

APPLICATION OF DESIGN FOR MANUFACTURING APPROACH TO DESIGNING A SHAFT OF A GEARBOX, IN CATIA V5

Daniel-Constantin ANGHEL¹, Nadia BELU¹

¹University of Pitesti, Romania

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Abstract: *This paper presents a way to implement some aspects of the concept of design for manufacturing, to design a product in the automotive industry. The product to be developed is a shaft of a gearbox.*

Since the early stages of design of the product, the design of manufacturing technology will begin. The design errors will be detected without the high impact on technology of execution of the piece.

The integration of this concept in product design enables designers to optimize the technological form of the product.

Keywords: design for manufacturing, design of product, CATIA V5

INTRODUCTION

Perrin [1] says that 75 to 90% of project/product costs are determined during the first 7 to 8% of development time. In order to increase performance of the product, it is important to take into account as early as the design phase all stages of product lifecycle, like the assembly, the manufacturing, the distribution and the maintenance etc. Also, the results of the design process can change the cost of manufacturing a product by 50% or more. This is therefore, the logical stage, at which to invest more time and effort into getting the design right first time. "The decisions made during the design process have a great effect on the cost of a product but cost very little."

DESIGN FOR MANUFACTURING (DFM)

Design for manufacturing (DFM) is an approach in which the products are designed so that their manufacture is carried out efficiently.

Design for manufacturing approach takes into account a range of information on:

- Sketches, drawings, product specifications and design alternatives;
- The assembly process;
- Estimate the manufacturing costs, production volume and the duration of manufacturing etc.

Design for manufacturing can be described by using the algorithm in Figure 1.

In order to estimate the cost of manufacturing can be used diagram presented in Figure 2, [2].

Manufacturing costs are the total costs in the system inputs (raw materials, energy, equipment, etc.) and exits from the system (finite parts, waste and disposal costs).

To achieve the best conditions a DFM approach will consider the following issues:

- The functional role of the piece to be designed;
- Number of parts to be made;
- Prescriptions quality piece;
- The material of the piece will be performed;
- Suitable manufacturing technology.

There have been proposed more models for studying the design activity. Some models are prescriptive, others are descriptive.

