THE INFLUENCE OF THE CRANIAL CREST AND THE MANDIBLE ON THE AERODYNAMICS AND FLIGHT BIOMECHANICS OF A BRAZILIAN PTEROSAUR

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Abstract: *This project was developed in partnership with Museu Nacional (UFRJ) and has two main goals: to evaluate whether the Brazilian pterosaur Thalassodromeus sethi was able to skim-feed and to understand what would be the biomechanical function of its prominent cranial crest. The Museum gave this research unlimited access to some materials from its collection, which were then digitized and numerically simulated in Ansys CFX. The simulations were performed with the mandibles immersed in water and with the crest flying in the air at various speeds and angles. The results showed that the jaws had low hydrodynamic drag coefficients and that the skimming technique would be less energetically costly for the bird Rynchops niger than previously thought. The simulations with the crest indicated that it was able to generate high torques and lateral forces, suggesting that this feature may have acted as a rudder. Besides, a mathematical model was developed to estimate the mass and the power curve of the pterosaur using exclusively aerodynamic arguments. The calculated mass of T. sethi was 12.1kg and its power curve not only indicated that the creature was able to fly, but that it could also feed by skimming from an energetic point of view.*

Keywords: *Numerical simulation, External flow, Aerodynamics, Biomechanics, Pterosaurs*

1. INTRODUCTION

This project aims to comprehend the feeding habits of the pterosaur *Thalassodromeus sethi*, one of Brazil's most valuable findings. The well-preserved and nearly complete skull has one and a half meter in length and is articulated with the mandible. According to Kellner (2006), it is the largest pterosaur skull ever found in Brazil and figures among the world's biggest. The great surprise of the discovery was the cranial crest that extended throughout the posterior region, almost doubling the size of the head.

Due to anatomical similarities , it is believed that the pterosaur in study had feeding habits similar to those of the bird *Rynchops niger*. The long, thin, sharp, toothless beak suggests that the creature was a *skimmer*, i.e., that it was able to feed itself flying low over aquatic environments with the tip of the mandible immersed in order to capture small fish and crustaceans. Many authors have discussed the possibility of *skim-feeding* on pterosaurs, but they have not yet reached a consensus; all hypotheses remain controversial. In fact, despite intense studies of these animals, little is know about their feeding methods and the biomechanical function of its large cranial crest.

2. OBJECTIVES

This paper has two main goals. The first is to evaluate by numerical simulations of single-phase flows if the brazilian pterosaur *T. sethi* was able to *skim-feed*. A comparison between the drag forces and metabolic power required during this activity for both the pterosaur and the bird *R. niger* will determine if this feeding method was plausible or not for those species.

The second goal is to analyse, with the aid of simulations and mathematical formulations, how the cranial crest influenced the animal's flight dynamics and how it complemented the body features of this unique reptile.

3. STUDIED MATERIALS

Three materials from the collection of Museu Nacional (UFRJ) were used in this project. They are:

1. A complete skull of the bird *Rynchops niger*;
2. The fossil holotype DGM-1476R, attributed to the pterosaur *Thalassodromeus sethi*;
3. A resin replica of the fossil holotype NMSG SAO 251093, a jaw fragment previously attributed to *T. sethi*, but now attributed to *Banguela oberlii* (Headden and Campos, 2014 and Veldmeijer *et al.*, 2005).

4. METHODS

The methodology of this study can be divided into three main stages: the scanning of the fossil materials presented, the execution of several numerical simulations - which would allow the analysis of forces, torques and pressures acting on the virtual models at different speeds and angles - and the development of a new method to estimate the mass and power curve of pterosaurs based solely on aerodynamic arguments.

4.1 Digitisation

Each of these pieces had to be scanned into the computer using different technologies due to material, size and shape differences.

The skull of the bird *R. niger* is very thin and fragile. It has a bone matrix covered by a keratin layer called rhamphotheca. In order to capture the details from the beak and facilitate the distinction between bone and keratin layers, the bird underwent a X-ray computed tomography (X-ray CT).

Due its lager size, both the *T. sethi* and *B. oberlii* fossil materials were digitised by a much simple method: a portable, commercial laser scan. Afterwards, the hollow and empty spaces of the *T. sethi* model were filled and dimensional corrections were made. The final result of the digitisation process can be seen at Fig. 1.

