UNIVERSITY OF PITESTI SCIENTIFIC BULLETIN

Faculty Of Mechanics And Technology AUTOMOTIVE series, year XXII, no. 26

DESIGN OF A LOW-COST CNC MILLING MACHINE, USING SOME ASPECT OF PARALLEL ENGINEERING CONCEPT

Daniel – Constantin ANGHEL[1*], **Mihai Octavian CRĂCĂNEL**
[1]University of Pitesti,

Article history:
Received: 11.08.2016; Accepted: 10.10.2016.

Abstract: *At the present time, the development of manufacturing technologies based on CNC systems allows of the industry to obtain the complex products at high quality, in a short period of time. Thus, in the universities of engineering exist a lot of courses of CNC manufacturing systems.*
The practical training is essential to improve students learning in design and manufacturing engineering. In the area of CAD / CAM, the high cost of CNC machines can be an impediment for giving to the students the possibility to interact with the CNC machine.
To resolve this impediment, it was decided to design and to produce a low-cost CNC machine.
This paper describes the development process for this machine. In order to reduce the costs, we have used a hardware Arduino UNO, a CNC shield, open source software (Arduino, G-Code and GRBL). The design was made in Catia V5 and SolidWorks. Most of the parts of the machine was manufactured and assembly in the laboratories of Faculty of Mechanics and Technology from University of Pitești.

Keywords: CNC machine, Arduino, open source hardware and software, low-cost concept.

INTRODUCTION

Parallel engineering is a systematic and comprehensive organizational approach of the company, based on the simultaneous and integrated comportment of the product life cycle, implementing multidisciplinary teams working in symbiosis and aiming at common production cost-time- quality. The main characteristics of parallel engineering are:

- parallel implementation of development activities;
- integration and consideration of downstream activities during the upstream activities;
- creation of multidisciplinary teams bringing together different actors involved in the product development project;
- optimization of existing development processes.

In the field of design, the main interests of implementing parallel engineering are reducing costs, reducing design and marketing delays, and improving the quality of products [1, 2]. Indeed, the integration of "downstream" trades in the design phase makes it possible to detect errors very early in the development process. The quality of the products is thus improved, the additional costs due to the modifications are eliminated and the time to market is reduced.
The implementation of parallel engineering is based on two fundamental principles: *the parallelism of tasks and multidisciplinary teamwork*.
The notion of parallelism can have two different meanings. The first concerns the comparison of development activities, in particular the simultaneous design of the product and its production process. The second concerns the simultaneous development of several solutions in order to make the best choices at the earliest and thus avoid costly iterations.
The principle of multidisciplinary team work makes it possible to take into account, at each level of development, considerations relating to the whole life cycle of the product. Thus, for example, manufacturing constraints must be considered in the early stages of design.
It should be noted that the transition from the sequential approach to the parallel engineering requires a change in the management process of the design process. The sequential method

*Corresponding author: daniel.anghel@upit.ro

has the advantage of clearly indicating to the different managers the appropriate moments of intervention on the future of the project where the information elements necessary for control and decision-making are available. With the second form of organization, managers have to adopt new ways of working in order to control the progress of the activities and their interaction. In this, the management approach is profoundly altered.

PARALLEL DEVELOPMENT OF PRODUCT/PROCESS

Parallel development of product/process can be described using the two algorithms, Pahl and Beitz algorithm and DFM algorithm, showed in Figure 1.
The 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.

