Applications of 3D scanning to shorten milling time of model in manufacturing large forms

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Abstract

This paper describes the process of manufacturing a soft core mold of formula student fiberglass body on a 3 axis milling machine. The paper presents two methods of producing the mold: first the conventional process and second the process optimised by 3D scanning technology. The aim of his paper is to determine if the 3D scanning could be implemented in manufacturing process.

KEYWORDS: **3D scanning**, **milling**, **CAD/CAM**, **toolpaths**

Introduction

Now, in the modern industry production has to reach higher level of products quality while minimizing the manufacturing costs. It is the same with milling forms and models in CNC machines. Particularly, rough machining operations have to remove material in the minimum time. Many of 3D CAM systems have functions to improve a milling process efficiency. For example it is trochoidal tool paths [7, 9]. The other parameter of milling operations is the optimization of feedrate [6, 8].

There are different methods of improving milling process [1], but we would like to show possible application 3D scanner to create the blank for 3D CAM system. We want to check that to reduce milling time and the manufacturing cost. It will be important for companies, which produce big elements with several meters dimension.

A good example of are big models to manufacture fiberglass mold. Laminated molds are used to produce components for trains, trams, yachts, trailers, caravans and the others. The companies produce models of soft material like expanded polystyrene (EPS) or extruded polystyrene (XPS). That allows to reduce the costs of material and time of operation, because it is able to mill faster. The first step is rough milling of a soft core. Tool paths are generated in CAM system, where a user selects a nominal shape and puts "minus value" of offset (about a dozen millimeters) – fig. 1a. Second step is coating outer surfaces with ceramic putty (paste) by hand above nominal shape (about a dozen millimeters) – fig. 1b. Therefore the thickness of the putty will count several millimeters. This layer is going to be durable and hard. It also happens the thickness of putty in inside corners of pockets is even bigger.

After drying is rough and finishing milling or only finishing milling, if the layer of pasta is equal – fig 1c. The outer surfaces of model has to be polish and covered separating material. At this time can be used this model to prepare split fiberglass mold. With this mold can produce many laminated components (fig. 1d) on different ways [3].

a) b)

c) d)

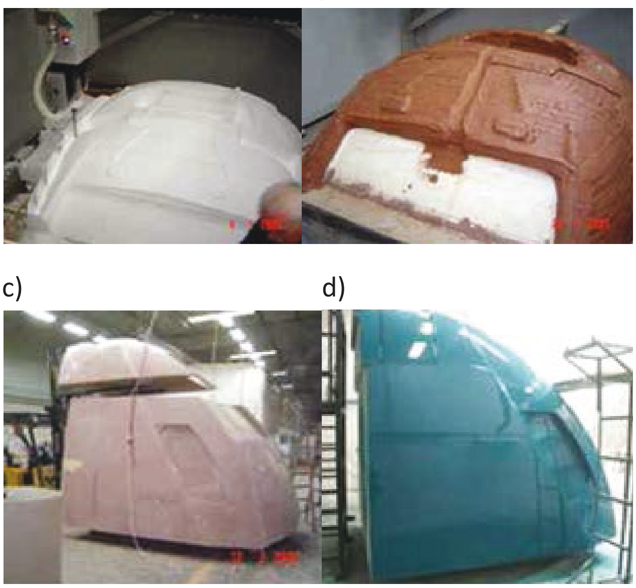

Fig. 1. *Tradition Comparison of two methods manufacturing model [2]*

The purpose and scope of work

The purpose of this paper is to compare two methods of milling large model for fiberglass mold. The first method is the conventional process which consists of milling an offset model, covering it with ceramic putty (paste) and finishing milling (fig. 2 – method A). The second method proposes to use a 3D scanner to generate an exact geometry of blank as a result from covering process (fig. 2 – method B). This eliminates the non-cutting movements and protects against overload tool and workpiece breaking out. It all could reduce the time of milling and minimize the manufacturing costs.