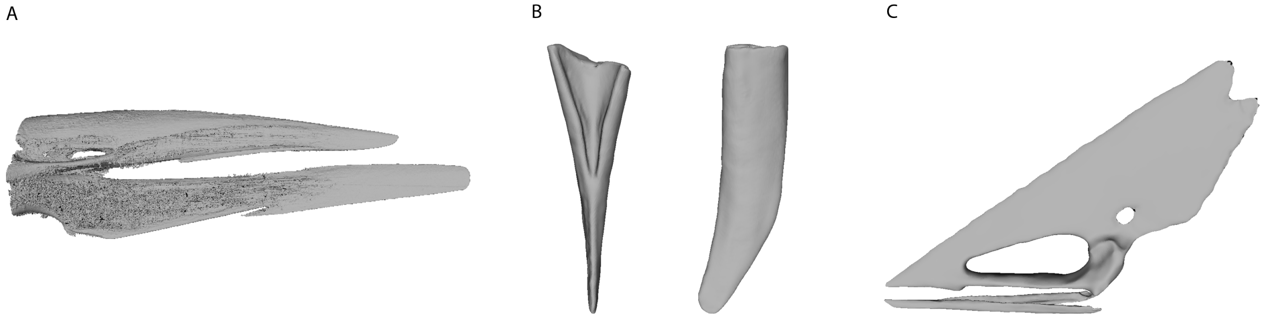

Figura 1: Digital models of the fossil materials. A - *R. niger*; B - *B. oberlii*; C - *T. sethi*

4.2 Numerical Simulations

The CFD simulations can be divided into two groups: the simulation of the three mandibles and the simulation of the cranial crest of the *T. sethi*. In all cases, the external flow was considered single-phase and in permanent regime.

For the simulations using the mandibles, the beaks were immersed by 20% in depth at the angles of 30º, 45º and 60º and the water velocity was varied between $1.8 m/s$ and $6.8 m/s$, giving a total of 18 simulations for each model and, thus, 54 simulations for all the three species. For the cranial crest of the *T. sethi*, the air velocity was set to be $15 m/s$ at the entrance. The crest was simulated with 2 different pith angles (0º and 55º) and 6 different yaw angles (0º, 5º, 10º, 20º, 30º, 45º), in a total of 12 simulations.

The boundary conditions sought to reproduce both the skimming and real flight conditions. In the inlet of the domain, it was defined a uniform, low-turbulent velocity profile in all cases. The boundary condition at the outlet was prescribing average static pressure in the area to be zero. The domain walls were defined as being in a free-slip condition. And finally, for the surface of the models, the non-slip condition ($\overline{u} = 0$) was used.

The meshes were generated with unstructured tetrahedral and prismatic elements, inflated from the surface. The final results of two of those meshes can be seen at Fig. 2 and Fig. 3.

In order to capture with accuracy the effects of the boundary layer and to allow the correct application of SST turbulence model in low-Reynolds regime, a mesh refinement was carried out near the surface of the models. This refinement allowed to reach a mean y^+ as shown in Tab. 1, which lists the number of elements contained in each mesh.

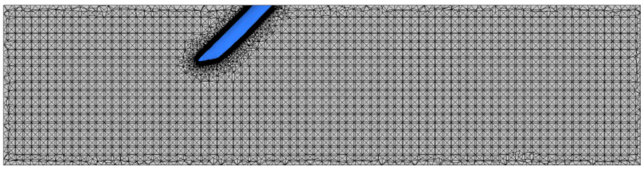

Figura 2: Generated mesh for the mandible of the pterosaur *T. sethi* in a 45º angle.

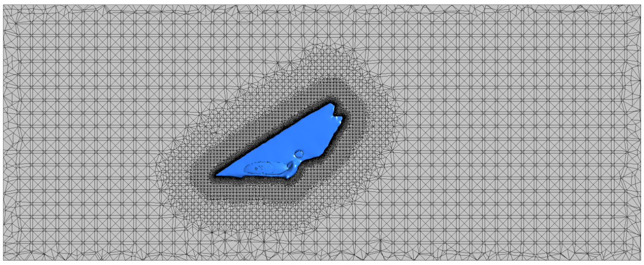

Figura 3: Generated mesh for the crest of the pterosaur *T. sethi* with a pitch angle of zero.

Tabela 1: Mesh Parameters

Case	Angle	Number of Elements	Mean y^+
R. niger Mandible	30º	1.235.625	~ 1.2
	45º	1.198.013	~ 1.2
	60º	1.270.858	~ 1.5
T. sethi Mandible	30º	3.118.734	~ 1.5
	45º	2.930.880	~ 1.5
	60º	2.325.684	~ 1.7
B. oberlii Mandible	30º	3.996.937	~ 1.5
	45º	3.445.978	~ 2.0
	60º	4.072.329	~ 1.7
T. sethi Crest	0º	2.917.551	~ 0.5
	55º	3.180.069	~ 0.5

4.3 Mathematical Methods

4.3.1 Mass Estimation

It is very hard to estimate the mass of extinct creatures; and this is due to the fact that almost the totality of the collected materials are either fossilised bones or a two-dimensional structure. Efforts to estimate the mass of pterosaurs and other extinct birds have been done for decades, but still there is not a convergence of values between the methods employed. Besides raising questions about the reliability of those methodologies, the results usually conclude that pterosaurs are unusually lightweight. The work of Witton (2008) not only describes the history and development of several methods, but also presents a new one. However, the biggest mistake of almost all those methods - apart from the incompatibility of results - is their attempt to correlate isolated cross-section areas or lengths to the total mass of a creature, i.e., the fact of not being a non-dimensional relation.

