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PANELING TECHNIQUES FOR USE WITH THE
VORLAX COMPUTER PROGRAM

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SUMMARY

A method is presented for determining the geometric input data required by the VORLAX computer program in order to accurately model an aircraft configuration. Techniques are described for modeling each of the major components of a configuration and for joining these individual components into a complete configuration. The effects of trailing vortex filaments and methods of avoiding their intersection with downstream panels are also discussed. The methods presented here are applicable to most conventional aircraft configurations.

INTRODUCTION

A generalized vortex lattice method of aerodynamic analysis and a computer program, called VORLAX, utilizing this method has been developed by the Lockheed-California Company (reference 1). The majority of the input data for this program consists of geometric data describing the configuration. This report describes several paneling schemes which can be used to generate the required geometric input data.

A given configuration is divided into a set of major panels with each panel describing a part or all of a component such as a wing, pylon, or fuselage as illustrated in figure 1. The major panels are subdivided by the program into minor panels, each containing an aerodynamic singularity. These minor panels may be spaced with either a linear or a cosine distribution in both the streamwise and spanwise directions. As many as 20 major panels and 2000 minor panels are currently allowed with symmetrical components being counted only once. The major panels may be input in any order as the program internally assembles the geometric data. Problems normally encountered in generating this input data include: (1) determining the correct location of the panels,

(2) connecting the panels properly, and (3) avoiding the intersections of trailing vortex filaments with downstream control points.

DISCUSSION

The following discussion is divided into several sections which describe the paneling of the individual components, the proper location of the panels, and the joining of the panels to define a complete configuration.

Wings

The wing of a configuration may be divided into as many major panels as necessary to define the planform subject to the constraint that the total number of panels used for the complete configuration may not exceed 20. The inboard and outboard edges of the major panels are usually defined by the leading and trailing edge breaks of the wing planform. However, when twist or camber varies non-linearly in the spanwise direction, more major panels should be used since the camber and twist boundary conditions for the minor panels are determined by linear interpolation across each major panel. Figure 2a shows an untwisted tapered wing for which one major panel is sufficient to define the planform. Figure 2b shows the same planform with the non-linear twist distribution shown in figure 2c. At least four major panels are required in this case to accurately model the given twist distribution. In order to maintain a near uniform distribution of singularities over the wing, the number of spanwise minor panels on major panel C should be approximately twice that on major panels A, B, and D. The use of uniform spanwise spacing of the singularities results in a smoother spanwise pressure distribution. Figure 3 shows a wing with the major paneling corresponding to the wing leading edge breaks. Here again the number of singularities on the major panels should be varied so that a near uniform spanwise distribution is achieved. When more than one panel is used on the wing, linear spanwise spacing should be used for the minor panels. Cosine spanwise spacing produces a concentration of vortices at the junction of the panels which in turn causes an irregularity in the pressure distribution at the junction.

Simple leading or trailing edge flaps may be modeled in the program. Experience with the program has indicated that these flaps should be simulated by defining a new flap panel rather than by modifying the wing camber line. The lateral edges of the flap panel should be at the same spanwise locations as the wing panel, as shown in figure 4. When the flap is defined as a separate panel, changes in flap deflection are easily made using the input parameters AINC1 and AINC2.

Horizontal and Vertical Tails

Horizontal and vertical tails are modeled similarly to wings with the spanwise major paneling determined by either leading or trailing edge breaks. However, since most tails have simple planforms without twist or camber, one major panel is usually sufficient. Due to the fuselage aftbody closure, a filler panel is usually required to seal the gap between the fuselage and tail panels.

For pitch plane runs, i.e., angle of attack variations only, the centerline vertical panels should be deleted since their presence triggers certain asymmetric calculations and increases run time considerably. Leaving out the panels does not change the results since they are located on the aircraft centerline and do not encounter any crossflow. On an asymmetrical aircraft the centerline vertical panels are required.

Fuselage

The fuselage may be modeled using either planar or fusiform paneling. The planar fuselage is the preferred representation when lift and induced drag data are desired, but the fusiform representation should be employed when pressure data are required. For the planar case the fuselage is represented by one or more zero thickness panels as illustrated in figures 5 and 6b. When working with a high fineness ratio fuselage, such as a supersonic transport configuration, the inboard edge of the fuselage panel is usually defined by the fuselage centerline while the outboard edge is defined by the wing root chord line. The camber on the panel is the same as the fuselage camber for the inboard edge and the wing root camber for the outboard edge. Subsonic aircraft

configurations, however, usually have a lower fineness ratio, are more blunt, and have a long cylindrical section. In these cases the inboard edge of the fuselage panel is again defined by the fuselage centerline but the outboard panel edge should extend most of the length of the fuselage in order to approximate the fuselage projected area. The fuselage camber, in this case, is used for the camber at both edges of the panel. For a configuration with a horizontal tail the outboard panel edge can be extended almost to the aft end of the configuration, thus allowing the attachment of the horizontal tail without having to use a filler panel. A vertical filler panel may be required on some configurations to connect the wing panel to the fuselage panel as shown in figure 5b.

Volume displacement effects are represented when the fuselage is modeled using fusiform paneling. For this method of paneling the fuselage is represented by a vortex lattice arranged on a series of concentric cylindrical surfaces, the cross-section of which is represented by a polygon. The number of sides of the polygon should be kept as low as possible with six sides usually being adequate to model most cross-sections. A reference polygon is defined in the area of the wing-fuselage intersection as illustrated in Figure 6c and 6d. The vertices of this reference polygon are located along radii at a distance from the center of the fuselage equal to the distance from the center of the fuselage to the wing-fuselage junction. One vertex is located at the wing-fuselage junction point and the remaining vertices are then positioned such that all the sides of the polygon are nearly equal in length. The area of these polygons varies as the cross-sectional area of the actual fuselage varies along its length except in the region of the wing-fuselage intersection and at the nose and tail of a slender pointed configuration. In the region of the wing-fuselage intersection the cross-sectional area is held constant in order to assure that no gap will occur between the wing and fuselage panels. The nose and tail of a pointed configuration should be arbitrarily blunted in order to prevent crowding of the vortices in these regions. When a fusiform fuselage is used, the fuselage should be divided into three segments with the break points occurring at the leading and trailing edges of the wing root. The number and spacing of the streamwise singularities on the centerbody should then be made equal to the number and spacing on the wing root panel. This panel matching produces a

smoother and more accurate pressure distribution on the fuselage centerbody as well as the wing root panel.

Nacelles

Nacelles are usually modeled with fusiform paneling although planar paneling can be used. For fusiform paneling, a hexagon or an octagon is usually used for the cross-sectional shape of the reference polygon. The area of the reference polygon is usually equal to the largest cross-sectional area of the nacelle. For nacelles with little variation in diameter along their length, a constant area nacelle should be used. This results in a simple model of the nacelle and also allows a rectangular panel to be used to model the pylon. For this case the area of the reference polygon is equal to the inlet area.

