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New Technologies, a Factor of Competitiveness for Today's Helicopters, a Must for Tomorrow's

by

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Abstract : The research activities undertaken since the late eighties in the field of materials and processes have strongly be directed towards the preparation of advanced technologies to be introduced in EUROCOPTER's new range of products.

So the new requirements imposed by the specifications and customers' needs of these new helicopter programs (TIGER, NH 90, EC 120, EC 135) such as :

- damage tolerance dimensioning,
- improvement of safety in case of incident (e.g. loss of lubrication),
- reduction of empty weights,
- reduction of operating costs,
- reduction of industrial costs,

have led EUROCOPTER to develop, characterize, and validate new suitable material/process couples that best meet these requirements.

- As concerns the metal materials, the major work has been focused on :
  - new heat treated titanium alloys (Ti 1023) which feature both a low specific gravity, high static and fatigue mechanical characteristics, and an excellent resistance to atmospheric and fatigue corrosion,
  - high characteristics light alloys such as MMC base aluminium, (2080, 15 % SiCp), and WE 43 magnesium featuring an improved resistance compared with conventional alloys,
  - gear and bearing surface hardening nitriding treatments.
- In the field of composite materials, EUROCOPTER has for some years been developing new composites of the 180°C class for structure and transmission applications which are now used on all aircraft to the new generation such as the TIGER, NH 90, EC 120 and EC 135.

The effort is now directed towards the standardization of materials and processes with a view to significantly reducing the qualification, procurement and stock management costs.

For the future and in order to still be competitive, EUROCOPTER has initiated its research activities on material and process technologies which will in the mid-term permit to :

- extend the application of composite materials to the transmission systems,
- meet, for all technologies, the new environment regulations without jeopardizing either the performance or the durability of the parts manufactured,
- improve the performance at temperatures above 120°C thanks to conventional prepreg or RTM and thermoplastic technologies.

The results obtained from test specimens and parts validate these new technologies on the new aircraft under development. Such technologies can be applied as potential enhancements to commercialized aircraft like the ECUREUIL, DAUPHIN and SUPER-PUMA.

METAL MATERIALS AND PROCESSES

The recent developments and improvements made regarding materials and the related processes applied to transmissions, including

- gearboxes and bearings,
- main and tail rotor,
- junction and suspension components,

significantly helped :

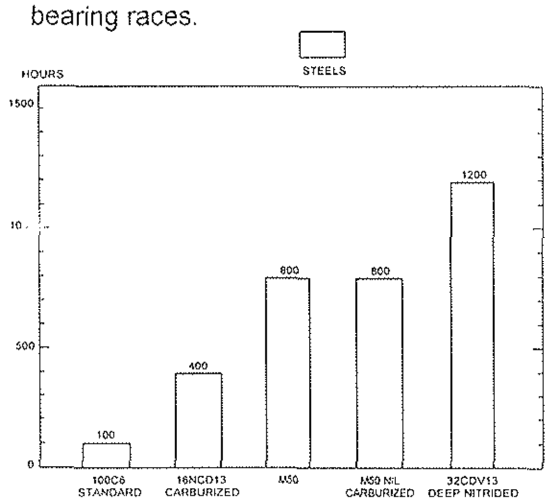
- on the one hand, observe the severe requirements of new specifications and regulations imposed to new generation helicopters (TIGER, NH 90, EC 120, EC 135), these include :
  - * reduced empty weight,
  - * damage tolerance,
  - * particular operating conditions (oil loss, etc...).
- on the other hand, improve the reliability of the transmissions while reducing the overhaul and maintenance costs in operation (DMC and DOC).

1. GEARBOXES

The most significant progresses were made with the « Deep Nitriding » technology for gears and bearings and the new magnesium alloy WE43 associated to an enhanced protection of the anodization type (HAE process) for casings.

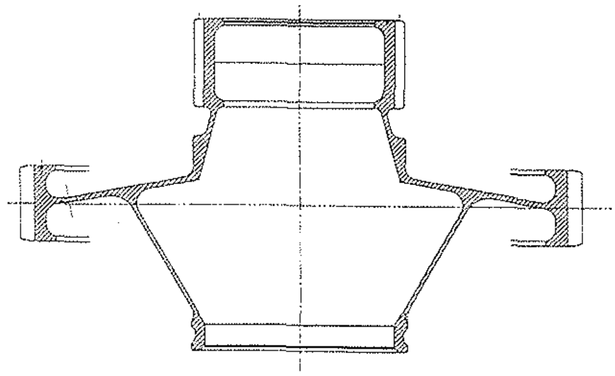
1.1 Nitrided gears and bearing races

32CDV13 steel nitrided to a low depth (0.3 to 0.4 mm) offered a good cost/performance compromise for gears over the last 20 years. The development of a « deeper » nitriding process helped check that this technology could also prove very efficient for roller and ball bearing races.

