Investigation into the effect of the pteroid bone on pterosaur flight

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Introduction

The pteroid bone was a true bone exclusive to pterosaurs. It was fixed to the wrist of all pterosaur species and could be projected forwards during flight or folded inwards whilst the pterosaur was on the ground. A smaller, ventrally projected wing membrane known as the propatagium was fixed to the pteroid and acted as an enlarged leading edge flap. Using computational fluid dynamics, it is possible to determine how the pteroid bone influenced the aerodynamics of *Anhanguera Santanae*, a pterosaur from the Cretaceous period.

Aims

- To determine how the pteroid bone was utilised by a pterosaur.
- To investigate the effect of the pteroid bone on pterosaur flight dynamics.
- To compare this data with existing data for conventional wing structures.
- To conclude on its function and effectiveness on pterosaur flight.

Previous work

There have been many notable studies into the anatomy of pterosaurs and their flight mechanisms. Much of this research however is contradictory as the fundamental characteristics of the pterosaurs are often disputed. The takeoff mechanism and arrangement of the pteroid are two examples of this uncertainty that were addressed in this investigation. The wind tunnel investigation by Wilkinson (2005) into pteroid function served as a theoretical basis for the models with morphological and anatomical data taken from Unwin (1996).

Method

A cross section of the wing was taken at the midpoint of the propatagium. Dimensions for the wing membrane were sourced from Wilkinson (2005) and Stein (1975). By altering the angle between the cheiropatagium and propatagium θ_{pd} (Fig. 1 a), it was possible to simulate the various ventral degrees of flexion of the pteroid (Fig. 2). These propatagium models were compared to a basic model without the pteroid or leading edge flap. The corresponding wing coordinates were inputted into Gambit, enclosed within a boundary to simulate a test section and meshed. Each model was then exported to Fluent and subjected to airflows ranging from 0° to 20° in accordance with those used by Wilkinson (2005). By analysing each simulation it was possible to determine the lift and drag forces experienced by the wing.