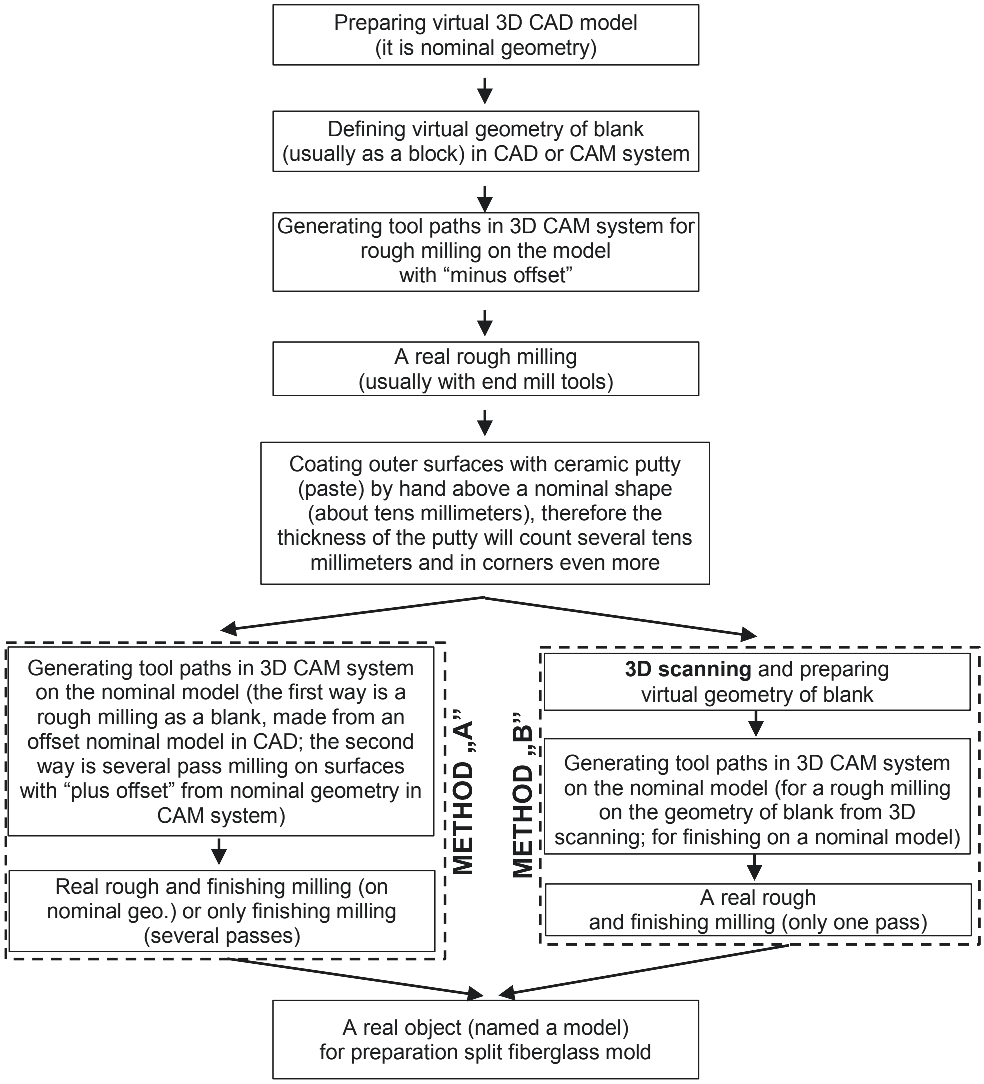

Fig. 2. *Comparison of two methods manufacturing model*

Object selection for analysis and preparing 3D CAD model

For the analysis has been chosen body shape of Formula Student car, designed and manufactured by students of Faculty of Automotive and Construction Machinery Engineering, Warsaw University of Technology. The selected project is a small one-seater vehicle with a length of about 2500 millimeters (fig. 3). Its body was made of fiberglass, by laminating in a split mold in 2012 year. The mold was made on the model (fig. 4). The production helped the company "Bella Zakład Kompozytów" Ltd. form Czosnów, near Warsaw [2]. On the fig. 5 is shown the virtual 3D CAD model as solid objet (closed polysurfaces). This model was remodeled in CAD system to of half model (fig. 6) and one surface (selected on fig. 6) was changed because it will be problem with 3-axis milling. After this geometry has been scaled up (1:5 ratio) to fit in the workspace CNC machine (we used AVIA VMC 650). On this model generated toolpaths of rough milling in 3D CAM system. The scale will change a value of time as a result of comparison of two methods manufacturing the model. Also it shows the difference between these methods: with and without 3D scanning. After scaling the 3D CAD model has dimensions: 500 x 127 x 117 mm. This geometry was imported to the 3D CAM system.

