Engineering Notes

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Effect of a Single Strake on the Forebody Vortex Asymmetry

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I. Background

IT is well recognized that the flow over slender bodies becomes asymmetric at high angles of attack. The subject has been studied extensively in relation to missile aerodynamics and, more recently, aircraft aerodynamics due to the increasing interest in the high angle-of-attack flight regime. The subject has been reviewed recently by Ericsson and Reding.[1]

On sharp-edged delta wings, where the separation location is fixed, the primary effect of the asymmetric vortex pair is to induce a rolling moment, which, under certain circumstances, can lead to a form of wing rock. When the leading edges are rounded, such as on a body of revolution, the asymmetric vortices are associated with an asymmetry in the flow separation. In this case, a large yawing moment can also be induced. This yawing moment can be so high that it can overcome the control moment available from a typical, fully deflected rudder.

Due to the undesirable effects associated with the forebody flow asymmetry, numerous means of alleviating the problem have been devised. These include methods such as blunting the nose, small strakes, trips, blowing, and suction. Whereas each of these methods are effective to a certain degree under different situations, there is still no general consensus on the fluid mechanism that leads to formation of vortex asymmetry.

An analogy with a cylinder in an impulsively started flow is often used to describe the asymmetric vortex flow over a conical forebody, and a hydrodynamic instability is suggested as the cause of vortex asymmetry. Simply put, above a certain strength, two vortices cannot coexist in a side-by-side fashion over a given space. In this situation, the presence of a perturbation is not necessary to maintain an asymmetric vortex pattern. This hydrodynamic prediction, however, contradicts the results of the Navier-Stokes simulation by Degani and Schiff.[2] In their study, a space-fixed, time-invariant perturbation is needed to obtain asymmetry. Once the perturbation is removed, the flow will return to the symmetric state. Furthermore, it was found that a perturbation closer to the nose will produce a stronger asymmetry. This points out the important role of the flow near the apex region.

The importance of the flow near the apex region is further exemplified by the experiment of Moskovitz et al.[3] They show that any asymmetric perturbation at the apex, even on the microscopic level, can dictate the form of flow asymmetry over the entire forebody.

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Whereas there seems little doubt that the asymmetry introduced by the perturbation at the apex plays an important, if not predominant, role in determining the flow pattern over the entire forebody, there still remains the question of how this asymmetry is being amplified downstream. The amplification of this asymmetry at the saddle point over and in between the two vortices is often cited as the mechanism responsible. This, however, may have ignored the possible importance of the vortex interaction in the form of mutual entrainment near the apex region and the stabilizing effect of the axial flow. The objective of this experiment is to investigate whether these effects play a significant role in determining the vortex asymmetry. A small strake was placed near the apex along the leeward axis of a tangent-ogive forebody so that the interaction between the two vortices is reduced in this region. A comparison between the flows with and without the strake would provide some insight into the matter.

II. Description of the Experiment

The experiment was conducted in the Eidetics 2436 Flow Visualization Water Tunnel. The facility is a continuous horizontal flow tunnel with a test section 24 in. wide × 36 in. high × 60 in. long. The tests were conducted at a flow speed of 4 in./s corresponding to a Reynolds number of 2.8×10^4/ft. A pressurized dye-injection system was used for flow visualization which was recorded using both a 35-mm camera and a videotape recorder.

The model used, sketched in Fig. 1, was a 4.0 caliber tangent-ogive forebody with a base diameter of 5.5 in. The length of the triangular strake was about 8% of that of the forebody, and the base height was about one-third of the local forebody diameter.

III. Results and Discussion

Figure 2 shows examples of the vortex flows over the forebody with and without the strake. Figure 3 compares the approximate vortex positions for the two configurations at different angles of attack. Without the strake, the forebody vortex flow becomes asymmetric at angles of attack above about 30 deg. The natural model asymmetry favors a left-vortex high-flow configuration and the asymmetry becomes stronger at higher angles of attack. With the strake, the vortex asymmetry is greatly reduced. Presumably, the large yawing moment associated with the vortex asymmetry has also been greatly attenuated. The placement of the strake was found to be very critical. A small asymmetry in the placement can lead to a strong asymmetry in the vortex flow downstream.

