INEXPENSIVE CAM PROGRAM FOR THE MANUFACTURING OF WING MOLDS

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ABSTRACT

A new computer program was written for manufacturing wing moulds on a 3-axis CNC machine. The aim was to reduce the costs and time of normal CAD/CAM processes and to write a dedicated computer program that could generate machine codes for complex 3D wing geometry.

A test wing section was manufactured using the machine paths generated by the new program. To verify the shape of the test section, the airfoil coordinates were digitally obtained and compared with the original designed airfoil shape. Very little deviation was detected and the method was thus found to be suitable for the manufacturing of moulds for gliders, where accuracy of the wing shape is of great importance.

INTRODUCTION

The development of a new glider is very time consuming and expensive. A large component of the cost is associated with the manufacturing of the high precision moulds from which the glider is built. These moulds were traditionally built by hand with the help of CNC-machined templates. The modern approach is to use computer controlled milling machines to cut a production mould from special stable mould materials.

This approach is very accurate, but also very expensive. The high cost stems for the high cost of the CAD/CAM software required to generate the tool paths and models for the milling machines, the operating cost of the milling machines and the high cost of special mould materials.

A new approach is proposed to reduce the cost of this technique, while retaining the accuracy. As a first step, a dedicated CAD/ CAM program was developed. This program can generate the CNC machining tool paths for any given three dimensional wing geometry like the wing/winglet transition area and the wing/fuselage junctions. The wing geometry is obtained directly from the airfoil data, thus the need to generate time consuming solid models of the moulds is not necessary. The cutting paths are then produced in G-code format for simple 3-axis milling machines. This can significantly reduce costs, as a very expensive 5-axis machine is not required.

CAD/CAM PACKAGES

Computer aided manufacturing (CAM) packages are used for accurate and fast manufacturing of products directly from a computer solid model, as designed in a CAD package. Almost any geometry can be machined with these modern packages together with sophisticated machinery.

Most existing CAM software available for mould manufacturing, like DelCam, Hyper Mill, CAMWorks etc. are integrated into computer design (CAD) packages for easy access to the computer model. Once the product is designed and drawn on the computer, the CAM add-on recognises the geometry and create the tool paths for machining purposes.

These CAM add-on packages have many features to simplify the manufacturing process. Some of these features include customizing tool shapes, extensive ranges of roughing strategies, various finishing strategies and tool path management to minimise cutting time. These packages are also capable of interfacing with various CNC-machines.

All of these packages can deliver accurate moulds with adequate surface quality, but are written for industry purposes with a variety of capabilities, which make the packages that more expensive due to high development costs.

NEW APPROACH

The available CAD/CAM packages are expensive therefore alternative ways of manufacturing wing moulds were investigated. The only way accurate moulds could be manufactured is by means of CNC-machining. The cheapest machine available that could manufacture the desired shapes for wing moulds, is a 3-axis CNC-machine. By using ball-nosed cutters, almost any wing geometry moulds could be milled with the necessary accuracy. By using simple 3-axis machinery, it was necessary to further reduce costs by eliminating expensive CAD/CAM software.

With a little bit of effort and time, a computer program was written that can generate cutting tool paths for complex three dimensional wing mould sections, for use with a 3-axis CNC-machine. The input parameters are simple, with no need for expensive CAD software to generate the desired model on computer. All that is needed is the various airfoil sections at specific locations, twist, sweepback, dihedrals and panel lengths. This information is readily available after the wing design is completed.

THE PROGRAM

For a designed wing/winglet tip section as seen in Figure 1, the computer program is able to create G-Codes that, with the help of a 3-axis CNC-machine, manufactures the mould (Figure 2). To generate the tool paths, the airfoil

