ABSTRACT

Development of Advanced Composites Technology for India's Light Combat Aircraft

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1.0 This case study covers the development of advanced composites technology for realization of India's Light Combat Aircraft, a fourth generation fighter. Use of advanced composites has helped in realizing an aircraft that is small, light, cost effective and easily manufacturable. This technology helped in reducing part count, reducing cycle time, enhance fatigue life and improve the case of upgradability. This technology which was developed at R&D Labs and academic institutions was successfully transferred to industry for regular production of airframe structure of Light Combat Aircraft.

2.0 The Light Combat Aircraft (LCA), is a multi-role Fighter Aircraft designed to meet the needs of the Indian Air Force for 21st century. It is the smallest aircraft in its class amongst the contemporary aircraft. The aircraft has basically unstable configuration controlled at all times by a fly-by-wire control system. The stringent flight performance requirements, the small size and a multi role function have resulted in a complex set of requirements on the airframe structure: complex and severe loading patterns, thin aerofoil delta wing with aeroelastic qualities, minimum loss of efficiency in control surfaces, etc. Moreover, the structure has to meet the durability requirements and provide access for easy maintenance of equipment. In order to meet these demands, it is necessary to have materials with high specific strength and stiffness which can take complex shapes easily. The aircraft being a fatigue-prone structure the fatigue resistance of the material became a significant parameter for choice of materials. The use of composites in LCA has been motivated largely by such considerations.

3.0 LCA structure and composites

The composites – in particular, the advanced fibre reinforced composites using carbon or aramid fibres in polymer matrices – offered several of these features as given below:

- Light weight due to high specific strength and stiffness
- Fatigue resistance and corrosion resistance
- Capability for high-degree of optimization: tailoring the directional strength and stiffness

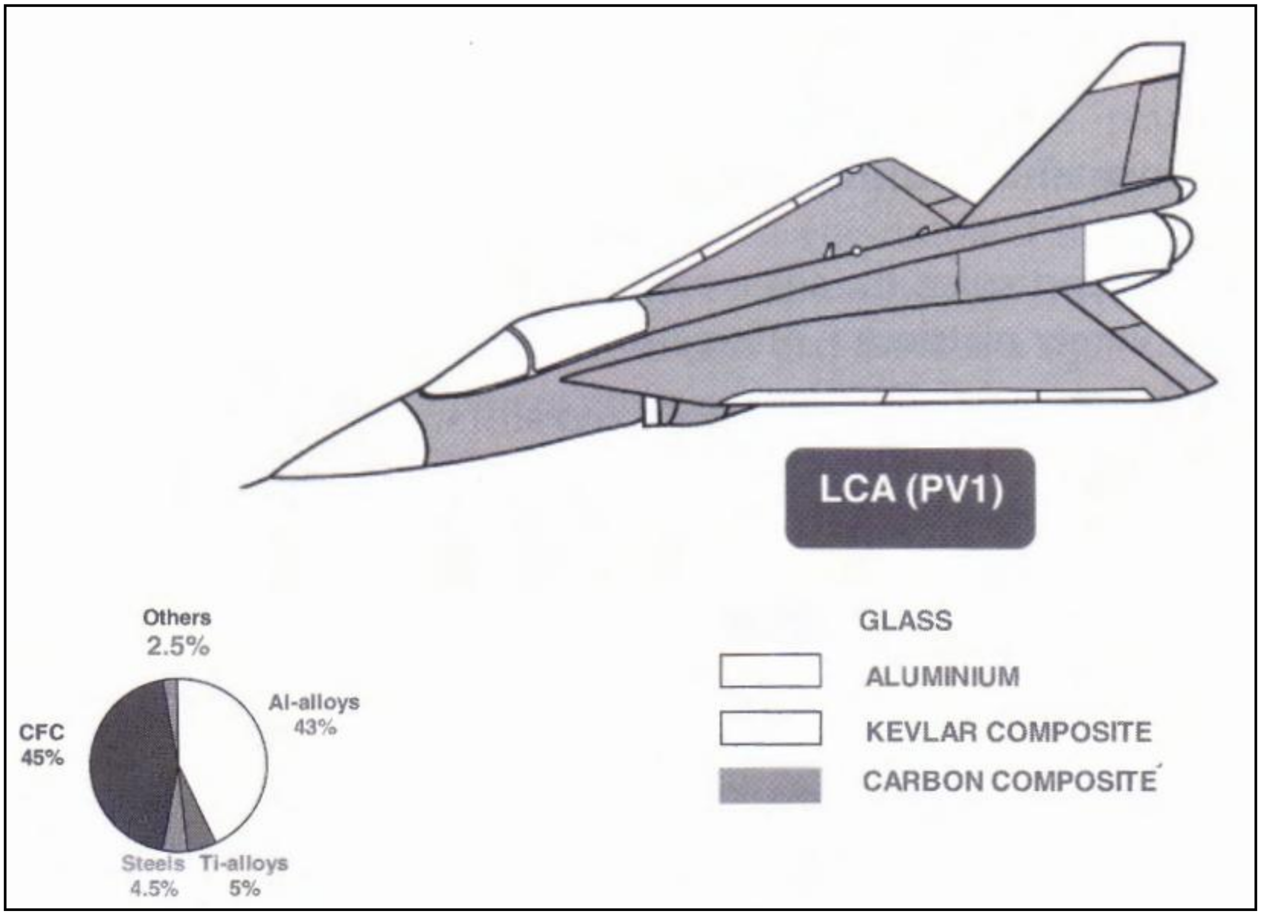
- Capability of moulding large complex shapes in small cycle time reducing part count and assembly times
- Possibility of low dielectric loss in radar transparency
- Possibility achieving low radar cross section.