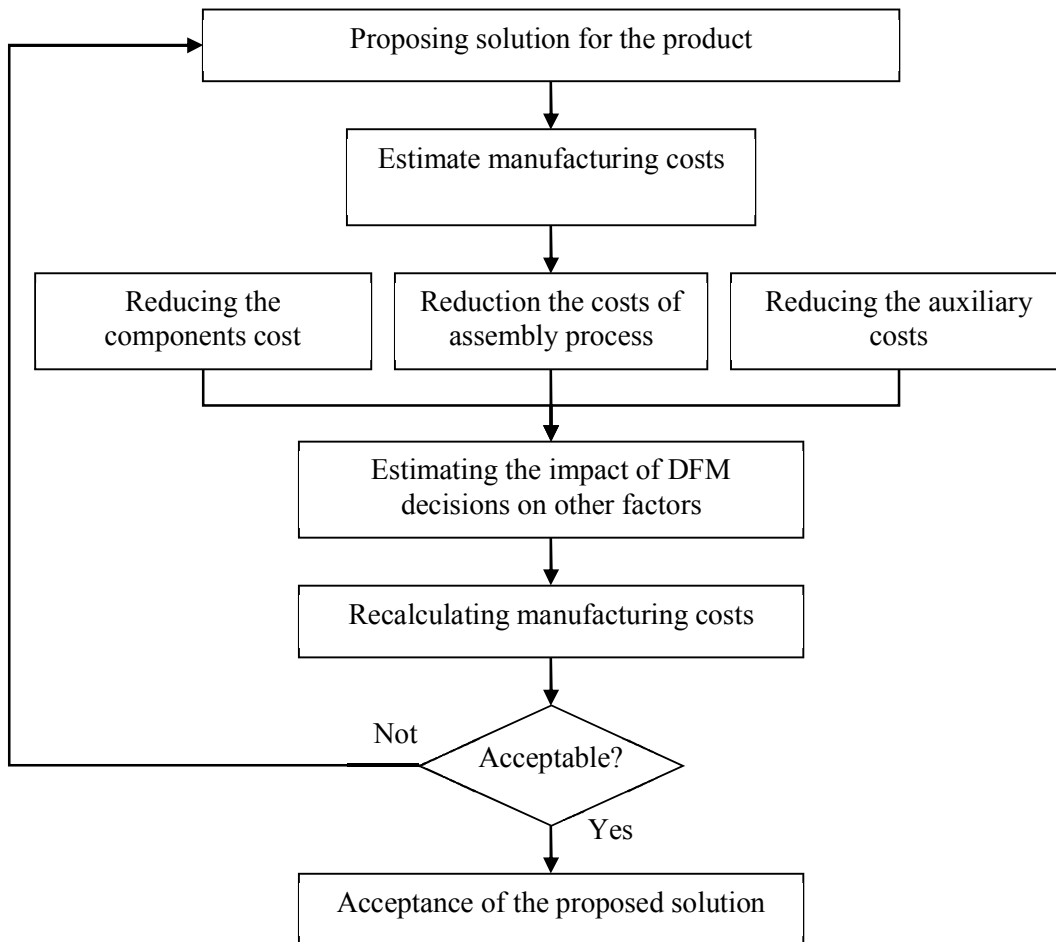


Fig. 1. DFM algorithm

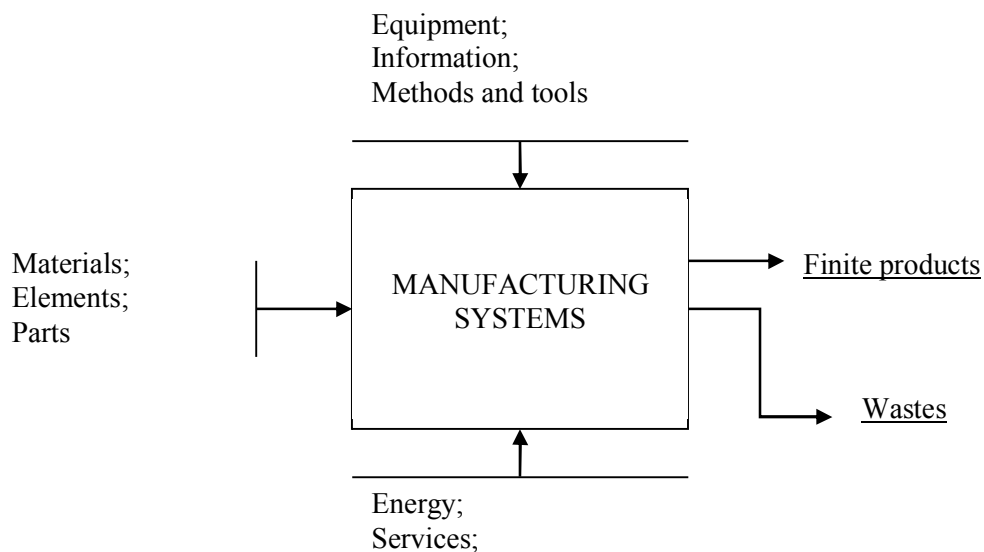


Fig. 2. Scheme of the manufacturing systems

According to the prescriptive model proposed by Pahl and Beitz [3], the design process implies a succession of stages. During these stages, the designers suggest theories, concepts, and suppositions to resolve the design problems. For our study we have use the model proposed by Pahl and Beitz in parallel with the model of developing manufacturing process, figure 3.