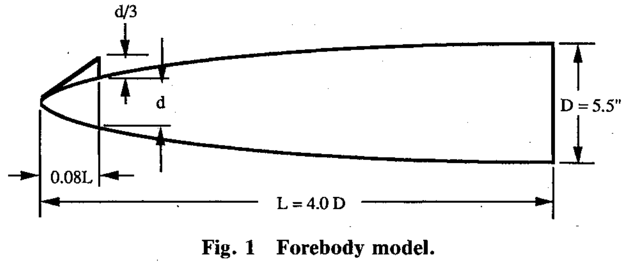

Fig. 1 Forebody model.

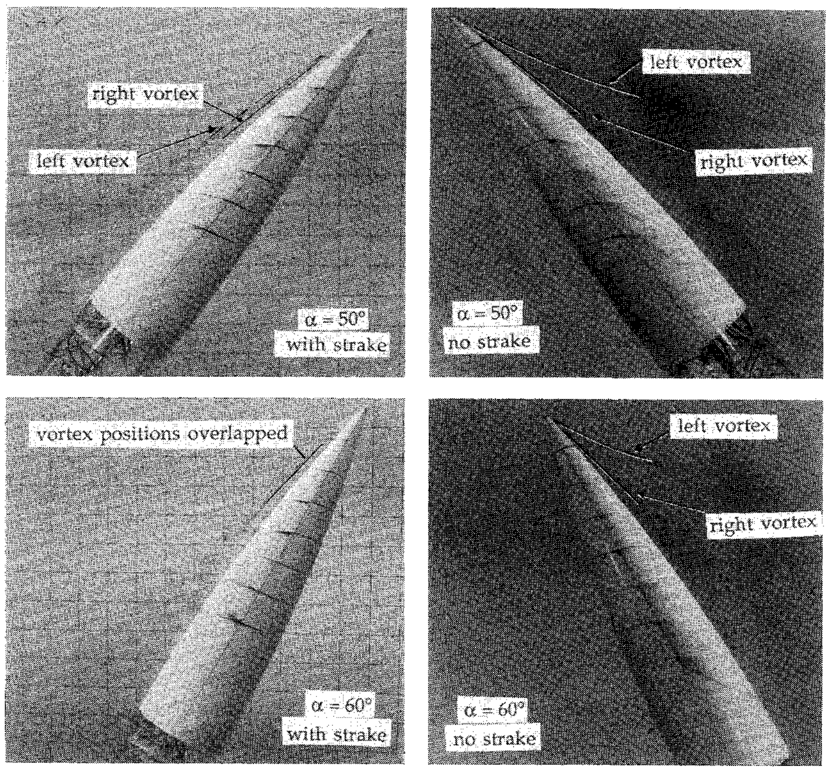

Fig. 2a Side-view examples of the flow-visualization results.

