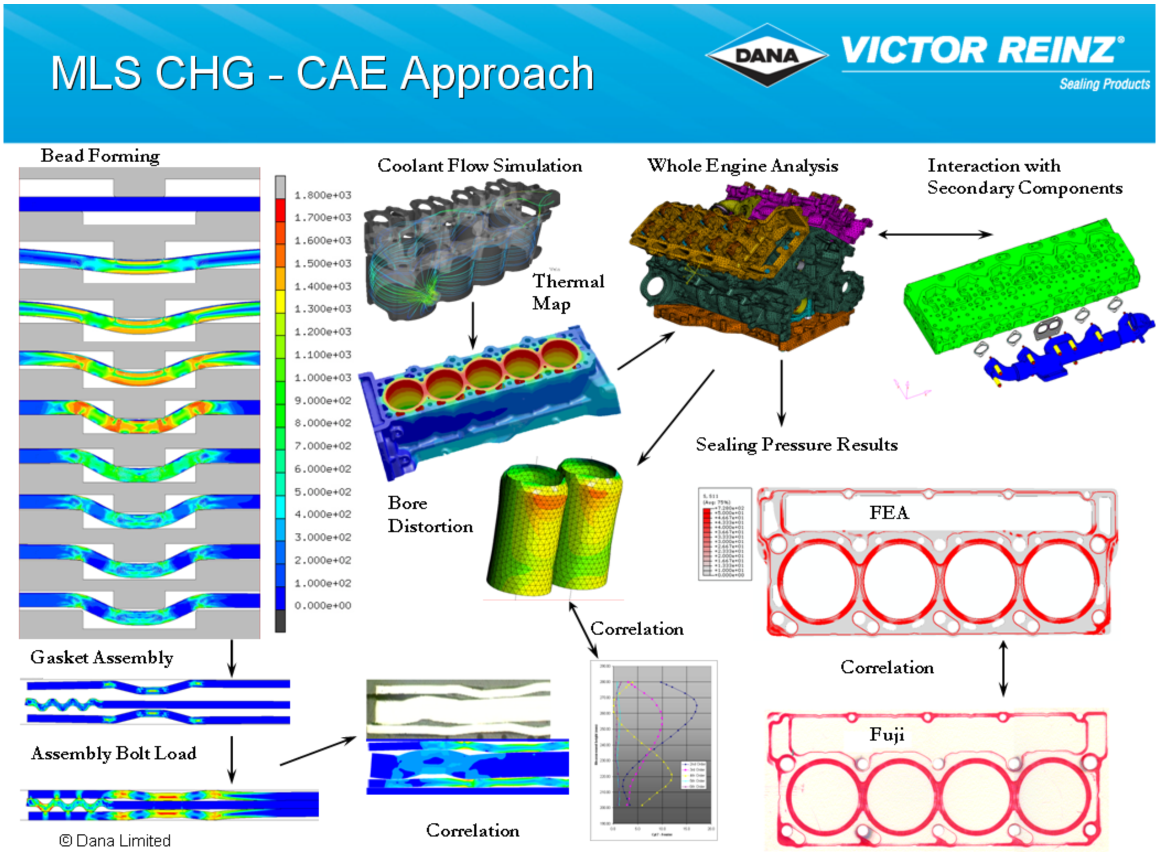

Figure 3: CAE Approach for MLS CHG

Previously, finite element engineers and CFD engineers used to work in separate environments, with certain scripts being used to transfer the results from one code to the other. This was a time consuming process, which quite often resulted in loss of accuracy and increased solution time. With the introduction of fluid-structure interaction (FSI) coupling solution into the mainstream market a few years ago, some of these problems could be solved directly using code coupling, without loss of data due to interpolation. Also, several new varieties of problems which represent more realistic scenarios can now be solved. This process has helped in creating the thermal stress analysis based on exhaust gas flow easier to analyze in a more time effective manner.

Similar advancements in technologies such as iterative solvers and parallel processing have resulted in analyses that used to take weeks to complete finishing in only a few hours. This has allowed the analyst to increase the model complexity and also add more components without sacrificing efficiency or cost.

In the future, these technologies will improve further, and new advancements in the solver technologies will lead to entire system simulation and possibly a "virtual" dynamometer environment which will allow engineers to check the performance of the engine and its different components without having to build any prototype parts. Final validation of the product will always remain.

The cylinder head gasket analysis process encompasses various analysis types ranging from manufacturing processes to thermal profile generation, combustion modeling, sealing functionality, and durability of the part. Because of the comprehensive nature of this process and the various design changes that involve data retention, record keeping is all the more essential for this flow process. Thus, incorporating this process flow into SLM provides standardization, transparency, consistency in simulation, as well as additional efficiency improvement. At the same time, it provides an efficient tool for managing this huge amount of information without any loss or misplacement.