The planar representation for nacelles is used only when the nacelle is merged with the wing as shown in Figure 7a. Since the nacelles are not on the aircraft centerline, a vertical panel as well as a horizontal panel is required. The areas of these panels are equal to their respective projected areas. Figure 7b illustrates the planar representation of the nacelle corresponding to the geometrical representation shown in figure 7a.

Horizontal Tail and Nacelle Location

Wing and fuselage camber and wing twist are handled mathematically in the program through the boundary conditions. The panels may, therefore, appear incorrectly located when plotted as geometrically defined in the program, i.e., without camber. This is most readily noticed on a configuration with considerable fuselage and/or wing camber. Figure 8a shows the geometrical representation of a configuration, figure 8b shows the VORLAX representation with a planar fuselage. The horizontal tails in figures 8b and 8c have been relocated from their original position relative to the wing root leading edge to a position such that the average vertical distance between the horizontal tail and the wing trailing edge is maintained. This places the tail in the correct location in the flowfield produced by the wing. In case the horizontal tail panel is no longer connected to the fuselage panels, a vertical filler panel must be used to reconnect the panels as shown in figures 8c and 9c. Small changes in

the vertical location of the stabilizer, as required to avoid the trailing vortex filaments from a wing or nacelle, have no appreciable effect on the results obtained from the program.

Figure 9 shows the front views corresponding to the side views of figure 8. The underwing mounted nacelles have been relocated for the VORLAX representation such that the distance between the wing lower surface and the nacelles is the same as on the geometric representation. This positions the nacelles in the correct wing flowfield location and also maintains the correct wing-nacelle interference effects. Short pylon panels have been added to connect the nacelle panels to the wing panels.

Panel Intersection

The intersection of the two major panels must always be at the edge of a panel. This forces the vortex filaments from the intersecting panels to be aligned and, therefore, they cannot intersect the control points of the adjacent panels. Figure 10a shows a wing with an intersecting vertical fin and pylon. One major panel would usually be sufficient to model this wing without the fin or pylon. However, with the fin and pylon, the wing must be divided into three major panels with the lateral edges occurring at the intersections of the wing with the fin and pylon panels. An alternate method of attaching the fin and pylon panels to the wing is to relocate them laterally such that they intersect the wing at the junction of two minor panels.

Figure 10b shows the intersection of a pylon with a fuselage and a nacelle. The pylon panel is connected between an intersection of the nacelle panels and an intersection of the fuselage panels. The pylon in figure 10b is composed of two major panels—one rectangular and one trapezoidal. In order to avoid having a zero length edge on a panel, a very short inboard edge is used on the filler panel. A trapezoidal panel is often required for sealing between the pylons, vertical tail, and horizontal tail and the fuselage. The filler panels should always be tangent to or outside of intersecting curved panels as illustrated in figure 10b.

Trailing Vortex Filaments

One of the problems encountered when modeling a configuration is that of the trailing vortex filaments from an upstream panel passing close to or intersecting the control points on a downstream panel. Every minor panel contains a horseshoe vortex with two trailing filaments extending downstream as illustrated in figure 11. When a trailing vortex filament crosses a downstream panel near its control point, a velocity is induced on the panel inversely proportional to the square of the distance between the control point and the trailing vortex filament. For very small separation distances the induced velocity on the minor panel is sufficient to cause a large error in the total force on the major panel. If the trailing vortex filament should intersect the panel at the control point, infinite velocities will be induced on the panel and the solution will fail. All panels must, therefore, be aligned such that the trailing vortices from one panel do not pass near or intersect the control point of a downstream panel. If a vortex filament does cross a downstream panel near its control point, the downstream panel must either be moved or its paneling rearranged so that all the trailing vortices are aligned (figure 12). For fine mesh paneling the interference usually requires that the downstream panel be moved out of the vicinity of the trailing vortices.

An option in the VORLAX program allows the wake vortices to stream away from the trailing edge of the major panel parallel to the x-axis or at a designated downwash or sidewash angle. Whenever a downwash or sidewash angle is specified, caution must again be used to make certain that the deflected trailing vortex filaments do not pass near or intersect a control point on a downstream panel.

CONCLUDING REMARKS

Methods of paneling an aircraft configuration in order to generate input data for the VORLAX computer program have been described. The techniques presented herein are adequate to model most aircraft configurations. Aerodynamic data obtained from the VORLAX program for configurations modeled using these paneling techniques have been very good. When paneling a configuration, the

most important items to remember are:

- (1) The location of a panel in the flowfield should be maintained relative to the location of the component most responsible for generating that flowfield.
- (2) All panels must be connected.
- (3) The intersection of trailing vortex filaments with downstream panels must be avoided.
- (4) The VORLAX representation should be kept as simple as possible.

REFERENCES

1. Miranda, Luis R.; Elliott, Robert D.; and Baker, William M.: A Generalized Vortex Lattice Method for Subsonic and Supersonic Flow Applications. NASA CR-2865, 1977.