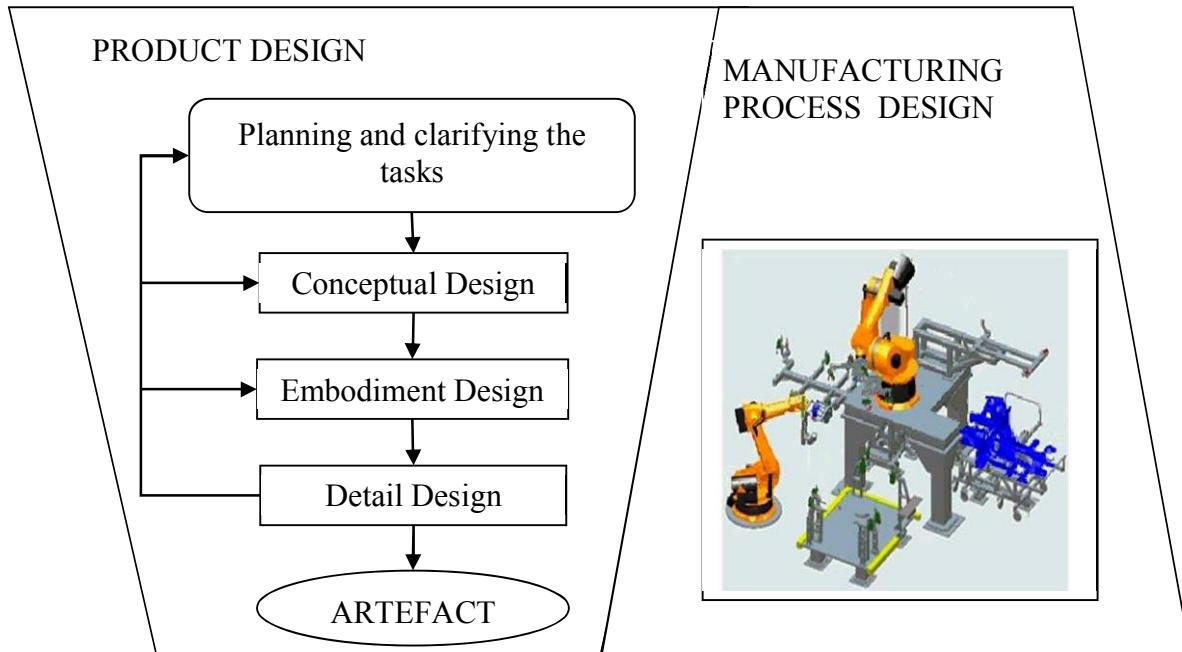


Fig. 3. Parallel development of product/process

CASE STUDY

The case study was conducted in Laboratory Design and Product Development at the University of Pitesti.

Planning and clarifying the task: All design challenges are ambiguous. The answer is always uncertain or ambiguous. Not all design solutions are equally good, however, and some are definitely wrong.

A shaft within a gearbox has been designed, taking into account its manufacturing technology. The shaft is part of a gearbox; on it is a pulley to lift a load of 1500N.

Conceptual Design: Conceptual design is just like it sounds the generation of a concept. Some of the terms used by Pahl and Beitz to describe it are: identify essential problems, establish function structures, search for solution principles, combine and firm up concept variants.

As a starting point, was considered the following functional diagram:

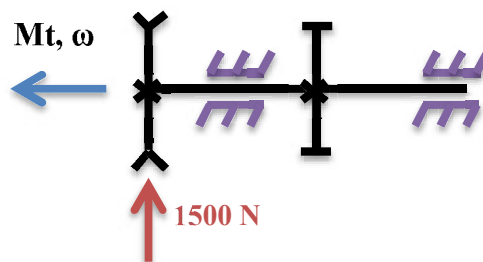


Fig. 4. The functional diagram

The functional diagram contains a pulley with a diameter of 200mm, a gearwheel, two bearings and a shaft. The wheels are fixed on the shaft by the feathers.

