

Paper No 67

CONCEPT STUDIES OF AN ADVANCED
COMPOSITE HELICOPTER FIN

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Blades and new Materials

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ABSTRACT

Composites have actually been used on helicopters since the end of the fifties, first for secondary structures, then for blades and hubs. They are now spreading to primary structures, their main objective being to reduce the empty weight.

This extension was favoured by the recent development of high performance fibers such as graphite or kevlar fibers.

The first applications to stressed structures of both helicopters and airplanes, dealt mainly with independent and small-size elements like control surfaces and stabilizers.

Subsequently, AEROSPATIALE decided to develop a composite fin and fan-in-fin assembly within the framework of a performance-improving exercise on the Dauphin 2.

The specifications of this new assembly are presented here from various viewpoints : weight, cost and performance improvement targets on the one hand, design requirements on the other.

We associated a graphite fin assembly with an enhanced composite-blade fenestron with a view to meeting the ambitious objectives retained.

The various development stages are subsequently described, from the stage of design and the selection of technological principles, via the implementation of manufacturing and inspection means to the substantiation and flight testing stage.

In conclusion, the results achieved during the development exercise, allow us to comply with the specifications.

The weight, cost and performance targets are achieved and the experience acquired to-date on composite blades and hubs give us all reasons to be confident in the in-service behaviour.

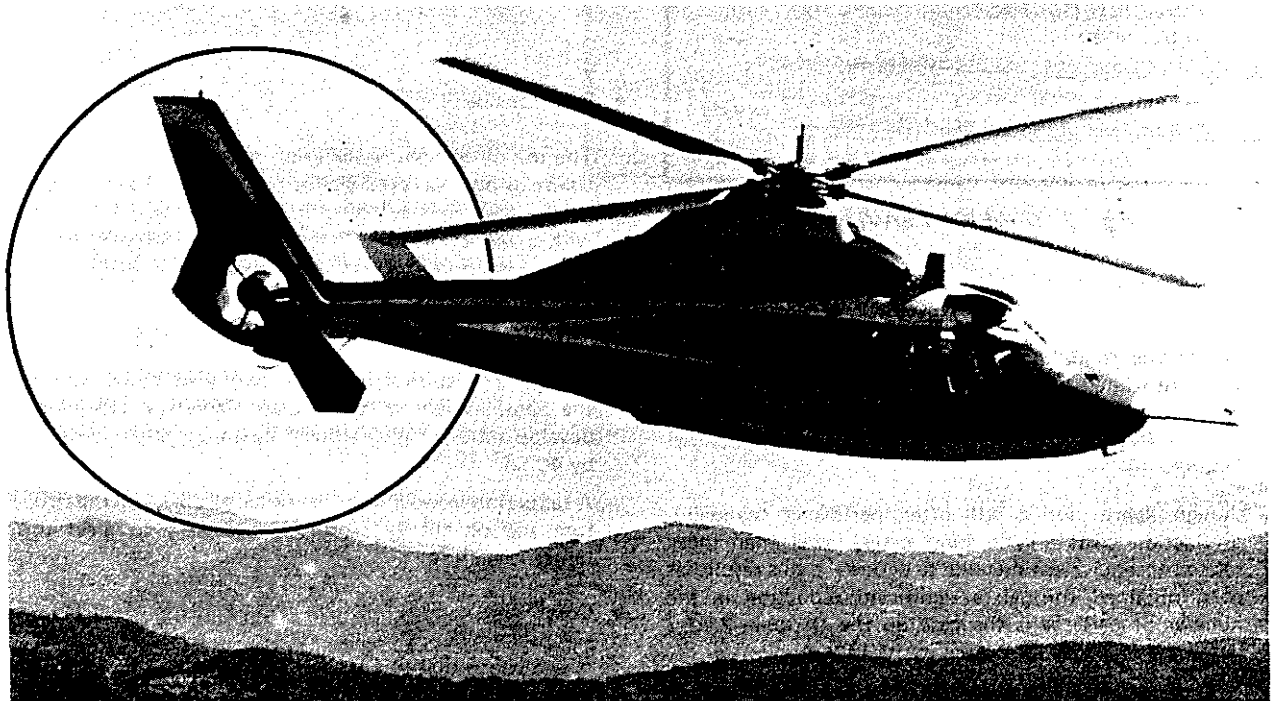


Fig. 1 : SA 365 N DAUPHIN 2

1- INTRODUCTION

The use of composite materials on helicopter structures is not new since glass / polyester fairings and cargo doors were fitted to the first «Aloette» aircraft at the end of the fifties.

Later on, the glass-epoxy / Nomex sandwich construction has progressively replaced the light-alloy sheet on most of the secondary structures.

Composite materials were used for the first time on production line in 1970 on vital components such as the main rotor blades. Fiber glass was used for the first time on a production helicopter rotor hub-the Starflex hub, as early as 1974.

Today, it can be noticed that the use of composite materials on structures has spread, e.g. graphite fiber on primary structures (tailplane, fins, tail boom, etc ...) and Kevlar fiber on secondary structures (fairings, cowlings, doors, etc ...).

Though these new technologies have not come of age yet, the advantages they bring about are significant already :

- owing to the fact that these materials have a strength/density ratio and a modulus/density ratio 2 to 4 times higher than those of metals, and because it is possible to orientate the fibers in the direction of the stresses they bear, significant gains in weight have been recorded, especially on mechanical parts by replacing steel with graphite.

