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DESIGN OF MOLD FOR HELICOPTER COMPOSITE ROTOR BLADE

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Summary: *This paper shows CAD/CAM programming technique of mold recess for helicopter main rotor blade. It is necessary to achieve high precision in this process. Due to the dimensions along one of the blade axis, the segmented mold is found necessary. In this paper the programming procedure is shown for one of these mold segments. The tool path simulation is shown as well as producing of APT and NC code with the verification of material removal. For realization of these processes CATIA's and Pro/Emgineer's tools were used. For chosen mold segment, machining has been done on machining center.*
Keywords: *CAD/CAM, mold, rotor, blade, composite*

1. INTRODUCTION

Most modern helicopter rotor blades are composite structures. Advantages of composite materials used in structures such as rotor blades are numerous. However, producing such structures represents complex tasks involving numerous disciplines.

Performance of helicopter is highly dependable on aerodynamic shape, dimensions and structure of the main rotor blades. Therefore it is necessary to achieve high precision and quality of the production during production of such composite structure.

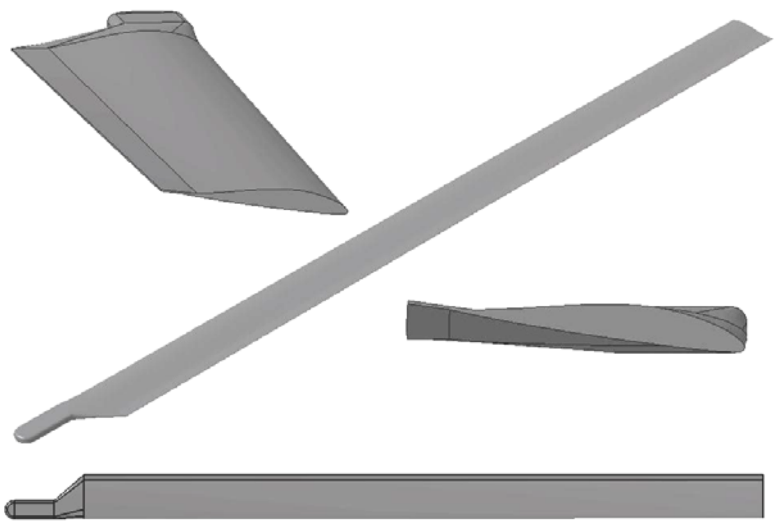

Figure 1: Main rotor blade

Blades for which mold is modeled are designed for VLR class helicopter. Twisted blade is 3.8m length with constant chord length 0.2m with same airfoil 8H12 along the blade (Fig 1.).

In order to produce high number of composite rotor blades of identical shape, it is necessary to have mold of suitable shape which can withstand loads while curing the composite structure. With metal molds higher geometrical precision can be achieved and it can be used more times than if the molds are made of some alternative material or with moldless method. Metal molds can be divided in upper and lower part, and both part can be used as the base for process of lamination (Fig 2.).

Figure 2: Composite blade laminating in metal mold

Technoeconomical conditions impose manufacturing technology. Composite structure manufacturing complexity joined with problems of long metal mold production puts several limits to these processes. To achieve high quality mold, one can use portal milling machines (Gantry type), but cost of material and its transport and manipulation tend to be quite problematic if the mold is not divided in segments.

To produce such a long metal part, a machine with dominant and elongnated X axis can be used, for example with parallel kinematic machines (PKM) and elongnated X axis [6]. To overcome these obstacles, mold can be divided in several segments, each consisting of its lower and upper part.

2. DESIGN OF MOLD

Blade dimension, relation of the width and span, leads us to the usage of segmented tool. Making of CAD model can be done using some of the modern 3D modeling software package. In this work two software package are used: CATIA and Pro/Engineer. Designing of the blade and modeling of the segments of the mold is done with aid of CATIA, while the problem of the machining of mold is done in several software environments (Pro/Engineer, CATIA, Master CAM) and various approach. Using various software programs is not affect design in negative sense, since the interchangeable formats, such as IGES and STEP, allows them use design different than currently active software.