Functional scheme leads to establishing a constructive form of the shaft (figure 5), this form will be gradually transformed into a technological form of the shaft. This technological form will be obtained based of the restrictions of manufacturing technology.

The torque of the shaft is: $M_t = F \cdot D / 2 = 1500 \cdot 200 / 2 = 150000 \text{ N} \cdot \text{mm}$.

For the shaft was chosen the steel 41CrNi12, $\tau_{at} = 75 \text{ MPa}$. The minimum diameter of the shaft should be less than 27 mm. We choose $d = 30 \text{ mm}$.

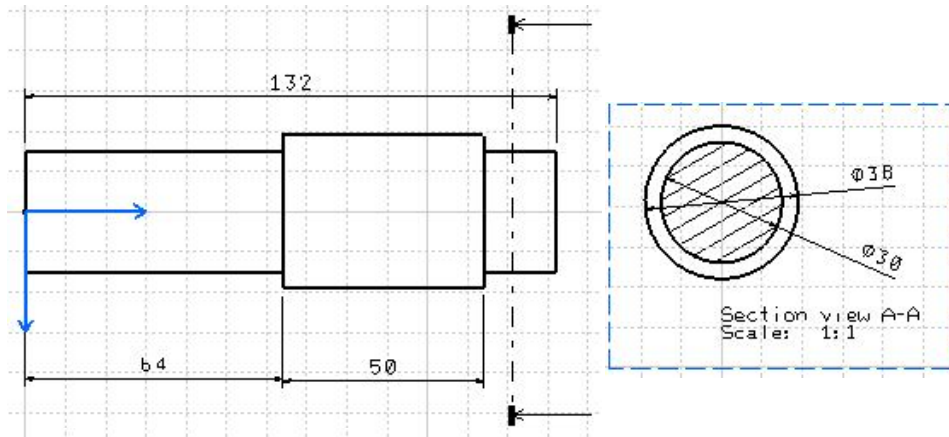


Fig. 5. The constructive form of the shaft

Embodiment Design: Embodiment design consists of preliminary layouts and configurations, selecting the most desirable preliminary layouts and refining and evaluating against technical and economic criteria.

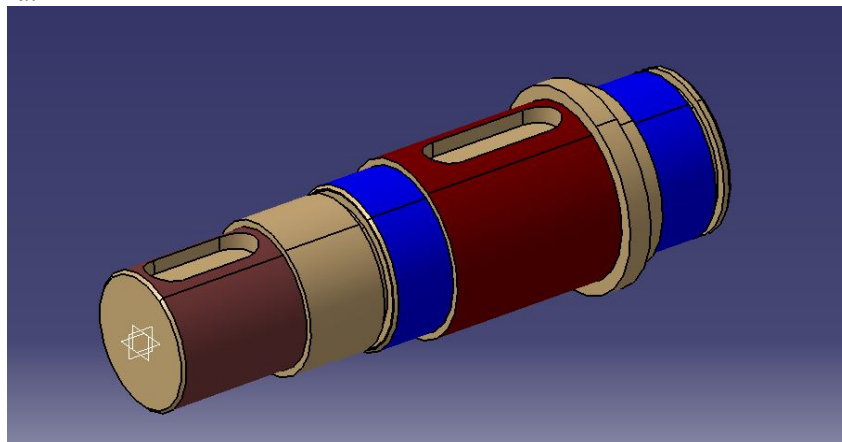


Fig. 6. Virtual prototype of the final product in CATIA V5

In order to reduce manufacturing costs, the different zones of the shaft, which will mount assembly components, will be isolated and will be accurately processing and another zones will be processing less precise.

Regarding technological restrictions in certain zones of the shaft will be made grooves to increase access of the cutting tools.

Depending on the manufacturing technology adopted, the technological form can be quite varied from case to case.

Another factor in determining the functional form is the possibility of assembly.