2. Simulation Life Cycle Management as Tool to Enhance Product Development and its Decision-Making Process for Powertrain Applications

2.1. What is SLM?

Management of large amounts of data is never easy especially when talking about the use of CAE as an up-front predicting tool. While simulation technology is constantly evolving to meet the demands of designers and engineers, there remains a wide disparity in the effectiveness of simulations to impact product / process design decisions. This disparity exists at multiple levels: across industry segments, across companies within an industry segment, across simulation disciplines (structural, fluid, chemical, etc.), within a company, and even across individual methodologies within a simulation discipline. The quest to markedly improve the efficiency and effectiveness of simulation remains a challenging but fundamental goal for many companies. [**1**]

The efficiency and effectiveness of simulation within a workgroup or enterprise is driven by several factors, including:

- Competency of the simulation technology and the people utilizing it
- Integration, adoption, and acceptance within standard business processes
- Capture, management, and reuse of the resulting intellectual property.

A well-known data management tool in the industry is Product Lifecycle Management (PLM). PLM systems have evolved rapidly in recent years and now provide collaborative virtual PLM of complex product, process, and resource information - from marketing and design to manufacturing and maintenance. The requirements of simulation technology, methods, data, and processes are in many ways more demanding than those associated with PLM, including:

- Data model
- Performance
- Context.

For example, the data generated through simulation can be divided into 3 main categories [**2**]:

- Data directly supporting product / process IP (intellectual property)
- Data supporting simulation IP
- Un-retained data.

The emerging attention focused on improving simulation effectiveness within PLM and scientific environments is referred to as Simulation Lifecycle Management (SLM) [**1**]. This covers the different disciplines involved in the thermal management / sealing system approach as described above.

The degree of integration across the simulation and product / process worlds will vary with organizational type and structure and is driven by a number of factors, but there are several critical principles that must be followed to achieve the full benefits SLM can deliver. At its core, a SLM solution must have been designed from the outset to possess the appropriate architecture to satisfy the integration, deployment, and maintenance demands of a broad and constantly changing set of information technology (IT) environments. Four functional elements that an effective solution must provide are [**2**]:

- Built-in collaboration
- Simulation data management

- Process automation, integration, and optimization
- Decision support.

The aspects of sealing systems for powertrain applications described above and its detailed complexity epitomizes the need for a SLM system. Collaborating with SIMULIA on developing and implementing SLM and developing specific features for our business needs provides us with the necessary tools to guarantee a functional system approach for the future. This is not only from a simulation perspective, but also from a management perspective. By studying the SLM architecture and the needs of our approach, we can ensure from the outset that all our structural, data, and documentation requirements are met both now and in the future.

2.2. Overview of SLM for Powertrain Applications

The introduction of SLM for the CHG analysis flow process begins with an initial assessment of the process. The goal of such an assessment is to look at the areas in the process which, when implemented through SLM, will provide productivity improvements, reduction in duplication of work, consistency, reuse of data, and also improvement in accountability. All of the parties involved with the design process need to be involved in this assessment process to provide a comprehensive understanding of the design analysis flow from a design concept stage to the prototype stage:

- CAE analysts
- IT
- Development engineering
- Applications engineering
- Sales
- Engineering management.

During the assessment for the CHG analysis process flow, several opportunities for automation to streamline the process tasks were reviewed based on the maturity of the sub-tasks in the process flow and ease of automating those tasks. Studying each task in the process flow in this way results in creating a less complex simulation template and also helps in identifying and defining the different attributes that may be used in data searches to find simulation results for a particular design instance.

Since there are always different instances of product development from the prototype phase to the full production phase, the variability of the gasket properties needs to be monitored, as well as how that variation may cause a change in gasket performance. This process is usually studied in CAE to implement any minor changes that may be needed in the production environment. Therefore, a material data generation flow process based on the part level is tied into the analysis flow process, as it is essential to provide a clear connection to the data that was used for the analysis. Ideally, in the product development cycle, data sets from test coupons are used for the initial simulations. Once prototype samples are made, those samples have to be checked against the test coupons for consistency in the material data. If the data does not match, the simulations must be repeated to show the effect of the change in data. The update in material properties needs to be highlighted to understand which steps in the process need to be updated, or in other words, which results are out-of-date. SLM implementation results in an effective way to manage this entire product development cycle.

2.3. Implementation of SLM for Powertrain Applications

SLM, as used in the product development process described here, is built on top of the V6 PLM platform as illustrated in Figure 4. This environment is one PLM environment for Dassault Systèmes and non-Dassault Systèmes applications that provides the specific capabilities that are needed across all industries to support an integrated environment. At the bottom of the chart is the V6 PLM enterprise foundation, which has an open architecture and embraces the service oriented architecture (SOA) standards. This single foundation provides a unified view and access to all information, whether this information is inside or outside Dassault Systèmes applications. For instance, in the orange databases could be other product management (PM) sources, enterprise resource planning (ERP) tools, or even unstructured data sources. On the SOA foundation is built native CATIA, DELMIA, SIMULIA and ENOVIA applications. This single foundation spans all engineering disciplines and business users to provide a paradigm that is common to all of the applications.

