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Aerodynamic Analysis of Different Angles in “L” and “V” Shaped Valari’s

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Abstract

The research explores aerodynamic flow properties which vary with changing angles in two forms of traditional South Indian weapon Valari. The paper focuses mainly on L-shaped and V-shaped designs to determine how different angular orientations affect aerodynamic performance by analysing stability and range as well as lift and drag characteristics. This investigation connects ancient indigenous skills with modern scientific knowledge through the combination of analytical analysis of the 2D Valari’s. Through interdisciplinary research scientists gain scientific understanding about a culturally important artefact while advancing current discussions around aerospace object design as well as sports engineering and biomimetic systems.

Keywords: Valari; Aerodynamics; Lift; Drag; Angle of attack; L-shape; V-shape**.**

1. Introduction

The Valari represents an indigenous throwing weapon which holds significant place in Tamil Nadu's historical background and traditional heritage of southern India. Throughout multiple centuries warriors along with hunters and game participants and ceremonial competitors utilized this weapon because of its excellent cultural significance alongside its intelligent construction methods and streamlined design. Many ancient Tamil literary works document the Valari which bore significance for the Pandya along with the Chola dynasties. Historical empires of the Pandya and Chola dynasties recognized the Valari as essential to their diplomatic and warfare operations because of their mastery in battle readiness and tool making. This distinctive weapon model sets the Valari apart from other weapons. Wood and metal served as the materials for constructing Valari that normally took the L or V shape. The creators purposefully constructed these forms because they resulted in superior flight performance. The practical experience of people who used and designed the Valari allowed them to understand how spinning objects behave in flight although they lacked formal education in physics or aerodynamics. The Valari functions differently from arrows and spears because it requires extensive rotational movement more so than linear thrust. Fast spinning of the Valari after release stabilizes the object while enhancing its accuracy during flight. Some Valaris types specifically featuring broad 'V' design elements show an ability to come back to their throwers just like famous Australian boomerangs do.

The scientific framework of Valari flight receives evaluation throughout this research. A detailed analysis examines the aerodynamics which arise from the form and the angle connection of the Valari's arms to one another. Physical principles regarding fluid dynamics and classical mechanics enable the analysis of the Valari aircraft's performance features including lift force and drag resistance and spin properties and stability dynamics. The ability to deepen our understanding about the Valari through historical and modern aerodynamic perspectives allows us to view it both as a weapon and an early engineering artefact which offers valuable insights to contemporary practice.

2. Aerodynamics of Valari

2.1 Lift

Among all forces affecting the Valari's flight behaviour lift stands as the crucial element. The right-angled force known as lift enables objects to stay air bound. The Valari operates using lift principles in a diminished version because both planes and the toy utilize this force for flight. The Valari generates lift by spinning with its arm sections cutting aerodynamically through the airspace. Its shape alongside its motion causes air to speed up across one surface and slow down across the opposite surface of the object thereby creating an air pressure variance. The Valari rises into the air when air pressure across its surfaces differs because of this pressure pull. The lift-producing capability of Valaris items is best delivered by weapons with broader "V" shapes. An open and smooth angle creates optimal airflow for both of its arms to move with minimal disturbance. The weapon receives stronger overall lift force because the smooth airflow condition is maintained through this design. The "L"-shaped Valaris generate significant air turbulences through their pointed internal edges which decreases lift effectiveness while shortening the duration and smoothness of the flight. The Valari has better flight time and distance capability when it generates more lift force during its flight. The experimental results indicate that flights become longer and more stable when we increase the inner arm angle while conducting studies on Valaris geometric designs.