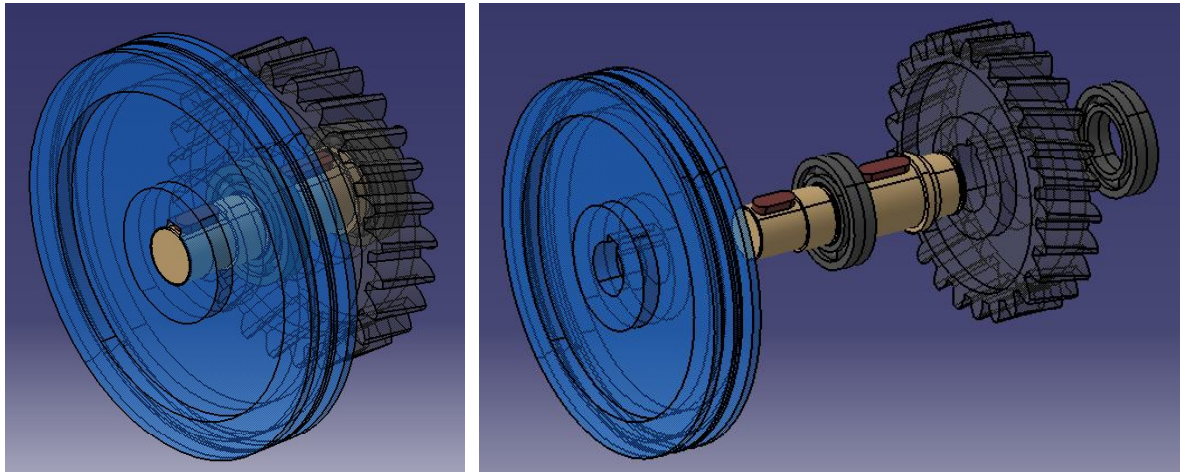


Fig. 7. The possibility of assembly/disassembly

The technological form is transformed for optimize the trajectories of cutting tools, and to simplify their geometry.

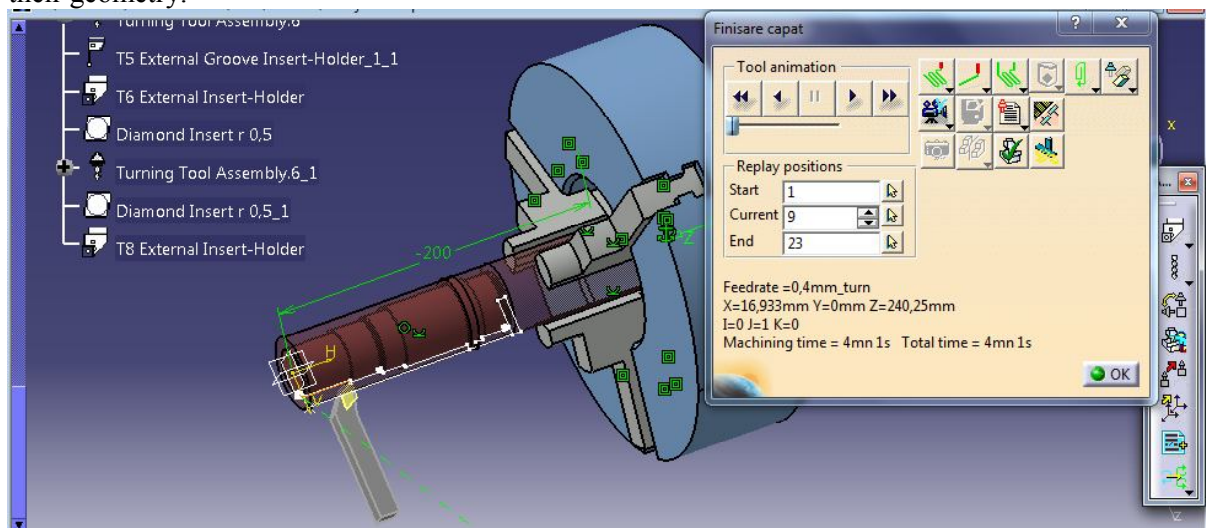


Fig. 8. The trajectories of cutting tools during the machining process

In order to align the piece in rapport at with the reference system of the machine tool, it needs to present a series of orientation surfaces.