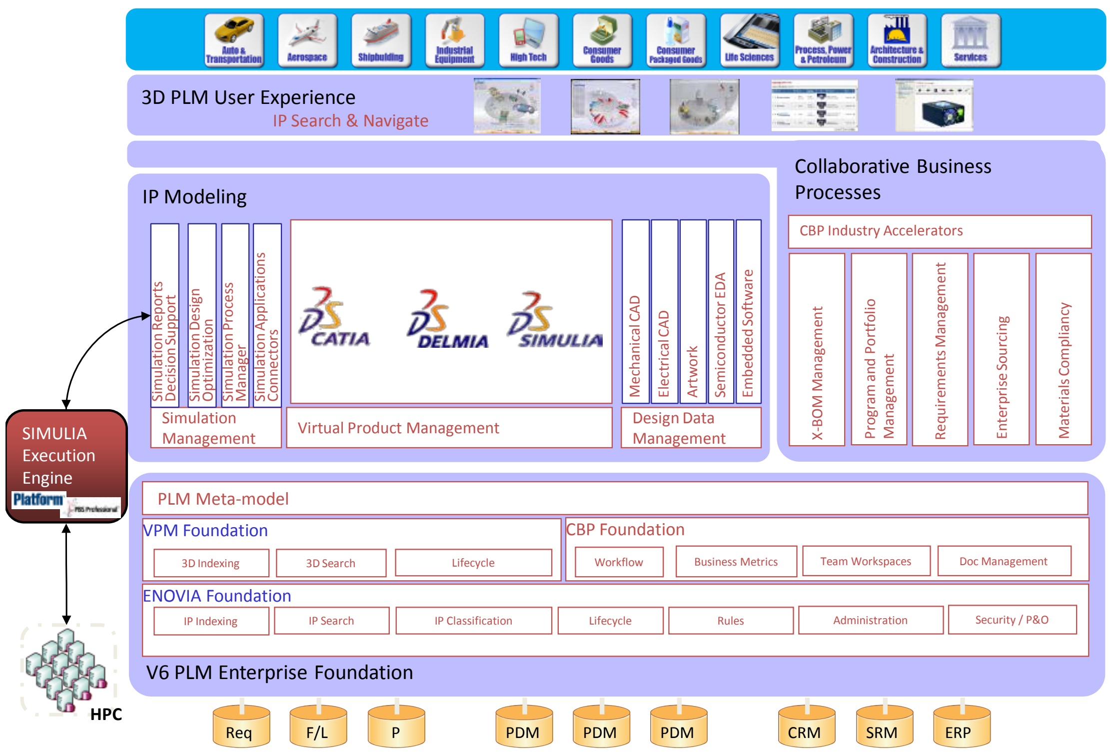

Figure 4: V6 SLM Platform

Next is the collaborative business process layer. It extends from left to right and unifies all engineering disciplines which are on the left hand side and all PLM enterprise processes on the right hand side. The V6 PLM platforms support IP modeling in a single environment for all authoring applications and simulation applications, whether they are Dassault Systèmes applications like CATIA, DELMIA and SIMULIA, or non-Dassault Systèmes applications. The simulation data management needs to manage very heterogonous applications and data, and is optimized so that collaboration and data management can be done from anywhere using only a web connection regardless of the authoring applications. This results in a lightweight and flexible deployment of SLM.

Deploying a SLM system requires different servers each with a specific function that can each be located anywhere around the world. In a SLM system, there are SLM application servers which run the applications being used, file collaboration servers (FCS) which are used for storage, as well as local workstations that run the system and interface with the other servers. The applications and file storage servers take on a modular approach and are separate entities so that the different servers can be housed at any location around the world and all SLM users can have access to all of the components of the system. SLM integrates all of the different sources of information and brings them into a unified structure that can be accessed by users anywhere.

When a user accesses the SLM system on a local workstation, the process flow illustrated in Figure 5 begins. First, an applet starts on the application server. SLM exports the needed files for the activity from the FCS to a scratch directory on the user's local workstation. The user then uses the files for the activity on the local workstation. Upon completion of the SLM activity, the files are then imported from the local workstation back to the FCS. SLM then deletes the scratch directory on the local workstation. Having the system set up in this way allows files to be stored on servers that can be set up in different locations, while also allowing users from anywhere around the world to have complete access to the same information structure. With the increasing globalization of engineering and analysis, it is important for users to have access to the same information regardless of their physical location.