2.2 Drag

During flight operation the Valari experiences primary resistance forces from drag. The Valari meets resistance when it moves forward due to drag which acts against the direction of motion. Every object which moves through air will feel the force of drag acting against it. The drag force strength depends on the form and speed of the moving object as well as its surface quality. The Valari receives its drag from various physical factors: The overall shape of the Valari causes Form drag to occur. A bulky or angular Valari shape increases air contact that results in elevated resistance levels. Skin friction drag forms when air comes in contact with and rubs against the exterior surface of the Valari. When lift generates turbulence occurs that results in induced drag behind the object. The airflow becomes disrupted to a greater extent when L-shaped Valaris move which leads to higher experienced drag. The device experiences greater resistance because its arm angles create a bigger contact area that faces forward. A reduced speed and quick depletion of energy occur due to these factors. The V-formed Valaris achieve superior air passage because of their symmetrical structure which enables less turbulence. The broad angle of V-shaped Valaris allows them to sustain smooth airflow patterns while reducing the formation of air disturbances. The air movement generates reduced resistance which produces longer-duration flight. Knowledge about drag impacts both the Valari's possible range and its precision as well as its operational efficiency. The Valari's performance quality greatly enhances when designers implement wider angular elements and smoother surface structures to minimize drag.

2.3 Spin and Gyroscopic Stability

The Valari’s flight technique produces some of its most stunning characteristics through its spinning activity. The weapon achieves gyroscopic stability after proper launch when it starts rapid spinning motion. The spinning motion enables the Valari to combat orientation variations that would otherwise make it unstable in flight. Similar to a spinning top the Valari remains steady and upright due to its principle of stability. When the Valari rotates with greater velocity it becomes more challenging to disrupt its equilibrium. Angular momentum has a scientific name in physics. The turbulent spin of the Valari weapon generates angular momentum to produce air pathway stabilization. The distribution of weight also matters. L-Shaped Valaris achieve better spinning stability for brief flight distances because their weight distribution creates an unbalanced condition. While an imbalance helps stable flights in shorter distances it creates operational difficulties for extended flights. Due to wind variability Valaris undergo unstable motions by shifting direction and unsteadily oscillating. The mass distribution of V-shaped Valaris provides excellent stability without compromising control. A properly applied spin enables the Valari to execute longer and smoother flight paths. The right combination of rotation and launching angle allows some models of Valari to travel back to their thrower. Overall the spinning technique enables Valaris to travel with precise control. The weapon becomes unstable which results in quick falls or tumbling motion when the spinning motion is absent.

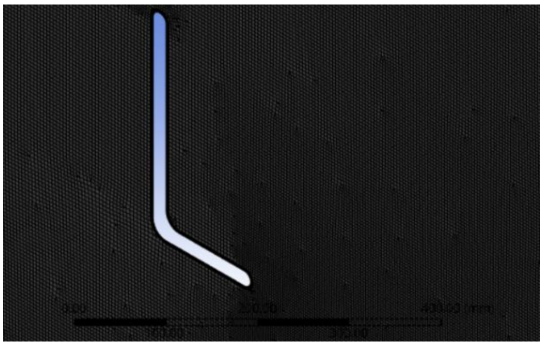
2.4 Angle of Attack

An important behavioural factor for Valari flight relates to how the aircraft meets airflow at different attack angles. The angle of attack (AoA) represents the measurement between airflow and the flat surface of an object according to aerodynamic principles where the object here is the Valari. When the Valari flies through the air after being dropped it presents a specific angle of inclination which defines its angle of attack. The flying distance and stability of the Valari become directly affected by this critical flying angle because it directly causes variation in lift and drag forces. An object's lift performance increases with greater angle of attack because it reveals more surface to air flow which creates enhanced upward forces. An elevated surface area due to its design creates more air resistance because of drag effects. A Valari aircraft will endure decreased travel range when its angle-of-attack is elevated because a higher upward force generates increased drag which leads to faster slowing down. When the attack angle is too shallow, the Valari will experience insufficient lift that hinders its ability to stay aloft beyond brief durations. When these circumstances occur the Valari drops at a rate that makes its effectiveness limited or results in unstable flight patterns. The airflow detaches itself from the Valari's arms' surface at steep flight angles thus creating unstable wake turbulence patterns which affects the weapon's stability. The weapon experiences a condition called flow separation which weakens its lift performance leading to unpredictable flights or tumble behaviours. The combination of research and other aerodynamic body analysis indicates that attack angles between 10° and 15° should generate optimal lift while minimizing drag performance. Studies about boomerang travel demonstrate that the most successful flight paths occur when throwing at angles between 10° to 15°. The same flight pattern detected in Valaris can very likely happen due to their matching spinning motion and unbalanced aerodynamic surfaces. A thrower must develop proper technique because it determines the attack angle of the flight path. The Valari's mid-flight behaviour depends significantly on the modifications thrown to wrist movements as well as arm motions and release angle. The desired flight path of Valari depends on how skilled the thrower is because experienced handlers automatically adjust the attack angle to create straight shots, curved paths or looping trajectories.

