VIRTUAL SIMULATION OF TURN-MILLING OPERATIONS IN MULTITASKING MACHINES

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Abstract: *This paper explains a reliable methodology to be followed by multitasking machines in turn-milling operations. The main objective is to highlight the importance of virtual verification. The possibility of working at the same time with both heads, Bottom Turret and B-Axis Head, considerably increments the risk of collision. Virtual verification of this kind of operations is compulsory, taking into account that any collision could be catastrophic for the machine and for the part. This will assure that the order and the synchronicity between the different activities is the correct one, respecting the transference from one spindle to another.*

Key words: *multitasking, CAD-CAM, turn-milling, virtual verification*

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1. Introduction

Nowadays the structural complexity and the wide range of different movements of multitasking machines makes more difficult the programming of machining operations. Setting the correct operations order is of vital importance in order to save time, being desirable to check if a tool path is acceptable before cutting the actual component (Bohez et al., 2003). To ensure that collisions are not happening, virtual verification needs to be carried out.

Firstly, it is worth mentioning that the CAD/CAM process of complex pieces is not an easy process. Defining a methodology that will ensure the reliability of the process could be really helpful. The first step will be selecting the CAD/CAM software, what is very important because some of them have many different integrated modules that will make the task easier for the user, not having to change the software. Many actual CAM softwares bring the possibility of including a virtual verification module where the virtual machine can be built. The programming of the CAM operations has to be carefully made taking into account the best strategies and at the same time the right order of the operations trying to optimize as much as possible. Once the CAD and the CAM of the part are defined and finished, it is necessary to program the postprocessor of the multitasking machine. It is very important to pay special attention to the postprocessor that will make the data transfer from Apt Format (CAD) to ISO Format (Ghinea et al., 2010). Postprocessors are personally designed for each machine configuration and for each NC. They include information such as the configuration, movements and axis limits of the machine and functions such as G and M of the NC. Finally, the CNC codes can be verified using virtual machine tool (Waiyagan & Bohez, 2009). When the CAM programs have been postprocessed, the next and final step is to virtually verify the different operations that will be carried out to obtain the final piece. Multitasking machines possibility of working at the same time with both heads, Bottom Turret and B-Axis Head, considerably increments the risk of collision. Virtual verification of this kind of operations is compulsory, taking into account that any collision could be catastrophic for the machine and for the part. This will assure that the order and the synchronicity between the different activities is the correct one, respecting the transference from one spindle to another.

The virtual verification software requires some information that needs to be included, the CAD files of the machine and its configuration as well as information such as axis travels and speeds. The type of NC and the postprocessed CNC programs of the part are also required. From the virtual verification it is possible to obtain several conclusions that could lead to a better machining. There are many beneficial results offered in manufacturing engineering because it represents an object-oriented methodology for the modelling and simulation of a virtual manufacturing environment (Liang, 2009). Collisions and unpredictable happening events are avoided towards high-fidelity machining simulation processes (Kadir & Xun, 2011). As a direct consequence, times and costs are reduced (Parpala, 2009) (Jayaram et al., 2010) resulting in good parts at first attempt which leads to optimal machining processes.

2. Methodology

The proposed methodology (Fig. 1.) has been followed to virtually verify the operations made in a turn-milling machine before real machining. In this case the first step has been the CAD design of a test part, whose geometry needs to be done making use of all the possibilities of the machine tool. After that, the CAM operations have been carefully programmed. For both CAD and CAM operations UGS software has been used. Afterwards, taking into account the characteristics of the machine, the number of axis, its configuration and limits, and the CNC functions, a personalized postprocessor has been programmed and its proper operation has been tested. For the last step, virtual verification, UGS software has been used. It is necessary to design the CAD of the machine and the tools and include them in the verification software to define the machine configuration. References, postprocessed CNC files and the type of CNC have also been included in the software.

