**AMRC**
Design and Prototyping Group

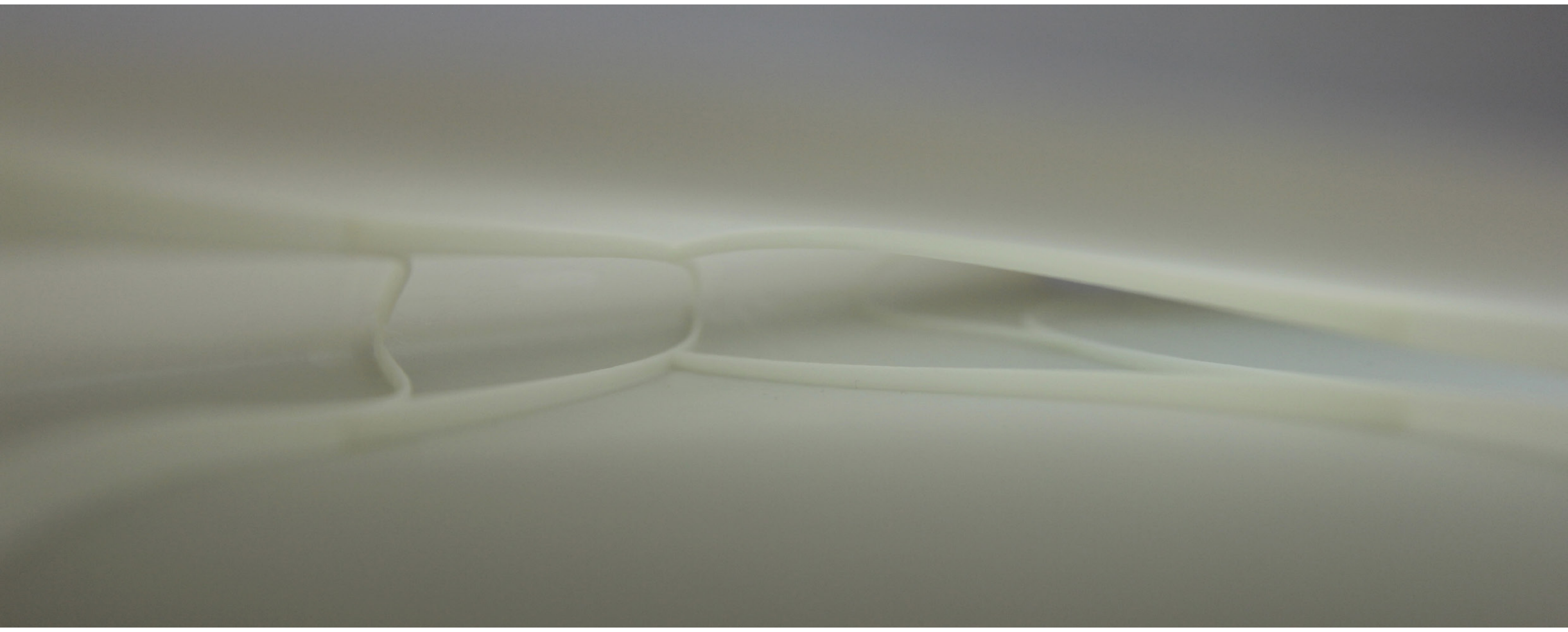
Case Study

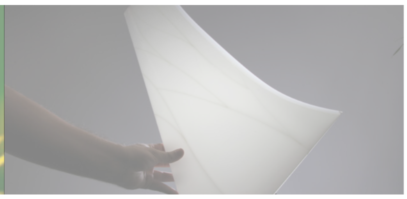
The University Of Sheffield.

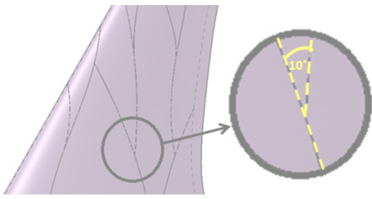
Advanced Manufacturing Research Centre

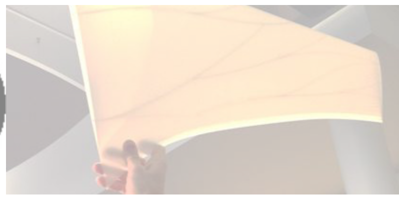
BOEING

# A Study of Fractal Geometry for Wing Design









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# 1 Summary

The AMRC Design and Prototyping Group (DPG) has carried out a study of self-supporting printed structures for UAV (Unmanned Aerial Vehicle) wing design.

