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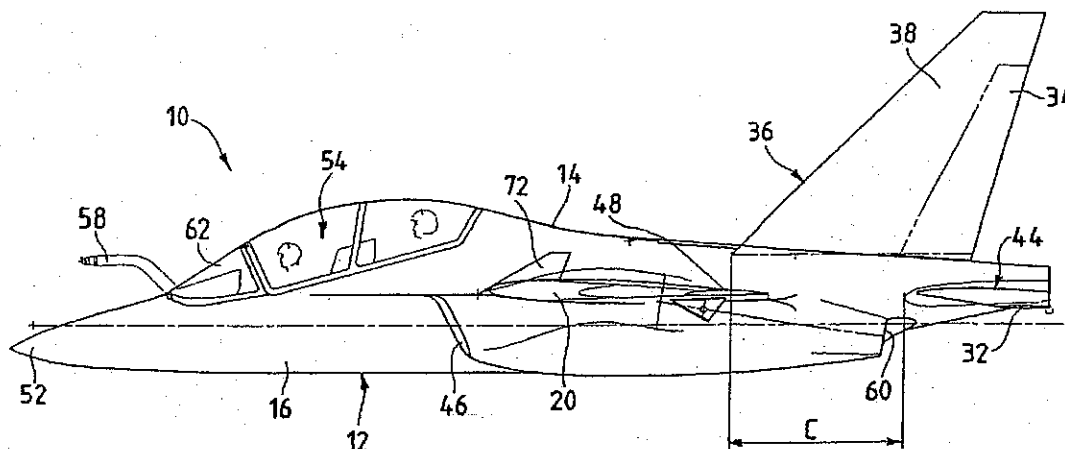
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(54) Title: AIRCRAFT CONFIGURATION WITH IMPROVED AERODYNAMIC PERFORMANCE



(57) Abstract: An aircraft (10), in particular a trainer aircraft with improved aerodynamic performance, having a configuration able to keep a directional stability and a very good aerodynamic behaviour even at very high angles of attack, where, traditional configurations prove themselves inefficient. In particular, this configuration foresees a forebody (52) with variable section, optimised for high angle of attack flights, a LEX vortex control device (72) at least one diverterless air intake (46), and a wing profile (18, 20) optimised in order to reduce the buffet effects typical of low aspect ratio wings with thin profile and variable camber. The aircraft (10) presents, finally, staggered tails (44 and 38), to optimise the aerodynamic performance.

AIRCRAFT CONFIGURATION WITH IMPROVED AERODYNAMIC PERFORMANCE.

This patent is referred to an aircraft configuration
5 with high aerodynamic performance; in particular the
aircraft according to the patent is designed like a
high performance trainer with secondary operational
capabilities.

Many aircraft have to be easily flown and must have
10 peculiar dynamic characteristics in accordance with the
mission to be carried out.

Typical examples of the above include light aircraft
for aerobatics, trainers and combat aircraft.

These aircraft often have to flight at a high angle of
15 attack (the angle between the aircraft and wind speed
direction at any time).

It is easy to understand that, under these flight
conditions, the aircraft has to be very stable and
easily controlled by the pilot, in order to maintain a
20 safe attitude during flight.

This stability is obtained using special automatic
equipment able to generate forces and moments to
counterbalance undesirable flight attitudes.

While the aircraft stability along the pitch axis can
25 be controlled optimising the static margin and time-to-

double amplitude, the presence of lateral-directional instability (on "roll" and "yaw" axes) at high angles of attack can be difficult to control even using highly sophisticated Flight Control Systems.

It is therefore necessary to maximise the aircraft lateral-directional stability up to high angles of attack in order to allow aircraft control/agility and to avoid flight departures and spins.

Usually and in particular lately, attempt has been done by simply modifying the fuselage aerodynamic shaping and other aircraft parts. Up to now those attempts have not lead to successful results.

In the frame of the requirements listed above, embodiments of the present invention may avoid the mentioned problems and, in particular, the problem relevant to an aircraft configuration with improved aerodynamic performance, able to optimise the aircraft behaviour especially during high angle of attack flights.

Embodiments of the present invention may present an aircraft configuration with improved aerodynamic performance, able to reduce buffet effects typical of low aspect ratio wings with thin profile and variable camber.

