AN OVERVIEW OF THE RTO SYMPOSIUM ON VORTEX FLOW AND HIGH ANGLE OF ATTACK AERODYNAMICS

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Abstract

In May of 2001 the Research and Technology Organization (RTO) sponsored a symposium on Vortex Flow and High Angle of Attack aerodynamics. Forty-six papers, organized into nine sessions, addressed computational and experimental studies of vortex flows pertinent to both aircraft and maritime applications. The studies also ranged from fundamental fluids investigations to flight test results. Selected highlights are included in this paper to provide a perspective toward the scope of the full symposium.

1 Introduction

A symposium on Vortex Flow and High Angle of Attack aerodynamics was held in Loen, Norway from May 7 through May 11, 2001. The Advanced Vehicle Technology Panel (AVT), under the auspices of the Research and Technology Organization (RTO), sponsored this symposium that was attended by several hundred scientists, engineers, and technical managers. The principal emphasis of the symposium was on the understanding and prediction of separation-induced vortex flows and their effects on vehicle performance, stability, control, and structural design loads. It is well established that separation-induced vortex flows are an important part of the design and off-design performance of conventional fighter aircraft as well as advanced military concepts.

The RTO has inherited the opportunity for sponsoring this particular international forum from its predecessor organization, the Advisory Group for Aerospace Research and Development (AGARD). Under AGARD, an informal infrastructure of international scientists and engineers has been established and has sustained research efforts pertinent to vortex flow aerodynamics. Some of the predecessor AGARD symposia on this topic are listed in Table 1 below [1-3]:

Year	Location	Title	Report
1990	Scheveningen, The Netherlands	Vortex Flow Aerodynamics	CP-494
1983	Rotterdam, The Netherlands	Aerodynamics of Vortical Type Flows in Three Dimensions	CP-342
1978	Sandefjord, Norway	High Angle of Attack Aerodynamics	CP-247

Table 1- Prior Vortex Flow Symposia under AGARD sponsorship.

A total of forty-six formal papers, organized into nine topical sessions, were presented along with a keynote address and a technical evaluation report. The symposium organization is presented in Table 2 on the following page.

For this paper a more condensed organization has been adopted. Selected highlights are presented to provide a representation of the scope and depth of the full symposium. The technical caliber of the RTO symposium was high, and it must be acknowledged that many important results could not be explicitly included in this overview due to space limitations.

Session	Title	Papers
I	Vortical Flows on Wings and Bodies	3
II	Experimental Techniques for Vortical Flows	5
III	Numerical Simulations of Vortical Flows	7
IV	Vortex Stability and Breakdown	8
V	Vortex Flows in Maritime Applications	6
VI	Vortex Interactions and Control	6
VII	Vortex Dynamics	3
VIII	Flight Testing	5
IX	Vehicle Design	3

Table 2- Vortex Flow and High Angle of Attack Aerodynamics Symposium organization (RTO).

2 Symposium Overview

In a keynote address, Lovell [4] presented an overview of vortex flow effects in the context of many current military aircraft as well as submarines and future concepts. He proceeded to classify these vortex flows into three categories:

- *(i)* those that are desired and therefore incorporated into the vehicle design process,
- *(ii)* those that cannot be avoided and thus must be accommodated in a design process, and
- *(iii)* those that were not expected and thus were not accounted for in the design process.

Vortex flow effects can be quite extensive for subject vehicle classes, and current design trends could actually increase the extent of this flow. At the same time, the character of these vortex flows is different from past experience, primarily due to the advent of shaping practices for survivability. All of this points to a sustained need to improve our knowledge and predictive capability of vortex flows.

2.1 Tools and Processes

Several papers specifically addressed or emphasized experimental test technique advances and needs. Only one computational fluid dynamics (CFD) study will be highlighted in this Tools and Processes section; the rest will be included in the subsequent sections. All flight-test results will be included in the section on vehicular studies.

2.1.1 Test Techniques

Ol [5] presented low Reynolds number delta-wing flow-field measurements that were obtained with stereoscopic digital particle image velocimetry (PIV) in a water tunnel. With this technique fairly detailed three-dimensional flow-field images were captured in essentially an instantaneous snapshot. The rapid measurement capability was also exploited so that unsteady attributes of the vortex flow could be measured.

An example is shown in Figure 1 below. The research was performed to study the passage toward stall of non-slender delta wings of 50^{o} and 65^{o} degrees sweep. This class of measurement and analysis could be very useful for CFD calibration purposes. It would also be useful to obtain this type of data at high Reynolds numbers such as to quantify ground-to-flight Reynolds number effects on the off-body vortical structures.

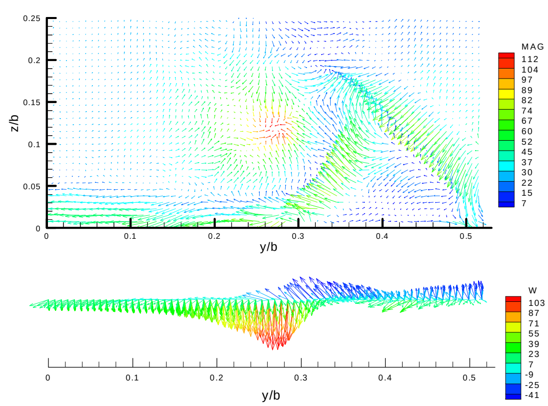


Fig. 1- Detailed PIV vorticity measurements for a 65^{o} delta wing. Ol [5]

Pressure sensitive paint (PSP) technology was highlighted in several papers, especially as regards the application to unsteady flow conditions. An example from Engler et. al. [6] is presented in Figure 2 for a cropped 65^{o} delta wing. In this work, data were obtained at a transonic Mach number of 0.8 and several angles of attack with the wind tunnel model rolling about the body axis at 10 Hertz.