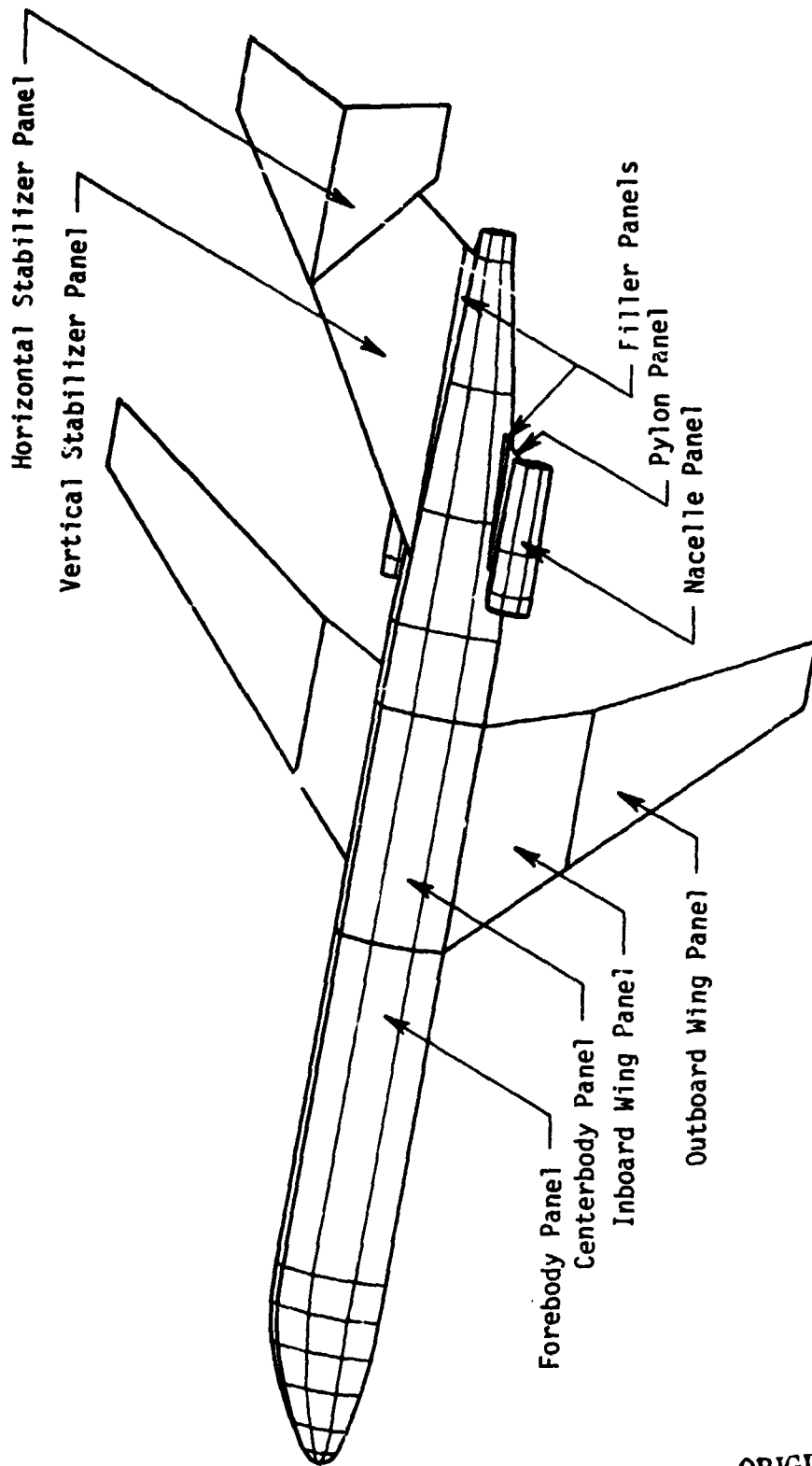
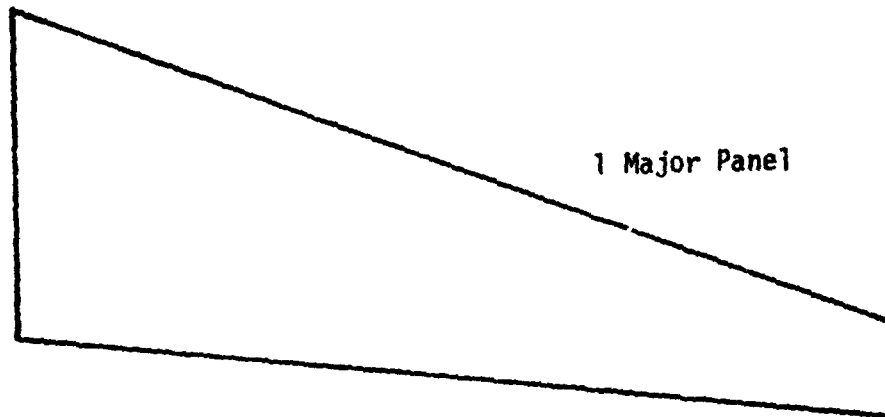
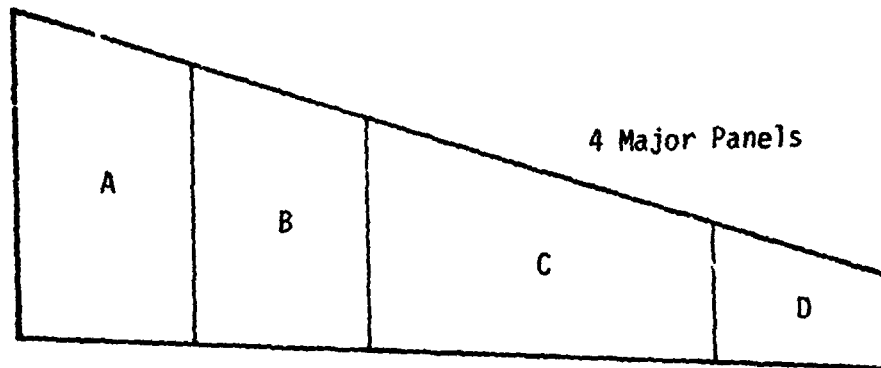


Figure 1. - Major panels defining a configuration

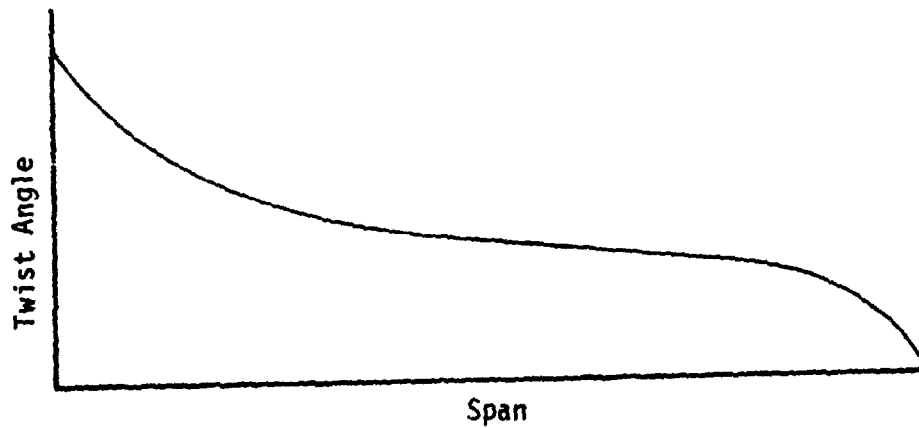
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a. Untwisted or linearly twisted wing

