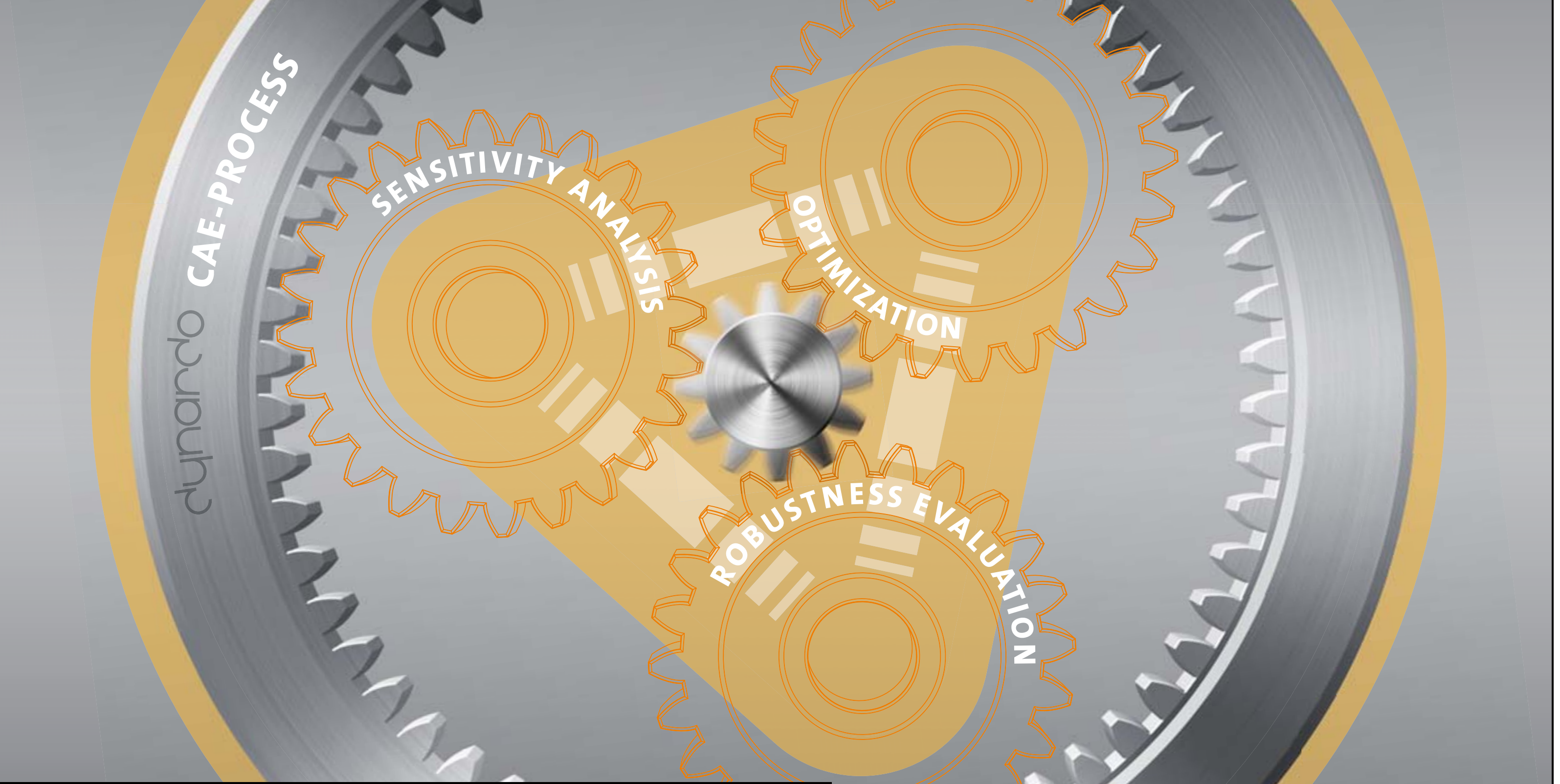


CAE-BASED PARAMETRIC STUDIES BY PROCESS INTEGRATION AND AUTOMATION

optiSLang supports generation of automated CAE workflows in order to provide the full capabilities of Robust Design Optimization (RDO) for a competetive product development.

