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SPECIFICATION OF SIMULATION DATA MANAGEMENT ENVIRONMENT INTEGRATED WITH PDM

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1 Introduction

The numerical simulation gradually became one of the industrial tools to reduce the design cycles while guaranteeing the improvement of the quality and the performances of the products. Current simulation approaches move towards the simultaneous analysis with multiple parameters such as stochastic simulations (statistical), multi-physics analyses or multi-scenarios analyses (for optimization) [1]. The direct impacts of these new approaches are the increase in the number of simulations and alternatives of simulation, the growth of the complexity of the simulation models, and therefore, the drastic increase in the volume of data. The handling of an exponential volume of data reinforces the importance to define a consistent simulation-data-management environment to improve the communication, the synchronization and the tractability of the data generated by the numerous loops of design/validation. This environment must guarantee homogeneity of the data (to ensure compatibility), a simple and transparent access, and an effective management of the important volume of data. This paper deals with the development of methods and tools to efficiently manage the simulation data in order to enhance the integration of the finite element analysis and the design activities in a concurrent engineering context [2].

2 The current simulation needs

2.1 Evolution of the simulation process

The current economic constraints lead companies to the development of a larger range of products within increasingly short times. The mechanical products result from the numerous activities of the development process. It is necessary to parallel these activities to drastically reduce time to market of product in order to be more competitive. In such a context, the concurrent engineering methods gradually became a competitiveness key. Indeed, the methods and systems of product data management and collaborative product life cycle management guarantee the control of the product development and the traceability of all the data issued by this process.

These last years, the use of the numerical simulation in the product development process became more and more common. The numerical simulation gradually evolved from operations carried out sequentially to a simultaneous approach with multiple parameters and alternatives of calculation. The increasing number of scenarios currently processed by numerical simulations, combined with the large range of the addressed application fields, strongly increased the volume of the data generated by these processes. This growth of the volume of data is increasingly fast, often much more than the data structuring and storage capacities of the companies. The huge increasing in the calculations number and their complexity makes the traditional tools of pre and post processing became unsuited to the resulting bulky importation of data. Indeed, the times for simulation pre-processing and results analysis, the taking into account of the modifications, the reliability of the CAD models links, the traceability and the capitalization of the results cannot be effectively ensured.

The evolution of the numerical simulation must thus be supported by formalization and structuring of the use of the calculation in project in order to integrate it in the product development process and to guarantee the obtaining of results for the final design decision-making. It must be also supported by an effective data management to facilitate the exchanges between the various engineering activities and to guarantee the reliability of the validations. The validity of the simulation software and methods is not called into question any more but the confidence in calculation issues is directly relating to the reliability of the data used in simulations. Then it is necessary to efficiently manage the simulation data. According to theses observations, some simulation data management systems were developed in an approach known as of SDM - Simulation Dated Management, like those specified in automotive industry by Renault, BMW, or Audi.

The environment of simulation data management proposed in this paper also answers to these issues and enriches the existing systems by a complete integration with the Product Data Management and Product Lifecycle Management systems.

2.2 Management of data resulting from simulation loops

The simulation process is not an isolated processing, it is an iterative approach, a loop of simulation aiming to determine and optimise, for example, the mechanical, vibratory, thermal performances of a new solution. These short simulation loops are used to optimize the design choices and to validate the progress of the CAD definition at each milestone.

Based on this point of view, multiple scenarios "what if" with several variables of analysis are created and compared to lead to the best principle solution. The variables are created and modified according to a reference simulation. Only the best result is returned to the department in charge of design. The need for fast validation in the simulation loops and at each great stage of the project implies a strong effectiveness in the pre-processing of calculation and much of reactivity in the taking into account of the modifications. Most of the time, the data coming from the simulation loops are stored locally in a directory structure. So the control and the history relating to the loops are lost. The efficient storage and organization of the data resulting from these simulation loops is one of the main objectives of the developed Simulation Data Management Environment (SDME). The SDME is based on a management software and a centralised database which capitalise information, skills and results of simulations. This centralised solution is very interesting in a multi-field environment insofar as it reduces the number of redundant data. Thus, a common meshing for several disciplines should be modelled only once, for instance, structural analysis, fluid dynamics analysis, thermal analysis, crash-test, etc. The capitalisation of the data should be ensured with transparent automated processing in order not to overload the user with additional tasks. Moreover, the production of reports in which appear the standard key results should also be ensured by the SDME in an automatic way.

