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(54) Aircraft fuselage tails

(57) An up-swept or raised fuselage tail of aircraft, in which the surface centre-of-gravity of the circular bulkhead cross-section is shifted downwards, so that on the underside of the cross-sections bulges arise, but the lower, upper and the side boundary contours remain unvaried in cross-section, i.e. the silhouettes seen from above and from the side are maintained. The intention is to improve the airflow over the fuselage underside, and thus reduce drag.

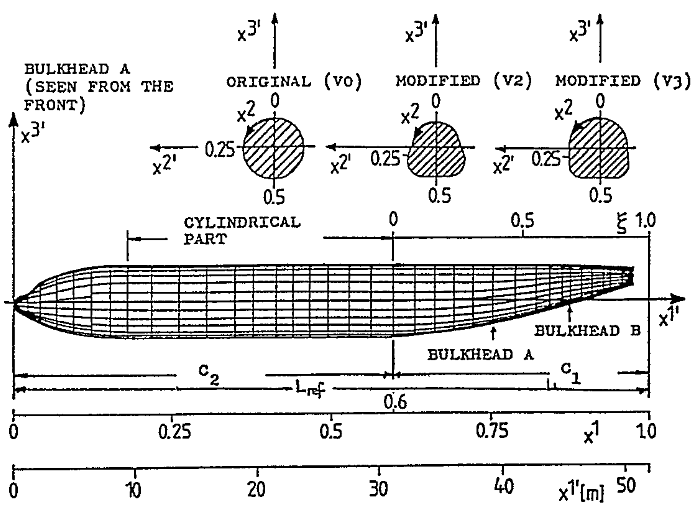

FIG. 1

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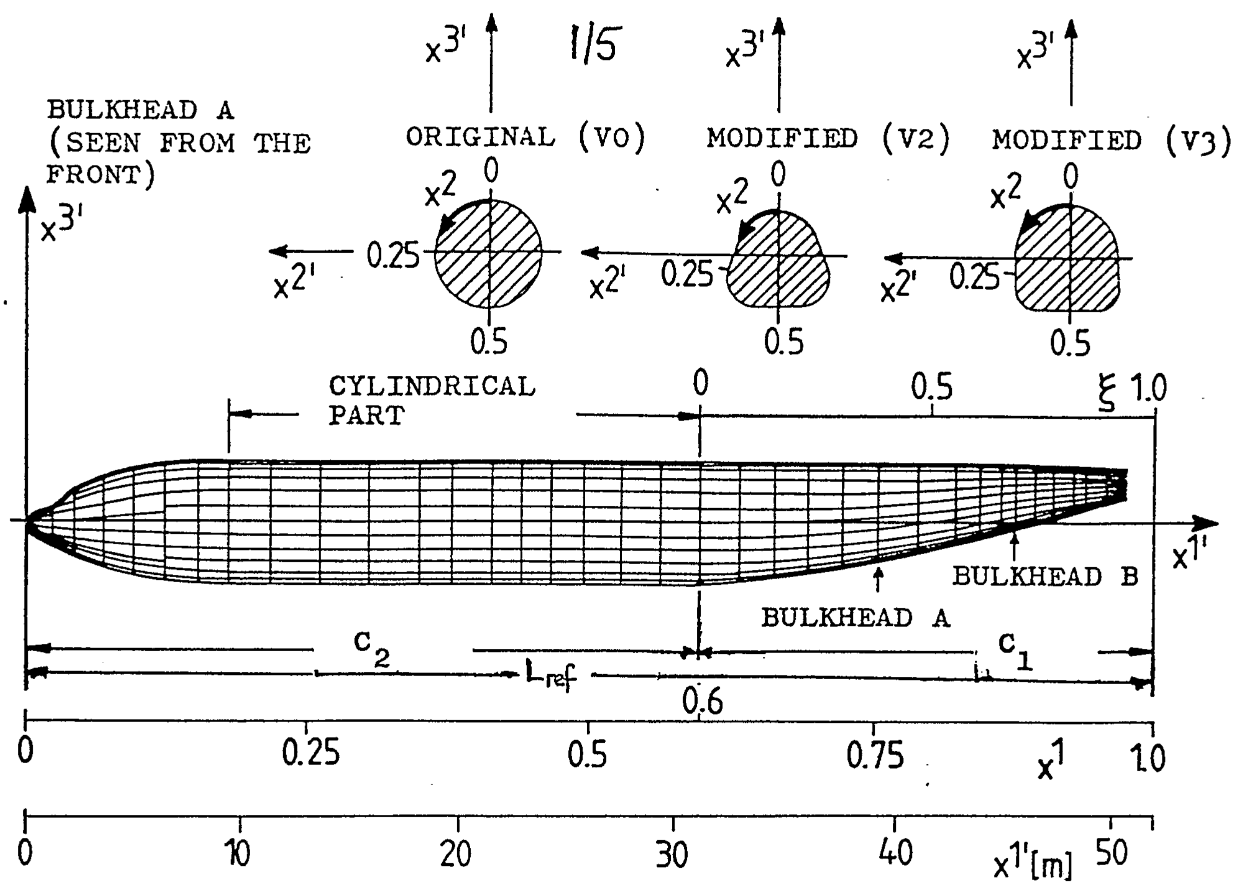
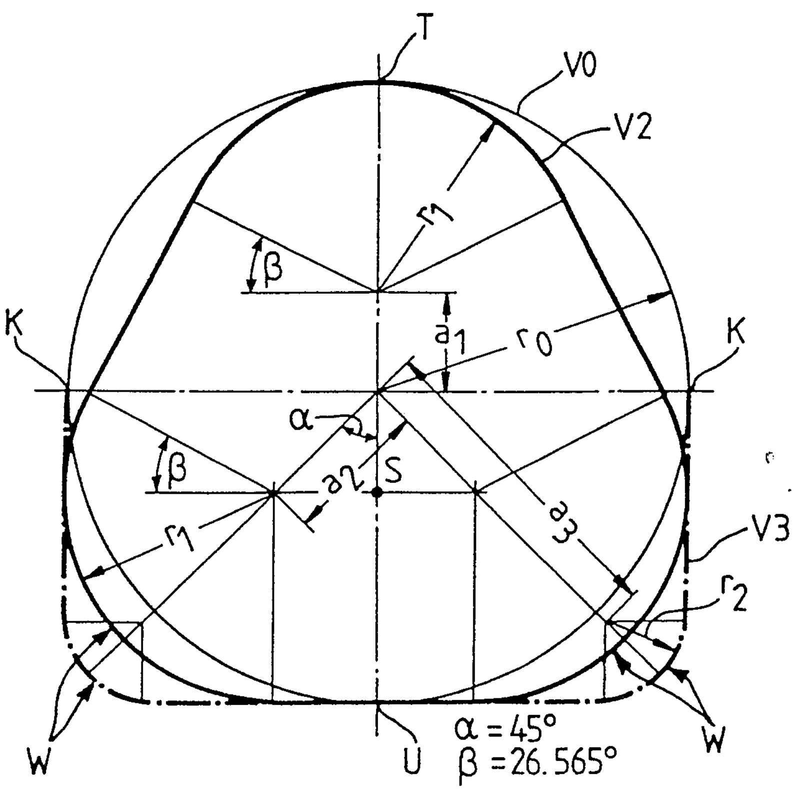