Skilled performers together with practice become essential to fully understand how to control the angle of attack.

2.5 Vortex Patterns and Flow Behaviour

The last stage of this discussion focuses on the movement of air around the Valari aircraft in its airborne state. The Valari generates specific airflow patterns behind it during its movement through the atmosphere. Certain airflow patterns of the Valari aircraft show vortices which develop when airflow becomes interrupted. Basically L-shaped Valaris produce additional vortices since their internal angles create abrupt airflow disruptions. The surface of the flying device produces points where air breaks loose which generates unsteady impactful airflow. The resulted decreased lift together with increased drag results in unpredictable flight control. The fluid dynamics of air movement remain uninterrupted by V-shaped Valaris due to their curving design. The weapon shape prevents vortex creation thus generating improved stability in its wake pattern. Flight quality improves through the mechanism that creates more controlled movements. V-shaped Valaris redirect air during flight in a way that causes the weapons to move in curved trajectories similar to how returning boomerangs function. The changing geometric shape of these projectiles induces both pressure movement and rotational forces which direct the flight into curved motion.



3. Methodology

Step 1: Geometrical Modelling

Therefore, the first step started with the creation of a two dimensional sketch of Valari using ANSYS DesignModeler. Two historical references were determinative on the basis of which two designs were considered, the L shaped Valari and the V shape Valari. The arms were modelled with uniform cross section and their overall dimensions standardized to allow fair comparison of the two shapes for both designs. The modelling of the arms was based carefully on realistic proportions and in particular their thickness, as well as the curvature perceived at the joints. Geometric accuracy was great to ensure that the models are as close to the real thing as possible.

Step 2: Meshing

In the end, the geometry was imported into ANSYS Meshing, where it was discretized into the domain. A mesh around the Valari surface was fine meshed with particular refinement in regions such as edges or inner corners where flow separation and vortex formation might occur.

Image 1: Meshing of the L-shaped Valari.

For meshing the Y+ value has been taken as 100 and the first layer of meshing has been taken as 1.8×10^{-3}m.

The meshing is same for all the experiments only the boundary conditions are changed. The boundary layer effects at the interface between two bodies having different surface characterizations were carefully introduced by local refinement. The mesh quality parameters such as the skewness and the orthogonal quality were monitored and optimized for mesh quality such that they were reliable and accurate.

Step 3: Setting Up the Simulation

Finally the meshed model was transferred to ANSYS Fluent for set up of simulation. As a steady state airflow model, a pressure based steady state solver was chosen. In order to simulate the turbulent nature of the flow, the k-ε (k-epsilon) turbulence model was used, since it provides good balance between computational cost and predictive accuracy. Air was taken as working fluid considered to be incompressible under standard atmospheric conditions (25°C, 1 atm pressure). They defined a velocity inlet for the incoming airflow, pressure outlet at the end of the downstream, and no slip condition on the surfaces of the Valari. Step 4: Simulation of Different AoA However, at next, we have simulation at different angles of attack. Systematic change of the Valari's orientation was achieved to simulate various angles of attack. The models were rotated in directions of 0°, 45°, 90°, 135°, 180° with respect to the incoming airflow. Each angle was run in separate simulations. The aerodynamic parameters of key interest (lift coefficient (Cl), drag coefficient (Cd), and pressure distribution) as well as streamline behaviour and vortex formation are discussed for all the configurations. Thanks to this step, the behaviour of Valari aerial performance regarding different throwing angles could be fully understood.

Step 5: Post-Processing and Analysis Finally, post processing of the simulation result was done using ANSYS CFD Post module. A variety of outputs were created-pressure contour plots that identify high and low pressure zones on the Valari surface, and velocity vector fields that indicate the direction and magnitude that the air moves around the arms. Area of flow separation and movement of vortices were visualized by streamlines. Furthermore, the lift and drag forces on the Valari were quantified at each angle of attack. Insights were developed regarding the aerodynamic efficiency and behaviour of Valari by comparing these results across different geometries and orientations, and relating the design and throwing technique.

