Predictive design analysis process model

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PREDICTIVE DESIGN ANALYSIS PROCESS MODEL

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1 Introduction

Computer-based design analysis, here confined to quantitative computer-based structural design analysis within mechanical engineering, is an essential part of most product development projects in industry and serves as an important source of information in decisions taken during the engineering design process; importantly, it aims at providing confidence in the decision on critical design parameters. It is moreover nowadays used on all levels of concretization of the product-to-be throughout the whole product development process. It must therefore address different sources and modelling of uncertainties and errors present in all areas of design (products, processes and organizations) during the whole product development process. To that end, the concept of predictive design analysis (PDA) has been introduced. PDA is a specific computer-based design analysis methodology [1] that supports the systematic handling of uncertainties and errors during the computer-based design analysis activity throughout the whole development of an artifact. Such a methodology includes: **(1)** Not only aleatory uncertainties (which have been the main focus of research and development in uncertainty-based design analysis), but also epistemic uncertainties associated with factors affecting the design analysis activities; **(2)** Operationally efficient and effective integration between the activities constituting the engineering design process and design analysis activities via an overall design analysis process; **(3)** Quality assurance aspects in terms of quality checks, verification and validation activities taking physical testing into account; **(4)** Progress monitoring throughout all design analysis activities from clarification to completion; **(5)** Traceability in utilized information, technologies and established results; **(6)** Information and knowledge re-use for an improved uncertainty treatment in future design analysis activities through establishment of lessons learned and best practice documentation as well as methodology development.
The main elements of PDA are presented next. They are numbered according to the list above.

2 Sources of uncertainties

Sources of uncertainties **(1)** to the design analysis activity are identified and grouped along their levels of influence on the activity: some appear at the activity level, some appear within the development project, some occur at the enterprise level, and some are outside the sphere of the enterprise, see Figure 1. The proposed classification has the advantage of indicating what leverage a stakeholder has upon such factors: the further from the analysis activity context, the more difficult it is to act upon them. Being aware of these factors should prevent fastidious iterations resulting from a poorly planned and organized design analysis task.

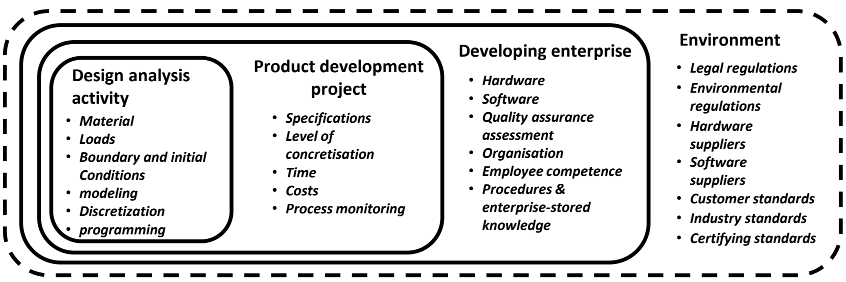

Figure 1. Sources of uncertainties associated with factors influencing the design analysis activity.

3 The PDA process model

The PDA process model **(2)** is formulated in general terms so that it can be adapted to majority of product development processes utilized in industry. It consists in the three main activities of analysis task clarification, analysis task execution and analysis task completion, displayed in Figure 2 together with their corresponding steps. The PDA process underlines the importance of identification and planning the task as well as interpretation and documentation of both results and experiences gained.

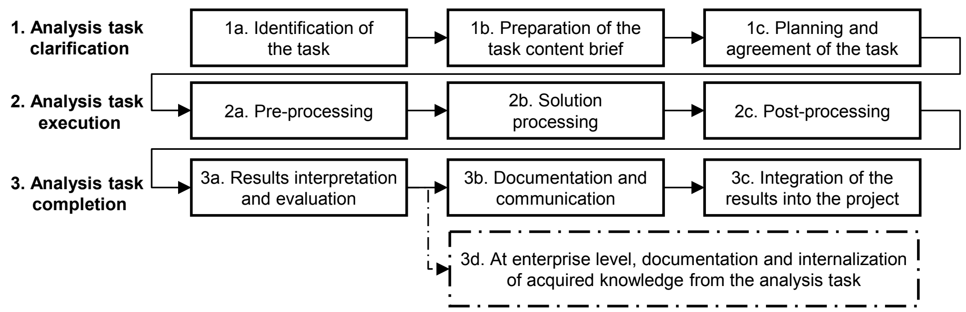

Figure 2. Overall design analysis process model with defined activities and steps.

The analysis task clarification (step 1) consists of the three steps. In the identification of the task (step 1a), the objective is to ascertain the task relevance and need for performing the design analysis activity, which is followed by the preparation of the task content brief (step 1b). The aim of the last step, planning and agreement of the task (step 1c), is to reach a mutual understanding and agreement about the task ahead. Within the analysis task execution activity (step 2) the agreed task is further processed in the pre-processing step (step 2a). After solutions have been established in the solution processing (step 2b), the analyses are verified and the accuracy of the results obtained is assessed (post-processing, step 2c). Interpreting and evaluating the established results and the model behavior (results interpretation and evaluation including validation, (step 3a) complete the design analysis task, and the outputs are integrated back into the project (documentation and communication and integration of the results into the project, steps 3b and 3c). The elicited analysis information and experiences gained are then also communicated to the enterprise for inclusion in the enterprise core knowledge system thus allowing for continuous improvement (documentation and internalization of acquired knowledge from the analysis task, step 3d) **(6)**.

4 Supporting activities

Quality assurance (QA) **(3)**: The QA process consists of self-checks and planned quality check (QC) activities with the purpose of revealing and capturing any deficiencies connected with both intentional and unintentional errors in the established computational models, results and approaches used for a certain design analysis activity. The QC should be considered as an iterative review loop in which the given remarks and comments on the work and responses to them are communicated back and forth between the analyst and the assigned resource for QC until mutual agreement and consensus are established regarding any concerns raised during the review. Within PDA, verification is interpreted as the assessment of the accuracy of the computational model of the design solution. Furthermore, validation within PDA is addressed as the assessment of the accuracy of the simulation results by comparison to data from reality by experiments (by means of prototypes) or physical measurements in working environments.
Progress monitoring **(4)**: Uncertainties connected with the project and enterprise factors (cf. Figure 1) not explicitly treated within the computational analyses model itself need to be addressed and communicated through status and progress reporting on the ongoing work.
Traceability **(5)**: All models, data and information established during the execution of the activity should be gathered in some form of tracking system that could either be in the form of engineering data management (EDM) or based on a file system approach.

5 Conclusion

The established design analysis process model within the PDA methodology provides an operational level model that can be utilized throughout the complete product development process to plan, execute and communicate the outcome of design analysis tasks in an industrial context.

6 Reference

[1] Eriksson, M.: "The methodology of predictive design analysis", *IMECE*, Montreal, CANADA, 2014