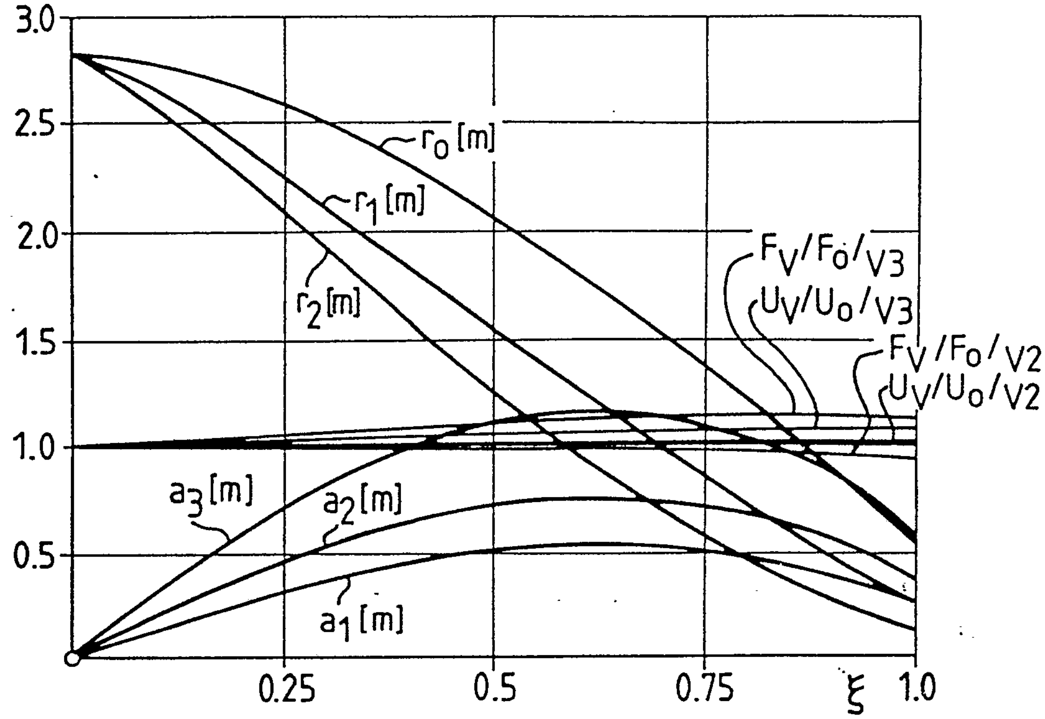
BULKHEAD A (SEEN FROM THE FRONT)
ORIGINAL (V0)
MODIFIED (V2)
MODIFIED (V3)
CYLINDRICAL PART
BULKHEAD B
BULKHEAD A
c2
c1
Lref
0.6
x1'[m]