HUBS :	- STARFLEX : 42 %
	- TRIFLEX : 50 %
BLADES	~ 0 %
PRIMARY STRUCTURES (GRAPHITE)	
	- HORIZONTAL STABILIZER : 30 TO 40 %
	- VERTICAL FIN (FENESTRON) : 22 %
	- TAIL BOOM : 15 %
SECONDARY STRUCTURES (GLASS → KEVLAR)	
	- FAIRINGS, COWLINGS : 15 %
MECHANICAL COMPONENTS (GRAPHITE)	
	- TRANSMISSION AND CONTROL ELEMENTS : 30 TO 50 %

Fig. 2 : WEIGHT SAVINGS

- due to the good fatigue strength properties of composites, associated with their excellent fail safe behaviour with respect to delaminations, rotors have now an infinite service life with a higher safety coefficient for accidental failures.
- though fabrication is still often performed manually, production costs are, in most cases, lower than those related to equivalent metallic structures ; this result has been obtained through a significant reduction in the number of parts as is the case on the Dauphin 2 fin / fenestron assembly illustrated in this report.

Besides, it can be expected that these costs will be further reduced owing to the efforts made now towards mechanization and automatization.

- no servicing and a reduced number of parts are two factors of primary importance which have led to a significant reduction in maintenance costs of composite elements ; the hub, in this instance, is a particularly good example.
- reparability and the absence of corrosion are two supplementary safety and cost saving factors.

On a modern new generation helicopter, such as the Dauphin, composite materials account for 23 % of the aircraft's empty weight, engines and ancillary systems excluded. The fin / fenestron assembly being developed, which is the subject of this report, will make it possible to raise this figure to approximately 26 % (Fig. 3).

Graphite is used on blades, floors, hoist arms, horizontal stabilizer and vertical fins. Fiber glass is used on solid parts subjected to fatigue such as the hub, the blade spars and the rotor suspension bars. Kevlar is widely used on secondary structures (radome, doors, fairings, cowlings).

We present here the latest development on the Dauphin 2 : the tail assembly. It comprises a horizontal stabilizer and lateral fins made up of graphite, a main fin made up of graphite and kevlar and a fan-in-fin type tail rotor with graphite/kevlar blades.

2- NEW CONCEPT BASE

It was decided, as part of the Dauphin 2 general performance enhancing, to equip this aircraft with a new fenestron ensuring better performance. This fenestron, with a diameter increase from 0.90 m to 1.10 m, is the outcome of the research work conducted over the past years and will be a flying example of a more advanced technology.

● Performance

The use of composite materials makes it possible to optimize as much as possible the fenestron design to obtain, on the one hand, an increased maximum thrust in hover with a reduction in the power absorbed at equi-thrust and a reduction in drag on the other hand.

● Weight

The target is to design a tail assembly which would have the same weight as the present fenestron but would develop a much higher thrust (maximum thrust increased by 40 %).

A reduction in weight on the order of 25 %, on the structure and on the tail rotor, is necessary to meet this target.

● Cost

It is obvious that this assembly must be developed at the lowest possible cost, using the appropriate materials, technologies and production methods. The cost price of the present assembly must in no way be exceeded.