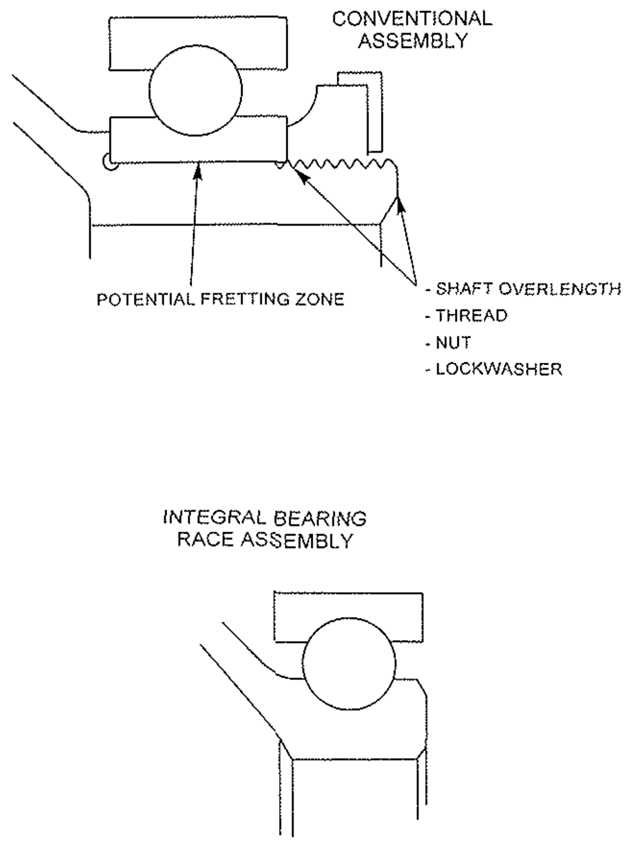


Endurance tests on bearing RIG

Considering these capabilities and qualities, it became possible to design and industrially manufacture complex shape gears including teeth and bearing tracks connected by thin wall webs as in the TIGER MGB combining wheel shown below :



Thus in addition to the weight saved as securing devices and internal bearing bushes were phased out, the wear and fretting/fatigue problems were also solved at the bearing journal of internal bushes on shafts.



Comparison between a conventional bearing assembly and an assembly with integral bearing race

The performance levels that were obtained helped claim :

- 5000 operating hours between overhauls,
- over 1 operating hour after oil loss for gear boxes in helicopters weighing 4/6-tons and more.

This technology was selected for the gearboxes of the new generation helicopters designed and manufactured by EC (TIGER, NH 90, EC 120 and EC 135).

1.2 WE43 magnesium alloy housings

Since helicopter have been flying, the experience acquired in service with conventional casings made of RZ5 (or ZE41) demonstrated that this magnesium alloy is sensitive to corrosion, particularly in attachment, connection and assembly zones where it is difficult to apply an environmental protection.

Aware of the need to reduce the maintenance constraints and overhaul costs imposed to the customers and also to save weight over aluminium alloy (20 to 40 % depending on circumstances), EC attempted to improve corrosion resistance with :

- more efficient protections, particularly in machined attachment zones,
- new alloys less sensitive to corrosion and more damage tolerant.

This led to :

- the selection of a new magnesium/yttrium alloy (WE43) developed by Magnesium Elektron (MEL),
- the selection of an anodization type protection (HAE) sealed with varnish).

The development and adaptation of new low pressure casting processes (REDEM by Messier and DPSC by MEL) associated to an optimization of the HAE protection helped obtain a highly efficient technology equivalent to if not better than AS7G06 aluminium alloy (A357) with chromic anodizing.

The different tests, performed on specimens and parts,

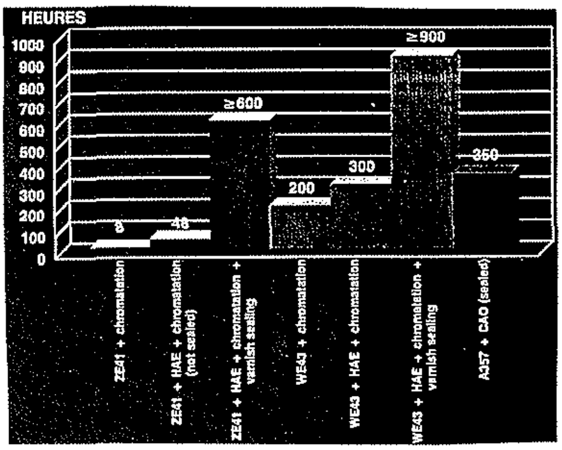
- corrosion with and without protection,
- fatigue,
- metallurgical dissection,
- damage tolerance

evidenced the advantages of this solution :

	Protection	Type of test	of (Mpa)
ZE41 T5	chromatation	Flat Bending	100 ± 69
	chromatation	Rotative Bending	± 60 to ± 105 (*)
	HAE	Rotative Bending	± 96
AZ91 HP T6	chromatation	Flat Bending	100 ± 68
	HAE	Flat Bending	100 ± 50
WE43 T6	chromatation	Rotative Bending	± 110
	HAE	Rotative Bending	± 94
	chromatation	Flat Bending	120 ± 80
A357 T6	CAO sealed	Rotative Bending	± 75

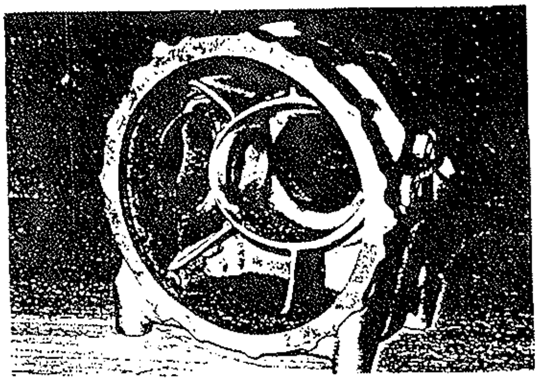
(*) Depends on foundry quality

Fatigue behaviour of cast Mg and Al alloys on samples, without overstress

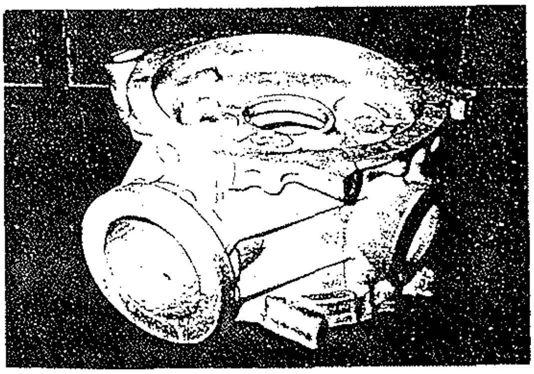


Corrosion behaviour of cast Mg and Al alloys, machined and protected, then exposed in salt spray (NFX 41-002)

That was retained for the TGB and RAGB casings in NH 90, MGB casing in EC 120 and MGB casing in TIGER (with HAE protection for RZ5 only).



