

## 3D Analysis of Machining of Wind Turbine Blade Using CAD/CAM Software Part 3. Simulation of machining in CAM environment

Karol Tucki, Mateusz Zimoch

Department of Production Management and Engineering, Warsaw University of Life Sciences – SGGW  
Nowoursynowska 166, 02-787 Warsaw, karol\_tucki@sggw.pl

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**Summary.** This work is an analysis of fabrication of a prior-designed wind turbine blade using the CAM system software. The presented research was realized on a 5-axis CNC machine.

**Key words:** geometry, blade, aerodynamic forces, calculations.

### INTRODUCTION

Robust growth of the CNC machines sector and, especially, 5-axis machines that promote modern fabrication technology, results in a situation where production of elements characterized by complex geometry is not as difficult as a few or a dozen years ago [3, 7, 8]. This is exemplified by the fact that such solutions are becoming more common in the energy and aviation sectors, where many of the designed parts must be characterized by highly precise and individual production [13, 17, 20].

Simultaneous 5-axis processing is a highly complex and difficult process that is impacted by a number of factors. The designer faces difficult and challenging tasks starting with modelling, selection of cutting tools, all the way to proper adjustment of the tool and finally setting the operating values of the machine. A way to facilitate such work is using specialized software based on CAD/CAM systems. They enable, at the stage of CAD design (Computer Aided Design), to create a 3D model of any degree of geometry complexity and next, using the CAM system (Computer Aided Manufacturing) it is possible to simulate the machining of the required part from a solid of similar dimension [1, 12, 15].

The spherical tool used in machining is the toroidal mill. It is described by two parameters – the diameter of the milling insert  $r_p$  and the radius between the axis of the mill and the middle of the insert  $R_T$  [18, 19]. Both the characteristics are given in Figure 1.

The surface of the described tool is composed of round cutting inserts that rotate around the mill's axis and perform the cutting work. Using such technology limits creation of

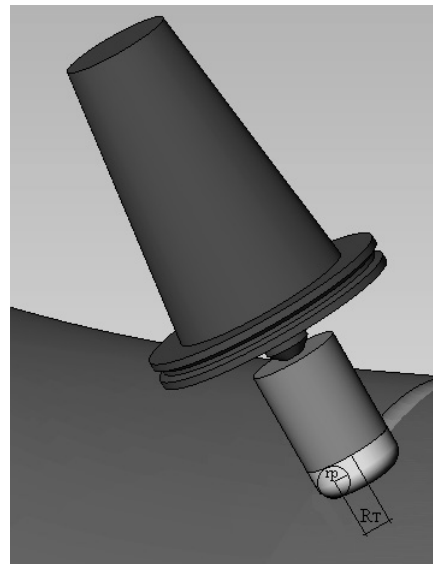


Fig. 1. The characteristics of the mill [own elaboration]

the notches and therefore provides better quality, innovativeness and reliability of machining. The notches occur in case of significant changes in the curves of surfaces that constitute a given element. These surfaces determine a non-uniform distribution of stresses, which greatly exceed the allowable or nominal values. From the construction perspective, notches are considered defects and should be avoided or removed both at the design and the production stages. Furthermore, setting a milling depth that is significantly smaller than the radius of the cutting insert makes the shavings thinner in relation to the feed and increases the length of the milling edge [5]. The above adjustment results in lower temperatures during the milling which enables longer feed and the milling speed, increasing the yield of this production method.

Setting the mill axis with the description of the drive angle in relation to the normal vector of the milled surface is nowadays the basic strategy used in programming CAM

systems for milling free surfaces. The scheme of determination of the tool's axis on a 5-axis CNC machine with face milling is given in Figure 2.

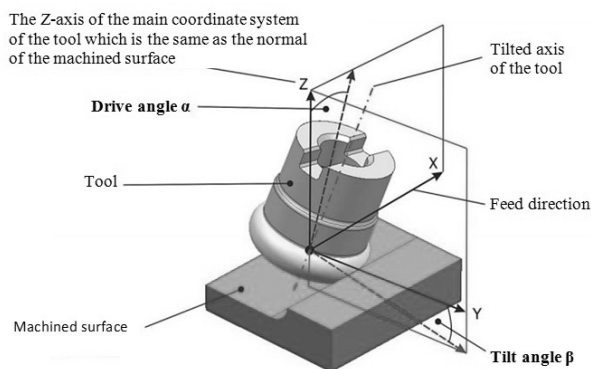


Fig. 2. Determination of the tool's axis on a 5-axis CNC machine [5]

The correct setting of CNC machine's parameters is the basis for creation of the designed item. To program the CNC machine the ESPRIT software will be utilized, which creates CAM codes that are fed to the CNC machine and determine its operation. The required values are defined at the software's entry. Next, on the basis of the choices made, a simulation of machining is performed in order to verify the correctness of the process.