The pressure sensitive paint had a fairly quick response time, and yet a key aspect of Engler's work was that the PSP measurements were anchored with several Kulite measurements. This appears to be a prudent practice for now, despite the significant advancement in PSP application technology.

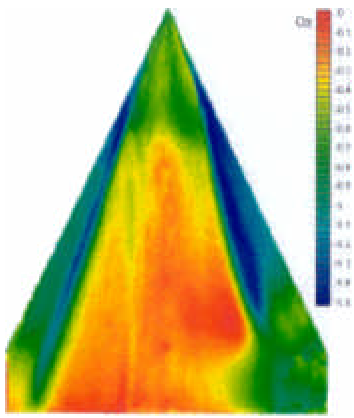
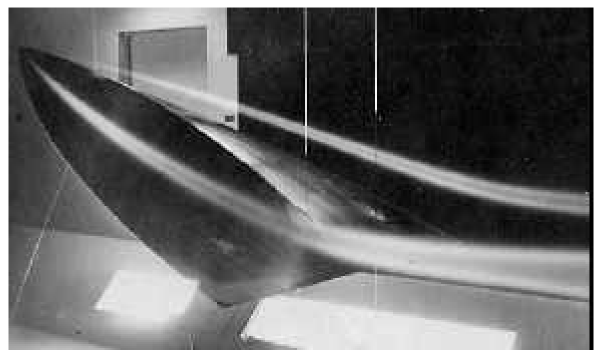


Fig. 2- Unsteady pressure sensitive paint measurements for a cropped 65^o delta wing. Engler et al [6]

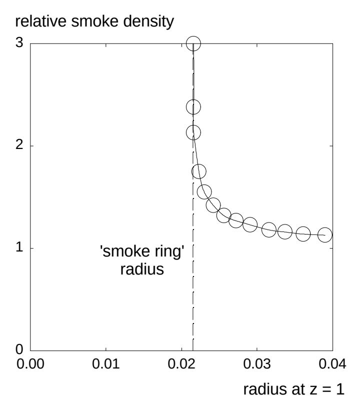
Greenwell [7] presented an insightful analysis of flow visualization attributes with an emphasis on the flow near the core of leading-edge vortices at typical wind tunnel conditions. The vortex cores are often visualized due to natural condensation effects or the introduction of seed particles to the flow. (See Figure 3a.) His analysis accounted for centrifugal effects due to particle mass as well as drag force effects associated with the local flow. The conical flow equations developed by Hall [8] were used to model the near-core flow field.

His results matched experimental observation very well, and demonstrated that any particle will depart significantly from the local velocity field in the vortex core. An example is shown in Figure 3b, where the balance of the aforementioned forces result in smoke particles only penetrating the core to a limiting radius; inside this radius the flow would appear to have an annular void. This presents a fundamental dilemma, at least at wind-tunnel model scales, to all flow-field measurement techniques that require seeding of any sort for measuring detailed flow properties within the core of a leading-edge vortex.

A review of experimental techniques as they pertain to vortex flows was presented by Hummel [9]. Hummel summarized much of the current knowledge of slender delta-wing vortex flows, and identified a number of information gaps that continue to inhibit our fundamental understanding of this flow. A new collaborative testing opportunity was also proposed to address many of these data needs.



a) Vortex core visualization



b) Limiting radius

Fig. 3- Particle effects near the core of a leading-edge vortex. Greenwell [7].

2.1.2 Computational Fluid Dynamics

Many excellent CFD studies were presented in the symposium, some of which will be discussed later in this paper. In one study by Pirzadeh [10], a new technique for adaptive, unstructured grid computations based upon the Reynolds-averaged Navier-Stokes equations was presented. The flow solver for this work was the USM3Dns code of Frink [11].

It is arguable that most computed vortex flows suffer from insufficient grid resolution in the vicinity of the off-body vortex structures. The vortices contain local extremma in flow properties, their location is of course unknown a priori, and details of the flow within the vortices can be important to significant phenomena such as vortex breakdown.

With Pirzadeh's approach, cells are adapted so they cluster in the vicinity of the vortex, but in such a way as to sustain adequate grid resolution away from the vortex as well. As a consequence of this adaptive approach, significantly improved correlation with experiment was demonstrated for a 65^{o} delta wing. A sample of the enhanced flow resolution for this wing with near-field vortex breakdown is shown in Figure 4 below. Good correlation with experiment was also shown for a more complex configuration. Additional assessments of this new capability are warranted.