Motivated by this issue, this work will present a new method to estimate the mass of flying creatures (extinct or not) using only aerodynamic variables with the hope to solve the stand-off between scholars in the field.

4.3.2 Power Curve

A key point to understand the flight of pterosaurs is based on the difference between the power required and the power available for this activity. In normal conditions, the flapping of wings requires the application of a force to generate lift and surpass the aerodynamic resistance. The drag force of a flying creature has two components: the parasite drag due friction and the induced drag associated to lift.

For any aircraft or bird, the curve of required power versus velocity is U-shaped, meaning that it is energetically costly to fly in very low or very high velocities rather than an intermediate, cruse velocity. And this fact has profound implications on several aspects of flight performance.

Before plotting such curve, parameters such as the mass of the animal, the drag and lift coefficients and the aspect ratio of the wings must be determined. To estimate the available power, calculations are often performed involving metabolic power and its conversion rate to the work done by the muscles responsible for flight. Nevertheless, since we are working with extinct creatures, these estimates are not easily calculated and are still themes for further discussions.

4.3.3 Equations

The method our work proposes is based on two central hypotheses:

1. In the most severe active, flapping flight conditions, all available power would be used to surpass drag;
2. In this condition, the maximum generated lift will be equal to the weight of the flying animal.

This thought could be equated in the following manner:

$$P_{AvailableFlight} = P_{Parasite} + P_{Induced} \tag{1}$$

$$F_{Lift} = F_{Weight} \tag{2}$$

The available power for flight activities can be calculated using Eq. 3:

$$P_{AvailableFlight} = m_t \alpha \beta \tag{3}$$

The weight, lift force, parasite drag and induced drag can be calculated by Eq. 4, Eq. 5 , Eq. 6 and Eq. 7, respectively.

$$F_W = m_t g \tag{4}$$

$$F_L = \frac{1}{2} \rho A_S C_L V^2 \tag{5}$$

$$F_{PD} = \frac{1}{2} \rho A_D C_D V^2 \tag{6}$$

$$F_{ID} = \frac{1}{2} \rho A_S C_{ID} V^2 \qquad C_{ID} = \frac{C_L^2}{\pi e AR} \qquad AR = \frac{b^2}{A_S} \tag{7}$$

Replacing those formulas on Eq. 1 and Eq. 2, we get a new system to be solved:

$$m_t \alpha \beta = \frac{1}{2} \rho A_D C_D V^3 + \frac{F_L^2}{\frac{1}{2} \rho A_S V \pi e AR} \tag{8}$$

$$\frac{1}{2} \rho A_S C_L V^2 = m_t g \tag{9}$$

Solving the system described by Eq. 8 and Eq. 9, we arrive at a formutaion to express the total mass and the maximum flight velocity of a flying creature, given by Eq. 10 and Eq. 11 below:

$$m_t = \frac{0.5 \alpha^2 {A_S}^3 \beta^2 {C_L}^3 e^2 \pi^2 \rho_{Ar} b^4}{g^3 \left(A_F C_D e \pi b^2 + {A_S}^2 {C_L}^2 \right)^2} \tag{10}$$

$$V_{Max} = \frac{\alpha A_S \beta C_L e \pi b^2}{g \left(A_F C_D e \pi b^2 + {A_S}^2 {C_L}^2 \right)} \tag{11}$$

Once the total mass of the pterosaur is found, it is possible to estimate the required power during flight as a function of velocity. To do so, just add up the components of the parasite power due and induced power due drag. When the pterosaur is skimming, an extra component due the profile drag of the mandible on the water must be added to the formulation.

$$P_{RequiredFlight} = P_{Parasite} + P_{Induced} \tag{12}$$

$$P_{ReequiredSkimming} = P_{Parasite} + Pot_{Induced} + P_{Profile_{Mandible}} \tag{13}$$