2.3 Interaction with PDM system

The Product Data Management systems [3,4] showed their effectiveness as regards the management of CAD data. They are fairly fulfilling the design activity needs, but they remain unsuited to the simulation activity needs, in particular regarding the management of simulation loops. Then, it could be interesting to dissociate SDM and PDM systems. The main approach for ensuring an efficient Simulation Data Management is to propose an environment guaranteeing a transparent interoperability with PDM. Indeed, the proposed SDME is designed to completely be connected with PDM in a local or remote way in order to ensure interoperability between the simulation and design activities [5,6]. Moreover, the SDME ensures mechanisms of dialog and control of the data coming from the PDM. For instance, the extraction of data from the PDM database by the SDME automatically starts integrated mechanisms which control the evolutions of the geometric models to ensure the data consistency.

3 Specification of the Simulation Data Management Environment

The aim of this paper is to introduce the purpose and structure of the proposed SDM Environment. The development issues will be not detailed.

3.1 Enhancement of synergy between design and simulation activities

The design and simulation activities are closely linked. The role of the design is to propose principle solutions and the role of simulation is to ensure the validation of them by calculation. This collaboration implies an improvement of control and structuring of the numerous exchanges in order to ensure the consistency and the reliability of the data. The strong interdependence of design and simulation activities justifies the fact that it is necessary to develop tools aiming at enhancing synergy between these two fields.

Many collaboration and management systems exist in the design field [7], but only few exist in the simulation field [8] and even less with regard to collaboration between these two fields. Without system for design and simulation collaboration, the links between the progress of the definition states of the design and calculation models remain dubious and the lack of traceability obstructs the connection between the changes of product specifications and the corresponding changes of the calculation results. The result of these uncertain links is the deterioration of the confidence in simulation. The proposed simulation data management environment was then specified to fill these gaps of collaboration.

3.2 SDME features

The following UML use-case diagram illustrates the main features ensured by the Simulation Data Management environment (figure 1).