Embodiments of the present invention may realise an aircraft configuration with high aerodynamic performance, able

to avoid successfully, the loss of lateral-directional stability and the negative effects generated by the engine flow next to the fuselage side wall and the horizontal tail, as far as drag, stability and longitudinal control are concerned.

Embodiments of the present invention may realize an aircraft configuration with improved aerodynamic performance, able to recover from spin, optimising, in general, the aircraft behaviour at high angles of attack.

According to an aspect of the present invention, there is provided configuration of an aircraft with improved aerodynamic performance, which allow to keep directional stability at mid/high angles of attack, said aircraft including a fuselage fitted with wings, at least one air intake and a fuselage forebody with tapering section, whereby in that said aircraft includes a Leading Edge Extension (LEX) Vortex Control Device shaped such to symmetrize the bursting of the vortex generated by such LEX at mid-high angles of attack, wherein the ratio between the LEX area and the corresponding LEX Vortex Control Device height is equal to 2,35 m with a tolerance range varying from +100% and -50% of said ratio, said LEX Vortex Control Device cooperating with staggered tails, obtained by the coupling of the vertical fin to the wing, whose leading edges overlap the trailing edges of each wing, in order to maintain lateral-directional stability.

These and other goals may be met by an aircraft configuration, with improved aerodynamic performance, according, to claim 1, to which we refer to.

Profitably, embodiments of the present invention may be designed, in particular, like a trainer with high performance and secondary operational capabilities.

The configuration may includes a twin engine "formula" and ~~It is~~ may be characterised by the presence of a range of very peculiar structural details.

The twin-seat cabin (in tandem) with interconnected flight controls ~~is~~ may be coupled with, a forebody with basically circular and variable section, characterised by low aspect ratio, optimised for high angles of attack flights. In this space a radar for the aircraft operational version ~~can~~ may be easily integrated.

The forebody shape and dimensions may be optimised in order to reduce its vortex interference on the aircraft aerodynamic characteristics at mid/high angles of attack; the mentioned characteristics allow to reduce the directional asymmetries at high angles of attack, typical of forebody with circular or elliptical section.

Moreover the wing profile may be different from the standard wing profiles, in order to integrate a system able to minimise the buffet effects, typical of low aspect ratio wings with thin profile and variable camber.

The aerodynamic design may include also a LEX (Leading Edge Extension) vortex control device, properly sized, in order to symmetrize the LEX vortex bursting at mid/high angles of attack, as the symmetric vortex bursting allows to keep the lateral-directional stability and the aircraft control at mid/high angles of attack.

Embodiments of the present invention may have, at least one engine air intake able to guarantee the performance and a proper fluid-dynamic interface with the engine; the design does not foresee the integration of a typical diverter on the upper lip of an air intake, integrated with a LEX.

Finally, the horizontal tail staggering may allow getting a decrease in the aerodynamic drag produced by the fuselage afterbody, to optimise the aircraft spin behaviour and to improve the aircraft aerodynamic design for high angles of attack manoeuvres.

Further goals and benefits of this patent shall be clear from the following description and from the attached drawings, provided solely, but not limited to a sample, as follows:

- 10 - picture 1 is a side view of an aircraft, in particular of a trainer aircraft, designed accordingly this patent;
- picture 2 is a top view of an aircraft, in particular of a trainer aircraft, designed
15 accordingly to this patent;
- picture 3 is a bottom view of an aircraft, in particular of a trainer aircraft, designed accordingly to this patent;
- picture 4 is a front view of an aircraft, in
20 particular of a trainer aircraft, designed accordingly to this patent;
- picture 5 is a back side view of an aircraft, in particular of a trainer aircraft, designed accordingly to this patent;
- 25 - picture 6 is a section, along the VI-VI line of

- picture 2;
- picture 7 is a partial and enlarged view of a detail of the aircraft configuration designed accordingly to this patent;
- 5 - picture 8 is a section, along the VIII-VIII line of picture 7;
- picture 9 is a section, along IX-IX line of picture 7;
 - picture 10 is a section, along X-X line of picture 10 7;
 - picture 11 is a section, along XI-XI line of picture 7;
 - picture 12 is a section, along XII-XII line of picture 7;
- 15 - picture 13 is a section, along XIII-XIII line of picture 7;
- picture 14 is a section, along XIV-XIV line of picture 7;
 - picture 15 is a section, along XV-XV line of 20 picture 7;
 - picture 16 is a section, along XVI-XVI line of picture 7;
 - picture 17 is a section, along XVII-XVII line of picture 7;
- 25 - picture 18 is an enlarged isoview of a detail of

the aircraft configuration designed accordingly to this patent.