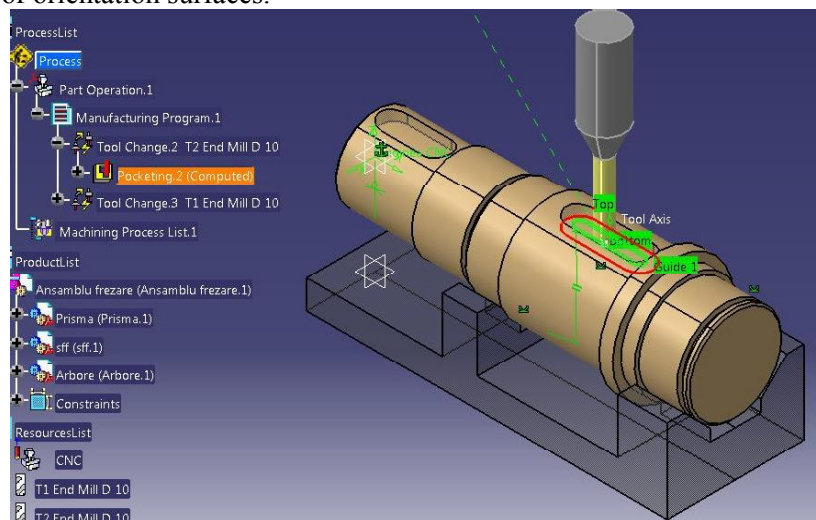


Fig. 9. Aligning the piece in rapport at with the reference system of the machine tool

Detail Design: The detail design includes specifying the materials, the sizes, the type and the size of wheels, where the attachment and assembly holes should be drilled, the size of the holes etc. It requires a lot of skills to specify this multitude of items correctly. Many alternatives and options should be considered during this part of the engineering design processes.

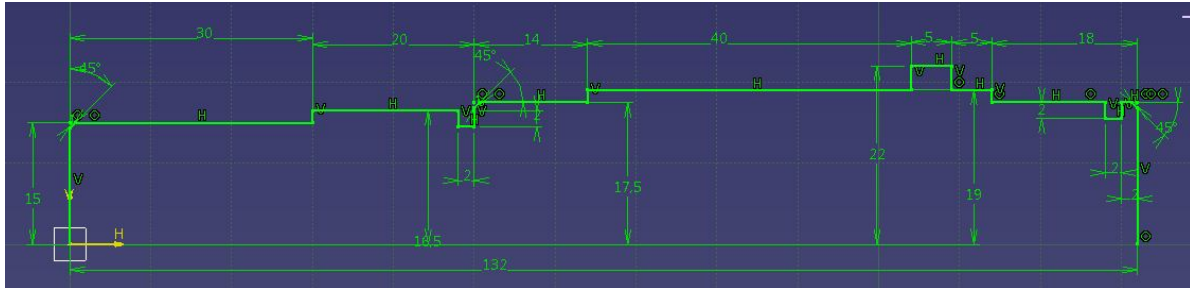


Fig. 10. The sketch of the final product

FINDINGS

Accomplishment of the design steps taking into account the manufacturing constraints makes to occur the iterative cycles during design process. During these cycles, the solutions proposed are subject to change in order to improve or correct certain geometric shape parameters, precision dimensional or material.