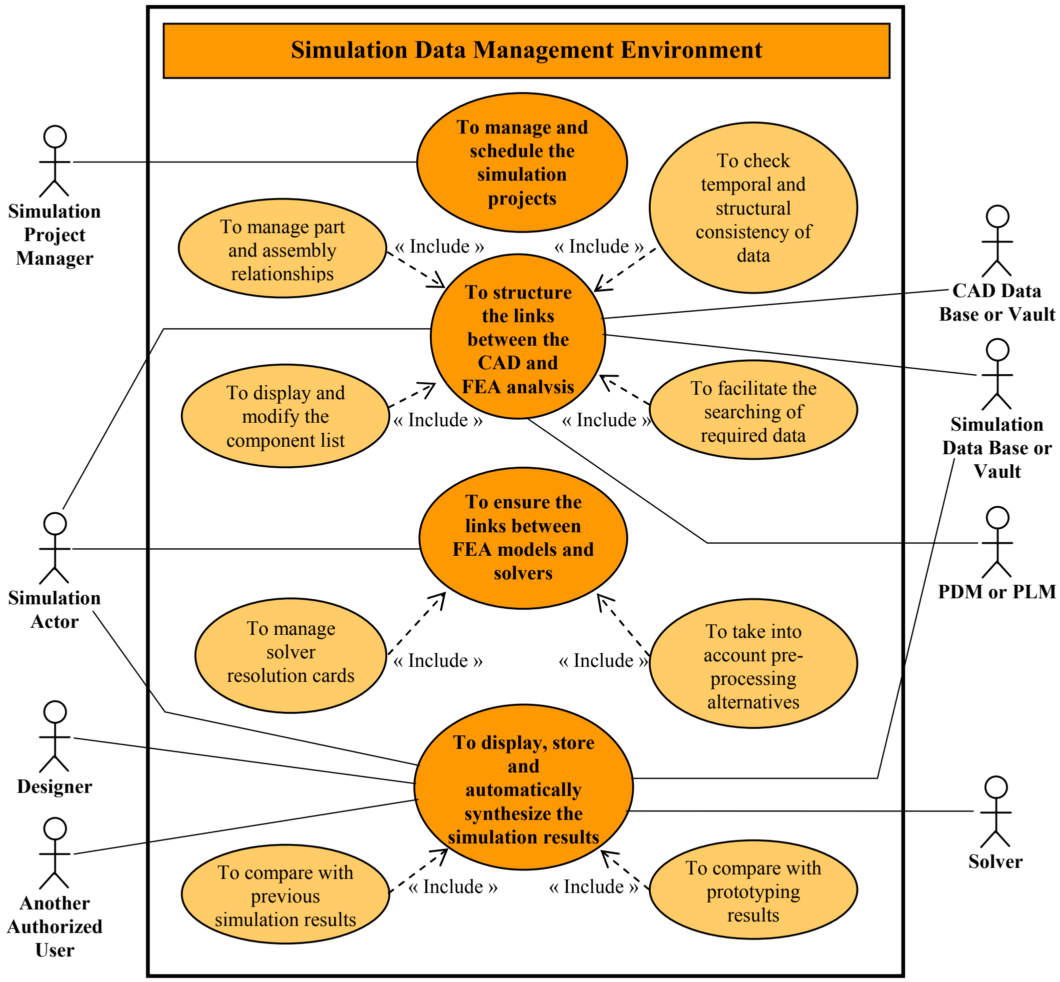

Figure 1. UML use-case diagram

Based on these features, the SDME ensures the management of all the data coming from the simulation processes and guarantees a strong link to the design data. Various kinds of actors can access to the functionalities of the SDME. Their roles in the project restrict the field of functionalities they are allowed to use. The SDME allows the management and schedule of projects by proposing means to define a planning and a workflow adapted to simulation requirements. The other main functionalities concern the organization and the visual representation of the links between design and simulation models and documents. The SDME also offers means to automatically display and synthesize the results of simulations in reports in which the relevant data is stored. The relevant data extracted from results is previously defined by the SDME users.

In order to structure the information, the design alternatives are represented by a tree structure. Each model of simulation has a kind of "pedigree" which specifies what is at its origin, the framework in which it was designed (project, team...), referenced CAD or 3D model, model confidence rating (defined by project actors), and all the required common data. The control of the simulation cycles allows to approach a broader range of alternatives and to evaluate more quickly the impact of them. This can potentially contribute to an improvement of the quality of the results and to an acceleration of the product development process.

3.3 Position in product life cycle

The SDME supports the management of all kind of data handled by the activities of the numerical simulation process. The SDME input data are mainly CAD models (geometric data) and PDM meta-data (like assembly relationships, additional documents). The SDME output data are processed FEA models and simulation issues (like validation reports or bill of analysis). The SDME interacts with the design, simulation and prototyping activities. Authorized project partners also have the possibility to use the SDME to get back previous results or to consult the advancement of the project. Figure 2 illustrates the simulation activities which are taken into account by the SDME and the other activities in interaction with it.