Fig. 3. *Shape of body Formula Student car selected to the analysis*

Fig. 4. *Model of body used to laminated split fiberglass mold*

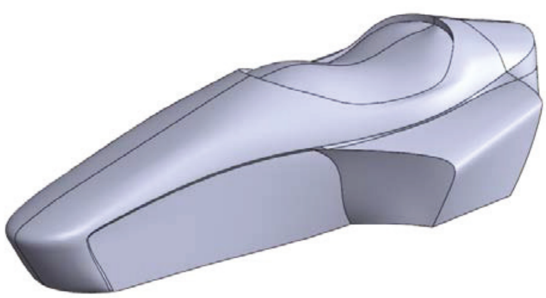

Fig. 5. *Virtual 3D CAD model of body*

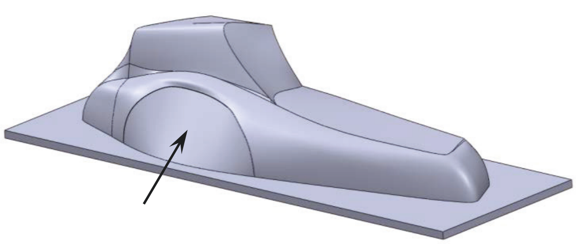

Fig. 6. *The half model prepared for generating toolpaths of rough milling in 3D CAM system with selected modifying surface*

First rough milling of blank

The first step was real prepared block of blank (stock) with soft material. We have chosen XPS, because is less dusty. The dimensions of block was about 600 x 150 x 150 mm and was fixed on the table CNC machine (fig. 7). This shape of block was also prepared in the 3D CAD system like a virtual geometry and was imported to the 3D CAM system. There both virtual geometries (model and blank) were oriented in one coordinated system (fig. 8). Blank was fixed to the bottom board by glue and screws, such to avoid damage to the cutter during machine (selected on fig. 8).

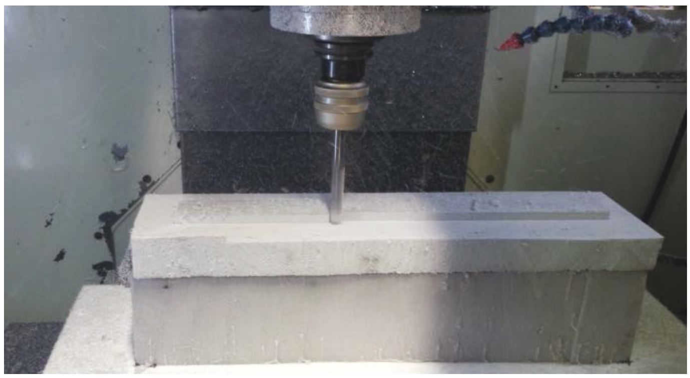

Fig. 7. *Start first roughing operation*

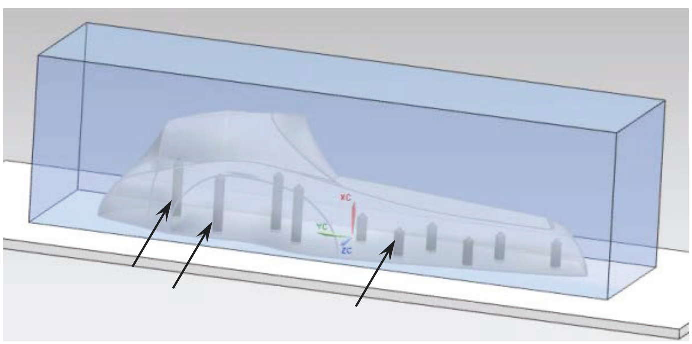

Fig. 8. *Setting of model and blank geometry*

In 3D CAM system was generated toolpaths of rough milling in 3D CAM system. Machining was done with end mill tool: diameter: 16 mm, tool length: 150 mm, flute length: 100 mm, flutes: 2). For the rough operation were used the following parameters: strategy: spiral, offset: -10 mm, step over: 50%, feed rate: 1000 mm/min, rotation speed: 7500 RPM, plunge feed rate: 500 mm/min, cut increment: 10 mm. The total time of milling was: 3 hours and 12 minutes. On the fig. 9 is shown the toolpaths of rough operation and on the fig. 10 is shown the simulation of milling. The result of rough milling was shown on the fig. 11. This object was coated by gypsum (like ceramic putty) by hand, above nominal shape (about tens millimeters) – fig. 12. The gypsum body was left to dry for 24 hours. After this was measured on the optical 3D scanner.