The designers used fractal mathematics to model an internal structure for a wing resembling that of an insect wing. The aim was to develop a wing that could be printed by the fused deposition modeling (FDM) process, using Acrylonitrile Butadiene Styrene (ABS) without using additional material for structural support. Lessons learned during this study will be used for future projects within the DPG and were used for the first UAV fixed wing prototype.

# 2 Introduction

The design and development of a fixed wing UAV is an ongoing project within the Design and Prototyping Group at the AMRC. One of the innovative design concepts, which the group explored, was strengthening the wing using a fractal structure rather than separate ribs within the assembly. Fractal structures can be seen in nature in trees, snowflakes and, more related to this case, the insect wing. Figure 1 shows insects in which the wings have a definite internal structure produced by the veins. The venation pattern is different for all insects, but serves the same purpose. It strengthens the wing and keeps a flexible surface.

**Figure 1 – Venation structure of insect wings**

# 3 Procedure / Methodology

The concept of a fractal structure was explored in order to create the model. The root of the structure starts at the base of the wing as seen in Figure 3. This base then divides into branches of length *L* and *R*, one to the left and the other to the right of the trunk at an angle *Θ* as shown in Figure 2. A structure is then formed on the wing which resembles that of a tree or insect veins.

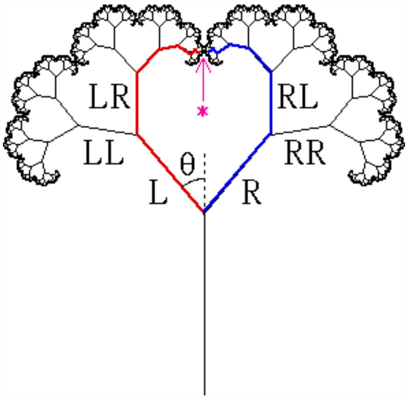


**Figure 2 – Fractal tree geometry definitions Yale (1)**

The coordinates for each point of the branch were calculated using an algorithm in C#. A basic outline was then drawn based on the coordinates and projected onto the wing using Catia as the CAD package. In order for the wing to be printed without the need for support material the angle between the two layers of material had to be less than 30˚. For this reason the branches of the structure were modified in order to have a maximum angle of 30˚ to the previous layer as shown in Figure 3. The model was then exported and printed on the Fortus 900mc 3D printer using ABS material.

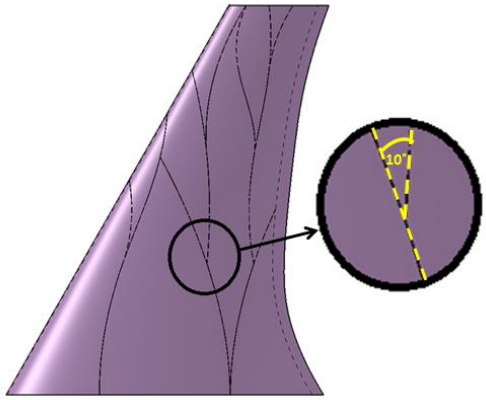


**Figure 3 – CAD model of fractal wing**

# 4 Results

A fully supported wing was printed using the methodology in Section 3, in the orientation shown in Figure 4a. No support material was required throughout the printing process, reducing the print time and production costs. The fractal structure can be seen in Figure 4b which is identical to the CAD model. Figure 4c illustrates the intricate internal structure of the printed wing.

**Figure 4 – a) Fully supported wing as printed b) Printed wing c) Internal structure of printed wing**

# 5 Conclusions

The wing was successfully printed using ABS material on the Fortus 3D printer in 4 hours. An improved understanding of printing unsupported structures was gained as a result of this study and will be used in future design projects.

# 6 References

1. **Yale.** Dimensions of Fractal Trees. *Fractal Geometry.* [Online] [Cited: November 17, 2014.] http://classes.yale.edu/fractals/FracTrees/SelfContact/SelfContact.html.

# Contact details

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