2d and 3d Modelling of Pterosaur Wing Aerodynamics

Alister Millard

Background

Pterosaurs were giant prehistoric gliders dominating the skies from the late Triassic period, (oldest of the Mesozoic ages) with the enormous wings spans up to 10m. It has been questioned how these creatures; comparable to light aircraft managed to take off and manoeuvre.

The pteroid bone appears to have played a major role in the flight mechanics by adjusting the orientation of a front wing flap. This created a high-lift capability which together with their pneumatic (hollow/light weight) bone structure enabled them to take off by merely facing an oncoming gust of wind. By modelling a pterosaur wing in computational fluid dynamics software it was possible to simulate the aerodynamics and therefore plot the flight characteristics.

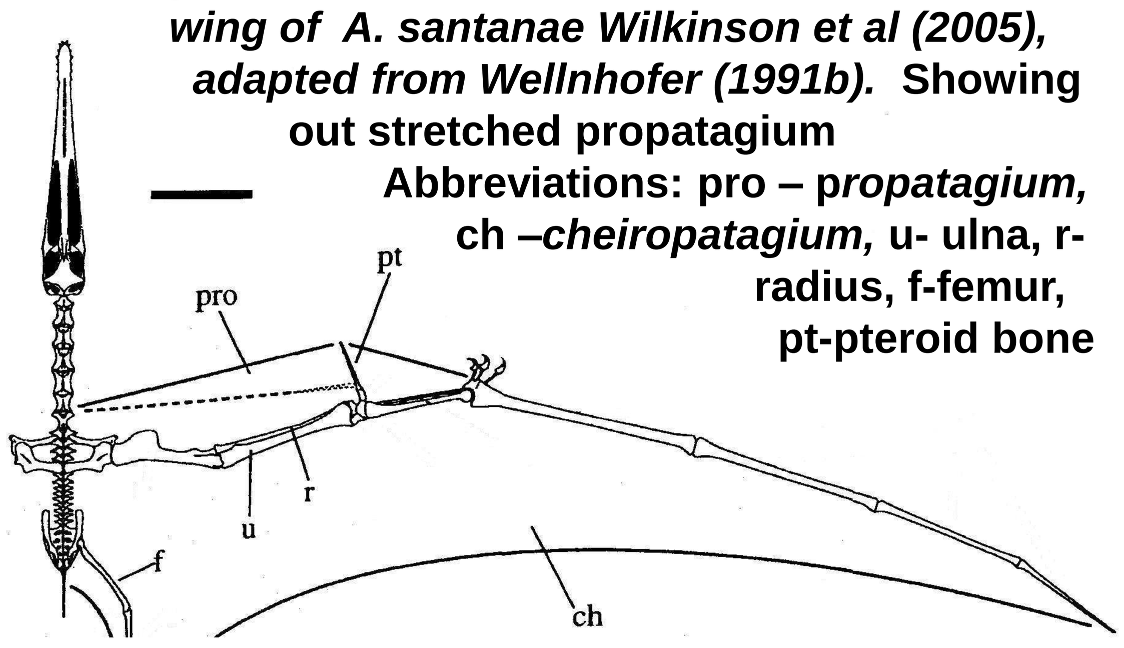


Figure 2 - *Reconstructed skeleton of the right wing of A. santanae Wilkinson et al (2005), adapted from Wellnhofer (1991b).* Showing out stretched propatagium
Abbreviations: pro – *propatagium,* ch –*cheiropatagium,* u- ulna, r- radius, f-femur, pt-pteroid bone

