



Experimental Study of the Visualization of Vortex Structures Ogives Revolution

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This paper concerns in particular the study by visualisations of the behavioural properties on the upper surface of an ogive of revolution having an apex angle of 68.6° at a low angle of attack and conducted at variable speeds. It has been noted that variations in speed have no influence at all on the behavioural properties of the development of vortex structures whereas, by contrast, changes to the angles of incidence do indeed strongly influence that development. The study of the ascent of the vortex breakdown at high angles of attack has revealed original behavioural properties which find expression notably in the discontinuous evolution, in terms of the apex angle, of those angles of attack which define the beginning and the end of the ascent of this vortex breakdown.

GJRE-J Classification: FOR Code: 090101



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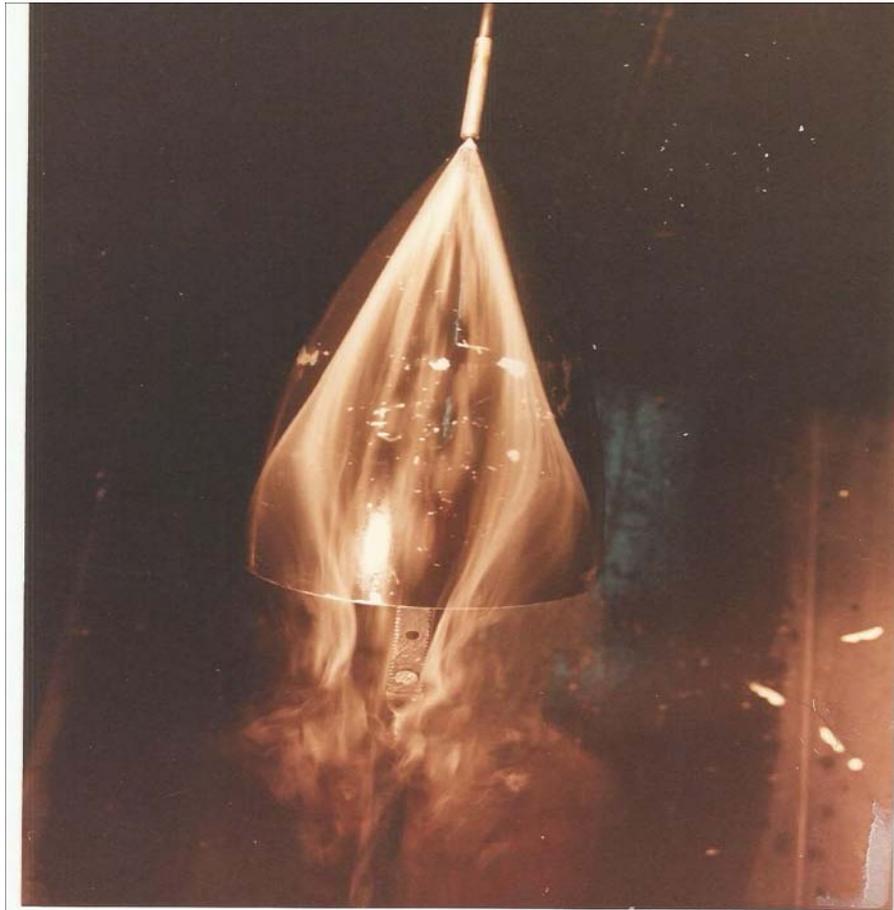
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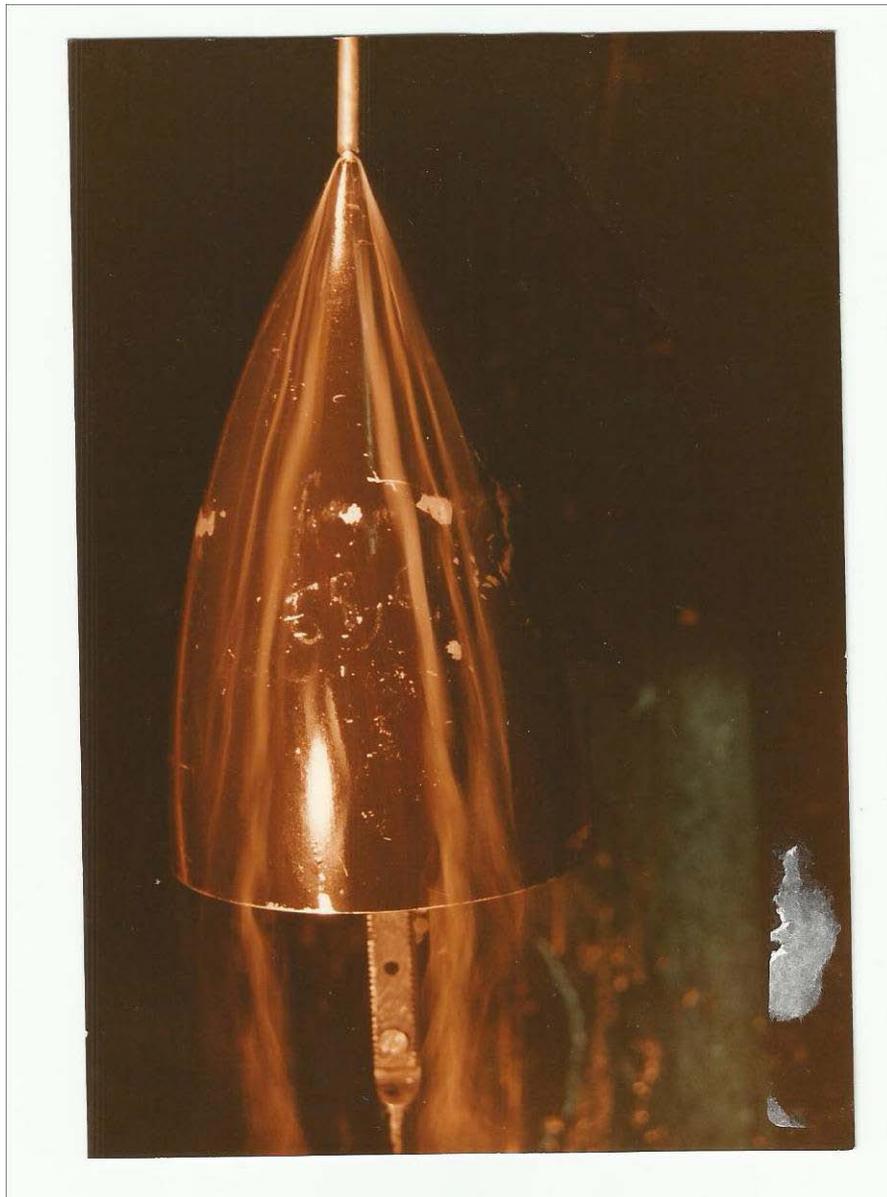
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View n° 1
 $\beta = 68.6^\circ$ $i = 8^\circ$
 $19000 < Re < 80000$

