Simplified Geometric Modeling of Complex Aerodynamic Shapes

Frederick L. Shope*
ARO, Inc., AEDC Division, Arnold Air Force Station, Tenn.

Abstract

THIS Synoptic describes two Fortran computer programs, KWIKNOSE and PREKWIK, which, for certain common aerodynamic vehicle configurations, allow simplified geometric input to the QUICK-Geometry System, which in turn provides geometric information to various numerical flowfield codes. For a wide variety in choice of input parameters, KWIKNOSE sets up the QUICK input for an arbitrary sequence of conical and ogival sections. In this process, KWIKNOSE performs the tedious computations necessary to locate the intersection points of successive arcs and to insert optional fillets or rounds over nontangent intersections. In addition, the code is capable of inserting arbitrary multiple slicing planes into the top, bottom, and side of the vehicle. Slicing plane intersections may be filleted or rounded. Thus, for a minimum of input and manual calculation by the user, KWIKNOSE is tailored to modeling the geometry of a sliced multiconic vehicle capped with an asymmetrically ablated nose. The PREKWIK code is designed to model various common aft body geometries.

Contents

Computational aerodynamics has advanced to the point where inviscid numerical flowfield solutions for three-dimensional geometries are commonplace, and computer programs are currently under development to compute fully viscous solutions for three-dimensional bodies, particularly for re-entry vehicle type geometries in supersonic and hypersonic flows. Clearly, the time is past when it is acceptable to intimately hardwire a specific geometry into a tailored algorithm, to develop a new computer program for each new geometry. Thus, the need for a generalized geometry package is apparent and has been at least partially satisfied by the QUICK-geometry system of Vachris and Yeager.[1] QUICK is a FORTRAN computer program which provides the user with a well organized method of constructing and interrogating the mathematical model of an arbitrary three-dimensional flight vehicle. The code was developed in two phases: the QUICKDEF phase, which provides facilities to build and check the geometry model, and the QUICKLOK phase, which provides geometric data to user programs without requiring the user to have detailed knowledge of how the model was constructed. The QUICKLOK phase of the QUICK geometry system is a subset of FORTRAN subroutines from the QUICKDEF portion of the code. The user interfaces his flowfield program and QUICK with one call to subroutine GEOMIN to read the geometry model and any number of additional calls to subroutine CSGEOM to generate surface coordinates and derivatives. The QUICK-DEF phase, of primary concern here, is a highly user-oriented program which aids geometric modeling by providing general curve-fitting services to define arbitrary bodies from a minimum of logical and numerical input. In essence, QUICK requires the user to define qualitatively each unique cross section of the vehicle in a plane normal to the coordinate axis of the vehicle by merely identifying the types of curves (lines, ellipses, parabolas, etc.) which form the segmented cross section. The cross sections then become numerically specific when the user further defines, logically and numerically, certain key control points which determine the intersections and slopes of the curves comprising the cross sections. The only two limitations imposed by QUICK upon the vehicle geometry are 1) that the vehicle must have a vertical plane of symmetry and 2) that each cross section must be definable in terms of a single-valued radius vector swung about a single point within the cross section. While these limitations prevent complete treatment of certain vehicle geometries (such as engine inlets, oblique wings, or double vertical stabilizers), QUICK is an important advance in the description of vehicle geometry and helps make practical the solution of flows over such complicated bodies as the space shuttle orbiter.

However, the acquired capability to compute three-dimensional flows does not eliminate the need to treat geometrically simple bodies such as blunted multiconics with slices. The design of re-entry vehicles, wind tunnel calibration, and development of state-of-the-art flowfield programs, as examples, all generate a continuing need to compute flow solutions for simple bodies. Re-entry vehicle design, in addition, requires a knowledge of the effect upon the flow of various asymmetrical noses resulting from ablation. The QUICK code is a milestone in vehicle geometry modeling, but has the practical disadvantage that modeling a simple geometry, such as a spherically blunted cone, requires about thirty data cards. However, the user of the flow solution would consider the entire cone geometry specified by only three numbers (e.g., bluntness ratio, cone angle, and a length scale) and would likely wish to run a matrix of them. Such logic has led to the development of several setup codes (PREKWIK and KWIKNOSE[2]) which prepare the QUICK input from a minimum of geometric input for a variety of nose and aft body configurations. Use of these setup codes with QUICK makes modeling of geometry trivial for the programmed configurations while retaining the more general capabilities of QUICK via manual preparation of the input.

As an example, consider the hypothetical re-entry vehicle of Fig. 1, which was modeled via KWIKNOSE and QUICK and sketched by a computer graphics program also based on QUICK. This vehicle is a bent cone with slices on its aft end and capped with an asymmetrical indented nose. Using KWIKNOSE, this geometry was modeled with 12 data cards, while the QUICK input deck assembled by KWIKNOSE for the user—or otherwise manually prepared—contained 100 cards. KWIKNOSE is designed to model any vehicle whose

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*Research Engineer, Project Support and Special Studies Section, Aerodynamics Projects Branch, von Kármán Gas Dynamics Facility. Member AIAA.