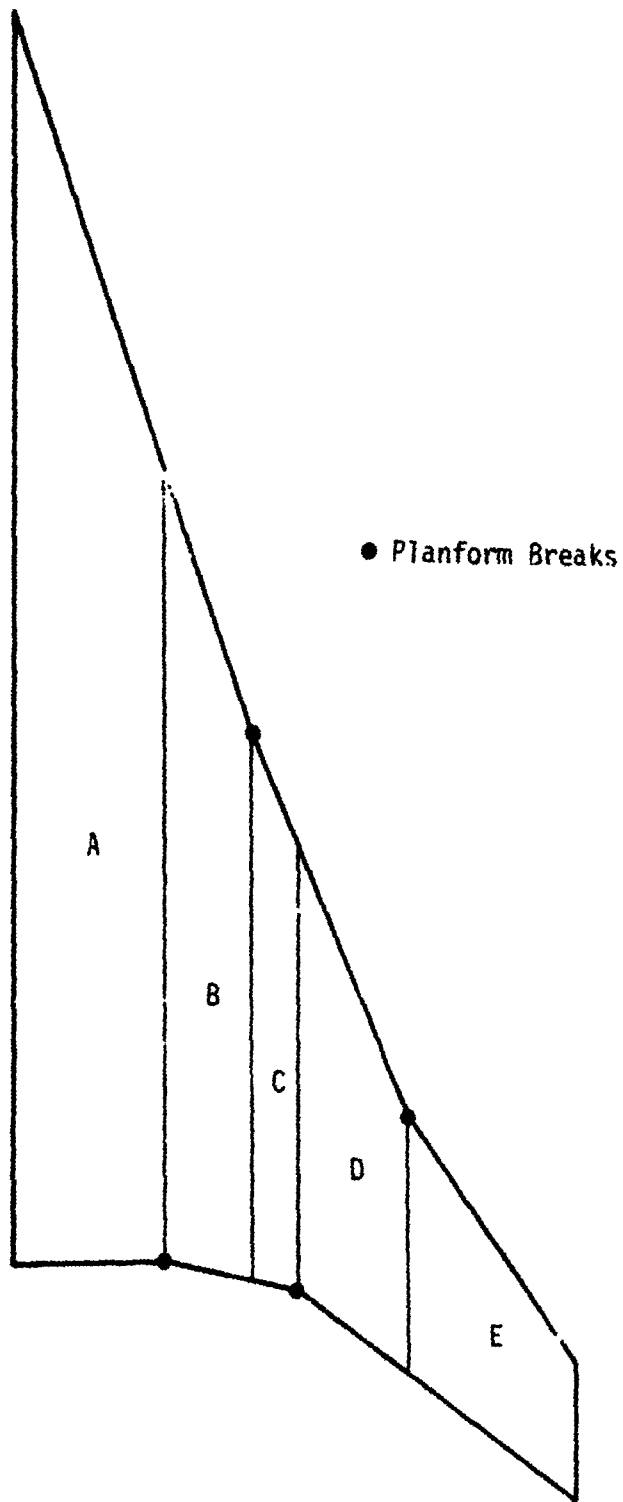


b. Non-linearly twisted wing



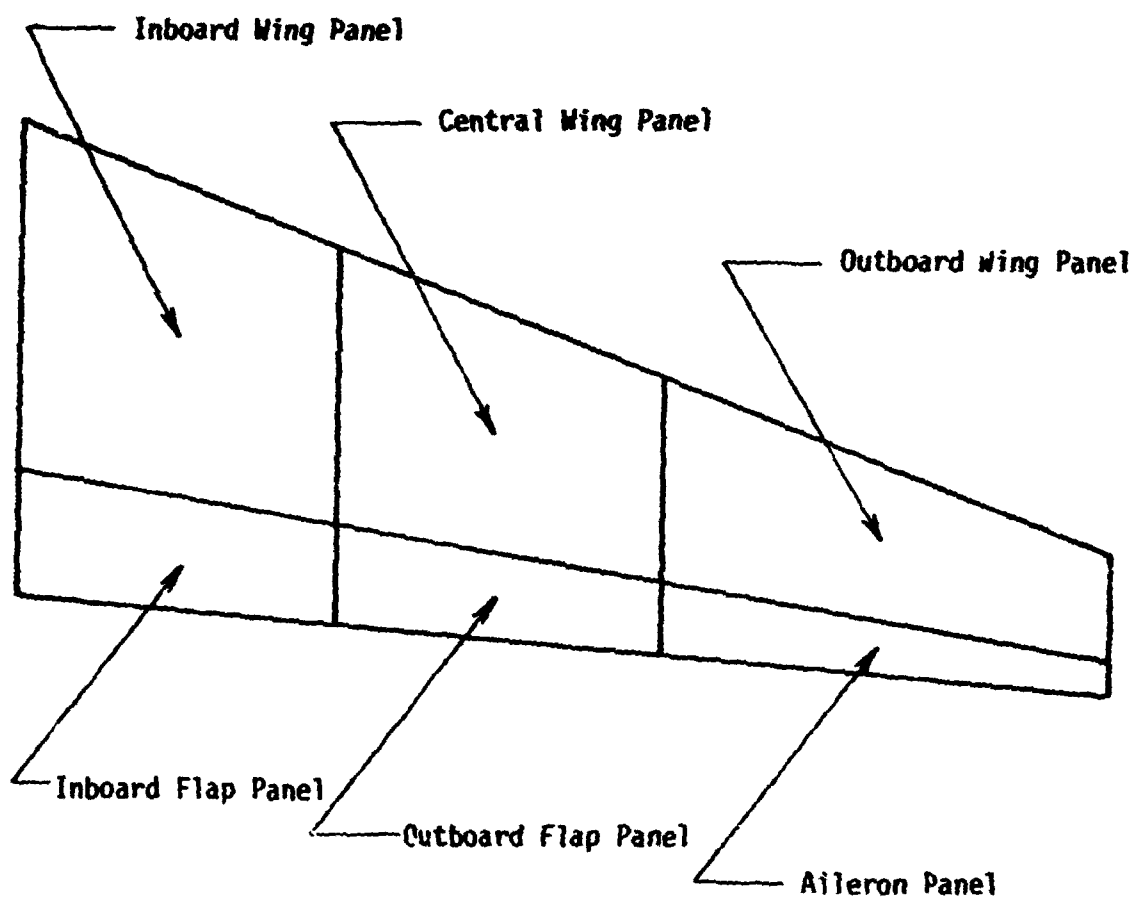
c. Twist for wing in figure b

Figure 2. - Paneling corresponding to wing twist



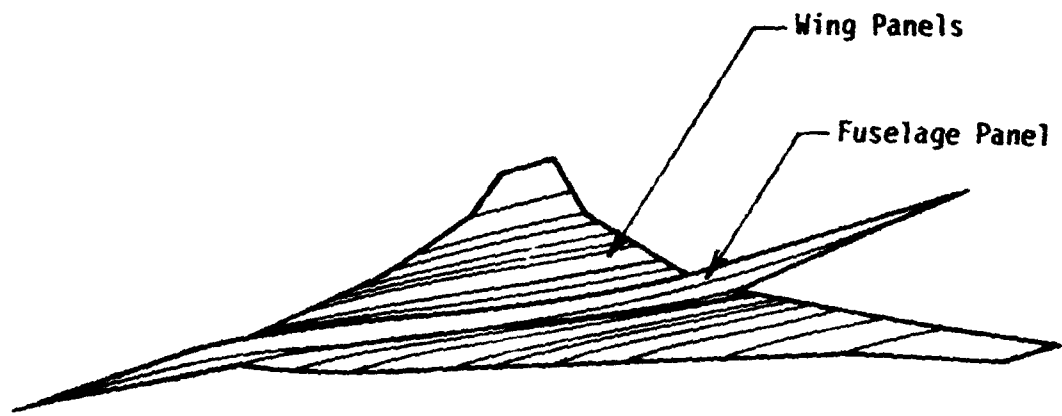
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Figure 3. - Paneling corresponding to leading and trailing edge breaks