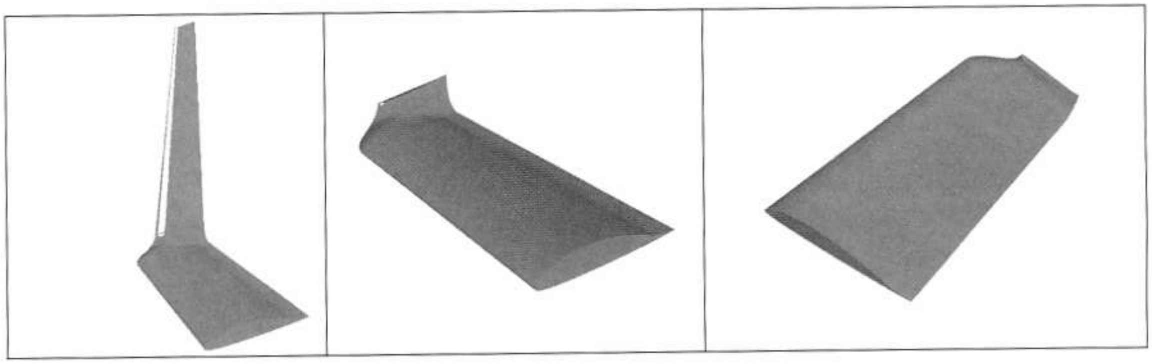

Figure 1 Winglet geometry

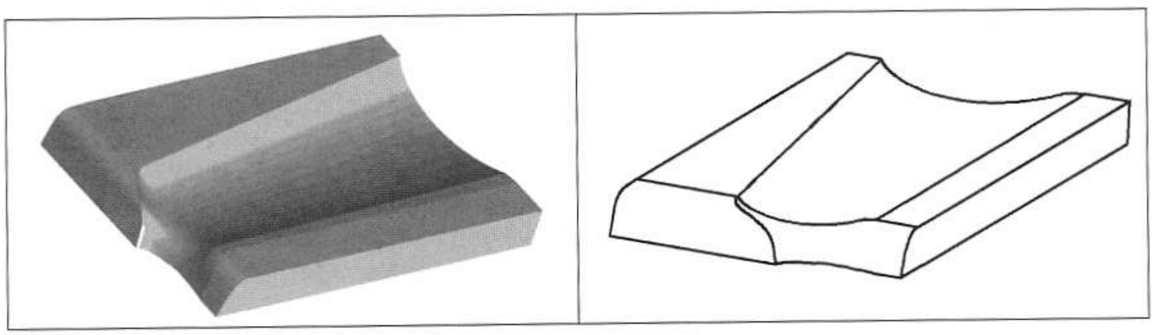

Figure 2 3D view of the mould (top) for the tip section

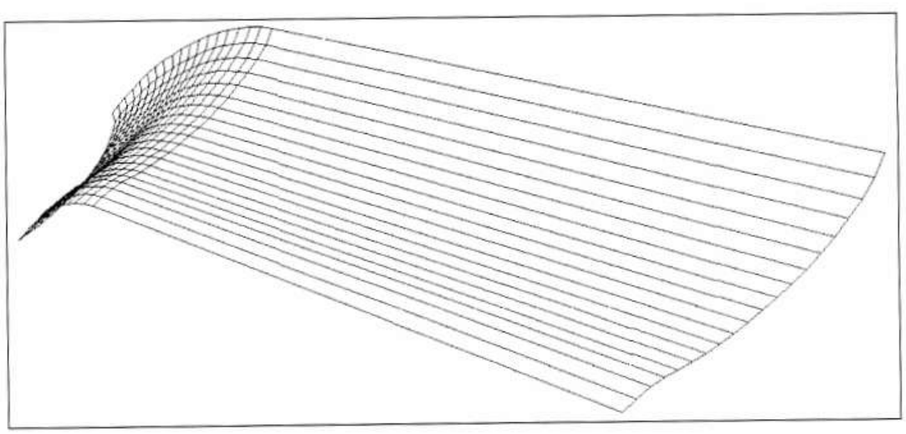

Figure 3 Surface grid for the tip wing section

data at each section, panel lengths, twist etc. is necessary to generate a surface grid. (Figure 3.)

A coarse surface grid (for better visual display) is shown in Figure 3. The number of panels can be adjusted to acquire a higher surface accuracy. For rough-out procedures, for example, one don't need a fine surface grid, otherwise the machining time would be too long.

After the surface grid is generated, a rough-out path can be established. The rough-out procedure is needed to rough out the waste material to a point near the surface from where a ball-nosed cutter can be used to cut the surface. Ball-nose cutters, that is used for the surface finishing, can only mill small depths in comparison to rough-out cutters, which is flat faced. It is thus a lot quicker to rough-out the waste material with a rough-out cutter than it is with the ball-nosed cutter. It also saves the ball-nose cutter for good surface finishing, where it is needed.