View n° 1 : the study to evidence a low incidence of birth vortex structures that will become a stable average impact is concentrated and pass a web structure in the classical.[22,33and38]

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View n° 2

$$\beta = 68.6^\circ \quad i = 32^\circ \quad \omega_1 = 12.9^\circ \quad \omega_2 = 18.4^\circ$$

$$19000 < Re < 80000$$

View n° 2 : when the incidence is increased, the main vortices and the secondary vortex torque are now observed, the speed remaining constant. However, variation in the speed have no effect at all on the formation of vortex angle of 28° . [22,33,35]



View n° 5
 $\beta = 68.6^\circ$ $i = 70^\circ$
 $19000 < Re < 80000$

View n° 3 : At 70° incidence i , I notice the fusion vortex bursts which are unstable and back to the top of the cone of revolution. the application of this phenomenon of vortex breakdown in the solar collectors has baffles variables [22,33, 36, 37].



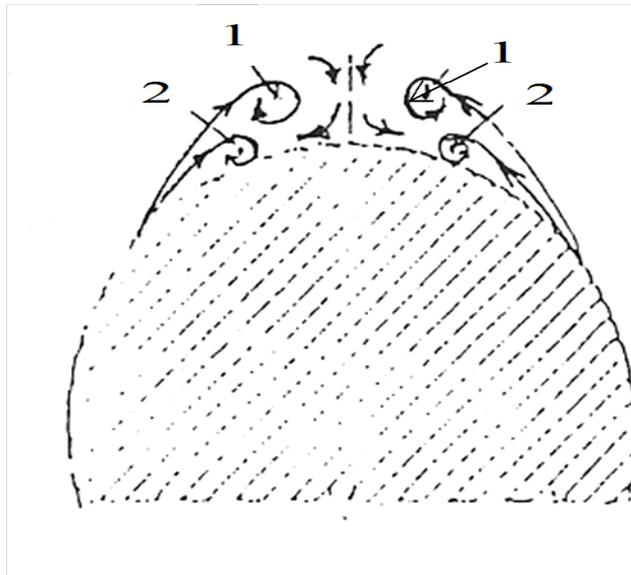


Diagram n° 1

1: interior vortex
2: exterior vortex

[8,22and 34]

I. CONCLUSION

While, on a wide range of Reynolds, the preferential nature of the intervortex angles present on the upper surface of delta and gothic wings and of ogives of revolution would seem to be fully catalogued, the very existence of **the law of filiation** relative to such slender bodies expresses a certain universality of behaviour and reveals the fundamental feature of our study.

At the present time, however, no complete theoretical approach would seem to be capable of providing a straightforward explanation of the simplicity of these results. The progressive evolution from elementary vortices of the sheer flow before take-off towards a particularly stable vortex system, wherein spatial positioning reveals an original organisation, still remains today an enigma. It is, of course, difficult to prejudge the lines along which one or more future studies may follow, studies which could lead to a theoretical explanation. However, perhaps we may be permitted to note that the phenomena, in which the sine squared of an angle also plays a part, are created by the simple structures of stationary and unsteady fluid mechanics.

It is in this way that the flow - emitted by an ogive of revolution having a demi-span of θ at its summit on a tridimensional dipole with the same axis as that of the cone, or with its summit at the centre of a vortex ring equivalent to the dipole - is proportional to $\text{Sin}^2\theta$. This is how energy - emitted by an oscillating electromagnetic dipole (with properties analogous to those of the oscillating fluid dipole that plays a part in aerodynamics or in hydrodynamics) in a θ direction with regard to the axis of the dipole - is, energy too, proportional to $\text{Sin}^2\theta$ or to $\text{cos}^2\theta = 1 - \text{sin}^2\theta$ in the case of the acoustic dipole. It is

also a law in $\text{Sin}^2\theta$ that gives the dependence, with regard to the angle of attenuation of the second sound thermal waves in liquid helium, by rectilinear vortices which form the θ angle with the direction of the propagation of this wave.

It is, moreover, by coupling this law with the concept of that preferential angle, formed by helicoidally vortices with their axes, that the authors of the papers referred to in [1] and [2] interpreted the discontinuous angular behaviour of these vortex systems in liquid helium [1, 2 and 19].

Finally, and this ultimate remark is probably not the least important one, the suction force, to which a profile - an infinitely thin and localised plane, let us remember - is subjected in the immediate vicinity of its leading edge, is, that force, too, proportional to the sine squared of an angle, in this case the angle of incidence.

As concerns the possible links, of the phenomena we have described, with the properties of an emission or of an absorption of a flow or of a wave - whose source may be dipolar or multipolar - it is perhaps interesting to note that the range of speeds of a tridimensional dipole {characterised by the angle between the radius vector of a point of the fluid and the speed of this fluid} is linked to the angular positioning of this point, with regard to the dipole {characterised by the polar angle between the axis of the dipole and the radius vector}, by a series of striking correspondences between the most simple preferential angles. Moreover, if we now consider the force of interaction between two dipoles of relatively simple orientation - the most simple is one with two parallel dipoles, but numerous other layouts give equally curious results - the range of interaction forces {characterised by the angle between the radius vector

joining the two dipoles with this interaction force}, possesses, in its turn, together with the two other ranges of relative positioning and of speeds {characterised as described above}, two new entireties of quite striking correspondences **E. TRUCKENBRODT** [24].

Where the notable orientations of interaction forces between two parallel dipoles are concerned, and with regard to the common direction of the axes of these dipoles, we have extracted a few particular cases from the general calculations made by **W. KÖNIG** [25] and from his final result given in **J.W-C. RAYLEIGH**'s very famous book on acoustics [26].