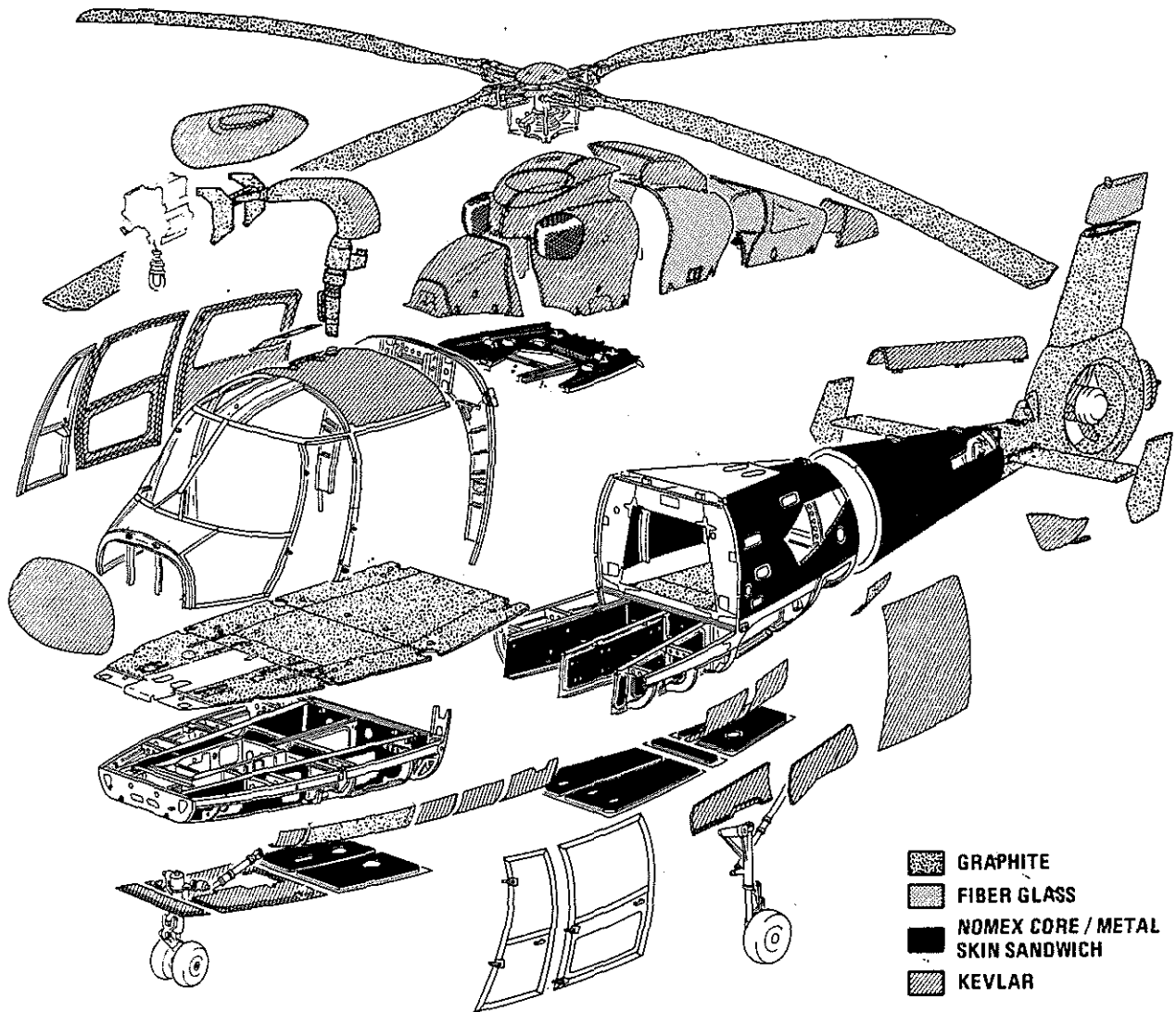


Fig. 3 : LOCATION OF COMPOSITE ELEMENTS ON THE DAUPHIN 2

● **Service life**

Structural elements (tail plane, fins) are statically dimensioned in compliance with the regulations in force.

The service life of dynamic elements must be higher than 5,000 hours and infinite, if possible.

● **Environment**

This unit must be able to withstand without damage, ambient air temperature from -55°C to -70°C and humidity levels up to 100 %.

Higher temperatures on the order of 100 to 120°C can be reached locally due to the exhaust gas flow in certain flight configurations.

The blades must be protected against sand and rain erosion, as well as against U.V. radiation.

An adequate lightning protection is to be provided and the assembly must be capable, if necessary, of the provision for flying in icing conditions.

● **Noise level**

The noise level generated by the new assembly shall remain lower than that of the initial assembly.

● **Operating data**

Sud-assemblies and detail parts must be interchangeable, especially rotor blades. Unbalance can happen and can be corrected by the operator.

Rotor maintenance is to be carried out «on condition» and on scheduled inspection basis. M.T.B.F. (mean time between failure) must be greater than 1,000 hours.

Maintenance of the structure must be as limited as possible and time between major inspections must be at least 4,800 hours or 10 years, the objective being to reach 6,400 hours progressively. The structure must be repairable.

Ship-based aircraft shall have a foldable fin upper section to ease parking and handling operations.

3- DESIGN

● Aerodynamic options

– Fenestron fin

Various improvements were brought to the Dauphin 2 initial design in order to meet the objectives set :

- . Improved inlet shape and tunnel divergent
- . Optimized tunnel diameter-to-width ratio
- . Truncation of structure rear section.

The original upper fin airfoil NACA 4415 to 4412, fin setting, twist angle and area, have been retained.

– Horizontal stabilizer and lateral fins

The constant section of the horizontal stabilizer is of the NACA 5412 type with trailing edge strip.

The lateral fins airfoils are symmetrical with a constant setting.

– Rotor

Its diameter is 1.1 m and it is fitted with 11 twisted blades rotating at a speed of 3515 r.p.m.

● Use of CAD methods (see Fig. 4)

The new concept of the fin / fenestron assembly widely incorporates the CAD methods which the Helicopter Division has been using for several years.

The shapes were entirely designed on interactive computer terminals using the Aerospatiale 3-D «SYSTRID» programme.

Computerizing made it possible to run quickly several profile optimizations during the design stage without affecting the programme schedule.

Besides, the fact that the outline drawing was examined on the screen, over various angles and perspectives, revealed the defects which could have hardly been detected in projection and made it unnecessary to prepare a mock-up. This resulted in a shorter development cycle.

Most of the production drawings were defined on CAD too, using the CADAM system.

● Technological options – Description

– Reasons for these options

The objective was to design a new larger assembly with better performance but with no increase in weight, at a lower cost price and with reduced operating costs through an increased reliability and a relaxed maintenance procedure.

A design-to-cost exercise soon evidenced that high

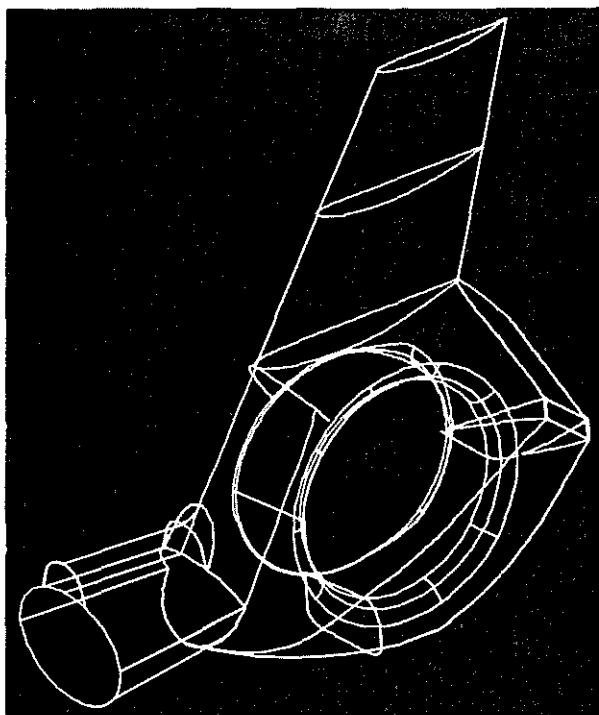


Fig. 4 : USE OF CAD IN THE DESIGN

performance composite materials such as graphite and Kevlar allowed to reach the best global compromise.