After the process of blade preliminary design, its geometry is modeled in CATIA V5 package. Geometry shape of the blade defined by aerodynamic parameters determinate shape of the both, upper and lower part of the mold. The process of the mold modeling is done also in CATIA V5 working environment using its advanced tools options upon the blade model is finished.

Design of 3D shape of the mold, which is done in CATIA environment this way can be exported to the environment of Pro/Enginner later, Fig. 3.

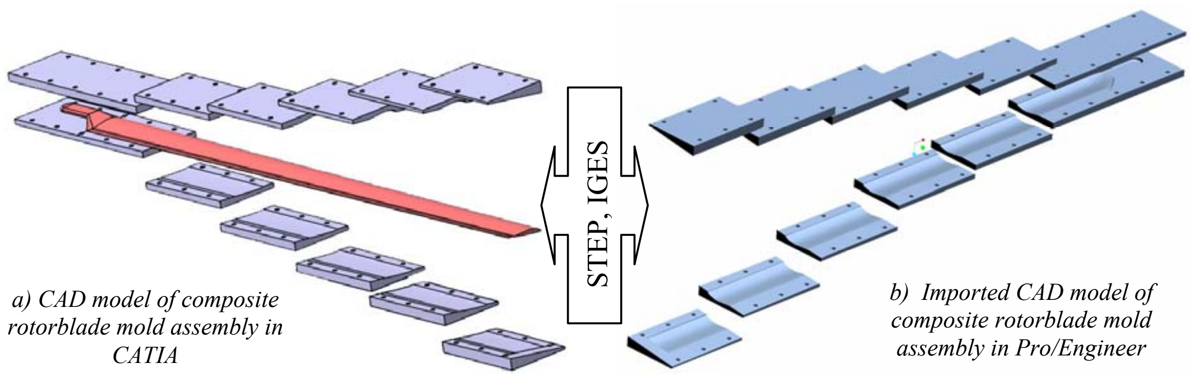

Figure 3: CAD models of composite blade mold segments

Since we are dealing with the segments of the mold, we need to take care of bonding them together to form upper and lower part of the complete mold. Bonding of the segments is done by bolt conection to the common surface

3. DESIGNING OF THE PRODUCTION TECHNOLOGY

Mold machining problem consists of translating 3D geometry information to tool path in order to make it on specific machine. According to available recourses, machining is done on the ILR HMC 500 machining center. Before materialization, geometry has been considered in few software environment already mentioned.. Figure 4. shows cycle of making segment of the rotor blade mold using CAD/CAM system. Starting with rotor blade model (1), model of the mold is created. Due to the mold length, it is divided into the segments in upper and lower set (fig 3. and fig. 4). The procedure is shown for one segment only since the analogy is obvious for other segments. Chosen segments (2) whose machining is object of this paper, are given as CAD model in the assembly in figure 5. Using CAM option, simulation and generation of toolpath is achieved (3). This enables consideration and analysis of different machining approaches, before actual machining. Good feature of modern software packages with CAM possibilities is quality animation of material removal (4) which enables verification of the program in computer and noticing of possible mistakes before machining. After this simulation testing and verification of computer models, machining follows (5).