These composites materials also had some inherent weaknesses:

- Laminated structure with a weak interface resulting in poor resistance to out-of-plane tensile loads
- Susceptibility to damage by impact and strong possibility of internal damage going unnoticed
- Moisture absorption and consequent degradation of high temperature performance
- Multiplicity of possible manufacturing defects and significant variability in material properties

Even after accepting these weaknesses, the projected benefits were significant and almost half of the airframe (by weight) has been built in composites as highlighted in Figure 1. All this was, of course, not without its share of hassles. The challenges of using composites on such a large scale were many. The composites were not only new but also non-conventional: they were anisotropic, inhomogeneous, had different fabrication and working methods and also different controls for quality assurance. They had a complex material behaviour under load requiring new and complicated analysis tools. Moreover, the behaviour was not always predictable by analysis and this made reliance on several expensive and time-consuming tests unavoidable. There was also a large gap in both design and fabrication technology: even though composites were being made in the country for some space applications or for non-structural or secondary applications in aircraft, the technology for fabrication of load bearing structures in composite materials with service temperatures beyond 80^0C was non-existent. Further, the lack of infrastructure in terms of facilities and trained manpower indicated a time-consuming process of learning and development before putting the technology to use. The challenge was, therefore, as much organizational and managerial as technical and technological.

Fig.1: **The LCA and composite components. The pie chart shows the use of composites vis-à-vis other materials**



4.0 Various composite components of LCA are listed in Table 1. Some of the significant details and features of technology in individual components are also given in this table.

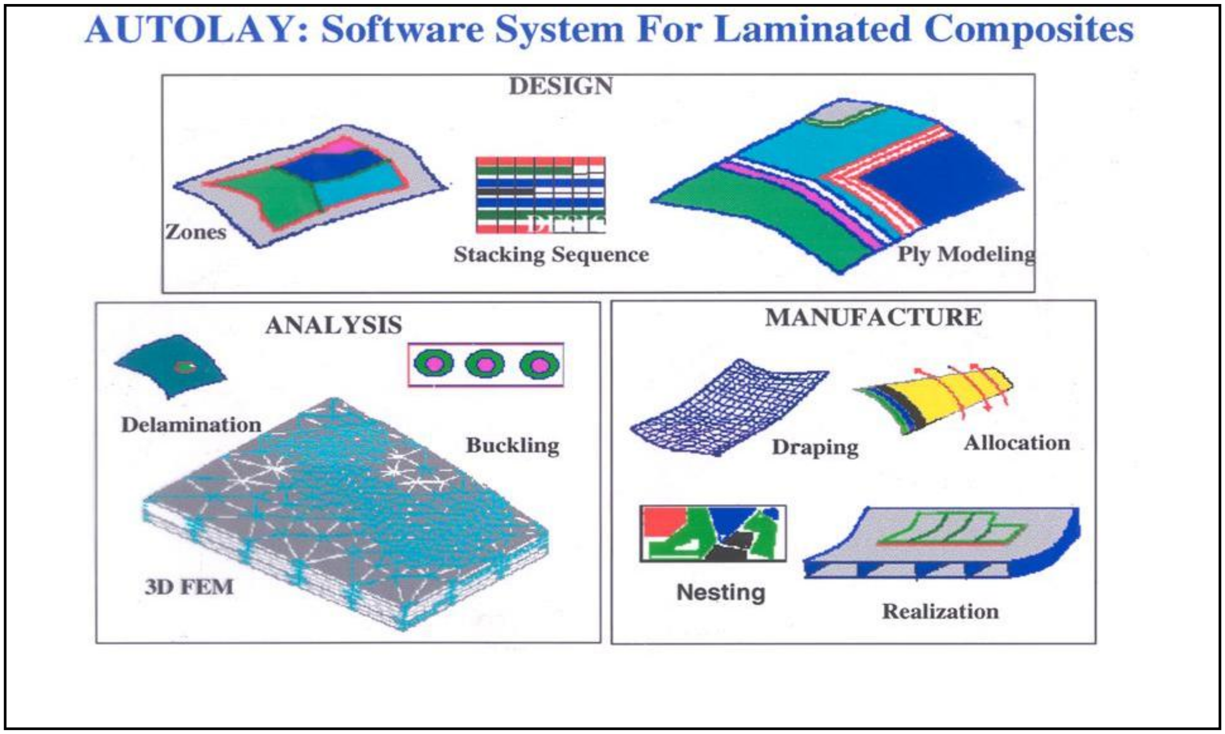
Table 1: **Composite components in LCA**