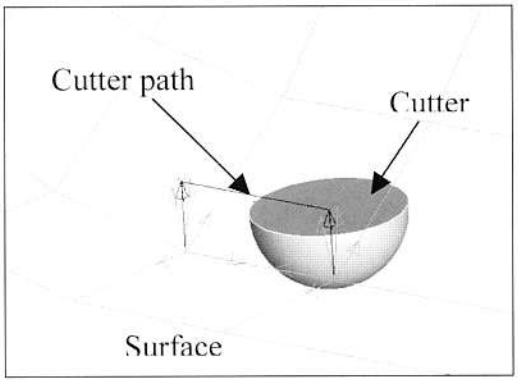

Figure 4 Positioning of the cutting bit

The rough-out path is found by moving the cutter along the surface grid, while calculating the height of the cutter for the specified minimum distance from the surface. The cutter will then move linearly between these calculated points on the grid. Negative values for the minimum height can also be given in cases where the cutter must make incisions in the surface, for example, if a small epoxy gap must be cut at the leading edge of the mould. In cases where the depth of the surface is deeper than the rough-out cutter's shaft length, multiple passes can be made over the surface to acquire the desired minimum height. After the rough-out process, the surface cutting can proceed by using ball-nosed cutters of various diameters.

By using 3-axis CNC milling machines, smooth 3D surfaces can only be cut with ball-nosed cutters. Using ball-nose cutters for the surface cutting procedure, the offset from the surface must be calculated at each grid point to establish the correct cutter path. At each grid point the cutter is thus positioned perpendicular to the surface at the distance of the cutter radius. To determine the position precisely perpendicular to the surface, the mean vector of all the cross products from surface vectors is calculated, as can be seen in Figure 4 (Ellis & Gulick, 1994)

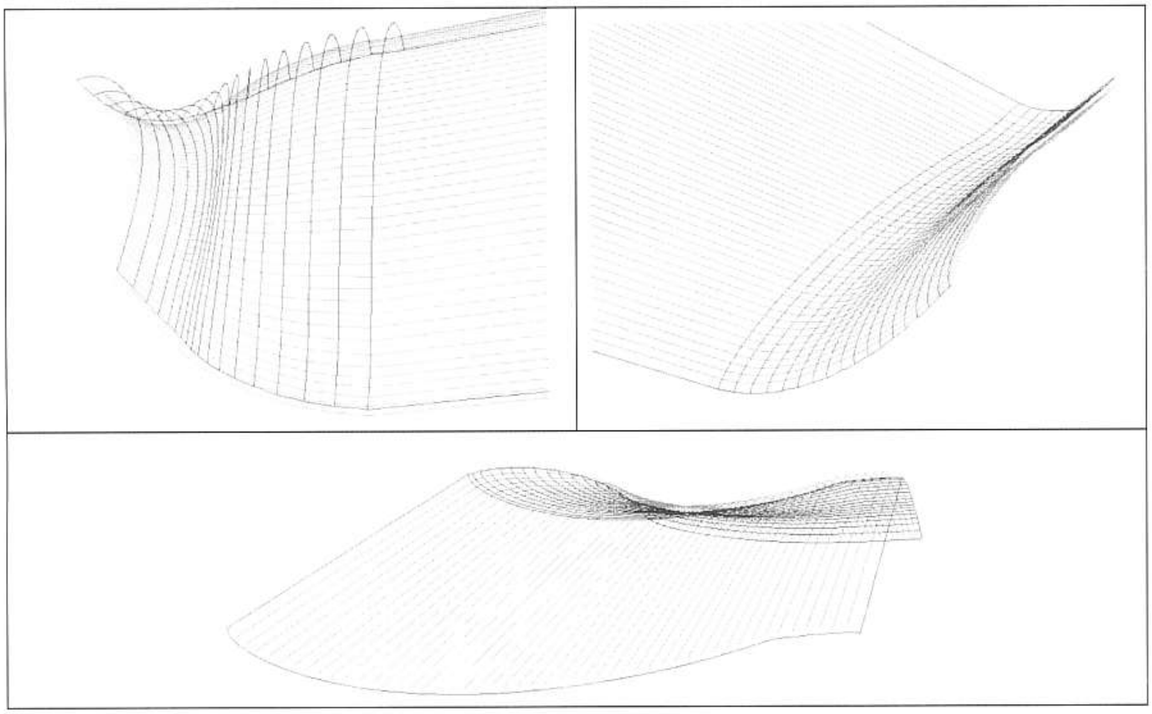

Figure 5 Cutter paths for the wingtip mould

VALIDATION OF THE PROGRAM

All the effort required to design a new airfoil demands that the shape of the end product will be exactly the same as was intended. It is therefor necessary to establish the accuracy of the new program before the system can be used in the manufacturing of new moulds. Not only is it important that the shape of the moulds are correct, but a good surface quality is also necessary. If the surface quality is not sufficient, hand finishing will mean lower surface accuracy, which is unacceptable. The goal is then an accurate mould with adequate surface quality straight after milling.