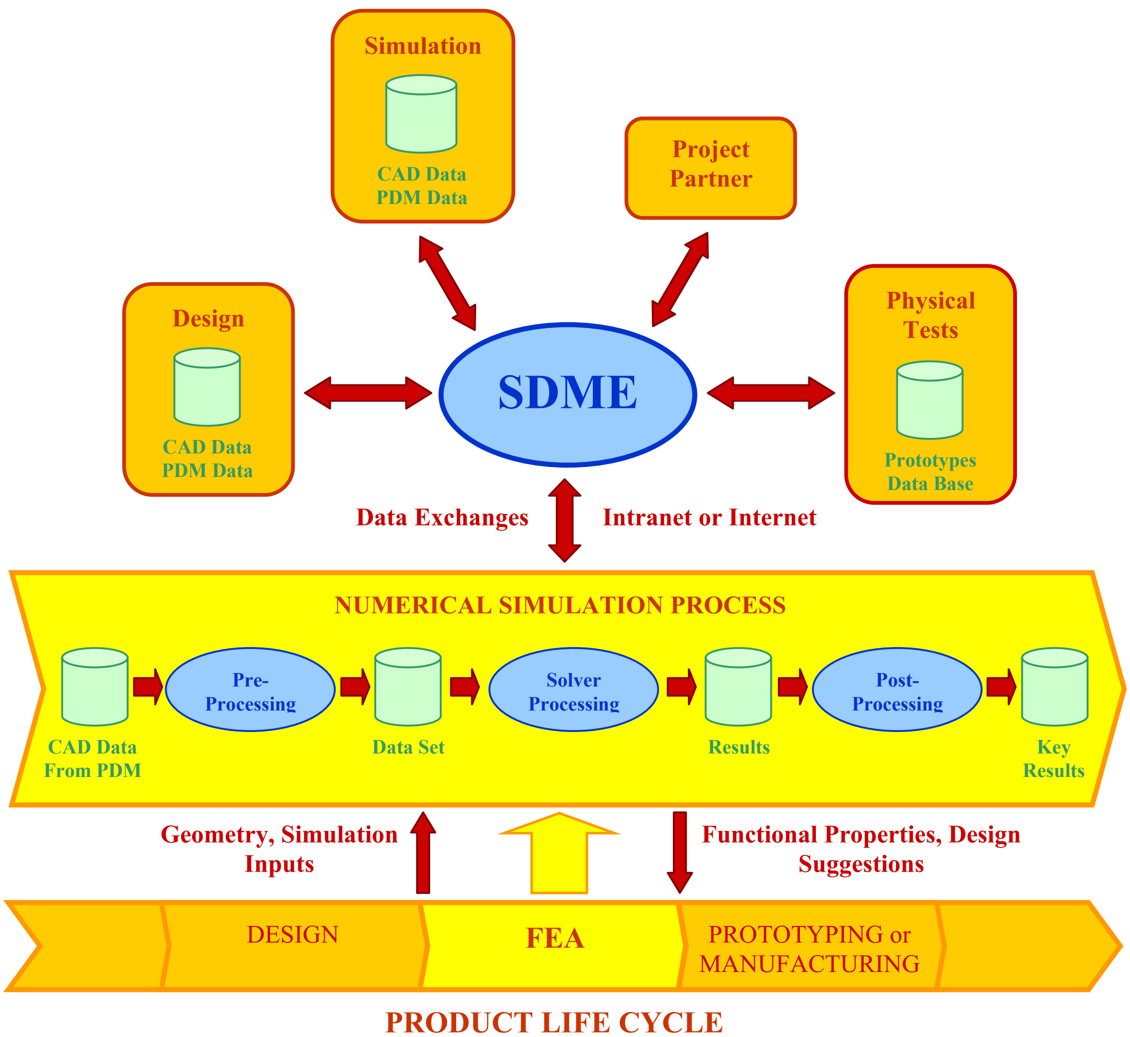

Figure 2. Position in product life cycle

3.4 Data managed by the SDM Environment

According to classical simulation approaches, various kinds of data are managed by the SDME at each main simulation stage:

- Pre-processing: meshed parts, assemblies of meshed parts, load cases, combinations of assembly and load cases, annotations, results of previous simulations, creation dates, people, teams, projects relating to this analysis,
- Processing: directives of simulation read and carried out by the simulation software, components properties, physical properties of materials, boundary conditions, initial conditions, parameters of simulation piloting, application used and its version, computing time, physical means implemented,
- Post-processing: processed model, post-processing data (raw results, curves, images, and videos), automatic generation of an analysis report key results, comparisons with the previous studies, and adequacy of the results with respect to the bill of design.

3.5 Behavior of SDME

Figure 3 illustrates how the Simulation Data Management Environment works. It also details the connexion with the large range of system available in the company for product development process.

The definition of the numerical simulation model is based on successive data imports from the CAD repository with regard to the specifications of the bill of design and to the information provided by the PDM. The imported data are organized in a hierarchical way in a tree structure and a history of the loadings is created in parallel. At this stage, it is possible to seek similar FEA models which have already been processed in previous simulations and store them in the tree structure as consultable links. Each entity of the model is then pre-processed in the simulation software and is recorded in the SDME specific database. The various meshings, boundary conditions, load-cases, materials characteristics, laws of behaviour (coming from the material data base) relating to the model of simulation appear as entities in the tree structure. All additional information added by the user, such as particular configurations of the model, possible simplifications (rigid bodies) and additional geometries (external elements such as numerical human body in crash simulations) are taken into account in the SDM tree structure.

The model is then processed by an external finite elements solver. The simulation results are stored in the SDM database and the relative links are created in the model tree. The automatic synthesis of the relevant results is then carried out to create an analysis report. Afterwards, the experts can deliberate on the viability of the design through the SDME. All their decision-making and arguments are stored in the SDME database. If the results of simulation are not satisfactory compared to the requirements list and product specifications, a new loop of optimization is launched. Another design or simulation alternative of the model is considered and a new cycle begins. If the results are satisfactory, a validation report is sent and storage into the PDM. At this stage, the geometric entities of the numerical simulation are compared with those used by the design in order to check if the geometric model did not evolve during the analysis time. These checks all ensure the temporal consistency of the data. If more information is added to the CAD model during the product development process, the data can be automatically updated.