What will be the most important features of product development processes in the future?

There are a lot of key words dealing with the enhancement of production processes like the Internet of Things or Production 4.0. However, in the end, it all comes down to a single point: to stay competitive on the international market where the most important issue is delivering better products. Here, "better" does not only concern features, it also aims at better quality. Additionally, customers ask for more enhancements in less time. To solve these requirements, production cycles are getting shorter and shorter. In addition, conflicting goals regarding quality aspects, product robustness, production cost and time to market have to be considered. In the classical product development processes (PDP), this problem was solved by using more resources. Now, we are faced with goods which have such a high complexity that even extensive development teams cannot control them anymore. To couple these facts with the requirement of product optimization, a new philosophy in the development process has to be established. Dynardo provides a procedure, called CAE-based RDO, which meets these challenges. Thus, it is possible to accelerate PDP as well as to introduce optimization strategies and "built-in" quality management.

Regarding this issue, different approaches exist like V (W, X, Y) – models, Kaizen or DMAIC circles. They all have two things in common. First, they state the necessity to connect all parts of the production cycle. Intended or unintended, a lot of companies have already implemented this strategy. Engineers and designers dealing with early production phases have to communicate with sales and support departments and vice versa. This principle is applied to all stages of the PDP. Secondly, the product development is not a straight one way road but needs to be thought and lived in circles of communication. Nowadays, the aim is to improve the product regarding weight, NVH or resource efficiency. Furthermore, the end user also expects a creative design. For that reason, PDPs have to be considered as early as possible in the development process.

How can these concepts be transferred to real world usage?

The approach mentioned above illustrates a theoretical philosophy. To reach a benefit, it has to be applied to real processes. This can be economically accomplished when the philosophy is applied to a technical part or constraint. From Dynardo's point of view, this can only be achieved if the techniques are "built-in". Everyone in the PDP-cycle has a strategy to solve a given task. No one starts from the very beginning. There is personal experience and education regarding tools and established processes. And even personal preferences have to be taken into account. It cannot be the aim to force all participants to throw away their solutions and forget about valuable experiences.

The best way to address these boundary conditions is using the principle itself. Implementing the approach should be an iteractive cycle. Thus, "the way to the better" (Japanese for Kaizen) can be found. This way is the most economical one and guarantees success. Each part of the PDP can define its own improvement pace. In fact, the existing processes have to simply be connected. Therefore, it would be helpful if all involved specialists have access to a single collective hub where they can share their knowledge and skills. The benefit of this teamwork is evident.

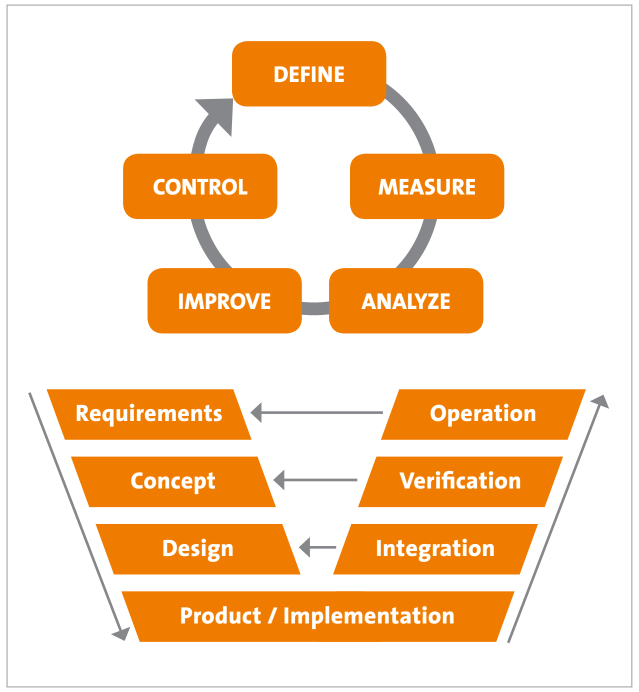
In the following, it will be described in detail how the concepts can be transferred into a continuous improvement procedure that satisfies the future needs of product development processes. These issues will be addressed:

