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Computer-Aided Manufacturing of 3D Workpieces

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Computer-Aided Manufacturing (CAM) assumes to use dedicated software for controlling machine tools and similar devices in the process of workpieces manufacturing. CAM is, in fact, an application technology that uses computer software and machinery to simplify and automate manufacturing processes. CAM is the inheritor of computer-aided engineering (CAE) and is often used conjunctively with computer-aided design (CAD). Advanced CAM solutions are forthcoming and have a large coverage, from discrete systems to multi-CAD 3D domain. CAM does not supersede the necessity of human factor intervention, as production engineers, programmers or operators, but intercedes the knowledge of experimented manufacturing engineers by using performant devices, while enhancing the competences of new professionals by having access to latest modern equipment. CAM runs along with CNC machines. The purpose of CAM-CNC system is to reduce as much as possible the intervention of human factor, thus reducing human error. The present paper follows to highlight the advantages of CAM-CNC system on a 3D workpiece manufacturing.

Keywords: *3D models, Computer-Aided Design (CAD), Computer Assisted Manufacturing (CAM), Computer Numerically Controlled (CNC)*

1. Theoretical background of CAD and CAM techniques.

Few people remember and even fewer still use pen and paper for making 2D design of a workpiece. Imagine what time consuming this is, not even considering the 3D design of the piece, [4]. For these cases computer-aided design, in short CAD, comes very handy. The design engine of CAD is indeed a computer and the specific tool for this is characteristic software. The implementation of CAD in design practice is a true leap in process of development of design strategies and techniques, [8]. Its use does not change the nature of the design process but as the name states it aids the product designer. The designer is the main creator in the process, in all stages, from defining to implementing the design.

The functions of CAD system is to provide the designer:

- Precisely generated and lightly adjustable of the graphical representation of the design.;
- Carry out complex design analysis in shortest time. Using Finite Elements
- Enlist and recall design data unalterably and with high speed.

First uses of CAD were 2D designs compared to nowadays when 3D assemblies can be created, analysed, modelled and used for building prototypes. Using CAD systems has the advantage of decreasing final costs of a product by gaining time with design creation and by precocious detection of its faults.

We can conclude that computer-aided manufacturing, developed with new industrial technologies, going together with computer-aided design systems, to create a workpiece. We can say that CAM systems are congenial with computer numerical control (CNC), [1].

These systems distinguish from previous versions of numerical control (NC) in that diagrammatic information are encoded mechanically. CAD and CAM use computer-based technique for encoding graphical information, there is tendency for the processes of design and manufacture to be incorporated [3].

Nevertheless, the design process must be undertaken with comprehension of the essence of the manufacturing process. The abstract superposition of design and manufacture is representative for the eventual advantage of CAD and CAM and the idea they come in conjunction as a single unit [6].

2. Design and Manufacture a rotor blade of a water turbine

As shown in the previous section, CAD and CAM techniques go altogether in most cases. The most common situation where CAM systems are involved in industrial processes is when using CNC machines.

CNC machines (computer numerically controlled) are the improved versions of conventional industrial machines used for manufacturing assembly parts. A comparison between the two versions is shown in figure 1. Few of the advantages brought by CNC machines are flexibility, precision, reproducible, an improved processing and possibility of reducing or eliminating human intervention.

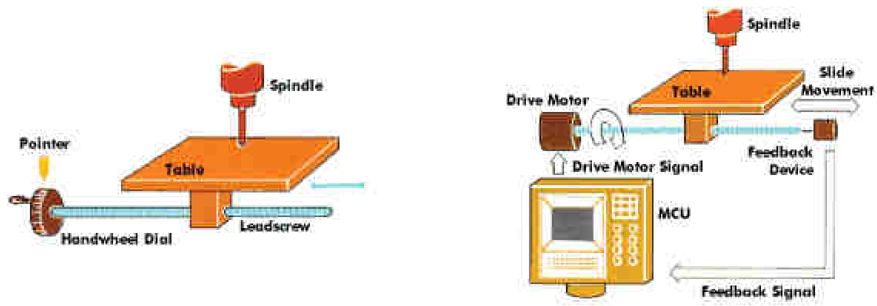

Figure 1. Conventional machine VS CNC machine

A 3D model of a rotor blade is shown in figure 2. The model is as well analyzed under the aspects of its deviations. The issues of interest are red shape marked parts of the designed piece. The colored scale is used to easily show areas that are within tolerance, bordering tolerance, and out of tolerance. Green marked areas have no deviation. Red and yellow marked areas need a plus of material up to 7.5mm, respectively up to 10mm, while blue and green areas need less material down to 5mm, respectively down to 10 mm.