The equations for each one of those power componentes can be calculatet using the equations Eq. 14 to Eq. 16 below:

$$P_{Parasite} = F_D V = \frac{1}{2} \rho A_D C_D V^3 \tag{14}$$

$$P_{Induced} = F_{ID} V = \frac{F_L^2}{\frac{1}{2} \rho A_S V \pi e AR} \tag{15}$$

$$Pot_{Profile_{Mandible}} = \frac{1}{2} \rho_{H_2O} A_{D_{Mandible}} C_{D_{Mandible}} V^3 \tag{16}$$

The value, meaning and references for all mentioned variables can be found at Tab. 2 below:

Tabela 2: Variables and its values

Variable	**Definition**	**Values for *T. sethi***	**Values for *R. niger***	**References**
α	Specific output power of the flight muscles	$100W/kg$	$100W/kg$	Marden (1994)
β	Ratio between the mass of flight muscles and the total mass	0.20	0.20	Marden (1994)
ρ_{Air}	Air density	1,2kg/m^3	1,2kg/m^3	-
ρ_{H_20}	Water density	995kg/m^3	995kg/m^3	-
C_D	Body Drag Coefficient on air	0.25	0.20	Pennycuick *et al.* (1996)
$C_{D_{Mandible}}$	Mandible Drag Coefficient on water	0.175	0.234	From CFD simulations
C_L	Lift Coefficient from the wings	0.30	0.35	Airfoils and bird wings (Withers, 1981)
A_D	Body cross-section area	0.344m^2	0.063m^2	Measures from images and photographs
$A_{D_{Mandible}}$	Projected area of the mandible on the direction of the flow	1.3x10$^{-3}m^2$	1.410$^{-5}m^2$	Measures from the digital models
A_S	Maximum projected area of the wings	2.57m^2	0.12m	Measures from images and photographs
g	Acceleration due to gravity	9.81m/s^2	9.81m/s^2	-
b	Wingspan	4.35m	1,2m	Kellner and Campos (2002)
AR	Aspect ratio	b^2/A_S	b^2/A_S	-
e	Wingspan efficiency factor	0.83	0.83	Spedding and McArthur (2010)

5. RESULTS AND DISCUSSION

5.1 Aerodynamic Features

The pterosaur *T. sethi* has a series of features that indicate aerodynamic abilities intrinsic to its flying style. Figure 4 correlates some constructive characteristics of airplanes and the aerodynamic features of *Thalassodromeus*.

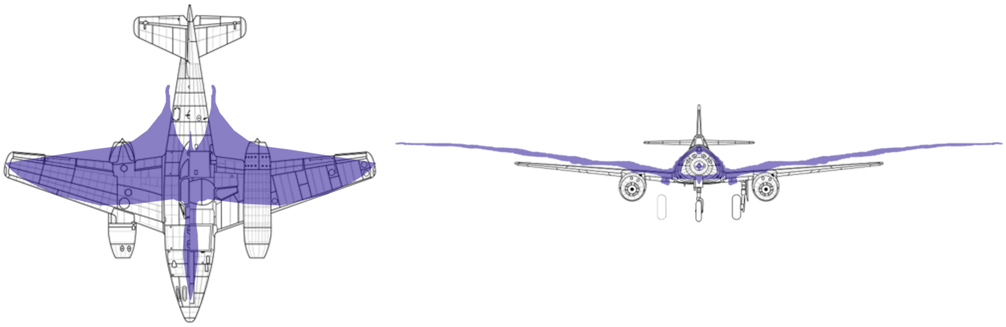

Figura 4: Collage of images showing the airplane Messerschmitt Me 262 and the pterosaur *T. sethi*. (Adapted from the original drawing "Messerschmitt Me 262 Schwalbe 3D drawing"by Voytek S., used under CC BY-SA 3.0)

This image show that both the German plane Messerschmitt Me 262 and the pterosaur *T. sethi* shares features such as: low-wing, swept-wing, positive dihedral angle and same transversal geometry. The low-wing configuration is associated to good flight maneuverability, what can be quite favourable to a fast, predator pterosaur as *T. sethi*. However, this type of wing does not provide lateral stability, but this deficiency is corrected by the positive dihedral angle – estimated of 10^o –, which allows the creation of a restorative momentum. Finally, the swept-wings – swept angle estimated of 17^o – brings another advantage: the directional stability, helping the pterosaur align itself with the flow.

The cranial crest of *T. sethi* is one of the biggest unknowns of this research. As will be seen within the next sections, it has, indeed, aerodynamic influence. Something as sharp and prominent in front of an aircraft or winged creature provides a very undesirable instability since any variation or change in the direction of the flow will generate forces able to rotate it or misalign it from their default route. For a predator that can be very advantageous as it allows to change direction quickly in order to track the movement of prey. However, the control mechanisms that help the performance of this activity are not yet known.