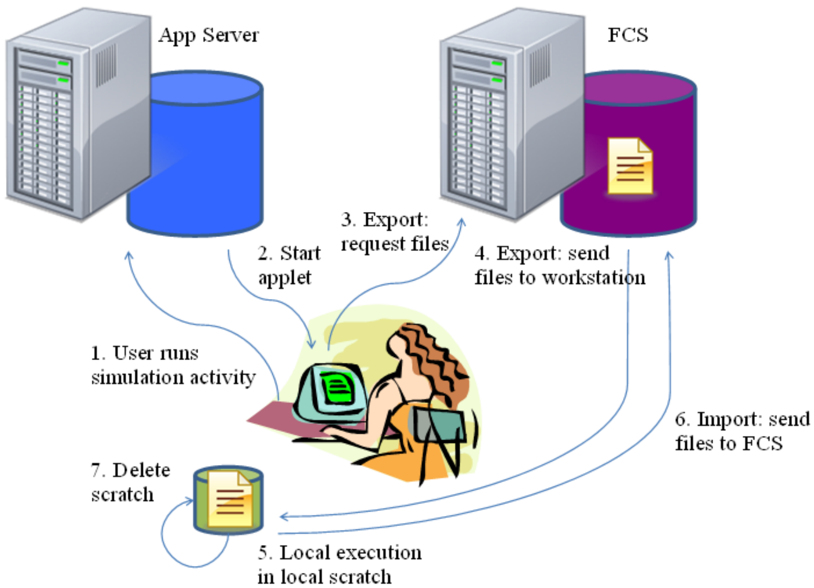

Figure 5: SLM System Architecture

Since engineering design and analysis has become a global process, users from different locations all over the world need to have a unified approach to engineering strategy. In a SLM system, workflows are implemented through the use of user-defined standardized templates. Each template is prepared for a specific workflow and the same workflow is used by all users of the template in SLM. In a typical sealing system as illustrated in Figure 2, there are multiple types of sealing products and therefore multiple types of simulations that need to be performed on the components that make up the system. The different steps in each analysis that need to be performed are:

- Meshing of CAD models
- Input file generation
- Material property generation
- Assembly of system
- FEA analysis run
- Post-processing
- Report generation
- Results review and decision-making.

SLM can streamline each of these tasks into templates that standardize the process flow for all users. By using templates to define the simulation process workflow, all users follow the same standardized process.

Users will be less likely to miss steps in the analysis and each analysis can easily be passed to different users at different locations without the need to explain which tasks have been completed, thereby reducing the time it takes to complete an analysis by facilitating a 24x7 approach to engineering. By using SLM to launch each activity in the simulation process, all users are assured to be using the same software and the same standards, so the location of an individual user doesn't matter. Each time there is an update to software or a process flow, the template can be updated in a central location and all users can be automatically upgraded simultaneously to ensure that all users remain consistent with their work.

In addition to standardizing the engineering process flow, using SLM also standardizes file sharing and storage architecture. Defined within the SLM system are import rules and export rules that define which files are saved and which files are deleted after each simulation activity is completed. Often times in an analysis, there are several iterations of files. Additionally, when different users are working on a simulation, duplicate files are often created that can drastically increase the storage space required. With SLM, no duplicate files are created and a standardized naming structure can be used so the large amount of data files that are generated can be easily found for future work regardless of where the file originated.

With the enormous amount of data generated in system simulations, SLM is an effective way to manage the data that is received and generated. One of the reasons so much data is generated is due to the number of design iterations that occur during a typical CHG development process. Typical activities in a CHG development process from a CAE perspective contain the following:

- Import of the different hardware components as CAD files, including:
    - Cylinder Head
    - Cylinder Block
    - Bolts
- Import of the initial CHG model
- Generation of the FEA models
- Import of the material data
- Setup of the input decks
- Simulation (this might include a possible restart analysis)
- Post-processing
- Report generation
- Finalizing simulation project.

To optimize a sealing system effectively, several design changes are often made to each component during the engineering process. Each design change requires a new simulation, thereby generating a new set of data. With so many design revisions, it can become a very complex task to keep track of the different revisions of each component that is used in a particular simulation. SLM uses impact graphs to easily illustrate which version of a particular component is used in a simulation, as well as which simulation activities need to be performed when a design revision to a particular component occurs. The impact graph visually illustrates which versions of the various components of a simulation were used in the analysis and which output database was post-processed to create the final report. When a particular component is updated to a new revision, the impact graph clearly shows which simulation activities that change impacts. The SLM user immediately knows which tasks in the workflow need to be carried out again to accommodate the design change. The impact graph is also useful when tracing a file's origin back to its original CAD geometry. Of course, the CHG development process mentioned above consists of more steps than could be shown here. Those steps contain even more details to ensure consistency, quality, flexibility, and efficiency in the CAE process. For example, Figure 6 illustrates an impact graph for part of the CAD import and meshing activities for the CHG application. These activities can be done simultaneously.