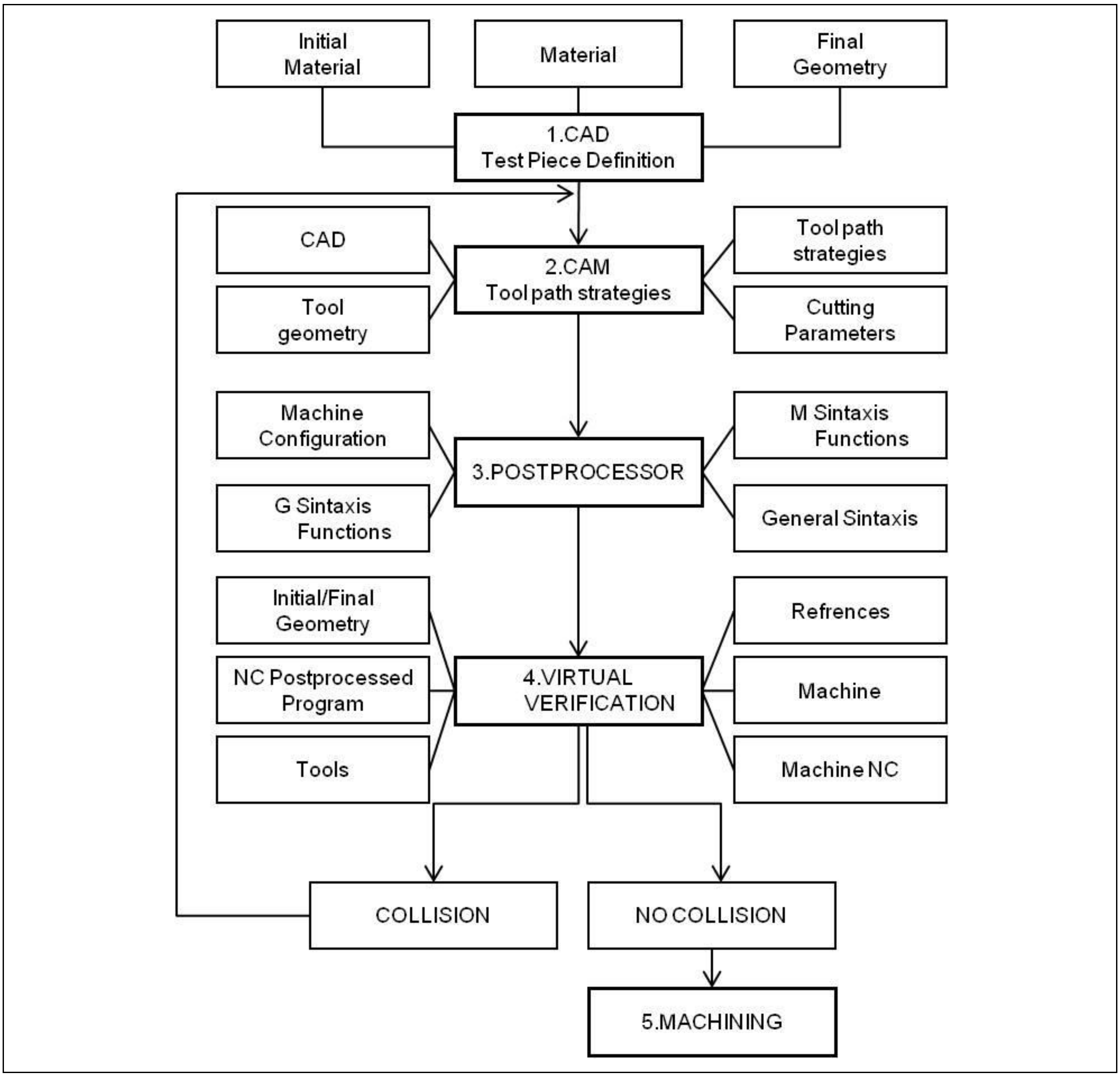


Fig. 1. Methodology

After the previous steps have been followed, it has been possible to verify possible undesirable errors that have been modified until the virtual machining (Fig. 2.) has reached the real machining conditions. On one hand, it is possible to analyze and avoid machining collisions that could cause waiting times and incremental costs. The cost due to production stop and machine reparation are two aspects that a correct virtual verification process can avoid. On the other hand, the machining part will not be damaged obtaining a part that meets all the demanded requirements. Not only that, but some virtual verification softwares can also analyze the surface finish in order to determine whether it is the required or not (Yingxue Yao et al., 2006).