5.2 Mandibles Simulations

5.2.1 *T. sethi*'s mandible

For the *T. sethi* and all other mandibles, the forces found when the jaw was at an angle of 30^o with the surface were lower than the forces when the angles were 45^o and 60^o. And this is due to the fact that the frontal area (projected area) is smaller in small angles and higher at greater inclinations.

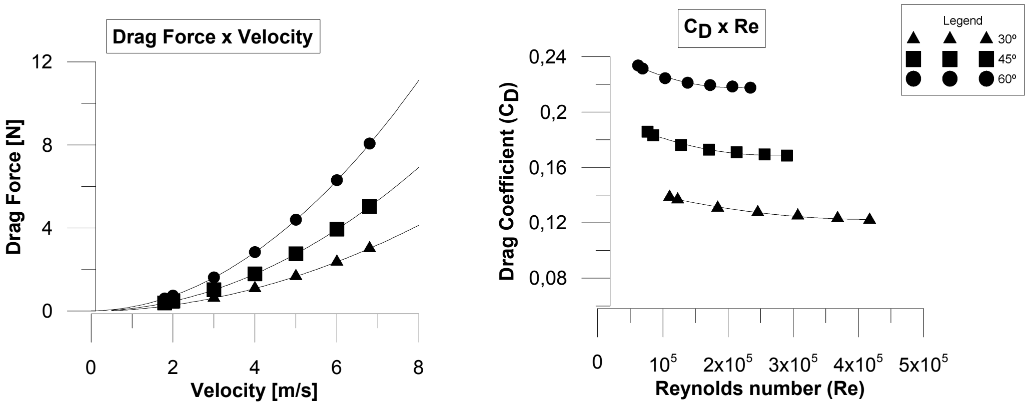

Figura 5: Graphs of Drag Force and C_D x Velocity for the mandible of the pterosaur *T. sethi*

In the case of *Thalassodromeus*, Fig. 5 shows that the measured drag forces range from 0.2 to $3N$ when the mandible is at a 30^o angle. By doubling the inclination (60^o), the forces are now between 0.6 and 8 N. All these values are within the range of the results found by Humphries *et al.* (2007), partially validating the simulation method employed.

From the calculated drag force, the drag coefficients could also be derived. For the *T. sethi*, the C_D range from 0.12 to 0.24 depending on the angle. However, these are still quite hydrodynamic values.

5.2.2 *B. oberlii*'s mandible

The simulation results with the jaw of *Banguela* were very similar to those found for the *Thalassodromeus* and are also in accordance with the experimental values described by (Humphries *et al.*, 2007). Figure 6 shows the results of the measured drag forces and drag coefficient for the speed range mentioned.

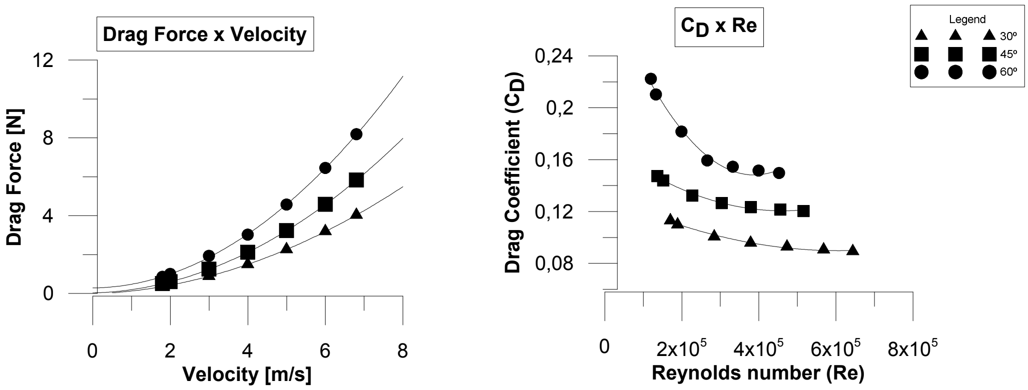

Figura 6: Graphs of Drag Force and C_D x Velocity for the mandible of the pterosaur *B. oberlii*

The smaller force found was $0.35N$ in the situation of a 30º inclination and speed of $1.8m/s$. The greatest recorded intensity was $8.2N$ in the case of a 60º angle and the flow velocity being $6.8m/s$. The calculated drag coefficient also show that the mandible of *B. oberlii* had a very hydrodynamic shape, with values as low as 0.09, lower than those observed for the *T. sethi*.