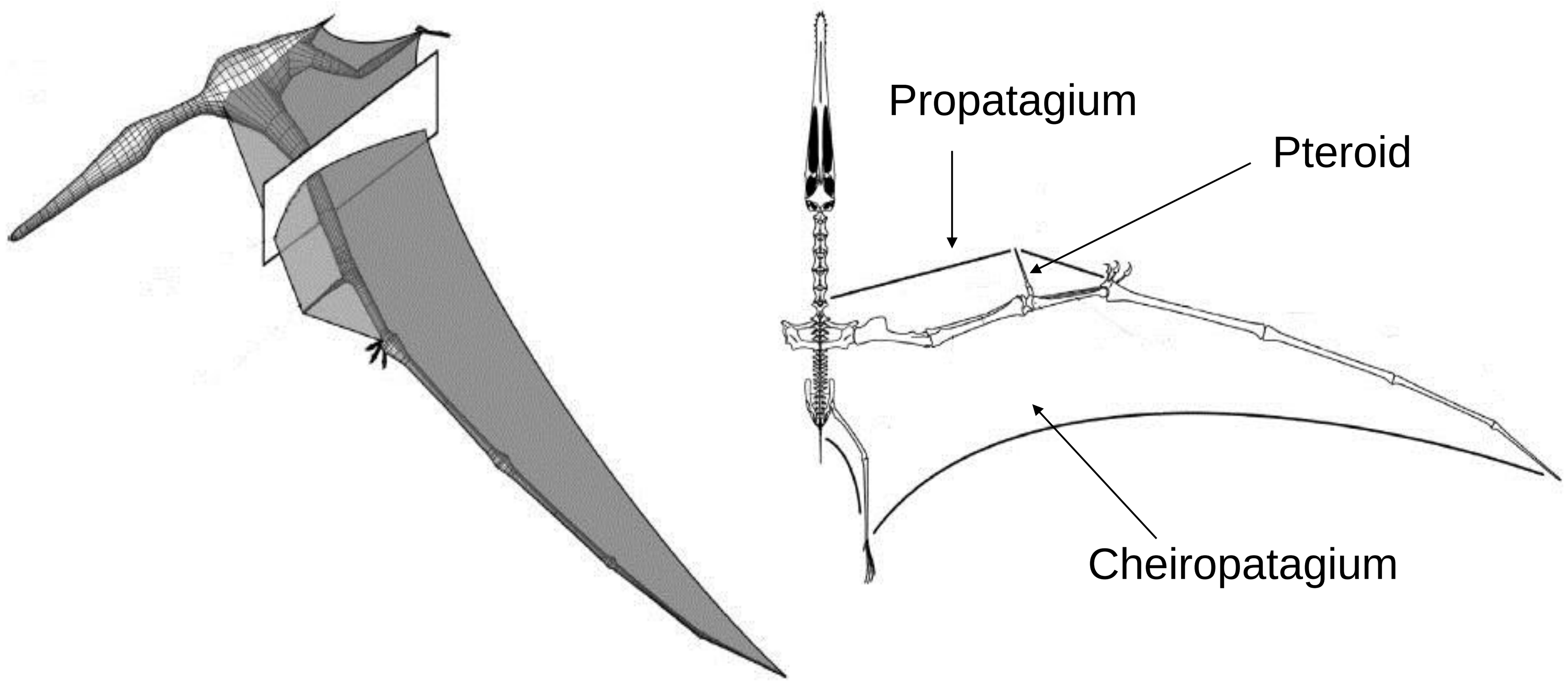

Fig.1 – a. Position of the wing cross section adapted from Wilkinson (2005)
b. Plan view of *A. Santanae* adapted from Wilkinson (2005)

Fig. 2 - 30° θ_{pd} Gambit model

Results

- The inclusion of the pteroid gave increased flight efficiency at lower angles of attack (Fig. 5).
- The total lift force experienced by the wing was increased for each propatagium model when compared to the basic model.
- For higher angles of θpd there was also a large increase in drag because the camber of the wing was much larger (Fig. 4).