Casing of TGB / NH 90



Main casing of MGB / EC 120

It is planned with this selection to reduce :

- overhaul costs by at least 80 %,

- maintenance costs by at least 50 %.

2. ROTORS

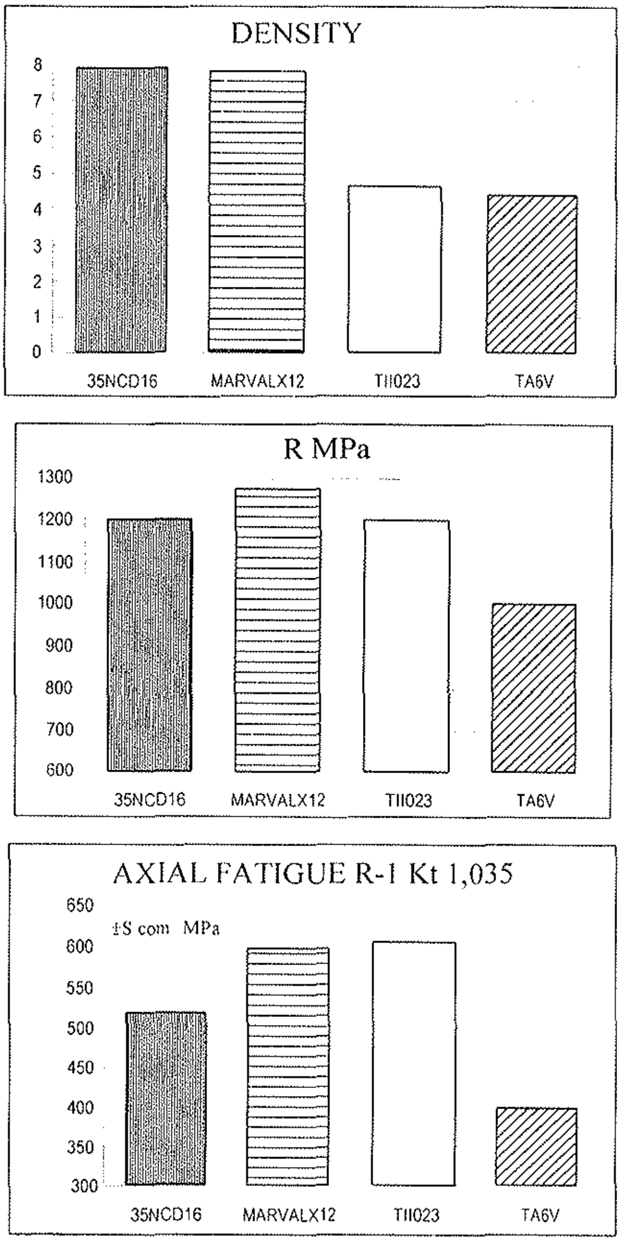
The search for maximum weight saving on the major rotor parts, in particular, led to a severe competition between different types of materials available on the market.

The titanium alloys and the metal matrix composites proved the most suitable because they offer the best density/rigidity/fatigue resistance compromise.