4. Data Analysis

4.1 L-Shaped Valari

To understand the aerodynamic behaviour of the L-shaped Valari, simulations were carried out at five angles of attack: **0°, 45°, 90°, 135° and 180°**. The analysis focused on velocity magnitude contours, vortex formations, and flow separation patterns that indicate lift and drag characteristics.

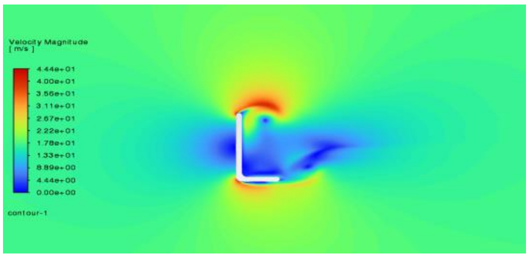


Image 2: 0° AoA

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At first, when the Valari is at 0° then it is facing the airflow in a neutral orientation. Leaving the velocity contour, the flow near the arms is symmetrically arranged, while velocity gradients are slight on both sides. The incoming flow is met directly along the front edge leaving a stagnation point region, which experiences a high pressure (low velocity), and fast flow on the outer surfaces by residing directly along the axis of the flow. It is seen that some minor flow separation at the internal corner resulting in small wake zones. In all, the drag should be moderate and lift should be minimal as it is symmetric. The result is that the streamline remains attached, a sign that the flow is steady and stable aerodynamically.

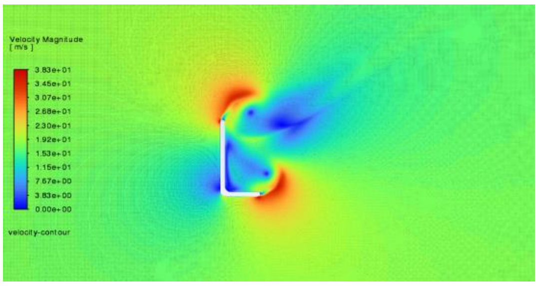

Image 3: 45° AoA

Around 45° the aerodynamic behaviour of the Valari is changed immensely. A sharp angle at the front is experienced by the flow and two strong vortex regions are then formed on the sides of the internal curvature. One phenomenon is that the magnitude of velocity grows near the outer edges and another is for flow separation behind the structure in which there are distinct low velocity zones (blue regions). It produces increasing pressure differential between the top and bottom surfaces (pressure differential) and hence can generate higher lift. However, drag is increased by the greater flow disruption. It seems that this angle is a good compromise between the values of lift and drag, leading to the possibility of an optimal flight performance.

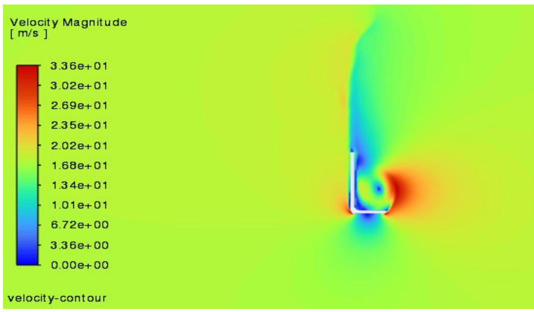

Image 4: 90° AoA

The Valari's flat side is perpendicular to the flow at 90° resulting in exposure of the largest frontal area. The scale in the velocity contour clearly shows large flow stagnation at the leading edge and a large wake zone and flow separation behind the Valari. Both the high pressure region in the front region and low pressure mean turbulent wake behind have a highest drag as seen from the three cases. Due to the vertical orientation that is symmetric and complete disruption of streamlined flow, the lift generated is minimal. The structure acts like a bluff body and suffers high resistance forces in this position.