This new structure and this new rotor were designed to be of composite materials, in order to reduce the number of parts and assemblies and to find the best compromise between weight reduction and production cost.

As a provision for a possible difficult choice, a maximum value has been set for the cost of the «saved kilogramme».

Actually, choosing was very seldom necessary ; we shall see later on, in the global evaluation, that the cost-to-weight objectives were met.

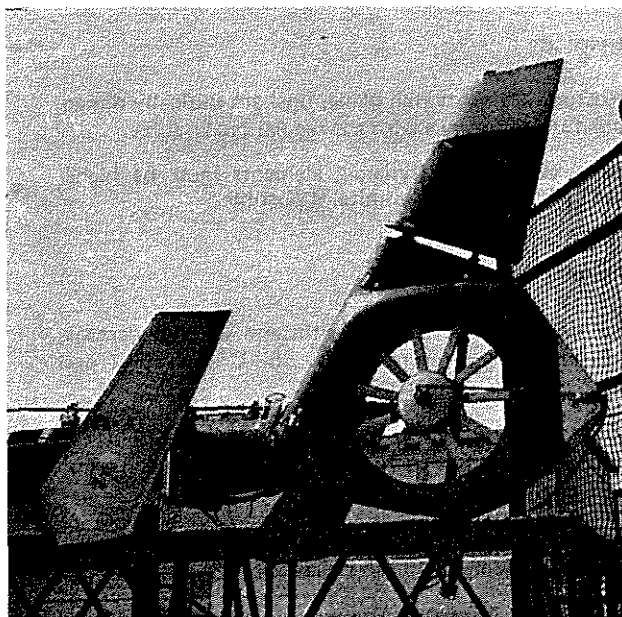


Fig. 5 : COMPOSITE FAN-IN-FIN AND TAIL PLANE

— Fenestron / fin structure (see Fig. 6)

The stressed structure is entirely made up of epoxy resin preimpregnated Kevlar or graphite single or two direction fiber cloths, either as a single block construction in heavily loaded areas or areas stabilized through a sharp curvature, or as a sandwich construction with Nomex honeycomb filler in sections where loads applied are lesser.

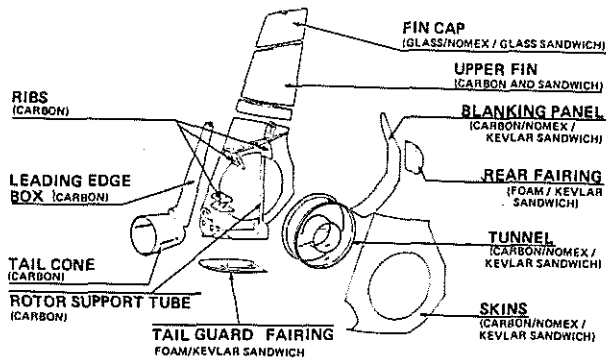


Fig. 6 : EXPLODED VIEW OF THE FIN/FENESTRON ASSEMBLY

The structure was divided into two main elements in order to accommodate an optional fin folding system intended for ship-based versions :

- a lower element or fenestron fairing
- an upper element constituting the fin.

In the basic version, the two elements are assembled by means of four bolts. The optional folding system consists in replacing two bolts with two mechanically retractable pins, the fin pivoting then on the other two bolts. The four attachments are so dimensioned that if any one of them fails, the others will keep the system fail-safe.

The fenestron fairing consists of a leading edge box, a tunnel and an assembly of ribs and skin panels bonded together. However, a few rivets have been used in particularly heavily loaded areas.

The leading edge box is a single block graphite element. Its lower truncated section, accommodating the traversing horizontal stabilizer, is bolted to the tail boom. The extremity of the integrated oblique spar is provided with doublers adequate for picking-up the folding system attachment fitting.

The tunnel (see Fig. 7) is of a Nomex honeycomb sandwich construction with two outer plies of graphite and one inner ply of Kevlar for stabilization. The use of composite materials has enabled us to improve the aerodynamic characteristics of this assembly and to obtain most satisfactory dimensions, which would have been very difficult to achieve with conventional materials.

All ribs are made of graphite. Their functions consist in stabilizing the skins and in distributing the loads generated by the rotor, the fiber glass tail guard and

the upper fin.

The skin panels are of a Nomex sandwich construction with two outer plies of graphite and one inner ply of Kevlar. The sandwich construction is not used in heavily loaded areas since the large thickness necessary to withstand the loads is sufficient to ensure stability.



Fig. 7 : AIR DUCT

On assembly, light-alloy attachment fittings are integrated in the lower part for the tail guard pick-ups. In this particular instance, the cost-to-weight analysis of the composite attachment fittings was much higher than the ceiling set for the cost of the «saved kilogramme».

The primary structure described above is fitted with Kevlar-Nomex or Kevlar-foam composite fairings at tail guard, tail cone, rotor hub and tail gearbox.

The upper fin is made up of a twin spar graphite structure with single block graphite / Kevlar skins for the leading and trailing edge pockets and a Nomex core sandwich construction between the two spars.

The attachment fitting pick-up doublers are integrated at both spar ends.

The upper end is closed by means of a light-alloy rib connected to the tail boom by a bonding braid in order to ensure efficient lightning protection (see Fig. 8).

The fin cap, which is screwed onto the top of the fin, is made up of a Nomex-glass-cloth sandwich construction.

Obviously the whole of this composite structure has been subjected to a certain number of technological trials to test the production methods, mould concept, draping characteristics and cloth cutting.

It has often been necessary to adapt the concept to the production technique.

