Computers in Industry 66 (2015) 11–20

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

A meta-model for knowledge configuration management to support collaborative engineering

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ARTICLE INFO

Article history:
Received 18 March 2013
Received in revised form 11 June 2014
Accepted 13 August 2014
Available online 3 October 2014

Keywords:
Knowledge configuration management
Concurrent engineering
Numerical simulation

ABSTRACT

This paper focuses on industrial design and simulation processes especially in automotive and aerospace areas. Designers use business models (called expert models) such as CAD (computed aided design) and CAE (computed aided engineering) models to optimize and streamline the engineering process. Each expert model contains information such as parameters, expert rules, mathematic relations (parametric models, for example) which are shared by several users and in several different domains (mechanical, thermal, acoustic, fluid, etc.). This information is exploited at the same time in a concurrent engineering context. It is the basis of an imperfect collaboration process due to the fact that existing tools do not manage encapsulated information well and are unable to ensure that parameters and rules are consistent (same value of parameters for example) throughout different heterogeneous expert models. In this context, we propose an approach to manage knowledge using configurations synchronized with expert models which enable designers to use parameters consistently in a collaborative context. Our approach is called KCModel (knowledge configuration model): it allows acquisition, traceability, re-use and consistency of explicit knowledge used in configuration.

1. Introduction

In this section, we browse the engineering process to identify design and simulation methods which are performed in product development. It allows fixing the problem about using parameters and constraints in CAx model illustrated in the next section.

1.1. Product design

Within the current economical and industrial context, companies would like to obtain a better cost control and to streamline their product design in order to reach the famous "cost/quality/delay" objectives [1,25,39]. It involves the development of new methods in design process [3,24], with the enhancement of concurrent engineering contexts [4,35,23]. Indeed, the design process has evolved from sequential engineering [29] to parallel design activities and therefore the development of collaborative and shared contexts of information and data (parallel activities need to use and share information and data at the same time in the good version). These developments were followed by a new design approach called KBD: knowledge based design or more generally KBE: knowledge based engineering [26,27,31]. Thus, companies understood the advantages of capitalizing on and re-using knowledge in product development.

Furthermore, nowadays, with the use of 3D geometrical product components in CAD files, engineers include parameters and expert rules to drive the geometry in CAD models through parametric and variational approaches (4D CAD [18]). The aim is to reduce routine design (80% of the estimated design process [32]), test a large range of product architectures, especially in the upstream phase of the design process and enhance the product quality with time and cost reduction. This is in accordance with DFX: the Design for X approach [21] which emphasizes the importance of considering the overall constraints of several design activities, and especially in the upstream phase of design process, to avoid major conflicts and to limit the redesign cycle. Although the design process has evolved, the numerical simulations have

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http://dx.doi.org/10.1016/j.compind.2014.08.001
0166-3615/

also evolved considerably to become a key area in product design. Initially used at the end of the design process as validation or presentation of activities, simulation is currently used in the overall design process and especially in the upstream phase (trade-off, pre-sizing) using CAD/CAE integration and parametric models.

1.2. Numerical simulation

Nowadays it seems as necessary to use numerical simulation to lead the way to innovation. In the early design phases numerical simulation allows for the management of a better and quicker design [1,10]. This is particularly true in the area of mechatronics systems (combination of synergistic and systemic mechanical, electronic, computer, control, and systems design engineering) and specifically in the automotive and aerospace industry. Mechatronics is rapidly evolving towards a numerical simulation driven design approach which integrates increasingly complex models and simulations in various areas of expertise.

Numerical simulation driven design leads to many heterogeneous computational models which interact with each other. The large amount of miscellaneous information handled in this process, combined with the low level of interconnection between modeling and simulation software tools, often leads to data discrepancy and inconsistency [33]. Indeed there is a gap between designers and analysts. Moreover, data and information are often scattered and duplicated, thus preventing data consistency, traceability, and re-use, and inhibiting the following of design step sequence. This situation prevents companies from turning the information and know-how embedded in their geometric and simulation models into a shared structured knowledge that can be extracted [2,19,22].

