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A precise milling of integral blade rotors by using different strategies

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Abstract
The new trend of single-aisle aircrafts and sustainability requirements of noise and emissions reduction led to increase the number of monolithic components inside the engine; this is the case of integral blade rotors (IBRs). These components are made of difficult-to-cut thermoresistant superalloys as Ni-based or Ti alloys aligned with extremely complex geometries and tough finishing requirements. With the aim of analysing the optimal manufacturing technique, this work presents the comparison between different machining strategies applied to a complex surface, such as conventional point milling, the use of different mathematical algorithm to approach the surface to a developable surface to be machined using flank milling, or the use of the new technique known as Super Abrasive Machining (SAM). A entire Blisk composed of several blades was selected as the demonstrator, divided by sectors where it is shown the differences between selected strategies. Measuring is considered a critical stage for the accuracy of different machining processes, measuring final geometry and comparing the dimensional deviation and the obtained roughness with the original design. Additionally, an economical assessment is performed to scale the productivity of each strategy in terms of manufacturing costs and time. Hence, it is presented the main advantages and drawbacks for each strategy, concluding the optimal one for these type of components.

Keywords: IBRs, thermoresistant superalloys, point milling, flank milling, Super Abrasive Machining, accuracy, precision

1. Introduction

The aeronautical industry is suffering from a growing tendency due to the sector strict requirements, the globalization and the demand of noise and weight reduction in the new aircrafts and engines. The evolution of engine components from assembled disks to integral rotary components (see Figure 1) implied a major focus on improving manufacturing processes in terms of productivity [1].

Figure 1. Blisk exhibited in the EMO Hannover 2019

The manufacturing of these complex components led to many challenges to be faced in the industry from the initial conception to the final delivery to the market. Among them, it should be pointed out the low machinability of composed materials and the tough finishing requirements. The presented work performs an analysis between different productive processes for finishing stage (conventional milling, algorithm-based milling and super abrasive machining) considering the manufacturing time, cost and obtained finishing roughness.

2. Methodology

Figure 2 represents the manufacturing flowchart recommended for complex geometries that require 5-axis simultaneously movements.

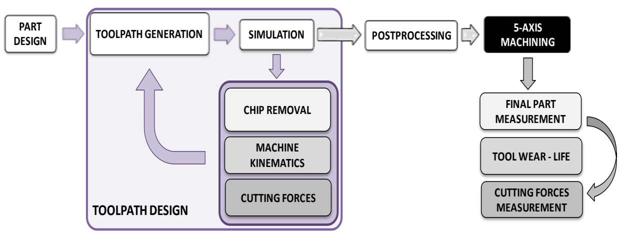

Figure 2. 5-axis machining process for complex geometries

According to the defined process to be followed by the three proposed solutions to manufacture a blisk made of Inconel®718, there are some common stages that should be considered. The first one is related to the design and industrial requirements definition, then the CAM programming for complex 5-axis tool-path generation [2], then it is needed the process virtual verification in order to predict and avoid collisions or machine kinematics limitations. As a final stage is the post-processing, the manufacturing process and the measuring analysis.

In the same line, improvement requirements in this area of knowledge leads many research to consider other alternatives to this traditional methodology with new manufacturing technologies, as Electrochemical machining, linear friction welding, laser cladding or a new trend known as Super Abrasive Machining [3,4].

4. Experimental set-up

Figure 3 presents the different steps performed during the experimental set-up. For those experiments it was selected a blade geometry and each blade was manufactured using different processes, the conventional milling process under tool providers recommended cutting conditions, the milling process supported by mathematical algorithm to use flank milling strategy and, finally, a new abrasive process known as Super Abrasive Machining (SAM).

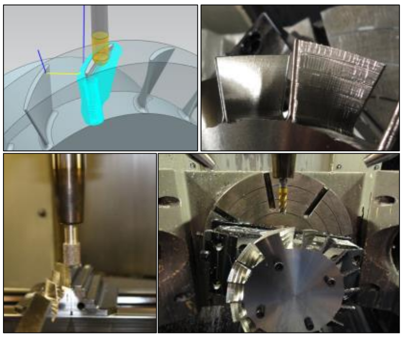

Figure 3. Case study: Blisk machining in a 5-axis multitasking machine

Hereafter, it will be described more in detail the selected finishing process and manufacturing conditions to be compared.

Related to the conventional milling process, it should be highlighted that there is a huge variety of cutting tools and CAM environments. However, the main used strategy is the point milling. This strategy presents different drawbacks such as final accuracy or machining time. On the contrary, this strategy is adequate for non-developable complex surfaces.

With the aim of offering a solution to these point milling disadvantages, it is presented an algorithm based solution to adapt the complex non-developable surface to a developable surface. Therefore, the point milling could be substituted by the flank milling strategy. This solution will imply a minimization of manufacturing times and better surface quality.

Finally, considering new manufacturing processes, the SAM is defined as grinding at machining conditions. Hence, the advantages from both processes are involved in this process. Finally, the developed algorithm could be applied to this process in the same way as the conventional milling.

Table 1 shows the selected cutting tools and process parameters for finishing blisk blades.

Process	Tool	Parameters
Milling	Ball nose end ø6	F= 400 mm/min, S= 4000 rpm, ap= 0.6 mm, ae= 0.5 mm
Milling with algorithm	Tapered ball noseend ø1.5 α3°	F= 500 mm/min, S= 6000 rpm, ap= 24mm (tool length), ae= 0.2 mm
SAM	Diamond & CBN Electroplated tool ø20mm	F= 500mm/min, S= 14000 rpm, ap= 20mm, ae= 0.2 mm

Table 1 Processes parameters and cutting tools

3. Results

Related to the obtained results, Figure 4 shows the comparison between these three processes in terms of time, price and roughness. It was shown that related the price and the machining time, the three of them works within the same range. Nonetheless, regarding the surface roughness, the algorithm-based milling and the SAM present a crutial improvement compared with the conventional milling.

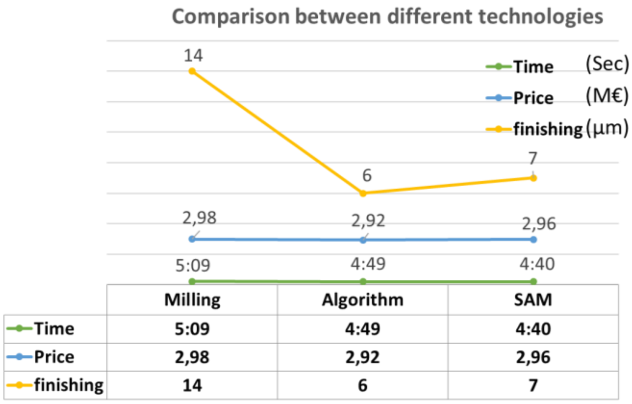

Figure 4. Case study: Blisk machining in a 5-axis multitasking machine

5. Conclusions

The presented work performs an initial analysis related to blisk blades machining processes using different techniques. Observing obtained results, it is opened a new researching line related to flank milling algorithms and new alternative processes to obtain a more productive manufacturing process for these complex components.

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