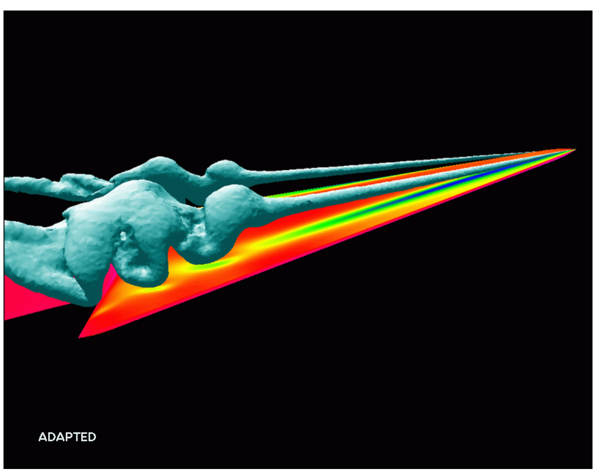


Fig. 4- Adaptive grid vortex breakdown solution. Pirzadeh [10].

2.1.2 *Flight-Test Technology*

A variety of flight-test results were included in the symposium which included flow-field visualization, flow-field measurement, and vehicle performance measurement. The majority of the measurement technology has already been established, and as such the flight-test results will be highlighted in the section on vehicular studies.

2.2 Fundamental Vortex Studies

Fundamental studies were reported in several sessions of the RTO symposium. With this fundamental research, vortex phenomena that pertain to vehicular performance can be studied and understood in much greater detail by exchanging configuration complexity for flow physics resolution. Such studies are typically performed on simple shapes, like the delta wing, or with idealized flows, like an isolated vortex.

Among the sessions with fundamental studies, it was noted that a number of papers addressed vortex breakdown, unsteady vortex flow effects, and multiple co-rotating vortices. Some of these results are highlighted in the following sections.

2.2.1 *Vortex Breakdown*

Cary and Darmofal [12] reported a very careful computational study of vortex breakdown physics for Burgers vortex confined within a tube. One example from these detailed computations of transient bubble formation along the vortex core is shown in Figure 5 below. The authors demonstrated that the onset

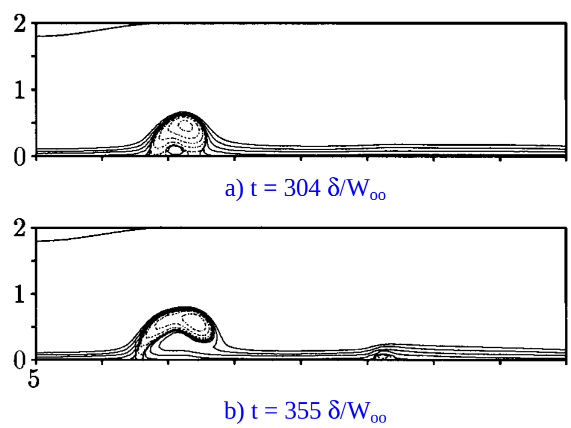


Fig. 5- Transient bubble formation due to $\Delta\Omega$. R_δ = 1000. Cary and Darmofal [12]

of axisymmetric vortex breakdown for the subject vortex corresponded to a condition of local criticality as determined from a local eigenvalue problem. Weak non-axisymmetric flows were also analyzed, and it was shown for this composite flow that the underlying axisymmetric flow still established criticality for vortex breakdown.

Thomer et. al. [13] used both Euler and Navier-Stokes formulations to simulate the interaction of a longitudinal free Burgers vortex with a normal shock wave. The initial condition for vortex circulation was varied such that vortex breakdown developed among the cases included in the study. These very careful computations included a detailed view of the flow within the breakdown bubble and an example is shown in Figure 6 below. A breakdown criterion was also developed that correlated well with computational and experimental findings.

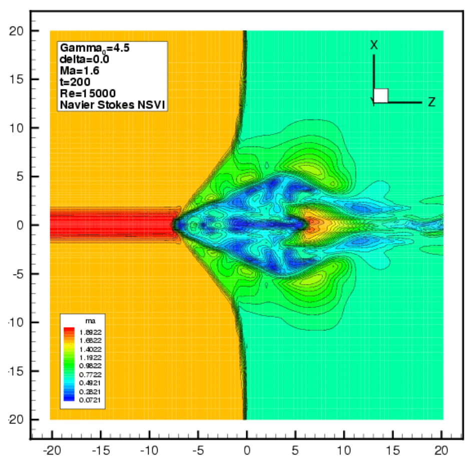


Fig. 6- Mach contours for normal shock-induced vortex-breakdown. Thomer et. al. [13]

In a paper by Huang et. al. [14], results were presented from a critical assessment of over sixty experiments that addressed vortex breakdown location over delta wings in steady flow. The authors showed that there is considerable uncertainty in the progression of the burst point over the delta wing as angle of attack is increased. It appears likely that a variety of experimental conditions among the historical database were not sufficiently controlled or, in some cases, even reported. Although a number of these tests may have been well performed for their time, the results of this useful document demonstrate why some fundamental tests can need to be revisited from an advanced knowledge perspective.

2.2.2 Unsteady Effects

Turning to unsteady aerodynamics, Huang and Hanff [15] addressed modeling techniques to simulate the vortex breakdown location over a 65^{o} delta wing undergoing various dynamic motions. Their approach was based on a nonlinear indicial response method coupled with a nonlinear formulation as proposed by Tobak and Schiff [16]. It was shown that the vortex breakdown location could be approximated by the superposition of three convolution integrals of certain response functions in a way that captures nonlinear effects. Very accurate estimates by this technique were demonstrated for a rolling motion (Figure 7) and the authors stated that similar procedures could be used for other motions of interest.