Figure 4: CAD/CAM system application

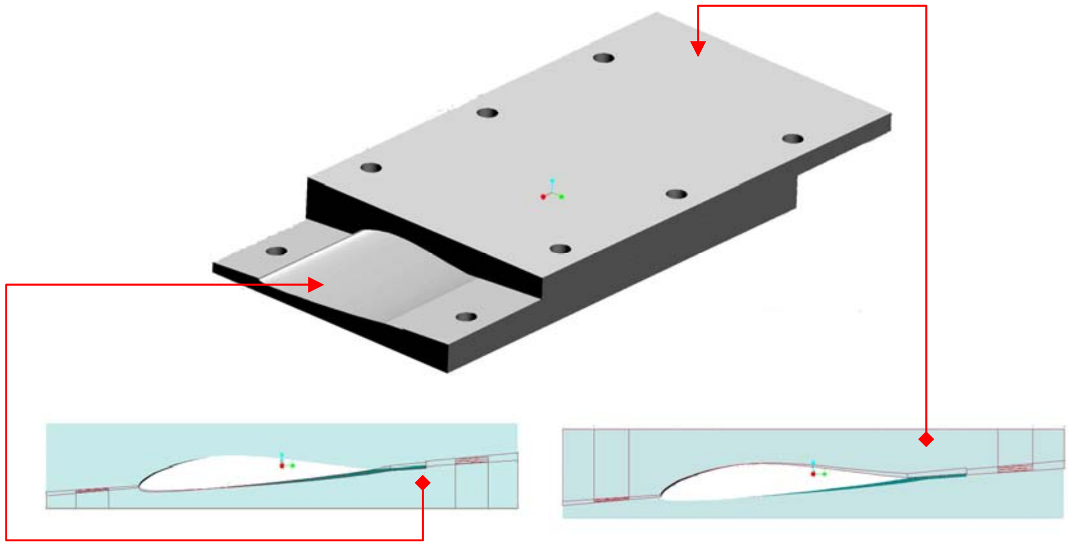

Figure 5: Two segments assembly example

Figure 5. shows tool path screen during simulation, and figure 6. shows screens of material removal simulations. Testing and verification of the machining is done in all three softwares to compare strategies of maching and results in order to choose optimal solution.