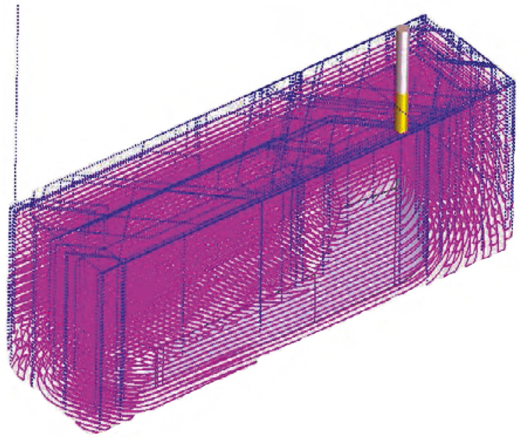

Fig. 9. *Toolpaths generated in CAM system*

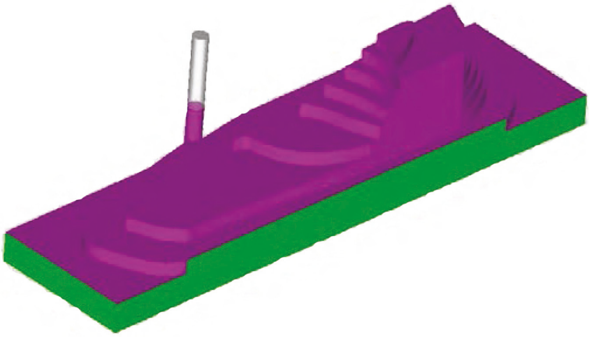

Fig. 10. *Simulation of milling*

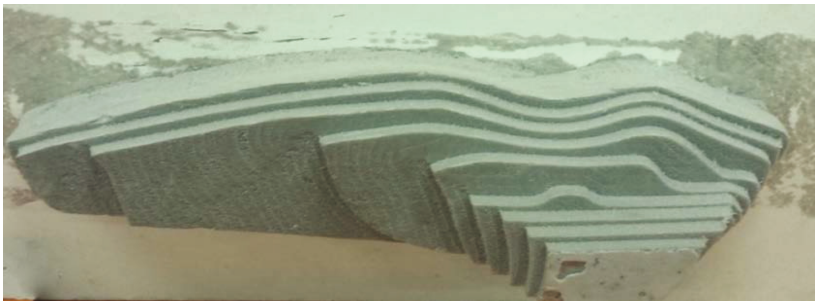

Fig. 11. *Result of rough milling*

Fig. 12. *Gypsum body*

3D scanner of gypsum body

For method B we scanned of the gypsum body. We used 3D optical scanner ScanBright from Smarttech Company. It has got a multimedia projector, with lights the black-white strips on the measuring object (fig. 13). The distance between the body and the 3D scanner was set to approximately 1,3 meters. The scanner records the view by the 5 MPixels camera. The system Mesh3D computing the result of measuring to the cloud of points (fig. 14). If the object has more complicated shape, it is necessary to scan on different direction. In this way we have to reorient clouds of points on one coordinate system. This operation can add little deviation. Our shape of body has to be scanned from 6 directions. On the fig. 11 are selected each cloud different colours – orange, violet, white and green. The duration of 3D scanning process took 1 hour.