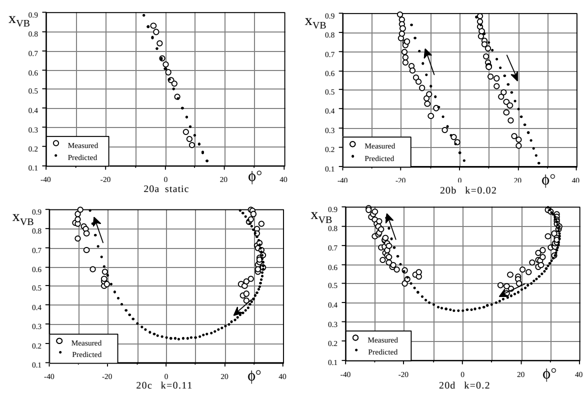


Fig. 7- Vortex breakdown dynamics via response surface modeling. Huang and Hanff [15]

Hysteresis effects associated with near-field vortex breakdown were studied in several papers. Planckaert [17] adopted a variation on the Polhamus suction analogy [18] to approximate vortex breakdown effects on a delta wing. Coupled with a neural net, this technique provided an exceptional model of force and moment hysteresis effects for angles of attack ranging from -20^{o} to 90^{o}. It would be useful to assess these modeling techniques [15, 17] for other dynamic motions as well as other geometries.

In a study by Goertz et. al. [19] a multiblock Navier-Stokes code was used to predict both steady and unsteady aerodynamics of a 70^{o} delta wing. Considerable attention was paid to computational uncertainty associated with the effects of grid topology and refinement as well as other numerical parameters for a high angle of attack of 35^o with steady boundary conditions. An example of the unsteady predictions for a sinusoidal pitch oscillation is shown in Figure 8 for both inviscid and laminar flow solutions. Agreement of the laminar CFD with experiment was good at low angles of attack; the experimental high angle of attack hystersesis loop aerodynamics appear to require turbulent flow simulation in association with vortex breakdown effects.

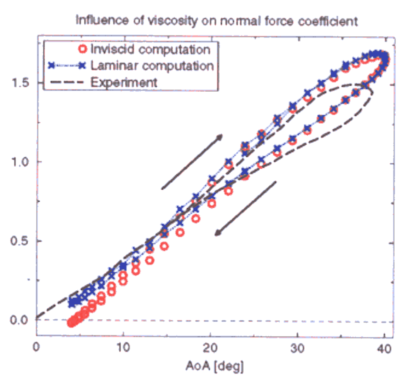


Fig. 8- Prediction of the normal force hysteresis loop for a 70^o delta wing oscillating in pitch. Goertz et. al. [19]

Unsteady blowing effects on vortex force and moment properties were presented by Mitchell et. al. [20]. Several different blowing and suction concepts were assessed, both experimentally and computationally, for a 70^o delta wing at low Reynolds number. One of the more interesting results was for a concept of periodic blowing/suction from the leading edge such that the net mass flux of this blowing system was zero. Tests were performed in a water tunnel, and the results demonstrated extensive effects on the vortex trajectory and wing aerodynamics from this type of blowing.

Unsteady Navier-Stokes calculations were performed to simulate this flow, and considerable attention was paid to numerical uncertainty (e.g., grid resolution, time step considerations, etc.). The resultant computations were shown to provide a good simulation of the experimental findings, and a sample result is shown in Figure 9. The vortex trajectory oscillated with the blowing, and the CFD iso-surfaces of the vortex location correlate well with the experimental results. Extension of this study to high Reynolds numbers would be of interest.

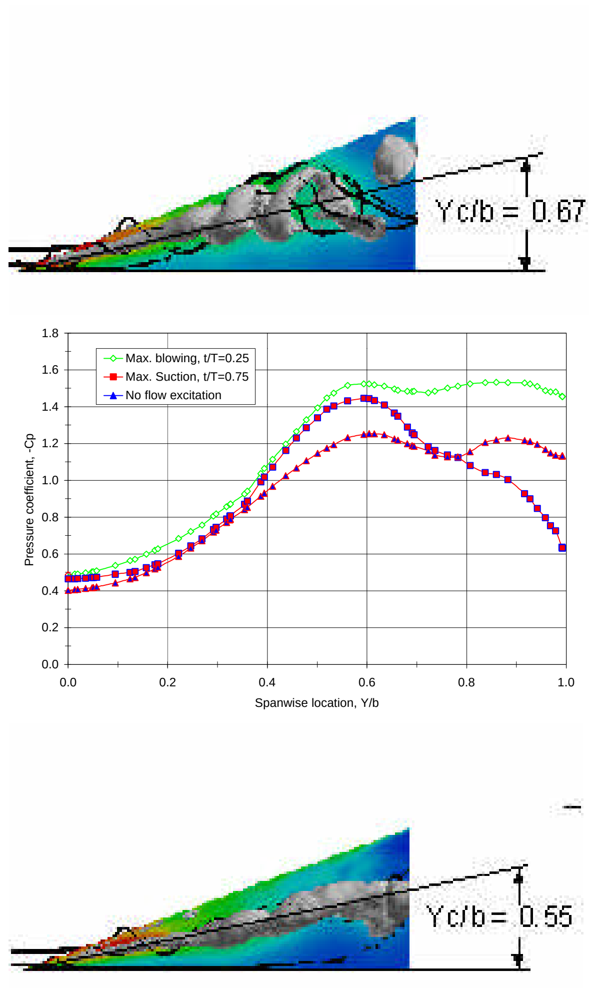
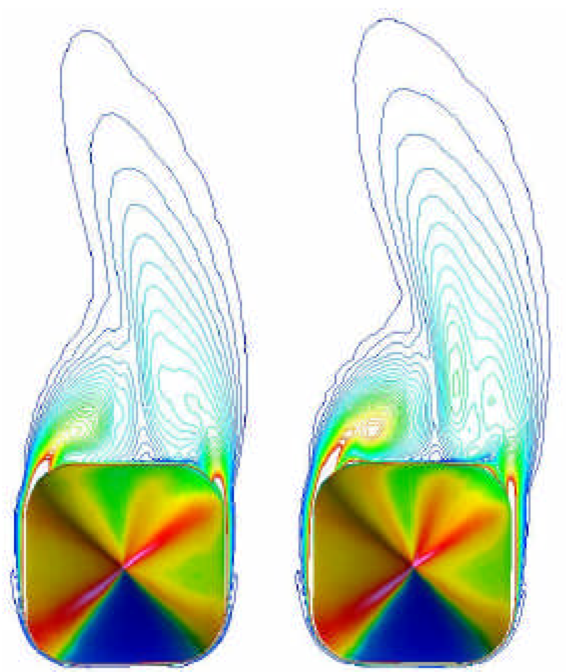