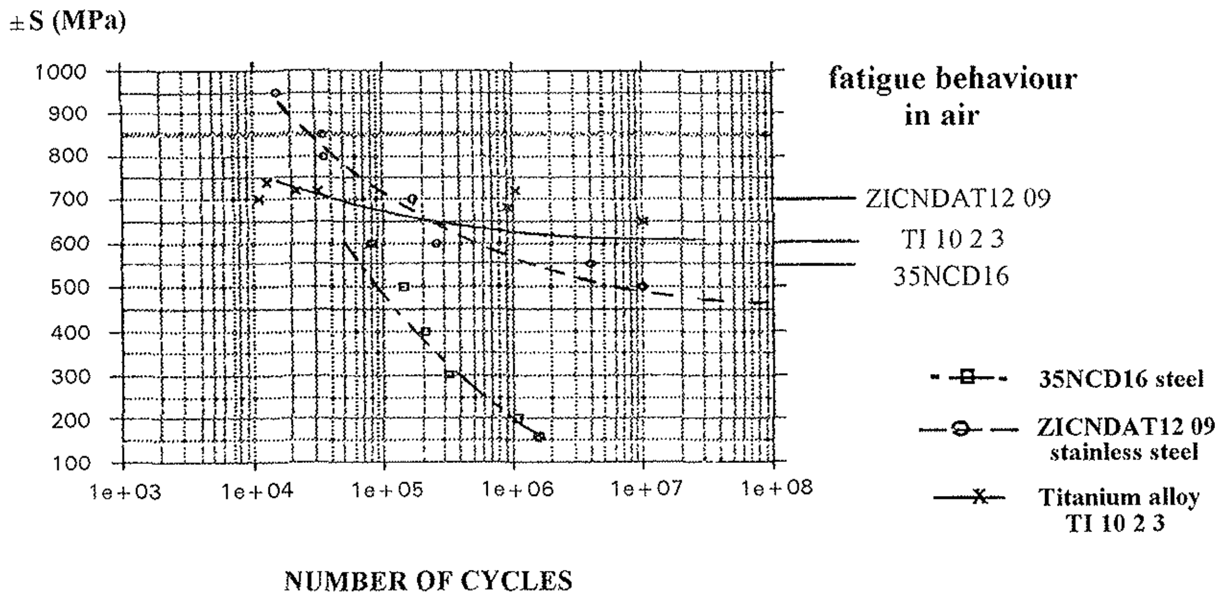
2.1 Titanium alloy Ti 10.2.3

Compared to high resistance stainless steels e.g. MARVAL X12 (E.Z1CNDAT12.9) or 15-5 PH (E.Z6CNU15.5) and conventional titanium alloy TA6V limited by its fatigue resistance, EC research work helped evidence the advantages of the new Ti 10.2.3 heat treated titanium alloy that offers :

- a density 1.7 times lower than that of steels,
- mechanical (static and fatigue) characteristics equivalent of those of high performance steels,
- satisfactory forging and quenching qualities for complex and massive parts,
- a very good resistance to atmospheric corrosion and corrosion fatigue.

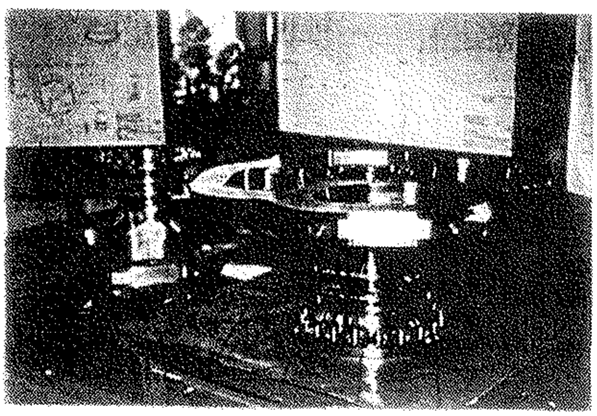


Ti 10.2.3 performances

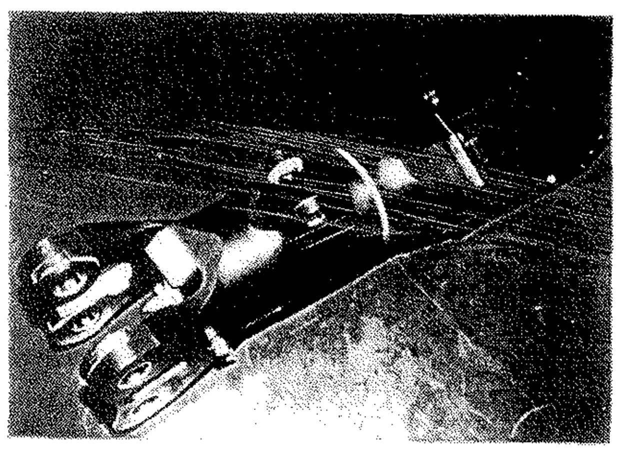


Corrosion fatigue endurance in salt spray for smooth specimens

Selecting this alloy for the main rotor hub and sleeves, the tail rotor drive shaft and the flapping weights of the suspension system in the NH 90 helicopter helped save approximately the weight of one passenger (70 kg).



NH 90 Main rotor hub and sleeve made of Ti 10.2.3



NH 90 Main rotor hub and sleeve made of Ti 10.2.3

This alloy was also retained for the main rotor hub in the EC 120 helicopter.

2.2 Metal matrix composites

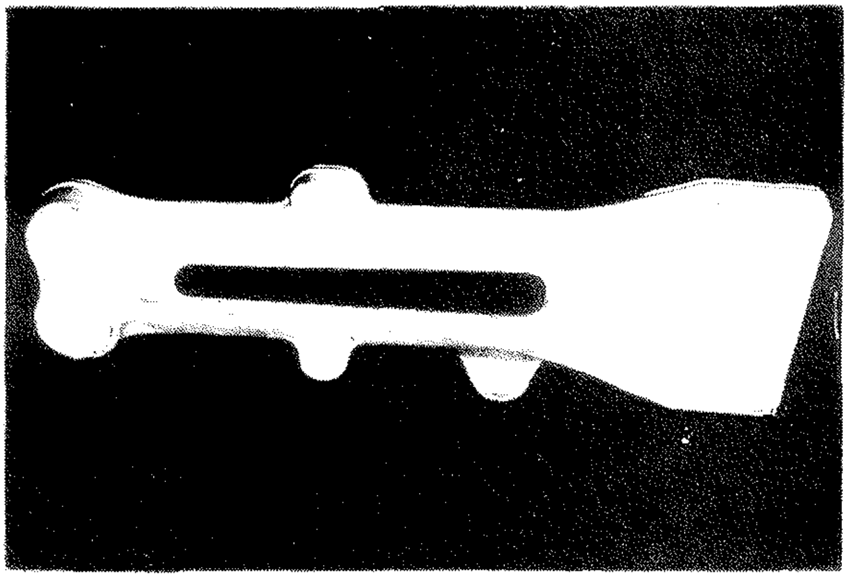
The arrival on the market of an aluminium matrix composite reinforced with silicium carbide particles (X2080 15 % SiCp) developed by ALCOA offering compared to conventional type 7x75 aluminium alloys a significant increase of the elasticity modulus and fatigue resistance (with and without fretting corrosion) as well as a significant reduction of the thermal expansion coefficient proved of great to interest to EUROCOPTER.

