PAPER Nr.: 72

Advances in composite manufacturing of heli components

–Impacts on factory installations and methods–

by

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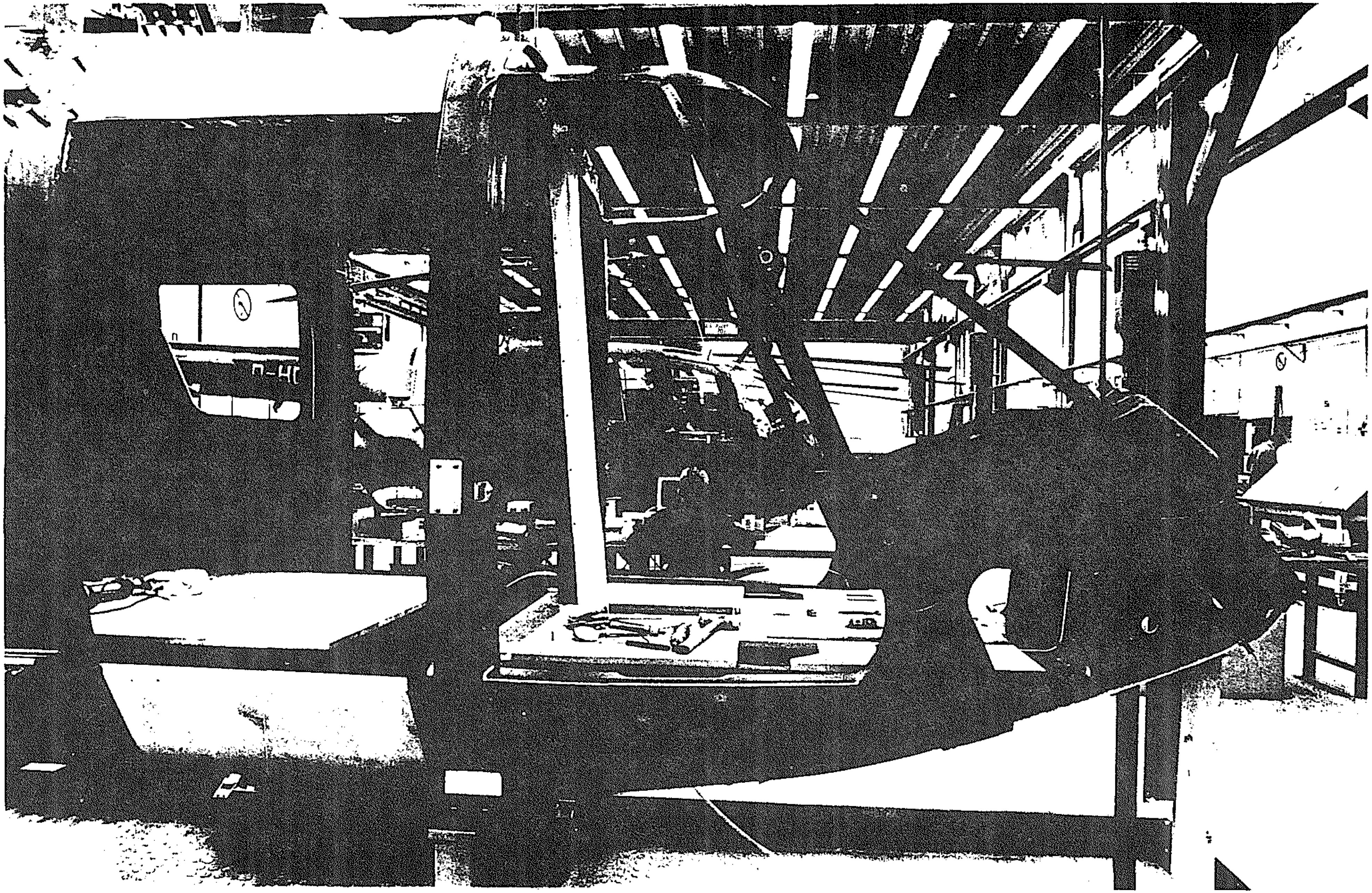
SEPTEMBER 12 - 15, 1989 AMSTERDAM