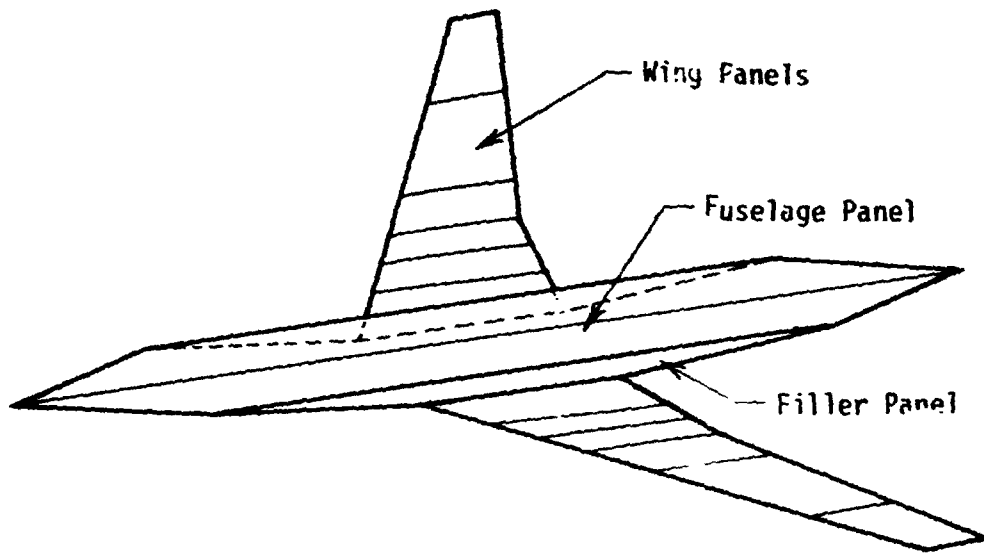


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Figure 4. - Wing with flap paneling