Component and material	**Special features**		
	Geometric	**Design**	**Process/fabrication**
1 Wing - Skins 2 (C – Epoxy)	2.5 m X 4.5 m. About 50 zones of thickness and lay-up variation	Use of AUTOLAY Software for optimized lay-up design	Autoclave moulding: Metallic tooling
- Spars B (C – Epoxy)	C – Section; 0.5 m to 1.6 length with twist and change of section	Use of woven reinforcement for good drapability	Composite tooling use of AUTOLAY for surface development
C Assembly	Fastened assembly using special bolts	Accurate jigs	Drilling of 6000 holes to match. Match between spars and skin. Sealing
2 Fin - Torque Box (C – Epoxy)	2 m X 1.2 m box with spars and ribs of varying depth	Co-cured construction. Fasteners eliminated	Composite tooling with expandable elastomeric mandrels
3 Rudder - I S Box A (C – Epoxy)	1.2 m X 0.25 m	Co-cured construction	Composite tooling with expandable elastomeric mandrels
- Aft Box B (C – Epoxy, nomex)	1.2 m X 0.25 m	Sandwich construction	Adhesive bonding in autoclave
4 Elevons - I X Box A (C – Epoxy)	1.8 m X 0.5 m	Co-cured construction	Metallic tooling with expandable metallic mandrels
- Aft Box B (C – Epoxy, nomex)	1.8 m X 0.5 m	Sandwich construction	Adhesive bonding in autoclave
5 Radome shell - (Aramid polyester)	Contoured conical shell; base diameter 1.3 m, length 2.2 m	Thickness decided by electrical consideration. Close tolerance on thickness required	Matched-die moulding with contour-woven socks and wet lay-up
6 Engine bay door - (C – Epoxy, nomex)	2 m X 1.4 m curved part	Sandwich construction. Removable structural member. High temp requirement near	Adhesive bonding in autoclave

		engine	
7 U/C bay door - (C – Epoxy, nomex)	Various sizes and complex shapes	Integrity stiffened panel. Removable structural members	Co-curing for integrally stiffened panel
8 Various panels, hatch-doors etc.	Various sizes and shapes about 40	Mostly sandwich construction	Adhesive bonding in autoclave
9 Fuselage A stiffened skins	1 m X 2 m with cross stiffeners, curvature and cut-outs	Co-cured co-bonded construction; optimized for buckling	Composite tooling with core autoclave moulding
B Frames	1 m X 1 m baffle-like contoured	Co-cured co-bonded construction	Composite tooling with core autoclave moulding

5.0 To enable efficient design of composite parts, the design team developed specialized CAD/CAE/CAM tools that enabled efficient design of complex parts such as wing skin. Fig. 2 provides the key capabilities of this software named AUTOLAY.

Fig. 2: **AUTOLAY**



This software was later commercialized. After necessary customization, this software was used by companies such as Airbus. Later this software package was transferred to Infosys for further commercial exploitation.

In addition to development of CAD/CAE/CAM tools, the labs which participated in the programme, also developed specialized autoclaves and NDT equipment. National Aerospace Labs developed the Autoclave to make the wing skins. The lab has transferred the technology of making autoclaves to the industry for further commercial exploitation.