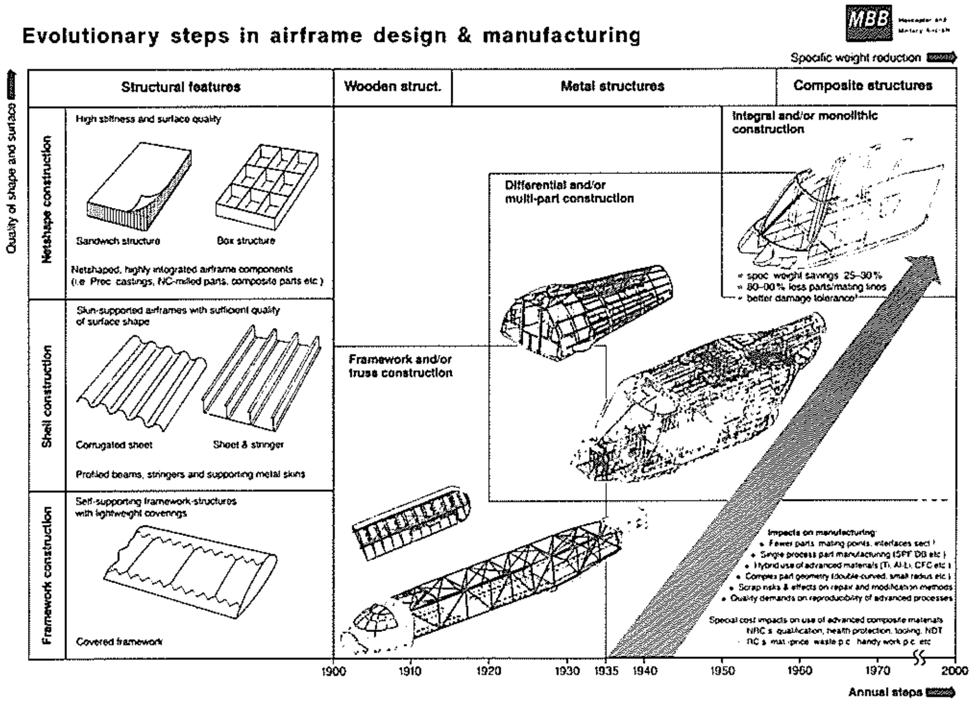
Advances in composite manufacturing



Experimental Shop, Ottobrunn 05.30.1989

In the past, airframe manufacturers and subcontractors throughout the world have spent considerable time and financial resources on developing advanced manufacturing facilities and techniques for composite structures. An extensive selection of technologies is available today, and the approaches even within my own company differ widely according to the field of application as well as to load and performance specifications. (Fig. 1)

fig. 1



Encouraged by the successful introduction of advanced composites in the production of rotor blades more than 25 years ago, the evolution of airframes followed the path towards lightweight fuselages in composite design.

Today it is known that one can best save on specific weight in the case of highly loaded structures with only a few load introduction areas and insert bridges by using a sandwich design made of advanced composites. For medium loaded structures or fuselages with many load introduction areas, hand holes, edges etc. the box-type construction may be the more efficient composite solution. Both solutions are normally highly integrated and sometimes even manufactured in one shot, that is to say, with a minimum of process cycles.