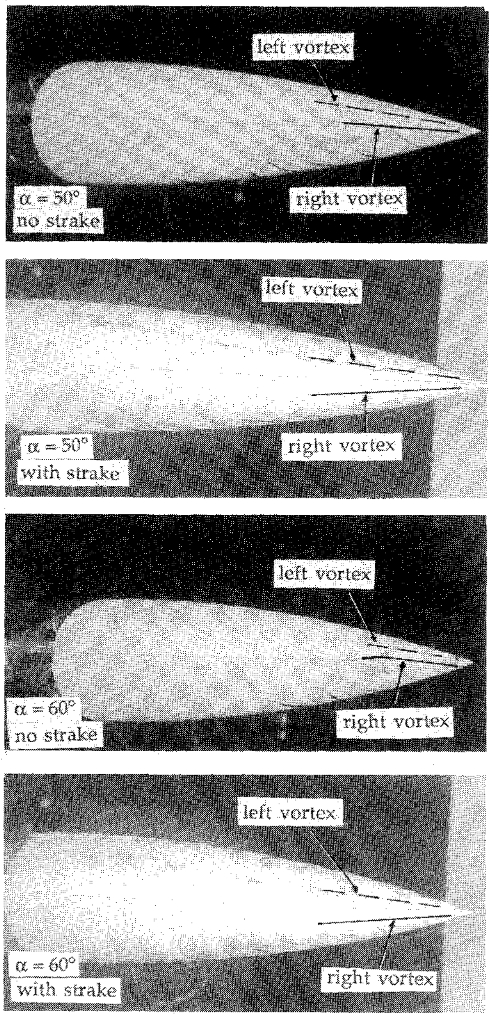

Fig. 2b Planform-view examples of the flow-visualization results.

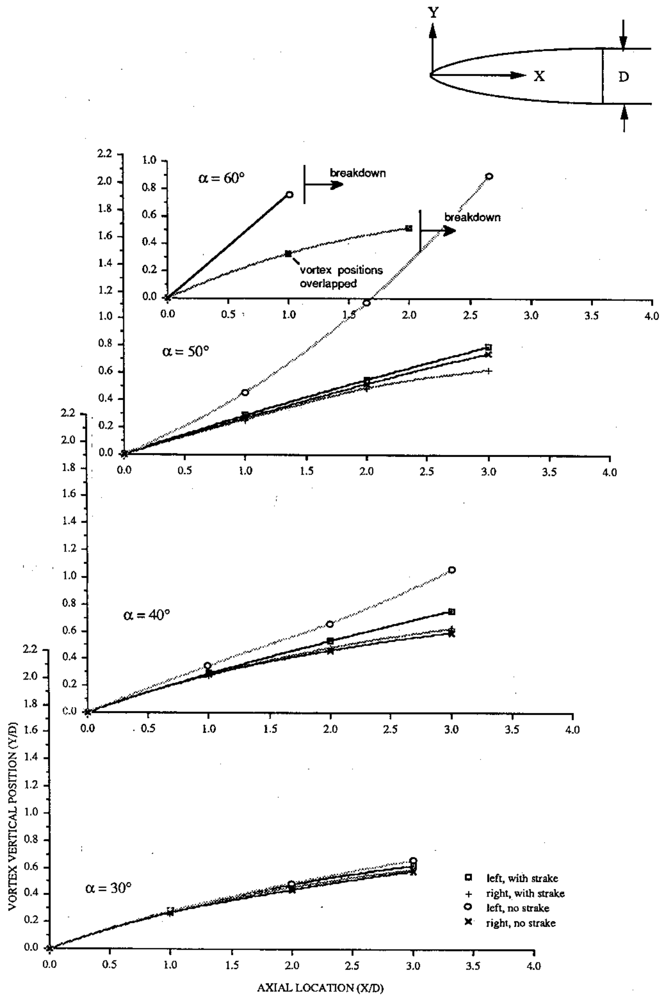

Fig. 3 Approximate positions of the vortices above the model centerline.

There are several points of interest for discussion. The results show clearly the importance of the flow at a small region near the apex which forms the core of the vortex. The flow in this region is highly three-dimensional in nature and strongly influenced by the axial flow in most situations and thus is not accurately simulated by the impulsive flow analogy or by the conical flow assumption. By reducing the interaction or entrainment between the flows on the two sides, the flow asymmetry caused by the perturbation imposed at the apex is not being amplified farther downstream. In other words, the amplification of the asymmetry seems to take place mostly near the apex. While Moskovitz et al.[3] suggested that the effect of blunting the nose was mainly a reduction of the model asymmetry, because a blunted nose is easier to machine, it would seem that the effect may also be the result of the modification of the flow near the apex region. That is, blunting the nose has a similar effect of reducing the flow interaction as the strake.

References

[1]Ericsson, L. E., and Reding, J. P., "Aerodynamic Effects of Asymmetric Vortex Shedding from Slender Bodies," AIAA Paper 85-1797, Aug. 1985.