These references contain expressions of : the components of the force exerted by one sphere on another in the presence of a uniform wind pattern to infinity; where the fluid flow is perfect; the line joining the centres of spheres forming the θ angle with the direction of the wind to infinity - this force is the same as that exerted by one sphere on another when those spheres are moving parallel to each other and at the same speed in an immobile fluid to infinity - but it is known that each of these spheres is equivalent to a tridimensional dipole.

The sole particular cases commented on by **W. KÖNIG** [25] and **J.W-C. RAYLEIGH** [26] are those where the centres of the spheres are aligned, {i.e. in the direction of the wind}, and where these spheres therefore exert on each other a repulsion force {i.e. perpendicularly to the wind} with, in this case, a gravitational interaction force which explains the formation of very fine powder ridges, perpendicular to the axis of a sound tube, within its antinodes (ventral segments) of vibration.

But a whole series of other consequences from the general formulae found in references [25] and [26] seem, they too, to be very significant. One of the most important of these particular cases seems to us to be that where the interaction force between two parallel dipoles is itself parallel to them. Formula n° 4 on page 47 of reference [26] immediately shows that this case corresponds to the θ angle, cancelling the Legendre polynomial $1-5\cos^2\theta$, i.e. at

$$\cos\theta = \frac{1}{\sqrt{5}} = \frac{2}{\sqrt{4(4+1)}} = \cos\theta_{42} \quad (10)$$

according to the defining formula of preferential angles given at the beginning of this paper.

This angle $\theta_{42}=63.4^\circ$ is, moreover, the angle between the diagonals of the famous "Golden Rectangle" discovered by architects and employed by them from time immemorial [21].

In this same train of thought, it is striking to note, in references [27 to 29] the role played systematically by the angle $\theta_{32}=54.7^\circ$ (cancelling the Legendre polynomial $1-3\cos^2\theta$) in the sound emission of an axisymmetric jet and of two interaction forcing vortex rings or of one forcing vortex ring in the presence of a sphere.

In short, many other well-known hydrodynamic and aerodynamic phenomena are rich in preferential angles, the theory of which has at some or other been fully elaborated. This is the case found in the very subtle and elegant theory described in particular in the works of **H. LAMB** [30] and of **J. LIGHTHILL** [31]. In the wake, the crests of waves, in a curvilinear triangle form, will in fact each disappear at two counter flow points, the alignment of which, along two right-hand sides, determines a total span of the wake at twice 19.4° here and there of the axis of this wake, axis with which the counterblow tangents, associated with the crests, form an angle of 54.7° while also forming with each corresponding edge of the wake an angle of 35.3° {i.e. $54.7^\circ - 19.4^\circ$ }.

It is there where the following relation is to be found, never interpreted before now, in terms of preferential angles :

$$\theta_{32} = \theta_{22} + \theta_{88} \quad (11)$$

$$54,7^\circ = 35,3^\circ + 19,4^\circ \quad (12)$$

The link between the wake of a ship, being the result of the combination of bidimensional surface waves shed in various directions, and the phenomena described above may appear at first sight to be very mysterious. We may, however, be permitted to reason that the paper by **E. LEVI** [32] under the title "An oscillating approach to turbulence", so suggestively illustrated by figure n° 1 on page 352 of his study {an illustration which represents the frontier of a wake or of a maximum layer as a swell induced by the emission of vortices} perhaps provides the starting point of a profitable line of further research which could lead to a better understanding of the omnipresence of preferential angles and of their filiations in tridimensional flows, and in particular in those developed around slender bodies.

The essential question to be pursued, and one which remains as yet to be entirely addressed, seems to us primarily to lie with structures and wave propagation. What is required is the explanation of the link between those preferential angles, which appear in structures exterior to the borderline layer, and structures, which would also probably need to be termed preferential angles, to be found in the forms and modes of wave propagation. The latter have recently been the subject in a close study of "the coherent structures of turbulence", structures that are, in particular, present in laminar-turbulent transition zones or in zones of anisotropic turbulence, especially where they relate to layers.

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