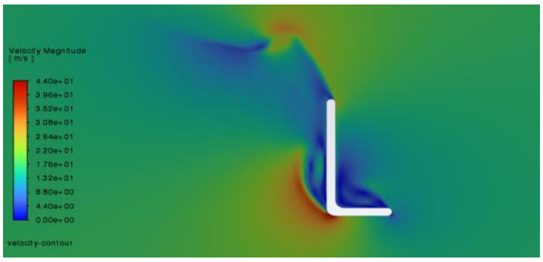

Image 5: 135° AoA

The Valari set at 135° results in flow that impacts both its slanted surface and inside corner thus producing an extremely unbalanced flow distribution. The flow velocity reaches its peak intensity on the outer curved component yet maintains zero velocity areas behind the inner boundary which results from separated flow and moving vortex systems. The contour pattern shows medium to strong turbulence formation mainly affects the structure's lower portion.

The angle causes many interacting vortices that produce lift from air deflection while developing significant drag through uneven airflow. This setup demonstrates intermediate aerodynamic characteristics because it lies between optimized operation and excessive instability.

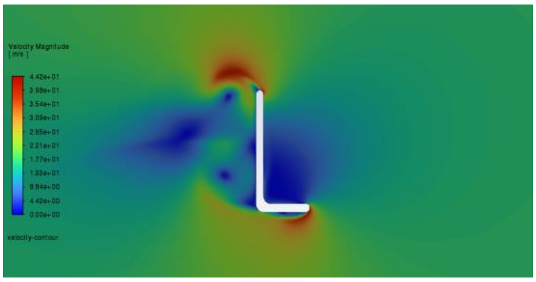

Image 6: 180° AoA

From the rear point until it reaches 180° the Valari becomes fully reversed so the vertical surface faces directly towards the streaming flow. A significant flow stagnation occurs at the leading edge while the structure generates an elongated symmetrical region of slow-moving air. The velocity contour demonstrates both high pressures accumulating on the contact surface while showing major flow slowing down inside the wake zone which indicates high drag.

The backward-facing symmetric orientation leads to minimal lift generation which makes this configuration function as an obstructing surface for airflow. This orientation demonstrates the worst aerodynamic performance because resistance forces along with flow separation control the flow behaviour.

4.2 V-Shaped Valari

The V-shaped Valari evolves from the L-shaped arrangement, making the arms of both the vertical stem and the horizontal arm the same length. Due to this, the Triumph Rocket III has a sleek and stable V shape, with a tighter angle near the centre.

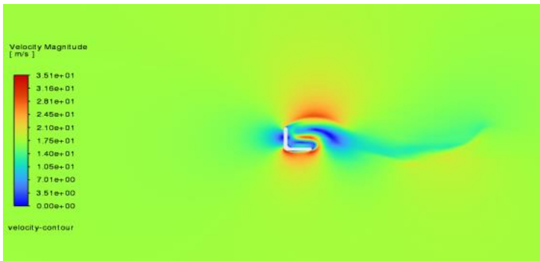

Image 7: 0° AoA

At this point, the water arrives at the V-shaped head of the Valari section. The laminar air flows in a similar manner, except at the edges where it becomes somewhat quicker and behind the center curve where a low-pressure zone occurs. A slight wake area on the velocity contour points to average drag. Thanks to having a balanced shape, the lift is minimal and this, along with its smooth contour, leads to less difficulty flowing through the air.

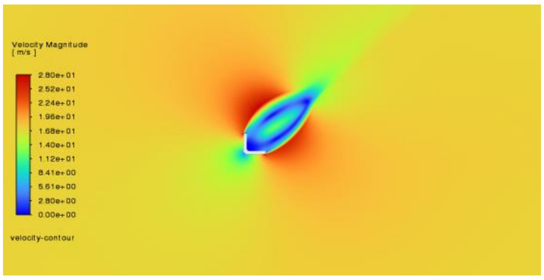

Image 8: 45° AoA

When the angle is 45°, the air flow runs straight into the angled surfaces. As a result, the pressure isn't distributed evenly and separate flow patterns can be seen within the corner. You will see that, around the upper outer edge, the velocity is higher and near the rear, the speed is much lower. Along the inner side, vortices form, creating some extra lift. With more turbulence, drag increases, but the angle might lead to better performance when flying turns.