Making reference to the mentioned pictures, an aircraft, in particular a trainer aircraft, having a
5 configuration with improved aerodynamic performance, accordingly to this patent, is generally indicated with reference 10.

The aircraft 10 includes a fuselage 12, having an upper side wall 14 and a lower side wall 16, and two wings,
10 respectively a right wing 18 and a left wing 20, fitted to the fuselage 12.

The right wing 18 has the tip 22, while the left wing 20 has the tip 24.

The aircraft 10 features also a rudder 34, fitted to
15 the vertical fin 38 and a horizontal stabiliser 44 having a right horizontal stabiliser 26 and a left horizontal stabiliser 28 and relevant tips 30, 32.

In preferred or realising, but not limiting forms of the patent, as already mentioned above, the type
20 configuration is a twin-engine formula and foresees two air intakes 46 for the engines 48, with relative engine nozzles 60.

Finally, in the fuselage forebody area 52, in which a radar for the aircraft 10 operational version could be
25 integrated, a two in tandem pilot cockpit 54 is

installed, with interconnected flight controls, protected by a windshield 62. A probe 58 could be foreseen, in order to carry out in flight refuelling for the aircraft 10.

5 With reference to pictures 2 and 3, each wing 18, 20 of the aircraft 10 presents outer ailerons 56 and take-off and landing double slotted flaps 64, integrated in the trailing edge 70 of each wing 18, 20, and other devices for wing camber optimisation (leading edge droops) 66,
10 integrated in the wing leading edge 68. Their profile is shaped following a particular geometry, on the basis of the general aerodynamic design mentioned in this description.

In particular, the technical characteristics of the
15 aircraft 10, aimed to obtain high aerodynamic performance and flight stability, according to this patent, are as follows.

First of all, the aerodynamic design is characterised by the presence of a LVC ("LEX Vortex Controller")
20 device to control the LEX ("Leading Edge Extension") vortex at mid/high angles of attack (ref. 72, picture 1).

The LEX, with gothic platform equal to 6,4% of the reference wing gross area (as per this patent), allows
25 vortex lift generation at high angles of attack and LEX

design is further refined integrating the LVC ("LEX Vortex Controller") at its tip, in order to ensure the vortex symmetric bursting at high angles of attack for sideslip attitudes and prevent loss of lateral-
5 directional stability.

The LEX vortex controller sizing 72 depends on the front LEX size and, in any case, the bigger the LEX is the higher the LVC must be; the tolerance can be defined by the ratio between the LEX area and the
10 height of the corresponding LVC. The design point of this ratio is equal to 2,35 m and the applicable tolerance range varies from +100% and -50% from the design point.

The fuselage forebody 52 shape of the aircraft 10 and
15 its dimensions are even more optimised in order to reduce its vortex interference on the aerodynamic characteristics of the aircraft 10 at mid/high angles of attack; the mentioned characteristics allow also to reduce the directional asymmetries at high angles of
20 attack, typical for the forebody with standard circular or elliptical sections.

The forebody 52 of the aircraft 10, according to the patent, shows a range of forebody sections with different geometry starting from the apex 74 up to the
25 forebody edge merging with the LEX apex.

- An exemplifying and preferred, but not limiting way, of the geometric shape and of the sequence of sections with different geometry, between the apex 74 and a section referred to the quote 76 (positioned more or less at the beginning of the twin-seat cabin 54), is presented, in sequence, at pictures 8-17, from which is inferable that from a roughly low aspect ratio circular section (pictures 8-11) a chined section is got (pictures 12-17).
- 10 From the mentioned pictures is clear the shift of the forebody 52 from the longitudinal axis K, from the apex 74 up to the reference section presented in picture 17. In particular, according to a preferred form of the patent, the ratio between the length of the forebody 15 52, starting from the apex 74 up to the section along the XVII-XVII line (reference L), and the average between the lengths A and B of the two axes of the section (section presented in picture 17), presents a value of 1,873, with a tolerance equal to $\pm 10\%$.
- 20 The structural peculiarity and its effect on the flight conditions come out from the combination of the parameter mentioned above (plus or minus the tolerance, if any) and the sequence of the forebody 52 sections, from the apex 74 of the aircraft 10 up to the reference 25 section along XVII-XVII line.

