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PERFORMANCE COMPARISION BETWEEN 3 AND 3+2 AXIS MACHINING CAPABILITIES

Andrei KOZUK, Petru BERCE

Abstract: *In this article two CNC machines, one with 3+2 and one with 3 axes are analyzed from the perspective of performance. Time results are compared in order to get the performance of the two machines during a series of 2 real tests and 8 simulated tests.*
Key words: *3+2 axes machining vs. 3 axis machining, 3+2 axis machining capabilities, performance comparison.*

1. INTRODUCTION

In this article a series of analysis will be presented. This analysis was designed to fulfill the needs of SC Comelf Bistrita, a company who is the beneficiary of this study. This article will underline some problems, the proposed solutions and new approach will be proposed to take in consideration.

Current study is correlated with the actual technical stage and capabilities of SC Comelf SA Bistrita in matter of tooling and machining technologies available inside of the company.

There is a focus on international level for big companies that are interested in analyze the impact on their budget in case of implementation of a 3+2 axis machine. The studies have both economic and technical aspects, taking in consideration the quality of surfaces, possibility of expansion of their products range, time impact on products, etc.

2. THE PROPOSED PIECE FOR ANALYZE IS AN WIND TURBINE MOLD SEGMENT

The proposed piece for analyze is a wind turbine mold segment presented in the figure below.

Production process

- A master blade is made, after this the copy are made

Fig. 1. Wind turbine mold segment.

Fig. 2. Wind turbine blade

- This master is the reference for the mold construction. This Mold is a two piece mold.
- The two piece of the blade is made of resins;
- After the resin solidified the excess resin is cut off in order to get a perfect fitting of faces;
- A rigid fiberglass is inserted in the center of blade in order to get a stiffener construction. This will confer a better stiffness from the base to the tip.
- The second half is glued to the first and will be inserted into the mold in order to keep the geometry during solidification.
- Any imperfection is fulfilled and grinded down. After the final retouch the blade is sandblasted in order to get a smooth surface.
- The blade is painted at the end.

This procedure principle is presented in the figure below:

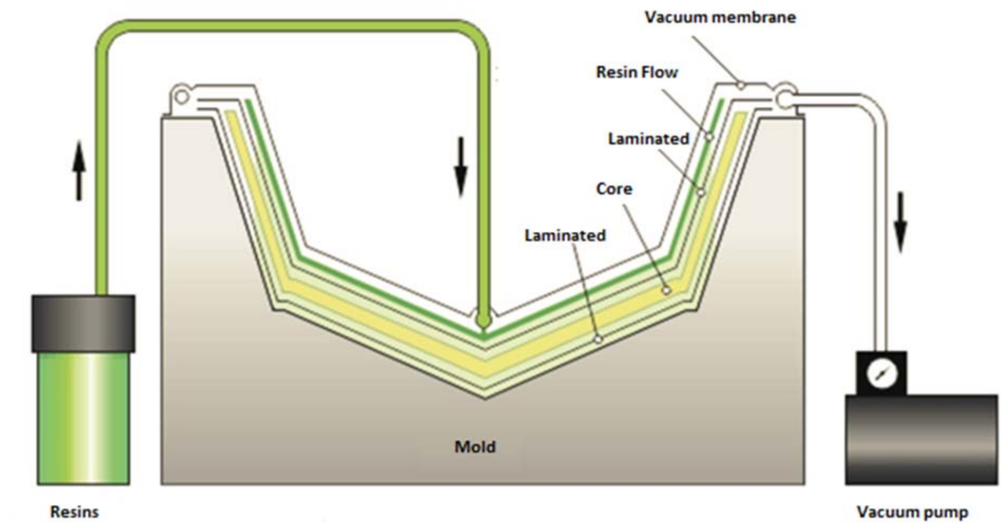

Fig. 3. Casting process [SSC1]

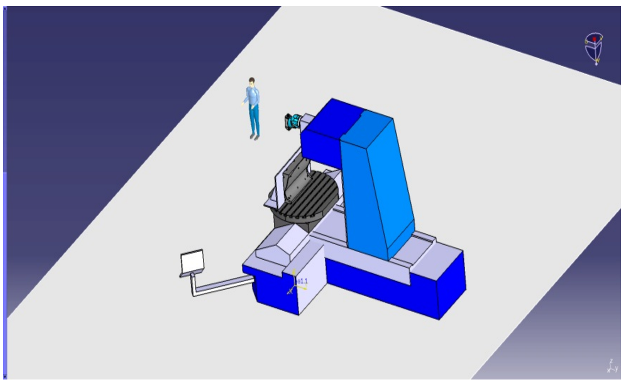

Fig. 4. Holding of work piece on the CNC machine

For a better representation the Delmia software from Dassault Systems was used to schematize the fixture of mold on the working table. The mold was modeled in Solid Works, was positioned on the machine's holding and simulated the CNC program.