[2]Degani, D., and Schiff, L., "Numerical Simulation of the Effect of Spatial Disturbances on Vortex Asymmetry," AIAA Paper 89-0340, Jan. 1989.

[3]Moskovitz, C. A., Hall, R. M., and DeJarnette, F. R., "Effects of Nose Bluntness, Roughness and Surface Perturbations on the Asymmetric Flow Past Slender Bodies at Large Angles of Attack," AIAA Paper 89-2236, Aug. 1989.

Synchronization and Time Tagging in Distributed Real Time Simulation

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I. Introduction

By definition, real time simulation runs as fast as the real world process it simulates. With proper calibration, this holds true on the average. However, "in the small" the digital processes proceed by leaps and bounds and deviate considerably from the uniform flow of time. Time evolution is computed in steps. Typically, time is divided into frames. All of the processes that occur in parallel during the frame are computed during the frame, in sequence. Some of the frame time is used for computer housekeeping and communications. Some usually is surplus and remains idle.

The frame becomes the natural unit of time for simulation. It may be neither possible nor useful to measure an increment of time finer than a frame.

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The situation is more complex when multiple processors, computing in parallel, are involved. Different machines may run different cycles. Some may be asynchronous, and some may adjust their step time to the workload. Even when all frames are of equal duration, they are not directly comparable unless steps are taken to synchronize them. And even then, the correct time tag of any information may not be clear. Variables computed by processor X and used by processor Y may have been transmitted several times through a bus or local area network. The values used or recorded could be several frames old.

See Refs. 1 and 2 for a review and further references on the effects of temporal fidelity on simulator effectiveness.

As more and more demand is made on simulation in the fields of training and testing of airmen and design and evaluation of airframes and avionics, the need to quantify the meaning of time tagging becomes more crucial. This is required in the assessment of simulation fidelity and for the correct interpretation of information gathered from simulation studies.

This paper outlines a system of timing for distributed real time simulation. Both hardware and software are involved. Three different times are invoked: time of day, mission time, and dynamic time. All three are relative times referred to an arbitrary starting point. All three are reckoned in ticks. Time of day is a continuously running count. Mission time skips periods when the simulation is frozen. Dynamic time addresses the distinction between the time a computation is made and the time at which the result is valid.

Between them, the three time definitions provide the analyst with the tools to decide what takes place when, in simulation and in the real world process being simulated.

II. Time of Day

Time of day (TOD) is defined by a common timing signal distributed to all processor boards. This signal may be the basic simulation frame count or it may be a faster count whose frequency is an integral multiple of the frame count. In this case, a new frame is started every *n*th count. Individual counts are available for timing finer than a frame.

Mission time is maintained as a tick count in a register or memory location that is available to all processes, real time as well as control functions, to read. In a distributed system, each processor or chassis maintains its own TOD count. This permits independent operation. It also ensures that time can be determined locally without undue delay and without an undue burden on intercomponent communications.

In the McDonnell Douglas Helicopter Company (MDHC) facility, TOD is a 59.94 Hz signal derived from the image generation system and defining the basic frame of the out-the-window visual. The signal is distributed by coaxial cable to the many processors. Typically, these are 68020 processor boards in VME chassis. The timing signal is wired into an unused line in the backplane, where every processor board picks it up. Each processor then maintains its own TOD count in an onboard memory location. The processor can access its own time count over a local bus. At the same time, the location is also available to external processes over the VME bus. In particular, the system control station (SCS) has access over Ethernet to each VME bus and can read and write each processor's memory.

III. Synchronization

The distribution by wire assures that the ticks counted by the different processors are synchronized to within nanoseconds (representing the differences in wire length). However, at this point, the TOD count maintained by different processors is different because the processors are independent and start operation asynchronously. Synchronizing the TOD counts of the different processors is a task to be accomplished as part of the global system initialization by the SCS. The process consists of SCS reading its own TOD and writing the same