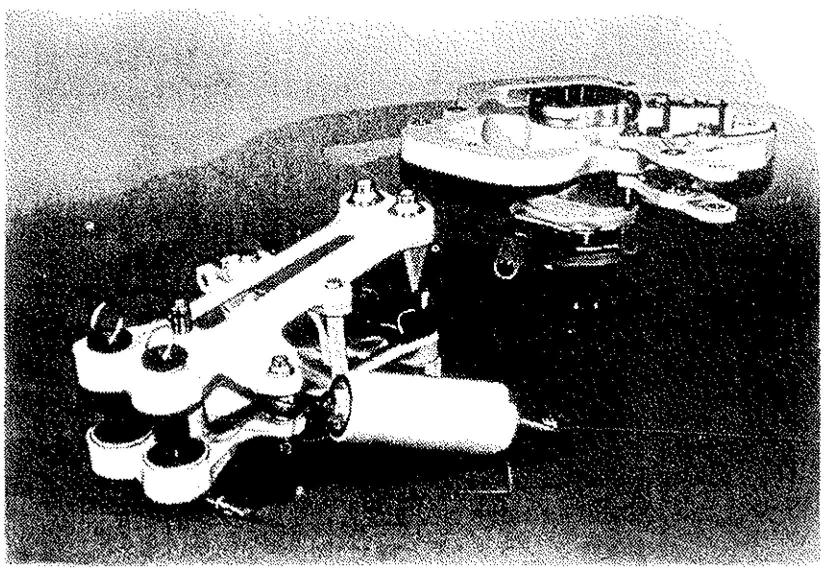
This composite was then selected to optimize the main rotor hub sleeves in the EC 120 helicopter.

These precision die forged sleeves have been fitted to the main rotor hub of the first prototype.

Furthermore, this composite has also been selected for the fixed swashplate in the EC 135 helicopter and shortlisted for the swashplates in the NH 90 helicopter.

Its high price, acceptable for this application, is the limiting factor in the development of new applications.





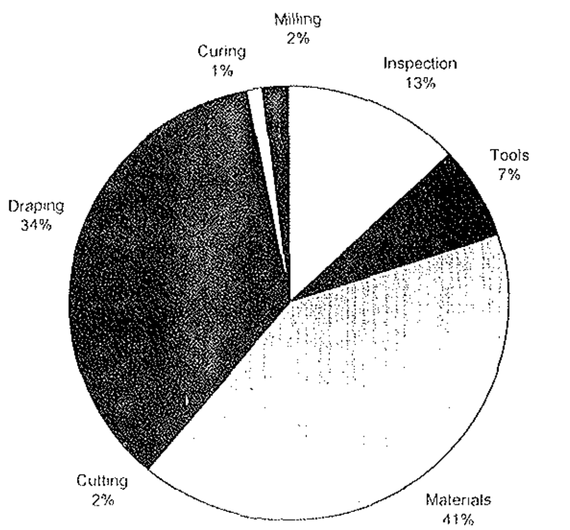
EC 120 Main rotor head sleeve flange die forging made of CMM SiC/ALU

ORGANIC COMPOSITE MATERIALS

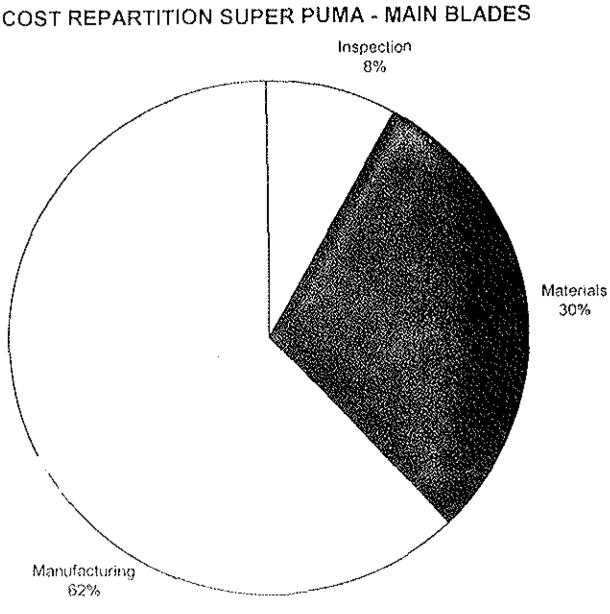
In the last five years, composite materials were introduced in the manufacturing process of a large number of helicopter fuselage parts to reach up to 40 to 50 % of the helicopter's empty weight (without the engines and equipment) on the TIGER or NH 90 helicopter.

This technology allowed the expected weight savings to be achieved but introduced over costs, all the more so as these technologies represent an appreciable share of the cost of the parts.