### CAM PARAMETERS

Determination of all CAM parameters transferred to a CNC machine remains the responsibility of the designer. The chosen values are based on the knowledge and experience of the said designer [2, 6]. The first and basic values are feeds and milling speeds [4]. In the examination performed the values selected are presented on Figure 20, which reflects the interface of the ESPRIT software. Additionally, the cutting tool was selected fi100r10, in form of a toroidal mill with the cutting insert radius of 10 mm and the radius between the axis of the tool and the middle of the insert of 100 mm. The next stage in creation of the code for simulation of machining is determination of the accuracy and the cutting path. The lower the tolerance, the better adjustment of the tools' path and the denser the paths are. For this type of processing the recommended value is 0.5 mm (by the software's developer) and such one was selected for further analysis.

The path that is projected onto the working element is spiral-shaped. This determines placement of the tool at the middle of the resultant curve and continuity of machining without the need to drastically change the processing direction during operation – which is important when working on elements where the length parameter is much larger than the width parameter [9, 11]. The remaining values related to the path were adjusted to its type by the ESPRIT software.

The last stage before commencing machining is setting the work tool. The orientation was defined as perpendicular

to the model. The angles in the pass line and the perpendicular surface, which determine the tilt were chosen at 4 degrees. Additionally, by enabling the “auto-tilt” option, the software enables automatic change without following the perpendicular placement of the tool, in order to select and process areas that are inaccessible without changing the tool angle.

In order to avoid collisions and unwanted damage to the milled material and the milling machine, the value of “collision detection” was set to 0.01 mm. This means that the machine's tool holder will stop the simulation or machining if it approaches the model too close.

### SIMULATION OF MACHINING IN CAM ENVIRONMENT

The 3D model created in the CAD system will be created on a 5-axis CNC machine on basis of parameters presented in chapter four in paragraph “CAM Parameters”.

The realization of simulation begins with creation on the blade of a spiral milling path for the tool with adequate feed adjusted for the chosen deviation (Fig. 3).

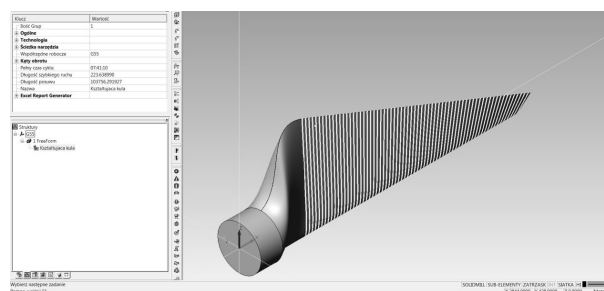


Fig. 3. CNC's tool path – ESPRIT software [own elaboration]

For the resultant path generated is machining time, which is 15 minutes and 22 seconds. Additionally, the program is able to continuously verify the position of the tool on all five axes in all the pool positions. An example of this verification is presented in Figure 4 below. The tool is located near the end of the blade and its detailed parameters are given in the table near the model (Fig. 4).

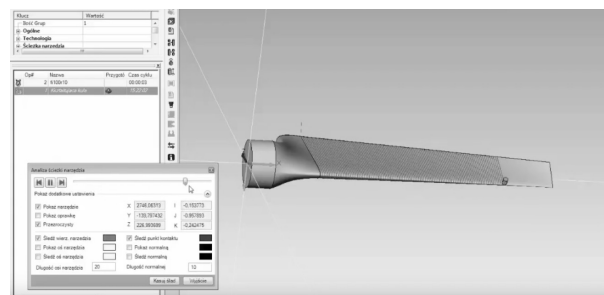


Fig. 4. Tool path analysis – ESPRIT software [own elaboration]

The machining process is presented in Figures 5, 6, 7. The green path shows the material after machining and the grey field is the blade's field that the tool did not yet process.

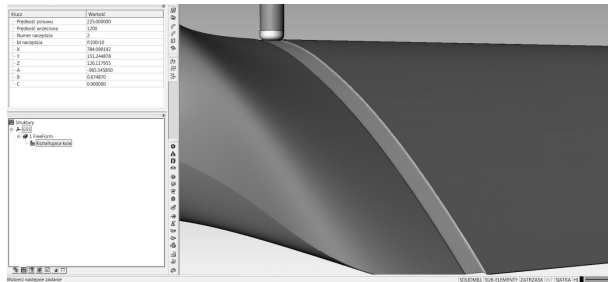


Fig. 5. SE isometric view of simulated machining of a wind turbine blade – ESPRIT software [own elaboration]

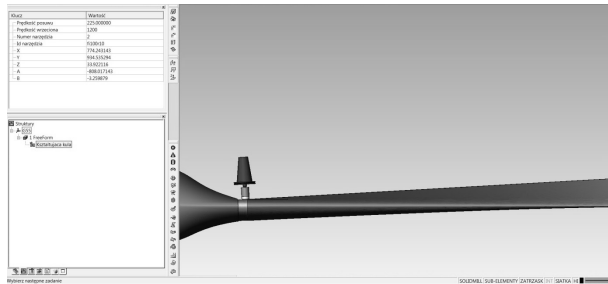


Fig. 6. Front view of simulated machining of a wind turbine blade – ESPRIT software [own elaboration]