This brings me to a basic question on future manufacturing technology. Who or what is going to be the future workmate in the composite shop ? (Fig. 2)

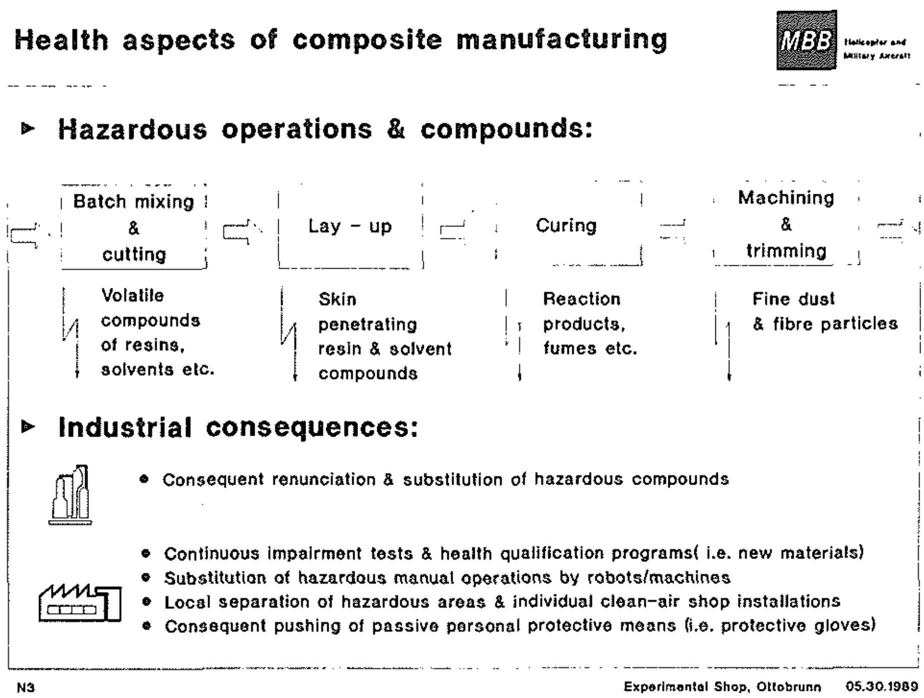
fig. 2

Will it be a robot or maybe a workmate in protective clothing or just a normal craftsman ?
To answer this question, we have to analyse the manufacturing process in two aspects:

The first aspect is : Health impairment
The second aspect is : Cost effiency

In planning a lay-out for a composite plant we have to be thoroughly aware of potential health risks involved in storing, handling and processing composite materials. (Fig. 3)

fig. 3



Although the chemical industry strictly bans and replaces any known hazardous compound out of its mfr. program, there will still remain a considerable risk that existing or future compounds may be declared to be health impairing, or even worse, carcinogenic.
This is partly due to the diversity of materials with low purchase quantities in the airframe industry and to the less comprehensive impairing tests of advanced materials compared for example to the automobile industry. Once a material in aerospace industry has been qualified and established in a program, a complete substitution will last at least 3 years. (Fig. 4)