Besides, there had been many improvements in virtual verification softwares. Nowadays it is possible to optimize machining operations when working at this final virtual verification step.

- Toolpath segmentation or partition.
- Cutting parameters recalculation. They are recalculated for a faster machining process.
- Engage/Retract movements reduction. These initial and final non-cutting movements are optimized to adjust times as much as possible.
- Feed rates/Spindle speed optimization.
- Cutting parameters personalization. It is possible to save some data in order to use it again when dealing when a previous material that has been milled.
- Feed rates recalculation depending on the remaining material. When there is little remaining material to cut the feed rate can be doubled and when there is a lot of material to cut it is reduced.

Thanks to these applications it is possible to modify the CNC program without having to go back again and modify it at the CAM stage.

The application of this methodology is limited technologically advanced industries engaged in machining operations concerning complex machine kinematics, machining processes and geometries. It is also reasonable following it for short series production or for the first parts of large series.

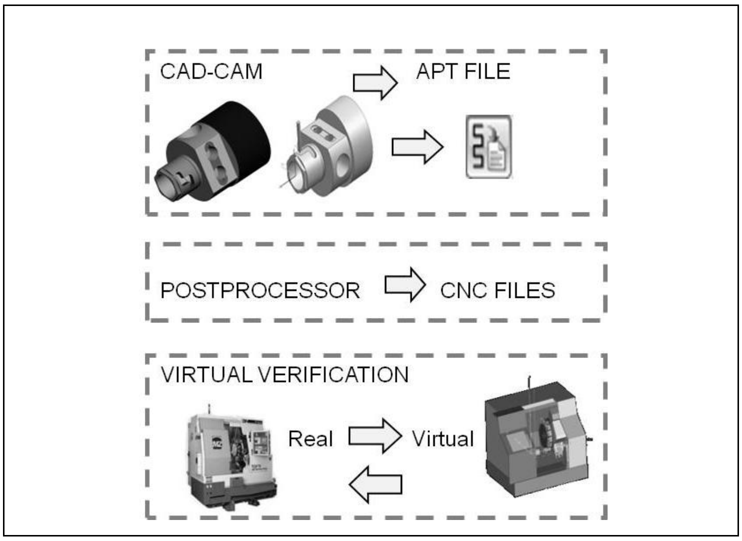


Fig. 2. Virtual verification process

3. Real application

The methodology has to be followed to finally machine a real part that in this case is a prototype part for the aeronautical sector made in aluminium. The postprocessor for UGS has been particularly programmed for the machine tool available, that in this case is a turn-milling machining centre TC25BTY from CMZ Machinery Group (Fig. 3.) and the NC is a GE Fanuc Series 31i-model A. The CAD of the machine is progressively included in the machine verification module and the kinematics of the machine is defined. The machine Base is the element the rest elements depend on. Z axis hangs on the Base of the machine. At the same time, X axis depends on Z axis and Y axis depends on X axis. The CAD models are associated to the corresponding axis. The turret of the lathe contains the geometry of the tools and its relative position. Each element position is related to the machine coordinate system. Motor tools or live tools are used for milling and turn-milling operations and its rotary movement needs to be specified. The left spindle is responsible for the part rotation or its locking when milling operations are carried out. The tailstock is attached to the Base model as well as the doors of the machine. Besides, it is also necessary to find a control that corresponds with the real numeric control installed in the machine to be able to read and understand all the commands included in the CNC code.