In picture 18 is also shown in detail an engine air intake, indicated as item 46, which contributes to guarantee the performance of aircraft 10, above all as far as the fluid-dynamic interface with the relevant jet engine is concerned.

The air intake 46 shows a variable leading edge radius optimised in the lower part in order to reduce the engine face flow distortion at high angles of attack and in the side part in order to reduce the transonic spillage drag.

In particular, the inner lip average leading edge radius 76A is equal to 7 mm, while the lower lip average leading edge radius 78 is equal to 17,5 mm and that of the outer lip 80 is equal to 14 mm, so that the capture area of the air intake is about 0,322 m², and the throat area of the air intake is about 0,257 m² and the engine face area is about 0,273 m² (this values are referred to one air intake).

The air intake 46 is diverteless on the upper side of each air intake side and integrated with a LEX, thanks to the peculiar ratio between LEX length and shape; effectively the LEX acts as a shield at high angles of attack.

The air intake can foresee also the presence of two additional blow indoors (not showed in the pictures),

positioned on the upper wing-body junction between wing 18, 20 and fuselage 12, which open when the pressure in the duct is lower than pressure on the upper wing-body junction, thanks to pre-loaded springs integrated in
5 the blow indoor hinges.

These blow indoors aim is to reduce, when they open, the local angles of attack on the air intake lips 46 at high angles of attack, reducing the air mass flow quantity passing through the above mentioned air intake
10 46.

One of the characteristics that guarantee the high performance, the stability and the aerodynamic structure of the aircraft 10, is the staggered tails 44 and 38. They allow to reduce the aerodynamic drag
15 generated by the fuselage afterbody, to optimise the spin behaviour of the aircraft 10 and to improve its whole aerodynamic design for high angles of attack flights.

The vertical fin with trapezoidal platform includes the
20 rudder 34 and is coupled to the wing. This means that the leading edge of the rudder, indicated as item 36 in picture 1, overlapping the trailing edges 70 of each wing 18, 20, in order to allow the recovery from the spin and to optimise the behaviour of the aircraft 10
25 at high angles of attack.

The horizontal tail with trapezoidal platform, is moved by two independent actuators which allow its symmetric and asymmetric deflection. The horizontal tail presents a hinge axis, indicated as item 86 in picture 2, which is oriented, on the right and on the left, of about 7,5°, from a lateral axis 88, in order to optimise the hinge and the inertial moments.

The staggered tails can be further characterised by a tolerance referred to the ratio between quote C, showed in picture 1 and defined as the distance between the apex of the vertical fin root chord and the apex of the horizontal tail root chord 44, and the tail arm, equal to 4181 mm; it follows that the reference ratio given above is equal to $1932/4181 \text{ mm} = 0,462$, with an applicable tolerance equal to 10%.

Also the wing profile is modified and optimised in comparison with traditional trainer aircraft, in order to reduce the "buffet" effect, considering the characteristics of a low aspect ratio wing with thin airfoil and variable camber.

According to the patent, on the contrary, a wing with trapezoidal platform and mid aspect ratio ($AR=4$) is used, characterised by the presence of a saw tooth (showed as S in picture 2) at 67,5% of the gross wing span; the modification, in comparison with standard

wings, is first of all related to the leading edge radius, showed as R in picture 6 which was circular (prior art) and now becomes triangular, in order to optimise the stagnation point position, in presence of
5 the leading edge 68 and of the "Leading Edge Droops" 66 deflected at mid angles of attack.

As clearly results from picture 6, which shows an enlarged section along VI-VI line of picture 2, each wing 18, 20 presents a variable camber profile, both
10 along the leading edge 66 ("Leading Edge Droop") and along the trailing edge 70, near the ailerons 56. The ailerons are scheduled only in transonic regime, to have a camber reduction in order to reduce compressibility effects.