The anatomy and similar geometry, the absence of teeth and other factors have led scientists to believe that the fossil DGM 1476-R and NMSG SAO 251093 were from the same species. Although nowadays they are treated as distinct species, it is undeniable that the mandibles of *B. oberlii* and *T. sethi* have several characteristics in common. Being distinct species or not, *B. orbelii* and *T. sethi* have mandibles with such similar hydrodynamic behaviour that it suggests they are relatives from the evolutionary point of view, with a not too distant common ancestor.

5.2.3 *R. niger*'s mandible

The tip of the skimmer was also simulated to validate the strong claims and dubious methodology of the work of (Humphries *et al.*, 2007). Figure 7 shows the results for the force and the drag coefficient.

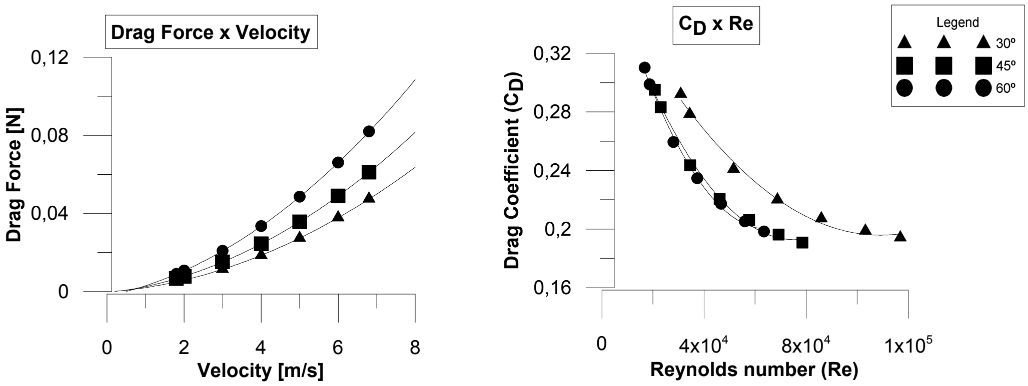

Figura 7: Graphs of Drag Force and C_D x Velocity for the mandible of the bird *R. niger*

The forces observed at the jaw of *R. niger* is about a hundred times lower than those found for the *T. sethi* and *B. oberlii*. Additionally, while Humphries *et al.* predicted forces ranging from 0.07 to $0.72N$, the simulations in this work have shown forces with a lower order of magnitude, ranging between 0.005 and $0.082N$.

R. niger's small, thin, light and sharp mandible may suggest small drag forces. Furthermore, if the results found with simulations for the jaws of *T. sethi* and *B. oberlii* were consistent with the experimental results in the water channel described by Humphries *et al.*, the simulations performed for the *R. niger* should also bring reliable results. This disqualifies the method used in that article, whose authors approximated *R. niger*'s mandible by a reversed NACA 0012 aerofoil.

Figure 7 provides another intriguing result. The drag coefficient with the submerged mandible at 45^o and 60^o are smaller than the mandible at 30^o, although this configuration do provide smaller forces and have smaller frontal area. Something that might explain this result is the presence of inclined grooves at the mandible. Such grooves could help maintaining the flow laminar on the surface or interact with the emitted vortices to reduce drag. This feature can be found in other animals - such as in the skin furrows of the blue whale and in the dermal denticles of sharks - and is even used in sports clothes and small boat hulls, all with the same purpose. Anyway, this result needs to be assessed more rigorously in future experiments and simulations.

5.3 Mass and Power Curves

Solving the equations Eq. 10 and Eq. 11 with the parameters listed on Tab. 2, the *T. sethi* has an estimated mass of $12.1kg$ – almost two times the value estimated by Humphries *et al.* (2007): $6.23kg$ – and could reach a maximum flight velocity during active, flapping flight of $16.0m/s$. Figure 8 shows the complete power curve for the pterosaur *T. sethi* and the bird *R. niger*.