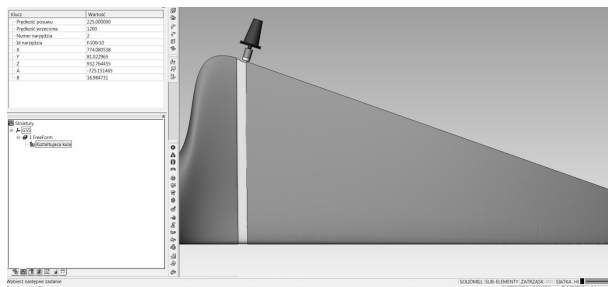


Fig. 7. Top view of simulated machining of a wind turbine blade – ESPRIT software [own elaboration]

Geometry of the blade determines the utilization of the 5-axes of the CNC machine. This is clearly visible on subsequent Figures that present the locations of the toroidal mill. In the first figure one can see the maximum value of the tool tilt when machining the ridge of the blade and in the next figure the maximum value of the driving angle when machining the top, 8, 9).

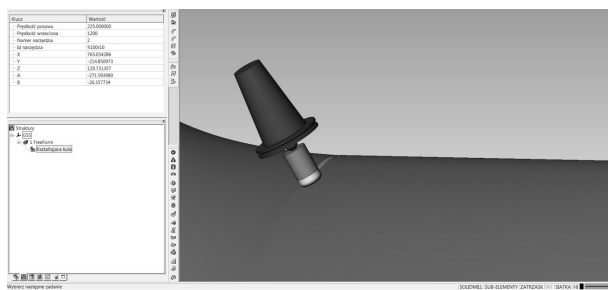


Fig. 8. Maximum tilt angle during simulated machining of a wind turbine blade – ESPRIT software [own elaboration]

Finally, after the calculated time, the final machined 3D model of the wind turbine blade was created. The object is

presented in Figure 10 and ends the work on the realization of the simulation.

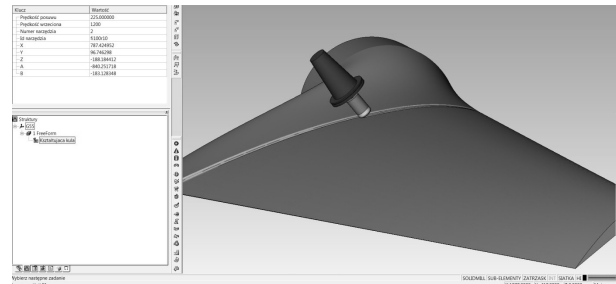


Fig. 9. Maximum drive angle during simulated machining of a wind turbine blade – ESPRIT software [own elaboration]

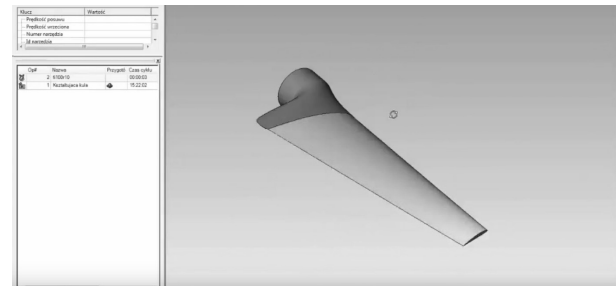


Fig. 10. Finished 3D model of wind turbine blade – ESPRIT software [own elaboration]

## CONCLUSIONS

1. Machining of the wind turbine blade was simulated on a 5-axis CNC machine using ESPRIT software on the basis of selected CAM parameters. Due to the type of selected production, the surface of the element is characterized by low roughness which results in better operating characteristics,
2. Automation and simulation of this process results in elimination of errors created during the design process and avoids the risk of damaging the CNC machine. All these factors significantly lower the production costs. These are also lowered by the lack of trial runs to check the correctness of production of the designed element – the whole verification of the process is realized using the simulation,
3. The precision and accuracy of CNC machines results in the creation of identical parts, characterized by complex geometry in a short time. For the examined blade it is 15 minutes and 22 seconds. This enables the use of such solution in mass applications.

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ANALIZA 3D OBRÓBKI SKRAWANIEM ŁOPATKI  
TURBINY WIATROWEJ PRZY WYKORZYSTANIU  
OPROGRAMOWANIA CAD/CAM  
CZ. 3.: SYMULACJA OBRÓBKI SKRAWANIEM  
W ŚRODOWISKU CAM

**Streszczenie.** Praca stanowi analizę symulacji wytworzenia zaprojektowanej łopaty turbiny wiatrowej przy użyciu oprogramowania pracującego w systemie CAM. Przedstawione badanie przeprowadzono na pięcioosiowej maszynie numerycznej.  
**Słowa kluczowe:** geometria, łopata, siły aerodynamiczne, obliczenia.