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Method and Tools for the Effective Knowledge Management in Product Life Cycle

S. Tichkiewitch

Abstract The analysis of the factors linked to the life cycle of a product shows the need of the integration of the actors acting in this cycle and of their different cultures. For such integration, the concurrent engineering has to use a multi-view cooperative integrated design modeller taking into account a product model and an activity model. This modeller must be linked with a knowledge management system. This chapter presents three examples of industrial application of integrated design in the sectors of automotive, metallurgy and wood furniture's.

Keywords Integrated design · Product life cycle · Knowledge management

1 Introduction

Results of actual product designs are the combination of different concerns such as concurrency, globalization, environment, innovation, complexity or cost. The open world-wide market proposes to the customer a lot of choices that increase the concurrency among the firms, asking them to put on the market a product with short life duration at the better price. In order to reduce the costs, entrepreneurs do not hesitate to transfer the manufacturing of the product in low labour cost countries, that imply to take into account new cultures when we want to introduce the manufacturing constraints during design process, but also increase the CO₂ emission due to the logistic transportation. The reduction of the time a product can survive on the market pushes the designer to innovate to be the first on this market and to take advantage. Innovation is often the result of technology transfer and only can be done by understanding different cultures too. Complexity is

link to the fact that many products are now the result of more than one technology (mechanics, electricity, electronics, software...) which interact the ones with the others and cannot be apprehended by only one person.

In order to take into account these global factors in the design process, we need to ask the different actors being concerned with one aspect of the life cycle of the product to act in an integrated design process. The description of this integration in design will be the subject of the second chapter. In the third chapter, we will treat about the knowledge management as knowledge is the main object that the actors have to share. Industrial application of integrated design will be the object of the fourth and last chapter.

2 Integrated Design

In order to optimize the global cost of a product (cost to design, to manufacture, to put at disposal, to use and to maintain, to recycle or to destroy...), integration requires embracing the whole of the phases of the life cycle of the product [1, 2]. This can be made by putting in the same place the whole of the people intervening on the product at one moment or another of this life cycle. Thus we saw setting up in the 90th the "project space" at Renault or the "square field" at Facom [3]. But it is not sufficient to gather people around the same table if it is wished that they communicate. Still is necessary that they can be included by having a common culture. It is necessary to create objects of exchange to create potential links.

If each trade built a vernacular language for its own use, there exists only little of universal language allowing a common understanding. The geometry belongs to these universal languages, and this is why the CAD software developed also quickly because any trade uses the geometry. But other concepts are exchanged only by two specific trades and require to be jointly defined. These common concepts form intermediate objects, objects of mediation, basis of the vehicular

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language. It is the case for example of a bur on a stamping part which is carried out by the forger but is removed by manufacturing.

One of the effects of the globalization makes that the actors can be distant several thousands of kilometers and that they cannot be joined together around the same table. It is then necessary to create a virtual space of meeting, with access to a common database and with communications tools.

We postulate that to carry out a good integration, the actors must react to the just need. This means that an actor must be able to add to the common pot a constraint as soon as it feels the need for this constraint, but only if it can justify this need. To preserve these justifications makes it possible to spin the web of the relations binding the various data. With the just need, the product is defined by a process of emergence. The total definition of the product is done more and more finely, on the basis of a vague unit to arrive at a very precise image.

Belloy showed that a first phase of the study is the work of the technologists, people able to choose some physical principles making it possible to answer a function and to extract the various technological solutions from them [4]. They carry out coherent choices to answer the various functionalities of the problem and this until defining the set of functional surfaces. For example, these surfaces can be a technological surface (gears or bearing), a surface support of a flow of fluid (blade of a turbine) or an aesthetic surface. It is when the technologists listed the whole of the functional surfaces which it is time to join together the various actors of the life cycle of the product to make emerge a solution.

Complexity is taken within the definition of Nam Suh, based on axiomatic design [5]. In Fig. 1, the design passes from a domain to another (customer, functional, physical and process) by a linear transformation of the variables (for example of the functional requests to the parameters of design), transformation which can be put in the shape of a matrix.