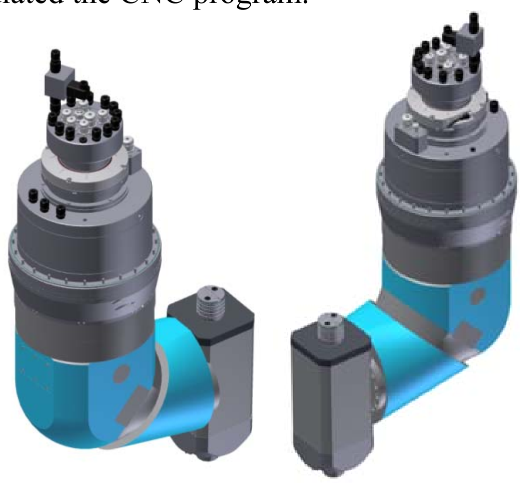

Fig. 5. Indexing head

Milling power calculation

For calculating the milling parameters we take in consideration the worst situation when we have a material with less than <32 HRC at a speed of 120 m/min. Also a mill with tungsten carbide is used in order to offer a higher surface finish, with a diameter of Dc=50mm, 4 teeth and a step of 39,2 mm.

$$n = \frac{1000v}{\pi D}\ rot/min, \quad (1)$$

$$n = \frac{1000 \cdot 120}{\pi \cdot 50} = 764\ rot/min \quad (2)$$

Where v is the speed of chipping and D is the diameter of the tool.

a. Feed rate is determined with:

$$v_f = s \cdot z_n \cdot n\ mm/min, \quad (3)$$

Where s represent the feed rate on each teeth and , mm/teeth, and z_n number of teeth ;

Feed rate recommended for a mill with the D diameter bigger than 25 mm for a width of chip t of 1 mm is 0,15 mm/min:

$$v_f = 0{,}15 \cdot 4 \cdot 764 = 458\ mm/min \quad (4)$$

The values of CF and its exponents XF, YF, for S355JR steel are:

CF = 63
XF = 1,07
YF = 0,72

Medium width of chip is calculated with:

$$a_m = s \cdot \frac{\sin\varphi}{2} = f_z \cdot \sqrt{\frac{1-\cos\varphi}{2}} \quad (5)$$

Where φ [°] – is the contact angle between tool and material, in our case is 45°.

$$\cos\varphi = \frac{\frac{D}{2}-t}{\frac{D}{2}} = 1 - \frac{2t}{D} \quad (6)$$

At the end we have:

$$a_m = s \cdot \sqrt{\frac{t}{D}} \quad (7)$$

$$a_m = 0{,}15 \cdot \sqrt{\frac{1}{50}} = 0{,}15 \cdot 0{,}14 = 0{,}021\ mm \quad (8)$$

$$e = t/\sin\varphi \quad (9)$$

$$e = 1/\sin 45^\circ = 1{,}41\ mm \quad (10)$$

The force is:

$$F = 63 \cdot 50^{1{,}07} \cdot 0{,}15^{0{,}72} \cdot 1 = 1056{,}87\ N \quad (11)$$

$$P = \frac{1056{,}88 \cdot 120}{6120} = 20{,}72\ kW \quad (12)$$

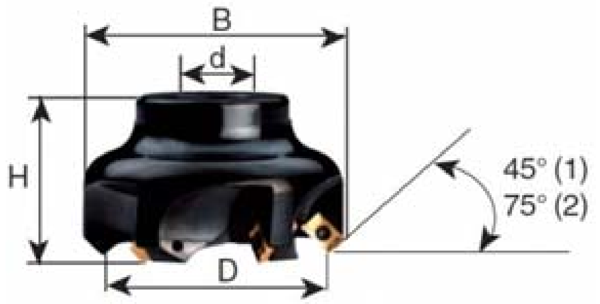

Fig. 6. End milling tool

Compared results obtained on the two configurations of machines 3 and 3+2 axis:

Depending on the complexity of surfaces executed and machining times we can determine if we need more axis added to the machine.

A more complex machine is initially a big investment, in time it could be a really economic way in order of reducing time and save money for a company.

The complexity of parts, precision, surface quality with such a machine could be increased, reducing the manufacturing times, number of positioning of work piece and costs of machining, energy savings, etc.