- Techniques to get better products
- Connection of all necessary CAD/CAE Tools
- Ansers how these tools can be combined
- Generation of a platform for collaborative work

Virtual product development and multiple disciplines

As the product cycles are continuing to get shorter and requirements are rising, complex and expensive hardware tests need to be replaced at least partially by CAD, CAE or CAM. Regarding the "rule of ten", as a strategy for resolutions of measurement systems, those techniques need to be used in early production phases. Using this technique is common and necessary to be competitive on the international market. Here, the engineer has the most intervention options at a comparatively low cost level. Virtual product development using the power of simulation needs to be introduced. In the meaning of the "cycle concept", the usage of Virtual PDP (VPDP) needs to be extended. Hardware tests still capture an extensive part of the modern product development. Of course, CAD-based product designs need to be validated in the real world. Here, data from the production line is the input for products of the next generation. How test engineers are involved in this concept will be illustrated later in this article.

A product idea mostly starts with a drawing and makes CAD (Catia, Creo, Nx, Solidworks etc.) an appropriate starting point of virtual product development. Once a design is created, a structural analysis can use the model for meshing and solving. To obtain the best information about the design performance, the CAD model needs to be as realistic as possible. At the same time, because of restricted computation power, the simulation model also has to be simplified. Therefore, many CAD tools or extensions exist for defeaturing purposes. They simplify the simulation model while keeping the original CAD untouched. An expert decides which detail level has to be chosen. This decision can be part of an automatized workflow. If different scenarios or load cases are defined, they are all applied to the same geometry. To consider all disciplines, more influences have to be included. Beside structural constraints, a product needs to satisfy e.g. economic requirements as well. These can be considered by implementing standard tools like MS Excel into the automated workflow. To summarize, the results need to be communicated and discussed. As a consequence, all data can be collected and processed as well as meaningful reports can be created automatically.

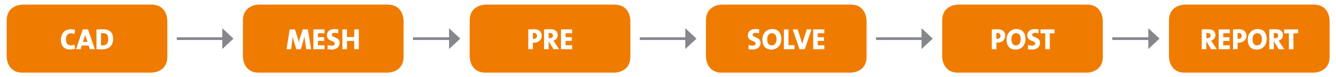


The challenge now is to tighten the processes and to combine all disciplines. This can be achieved by using one collective hub to build an automatable multi-disciplinary process. Thus, a designed concept can be proven through calculation. If all of these disciplines are connected in a standardized workflow, the designer can evaluate the concept by some mouse clicks. Through the described automation, the virtual product development receives a standardization. A "built-in" quality assurance is inherited by the whole VPDP.

Parametric studies

Once a standardized and automatable workflow is set up, it can be used for parametric studies to:

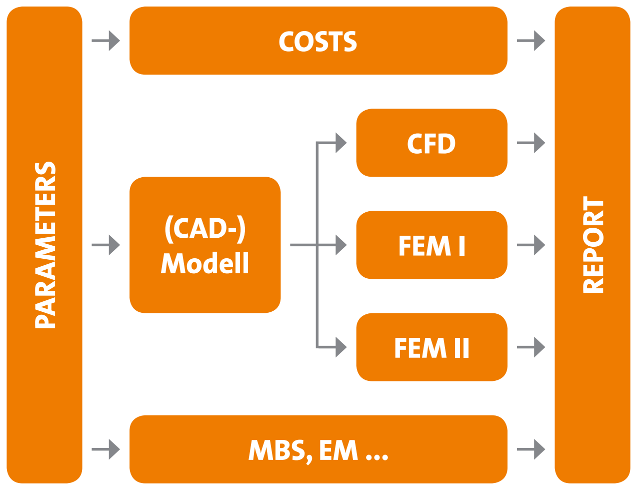
- Understand the design by conducting a sensitivity analysis
- Improve the design by using methods of optimization
- Validate the quality of the design by conducting a stochastic analysis



There are several solutions for parametric studies delivered within CAE codes. One example is the ANSYS Workbench. Here, parametric CAD and CAE can be connected to one complete multi-physics simulation workflow. ANSYS Workbench established a powerful parametric modeling environment including interfaces to major CAD programs in order to secure the availability and generation of suitable CAE parametric models as a key requirement. It has the capability to collect CAE and CAD data in a central parameter manager. Consequently, the system integration, process automation and job control are also integrated into ANSYS Workbench to update one or multiple designs from the parameter manager.