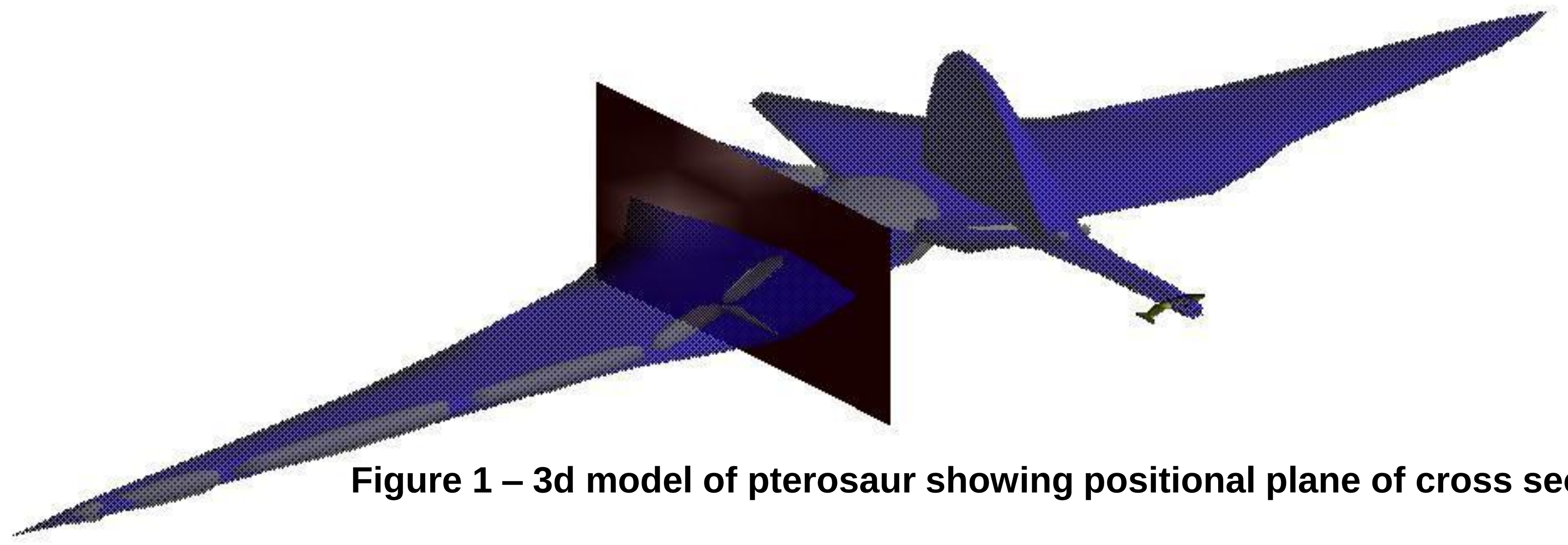


Figure 1 – 3d model of pterosaur showing positional plane of cross section

Previous theories

There has been much debate regarding the orientation of the pteroid bone. Recent theories have highlighted the full potential of its function in adjusting the orientation of the propatagium, a front wing flap with significant influence on lift and drag forces.

Task

The aim of this project was to create 2d and 3d computer models of a pterosaur and its wing structure; use these to analyse flight dynamics and look at pterosaur behaviour and select an appropriate model to analyse the possible high lift function of the front wing flap.

Method

A diagram of the right wing skeleton (Figure 2) was used as a template to construct a 3d model. A cross section of the wing was taken at the red plane in Figure 1 to create 2d models in Fluent and Java Foil. The 2d model is shown in Figure 3. Data from 2d CFD was then analysed. Stall speed and powered flight requirement shown in Graphs 3 and 4 were derived using Gray's (1968) formulae. The method of setting up a 3d CFD analysis was achieved with the import and export of files through a sequence of programs from Studio Max, AutoCAD, Solid Works and finally to Gambit.