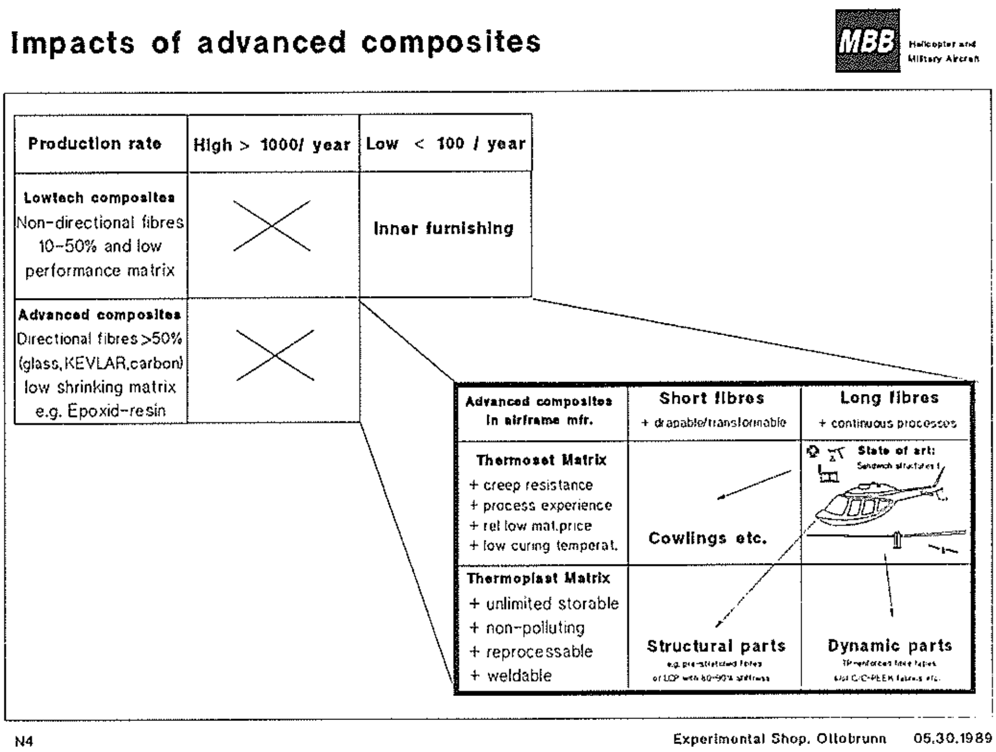


fig. 4

The introduction of long fibre composites and epoxy based adhesives in the production of helicopters changed the mechanical manufacturing process into a chemical and physical manufacturing process with considerable shop floor investments. These investments were to ban any remaining health risk contained in handling advanced composites based on thermoset resin systems. Modern composites plants usually consist of dislocated mfr. areas with specific clean-air or suction systems for all kinds of volatile resin compounds as well as fibre particles.

Within the processing industry we have learned to take the so-called "subacute" exposure to resin systems, solvents, fine dust particles etc. as serious.
Today we all know that the careless exposure to these materials, for instance by prepreg lay-up without protective gloves, may cause allergic reactions, eczemas or even worse acute itching rash.
Such symptoms normally subside when the correct use of protective measures both for the exposed operators as well as for the working areas is re-established. Special attention has to be paid to providing the operators in the composite shop with comprehensive health information and education on the correct and safe use of thermoset materials. (Fig. 5)