FIG. 1



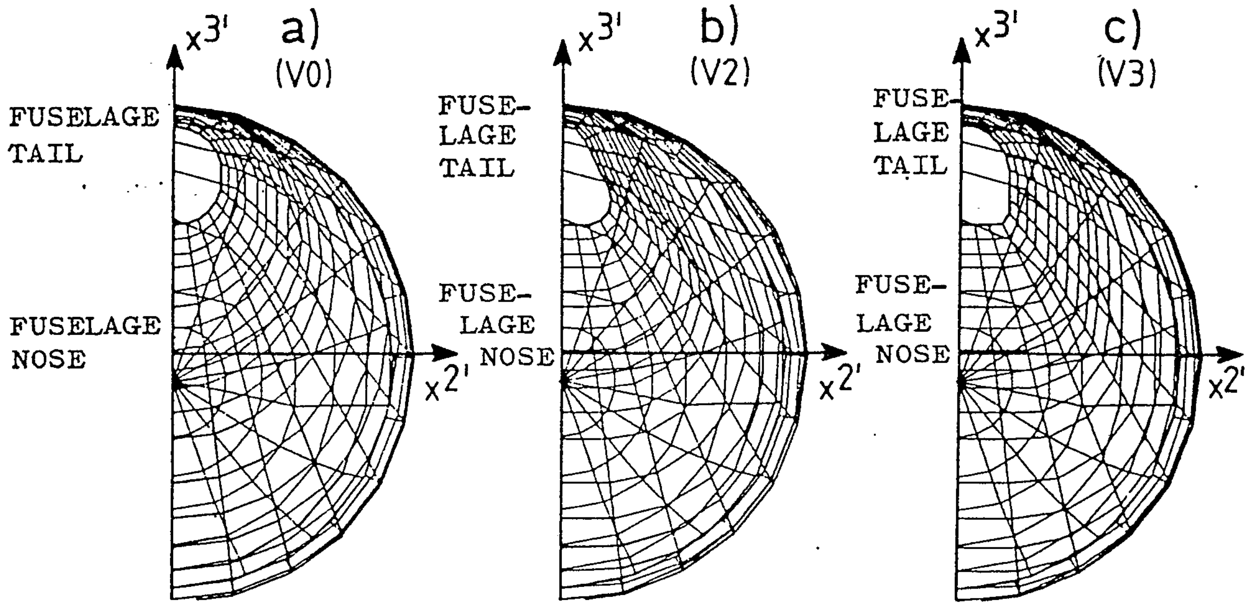
T
V0
V2
V3
K
S
U
W
α = 45°
β = 26.565°

FIG. 2



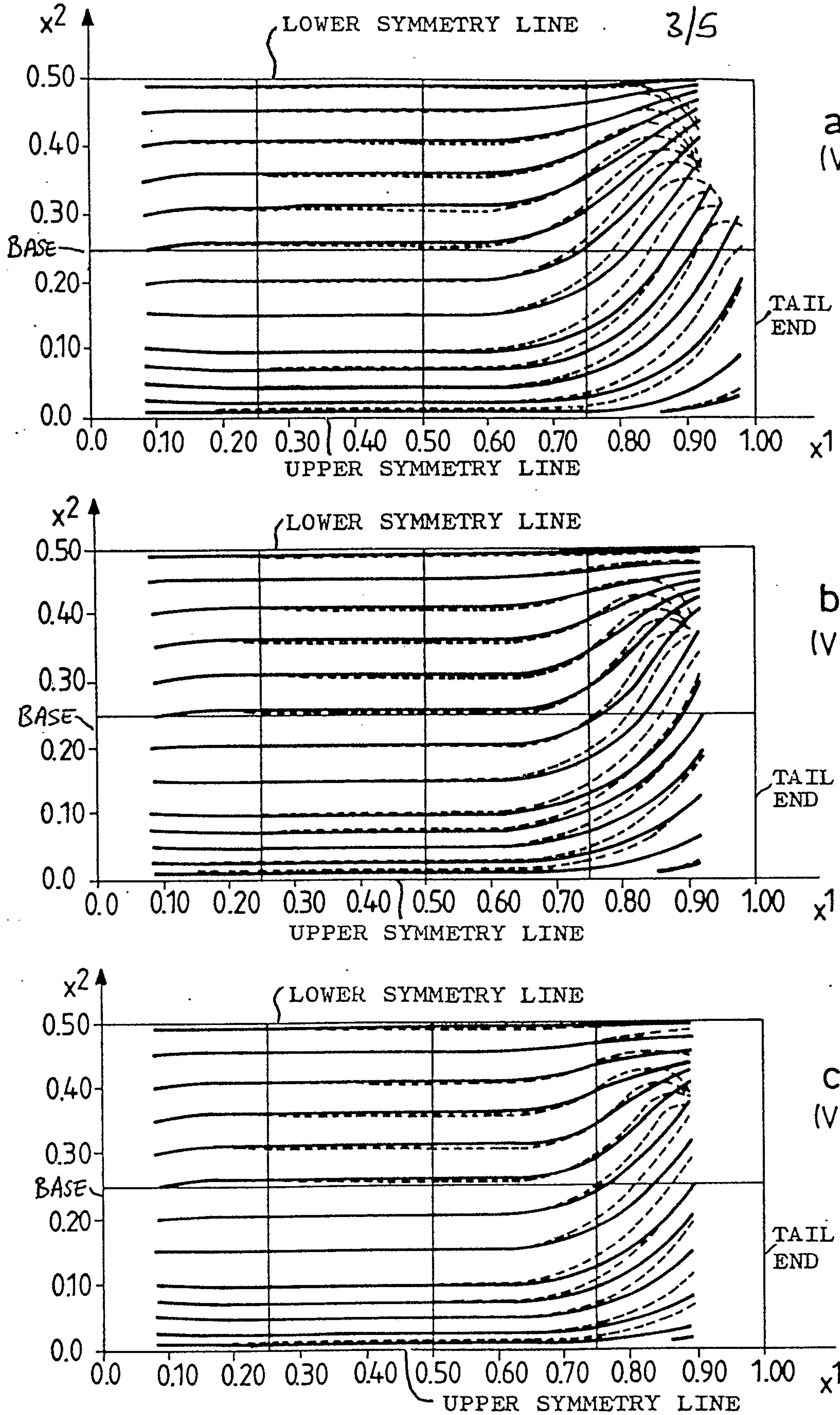
3.0
2.5
2.0
1.5
1.0
0.5
0.25
0.5
0.75
ξ
1.0
r0 [m]
r1 [m]
r2 [m]
Fv/Fo/V3
Uv/Uo/V3
Fv/Fo/V2
Uv/Uo/V2
a3 [m]
a2 [m]
a1 [m]