For the validation of the program a test section was milled using laminated super wood as the cutting material. The test wing section consisted of a 400mm chord, flapped airfoil. Both the top and the bottom sections were milled, together with the flap moulds using a Bosch 3-axis milling machine. The bed size of the milling machine is 3m by 1.5m.

A 3.175mm radius cutter was used for the nose sections where a 6.35mm radius cutter was used with the rest of the mould for better surface quality and less milling time. Figure 6 shows the mould for the bottom surface, right after milling. Also visible is the 2mm epoxy escape canal that was cut at the leading edge. Figure 7 shows the top section right after milling. Some errors were detected that were caused by inadequate lamination of the super wood. The density of the super wood differs from the outside to the centre. This causes a rough surface which is inadequate. Thinner super wood sections that was used with the flap sections Figure 8 showed better results with a much higher surface quality due to higher densities of the wood.

Looking at the accuracy, Figure 9 shows the original airfoil that was designed, with the co-ordinates of the CNC-machined airfoil as dots. The co-ordinates were obtained via digitising techniques. Figure 10 shows the deviation of the machined airfoil from the original. Fifty five points were taken on the upper surface and compared with the original airfoil. The graph shows that the maximum deviation is under 0.1mm, where the mean deviation is about 0.02mm. Comparing the pressure distribution between the original and milled airfoil (Figure 11), one can see little differences, but the variation could be contributed to the digitising process which is totally accurate.

CONCLUSION

Although many other CAM packages exist on the market, a program that is specifically designed for wing mould manufacturing, was developed. The aim was for a program that would cut any given 3D wing geometry accurate and with good surface quality for a fraction of the traditional costs of CAM packages. This has been achieved with the new program that generates the tool paths used on a simple 3-axis CNC machine. The program includes rough-out procedures and uses ball-nosed cutters during surface cutting.

Choosing the right material for the moulds is important. Surface quality can vary dramatically with different materials. Although some materials may be more expensive, they will last much longer than materials like super wood which is adequate for a prototype moulds only.

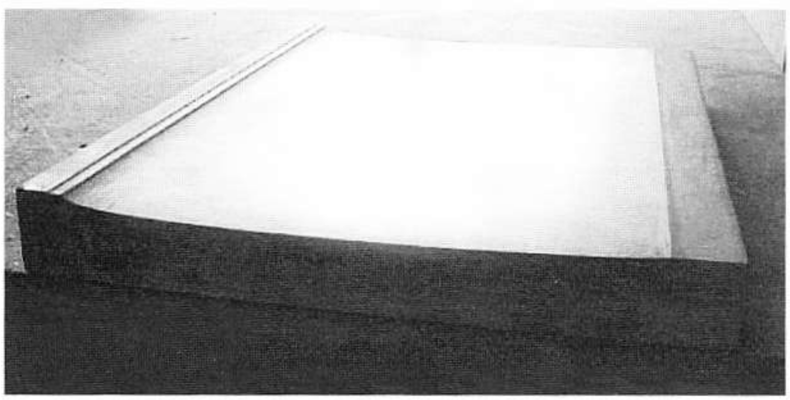

Figure 6 Bottom surface of test section

REFERENCES

Ellis, R. & Gulick, D. 1994. *Calculus with analytic geometry*. New York: Harcourt Brace College. 690-780.