Other solutions can be found, for example, in AMESim, FloEFD, Friendship Framework or Zemax. They all support the replacement of numeric values for parametric models of the underlying CAE process. This is combined with an automatized update of the model. Usually, this functionality is very powerful and generally usable as well as it supports HPC and simultaneous solving. But mostly there is a lack of connection to include other tools which are used in VPDP. Consequently, the provided algorithms for studies, the possibilities to define input parameters and the definition of observed outputs are limited to the common application fields of the solver. The majority of the VPDP software tools do not have an explicit parameter management system. In this list, very common codes like Matlab and special solutions like "in-house" tools can be found.

To overcome all of the mentioned constrictions, interfaces are provided to be used by process integration solutions. Different parametric environments can be collected and combined to one automatized parametric workflow for the modern product development. This software for process integration is the needed collective hub.



optiSLang

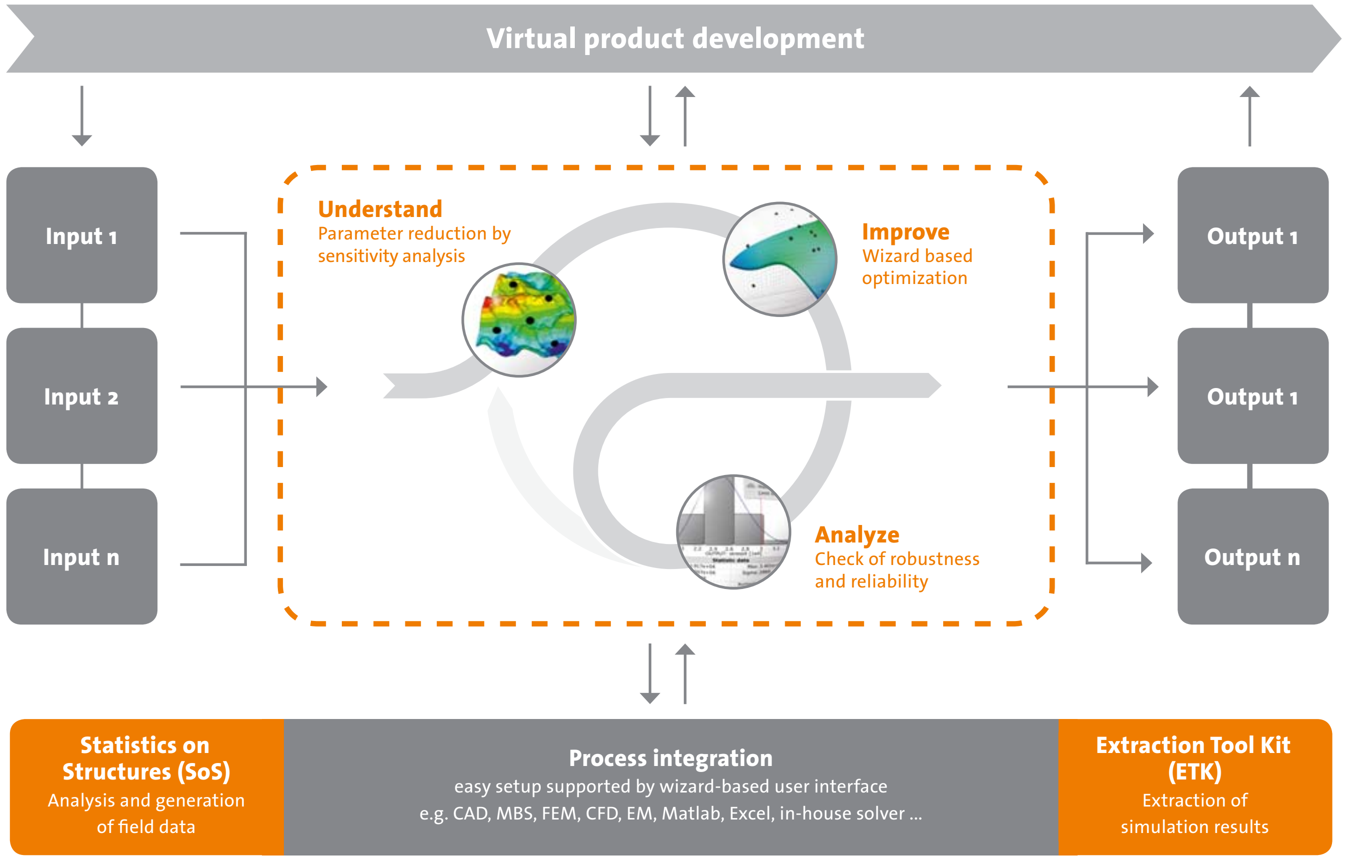
optiSLang is Dynardo's software for CAE-based sensitivity analysis, multi-objective and multi-disciplinary optimization, robustness evaluation, reliability analysis and Robust Design Optimization. In order to implement the described cycle concepts, optiSLang's former C/Fortran backbone of the interpreter language was transformed into modern modular C++ with Python bindings. This could be managed without rewriting all successful parts of the existing powerful algorithms. New algorithmic implementations, the toolbox for nature-inspired optimizers and improvements of the MOP were developed in C++ modules. Additionally, Dynardo already had a decade of scripting experiences in supporting HPC and automatizing CAE. This valuable knowledge was used to develop a new kernel for the workflow setup. The task was to replace the main part of the scripting solutions by more convenient elements. The development of the post processing tool ETK (Extraction Tool Kit) was also a very important step in the improvement cycle. Users of supported formats, e.g. Abaqus, had the opportunity to benefit from better assistance to parametrize and appraise responses. In 2012, version 4 was released with a new GUI and kernel.