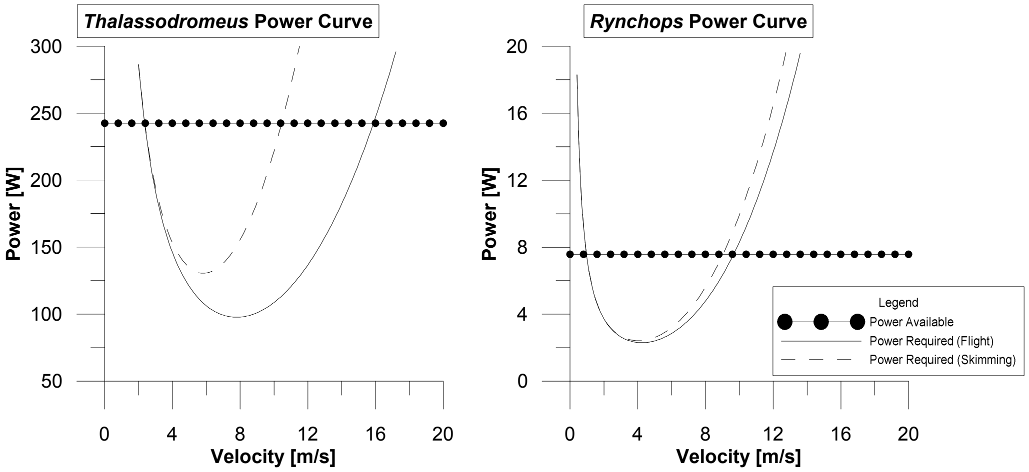

Figura 8: Calculated power curve for the pterosaur *T. sethi* and bird *R. niger*

The power available for the active flight - represented by the dash-dotted line in Fig. 8 - indicates the net energy limit available for flight activity with the flapping of wings. The required power curve - given by the solid line - is U-shaped, as expected due to the influence of parasite power (proportional to V^3) and induced power (inversely proportional to V). It indicates how much power is expended by the pterosaur to make the flight, surpass drag and maintain lift. The graph also presents the flight power curve during skimming (dashed line), as it considers the drag of the water at the tip of the mandible.

It is noticed that between speeds of $3.0m/s$ and $16.0m/s$ the power required for the flight is lower than the power available ($242W$) for this activity. Moreover, it is at the speed of $7.5m/s$ where the lowest expenditure of energy for the flight ($85W$) occurs, indicating the possible cruising speed of the creature. According to Chatterjee and Templin (2012), $7.5m/s$ is also the estimated cruising speed for the pterosaur *Tapejara*, evolutionary relative of *Thalassodromus*.

Taking the skimming activity into account, the graph shows that this activity was also plausible from an energy point of view and that it could be performed between $3.0m/s$ and $10.0m/s$. Besides, we can see that the minimum point of the skimming curve ($114W$) is at a velocity of $5.6m/s$, indicating that the fishing activity would have been carried out at speeds near this value.

In any case, even weighing about $12kg$, the pterosaur *T. sethi* was not only able to fly, but could also feed by skimming. Estimates suggest that the pterosaur had enough energy to perform these activities in a wide range of speeds and that, in its optimal speed (cruise speed), it would have a energetic reserve up to 65%.

This method was also validated with the bird *R. niger*. Using data from the simulations and performing some corrections on the variables' values to better tailor the model to reality, the mass of the bird was estimated in $0.379kg$, consistent to the value of some specimens reported in the literature ($0.350kg$).

In addition to proving the flight of the bird *R. niger*, Fig. 8 also indicates that the skimming was done between speeds of $0.9m/s$ and $9.7m/s$, with optimal speed near $4.0m/s$. This range is slightly wider that proposed by the work Zuzi (1962), which mentions that such fishing technique was carried out between 4.47 and $8.94m/s$.

All those results challenge the thesis Humphries *et al.* (2007), which states that no pterosaur weighing more than $1kg$ could *skim*. In addition, the new results also indicate that the energy expenditure for the *Rynchops* is lower than previously estimated by the team led by Humphries *et al.*, putting one more time the methodology of the latter article in check.

5.4 Crest Simulation

Figure 9 presents graphs for total drag force and drag coefficient plotted as a function of the yaw angle.

The total drag experienced by the crest of the *Thalassodromeus* is not modest. In more severe angles, drag can be as high as $65N$. The largest portion of this result is given by the lateral component acting on the crest. With an inclination of only 5^o, the estimated lateral force is $16N$, while the total drag is $17N$. Depending on the inclination, the magnitudes of the lateral forces may be as high as $45N$, corresponding to approximately 40 % of the total weight of pterosaur. This information is reflected in the crest drag coefficient, whose values fluctuate between 0.3 and 2.0.