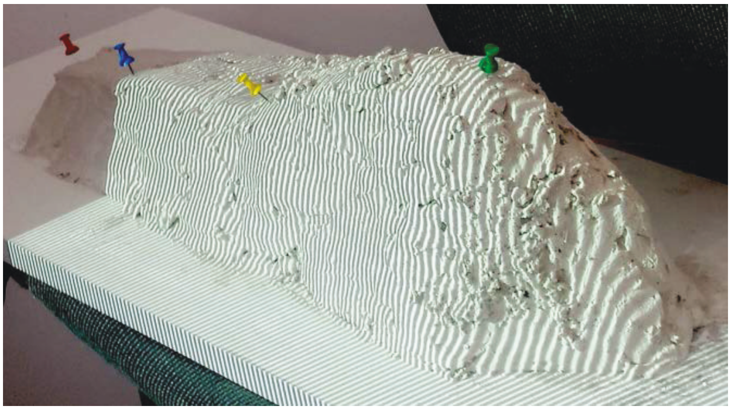

Fig. 13. *Scanning process*

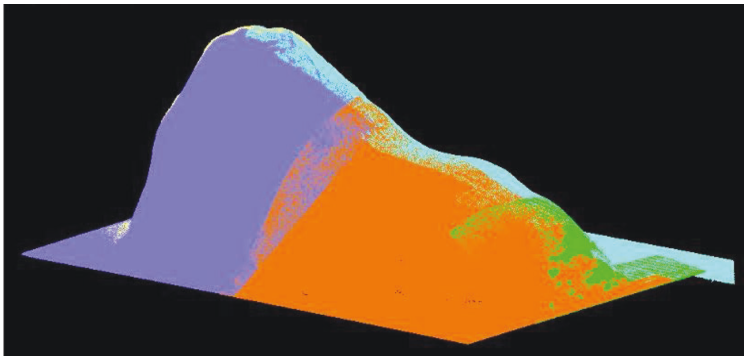

Fig. 14. *Finished cloud of points*

Prepare of toolpaths in CAM system on offset model of body

The milling operation was created in Edgecam with the following parameters: strategy: spiral, step over: 50%, feedrate: 1000 mm/min, speed: 8000 RPM, stock type: 50 mm offset, cut increment : 5 mm, intermediate slices: 2 mm. For the roughing operation, an endmill tool was created, with the following specifications: diameter: 30

mm, flute length: 100 mm, total length: 200 mm, flutes: 2.The total time for roughing operation was : 3 hours and 31 minutes.

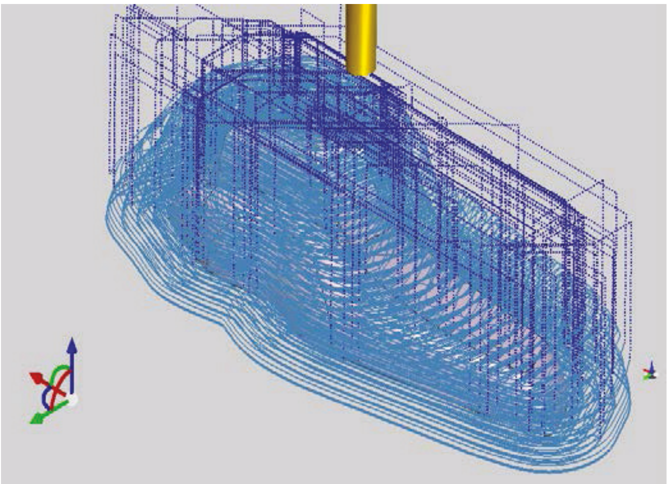

Fig. 15. *Toolpaths generated using thickness offset feature*

Prepare of toolpaths in CAM system on scanned model of body

The solid body resulted from the scanning process, was imported in CAM in design mode to be further processed. The CPL was placed in the left corner of the board, and oriented in the correct position using Rotate and Translate features. With Insert feature, the body that had to be milled was placed next to the scanned body. Using Rotate and Translate features, the formula student body was placed inside the stock.

In order to create the milling operation, we selected from „Mill Cycles" the Roughing feature. The tool used for milling was the same as in 3.5. The body was milled with the following parameters: strategy: spiral, stepover: 50% of diameter tool, feedrate: 1000 mm/min, speed : 8000 RPM, cut increment : 5 mm, intermediate slices: 2 mm. The total time for roughing operation was: 2 hours and 30 minutes.