FIG. 3



a)
(V0)
x3'
x2'
FUSELAGE TAIL
FUSELAGE NOSE
b)
(V2)
FUSE-LAGE TAIL
FUSE-LAGE NOSE
c)
(V3)
FUSE-LAGE TAIL
FUSE-LAGE NOSE

FIG. 4



——— FRICTION FREE FLOWLINE

- - - - - - - BOUNDARY-WALL FLOWLINE

FIG. 5

BULKHEAD A

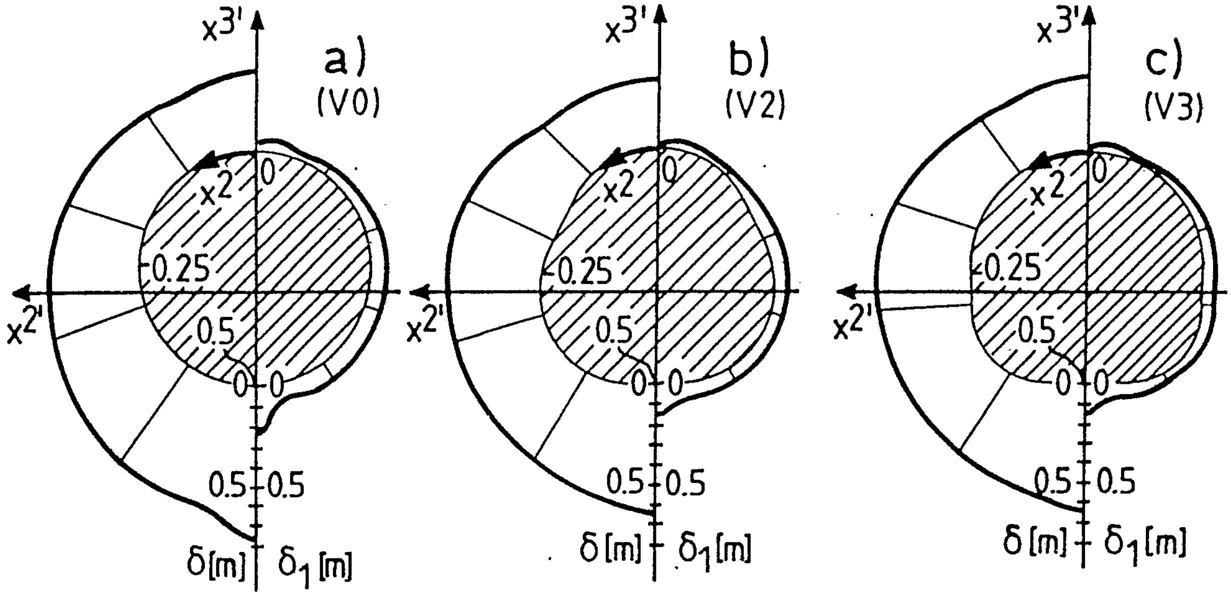


FIG. 6

BULKHEAD B

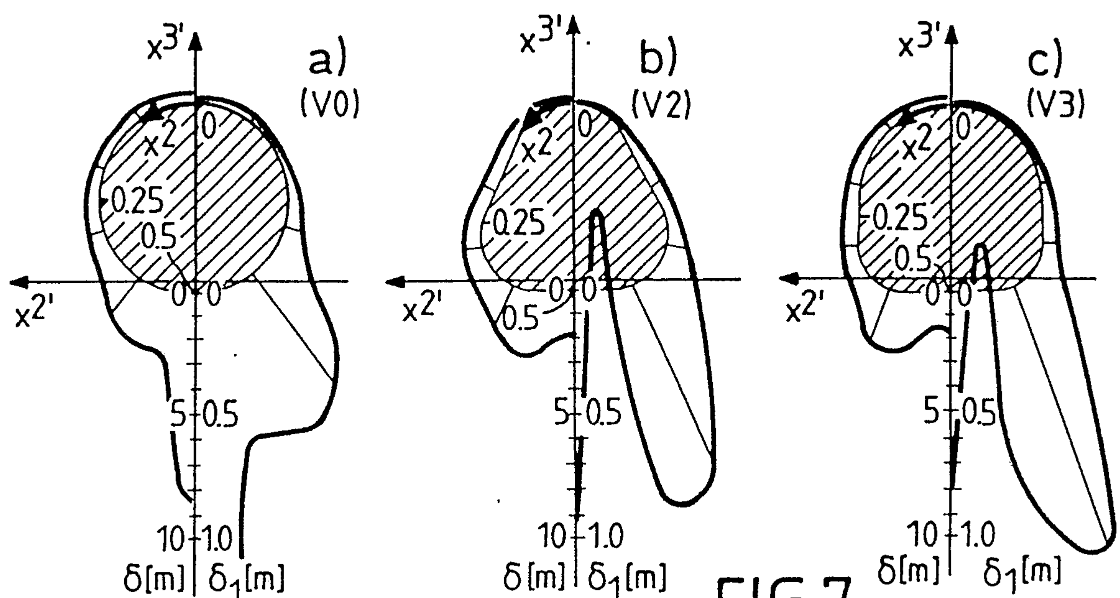
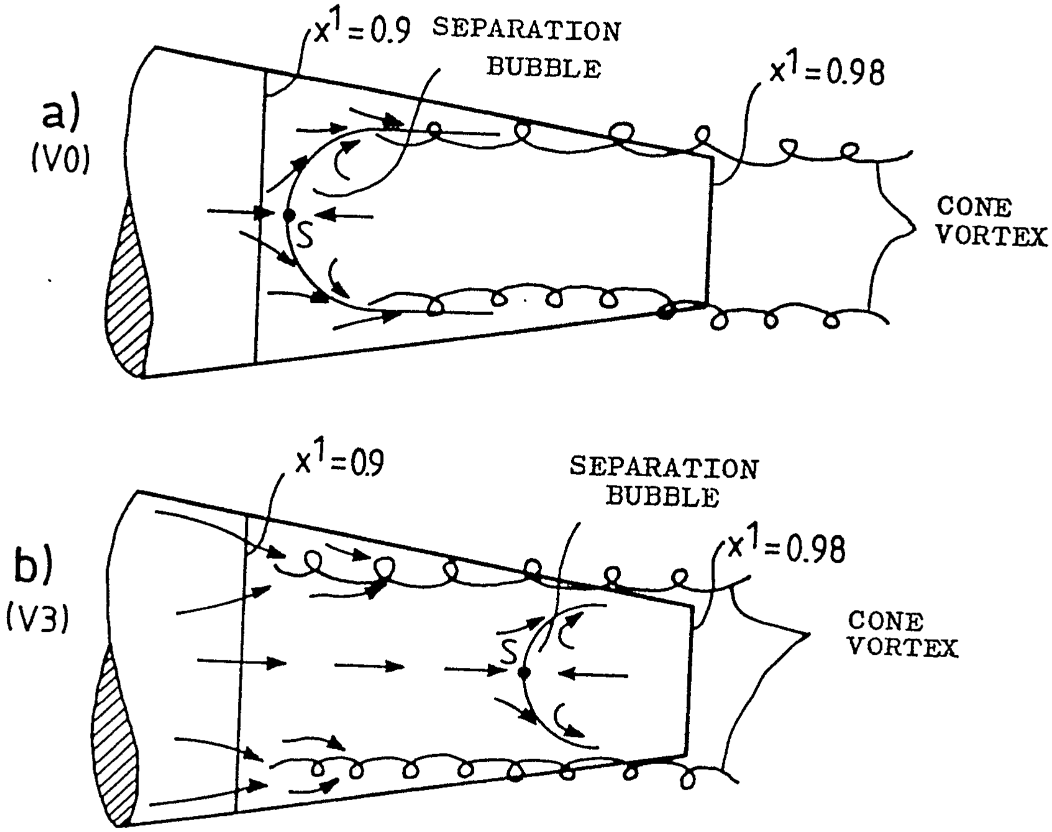


FIG.7



a)
(V0)
$x^1=0.9$
SEPARATION
BUBBLE
$x^1=0.98$
S
CONE
VORTEX
b)
(V3)
$x^1=0.9$
SEPARATION
BUBBLE
$x^1=0.98$
S
CONE
VORTEX

FIG. 8

SPECIFICATION

Aircraft fuselage tails

This invention relates to aircraft fuselage tails having a drawn-up tail cross-sectional shape which differs from a circular shape.

Such fuselage tails are known 'per se'. Thus, for example, DE-PS 674 433 already discloses a fuselage piece differing from the circular shape and US-PS 3 955 781 discloses a similar cross-section for a Delta-wing aircraft. Also known are the tail cross-sectional shapes of the known Airbus aircraft.

The problem underlying the present invention is to provide a tail cross-section modification in which the boundary-layer developnment – more especially at the tail underside – and the separation behaviour of the flow is improved and a reduction in drag of the fuselage as compared with the prior art emerges.