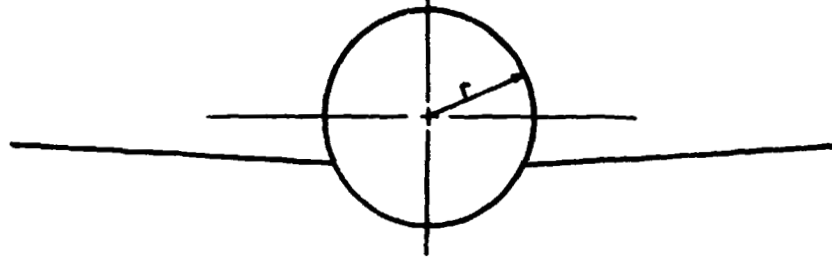
a. Supersonic configuration



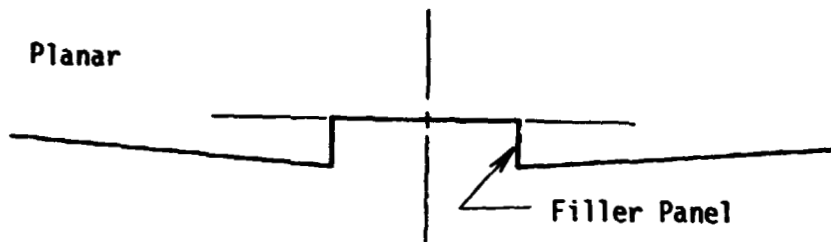
b. Subsonic configuration

Figure 5. - Planar fuselage paneling

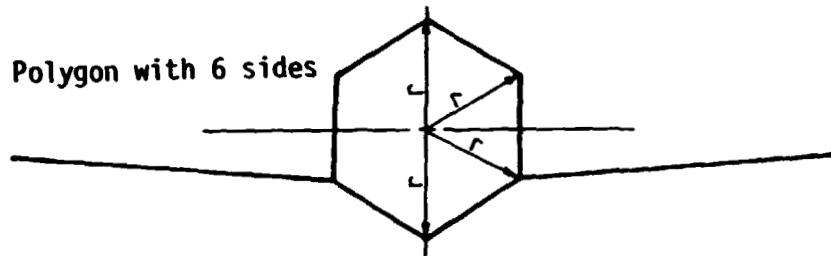
a. Configuration Cross Section



b. Planar



c. Polygon with 6 sides



d. Polygon with 8 sides

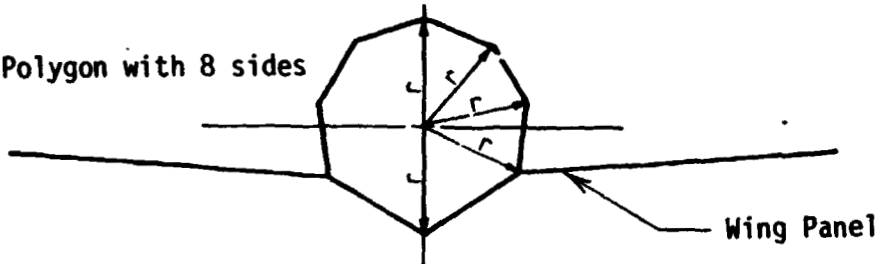
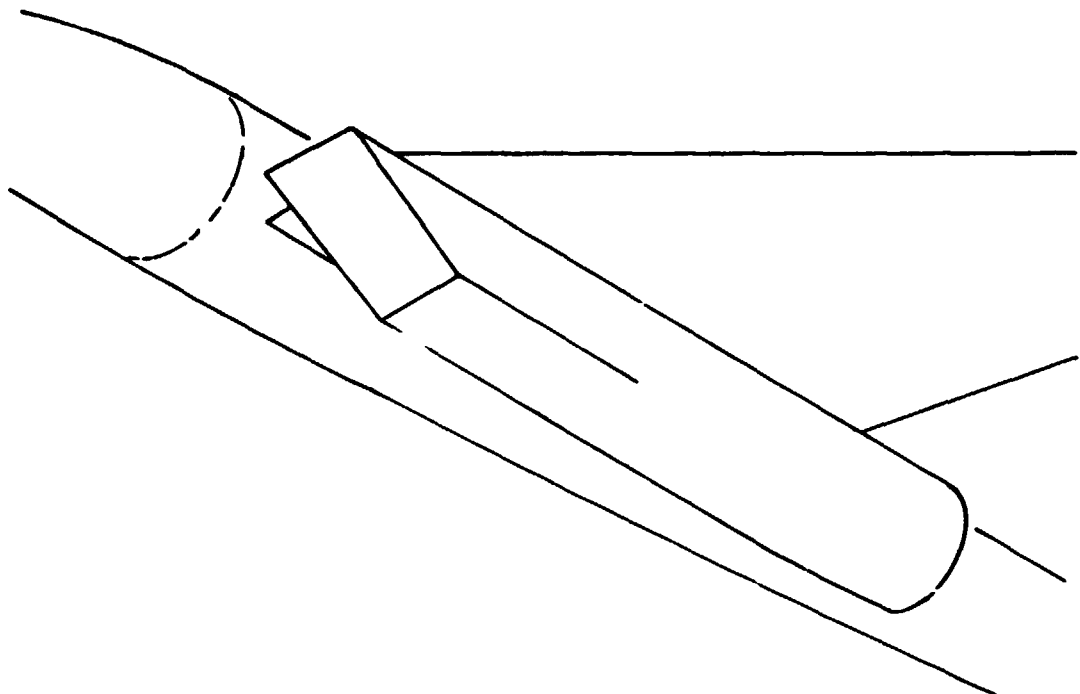
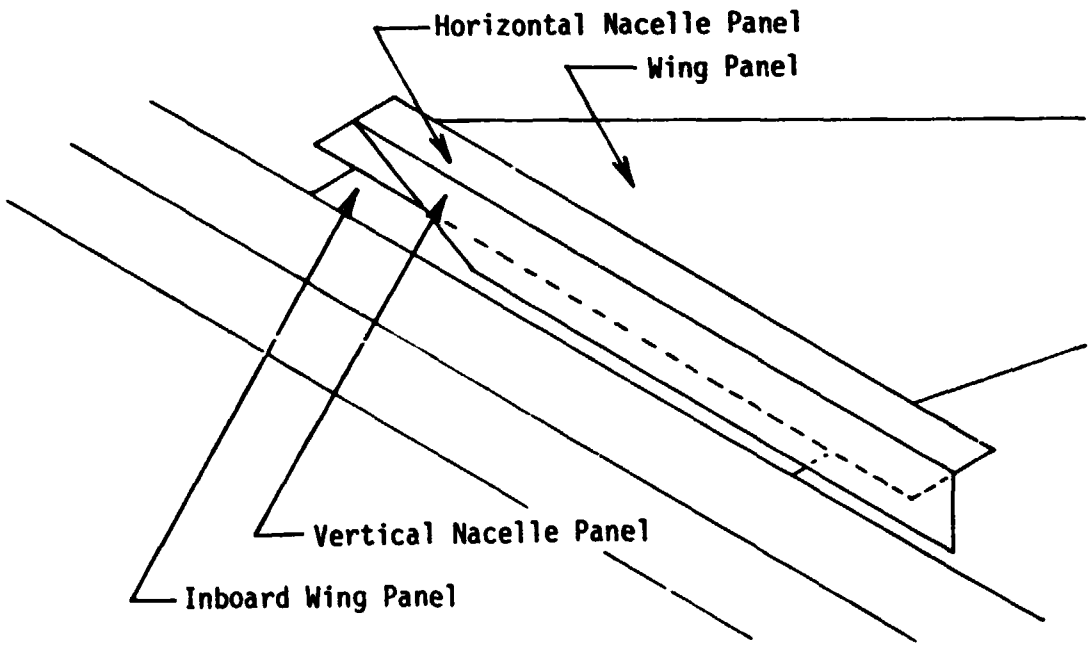