Tool integrations and collaborative work

optiSLang's GUI supports the interfacing to almost any software tool which is used in VPDP and fulfills the requirements to run in batch or to except parameter variation. The interfaces are mainly used "inside optiSLang". Thus, in optiSLang context, they are called "tool integrations". Many different VPDP software solutions are coupled with optiSLang. They are automatized either in a single solver process chain or in very complex multi-disciplinary and multi-domain workflows. Even performance maps and their appraisal can be part of standardized projects. The new generation of optiSLang provides direct access to the parametric modeling of CAE environments like ANSYS or SimulationX as well as to programming environments like EXCEL, MATLAB or Python. It allows users to combine several tools in sequences and iteration loops. For a constant workflow control, failed designs due to missing licenses, geometries unable to be meshed or any other inconsistency is secured. Here, the workflow stores the usable data for further execution. Of course, the support of different platforms, i.e. Windows, Linux and HPC as well as Cloud computing is provided. Thus, optiSLang is the solution to automatize VPDP.

All of the previously described workflows can be stored as reusable templates and made available for the entire VPDP team. Working this way guarantees the capturing of knowledge of each expert in the team. Every template is a version controlled building block. It can be used in a modular and flexible way within adaptive projects. While each expert

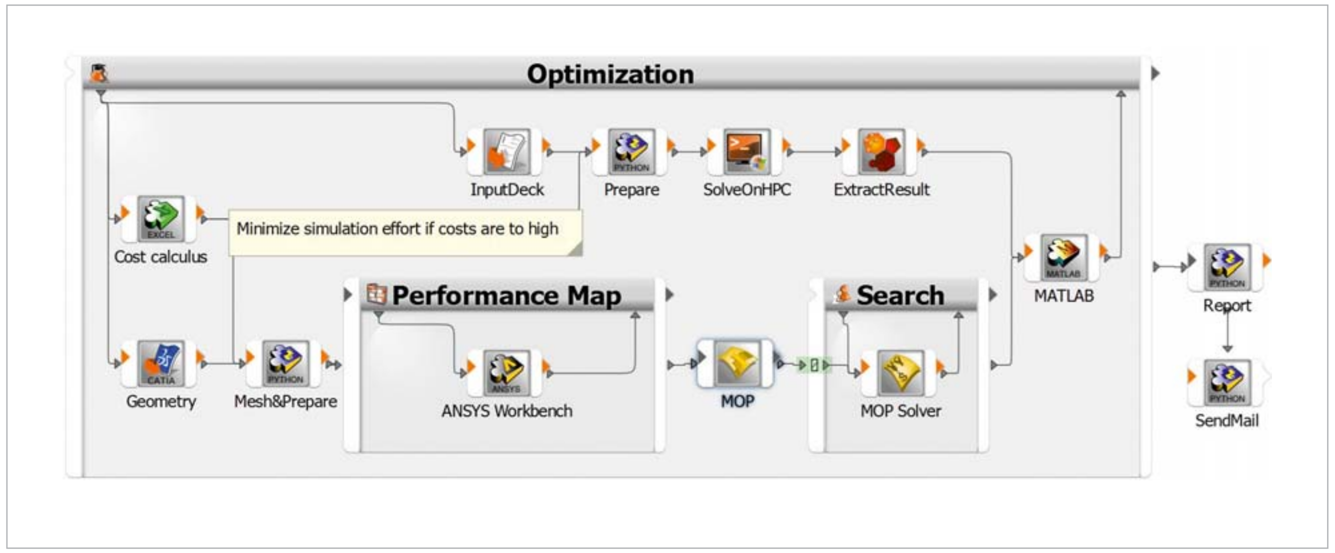
Title Story // Process Integration & Automation