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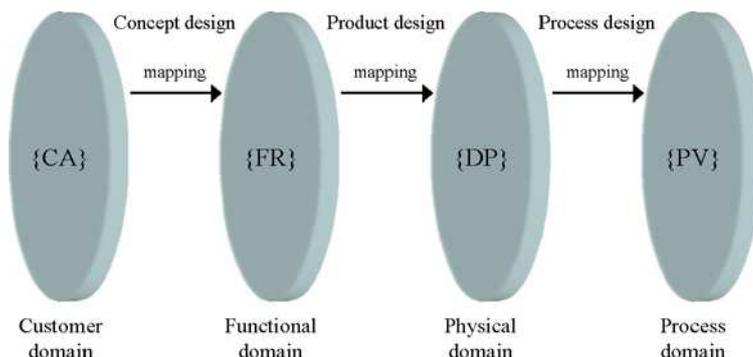


Fig. 1 The axiomatic design from Nam Suh

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \\ FR_4 \end{Bmatrix} = \begin{bmatrix} X_{11} & 0 & X_3 & 0 \\ X_{21} & X_2 & X_3 & 0 \\ X_{31} & 0 & 0 & 0 \\ X_{41} & X_2 & X_3 & X_4 \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \\ DP_4 \end{Bmatrix}$$

If the matrix is diagonal or triangular, there is a single step to pass from the functionalities to the parameters and we speak about noncomplex problem. In all the other cases, the problem is complex. The goal of a team of design is of course to find if possible a noncomplex solution to facilitate the adaptations of the parameters and to lead toward a robust design. But without knowing a priori the solution at the beginning of the design, we cannot know if the solution will be or not complex. At most can we hope for a non-complex solution and we speak in this case about imaginary complexity.

Pimapunsi [6] proved that integrated design can solve imaginary complex problems. Each column of the matrix can be regarded as representative of a contribution of a specific trade (Fig. 2). In this matrix, one of the lines must be with only one element not equal to 0. The corresponding actors, with the just need concept, must be able to associate a value with this element making it possible to bind a parameter to a functionality and to deduce from them the influences from this parameter on the various functions to be filled. The removal of a column gives an imaginary noncomplex system of a lower order.

Like previously said, integrated design request cooperative work tools being able to be used remotely and in a non-synchronous way. The co-operative design modeller

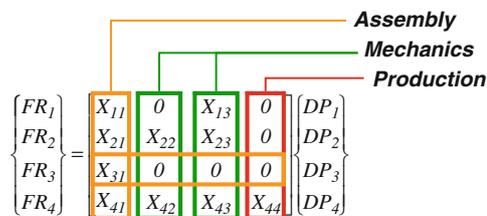
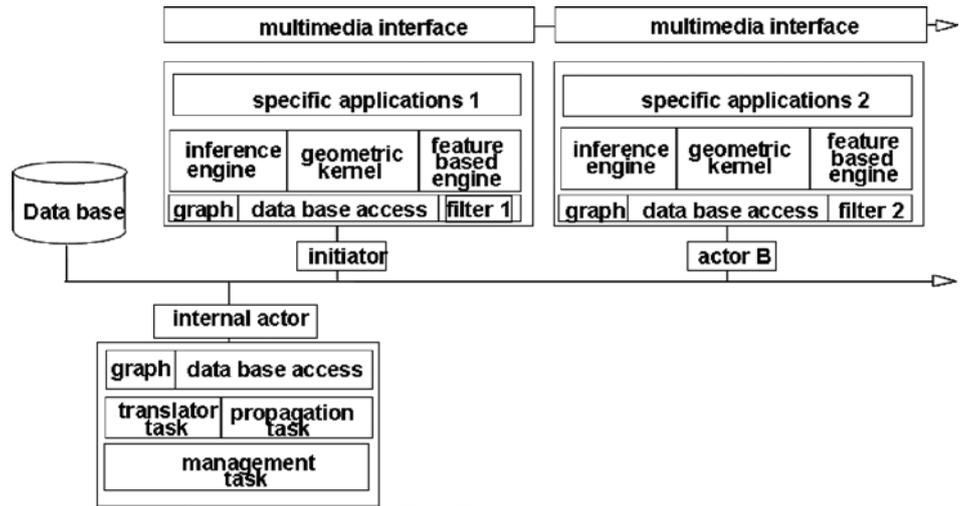


Fig. 2 The matrix of an imaginary complex problem

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Fig. 3 The cooperative design model