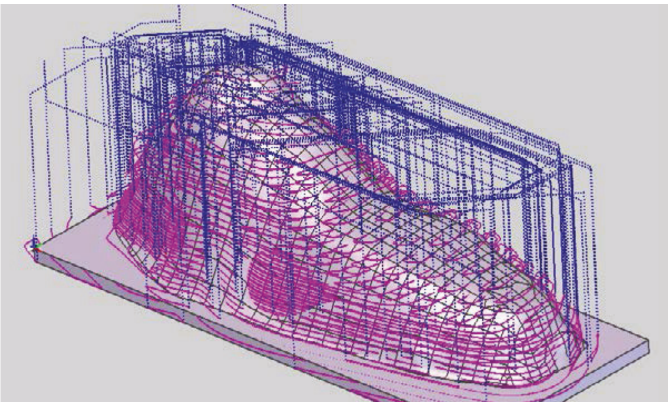

Fig. 16. *Generated toolpaths in CAM system*

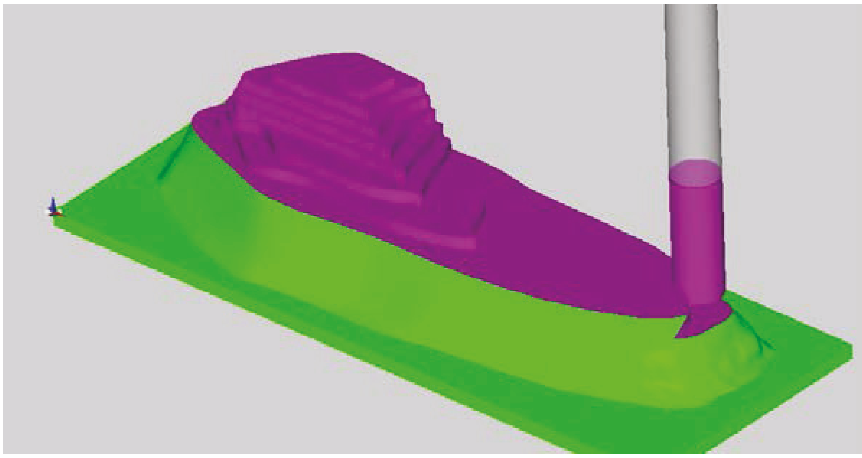

Fig. 17. *Simulation of milling in CAM system*

Comparison of methods

In image below is shown the difference between the offset created in CAD systems (blue), the 3D scanned body (green), and the body of formula student car (red). The process of manufacturing the soft core mold was the same for both of the methods up to covering with gypsum of the foam body.

In the first method the body was milled using an offset of 50 mm, resulting a stock with a volume of 9,1 dm3 and with a milling time of 3 hours and 31 minutes. The second method that involved the usage of 3D scanner, has generated a 3D stock of 7 dm3 and a milling time of 2 hours and 30 minutes, which is 30% less than the conventional method.

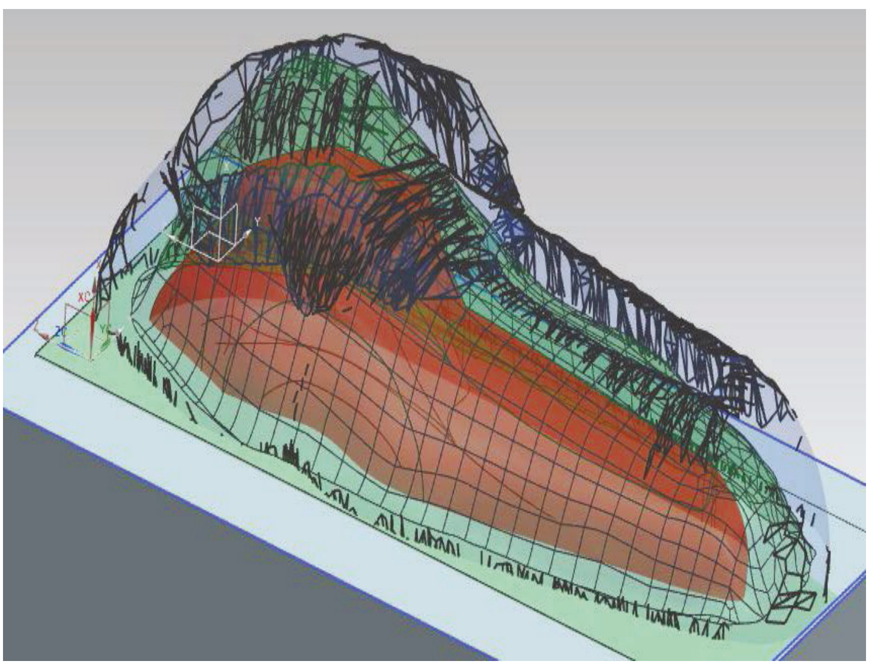

Fig. 18. *Differences between the stocks used in milling process*

Comparison of 3D paths in CAM systems

In fig. 7 can be observed that we cannot see where the tool is engaged in cutting the material, therefore we cannot further optimise the milling process by choosing an appropriate milling strategy. Also in this stage we cannot measure the real milling time, then we cannot predict the tool wear.