Figure 6. - Three methods of paneling a fuselage

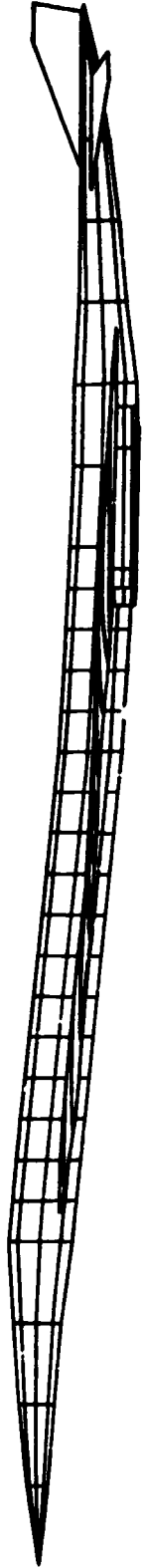


a. Physical Representation

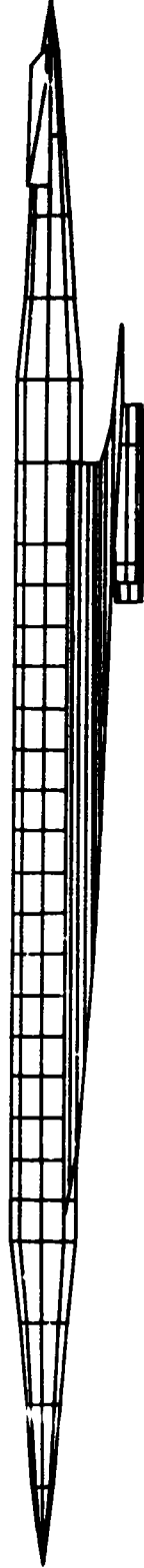


b. VORLAX Planar Representation

Figure 7. - VORLAX representation of nacelles



a. Physical representation

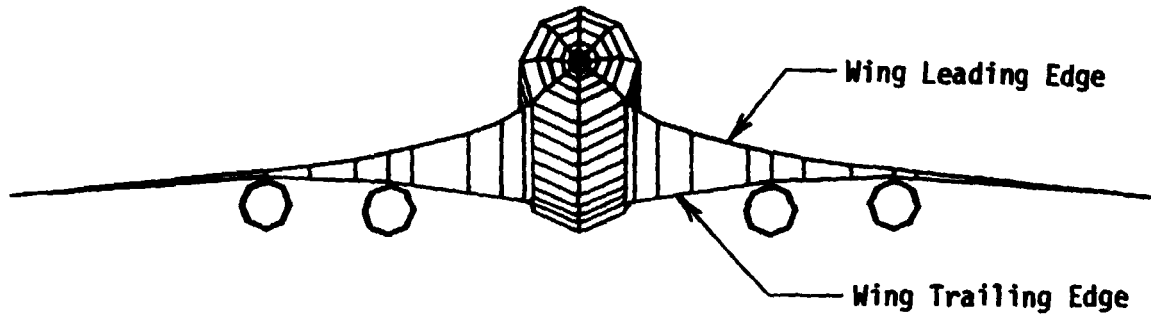


b. VORLAX representation with fusiform fuselage

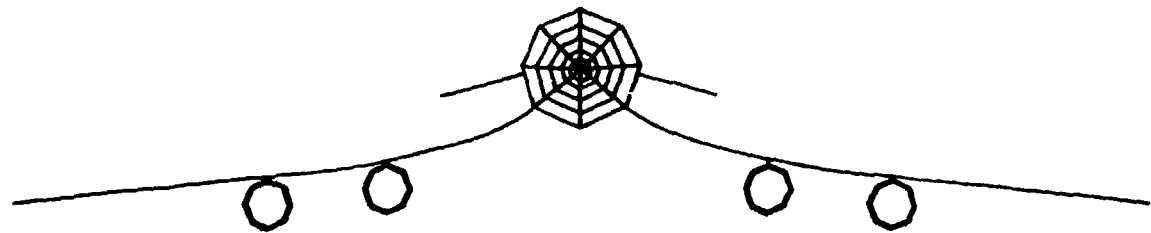


c. VORLAX representation with planar fuselage

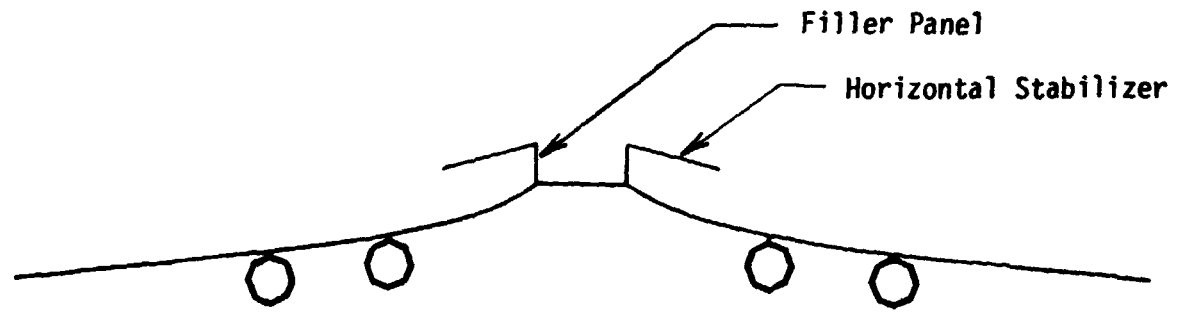
Figure 8. - VORLAX representation of cambered configurations