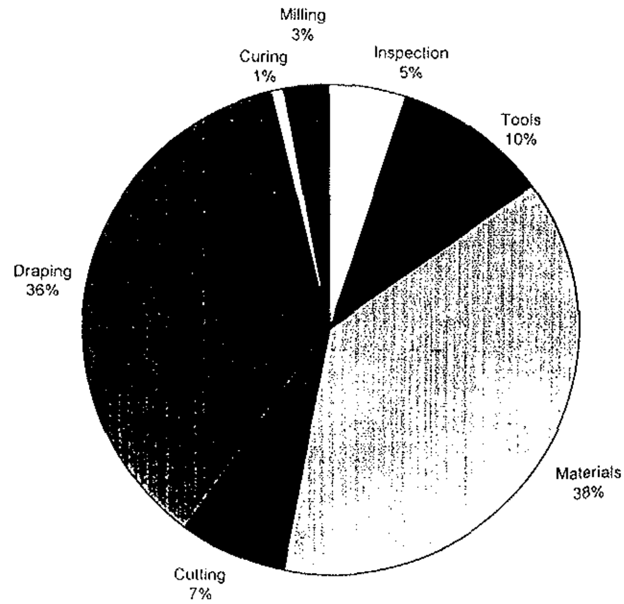
COST REPARTITION NH90 CARBON FUSELAGE PART



COST REPARTITION SUPER PUMA - MAIN BLADES



COST REPARTITION GLASS-FOAMED SANDWICH - AS 350 FAIRING



Cost repartition

Although the composite material technology cannot be challenged on certain families of parts (for example, the main rotor blades), the current requirements are to adopt, for any new application, a systematic approach of the best value analysis (the best technology for the best cost).

In this frame of mind, the technologies in which cost savings make up the main target were developped by EUROCOPTER.

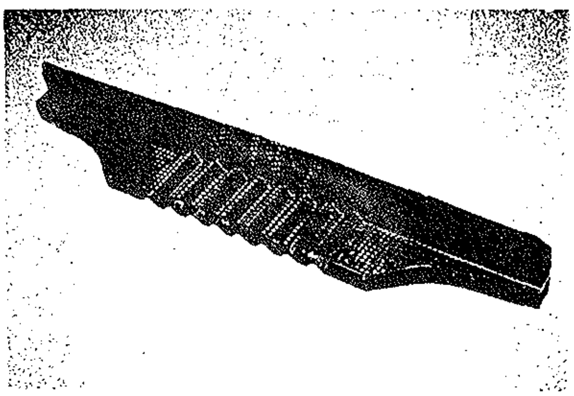
This work permitted the following results to be obtained :

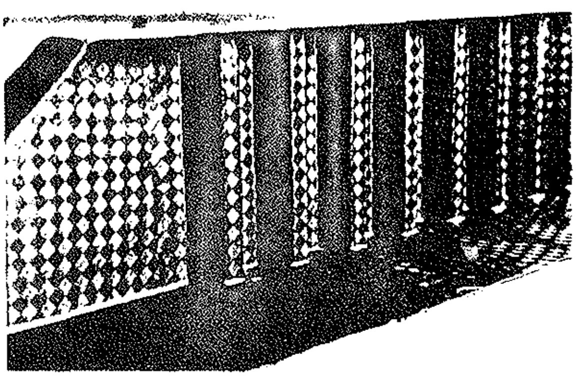
- harmonisation between the selected materials and processes (rotor blades, fuselage, ...),
- development of new technologies ensuring cost savings (RTM),
- Finally, the common integrations of technologies which permit competitiveness to be maintained in terms of performance (weight and temperature) are keeping in mind (bismaleimide).

3. FUSELAGE PARTS

Firstly, one should keep in mind the production of the fuselage for the first NH90 prototype with new 180°C class composite materials developed over the last few years (through joint research between ECF and ECD) with a view to their simultaneous application on the TIGER and NH 90 fuselage. This harmonisation effort significantly contributed to the reduction of the material and process qualification costs as well as the stock procurement and management costs (including at the supplier's), and to the improvement of the perenniality of supply for such materials.

Today, new developments are driven to reduce material costs, particularly on carbon fabrics costs.





12 K carbon fabrics feasibility part

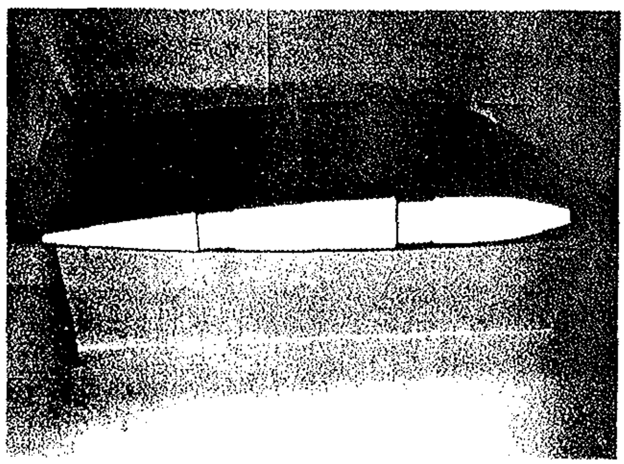
4. NEW RESINS FOR ROTOR BLADES

Extensive research work has been initiated over the last few years in cooperation with the suppliers, according to two objectives :

- finding alternative materials for the blades, meeting the technical requirements while integrating the economical (cost savings) and the environmental constraints (new regulations on the environment),
- reducing the number of resins used, by developing a multi-purpose, high performance resin, in order to :
  - reduce the stock procurement and management costs,
  - limit our industrial vulnerability,
  - reduce the qualification costs.

These actions are consistent with the new definition of our policy in this field. They were conducted jointly between ECF and ECD.

Based upon the satisfactory results obtained in the evaluation of new materials for the spars and the skins, a feasibility demonstration study on blade sections was initiated and conducted successfully. This study will be followed by an application test on a demonstrator's rotor blades, with finally, the qualification of these materials and processes on newly marketed helicopters.