To solve this problem the present invention provides an aircraft fuselage tail having a drawn-up tail cross-sectional shape which differs from a circular shape, characteried in that the surface centre-of-gravity of the in themselves circular bulkhead cross-section is shifted downwardly so that, on the underside of the cross-section, archings-out arise, but the lower, upper and the side boundary contours remain unvaried in cross-section, i.e. the silhouettes seen from above and from the side are maintained.

The invention will be described further, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a schematic representation of the known Airbus modifications V0 as well as the modification of the described exemplified embodiment V2 and V3;

Figure 2 is a schematic representation of the fuselage modifications V0, V2 and V3 in the same system of co-ordinates;

Figure 3 is a diagram of the course of the radious r_o of the original bulkhead shape, of the parameters a1, a2, r1, a3, r2 of the modified shapes and the circumferential (U_v, V_o) as well as surface ratios (F_v, F_o) in the tail region (0 = 1);

Figure 4 shows the panel models of the right-hand fuselage half seen from the rear of a) = VO, b) = V2 and C = V3;

Figure 5 consists of three diagrams of the friction-free flow lines and boundary-wall flow lines in the x^{α}-plane of V0, V2, V3 in accordance with Figure 4;

Figure 6 shows diagrams of the boundary-layer thickness and displacement thickness in the case of bulkhead A in accordance with Figure 1;

Figure 7 shows diagrams of the boundary-layer thickness and displacement thickness in the case of bulkhead B in accordance with Figure 1; and

Figure 8 is a schematic representation of the approximate separation shapes, in which respect a) = the separation shapes at the fuselage V0 and b) = the separation shapes at the tail modification V3.

The object underlying the present invention has been to find a modification in which – without losses of the previous performances and values – the circular cross-section can substantially be retained. This modification has now been found to the effect that the circular cross-section at the tail is provided with archings-out 'W', namely in such a way that the silhouettes, seen from above and from the side, are maintained. For this, underlying the calculation and modification are: At the start of the fuselage tail in accordance with Figure 1 the deformation is zero ($\xi = 0$) and at the end maximum ($\xi = 1$). The tail co-ordinate is coherent with the $x^{1'}$ -co-ordinate as follows:

$$\xi = c_1 (x^{1'} - c_2)$$

In this respect is $c_1 = 1 / (L_{ref} - c_2)$; c_2 = length as far as the tail start.

The course of the distance a_3 and of the radius r_2 is linear in ξ:

$$a_3 = \frac{3\sqrt{2}}{4} r_o \cdot \xi;$$

$$r_2 = r_o (1 - 3/4), \text{ i.e. } r_2 = 0.25\, r_o;$$

in which respect, however, r_o (the radius of the circular bulkhead shape) extends non-linearly with ξ. The cohesions can clearly be gathered from Figure 2.

In Figure 3 the aforesaid functions are represented and moreover the circumferential ratio U_v/U_o, in which designated by U_o is the bulkhead circumference of the prior art and designated by U_v is the modified shape in accordance with the exemplified embodiment. Furthermore, the surface ratio F_v/F_o for the two modifications V2 and V3 is shown and it can be seen that for the modification V2 both ratios lie close to 1, so that this tail has the same washed surface and the same colume as the known Airbus modification V0.

In the case of the new modification V3 it can be seen that both the washed surface and the volume are distinctly larger than in the case of V0. In Figure 4, for this purpose, the panel models with regard to the aforesaid modifications V0, V2 and V3 are given.

In Figure 5 the comparison of the friction-free flow lines and boundary-wall flow lines in the x^{α}-plane is shown. It is shown, that, on the upper side, the friction-free flow for V0 is most strongly divergent and weakest in the case of the modification V3. The convergence at the underside is indeed weakest for the modification V2, but here for the boundary-layer behaviour additionally the flow-line curvature is determining. This shows in the case of V0 a quite strong running together of the boundary-wall flow lines at the fuselage underside, whilst those for V2 extend directly on the lower symmetry line almost parallel thereto and for V3 are even slightly convergent.

In order now to be able to made a statement regarding the probable separation behaviour, further calculated variables have to be drawn upon and they yield the situations, shown in Figures 6 and 7, in the case of the bulkheads A andB in accordance with Figure 1. In Figure 6 the boundary-layer thickness δ and the displacement δ_1 in the fuselage cross-section in the case of bulkhead A ($x^1 = 0.74$ and $x^1 = 0.89$) are shown and it can be seen therefrom that in the cross-sectional plane $x^1 = 0.74$ in all three cases V0, V2 and V3, the entire flow at the lower symmetry line is convergent. This leads to the discernible thickening of the boundary layer in this region. Quite different are the thickness distributions in the case of bulkhead B with $x^1 = 0.89$ in accordance with Figure 7. Whereas in the case of fuselage V0 directly at the lower symmetry line a severe thickening takes place, in the case of the modified fuselages V2 and V3 there is only a buckling or bulging of the thickness contours beside the lower plane of symmetry, which in the case of V3 is particularly strongly fashioned.