Collisions, out of range movements or excessive material removal are the kind of warnings the softwares detects. When a collision is found during the simulation process the machining strategies are modified and the simulation is ran again to verify and to obtain a process without collisions.

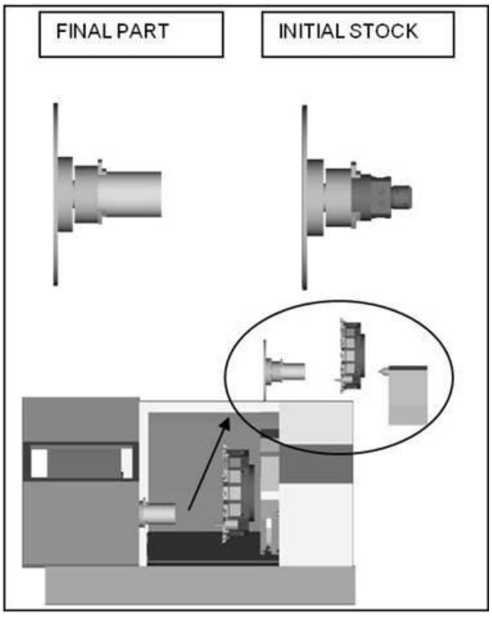
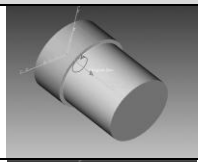
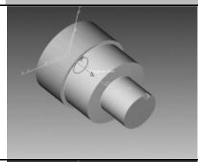
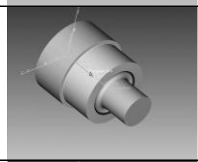
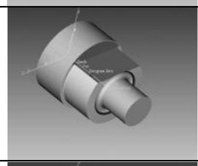
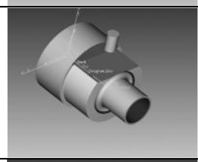
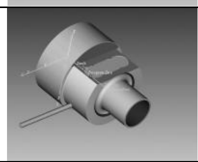
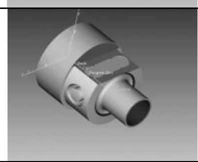
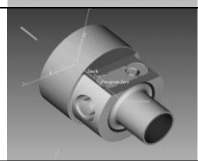
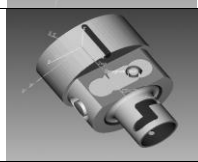
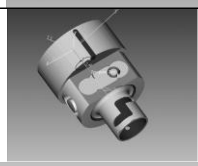


Fig. 3. CMZ TC25BTY Virtual machine tool

As it is shown in Tab. 1. the part requires milling, turning, drilling and turn-milling operations. The order and the synchronicity between them determine better or worse machining times.

Nº of phase Subphase Operat.	Phase Description: Phase(1000,2000...) Subphase (1100,1200...) Operation (1101,1102...)	Fixtures Tools Control tools	Cutting conditions				Time (min)	IMAGE Drawing of the part throw the different stages of the proccess. Initial dimentions, fixtures, tools.
			Vc m/min	ap mm	ae mm	fn/fz mm/rev		
1	Rough turn OD 1	CAPTO system Turning tool OD_80_L	300	3	-	0.3	6	
2	Rough turn OD 2	CAPTO system Turning tool OD_80_L	300	3	-	0.3	13	
3	Groove OD	CAPTO system Turning tool OD_80_R	200	1	-	0.2	9	
4	Cavity mill 1	CAPTO system Flat end mill Ø 20	250	5	10	0.1	10	
5	Rough turn ID 2	CAPTO system Turning tool OD_80_L	300	2	-	0.3	20	
6	Cavity mill 2	CAPTO system Flat end mill Ø 16	200	2	12	0.1	15	
7	Drill 1	CAPTO system Drill Ø 16	250	-	-	0.2	18	
8	Drill 2	CAPTO system Drill Ø 8	250	-	-	0.14	9	
9	Z Turn-milling	CAPTO system Ball end mill Ø 10	200	1	10	0.1	25	
10	Nut Variable contour	CAPTO system Flat end mill Ø 8	300	5	6	0.1	5	

Tab. 1. Real application

4. Collision simulation case

In this case a collision due to an error in the tool length for a turn-milling operation is simulated.