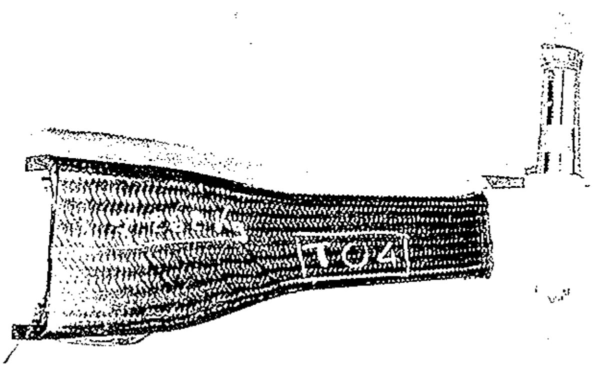
Section of a rotor blade made of new resins

5. THE RTM TECHNOLOGY
(« Resin Transfer Moulding »)

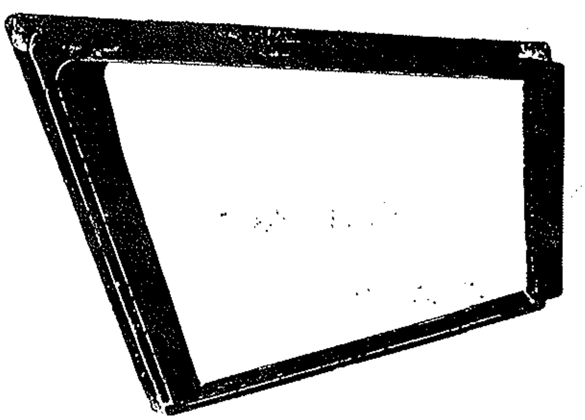
Developed intensively by all American manufacturers, notably by SIKORSKY and MDD, this technology introduces the advantage of appreciable cost savings, compared to the conventional technologies of laid up composites, for thick or complex shaped parts with integrated functions.

Thanks to the experience acquired in Marignane for more than 15 years (with the DAUPHIN AS366G) (hoist) and the recent progress of this technology in the field of materials (resins and reinforcements) or the resin injection processes, a certain number of probatory parts were manufactured in the last two years :

- the landing gear strut created in the scope of the composite landing gear exploratory development, on a SUPER PUMA topic,
- the NH 90 pilot door produced in parallel with the laid up version, it is representative of complex, hollow body parts.



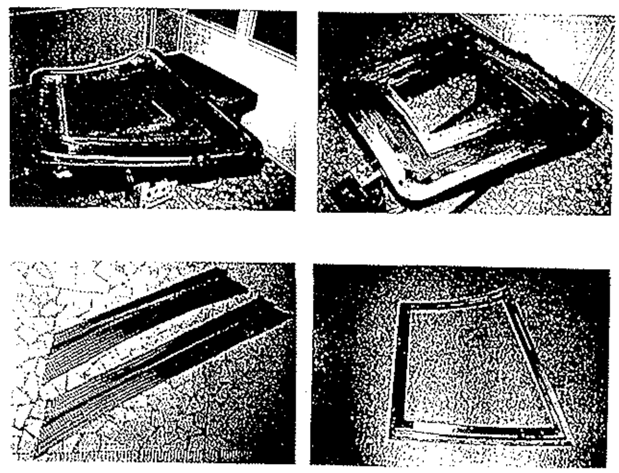
Landing gear leg made of RTM composite

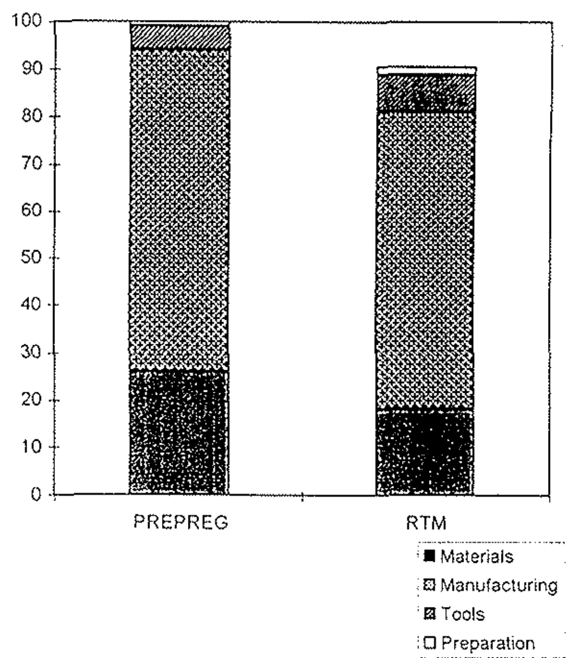


First pilot's door made of RTM composite

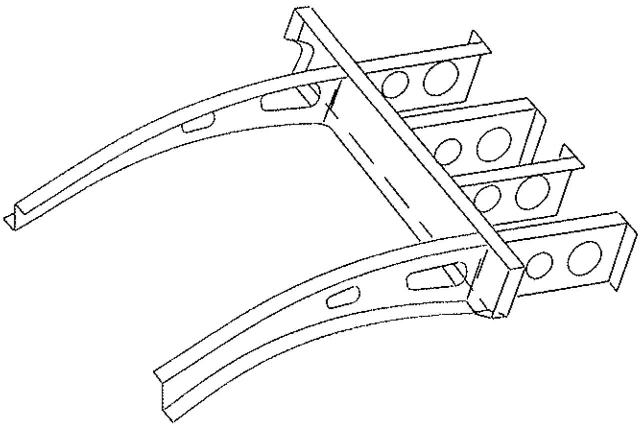
The development of this last part will be followed up in order to validate this RTM technology and to permit its introduction into a series-production application on a marketed aircraft.