2. Sharing parameters and experts rules through several CAD and CAE models

CAD and CAE models used in upstream design activity enable linking between the geometrical design and numerical simulation to construct "workbenches" dedicated to specific product components and physical domains (e.g. the thermal piston workbench, the cylinder-block workbench, etc.). The workbench allows engineers to test several component architectures very quickly and identify the main design concepts. It is an iterative process during which engineers modify parameters and expert rules encapsulated in CAD/CAE files, which represents relevant information to capitalize. The entire workbenches (also called expert models) are very different and heterogeneous because they are used in a large diversity of practice, with a diversity of tools, in a diversity of physical domains and moments in the design process. The expert models are based on various geometric representations with the advantage of product representations tailored to each individual situation. However, they introduce many difficulties in piloting, maintenance, consistency and access to the valid information, which all make them cumbersome to use and hence inhibit innovation. Thus the knowledge encapsulated in each expert model can potentially be used by another one and so has to be shared and coherent. Today, it often happens that calculations are started using the wrong parameter configuration in different workbenches on related parts, which leads to a greater or lesser loss of time and money depending on the moment of discovery of the error.

Thus our problem is focused parameters and constraint encapsulated in CAx models which need to be exchanged and consistent in the design process. We identify four views to describe the problem (Fig. 1); they are called ITRC for identification, traceability, re-use, and consistency. Several workbenches are used at the same time in a concurrent engineering context. Every CAD or CAE model encapsulates knowledge as parameters and rules which need to be shared and coherent throughout design and simulation activities (during iterative and dynamic modification process).

The first problem is focused on parameters and rules *Acquisition*: they are extracted in each individual model unit, thus causing duplication and bad lifecycle management. Parameters and rules need to have their own lifecycle independent from the model lifecycle.

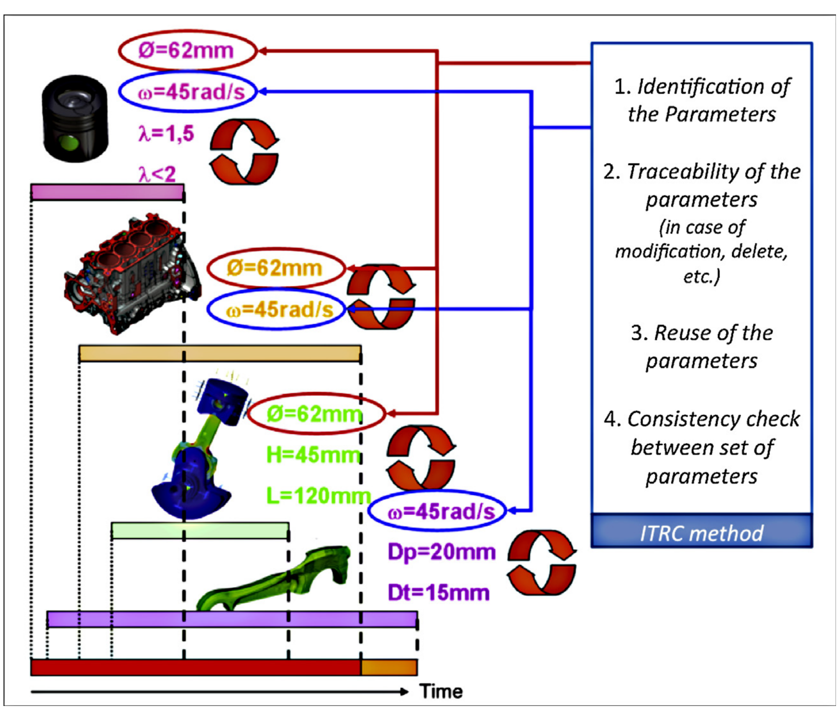

Fig. 1. ITRC issue.