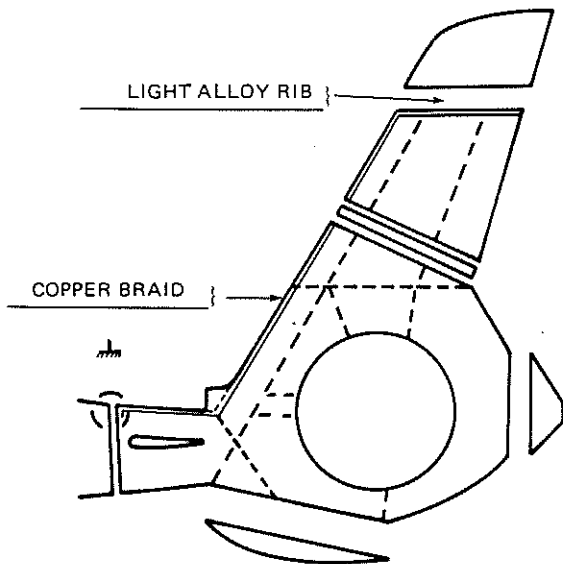


Fig. 8 : LIGHTNING PROTECTION

— Horizontal stabilizer - lateral fins (see Fig. 9 and 10)

The horizontal stabilizer traverses the tail boom, to which it is secured by means of two pins. It is made entirely of graphite and comprises two variable thickness spars, a skin made up of a three-ply bidirectional cloth, a central rib and two end ribs to which the lateral fins are attached.

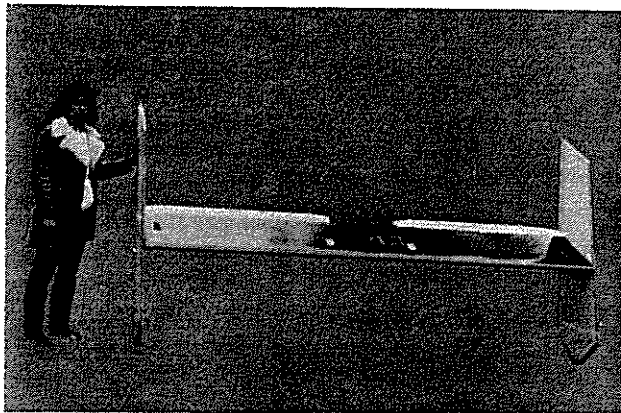


Fig. 9 : GRAPHITE/EPOXY HORIZONTAL STABILIZER AND LATERAL FINS

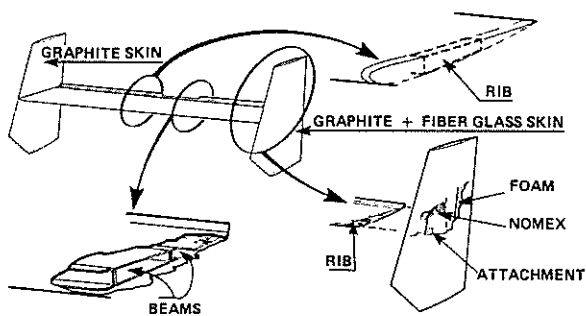


Fig. 10 : EXPLODED VIEW OF THE HORIZONTAL STABILIZER AND LATERAL FINS

The lateral fins are of a sandwich construction with a Nomex or foam core and a one-ply graphite skin plus a light glass-cloth finish.

The six-point fin-to-stabilizer attaching area is reinforced by means of an additional graphite cloth.

The horizontal stabilizer / lateral fin assembly involved no special technical problems and was thus industrialized right from the start of the Dauphin 2-SA 365 N production.

● Rotor (see Fig. 11, 12 and 13)

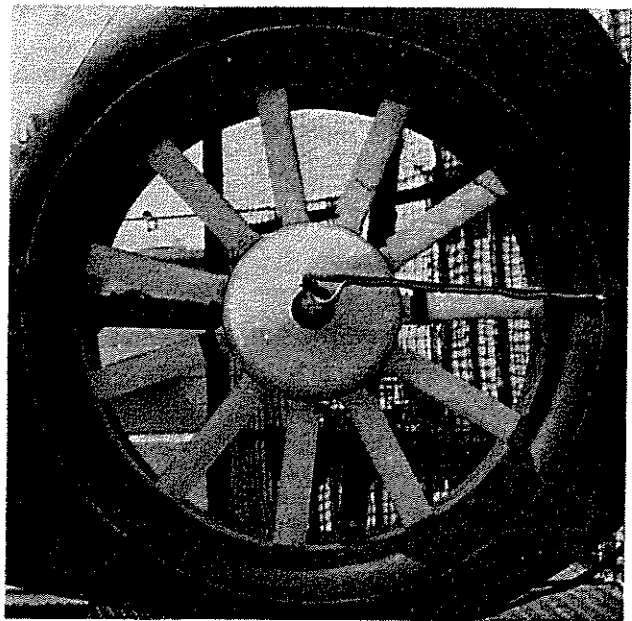


Fig. 11 : GENERAL VIEW OF THE FENESTRON

The rotor is held in position in the tunnel by the tail gearbox which is attached, by means of an integrated flared section and two bolts, to a graphite tube embedded in the structure.

The design of this assembly is such that if one bolt fails, the remaining bolt and the flared section will withstand all the loads.