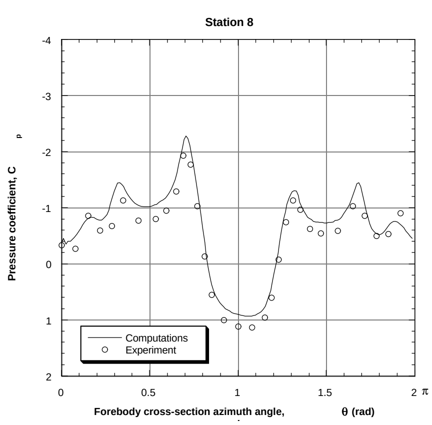
Fig. 9- Unsteady blowing effects for a 70^o delta wing. Mitchell et. al. [20]

Unsteady forebody flows were also included in this symposium. Van Dam et. al. [21] presented results for smooth-sided two-caliber tangent-ogive bodies at high angle-of-attack rotary conditions. The bodies had either a circular or rounded-square cross-section. Data were obtained from two facilities, and once again very careful numerical modeling assessments were reported.

Low speed results were shown for 60^o angle of attack and a normalized rotary rate about the wind axis of $\Omega b/2U = 0.2$. Although force and moment comparisons were not made, the computed and experimental pressures matched well for multiple stations on the ogival forebody. An example of these results is shown in Figure 10 below.



a) Baldwin-Lomax (l) and Spalart-Almaris (r) turbulence models



b) Correlation with experiment

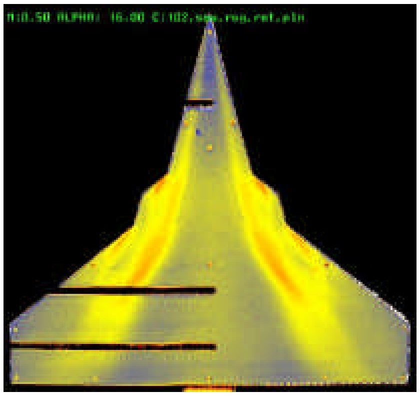
Fig. 10- Rotary flow about a square-sided tangent ogive. Van Dam et. al. [21]

2.2.3 Multiple Co-rotating Vortices

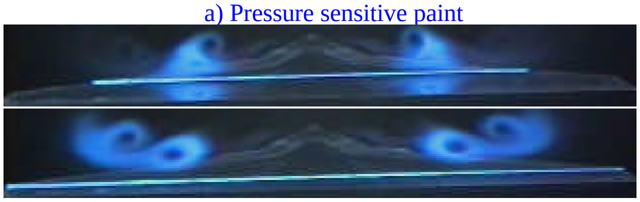
The vortex flow results summarized thus far have for the most part been dominated by a single primary vortex system with all the corresponding secondary and sub-order vortical structures. In a number of studies, multiple primary vortices that co-rotate were studied, and it appears that this particular type of vortex flow structure may be more common than had been appreciated. The interaction among these vortices can alter the vortex flow aerodynamics.

In an example for which this multiple vortex flow was intended, Gonzalez et. al. [22] reported the results from an experimental investigation of double delta wing geometries. A 76^o/40^o double delta wing was used to experimentally study the effect of fillet planform shape (at the sweep discontinuity) on the vortex flow aerodynamics, and four fillet shapes were studied. A very thorough suite of instrumentation technology was used for this study that included static surface pressure taps, pressure sensitive paint, six-component forces and moments, and off-body laser-vapor-screen flow visualization. Representative results are shown in Figure 11 on the following page, and this diverse suite of measurements provided a thorough understanding of a very complex and interacting vortex flow to be reported. Different fillet geometries affected the interaction of these vortices with significant consequences on the maximum lift coefficient as shown in Figure 11d. Gonzalez' data could be useful for future CFD calibrations.