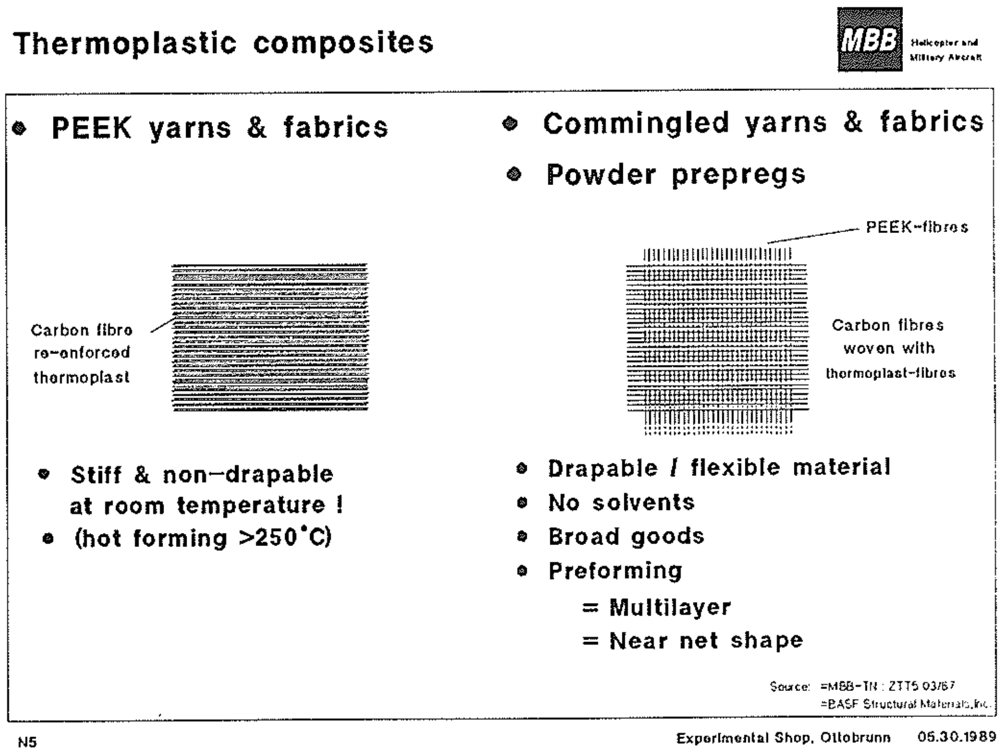
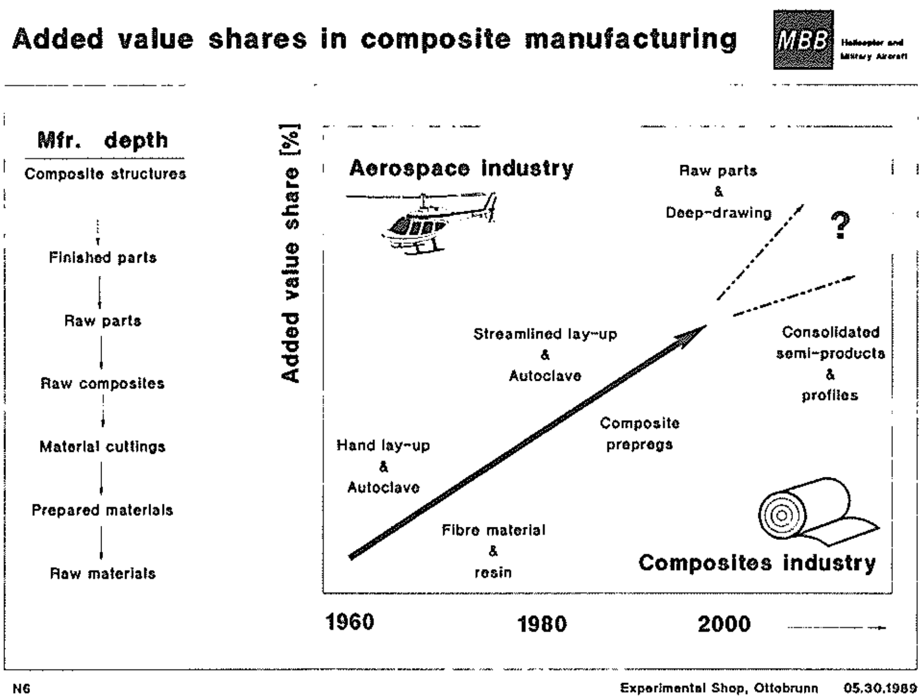


fig. 5

Although today the use of fibre reinforced thermoplasts in the helicopter industry is still in the stage of feasibility studies, we should closely observe the development of price and performance of these nonpolluting new composites. Safer thermoplastic materials with sufficient lay-up characteristics at room temperature may soon be available for manufacturing.
The prepregs on the right side of this figure already fulfill the drapability specification at room temperature and may be a promising approach to health safety in composite manufacturing. (Fig. 6)

fig. 6



With respect to the high cost implications of qualification programs for advanced materials, cooperation between partners in international airframe programs as well as in the composites industry has to be as close as possible.
Both the chemistry and aerospace industries have to be aware of the increasing cost risks involved, depending on the degree of their engagement in advanced materials.

Expensive material qualification programs as well as considerable plant investments for health and environment protection have been the admission charge to a new technology. Now we have to make sure that this financial burden will be paid back by a cost-effective and streamlined production line. Comparing recurring costs in the aerospace industry, we must carefully analyse the variety of materials and existing structural design solutions in composite production. (Fig. 7)