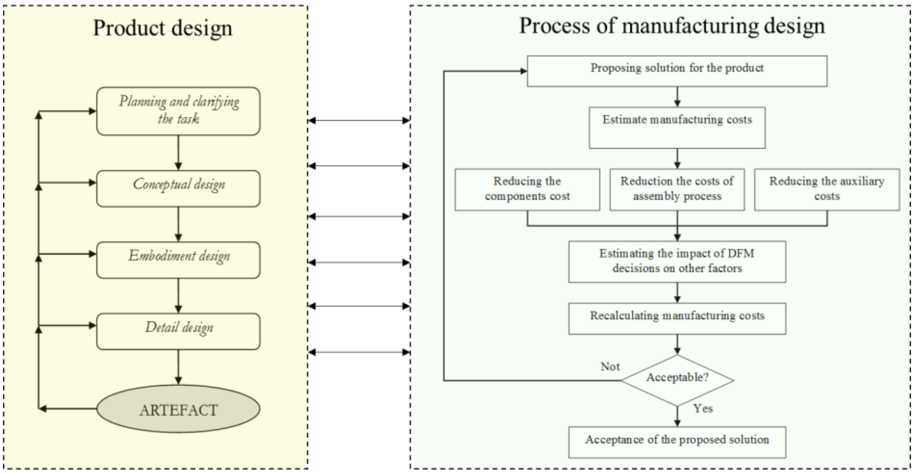

Figure 1. Parallel development of product/process algorithm

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.

DESIGN OF THE PRODUCT

The design of the product was realized in the *Laboratory of 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 CNC machine has been designed, taking into account some aspect of parallel engineering concept.
This machine is destined for the CAD/CAM laboratory of the universities and will be a cheap solution for giving to the students the possibility to interact with an CNC machine.

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 representation:

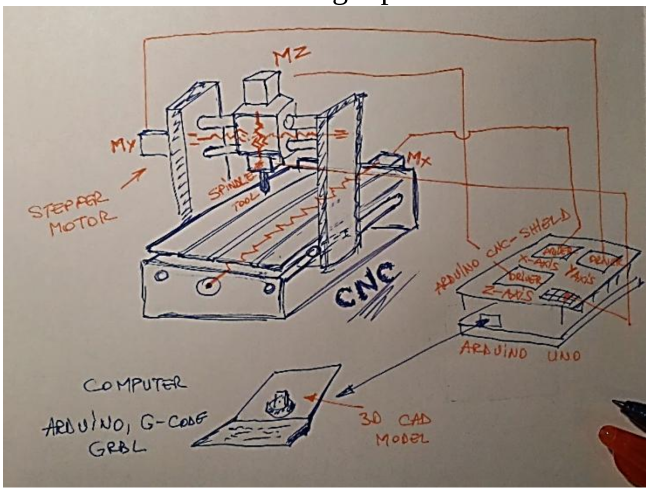

Figure 2. The schematic of the CNC machine concept

The schematic contains the computer, the concept of the CNC machine, the CNC shield with an Arduino Uno board, the drivers for the motor stepper and the logical and electrical connections.
This representation leads to establishing a constructive form of the CNC machine, this form will be gradually transformed into a technological form of machine (all of the parts of the machine will be optimized in order to minimize the costs, the time to manufacturing, to make simpler the assembly of the product). All this technological forms will be obtained based of the restrictions of manufacturing technology.

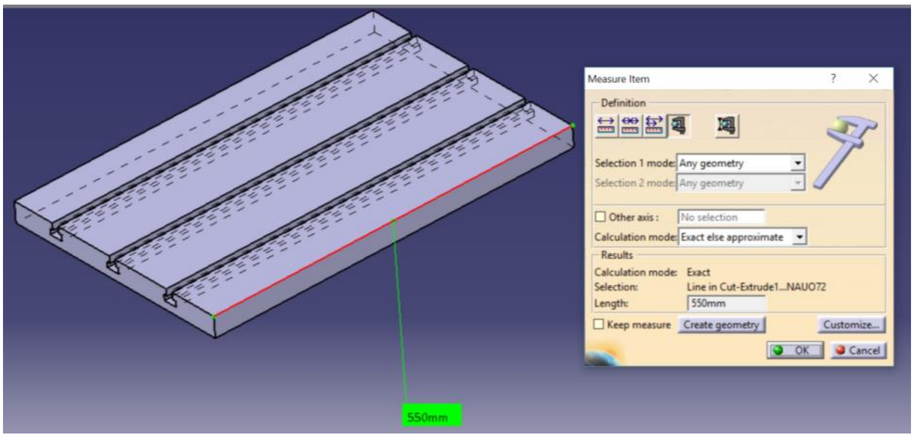

Figure 3. The constructive form of machine tool table

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.