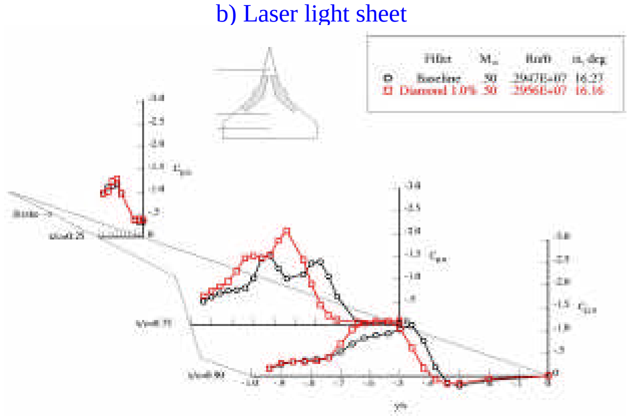
Ghee and Hall [23] assessed vortex-shedding effects for an Uninhabited Combat Air Vehicle (UCAV) concept that is shown in Figure 12. The investigation was primarily experimental. Once again a very thorough suite of measurement technologies was used to gain understanding of this flow; the measurements included six-component forces and moments, surface fluorescent oil flows, static and dynamic surface pressures, hot-wire flow field data, and laser-vapor-screen off-body flow visualization. This class of vehicle can exhibit some challenging vortex flow effects due to the



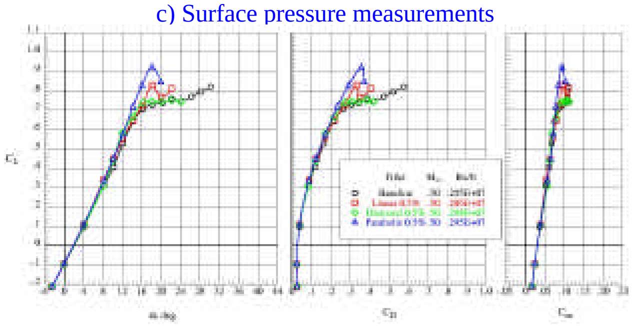
a) Pressure sensitive paint



b) Laser light sheet



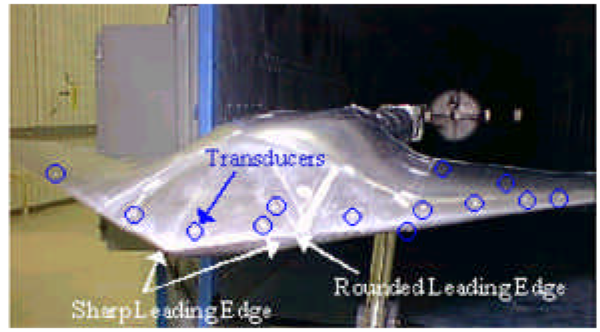
c) Surface pressure measurements



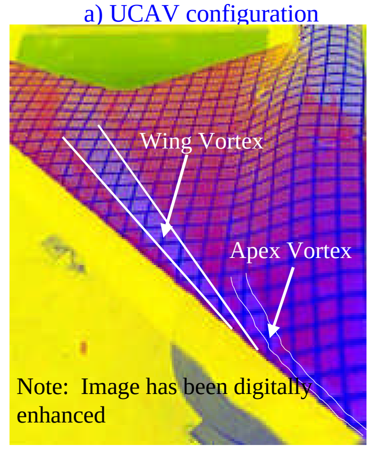
d) Force and moment properties

Fig. 11- Multiple primary vortices for a double delta wing. Gonzalez et. al. [22])

moderate sweep (approximately 48°) and small leading-edge radii that are incorporated for survivability. The results showed a multiple primary vortex system that most likely formed



a) UCAV configuration



b) Multiple vortex formation

Fig. 12- Multiple co-rotating vortices on a UCAV concept. Ghee and Hall [23]

in association with the spanwise variation in leading-edge radius on this constant-sweep wing. A third primary vortex system was inferred on the outboard portion of the wing.

Multiple co-rotating primary vortices were also discovered in flight during the F-106 vortex flap flight experiment. (See Figure 13.) In this vapor screen image from Brandon et. al. [24], an inboard vortex can be seen to shed from the flap and persist over the wing, and a second primary vortex can be seen outboard. Additional aspects of this vortical structure will be discussed in the following section on vehicular studies.

2.3 Vehicular Studies

The RTO Symposium included a number sessions directed at vehicle performance and design issues for both aircraft and maritime applications. This was the first time the vortex-focused symposia of RTO/AGARD had been extended to include maritime work, and the extension was an excellent addition.

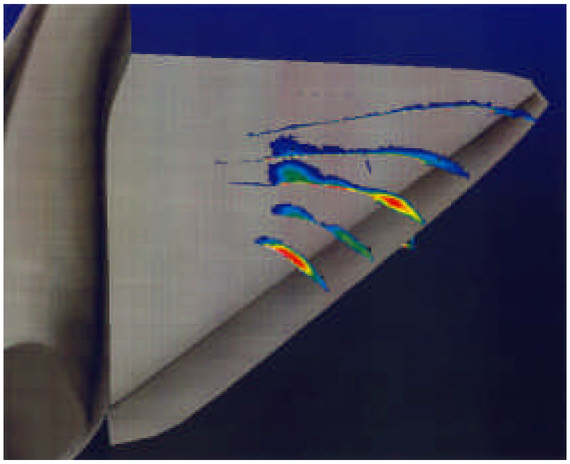


Fig. 13- In-flight vortex flap flow-visualization result for $\alpha=13^{o}$, $\delta_f = 30^{o}$. Brandon et. al. [24]

2.3.1 Preliminary Design

A number of papers addressed preliminary design considerations for which there can be more emphasis placed on rapid approximate methods to meet schedule requirements. Nangia [25] addressed some of the lower-speed aerodynamic design challenges of supersonic transport wings. Because these wings are designed primarily for efficient supersonic flight, the lower speed flight conditions can often include separation-induced leading-edge vortex flow effects. Nangia addressed the control and suppression of the vortex flow, and also demonstrated very effective use of the attainable leading-edge thrust theory of Carlson et. al. [26] for the analysis and design of these wings.