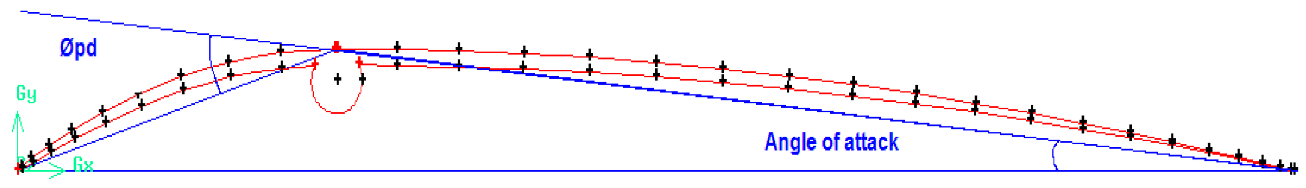
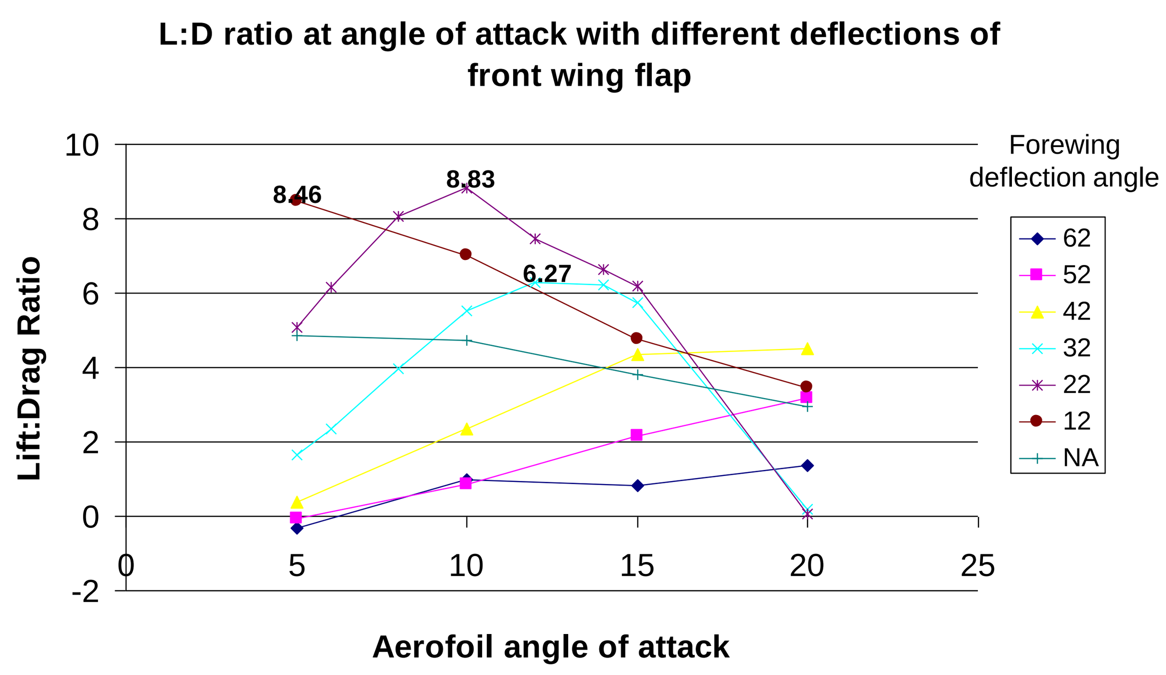


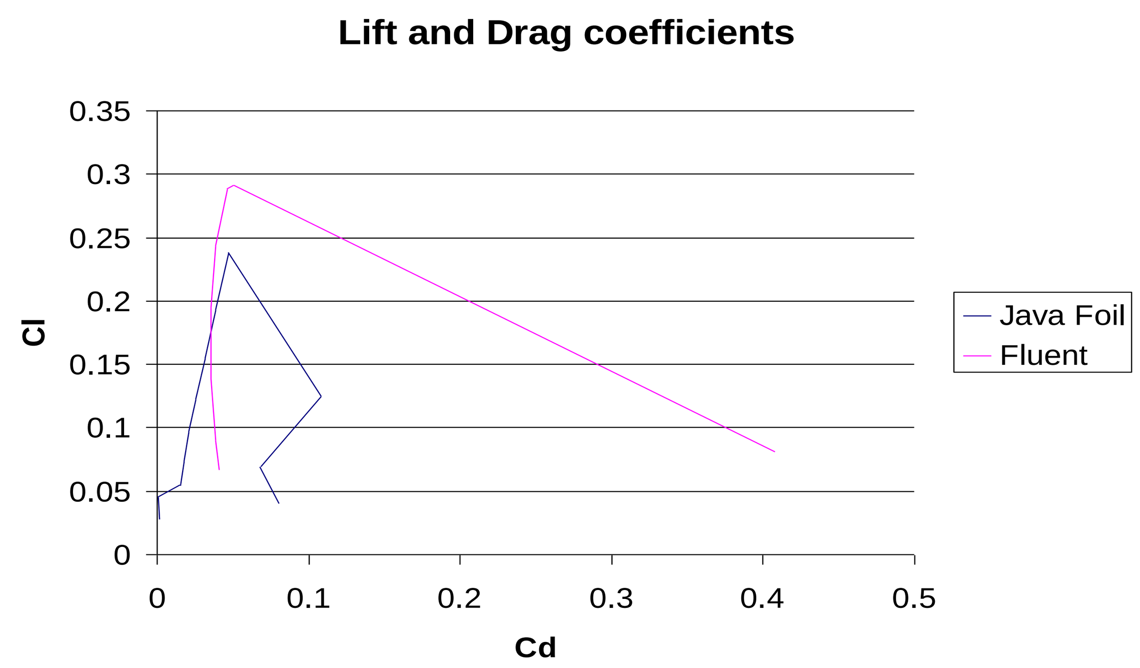
Figure 3 - Modified 2d Gambit model of pterosaur wing