a. Physical representation

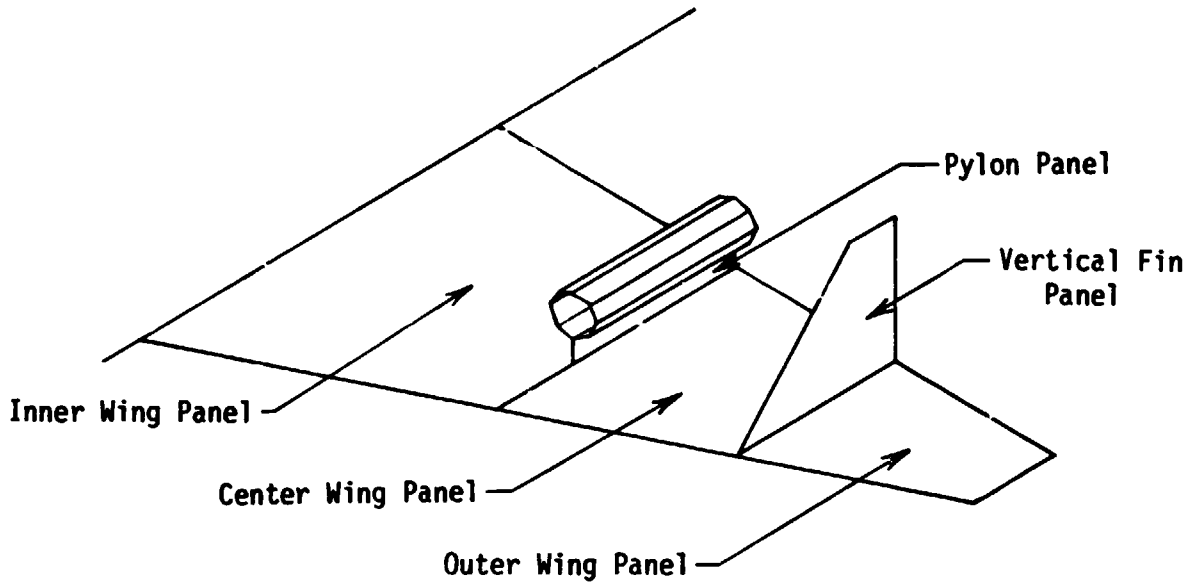


b. VORLAX representation with fusiform fuselage

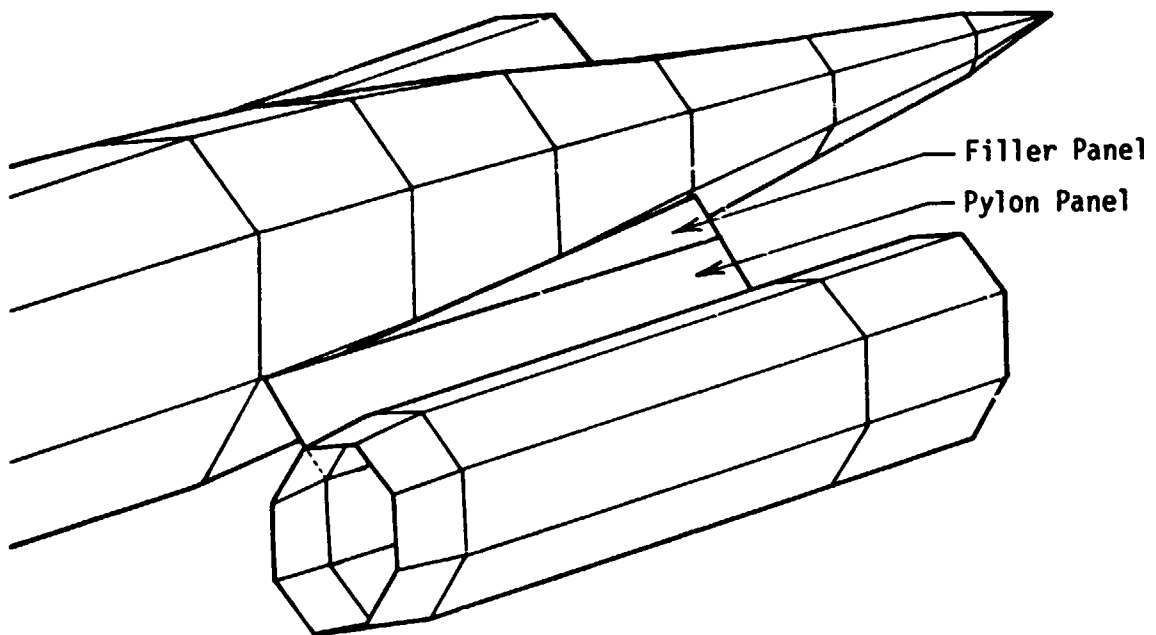


c. VORLAX representation with planar fuselage

Figure 9. - Configuration with under-wing nacelles



a. Intersection with wing panels



b. Intersection with fuselage panels

Figure 10. - Intersections of major panels

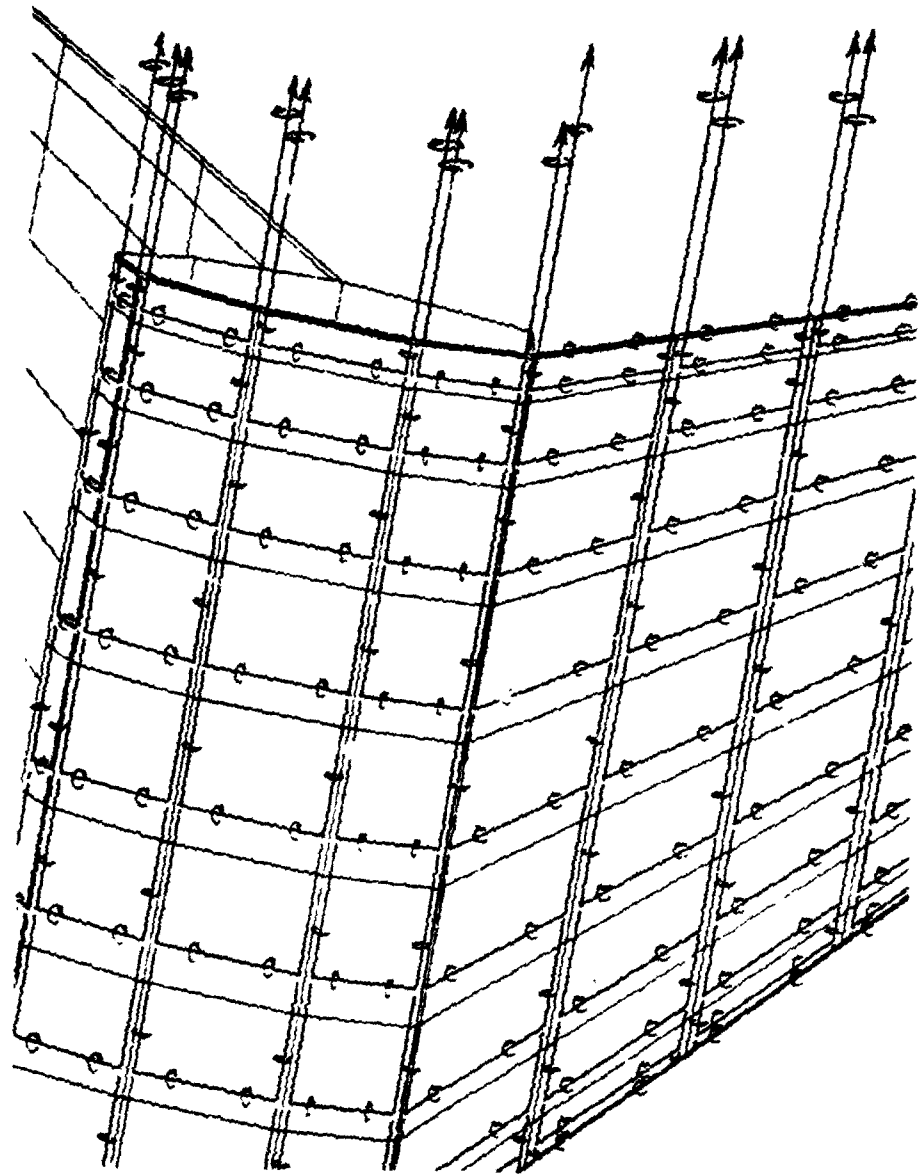
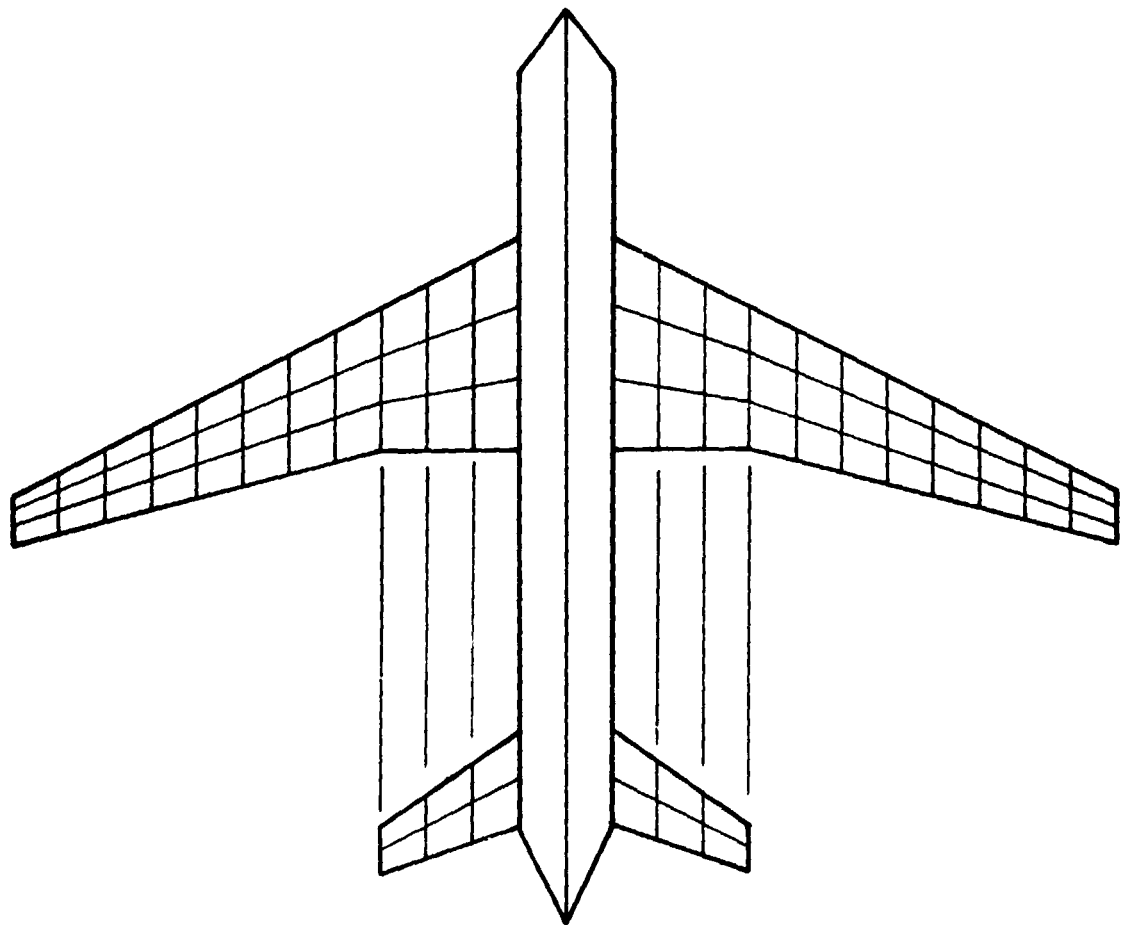


Figure 11. - Horseshoe vortices on a wing and centerbody



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Figure 12. - Alignment of horizontal tail panels with wing panels

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