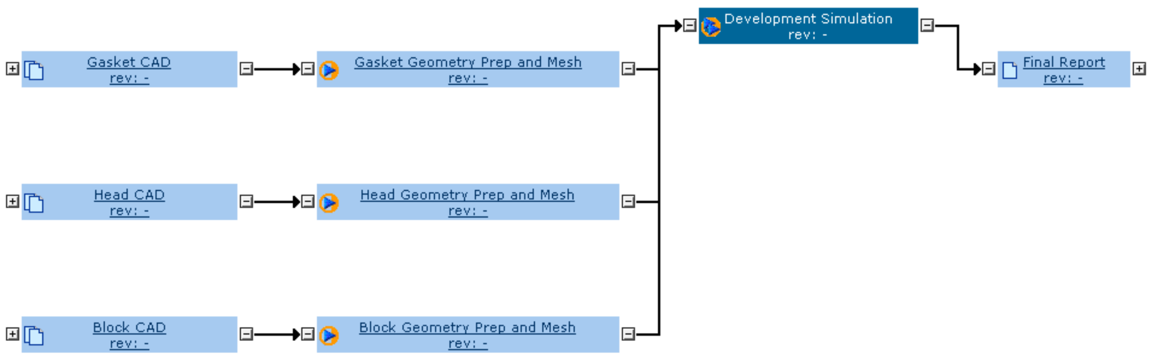

Figure 6: Impact Graph

By using the impact graph, if one user updates a particular file and then passes the analysis to another user, the user immediately knows which activities to carry out. The impact graph visually ensures that all users are working with the latest available information and data, thereby eliminating the possibility of an analysis report containing results for an out-dated component. Additionally, there are no check-out or check-in activities, which can slow down such simulation activities drastically. SLM therefore results in effective management and progression of the entire up-to-date lifecycle of a simulation. Each stage of a simulation process can be tracked by observing the simulation lifecycle, which is illustrated in Figure 7.

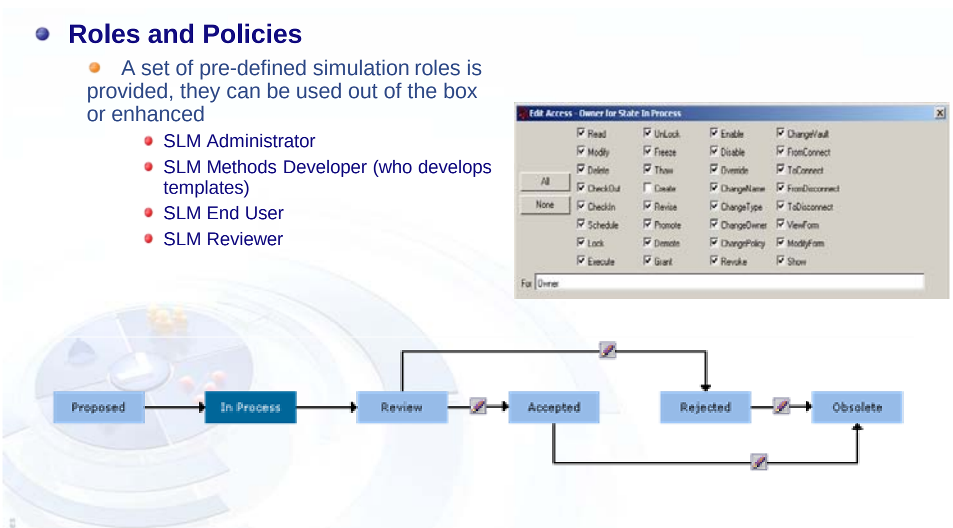

Figure 7: Simulation Lifecycle

The simulation lifecycle involves different user levels depending on the job function of the user. The different user levels can be divided into:

- Method developers
- IT
- General users
- Power users
- Decision makers.

Based on the user's level of SLM usage, each user requires different access rights:

- Admin rights for full control: usually reserved for method developers and IT support
- General read / write access without access to system information of any kind
- Read / viewing access.

SLM provides a standard set of simulation roles that can be assigned to the users. These roles can be adjusted and enhanced as required. SLM uses the combination of roles and lifecycles to track the maturity of a simulation through the analysis process development. At certain stages in the lifecycles, only certain operations are allowed by certain roles. The ability to customize the out of the box roles and lifecycles provides significant flexibility in controlling access to data and allows for only released data to be seen by the final consumers of the simulation data. Other users besides CAE analysts therefore become involved in the decision-making process. Tools such as 3D-Live can display the results in a simplified form so that non-FEA users, such as managers and applications engineers, can review the simulation results quickly and make decisions based on the results.

There clearly exists a wide range of users with different expertise that need access to the highly sophisticated SLM system. In order to be able to deploy such a complex system throughout an organization on a global basis, two things are essential:

- A bottom-up approach for implementation
- Ease-of-use.