Results

The CFD results as shown in Graph 1, support the high lift function of the broad propatagium from Wilkinson's physical wind tunnel models. The Fluent drag coefficient was more pronounced when compared to Java Foil (Graph 2). However, the accuracy of Fluent's ability to solve drag is questionable. The contour in figure 4 shows the point at which the mirrored vortexes are shed with a deflection of the front flap (Øpd) at 32°. The lift: drag ratio started to drop at an angle of attack of 13°. Front wing flap deflection allows slower stall speeds, as demonstrated in Graph 3, suggesting high manoeuvrability. The dramatic changes seen in stall speed, achieved with changed angles of the front wing flap, are compatible with a foraging style of aerial fish-eating. A dramatic increase in the power requirement from 15° and 20° angles of attack is evidenced in Graph 4. This power requirement would be difficult to maintain for long periods of time.



Graph 1 - Flight characteristics



Graph 2 –Correlation between Fluent and Java foil results

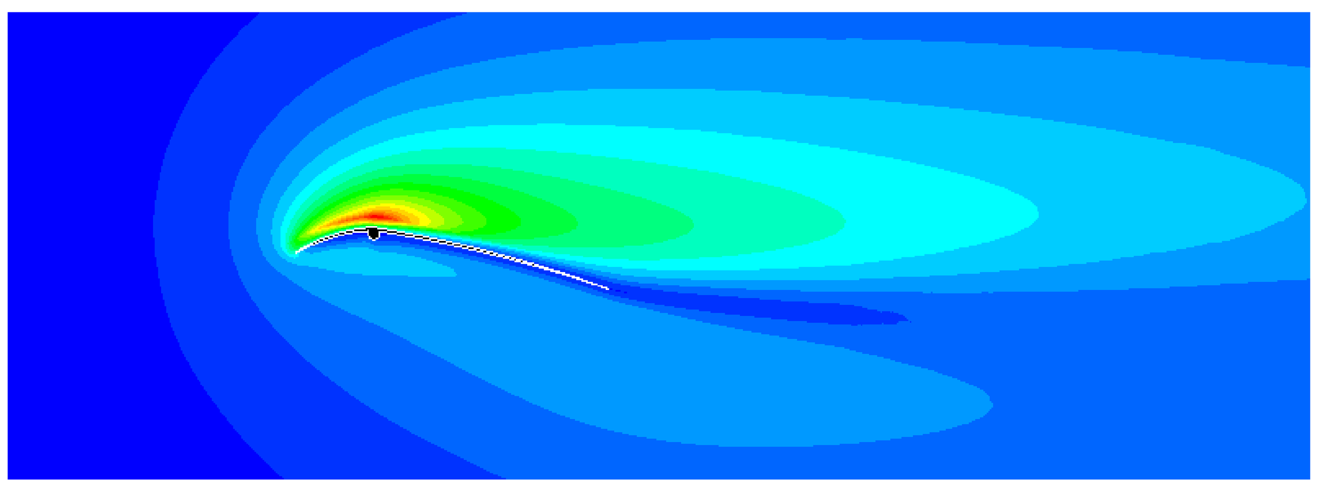
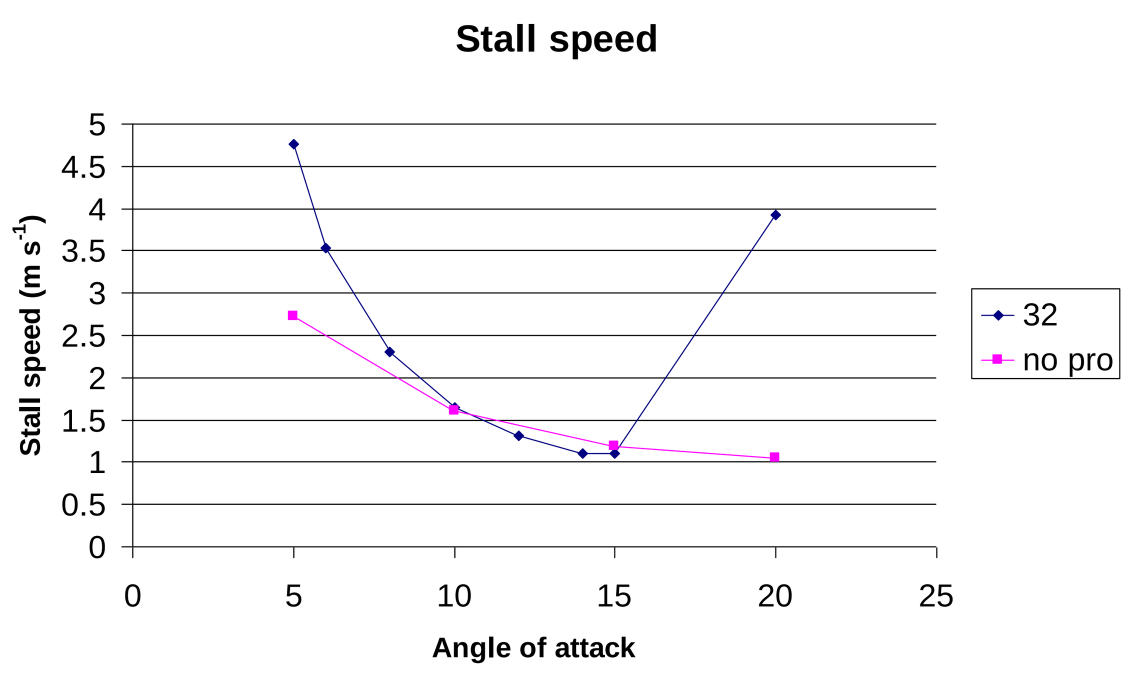
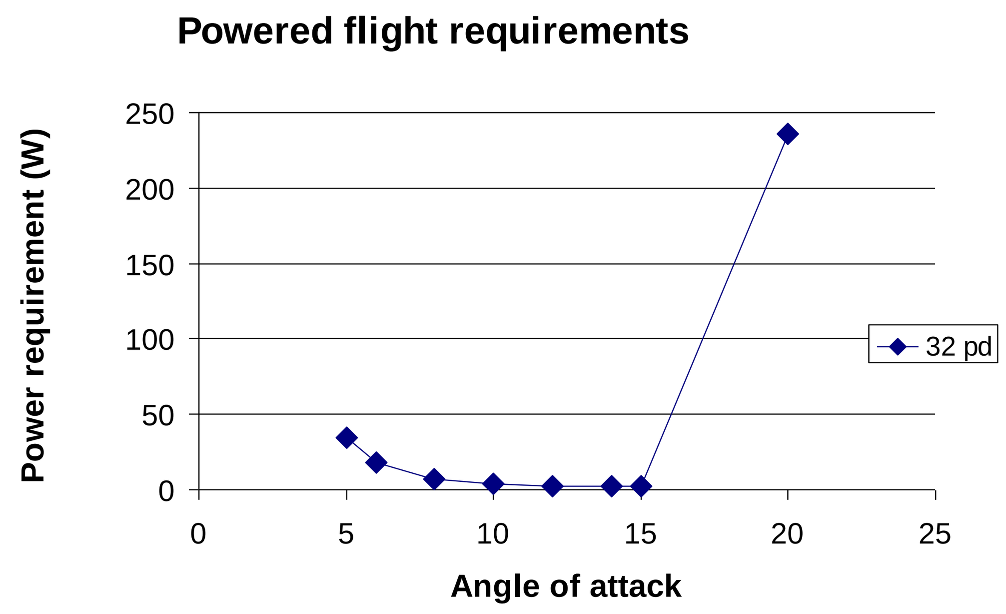


Figure 4 - *Turbulence Kinetic Energy* $m^2 s^{-2}$ *for 32° pd deflection at 14° angle of attack*



Graph 3 – Minimum flight speed



Graph 4 – Flight power requirement with front flap deflection on 32°

Conclusion

Research into Pterosaur flight mechanics infers a major role played by the pteroid bone in adjusting the orientation of the propatagium to achieve maximum control of lift and drag forces and hence, formidable manoeuvrability. Modelling in 2d supported the high lift findings of wind tunnel tests and 3d modelling could improve the accuracy of results if more soft tissue remains were found intact and actual wing parameters were known.

UNIVERSITY OF EXETER

School of Engineering, Computer Science and Mathematics