Image shown below which represents the optimised milling method, we can see clearly where the tool is engaged in cutting the material. Also we can determine if further modifications of toolpaths is needed. This method also reduces the stress on the milled surface and also diminishes the risk of material chipping.

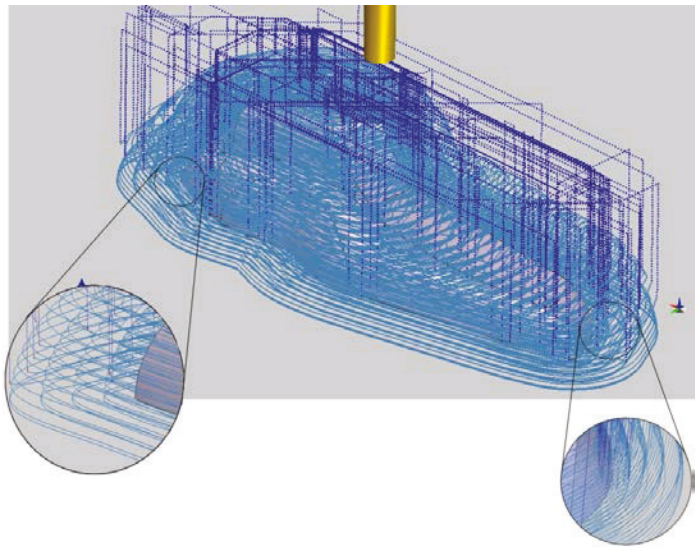

Fig. 19. *Toolpaths generated by offsetting the thickness*

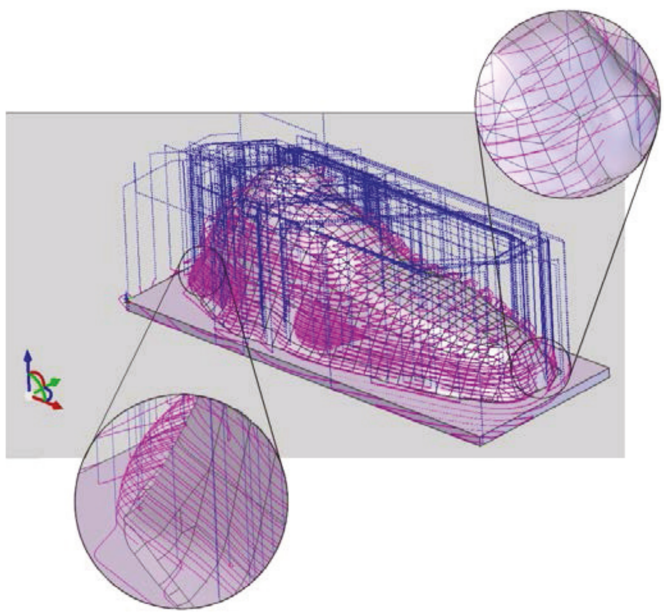

Fig. 20. *Toolpaths generated for scanned body*

Conclusions

It is clear that the only acceptable way of being a strong competitor in a continuously changing market, is to keep on researching of new methods to increase the efficiency of the production process.

The 3D scanner used to generate the model of the covered body reduced the milling time with 1 hour and 1 minute which means a reduction by 30% than the conventional process. By generating toolpaths that follow the 3D model, a constant stepover and cut increment are ensured, which can reduce the stress on the material and the chipping of the surface Another advantage is that the costs of using the 3D scanner is cheaper than the costs associated with the work of the milling machine.

Also the technology of handheld 3D scanners could reduce the processing time even more. Furthermore, the 3D model let us observe how the thickness of the material varies depending on the slope of the foam body which can be put into practice by workers to improve their skills in the hand lay-up process of covering the soft core body.

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