It is evident from Figure 6 that the boundary layer on the tail underside is thicker than on the upper side. The ratio of boundary-layer thickness to displacement thickness lies in the order of magnitude of the ratio in the case of the two-dimensional 1/7-power boundary layer. In the case of the fuselage of V0, the boundary layer at the tail underside is approximately 10% thicker than at the fuselage of V3. These ratios in the case of the bulkhead (Figure 7) show that the cross-section, laying at the leading edge of the elevator unit, for the modification V0 implies a bulging of the thickness contour, which indicates a vortex strand or vortex cone separation, which then, however, merges towards the lower symmetry line (x = 0.5) into a shape which implies a two-dimensional – possibly dead water – separation. It is different in the case of the fuselage with the tail modification in accordance with V2 and V3. Here the thickness contour is so bulged that only a vortex strand separation or vortex cone separation is indicated and not also a separation close to the lower symmetry line.

With respect to the wall shear stress distributions it can be said that in the case of the modification V0 at the lower plane of symmetry a severe decline can be ascertained, but in the case of the modification V3 these extend considerably more smoothly.

With respect to the separation behaviour in the case of the fuselage shapes V0 and V3 it can be seen that in the case of V0 with $x^1 = 0.9$ a closed separation bubble forms, which places itself over the underside of the tail, in which respect the bulging of the thickness contour jointly with the running together of the boundary-wall flow lines shows the possibility of an embedded cone-vortex separation to the left and to the right of the symmetry line (Figure 8a).

In the case of the fuselage having the tail modification V3 there is displayed with $x^1 = 0.9$ the cone vortex separation alone. Directly at the lower symmetry line the boundary-layer, separation parallel to this is hardly to be expected, i.e. the boundary layer is at the tail underside scarcely separation-endangered, in contrast to the modifications V0.

From the above statements and calculations it emerges that in the case of the drawn-up Airbus tail, by shifting of the bulkhead cross-section centre-of-gravity point 'S' downwards a more favourable boundary-layer behaviour at the tail underside can be achieved. The proposed tail modification V3 is easier to carry out compared with those of the prior art, since the original circular cross-section is retained, even if the volume and the surface are greater. This new tail modification has a more favourable separation and drag behaviour; the wing guides in the same way as the drawn-up tail the friction-free flow and thus the boundary layer under the tail and the incident flow of the elevator unit in the vicinity of the fuselage is improved.

CLAIMS

1. An aircraft tail having a drawn-up tail cross-sectional shape which differs from a circular shape, characterised in that the surface centre-of-gravity of the in themselves circular bulkhead cross-sections is shifted downwardly so that, on the underside of the cross-section, archings-out arise, but the lower, upper and the side boundary contours remain unvaried in cross-section, i.e. the silhouettes seen from above and from the side are maintained.

2. An aircraft tail as claimed in claim 1, characterised in that the radius (r_2) of the lower archings-out at the tail end ($\xi = 1$) corresponds to the shape

$$r_2 = 0.25\, r_o$$

in which respect (r_o) is the radius of the circular structure (V0).

3. An aircraft tail as claimed in claim 1 or 2, characterised in that the course of the spacing (a_3) and of the radius (r_2) is linear in the tail co-ordinate and can be determined in accordance with the formulae:

$$\xi = c_1(x^{1'} - c_2) \qquad (2)$$

$$\begin{array}{l} a_3 = 3 \quad 2\, r_o \cdot \xi \\ \qquad\quad 4 \end{array} \qquad (3)$$

$$r_2 = r_o\,(1 - 3/4\,\xi) \qquad (4)$$

in which respect C_1 is the length (L ref - C_2) and C_2 is the length from the nose tip as far as the start of the tail.

4. An aircraft tail as claimed in claims 1 to 3, characterised in that from the tail end to the cylindrical part a continuously sliding transition in accordance with the equations (3, 4) is effected.

5. An aircraft fuselage tail substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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