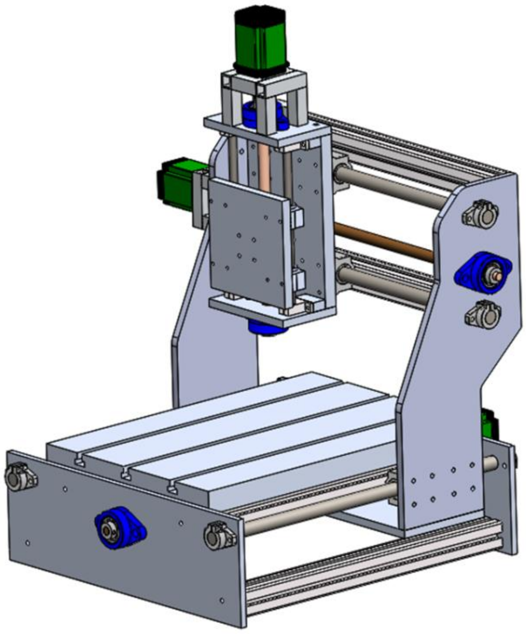

Figure 4. The 3D prototype of the CNC milling machine

In order to reduce manufacturing costs, the different zones of the machine tool table, which will mount assembly components, will be isolated and will be accurately processing and another zone will be processing less precise.
Regarding technological restrictions in certain zones of the machine tool table 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/disassembly.
The technological form is transformed for optimize the trajectories of cutting tools, and to simplify their geometry.

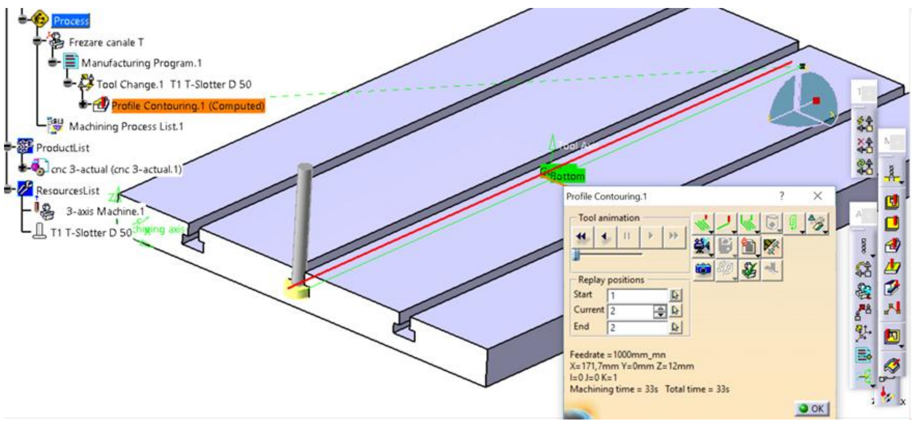

Figure 5. The trajectories of cutting tools during the machining process

Detail Design: The detail design includes specifying the materials, the type and the size of surfaces, 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.

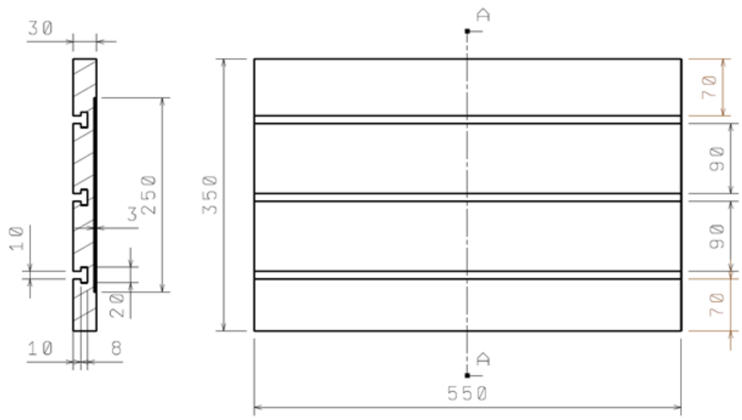

Figure 6. The sketch of the final product

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.