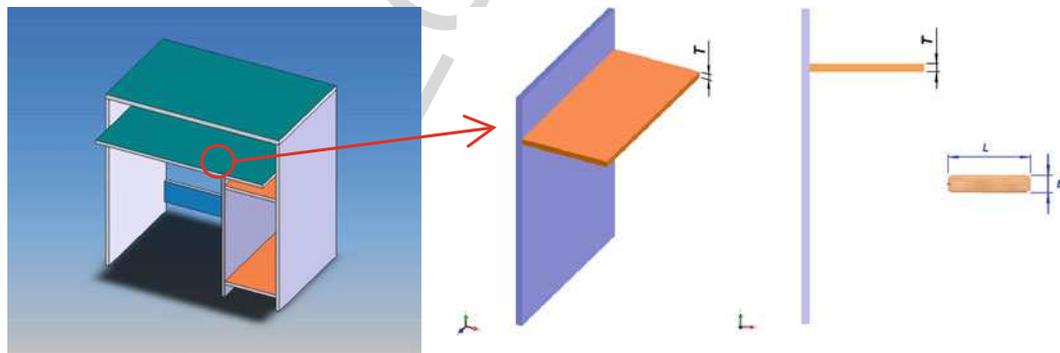
CoDeMo was created to meet this need [7]. Various actors can connect themselves to the same database, by representing each one a specific trade (Fig. 3). They have at their disposal some tools for the management of the access to the database, for the management of features, a geometrical engine and also tools for specific applications. A product model is used to store the whole of formal information which must be exchanged between the actors. The access to an informal communication system also allows intermediate exchanges. Some internal programs make it possible to put at disposal such tasks as translation, propagation or control of time.

These tasks constitute the internal actor. We can find in [8] more information relatively the product model used in CoDeMo and the multi-view representation of the product.

3 Knowledge Management

A product model is composed of a knowledge model and a data model. Knowledge can be factual or temporal [9]. Factual knowledge is the framework of the data model. We

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If a dowel is applied to fix a pair of parts
Then those two parts must be drilled
 If the thickness of the horizontal part is T mm
Then the diameter of the dowel is not more than $T/2$ mm
 If the diameter of the dowel is D mm
Then those two parts must be drilled with diameter D mm
 If the length of the dowel is L mm
Then the horizontal part is drilled $2L/3$ mm while the vertical part is drilled $L/3$ mm



Fig. 4 Knowledge about the assembly of particle board

160	Component_Name
161	Dowel Assembly name
162	Translation
163	Component Drilling Manufacturing name_1_USI
164	Component Drilling Manufacturing name_2_USI
165	Link name diameter name_diameter
166	Link name length length
167	Link name_1_USI diameter name_1_USI_diameter
168	Link name_1_USI thickness name_1_USI_thickness
169	Link name_2_USI diameter name_2_USI_diameter
170	Link name_2_USI thickness name_2_USI_thickness
171	Relation name_diameter name
172	name_1_USI_diameter name_1_USI_equality
173	Relation name_length name
174	name_1_USI_thickness name_1_USI_1/3thickness
175	Relation name_diametre name
176	name_2_USI_diametre name_2_USI_equalite
177	Relation name_longueur name
178	name_2_USI_epaisseur name_2_USI_2L3epaisseur
179	@

181 **Fig. 5** A translation file

182 use as factual knowledge features, with their names and their
 183 contexts, their characteristics and their behaviours. Temporal
 184 knowledge is used to make progress the resolution of the
 185 problem. We use for that the production rules, with a premise
 186 and a conclusion.

187 Before starting any design process, the different actors
 188 have to formulate the specific knowledge of their trade using
 189 the two previous models. As an example, Fig. 4 gives a series
 190 of rules allowing the assembly of a piece of furniture in
 191 particle boards and using a solution of dowel. A dowel is
 192 defined as a feature belonging in the context of technology.
 193 Its diameter and its length are 2 of their characteristics. If
 194 we want to use a dowel to fix 2 boards, we need to drill 2
 195 holes with some specificity. This rule permit to connect the
 196 design view (shape and size of the furniture), the technolog-
 197 ical view (the different boards and their relative positions),
 198 the assembly view (with the different possible hardware) and
 199 the manufacturing view (with tooling operations). As soon
 200 as the designer wants to use such dowel as an assembly solu-
 201 tion, CoDeMo will use a translation file (Fig. 5) in order to
 202 inform the different actors that they are concerned. The trans-
 203 lation file describes the evolution of the product model and
 204 CoDeMo can propagate the request in the different views.
 205

207 4 Industrial Applications

210 We present in this part three industrial applications which
 211 help us to build the integrated design theory and the CoDeMo
 212 application.

4.1 Integration of the Recycling of a Car During Design Process

In his thesis [10], Gaucheron shows that the design of a car is very dependent of the societal and economical criteria. The ecological solutions are more expensive and can be taken into account only if the regulation imposes a minimum ratio of recyclability. It is fact impossible to introduce a recycling parameter with the traditional parameters of the design: quality, cost, weight, time. Recycling will not be taken into account in the dynamics of a project. It is necessary that there are preliminary exchanges between the designers and the recycling team to find compromise solutions well before the setting in project. This work showed the importance to define a vehicular language making it possible to have objects of shared interest between the actors. Working on the cleanup methodology for the liquid of the windshield washer, Gaucheron showed the necessity to strongly be interested in the lid of the bottle because this lid of course interests the recycling to allow the cleanup with a nozzle, but also the technology for its manufacture, the architecture for its setting in position in a situation easy to fill.