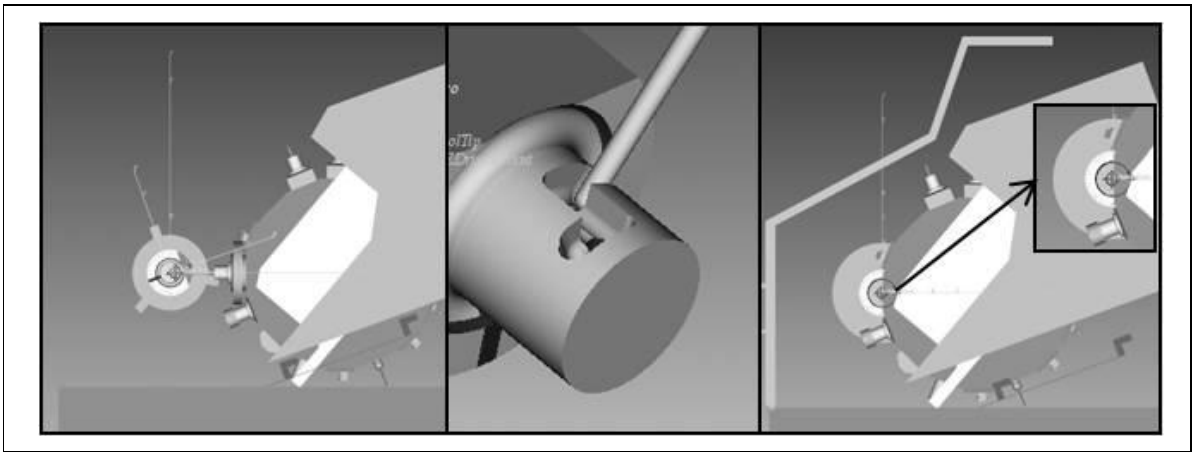


Fig. 4. Simulated collision and turn-milling operation

Fig. 4. shows the tools turret completely inside the part. On the left part of Fig. 4. the tool length is the appropriate one and on the right part the programmed length is not correct. Tools length and security distances have to be carefully checked. If the distance between the part and the turret during the tool change process is not enough some tools can also collide. Multitasking machines including Bottom Turret, B Axis Head and double spindle need special attention related to the transference of the part. When the part is being transferred from one spindle to another the B Axis Head and the Bottom Turret have to be sent to the security position where collisions are avoided. Finally, after the machining process has been fully simulated the final resulting CAD of the part can be exported to the CAD software and the final geometry can be compared to the initial one as to check that the part is acceptable.

5. Further steps

The research described in this paper will lead to a high-fidelity machining process that can be applied to more difficult and challenging machining operations and geometries. Further steps in the matter may be directed to virtually verify the machining of a propeller blade. The machining process will need to be carried out making use of the so-called “Pinch milling” which will consist on turn-ball-end-milling for contouring the blade. In this machining operation both turrets (Bottom turret and B-Axis Head) are used being indispensable to verify collision detection before the real machining process. On the other hand, the simulation of blade burnishing for improving both final roughness and fatigue endurance could also be carried out. Taking into account that virtual verification can also determine the finish surface accuracy, machining parameters could be adjusted, in relation to the results shown after virtual simulation, in order to improve the final result.

6. Conclusion

This paper shows the importance of the use of a reliable methodology for turn-milling operations when using multitasking machines. Virtual verification of the machining process will reduce the risk of collision, resulting in a much more reliable process. The reduction of collisions at the same time will result in an economic benefit for the user because extra charges due to collision reparation and production stop will not occur.

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