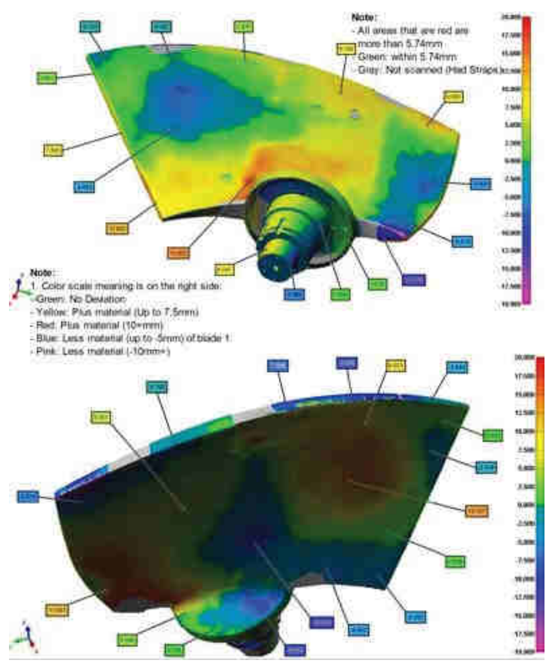

Figure 2. 3D shape design of a rotor blade from a water turbine [9].

The purpose of the design is as well to validate the overall condition of the rotor blades and to establish if they would be suitable to rehabilitate through welding, grinding and machining.

For manufacturing a rotor blade we use a vertical milling machine in three axes DMC 635v (figure 3), product of DMG-Gildemeister, Germany, that can process metal parts, with maximum travel on the three axes of X 635mm, Y 510mm, Z 460mm, maximum spindle speed of 10,000 rpm and maximum feed of 20,000 mm/min. It has a tool magazine for 20 tools with a fast double gripper, linear bearing guideway, conveyor for chip evacuation, work table with a fastening piece holder, pump for cooling liquid of the part and drive motor power of 13 kW.

The machine is equipped with a numerical control command system having a DMG SLIMline panel, Fanuc 32i technology, available with software for easy programming of processing cycles, 3D simulation and graphic assistance for fast adjustment, installation and diagnosis [7].

Figure 3. Vertical milling machine in three axes DMC 635v

The processed parts are stainless steel rotor blades (figure 5.a) used to produce a Francis turbine model. The rotor blade that will be processed is mounted on the fastening holder of the machine. The milling plate has to be pitched for processing. After the milling machine is started the cutting conditions are set from the panel and the milling programme is loaded. Screen's panel (figure 4.a) shows the progress of milling process on three coordinates and values for cutting conditions (that can also be manually set).

Therefore, the human factor interferes only at the beginning and at the end of the process. He uses graphical information from the design to create a programme which is loaded on CNC machine and ran. The milling process occurs accordingly. As it can be seen in figure 4.b, the milling process develops on CNC machine as the coordinate programme is established.

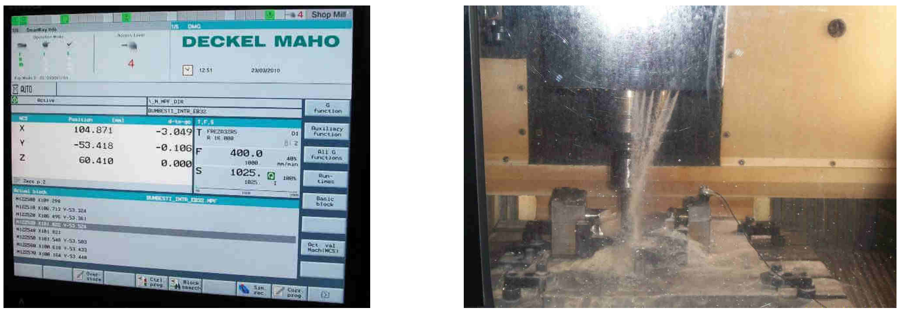

Fig.4.a. Setting up the milling program, [2]. **Fig.4.b.** Milling process in progress

Figure 4. Preparing and running CNC machine.

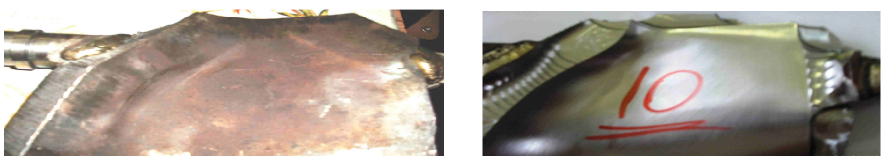

Fig. 5.a. Unprocessed rotor blade **Fig. 5.b.** Processed rotor blade

Figure 5. Manufacturing of a rotor blade

4. Conclusion

Nowadays every manufacturing plant uses at least one type of CAD/CAM system to design and produce part assemblies. Of course, these types of systems have their disadvantages but the benefits of using them outnumber.

For example, CAD/CAM systems have their own downsides in Product Lifecycle Management or machine process automation, system or server failures, hardware breakage, operator faults, but as well, the benefits are accordingly: improves machining capabilities, improves client accessibility, helps improve productivity of CNC machines, helps reduce material wastage, and the list can go on.

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