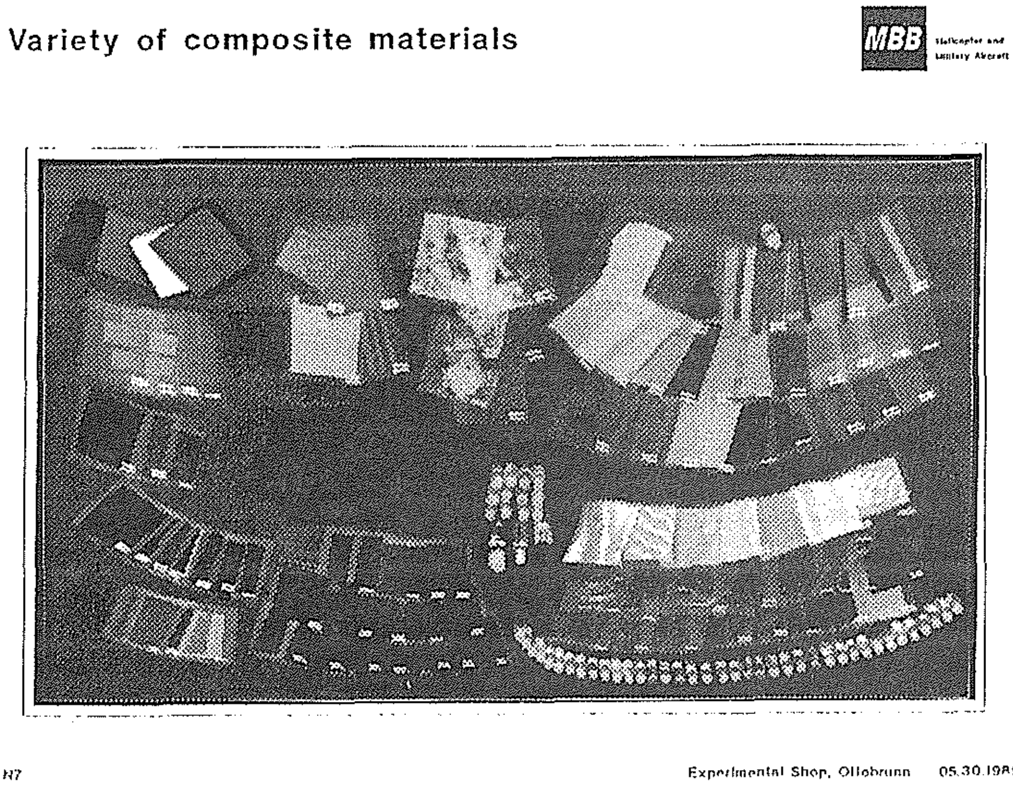
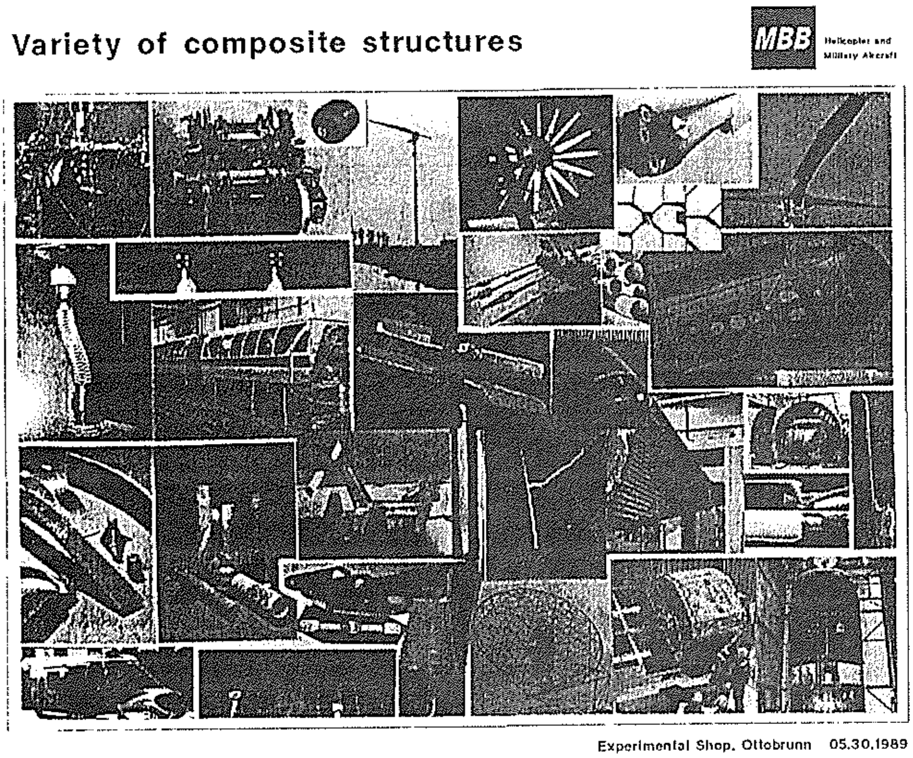