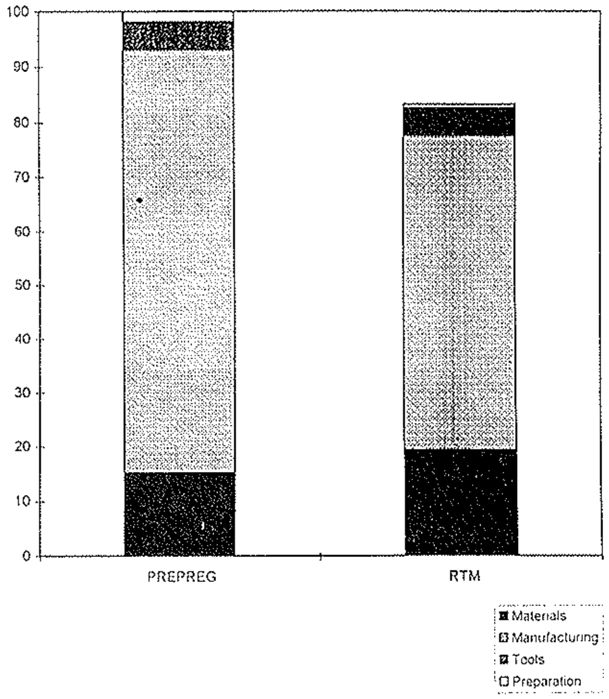
Therefore, compared to a conventional laid up composite reference part, the RTM technology permits 10 % cost savings in this application. On other parts cost savings up to 20 % can be envisioned.
However, the RTM technology should not be considered applicable to all cases but, if used judiciously, it should increasingly be applied to helicopters.





Pilot door made of RTM process
Production Cost repartition



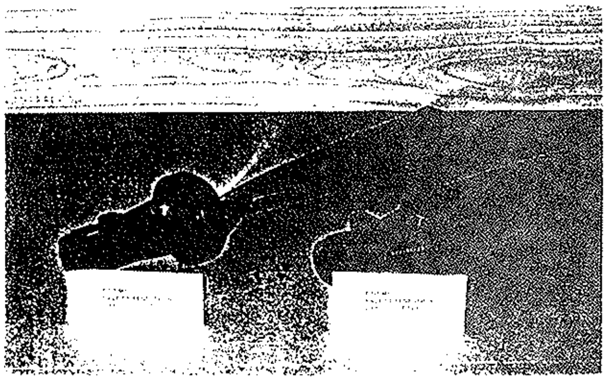


Cockpit beams made of RTM process
Production Cost repartition

Nevertheless, certain points remain to be clarified in this technology (qualification, industrialisation).
Considerable progress has already been achieved in the field of composite materials (the 3M company's PR500, Hexcel's RTM6) and in the field of preforms, which allow the technology to be already used on secondary class parts.

Moreover, the research progress on the RTM technology conducted in reply to the first Request For Proposals from the fourth PCRD should enable us to assess its technical and economical capacities in the field of complex mechanical parts (housings, swashplates).

Finally, this technology, owing to its capacity to permit the integration of functions, may be adapted to primary parts, or even to vital parts such as the tail rotor blades, in the short run.

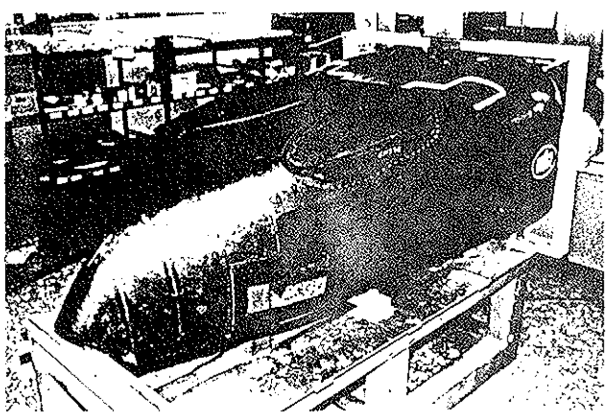


Rear blade in RTM process

6. ENGINE COWLINGS

BMI resins (Bismaleimide)

The evaluation work carried out in the scope of research over the last two years demonstrated that BMI matrix composites were capable of high temperature hold performance (200°C in continuous mode). The concrete result of these works is illustrated by the proof manufacturing of the TIGER helicopter's engine cowling/IR suppressor with a demonstration flight on the PT4 prototype in September 1995.
Thanks to these characteristics, this composite material may be claimed as a substitute for titanium, for this type of application, therefore ensuring weight savings in the order of 20 %.



TIGER engine cowling/exhaust gas deflector made of BMI composite

Conclusion :

During the last months, in a hard competition environment, EUROCOPTER has emphasized the new technologies interest for new imposed requirements (damage tolerance, operation and maintenance cost, new environmental regulations) by testing in flight on different prototypes (TIGER, NH90, EC 120, EC 135).

So in the metallic fields, following works were achieved :

- interest of fatigue and corrosion behaviour with Ti 10.2.3 alloys,

- good corrosion properties with the new association of WE43 magnesium alloy with HAE process,

- high level of characteristics of MMC materials.

In the composite fields, following conclusions can be mentionned :

- cost saving interest of RTM Technology on complex shape parts (with integrated functions),

- materials harmonizations on multipartner programs,

- high temperature properties on new thermo set matrix.

For the future and as mentionned above in this paper, new technologies can and must be one of the vectors to ensure such a successful outcome.