Both the above considerations and the novelty of these technologies call for tighter checks at three levels:

. on the product/supplier combination,
. during part fabrication,
. on the finished parts.

The finished part must be checked using non-destructive test equipment that matches the range of technologies (monolithic, sandwich, assemblies, etc.), the expected defects and the criteria for serviceability and scrapping.

By sectioning specimen parts, this program has been able to record the main defects (porosity, resin contents, delamination, waviness, etc.) and to characterize different non-destructive test methods and their sensitivities.

Clearly the currently available non-destructive test methods are not capable of detecting, locating and measuring all the defects. In these cases, e.g. waviness, misorientations on certain parts, the only way of guaranteeing an acceptable level of quality is by enforcing a stringent quality control during the manufacturing processes.

Apart from conventional inspection methods such as visual checks or tapping, ultrasonic techniques are currently the most effective and flexible.

It has proved possible to derive new industrial inspection concepts, applicable to production checks on composite structures, from conventional methods, e.g. ultrasonic contact, immersion, partial immersion (water jet).

Particular emphasis was given here to providing the operator with data processing functions, i.e.:

- remote loading of inspection procedures,
- a CADAM link,
- computation programs (bar charts, contours),
- real time attenuation and thickness distributions (A, B and C scans),
- automatic report printouts.

In addition inspection times can be considerably reduced by multiplexing systems.

At the same time the following studies were started and are still in progress:

- infrared thermography (using illuminators) to cut sandwich structure inspection costs,

- tomodensimetry, a high performance and versatile inspection technique but not yet suitable for industrial use.

d) Weight/Cost Balance

Although this program is not yet finished, a provisional comparison between a composite and metal center structure shows:

- a 21% saving in weight,
- but a 13% higher production cost (production run of 400 aircraft, with resources available in the near term).

This overcost is mainly due to the component cost (especially as regards main frames), although savings are obtained on other cost items such as assemblies and tools.

Component cost analysis identified two factors as responsible for most of the cost, i.e. materials accounting for 40-50% and draping for 30-45% depending on the parts. Other operations such as, cutting, polymerization and trimming had a very low cost impact.

These results indicate the actions to be given priority both in-house and at suppliers.

5. DEVELOPMENT HELICOPTERS

The experience gained in the composite structure research outlined above was put to use starting in 1988/89 for the development of:

- the Tiger central part of the fuselage structure (Figure 24),

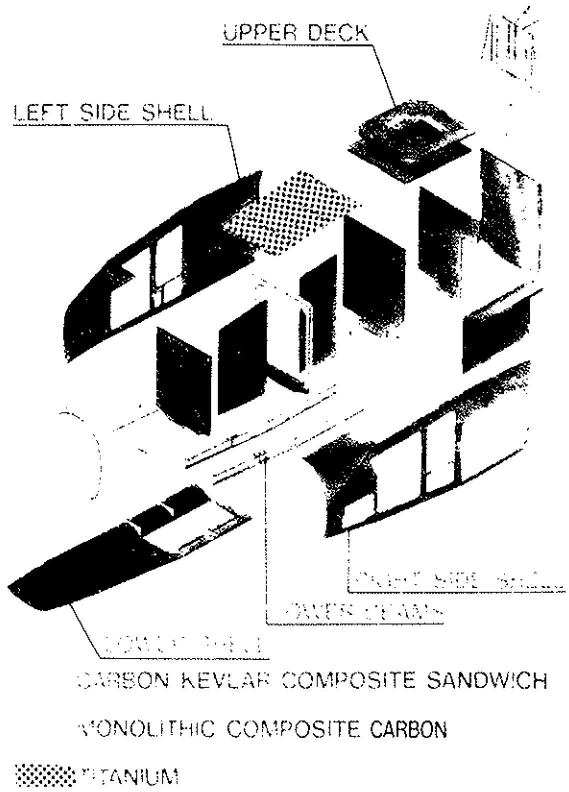

Figure 24- Tiger Composite Fuselage (Central Part)

- the aft central section of the new AS332 MKII fuselage structure (Figure 25).