Streifeneder, 2001: *Glasfaser flugseugbau, Hansjörg Streifeneder*. http://www.streifly.de/home.html

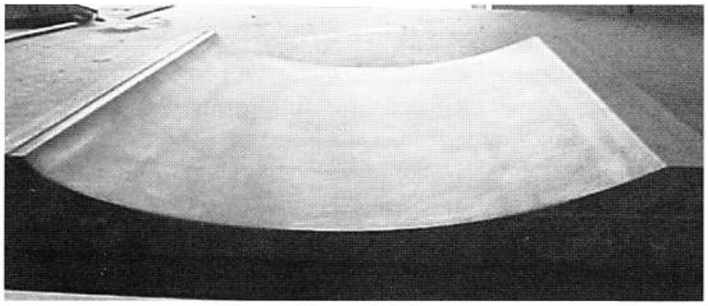

Figure 7 Top section of test section

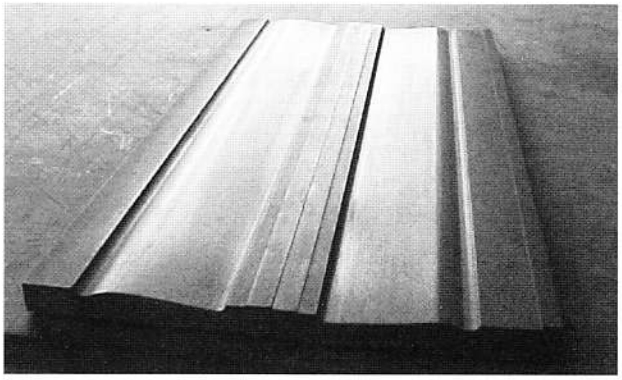

Figure 8 Flap moulds (top and bottom)

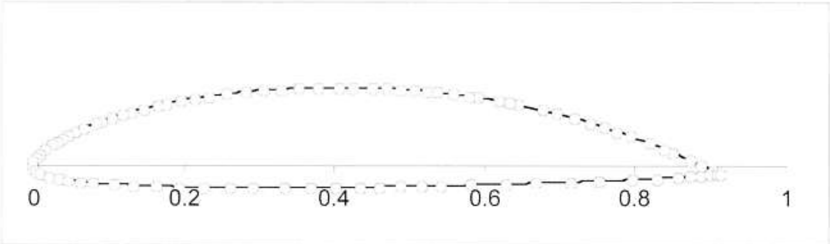

Figure 9 Original airfoil compared with mould (dots)

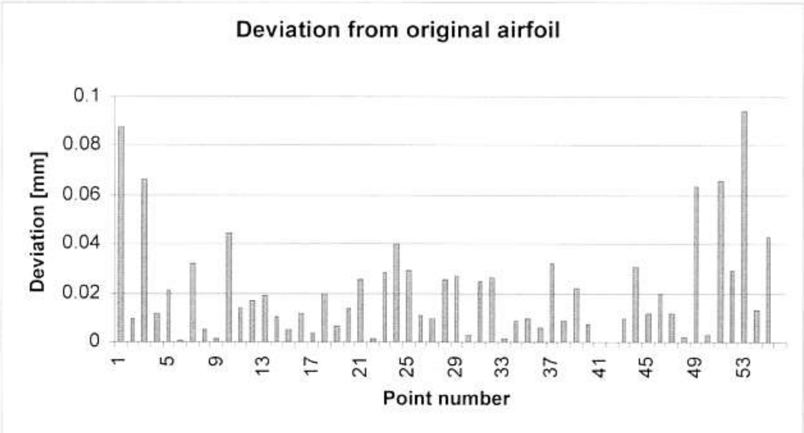

Figure 10 Deviation measurements

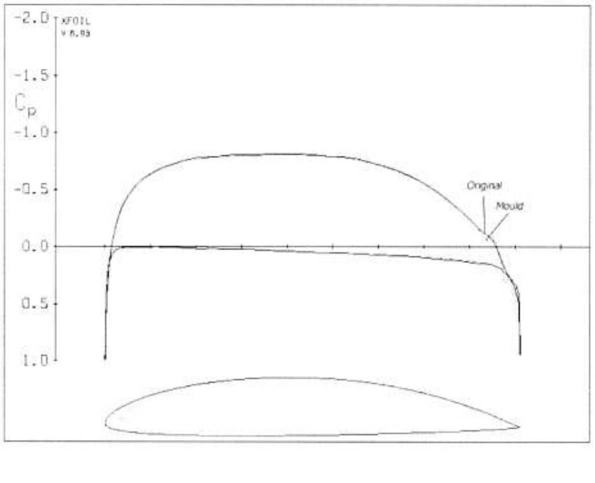

Figure 11 Pressure distribution comparison between original and mould airfoils (Xfoil)