A bottom-up approach ensures a full buy-in of the future user community at the same time, while allowing the functionality of the system to be pushed to the limit. The latter is especially important from a cost / performance perspective.

In order to fully utilize the performance of the complex system across a wide range of users in different disciplines, the system needs to be easily learnable, meaning that it must be intuitive. The 3D-Live technology is the key technology to ensure that the system is visual-driven. An example of a 3D-Live environment for powertrain applications is shown in Figure 8.

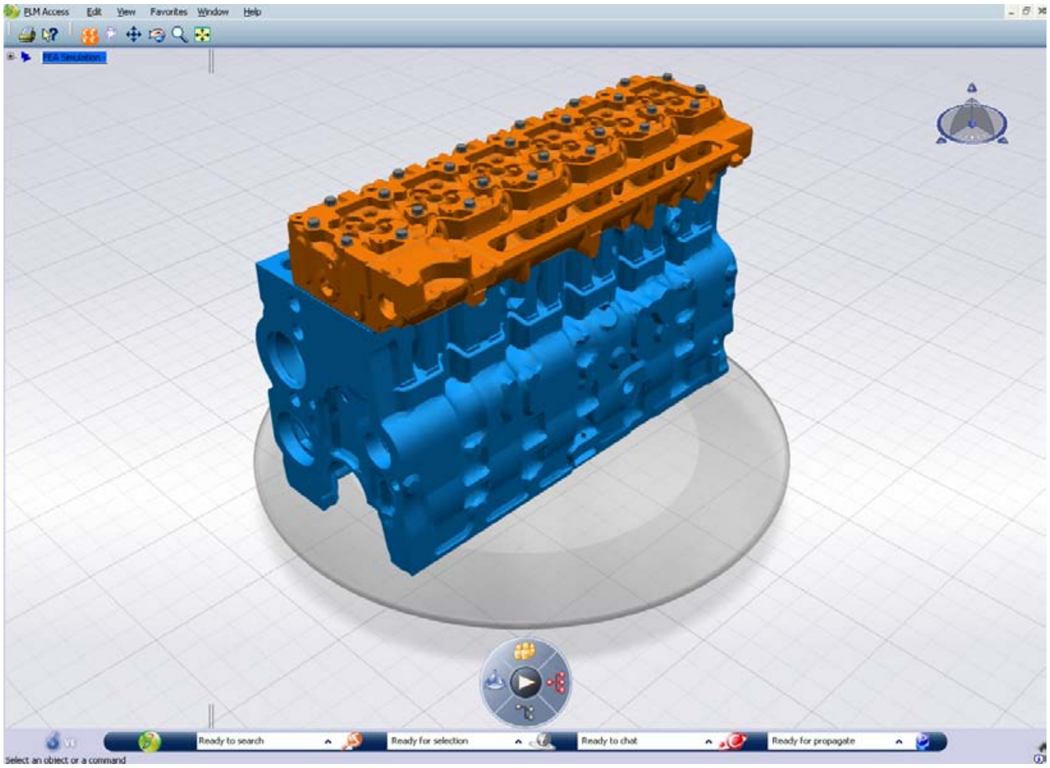

Figure 8: 3D-Live Viewing Environment - Powertrain Application

The 3D-Live environment consists of data and images organized according to each activity in the SLM process workflow. An end-user of 3D-Live searches for a simulation based on search parameters such as part number, customer, simulation name, etc. 3D-Live opens the process from the top level as shown in Figure 8. Expanding the process results in the turntable view illustrated in Figure 9.

The 3D-Live turntable contains results and input data related to each activity in the SLM process workflow. End users of 3D-Live that do not necessarily have FEA experience can easily rotate the display to navigate through the entire simulation process. The user can view simulation input data such as material properties and hardware models used in the analysis as well as the analysis report and other simulation results by expanding any of the activities on the turntable. Figure 10 illustrates the expansion of the assembled model, thereby allowing the user to see each component used in the analysis in a simple way.