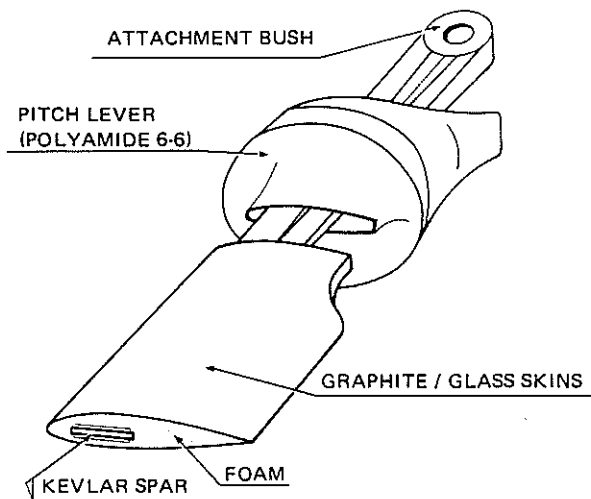


Fig. 12 : EXPLODED VIEW OF A BLADE

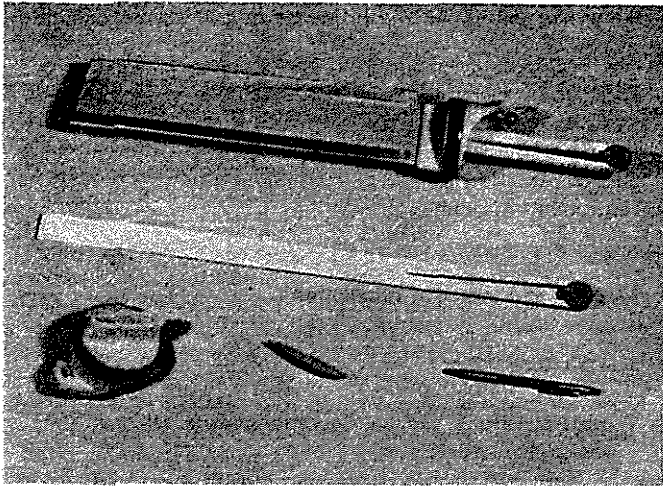


Fig. 13 : FENESTRON BLADE AND DETAIL PARTS

The rotor itself consists of 11 composite blades. Each blade is made up of a wound Kevlar bundle constituting the torsionable section taking up the centrifugal loads and the spar. Around this spar, we have a foam filler, two layers of graphite cloth and one outer glass cloth finish.

The leading edge is protected by a stainless steel sheet incorporated into the airfoil.

The blade root is moulded in polyamide 6-6 containing 30 % of fiber glass.

The simpler the concept, the better : the blade is attached only by one bearing and the Kevlar loom.

4-- FABRICATION

Given the limited amount of time allocated to the development and the introduction of series production for this assembly, the tools fabricated for the prototype will be used after minor modifications for the fabrication of series production parts.

The external shape of all sub-assemblies is given by a light alloy mould.

According to the nature of the sub-assemblies, moulding pressure is applied by 3 different methods :

- use of an internal silicone mandrel for graphite single block parts : horizontal stabilizer, fin leading edge pocket and tail cone, rotor support tube, and upper fin
- application of a pressure below one bar thanks to a vacuum bag and draining cloths, for sandwich construction parts : Fenestron tunnel, lateral skin panels, rear blanking panel.
- moulding is performed in a two-part mould (mould and counter-mould) for ribs, lateral fins, and rotor blades.

The various sub-assemblies of the main fin are bonded together on specialized tools that apply the necessary pressure thanks to small actuators and strips.

The assembly and bonding operation comprises 3 phases :

1. Constitution of the frame with the tunnel, the leading edge box and the tail cone, the ribs and the rear blanking panel.
2. Bonding of 1st skin panel.
3. Bonding of 2nd skin panel.

Removable sub-assemblies such as the horizontal stabilizer, the lateral fins, the upper part of the main fin, the fin tip cap and the rotor are then assembled by mechanical couplings.

5-- QUALITY CONTROL

We will not discuss here the dimensional checks performed systematically on this type of parts but rather the quality control procedures of material and parts imposed by this new technology and its use of composites.

Material quality control

This control is based on the results obtained in a preliminary phase called homologation during which the material and its associated supplier are approved and the parameters that must be checked upon acceptance are defined.

During the production phase, the supplier carries out the acceptance tests and the manufacturer performs counter acceptance tests only.

Tests are physico-chemical on preimpregnated products and mechanical on laminated materials.

Depending on future use, fatigue tests may be necessary, as is the case on the Kevlar spar or the graphite skin of tail rotor blades.

Fabrication monitoring

Process sheets are not yet frozen, therefore precautionary measures such as the systematic surveillance of the various operations (moulding, bonding, etc ...) by a controller need to be taken.

Moreover all curing parameters (time, temperature, pressure) are recorded.

Parts inspection

In spite of material quality control and fabrication monitoring, non-destructive inspection of sub-assemblies and assemblies remain necessary.

As the present study is still in an early stage, the non destructive inspection programme has not yet been fully developed.

Five local and one general procedures have already been selected :

- Manual checking of delaminations by ultrasound reflections on graphite single block parts.

- Coin testing of disbonds on sandwich constructions.
- Visual inspection of bonded sections.
- Transmission ultrasonic inspection of rotor support tube and attaching parts, by immersion (see Fig. 14).
- X-ray inspection of blade spar fibres alignment.
- Proof testing of stabilizer, main fin and rotor support tube at maximum flying loads with acoustic location of damage if necessary.