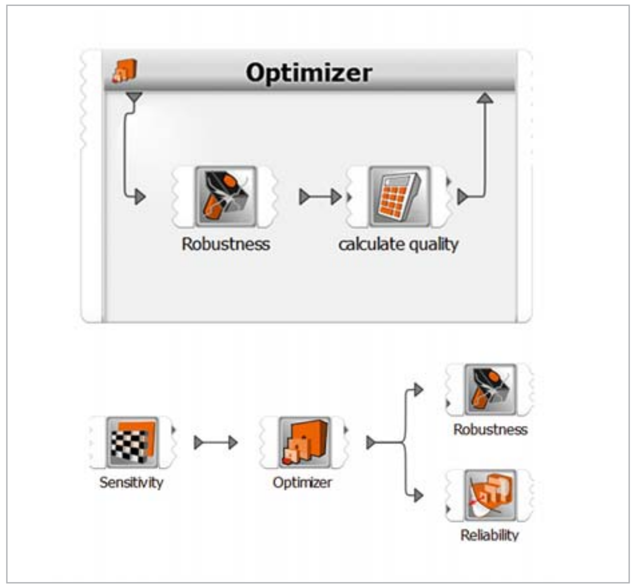
delivers quality assured sub-modules, the whole process becomes standardized. Used tools, algorithms and internal processes can be improved or changed while the entire PDP is stable and benefits from sub-upgrades. At the end, the whole team benefits from sharing knowledge in standardized processes by having quality assured PDP and has more time to focus on their following improvement steps for the process itself or for the product. Through the modular approach, the necessary flexibility to create modern and innovative products is guaranteed. The concept also assures collaborative, flexible and standardized work. Thus, optiSLang is the platform for efficient, future oriented teamwork.

Workflows for CAE-based Robust Design Optimization

optiSLang provides algorithmic building blocks for
- Sensitivity Analysis and MOP
- Multi-objective and multi-disciplinary optimization
- Robustness evaluation



Fully automated optimization workflow in optiSLang considering structural costs and metric of performance map, running several solvers and using HPC



Workflows for coupled and iterative RDO

All of the algorithmic modules can be used as a single system. They can also be combined in nested loops or complex sequential workflows. The setup of best practice procedures is guided and supported by wizards and default settings. Thus, with optiSLang, the generation of a workflow using the modules of sensitivity analysis, optimization and robustness evaluation is possible with a minimum of user input. A best practice management chooses, according to the RDO task, an optimization strategy with the most fitting and effective algorithms.