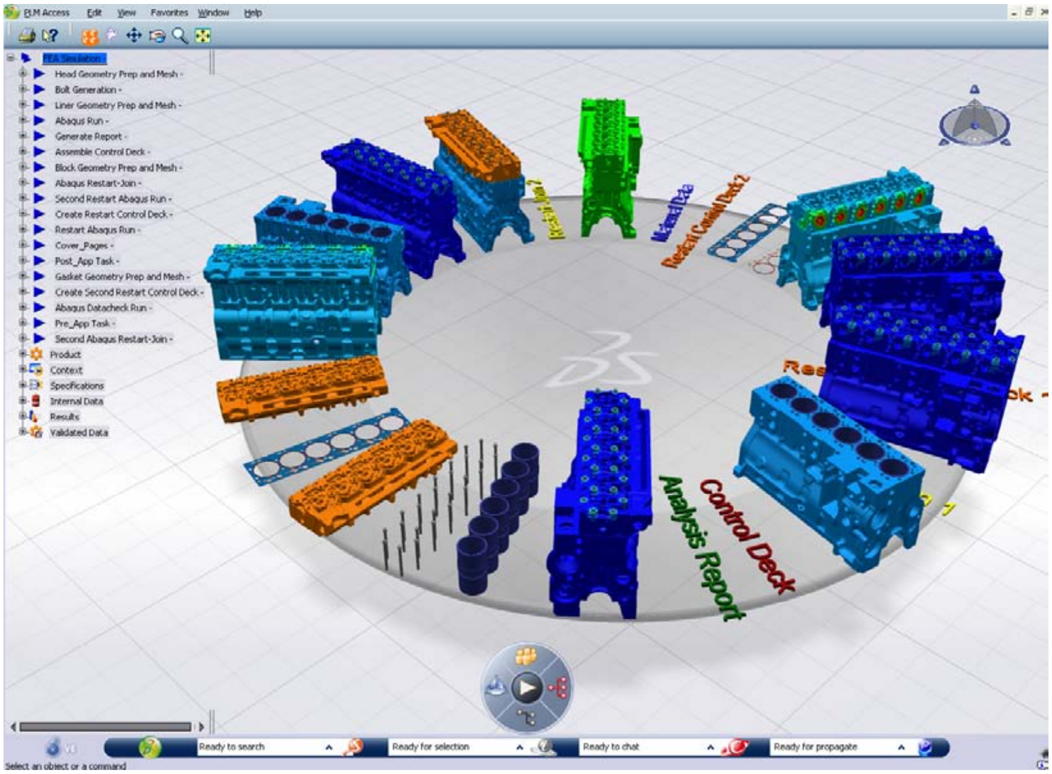

Figure 9: 3D-Live Turntable View - CHG Project

Using SLM tools such as 3D-Live integrates all users such as applications and sales engineers, lab technicians, CAE analysts, and managers into one unified system for data sharing and collaboration as well as results viewing.

In addition to the 3D-Live environment for viewing simulation results, with the globalization of the industry and the increasing use of 24x7 engineering in different regions of the world, there also exists the need to prepare reports and present results to customers all over the world in the same format. SLM allows the automation of several pre-processing and post-processing tasks in order to facilitate a standard procedure for pre-processing and post-processing activities. The integration of scripts within SLM also allows repetitive time-consuming tasks, such as report generation, to be completed very quickly and efficiently. The utilization of common scripts allows standardized result reports to be generated with a few clicks of the mouse. A common analysis report for a CHG is shown in Figure 11.