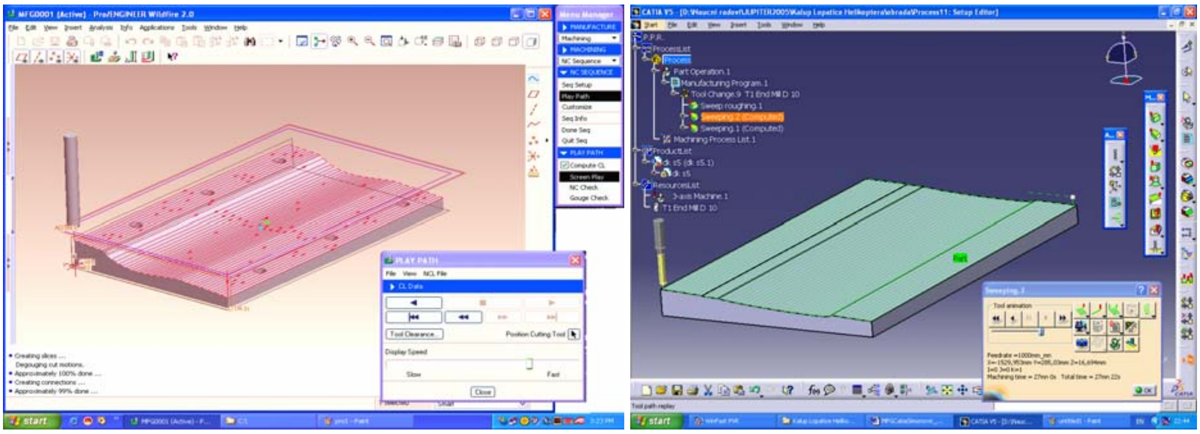

Figure 6: Tool path simulation in Pro/Engineer and CATIA environment

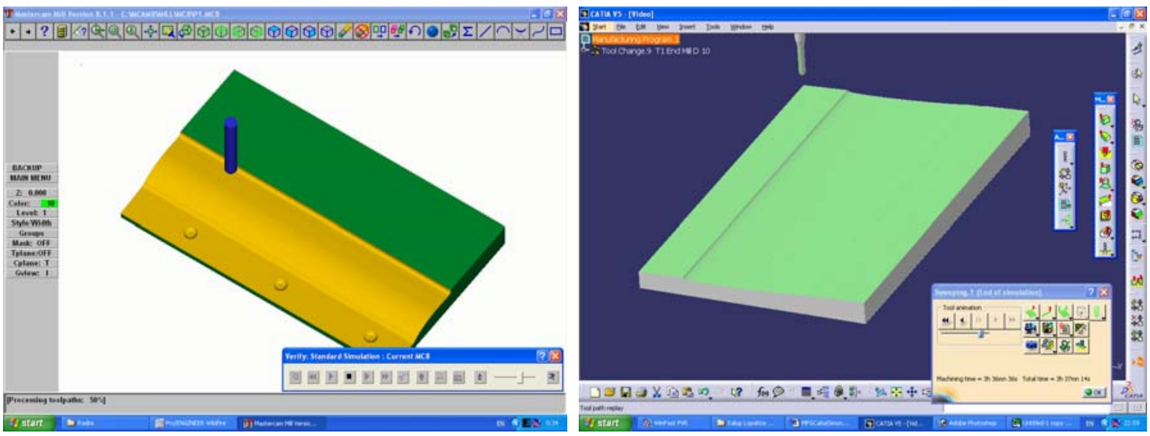

Figure 7: Material removal simulation during machining in Master CAM and CATIA environment

4. TEST MOLD SEGMENT MACHINING

Machining is conducted using available recourses and plans for machining of test peaces in soft material (polyurethane) on machining center ILR HMC 500. Machining of test piece, begining and the end, is displayed on figure 8.

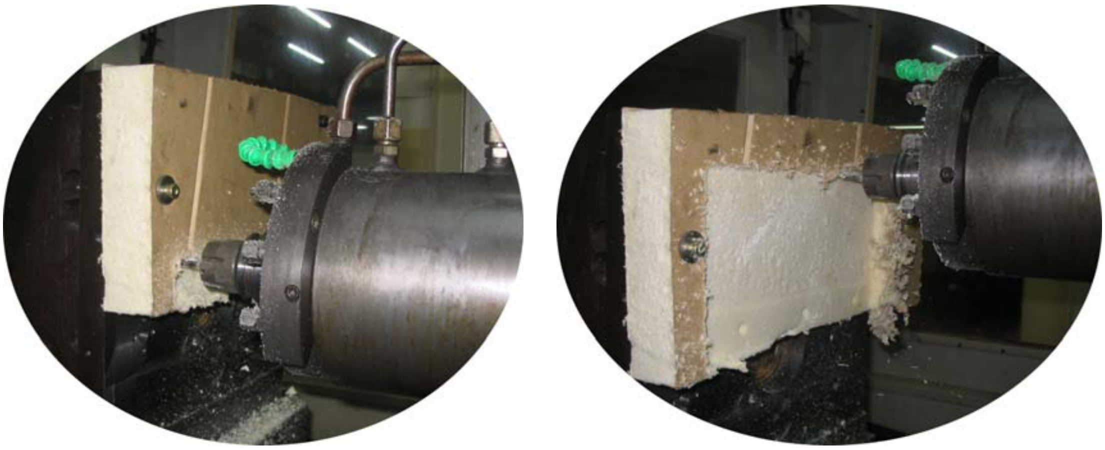

Figure 8: Example of tool machining on HMC 500

Figure 9. shows assembly of finished segments. These segments are cut on specified dimensions and put one above other. It can be seen in figure 9. difference between CAD model of the segment assembly and machined assembly to compare designed and achieved geometry.