A study on the recycling of a dashboard led to a solution suggested in Fig. 6. The board is not being encumbered with multiple accessories, is easily extracted, of low apparent density and made out of polypropylene charged with linen.

4.2 Integrated Design of a Die for Aluminum Extrusion of Profiles

The design of a die for the extrusion process is not an easy task because the extrusion process is very sensitive to different parameters such as dimensions, temperature of the billet, velocity of the mandrel . . . The process cannot be simulated by numerical analysis due to the very high speed for the strain ($> 10^3 \text{ s}^{-1}$), the constitutive equation being unknown at this



213 **Fig. 6** Recyclable dashboard of a Renault concept car

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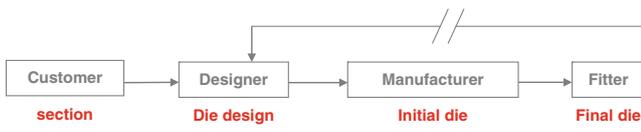


Fig. 7 The design process of a die for aluminium extrusion profile

speed, to the non stationary, non linear and 3D problem, to the fact that flow simulation software considers rigid envelop when the tongue at the die is mainly flexible.

For economical reasons, the die designer cannot pass more than 8 h on the design of a die, which would be largely lower than the time assigned for a basic simulation. As shown in Fig. 7, the design process starts with the section for the profile requested by the customer and proposes an initial die which has to be fit during the first step of the extrusion

process. Figure 8 shows that this fitting is not an easy matter to achieve and can be carried out only by fitters which have great experience. As this person is not being the initial designer of the die, it has there only very little feedback to define precise rules of design.

Noomtong added to CoDeMo [11] a case based reasoning module to capture the knowledge of the fitter and to facilitate the initial proposal for the design of a die. Figure 8 gives an example of such proposal for a hollow die (Fig. 9).

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4.3 Integrated Design of a Wood Furniture Made of Particle Boards or Fiberboards

Starting from the shape and the dimension of the furniture proposed by a designer, an integrated design software for the design of wood furniture has been realised during



Fig. 8 Some results for the fitting of a die

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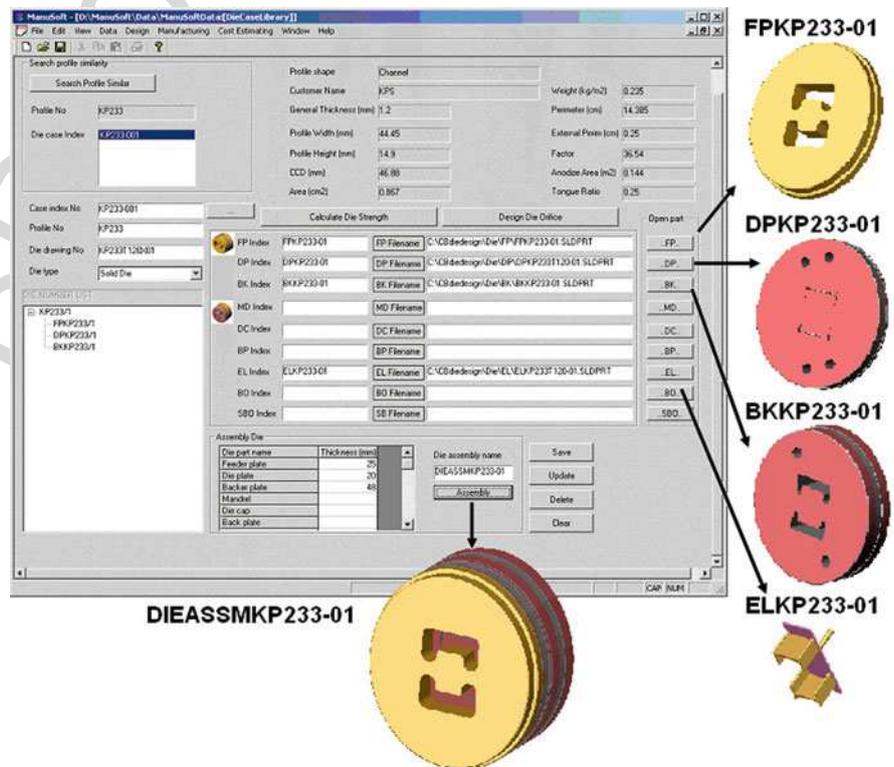