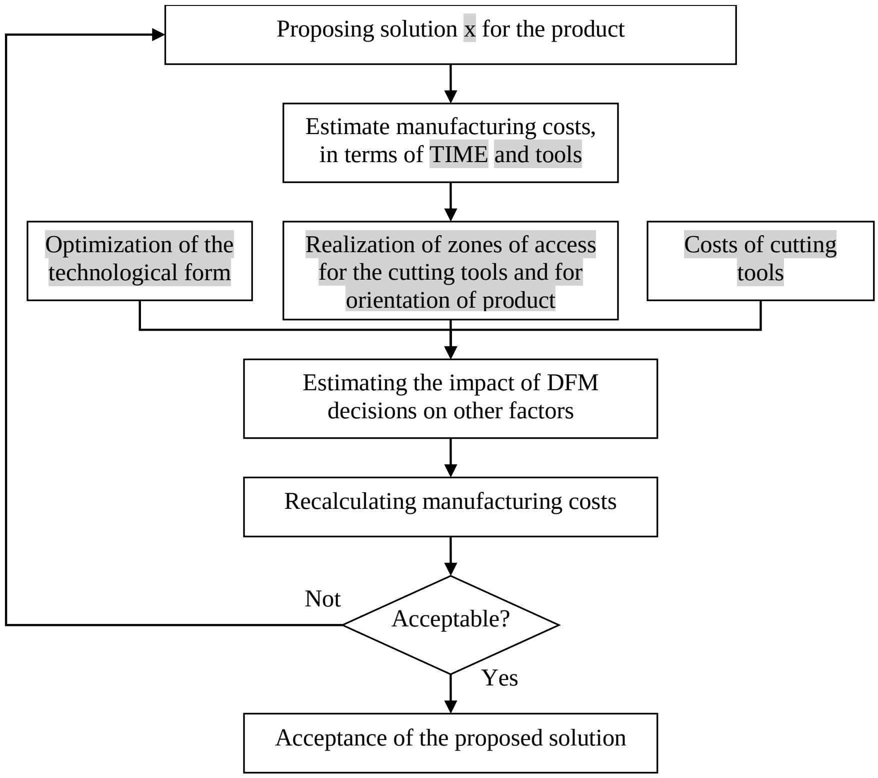

Figure 7. Example of applying of the DFM algorithm

CATIA V5 and SolidWorks 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 two-software utilised for designing the product give to the designers the possibility to develop in parallel the product and the manufacturing technology, allowing the optimize the technological form in parallel with the 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 has 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.

REFERENCES

[1] PERRIN, J., Concevoir l'innovation industrielle. Méthodologie de conception de l'innovation, CNRS Editions, 2001;
[2] ANGHEL, D., RIZEA, A., Proiectarea produselor, Editura universitatii din Pitesti, 2008;
[3] PAHL, G., BEITZ, W., Engineering Design: A systematic approach, Springer-Verlag, 1996;
[4] BOXBERGER, J., SCHLEGEL, D., LEBAAL, N., & GOMES, S. Design Support Based onto Knowledge to Increase Product Reliability and Allow Optimized Abacus Development. In IFIP International Conference on Advances in Production Management Systems (pp. 200-207). Springer Berlin Heidelberg, 2012.
[5] MISZTAL, A., BELU N., Model of areas for identifying risks influencing the compliance of technological processes and products. IOP Conference Series: Materials Science and Engineering. Vol. 145. No. 4. IOP Publishing, 2016.