15 Quantitatively, the design point of the chord percentage extension of the leading edge 68 is equal to 0,36%, with a tolerance between +0,5% and -0,2% from the nominal value, while the design point of the gross wing span at which the chord extension is applied, in
20 comparison with the standard solutions, is equal to 8,2%, with a tolerance between +10% and -5% from the nominal value.

Other characteristics of the aircraft 10 include the fuselage 12, which, in the afterbody 16, foresees the
25 integration of the engine nozzles and the presence of a

fuselage tail, indicated as item 90 in picture 3.

Also the area near the engine nozzles is optimised in order to reduce the negative effects, in terms of drag and longitudinal stability/control, generated by the engine flow next to the fuselage side wall 12 and the horizontal tail 44.

The aircraft 10 features also a tricycle landing gear, including a nose landing gear and a main landing gear. The nose landing gear is a leg strut, with four doors closing the bay, and backside retraction.

The main landing gear has frontside retraction in order to allow fuselage belly loads installation.

The aircraft 10 under this patent fits an automatic flight control system ("Fly By Wire"), digital quadruplex redundant, which allows to optimise the performance and the flight qualities; the system allows to improve the flight safety limiting, automatically, flight regimes, which could be uncomfortable to the pilot or could lead to lose control ("Carefree Handling").

From the above description the characteristics of the aircraft configuration with improved aerodynamic performance, subject to this patent, are resulting clear, such as its advantages.

It is also clear that several other modifications can

be applied to the structure of the aircraft in subject, without exceeding the novelties included in the concept of the patent. It is also clear that, in applying the patent, materials, shapes and dimensions of the above

5 mentioned details could vary in compliance with the requirements and the same details could be replaced with other details having the same technical characteristics.

CLAIMS

1. Configuration of an aircraft with improved aerodynamic performance, which allow to keep directional stability at mid/high angles of attack, said aircraft including a fuselage fitted with wings, at least one air intake and a fuselage forebody with tapering section, whereby in that said aircraft includes a Leading Edge Extension (LEX) Vortex Control Device shaped such to symmetrize the bursting of the vortex generated by such LEX at mid-high angles of attack, wherein the ratio between the LEX area and the corresponding LEX Vortex Control Device height is equal to 2,35 m with a tolerance range varying from +100% and -50% of said ratio, said LEX Vortex Control Device cooperating with staggered tails, obtained by the coupling of the vertical fin to the wing, whose leading edges overlap the trailing edges of each wing, in order to maintain lateral-directional stability.

2. Configuration of an aircraft as per claim 1, characterised by the fact that the mentioned fuselage forebody with low aspect ratio, shows a profile with variable geometry starting from the apex up to the edge coupling the mentioned forebody to the LEX apex, said profile shows, starting from the apex, a roughly circular section and then, at the LEX apex, chined section.

3. Configuration of an aircraft as per claim 1, characterised by the fact that the staggered tails is got coupling the vertical fin with trapezoidal platform to the wing and whose leading edges overlap the trailing edges of

each wing, in order to optimise the behaviour of the aircraft at high angles of attack.

4. Configuration of an aircraft as per claim 3, characterised by the fact that such tail staggering is got through a horizontal tail having trapezoidal platform and the capability of symmetric and asymmetric deflection the horizontal tail presents a hinge axis, which is inclined from a lateral axis of the aircraft in order to optimize the hinge and inertial moments.

5. Configuration of an aircraft as per claim 1, characterised by the fact that the air intake is diverterless on the upper lip of the air intake.

6. Configuration of an aircraft as per claim 1, characterised by the fact that the air intake shows a inner lip average leading edge radius equal to 7 mm, while the lower lip average leading edge radius is equal to 17,5 mm and that of the average outer lip is equal to 14 mm, so that the capture area of the air intake is about $0,322 \text{ m}^2$, the throat area of the air intake is about $0,257 \text{ m}^2$ and the engine face area is about $0,273 \text{ m}^2$.

7. Configuration of an aircraft as per claim 1, characterised by the fact that each wing of the aircraft shows trapezoidal platform and at least one saw tooth area in at least one part of the wings pan, this wing shows also a leading edge and radius(R)with triangular profile.

8. Configuration of an aircraft as per claim 1, characterised by the fact that each wing of the aircraft shows a variable camber profile, both on the leading edge and on the trailing edge, in order to optimise camber profile improving compressibility effects.