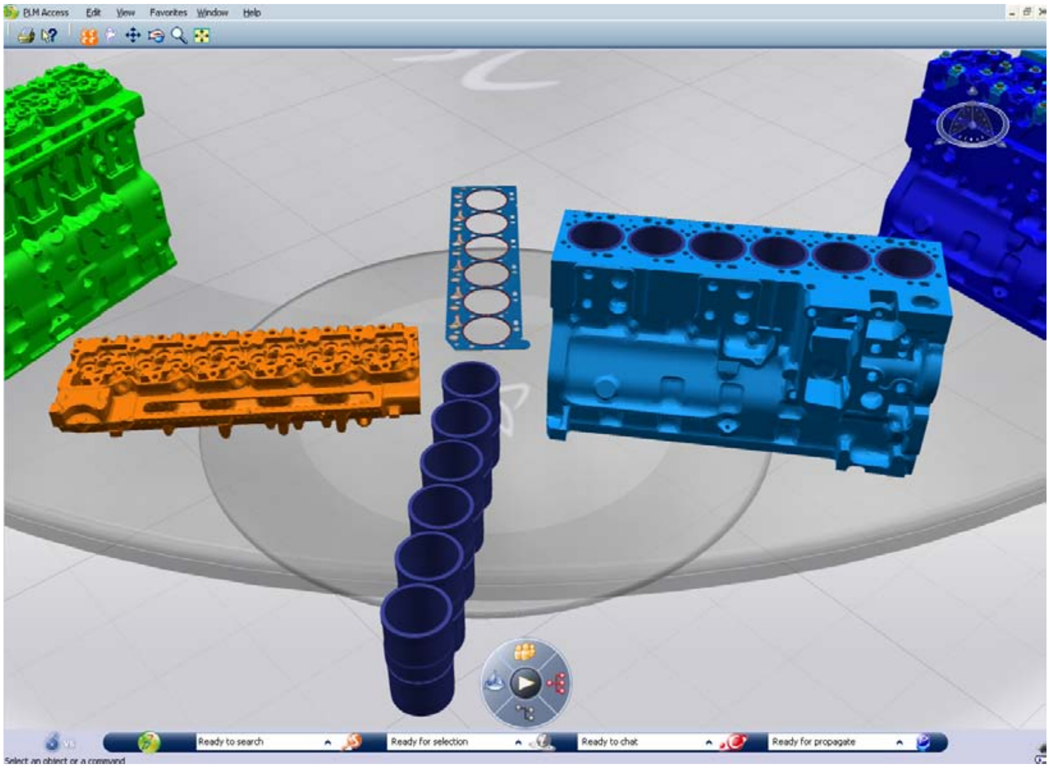

Figure 10: 3D-Live Expanded Activity View - CHG Project

Figure 11: CHG Report

The report contains the simulation steps, contour plots, results charts, as well as data tables. For an analyst to create the complete report from scratch, it may take days to complete. By integrating automated scripts into SLM, the above report can be generated in a few minutes, thereby leaving the analyst more time to analyze the results of the simulation. Because the report can be generated so rapidly, the results of new design iterations can be obtained very quickly, thereby allowing more design iterations to be completed in a shorter amount of time, which can accelerate the time-to-market for a new product design. Another significant advantage to using automation scripts for the report generation is that all of the reports have a uniform standard format no matter where the report is generated. In this way, the automation scripts are also centrally stored and managed, and updates can be pushed to all users at the same time through the SLM templates so that every SLM user is updated at the same time. This ensures that every SLM user is following the same set of standards and is using the latest versions of the software and the scripts. Additionally, every SLM user can understand the report no matter who generated it. Automation is therefore a significant part of a successful SLM implementation.

2.4. Advantages of SLM Implementation

Implementing SLM provides a significant opportunity to capture existing processes and best practice guidelines into managed shared documents within SLM. The shared best practice guidelines can then be promoted and managed as "group" level best practices and made readily available to analysts. By using the SLM system, all users follow the same workflow templates, and therefore perform the same steps in the workflow in the same order. All simulations are constructed and carried out using the same standard procedure. Since all users are following the same architecture and using the same tools for a simulation, the possibility of missing steps in an analysis is greatly reduced. By using standardized templates, quality of simulations is therefore ensured.

The standardized process templates also allow for a majority of the processes to be automated. SLM provides a versionable location to store and track automations, as well as a means to deploy them such that the correct versions are always available and are being used. In addition to simulation data and automation scripts, certain other libraries of files, such as internal data and other design-related data from customers which were loosely managed can be stored in SLM. These files can then be versioned as well.

Once the data is managed within SLM, all users also benefit from a more collaborative environment for data sharing, review, and re-use. When design iterations are made and new simulations are performed with different versions of components, it can quickly become confusing if the data is not managed in an orderly fashion. SLM eliminates the possibility of using out-of-date files by tracking the origin and use of every file entered into the system. When a file is updated, SLM tracks every location where that file is used and which tasks in a simulation need to be performed again because of the change. SLM can also trace which version of a particular component was used in different simulations. By easily keeping track of the latest file versions available, SLM ensures that reports are always prepared with the latest data available. Traceability and knowing where the files are being used also help in situations in which a file is found to have a defect (bug).

With the increasing globalization of engineering and the push to create around-the-clock engineering, traceability also enables different users to work on different tasks in the analysis and clearly see what has been completed. This eliminates the possibility of different users performing the same task and creating duplicate files, thereby reducing storage space needed for an analysis. SLM is also an effective tool when training new employees on specific workflows. In this way, SLM becomes a very useful tool for storing and sharing information.

Moving data into SLM provides search capability as well as more advanced permissions and ownership controls. SLM assigns user-defined attributes to the simulations so that simulation data are easily searchable. By being able to rapidly search simulation results, SLM results in significant time savings. Because SLM utilizes templates which are created with standardized naming processes, all searchable attribute names are uniform, thereby allowing users to find all results, rather than some results being eliminated from searches because attributes are spelled wrong. In this way, SLM becomes a very effective data management tool.

With all analysts using SLM, every user is using the same software versions, the same versions of the automation scripts, and the same format for the report. Data review by decision-makers also provides redundancy to analysis results. In this way, the simulations are all done following a consistent procedure no matter where they are performed and the reports all follow the same format so that all customers see the same results format no matter where they are located around the world.

3. Conclusions

SLM is proven to be an effective tool for managing large amounts of data as used in powertrain applications. At the same time, it drastically improves quality and consistency of simulations by virtually eliminating most common mistakes made by CAE engineers, such as inconsistent naming, using the wrong material data file, etc.

By integrating a much wider range of users into the CAE environment due to ease-of-use, SLM improves efficiency and thus, reduces overall development costs due to the fact that duplication can be avoided and turn-around-time can be increased.

SLM as a technology together with 3D-Live is only in the very infant stages, but the benefits of its implementation are already starting to be seen.

4. References

1. SIMULIA: The Case for Simulation Life Cycle Management; report 1 of 3; White Paper
2. SIMULIA: The Case for Simulation Life Cycle Management; report 2 of 3; White Paper