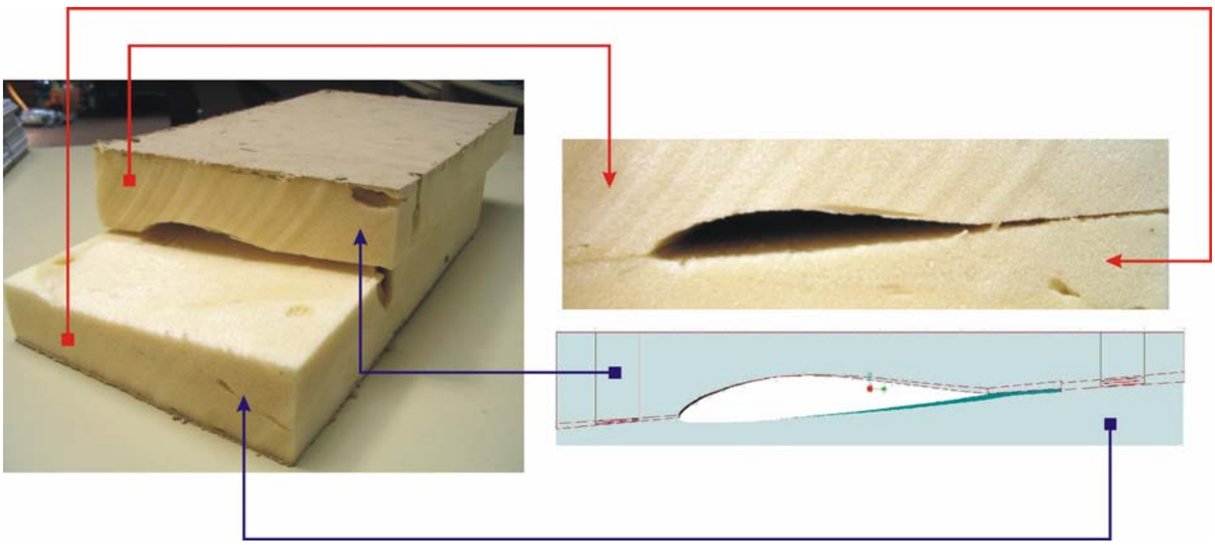

Figure 9: Assembly of the machined segments

5. CONCLUSION

Mold dimensions and available technologies for composite structure usually impose dividing the whole mold into upper and lower set of segments bonded together during the process of blade manufacturing. This complex assembly and its role during layering, assembling and curing of composite structure has to be manufactured and assembled with high precision.

Computer assistance is great advantage in composite rotor blade mold designing and machining process. Actual blade geometry complexity, impose usage of computer in order to get quality mold. In order to get quality mold geometry, the blade is transformed in 3D model to get 3D model of the mold. Such model is translated into 3D machining information for machining on the available machine. These processes are checked and verified using simulation of tool path and material removal and other options in available software packages.

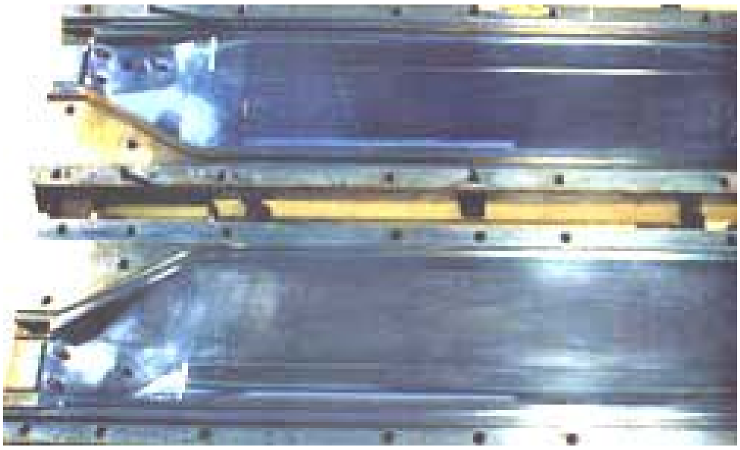

Figure 10: Finished mold example

To verify actual procedure one part of the rotor blade mold and corresponding upper and lower segment are selected to be manufactured in soft material. For these segments APT and NC code is obtain together with machining simulation. Post processing is done for FANUC control unit. Further work should consider manufacturing models of plastic and finally aluminum to get results similar to this shown in figure 10.

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