The graphical user interface supports the workflow approach visually. Single building blocks and algorithms are graphically coupled in order to show dependencies and scheduling. The relationships can be determined and controlled in one context. Easily understandable charts as well as control panels are displayed at the same time. This enables full access and traceability of the complete workflow. Conducting a sensitivity analysis, multidisciplinary optimization, robustness evaluation and reliability analysis with optiSLang enables you to:

- Quantify risks
- Identify optimization potential
- Improve product performance
- Secure resource-efficiency
- Save time to market

Interfaces and Extensibility

As stated before, openness of VPDP software tools is an important property. It enables the tool to integrate or to be integrated into other PDP environments. To fulfill these requirements, optiSLang provides several interfaces. The provided Python, C++ and command line interfaces allow the automatic creation, modification and execution of projects. For that reason, the usage within custom applications, e.g. PLM/SPDM systems, is secured. In PLM systems like Teamcenter, the team members can share their knowledge and use the work of others mutually. CAD models, simulation, workflows, product information and results can be managed in those systems. Through a flexible interface optiSLang supports commercial tools as well as versioning systems like subversion or even in-house solutions. This guarantees full consistency and traceability of PDP.

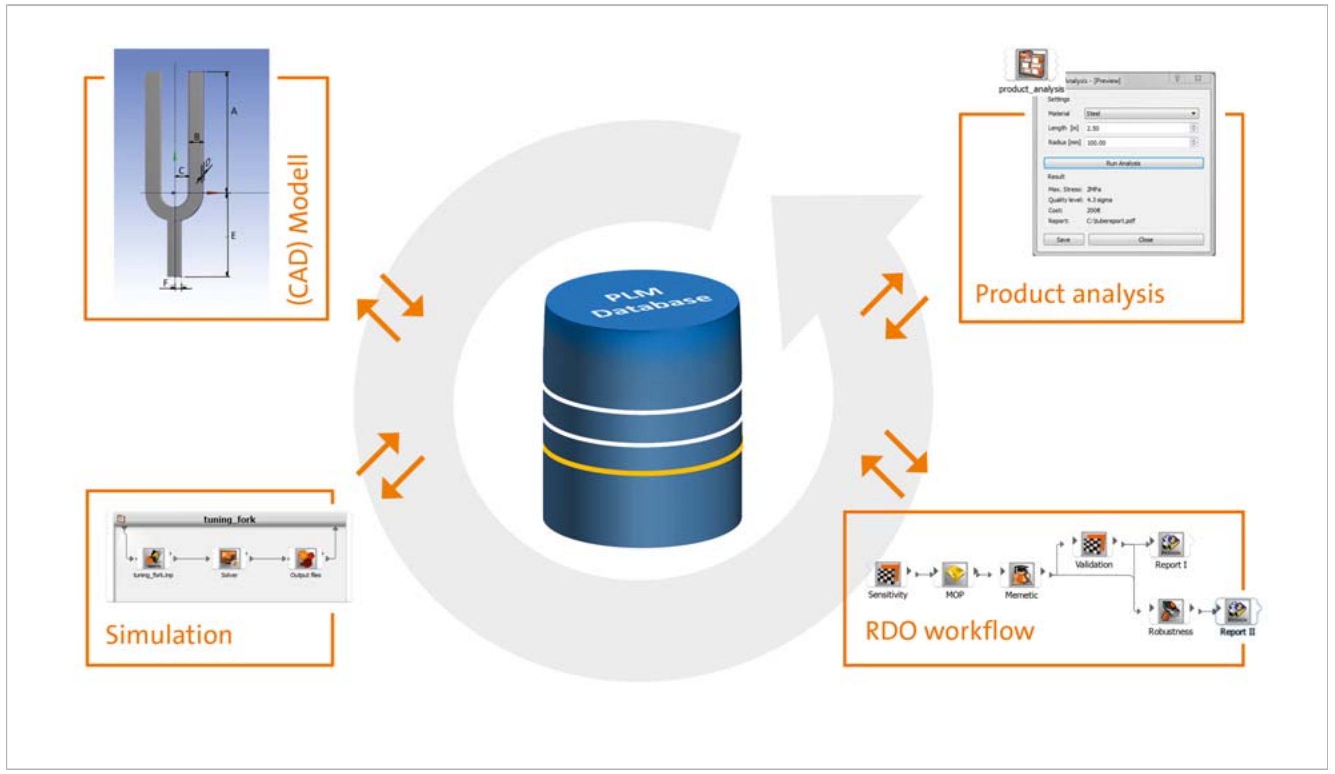
Additionally, optiSLang projects can be integrated into customized platforms. Repetitive and exhausting tasks can be standardized and automatized. One goal of these techniques is to provide standardized forms with a minimum of needed input to the rest of the team. Thus, even non CAE experts can become able to use the benefits of CAE-based simulation and generate optimal and reliable designs. A lot of successful implementations of optiSLang into company solutions were realized over the last years. Even fully automatized RDO workflows were generated. This enabled the establishment of company-wide standards in virtual product development. Hence the customer benefits from consistent and efficient processes.