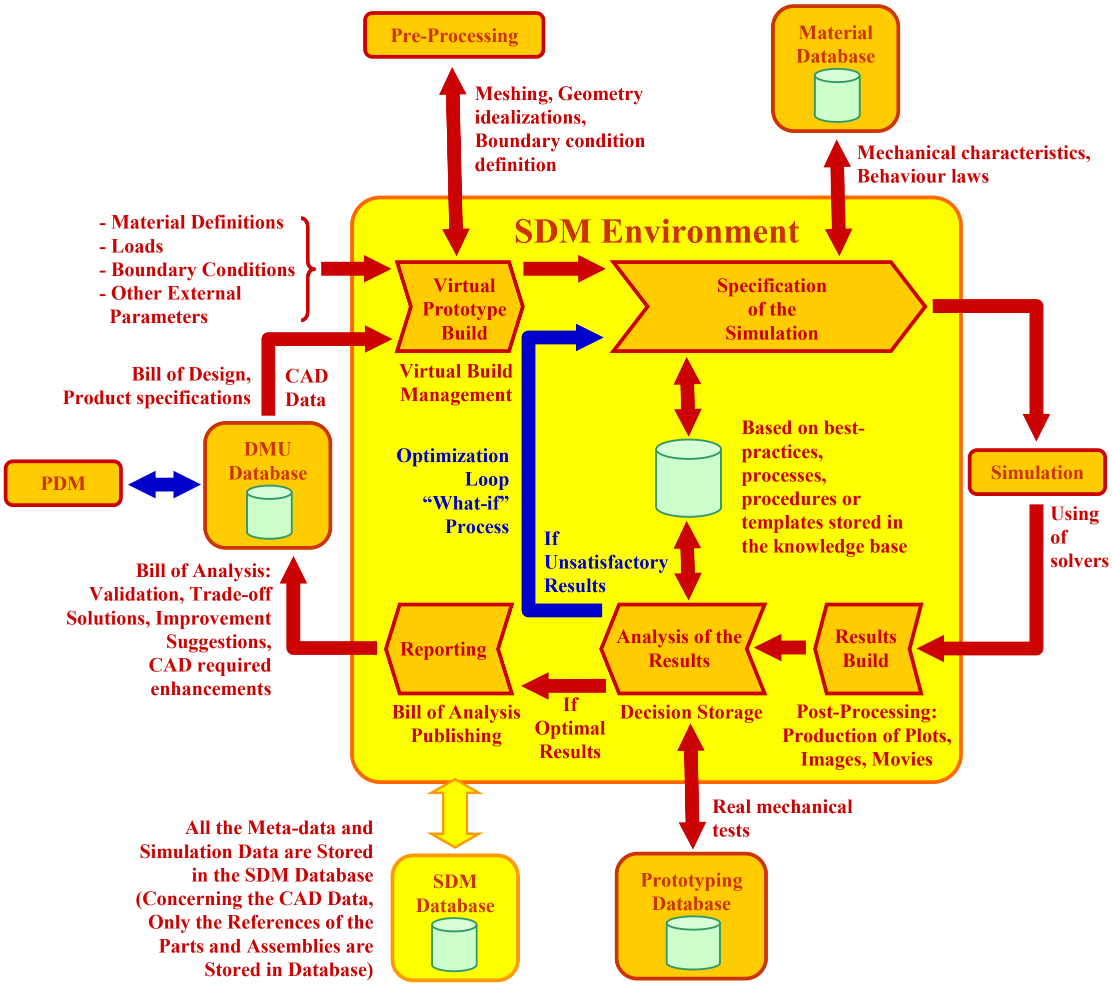

Figure 3. SDM Process

3.6 SDME, PDM and FEA software integration

Before discussing the integration of the SDM Environment with the collaborative product life cycle management system (PDM or PLM), it is advisable to introduce the differences which justify their splitting up into two distinct systems but with a close cooperationapproach.

The SDME is different from PDM and PLM insofar as it is dedicated towards the structuring of the various simulation alternatives in interaction with the activities of design. Another difference concerns the kind of handled data. Indeed, the differences between numerical simulation model and CAD model are as follows:

- The parts or components which have an essential functional role for the product do not have sometimes any influence on the result of the calculation and do not appear in the simulation model and vice-versa (for example mannequins in crash analysis);
- The corrections (idealization) of geometric data can sometimes be necessary to obtain specific meshings;

- The simulation model can have a different organization to enhance its control or the study of the results;
- The elements of the simulation model are assembled by specific connections (weld beads, particular contacts).