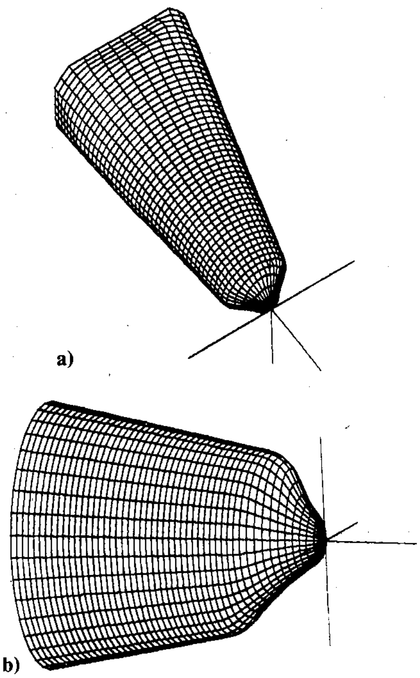

Fig. 1 Oblique view of asymmetrically ablated, bent, and sliced cone modeled via KWIKNOSE and QUICK: a) entire vehicle, b) nose region.

wind, yaw, and lee surface contours can be adequately represented by contiguous segments of circles and straight lines. The cross section at any axial station prior to slicing is assumed composed of two ellipses—one each for the upper and lower half planes. The code contains extensive logic to compute the coordinates of the segment intersections as well as to fillet or round sharp corners for a variety of input parameters. Most configurations modeled via KWIKNOSE to date were constructed directly from the given geometric data (e.g., model drawings) with little or no maunal computation.

While KWIKNOSE is tailored to modeling complex nose geometries mated with limited aft body configurations, PREKWIK is oriented toward various diverse aft body types. Geometries preprogrammed in PREKWIK include 1) basic multiconic vehicle with different nose options, bending options, and slicing options; 2) a vehicle composed of a series of deltas of uniform thickness with a spherical nose and circular leading edges; 3) a paraboloid of revolution or elliptic paraboloid; 4) an arbitrary body of revolution; and 5) a general asymmetric body with cross sections composed of two ellipses, body lines composed of arbitrary straight line segments following an elliptical or hyperbolic nose, and admitting arbitrary slices on the top, bottom, and side of the vehicle. Figure 2 shows computer graphics sketches of three typical geometries which can be modeled via PREKWIK and QUICK with only a few input cards.

Current applications of the QUICKLOK phase of QUICK, as well as the two set up codes, include the time-dependent blunt body program BLUNT[3]; the supersonic, three-dimensional, external, inviscid flowfield code STEIN[3,4]; and the multishocked, three-dimensional, supersonic finite-difference method of Kutler, Reinhardt, and Warming.[5] In the author's experience, adaptation of QUICK to a particular flowfield program is simple if the program's original

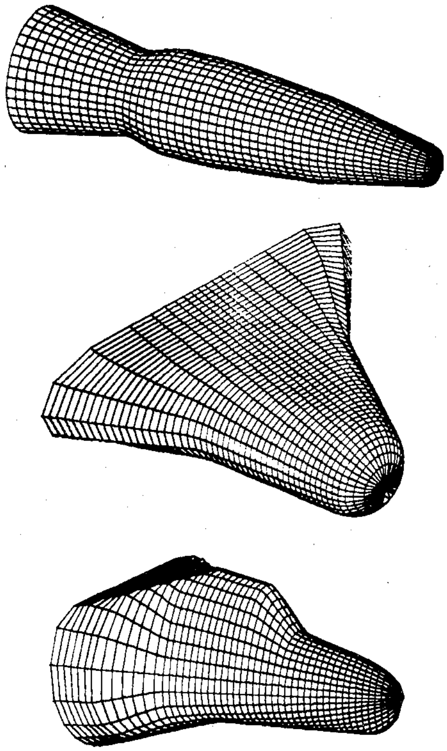

Fig. 2 Typical PREKWIK/QUICK models.

geometry package is modular in the sense of being confined to a small group of subroutines which are called whenever geometric data are needed.

In summary, QUICK, has been found to provide a convenient approach to modeling aerospace vehicle geometry. Consideration for its use in numerical flowfield computer programs should be given. Very rapid modeling can be obtained by using QUICK in conjunction with setup codes tailored to geometries of particular interest. KWIKNOSE and PREKWIK are examples of such setup codes and are tailored to special nose and aft body configurations. Detailed descriptions of the programs are given in Ref. 2.

References

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