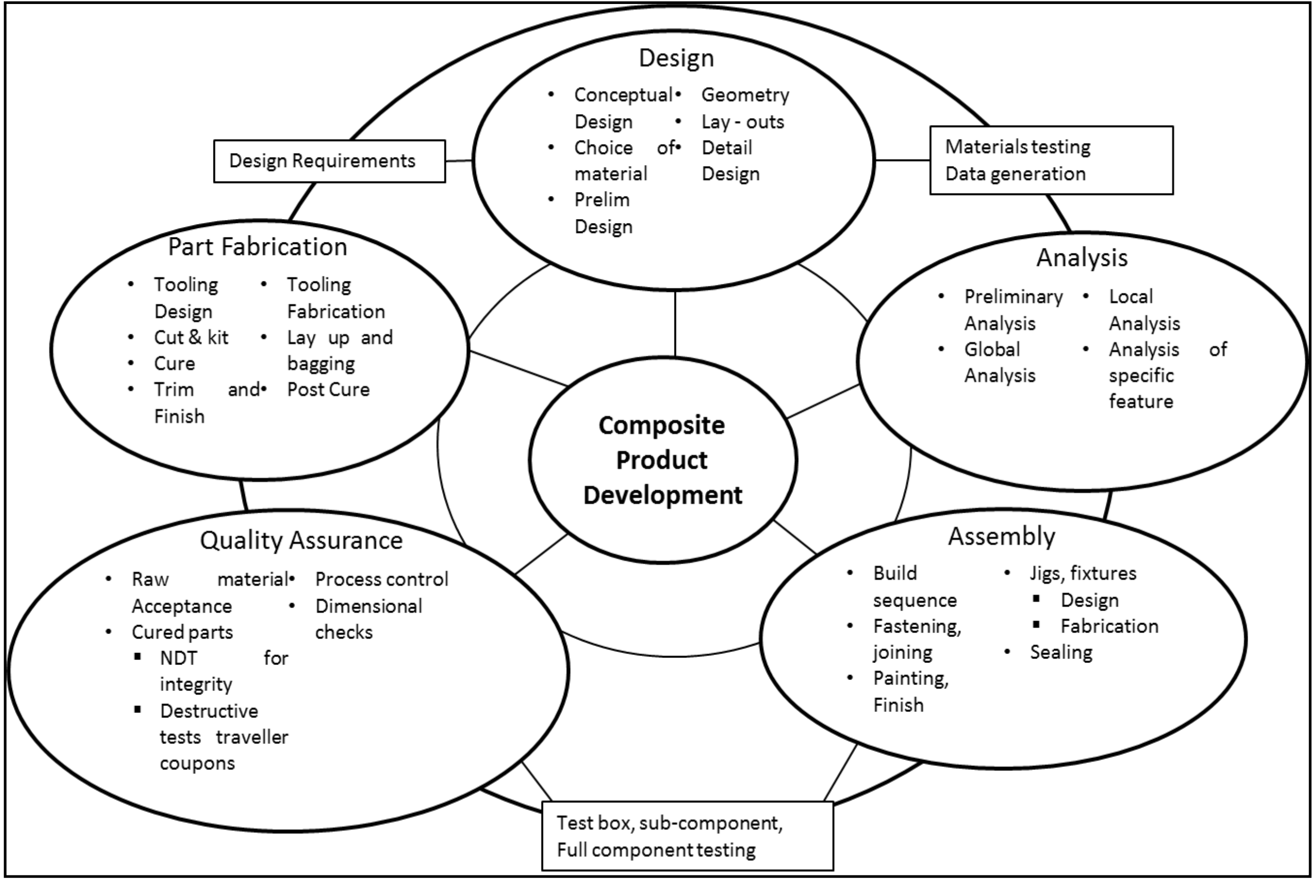
Centre for Artificial Intelligence and Robotics (CAIR) developed a large sized gantry based C-scan equipment for inspection of the composite skins.

Fig. 3: C-SCAN 5 AXIS GANTRY ROBOT

This equipment has been positioned at Hindustan Aeronautics Limited and is in regular use for production of composite skins.

6.0 As stated the major parts of the wing, all the control surfaces, vertical tail, doors, fuselage frames, fuselage skins, radome were developed using advanced composite materials. This involved finalizing design requirements, selection of materials, detailed design and analysis, development of fabrication technologies, development of NDT technologies, design validation and airworthiness certification. The tasks involved are shown below.

Various tasks and activities involved in composite product development



7.0 . Composites manufacturing technology was transferred to Hindustan Aeronautics Ltd and Tata Advance Materials ltd. The Autoclave technology has been transferred to Industry which is already supplying a range of autoclaves to various customers. The AUTOLAY software after due customization is already being used by customers such as Airbus. The 5 Axis C-Scan robot equipment is in regular at Hindustan Aeronautics ltd for quality control of Wing skins. The composites technology development and transfer to industry is a success story .