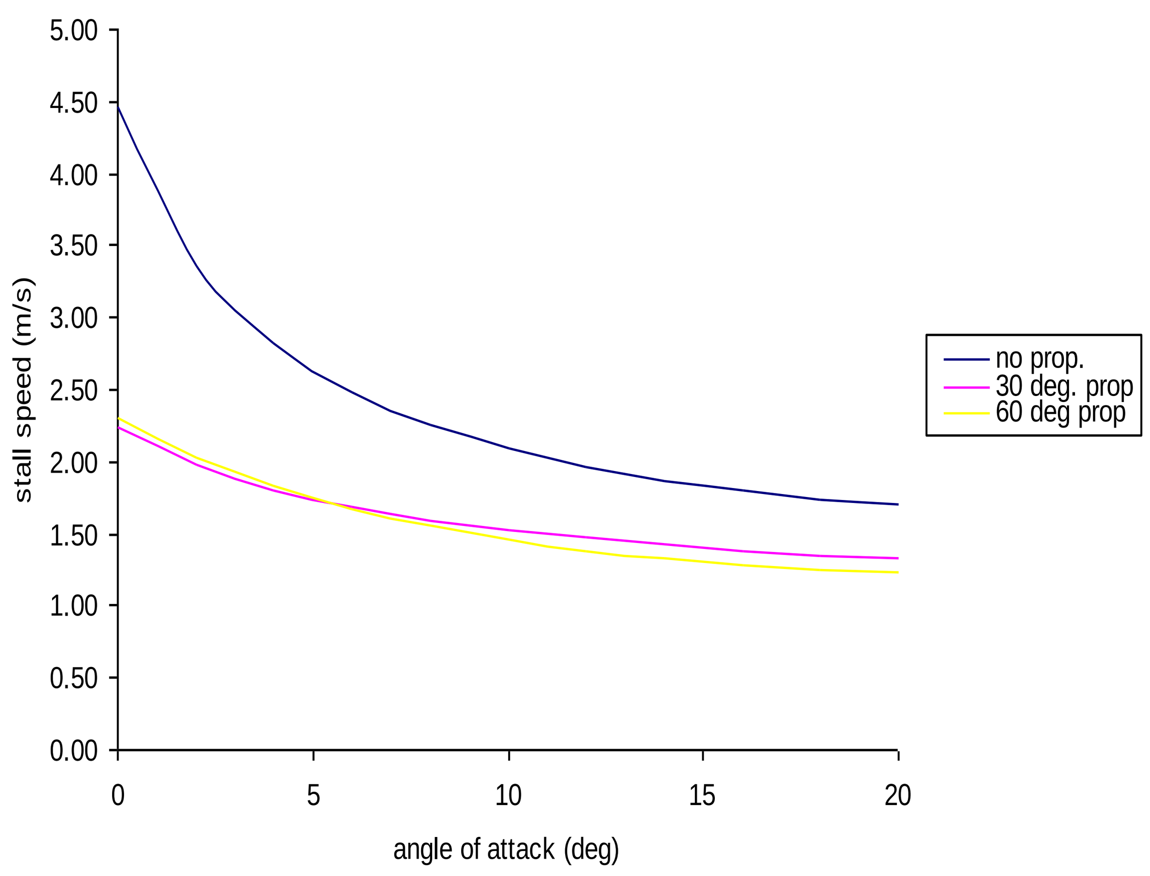

Fig. 3 – Graph of minimum flight speed against angle of attack

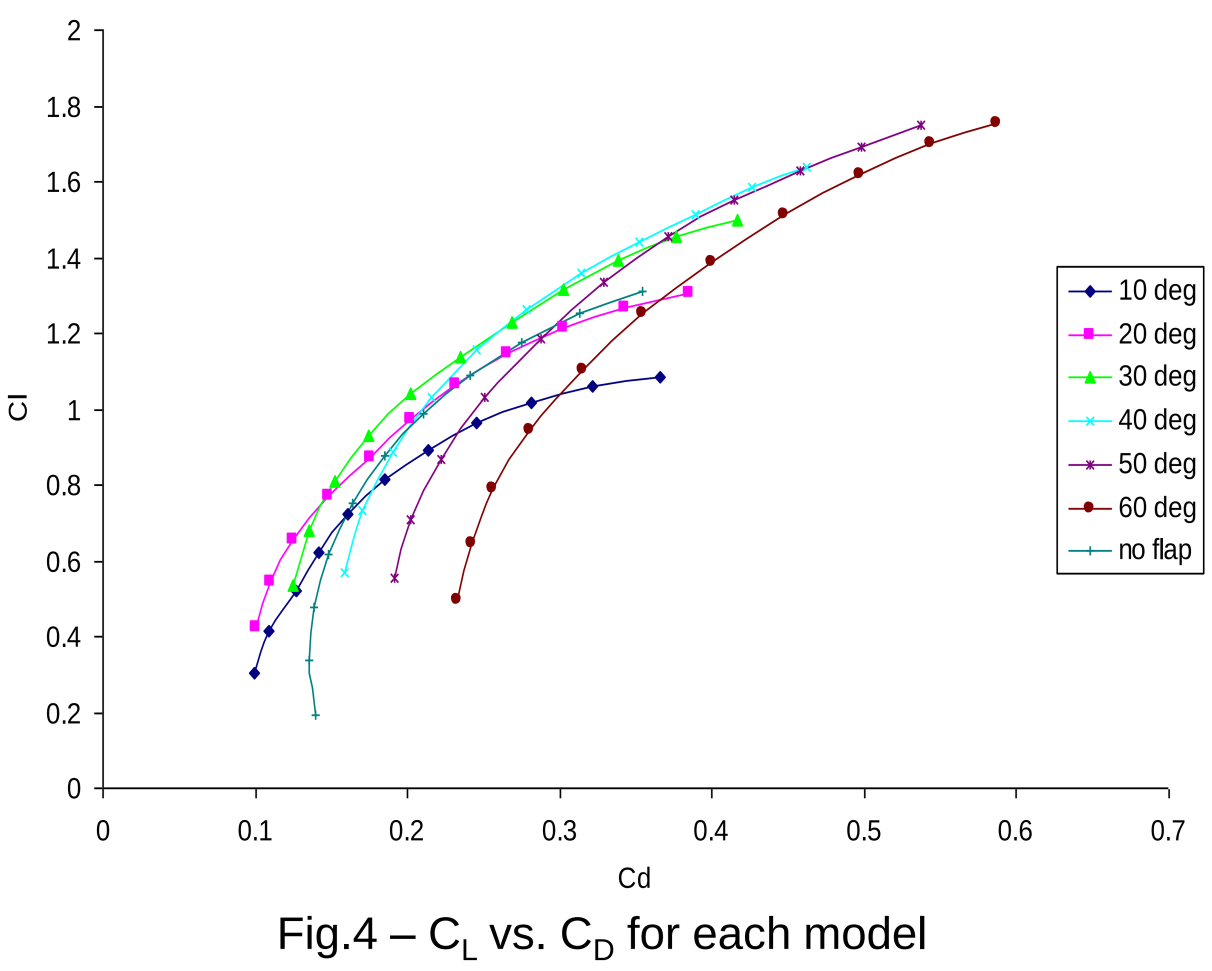

Fig.4 – C_L vs. C_D for each model

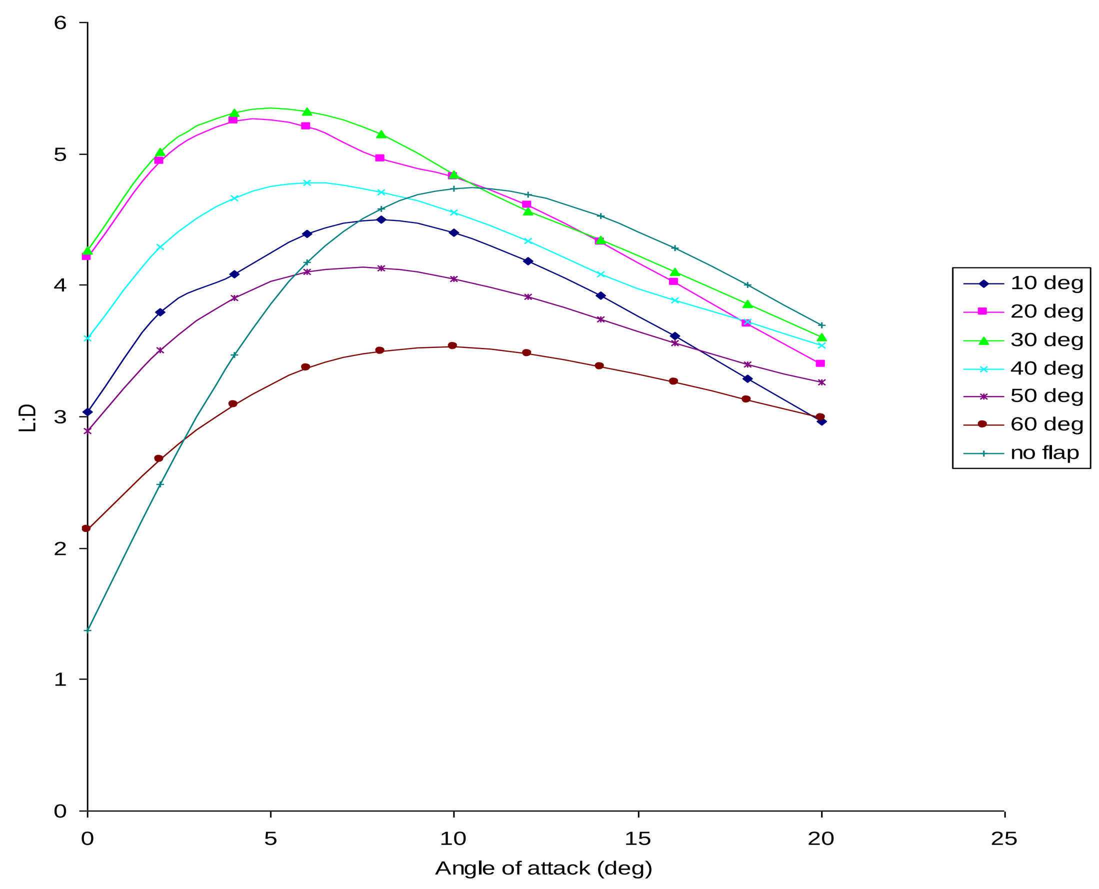

Fig. 5 – L:D ratio at corresponding angles of attack for each model

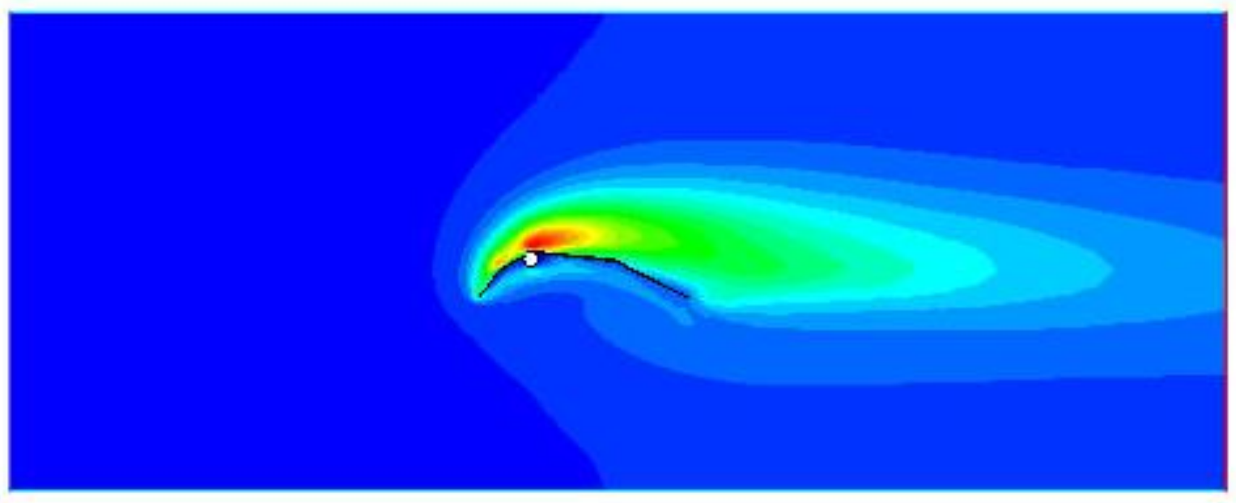

Fig. 6 – Contours of turbulent kinetic energy (m2/s2) for 60° propatagium model at 16° angle of attack (stall)

Conclusion

The effect of the pteroid bone was to increase the camber of the wing which allowed better airflow at higher angles of attack. An increase in the L:D ratio allows improved flight efficiency by reducing the energy required to initiate and maintain flight. Whilst on the ground, the pterosaur would fold the pteroid inwards to a medial position and would flex it to unfurl the wing for takeoff. The extra lift afforded by the propatagium was most apparent at low angles of attack allowing more efficient flight. The inclusion of a propatagium shifted the point of flow separation from the cheiropatagium to the top of the wing spar reducing the likelihood of stall at higher angles of attack (Fig. 6). The pteroid would be most useful during takeoff and landing and during flight manoeuvres. The increase in lift would allow the largest specimens to simply face into a breeze and spread their wings to take off and the decrease in stall speed would permit slower and more controlled landings (Fig.3).

References: Wilkinson, M., Unwin, D. M., Ellington, C. P. High lift function of the pteroid bone and forewing of pterosaurs *Proc. R. Soc. B* 2005
Stein, R. S.Dynamic analysis of *Pteranodon Ingens:* a reptilian adaptation to flight *Journal of Paleontology*, Vol. 49, No. 3 (May, 1975), 534-548
Unwin, D. M., Frey, E., Martill, D. M., Clarke, J. B., Riess, J. *Proceedings: Biological Sciences*, Vol. 263, No. 1366 (Jan. 22, 1996), 45-52

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