The distinction of the design and simulation management system is recommended. But it does not exclude to call for the same kind of software or basic technique. The PDM and PLM systems are already complex enough and it is not relevant to increase complexity by integrating the simulation data. Moreover, these systems, most of the time, were not be designed to ensure the simulation data management and even less to dialogue with the numerical simulation applications.

So, it sounds logic to dissociate the SDME from PDM or PLM system. However, although it is distinct, the SDME is designed in order to communicate with PLM by using an interface especially specified for this purpose. This interface is a kind of mediator which ensures a bidirectional and transparent communication between the software. It is via this interface that integration with the PDM is ensured. The SDME is designed to communicate with PDM and FEA software in a local or in a remote way. It integrates the STEP PDM Schema and OMG PDM Enabler standards to interact with PDM Software [9]. The PDM Enablers are a standards-based Application Programming Interface (API), specified in IDL, that makes PDM services available in a CORBA environment to other systems that require them (such as CAD and even other PDM systems). The PDM Enablers provide direct interfaces to support document management, product structure management, change management, configuration management (product options), and manufacturing implementation specifications, and include support for views, effectivities, and baselines. The SDME also implements the STEP AP209 to exchange simulation data with FEA applications. The ISO 10303-209 application protocol or STEP AP209 is dedicated to the exchanges of the design and the structural analysis of homogeneous metals and isotropic or anisotropic composite materials technical data. The STEP AP209 takes into account the geometric data of the products, the part assemblies, the associated finite element models, the material properties and the results of the simulations. It gives clear details on the structure of exchanged calculation data and the ways of controlling their conformity with the standard requirements. As part of these efforts, a SDM Schema will be defined to ensure the standardization of data exchanges induced by SDM software communication (succinctly introduced in section 5).

4 Benefits of an efficient simulation data management

The Simulation Data Management Environment ensures overall a simple and transparent access to the product data and information relating to the model of simulation. The automation of the management of the data resulting from the chain of simulation ensures consistency between models and traceability of information. The consistency of design and simulation data is also guaranteed with the synchronization of the data which is often difficult because of the long periods of time inherent to the simulation process.

The benefit of the SDME can be classified in two categories, quantitative and qualitative benefits:

- The quantitative benefits of the SDME are the simple creation and management of the simulation alternatives, the automatic data extraction and processing, the sharing of the simulation components and models, the centralized organisation of the data, the automation of the creation of the analysis reports and notes, the standardisation of calculation methods and the numerical validations history.

- The qualitative benefits are a better interoperability between simulation and design activities through dialogue with PDM, a great availability of the data, a friendly and efficient simulation management, a centralized control of the access, a better communication, an efficient model-documentation process, a control of the model quality, a capitalization of the simulation information, and a traceability of models, design alternatives and decisions.

Finally, it results from these benefits a reduction of data loading and models documentation times and an enhanced control of the engineering activities.

5 Future developments

Apart from this SDM Environment specification, a research effort is made to define a neutral file format fulfilling the SDM requirements: the SDM schema. This schema is defined in compliance with ISO 10303 STEP standard [10]. The aim of the SDM schema is to complete the neutral environment offered by STEP standard by specifying a neutral format to exchange product data between SDM and PDM systems. The implementation of the SDM Schema, PDM Schema (PDM neutral exchanges), STEP AP209 (FEA data) and STEP AP203 (CAD data) in design/simulation software will ensure a complete neutral exchange environment.

6 Conclusion

In this paper, we introduced the purpose and structure of the Simulation Data Management Environment. This environment aims to complete the existing Product Data Management systems by integrating the management of the numerical simulation data in a transparent and structured way. The SDME implements a set of methods and tools to guarantee the reduction of times required by simulation model creation, documentation and standard analysis. The SDME will greatly reduce the time spent in the routine tasks of relevant data extraction, management, storage and documentation. It should lead to an improvement of the quality of the results and to a reduction of the design / simulation cycle.

Acronyms

AP: Application Protocol

API: Application Programming Interface

CAD: Computer Aided Design

CORBA: Common Object Request Broker Architecture

FEA: Finite Element Analysis

IDL: Interface Definition Language

OMG: Object Management Group

PDM: Product Data Management

PLM: Product Life-cycle Management

SDM: Simulation Data Management

STEP: STandard for the Exchange of Product data model

UML: Unified Modeling Language

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