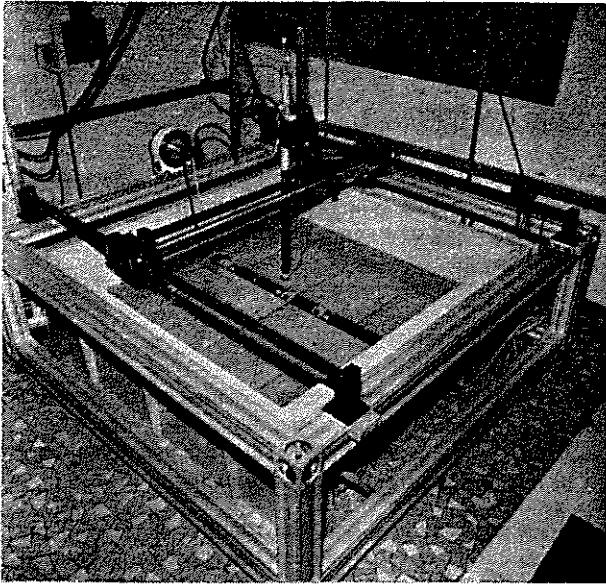


Fig. 14 : NON DESTRUCTIVE INSPECTION THROUGH ULTRASONIC TRANSMISSION BY IMMERSION

Use of other procedures is also envisaged :

- Inspection of composite / composite bonded sections by acoustic impedance measurement in the ultrasonic spectrum.
- Inspection of porosities and delaminations through ultrasound transmission by squatter.
- In the long run, comprehensive methods such as pulse laser holography and infra-red thermography could be employed.

Depending upon the future development of these procedures, proof testing of graphite single block parts could be abandoned.

6-- CALCULATIONS AND TESTS SUBSTANTATION

• Calculations

This new tail rotor fan-in-fin was designed with a view to meeting impending regulations concerning use of structural composite materials. These regulations take into consideration environmental effects such as operating temperature and ageing on both materials and bonded sections.

As no data was available, tests were carried out on specimens to determine the influence of the various parameters.

Calculation margins generally include the scale factor, the reference values obtained from test specimens, the influence of ageing and naturally, differences in tension and compression as well as stress concentration factors resulting from geometrical variations.

• Methods and means of calculation

- Structure

Six decisive flight configurations were selected to design the structure :

- . Pull out at 1.11 VNE for tail plane
- . Interruption of slip at V_{max} and stabilized slipping at V_{max} for upper and lateral fins.
- . Interruption of turn and lateral flight for gearbox support
- . Impact at $V_Z = 2$ m/sec. on tail rotor guard.

Considering aerodynamic loads on fins and tail unit, rotor thrust, loads on tail rotor guard and inertia effects in each flight configuration, calculations were carried out using conventional data processing methods and programmes ; the composite material was considered an isotropic material with the corresponding elasticity and shearing modulus. Test results confirmed the validity of this approach.

The finite element method was used to dimension the gearbox support composed of the graphite tube, the flared stub shaft and the gearbox housing ; rigidity at frames was taken into consideration. The rigidity and natural frequency of this assembly was thus verified. (see Fig. 15).

The upper fin attaching fittings were also designed with the finite element method. Satisfactory fatigue results were obtained for all vital attachments.

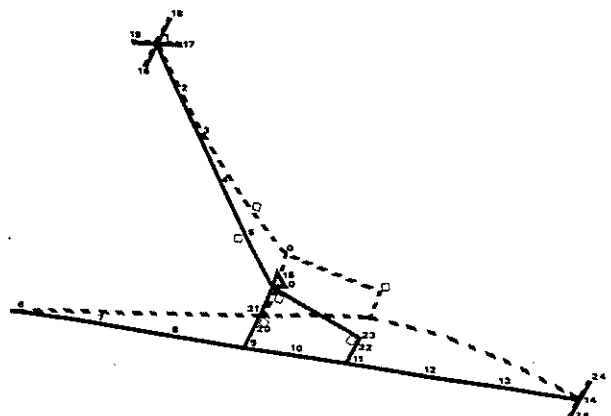


Fig. 15 : FINITE ELEMENT COMPUTATION METHOD APPLIED TO THE ROTOR SUPPORTING STRUCTURE

– Rotor

The rotor blades were designed to withstand temporary fatigue under centrifugal loads ; torsion and bending moments followed by relaxation were calculated as per the flight spectrum.

● Tests

– Horizontal stabilizer

A static test was carried out by application of loads distributed spanwise and centered at 25 % chordwise.

This test was followed up to twice the maximum flight loads and no fracture occurred in spite of the application of voluntary damage in the most heavily loaded areas. A margin equivalent to at least 33 % was thus demonstrated with respect to ultimate loads (1.5 times the maximum flight loads).

Rigidity and natural frequencies were then measured. Considering positive ageing results obtained on specimens with this resin curing at 120° C, this margin is thought to be sufficient to offset the resistance losses due to ageing.

A second component will go through a natural ageing cycle, a proof test at maximum flight loads and a temporary fatigue test.

Some follow-up specimens will go through the same ageing cycle and the results will be compared to those obtained by accelerated ageing (750 hours at 70° C and 100 % humidity).

– Lateral fins

The static test has demonstrated a 47 % margin as compared to ultimate loads.

• Main fin

A first static test was carried out on the most heavily loaded section : the leading edge box.

This test demonstrated the ultimate loads resistance with a non-representative fracture upon loads installation.

Considering future improvements and the good ageing behaviour of the 180° C resin used here, this result is considered to be satisfactory.

A prototype fin will be used for static fracture tests in September 1981. This component will first go through proof tests at various extreme flight load configurations and will also be used for performance measurements and reduced endurance bench testing.

A second fin will be used for adjustment tests and stress measurements in flight.

Finally, a third fin will be used for fatigue testing possibly following an ageing cycle.

-- Rotor support tube

The first two parts will go through static tests after voluntary creation of defects.

The following parts will be used for temporary and vibration fatigue tests.