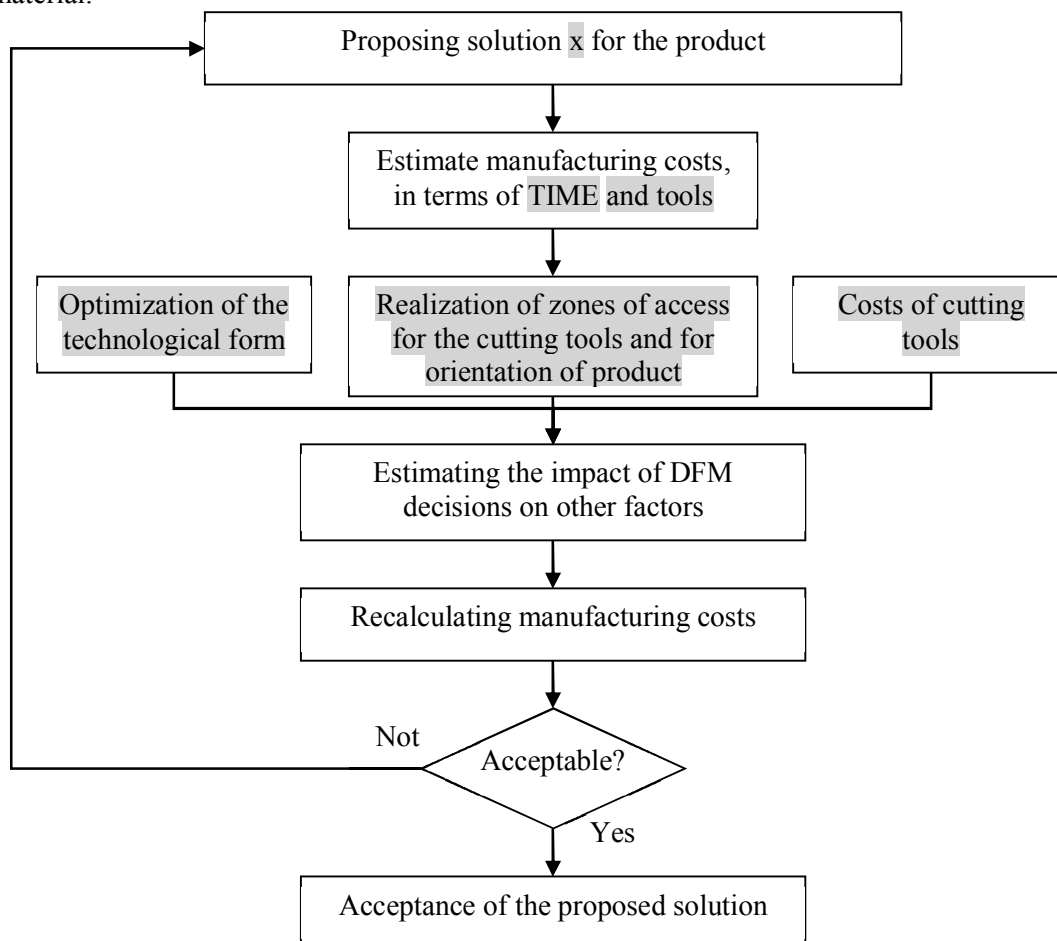


Fig 11. Example of applying of the DFM algorithm

CATIA V5 software enables parallel development of product and manufacturing technology, the shape of the processing zones resulting from tool trajectory optimization process in order to reduce manufacturing costs.

CONCLUSIONS

The software CATIA V5 enables product designers and manufacturing technology to work in parallel, allowing the establishment of technological form in parallel with the establishment of its manufacturing technology.

The parallel development can reduce design time, has influence on product realization costs and allows involving young designers with little experience.

On the other hand, at this stage, the costs increase much compared to the classical situation because the software is expensive, the specialists have need of expensive training courses, and lack of experience must be complemented by the support of software.

However, it is very advantageous from the point of view of the overall costs, and of the development time of the product.

In addition, successive changes on the form of the final product can be easily monitored, and any errors or deficiencies can be remedied in a short time, which in the classical approach requires a laborious and lengthy work.

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