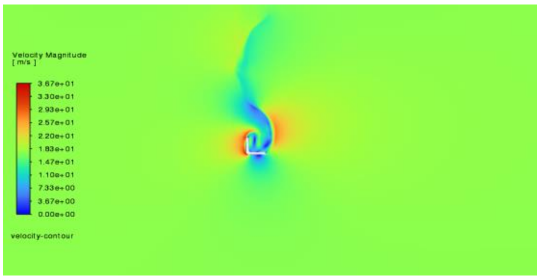

Image 9: 90° AoA

At 90°, the form of the vessel faces the direction of travel perpendicularly which results in the strongest possible frontal area. You can see big wakes in the blue regions behind the body in the contour plot. Ample turbulence appears by the riveted areas on the fuselage, making lift very low. Among all the angles, this shape gives the most resistance.

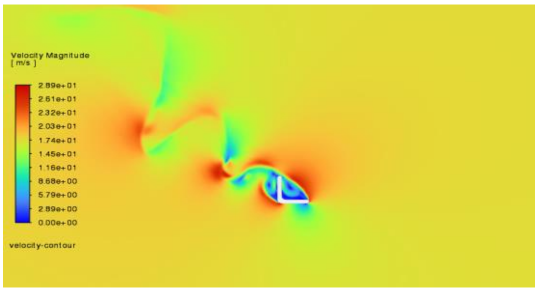

Image 10: 135° AoA

When the speed reaches 135°, the Valari flows into the elbow from behind which leads to a lot of reversal. One can notice strong vortex shedding and large parts of the flow that become detached. Air is trapped in the internal corner and makes the flow of air unpredictable. Since the lift cannot be easily predicted due to turbulence, the parasitic drag level is also higher. Most of the time, this position makes controlling the flight stable quite challenging, but it can alter how a drone spins or wobbles as it comes back.

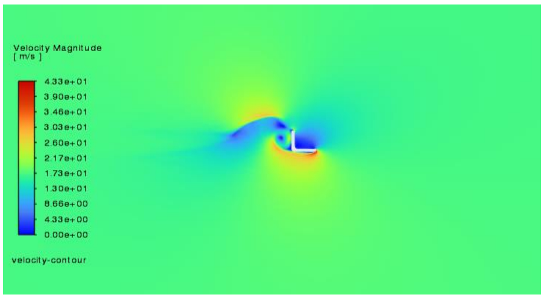

Image 11: 180° AoA

When the Valari's disc is turned 180°, the flow meets its flat backside head-on, just like it does at the 0° position. A high-pressure region is seen at the rear face and it is followed by a long section of low air pressure downstream. If a car rapidly decelerates, the wheels create a counter flow and form a vortex. Aerodynamics are poor since the surface of the plane is severely disrupted, causing both lift and drag to reach their maximum levels. An aircraft in this attitude does not usually fly for long.

5. Conclusion

It conducted a computer-based study of the V-shaped and L-shaped traditional Valari wings to observe their aerodynamic actions at different angles. Experiments at 0°, 45°, 90°, 135° and 180° angles showed that changing the flow characteristics helps explain differences in lift, drag, stability and the distance a plane could fly. Since the L-shaped Valari does not have any symmetrical side, its unusual flow patterns included the formation of vortices near the curves and significant flow separations at 90° and 135°. Building an airplane with moderate angles at 45° made it easier to fly far and under control. But having the plane oriented to the extreme made it much bumpier and produced a lot of wake, making it less efficient. However, the Valari which has both the L's sides equally long and joined at an acute angle, made the flow and symmetry better. As a result, turbulence behind the duct and flow disturbance reduced, mostly at lower and medium attack speeds. Enhanced stability and less drag were possible thanks to the V-shape making it easier for the air to stick to the wings. Because of these features, it can be flown in a stable and reliable way. In this comparison, we note that historic weapons naturally reveal a clear understanding of physical laws. By incorporating indigenous inventions with recently developed computer methods in this work, I have helped unite historical culture with modern science. The findings support our learning about historical South Indian martial tools and also suggest ways to apply them in aerospace, sports and biomimetic engineering. Focusing on aerodynamics allows the study to share and appreciate traditions as well as new trends and ideas.

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