The openness of Dynardo's software optiSLang also provides users with a plug-in for their own:

- Algorithms for DOE, Optimization, Robustness etc.
- Meta models
- Tool integrations

Current requirements for flexibility and upcoming requests for extensibility are satisfied by those interfaces. Thus, optiSLang is the platform to address future needs of PDP.

optiSLang inside ANSYS
ANSYS provides a customization toolkit for its Workbench. It can be used to extend its functionality. Based on this idea, a direct integration of optiSLang into the parametric modeling environment of ANSYS Workbench was developed to make optiSLang's state of the art RDO workflows available in this standard CAE environment. It can be accessed through a minimized user input and wizard guidance. The Workbench functionality was also broadened by optiSLang's signal processing integration. Users are able to implement responses which are not extractable or integrated in standard ANSYS Workbench, e.g. non-scalar responses like load displacement curves. Non scalar responses can be considered, for example, in parameter identification or optimization. If all parameters and needed VPDP tools are available in the Workbench parameter manager, optiSLang inside ANSYS is a useful integration mode. Alternatively, for integration of ANSYS Workbench projects in optiSLang, an integration node is available. This mode is recommended to be used for solving VPDP tasks which need additional parameters or for CAE-integration not yet provided inside ANSYS.



Sceme of a modern Product Development Process using collaborative work based on a PLM / SPDM data base and optiSLang

optiSLang Excel Add-in
Using its interfacing capabilities, MS Excel and optiSLang work together to support PDP. With the help of the Excel Add-in, external data, e.g. from hardware measurement, can be converted into optiSLang compatible formats. Consequently, the data from laboratories can be directly forwarded to sophisticated algorithms like optiSLang's Metamodel of Optimal Prognosis (MOP) and important coherences can be mined, visualized as well as extracted as functions. Thus, the first target of Robust Design can be addressed: A Better Design Understanding. Based on transferred observations, meta models are built and hard-ware tests can be replaced by those surrogates. While forwarding measurement data and applying standardized evaluation methods, the laboratory engineer can be integrated into the complete VPDP.

Conclusion

Finally, after discussing requirements and solutions, the following main preconditions of a successful product development processes in the future can be summarized:

- Automation and standardization of VPDP workflows
- Parametric studies and Robust Design Optimization
- Flexibility and extensibility
- Support of continuous improvement
- Enabling of collaborative work

As explained in this article, optiSLang fulfills all of these requirements. Using the software, existing flows can be implemented or standardized. The software package provides solutions for all phases of PDP. The fulfillment of future requirements and a continuous process of improvement are secured by modular and flexible concepts. Traceability and quality assurance are technically seized. The inherent usage of parametric studies and RDO leads to a "built-in" improvement of the product.

As shown in this article, optiSLang guarantees a cost efficient and successful development of better products.

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