Leroy et. al. [27] demonstrated a computationally efficient approach to model unsteady wake development. The approach was based upon a fairly classical panel-method approach, and results were shown for (i) a flapping variable geometry wing of moderate aspect ratio and for (ii) an oscillating low aspect ratio wing. With this formulation, wake vorticity is inherently preserved as contrasted to most CFD methods that can suffer extensive numerical dissipation of the wake vorticity.

In a related vein, Raj et. al. [28] assessed the suitability of Euler methods to provide preliminary design force and moment estimates for vehicles dominate by vortex flows generated from sharp edges. The work included an assessment of an unstructured Euler method to estimate vortex strength and trajectory for sharp-edged forebody flows (Figure 14), and useful force and moment estimates were obtained from two different unstructured Euler formulations. The Euler technology was more suitable to preliminary design rapid turnaround needs than viscous CFD.

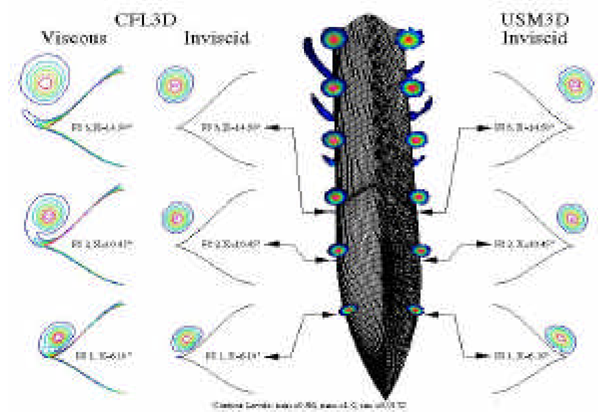


Fig. 14- Correlation between viscous and inviscid CFD vortex properties. Raj et. al. [28]

Rapid analysis was also addressed for cavity effects on store separation by Malmuth et. al. [29]. An inner/outer expansion approach was shown to provide promising store force and moment estimates at a fraction of the resources required for Navier-Stokes computations.

2.3.2 Aircraft Studies

A variety of flight test programs were presented along with summary data. This included an overview of the X-31 flight test program by Ross [30] and an analysis of high angle-of-attack yawing moments due to asymmetric forebody separation by Cobleigh and Croom [31]; this work included assessments of ground-to-flight effects.

Lamar [32] provided a summary of a very extensive set of flight data obtained on the F16-XL-1. This aircraft has a highly swept wing that is conducive to vortex flow studies (Figure 15). The measurement devices included static surface pressures, hot films, boundary–layer rakes, Preston tubes, and surface-tuft flow visualization. Data were obtained from low speed to transonic conditions and it is rare that such a extensive suite of flight measurements is achieved. The measurements emphasized wing upper surface vortex flows, and promising correlations with Navier-Stokes computations were shown.

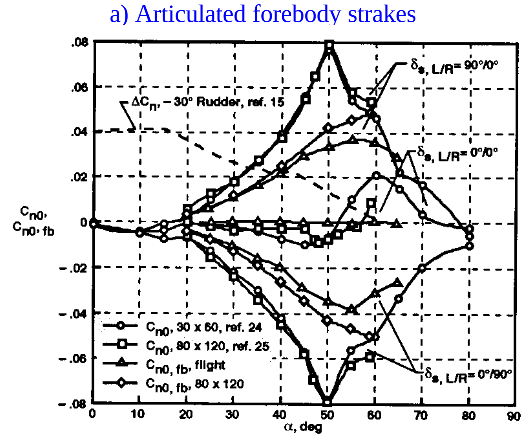
Fig. 15- F16-XL-1 research aircraft. Lamar [32]

Flight performance and flow visualization data were obtained on the F-106B aircraft configured with a vortex flap [24]. Results were summarized for a broad range of Mach numbers and angles of attack. The flap was designed to develop a single vortex, but as mentioned previously, multiple co-rotating vortices were discovered in flight. A surface flow image of this flow structure is shown in Figure 16.

Fig. 16- In-flight vortex flap flow-visualization result. α=10°, δ_f = 40°. Brandon et. al. [24]

The source of these vortices was traced to small geometric irregularities in the wing leading edge and was subsequently confirmed with wind tunnel testing. Despite the drastic difference in vortex flow structure, the vehicle performance was barely altered.

a) Articulated forebody strakes



b) Yawing moments

Fig. 17- F-18 forebody strakes and yawing moment effects. Fisher and Murri [33]

Finally, the F-18 High Angle-of-attack Research Vehicle (HARV) was used to study the effects of actuated forebody strakes on yawing moment control. The work was reported by Fisher and Murry [33], and a sample result is presented in Figure 17. The data demonstrate this to be a very effective yawing moment device for high angle-of-attack flight. Ground-to-flight correlations for this concept were also included.