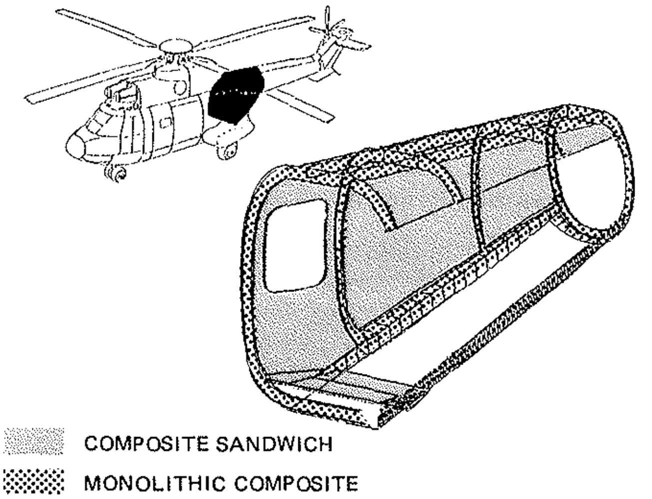

Figure 25- AS332 MKII Intermediate Composite Structure

Some details on the Tiger central structure (as currently defined) are given below:

- Material Distribution (Figure 26)
- Cost Distribution (Figure 27)
- Comparison of Composite and Metal technology (hull structure of Nomex/metal sandwich). (Figure 28).

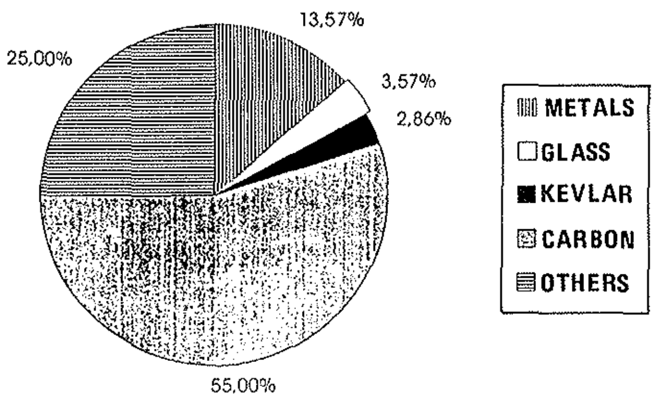

Figure 26- Materials distribution

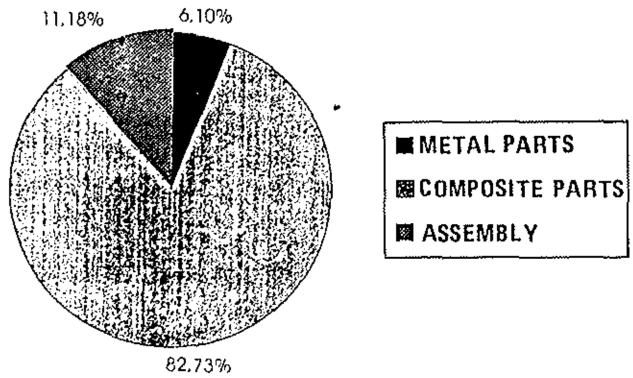

Figure 27- Costs distribution

$\Delta M/M_o$	(WEIGHT)	- 12 %
$\Delta C/C_o$	(COST)	+ 6 %
$\Delta N/N_o$	(NUMBER OF COMPONENTS)	- 50 %
$\Delta F/F_o$	(NUMBER OF FASTENERS)	- 80 %
INDEX "0"= METAL REFERENCE		

Figure 28- Technology comparison

Though a small cost penalty is apparent at this stage of the development and design, it is acceptable for production in a military program because of the weight savings.

6. CONCLUSIONS

The Helicopter Division's ongoing research effort over the past few years has generated a sound knowledge base permitting a growing and low risk utilization of composites in primary structures, in particular in the Tiger and AS332 MKII programs.

The research was focused primarily on medium (4-6T) and heavy (8-10T) helicopters whose exchange rate (acceptable cost per kilogram saved) is the most promising for the introduction of composite technologies, which is all the more applicable for military aircraft.

It was found that the application of composites in fuselages generally costs more than a metal baseline structure even though certain processes are automated. To a large extent this is due to the cost of materials, a factor over which we have little control.

This is a new cost situation compared to past 1970-1980 applications such as blades, hubs and secondary structures. In fact the reasons for this must be inherent in the type of part, in the more severe operating conditions, in the changing regulations and sometimes in underestimates.

The research into cutting the material, fabrication and inspection costs must therefore be continued, particularly because future applications are likely to occur in the civil market where cost is a crucial factor.

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LIST OF SYMBOLS

E	Young modulus
G	Coulomb modulus
D	Damping
T_g	Glass transition temperature
G_{1c}	Resin toughness