Fig. 9 The integrated die design for extrusion profile

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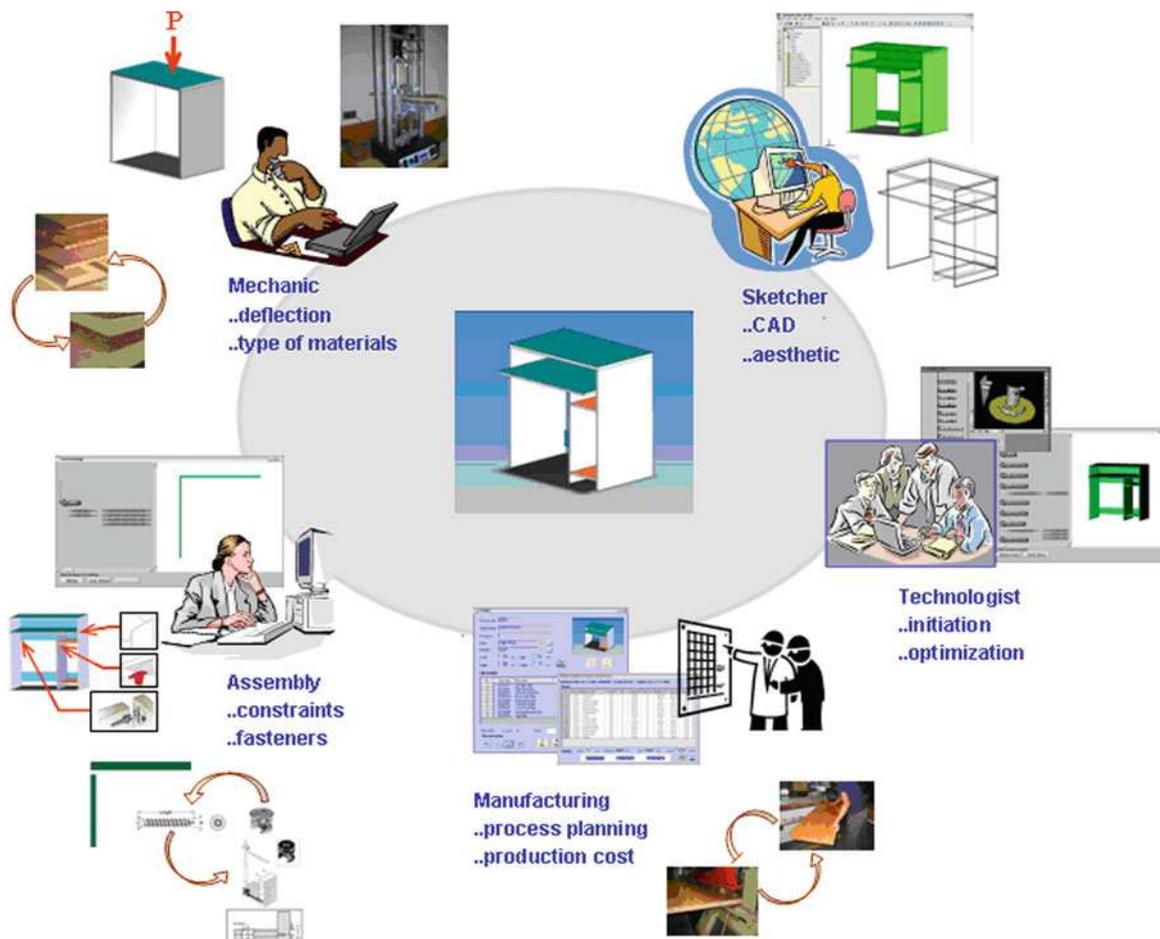


Fig. 10 Integrated design of a wood furniture

the PhD of Pimapunsri (Fig. 10). Such process needs the cooperation of the designer for the initial proposal, of the technologist for the description of the furniture in different boards, of a specialist of assembly to chose the best hardware to connect the boards, depending of the request quality and cost, the mechanical engineer to define the thickness of the board, depending of the norms and rules of the profession and of a manufacturer to define the planning and cots of the production system [12]. This work showed the capacity to design non complex solution using the integrated design process.

5 Conclusions

In this chapter, we had shown that the integration process in design is mainly a problem of coordination of actors. In order to communicate, the participants to the design process must first formalize their own knowledge before to exchange

about this knowledge with the other actors in order to find some common interest and to define vehicular objects.

Using a multi-actors and multi-views cooperative design modeller, whole the actors of the product life cycle can interact on the design process with the just need concept in order to emerge the solution. This allows finding a non complex solution, key for a robust design.

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372 **Chapter 3**

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