2.3.3 Maritime Studies

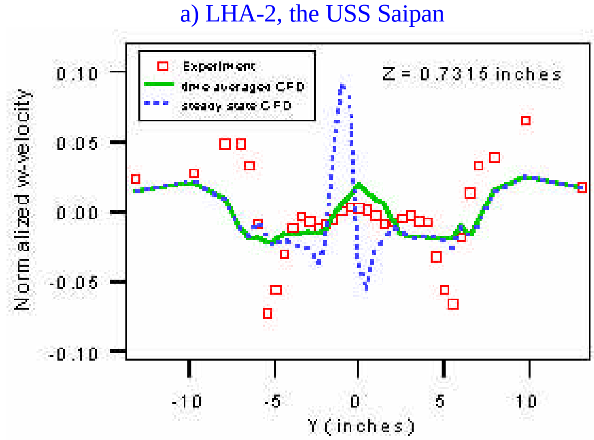
One session of the symposium was dedicated to maritime studies. All of the results were very well linked to various fleet issues, and the maritime research was an excellent extension to the symposium that has traditionally had an aircraft focus. Gorsky [34] presented an overview issues associated with maritime vortices and the status of computing these flows.

Computations were performed by Polsky and Bruner [35] to simulate the unsteady air wake over ship upper surfaces. This separated wake can include many vortices shed from the superstructure and other edges of the ship. Because aircraft must take off and land in this unsteady flow, it is of great interest to predict and eventually control it.

Unstructured CFD was used to model this complex flow. A Navier-Stokes technique was initially calibrated with wind tunnel data, and then time-accurate computations were performed to simulate the subject flow. The unsteady calculations were time averaged the same way that experimental measurements were averaged, and overall a good correlation was achieved given the complexity of this flow. (See Figure 18 for a comparison with wind tunnel measurements.) As a numerical study, “steady-state” solutions were also generated and demonstrated much poorer correlation with measurement, as would be expected. From this work it seemed compelling that the unsteady formulation was vital for achieving a reasonable correlation with full-scale ship data

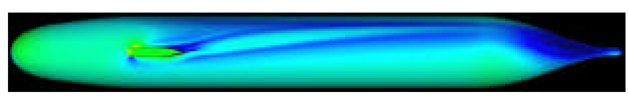
Several papers addressed submarine flows. In a paper by Watt [36] submarine dynamics were addressed to explain a roll instability that can occur during a rapid emergency rise. In work performed by Sreenivas et. al. [37] the

a) LHA-2, the USS Saipan

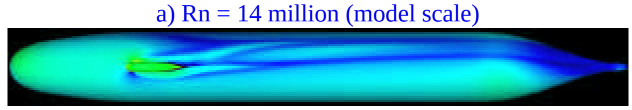


b) Steady and unsteady CFD comparisons to experiment

Fig. 18- Wind-over-deck ship computations. Polsky and Bruner [35]



a) Rn = 14 million (model scale)



b) Rn = 1000 million (full scale)

Fig. 19- Navier-Stokes predictions for high Reynolds number submarine vortices. Sreenevas et. al. [37]

roles of grid resolution and Reynolds number scale effects were studied for a notional submarine geometry with an unstructured Navier-Stokes code. (See Figure 19.) A good correlation with model scale data was shown, and significant grid resolution and scale effects were also discussed. Some full-scale Reynolds number flow features were absent at model scale conditions, and hence simple Reynolds number scaling would not account for the effects of these high Reynolds number flow structures.

3 Concluding Remarks

An overview of the RTO symposium on Vortex Flow and High Angle of Attack has been presented. The research from this symposium provided an indication of the complexity of these flows along with their many ramifications for military vehicle aerodynamics and hydrodynamics. The collective findings also provide a good benchmark for the status of experimental investigations, numerical studies, and design applications for separation-induced vortex flows.

A number of significant advancements in the measurement, prediction, and understanding of vortex flows have accrued over the ten years since the last AGARD symposium on this topic. Even so, this symposium has pointed to many current challenges and opportunities. High-quality vortex flow field measurements are still needed at conventional and especially high Reynolds numbers. Some fundamental tests from the historical database also need to be revisited from the current advanced knowledge perspective.

New computational methods to grid-resolve the off-body vortical structures are just emerging and warrant sustained development. New techniques for predicting vortex breakdown for simplified vortices have been developed, as have some novel modeling techniques for vortex breakdown effects on simplified wing aerodynamics. These methods need to be extended for more complex applications.

Several complex vortical structures are now receiving increased attention. Multiple co-rotating primary vortices appear to be more common than had been previously appreciated and present a new challenge for wing design and especially for CFD predictions. Unsteady effects associated with wing motion or forced blowing concepts are also being newly assessed. Unsteady PSP and unsteady CFD are beginning to be applied to study these flows.

Aircraft data for vortical flows present a good opportunity to assess ground-to-flight considerations. Maritime studies demonstrated many related issues to the aircraft motivated research. New capability to predict unsteady flow over ship decks is just emerging, and high Reynolds number submarine flows show structures not present at model scales. Finally, in this symposium the RTO sponsored the first combination of the maritime and aircraft communities for vortex flows, and further interaction between these groups could clearly be of mutual benefit to both.

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