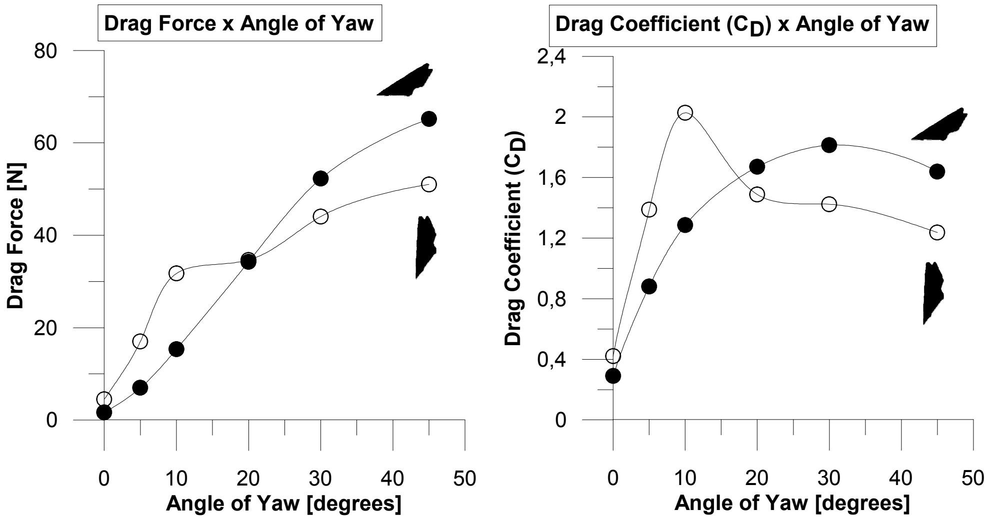

Figura 9: Graphs for Drag Force and C_D versus Angle of Yaw for the cranial crest of *T. sethi* in different situations

The intense aerodynamic influence of *T. sethi*'s crest gives strong evidence that it should also be accompanied by a biomechanical role on the creature. The magnitude of the lateral forces and its steep variations with every small change in the yawning angle indicates that the cranial crest could act as a rudder, i.e., a structure capable of rotating the pterosaur during flight. However, as already discussed, this structure is dynamically unstable and would require a sophisticated control mechanism for its correct operation.

6. CONCLUSION

This work performed an holist study of the aerodynamic influence that the cranial crest and the mandible had on the flight of *Thalassodromeus sethi*, a Brazilian pterosaur with unique anatomical features. Besides helping biologists and paleontologists to understand the evolutionary process of those creatures, this project also aims to provide engineering researchers some insight into drag reduction and flight control mechanisms.

Many papers on the flight of pterosaurs and birds either disagree with the same subject, either propose dubious methods and estimates, culminating in controversial results. Having in mind conducting a thorough and complete study, this research proposes a new methodology based on computer simulations and mathematical modeling.

Three sample materials provided by Museu Nacional (UFRJ) were digitally reconstructed by CT-scanning or commercial, 3D laser scanners. The digital models of the bird *Rynchops niger* and the pterosaurs *Thalassodromeus sethi* and *Banguela oberlii* were numerically simulated in external flow fields in order to give information about the forces at several speeds and angles.

In total, 66 numerical simulations were performed into two major groups: the simulation of three mandibles and the simulation of *T. sethi*'s crest.

The simulations with the mandibles aimed to estimate the drag forces acting on the jaws during hypothetical skimming activities. The values fond for both pterosaurs were in agreement with the experimental results of other studies, validating the simulations. The only exception was for the bird *R. niger* , whose values were about ten times lower than those found by other authors, showing that skimming is less energetically costly than believed. The anatomical and dynamical similarities between the mandibles of *T. sethi* and *B. oberlii* is an indication that these species are related from an evolutionary point of view, sharing a recent common ancestor.

The simulations with the cranial crest showed that its aerodynamic effects can not be neglected and that, due to high forces and torques observed with respect of the angle of the head, the structure could assume a biomechanical function of a rudder. However, something as prominent as this crest acting in front of the animal would provide an undesirable dynamic instability. For the *T. sethi*, this feature could have been an advantage as it may allow a more accurate pursue of its prey.

It was also performed a correlation between *T. sethi*'s characteristics and those found in aircrafts. This brief analysis pointed out several features on the pterosaur that indicate good aerodynamic abilities. The wings are low-fixed, swept and have a positive dihedral angle, bringing, respectively, maneuverability, lateral stability and directional stability.

Additionally, a mathematical model was developed solely with aerodynamic arguments to estimate the mass of *T. sethi* and its power curve. The calculated mass was $12.1kg$, a value much higher than that estimated by other authors $(6.23kg)$.

Nevertheless, its power curve indicates not only that the creature would have been able to fly, but it could also be able to feed by the skimming technique. Estimates suggest that the pterosaur had enough energy to perform these activities in a wide range of speeds and that, in its optimal speed (cruise speed), it would have an energetic reserve of up to 65%. This method was applied to the bird *R. niger* and returned satisfactory, consistent results.

Metabolically, there would have existed no constraints to a skim-feeding habit for the Brazilian pterosaur *Thalassodromeus sethi*, oppositely to what has been recently defended. Furthermore, other biomechanical and morphofunctional characteristics of *T. sethi* will be explored and addressed elsewhere in the future in order to unravel the lifestyle and feeding habits of this unique creature.

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