This kind of machines could have two structures:

- First structure use a rotating table
- The second structure have this rotating axes incorporated in the milling head

The biggest advantage of this machines are that they can execute high complexity surfaces with one configuration, that save dead times of machine during repositioning work pieces.

Another advantage is the high complexity of machining operations that can be executed with these machines with correlation of the axial movement and rotations, such complex parts can be executed other way only by casting. In aeronautical industry this releases new possibilities.

It can execute millings and drillings with high complexity of configurations without repositioning.

On the 5 axis machines we can use mills and drills less long than on other machines due the high positioning flexibility of head positioning, this reducing substantially the vibrations that appears during machining. Also this increases the quality of surfaces.

The CAD/CAM integration is more precise.

The biggest limitations of these machines are the clamping systems that must support high forces and it must not block the access of the machine to the piece.

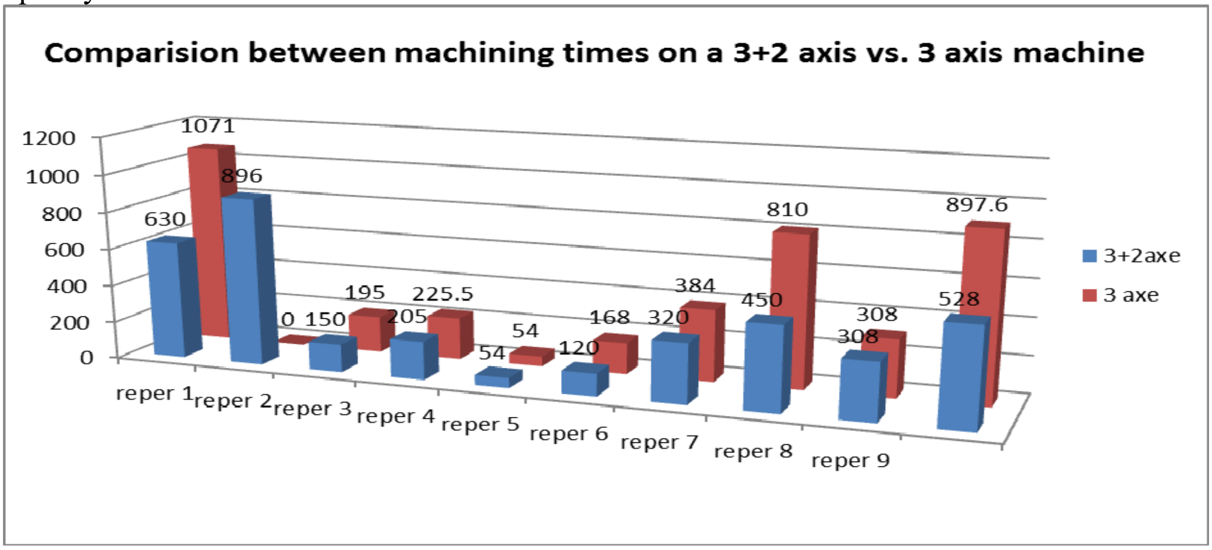

Fig. 8. Comparison between machining times on a 3+2 axis vs. 3 axis machine

3. CONCLUSIONS

It can be observed in the figure “Comparison between machining times on a 3+2 axis vs. 3 axis machine” that on the simplest pieces we get almost the same execution time, differs only the quality of surfaces. Instead, if we increase the complexity, the time easily double or it can be impossible to execute on a classical 3 axis machine.

The values of part 2 to part 9 are simulated values and the part 1 and part 10 are compared in the reality; this parts was executed in SC Comelf Bistrita on two different machines.

The increasing of percentage can be observed in the figure “Comparison between machining times on a 3+2 axis vs. 3 axis machine”.

As it can be observed, the increase of time is dependent on the complexity of work piece.

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Compararea performanţe între capabilităţile de prelucrare cu 3 şi 3+2

Rezumat: În acest articol două maşini CNC, una cu 3 + 2 axe şi una cu 3 axe sunt analizate din punctul de vedere al performanţei. Rezultatele masurate in timpi de executie sunt comparate; în scopul de a obţine performanţa cele două maşini sunt testate comparativ de-a lungul unei serii de teste 2 reale şi 8 teste simulate.

Andrei KOZUK, PhD student, Technical University of Cluj-Napoca, TCM, andreik80@yahoo.com

Petru BERCE, Prof.Dr.Ing, Technical University of Cluj-Napoca, TCM, berce@tcm.utcluj.ro