– Rotor blades

A part from basic material tests systematically carried out on composites (static and fatigue tests with influence of ageing), specific tests also proceed on the blades :

- Static test measuring centrifugal loads resistance
- Vibration fatigue test at blade root
- Temporary fatigue test on blade running section
- Vibration fatigue test on blade running section
- Rain and sand erosion test.

The first tests already demonstrated static resistance at ultimate loads and a fatigue life above 2,500 hours.

Bench and flight testing of complete assembly

Bench tests are carried out beforehand and used for a preliminary assessment of thrust-power and substantiate a significant enough endurance before flight testing.

The first bench test took place on July 10th 1981.

The first flight should take place at the end of August/early September 1981.

These tests are spread over 7 months, they include performance, flying qualities and sound level checking as well as complete measurement of stresses in the various flight configurations.

GENERAL EVALUATION

Although this programme is still in its development testing phase, it can already be said that the objectives set in the specifications will be reached.

Both thrust-power performance at ground run and the desired weight scales have been obtained. It should however be noted that the overall weight was strictly monitored and led to some design modifications.

A slight weight excess noticed during design was due to installation of a dual body servo-control provided with double hydraulic power supply source whereas the present version is equipped with a single-body servo-control.

	New as compared to former design weight	Weight gains resulting from use of composites at equivalent performance
fin/fan-in-fin structure	Identical	22 %
Horizontal stabilizer	Lighter	35 %
Lateral fins	Lighter	21 %
Rotor	Identical	24 %
Tail gearbox	Slightly heavier	—
Flight controls	Slightly heavier	—
Overall evaluation	Identical	17.8 %

As far as manufacturing costs are concerned, this evaluation is also positive. Thanks to systematic optimizations of production methods and equipment, to definition of original moulding techniques, to constant cooperation between production and design engineers for the best possible use of composite materials while reducing the number of parts and assemblies to a minimum, to technological tests meant to define the most appropriate cut-outs thus limiting scraps and improving draping of fabric and to participation of quality control engineers from the design stage to facilitate checking, we obtained in most cases very substantial cost

Comparison of Composite design / metal design costs from A/C serial number 100			
	Metal design	Composite design	Cost ratio.
Fin / Fan-in-fin structure			
- Material	Light alloy	Graphite/ Kevlar/ epoxy	2
- Manpower	231 parts 6,000 rivets	88 parts	0.5
Overall			0.67
Stabilizer			
- Material	Light alloy — steel tube	Graphite/ epoxy	5.6
- Manpower	63 parts 1,000 rivets	24 parts	0.1
Overall			0.44

Comparison of Composite design / metal design costs from A/C serial number 100			
	Metal design	Composite design	Cost ratio.
Lateral fins			
- Material	Metal sandwich	Nomex foam/ graphite-glass sandwich	6.6
- Manpower			0.42
Overall			1.1
Rotor			
- Material	Die forged light alloy blades Steel bundle	Foam-graphite glass sandwich Kevlar bundle	
- Manpower	35 parts	18 parts	
Overall			0.45

reductions as compared to the conventional design presently in production.

It is still too early to evaluate operating costs but Aero-spatale's experience with blades and main rotor heads ensures that use of composite materials and technological simplification of this new-design fenestron will considerably reduce the Direct Operating Cost. Cost reduction also springs from elimination of corrosion risks, increase in service life, improved reliability, simplified maintenance, lower spare part costs and use of simple repair methods already widely used on the blades.

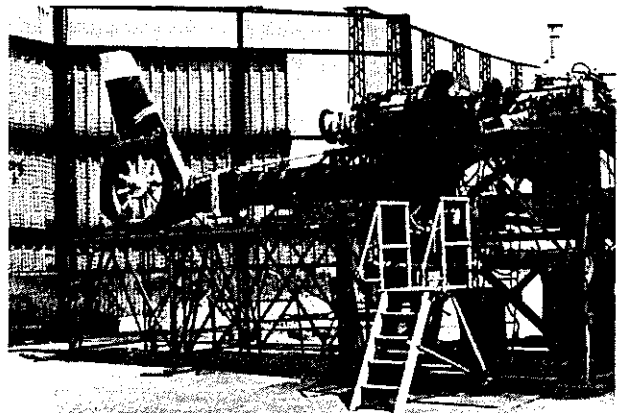


Fig. 16 : BENCH TEST OF THE FIN/FENESTRON ASSEMBLY

8-- CONCLUSIONS

The use of high resistance composite materials such as graphite and Kevlar permitted meeting the ambitious objectives set in the specifications for the Dauphin 2 enhanced fan-in-fin tail rotor and tail unit whose test yielded favourable results.

It was thus possible :

- To retain the original metal assembly weight despite a very large increase in performance, this gain would correspond to a 23 % structure and 24 % rotor lightening if the performance level was that of the original metal assembly.
- To decrease production costs noticeably by elimination of a great number of parts and assemblies in spite of the still high cost of the materials used.
- To lower the operating costs by an increase in reliability, elimination of corrosion risks, improvement in maintenance

through simplification in design.

- To increase safety through use of fail safe fibre composites.

The inspection methods to be applied in production are still being defined according to observations made during manufacture of the first assembly and experience acquired.

This application confirms the importance of composites in the manufacture of primary structures whenever the design is completely revised as a function of material characteristics and new methods of production.

A weight-cost comparative study must however be undertaken every time ; although composites prove highly useful for complex structure shapes as the fan-in-fin tail rotor, this might not be so for simpler structural elements.

Aerospatiale's Helicopter Division was first to generalize the use of composites on blades and main rotor heads and firmly intends to apply these materials to primary structures in so far as the cost efficiency ratio is demonstrated each time.