fig. 7

Today, we are able to handle and process nearly any combination of different materials such as fibres, resins, prepregs, foams, honeycombs etc. Prices, however, differ up to a factor of 30 even within one material group, as does for example the group of unidirectional carbon-prepregs which is mainly dependend upon the young's modulus ! Lot size, amount of scrap material, expiration date etc. are further factors that make it difficult to compare material costs.

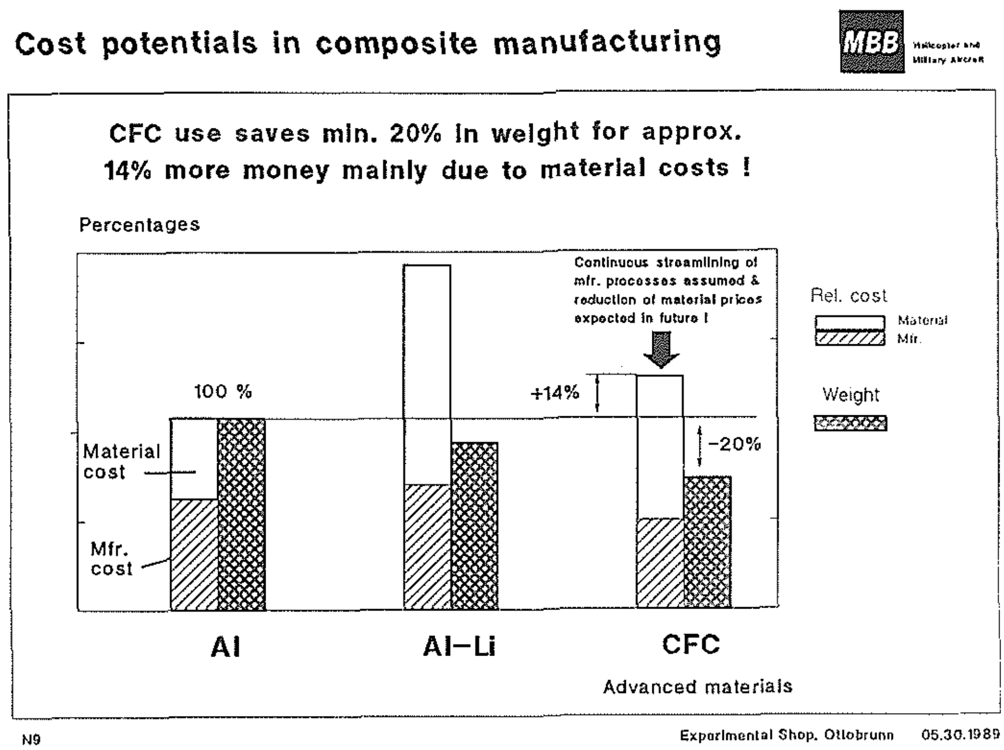
Concerning mfr. costs and manhours, the complexity and variety of design solutions in the aerospace industry make it even more difficult to judge according to a general yard stick. (Fig. 8)

fig. 8



This figure should give a slight impression of the nearly unlimited possibilities in design and functional performances one can achieve by using advanced composites. Calculations of mfr. costs, however, depend upon the individual process chain of these components and cannot normally be compared to each other. (Fig. 9)

fig. 9



After this introduction, I would like to compare the production-cost calculation of identical structures both in metal (here: Aluminium alloy) and carbon fibre reinforced plastic. According to this calculation, we have to assume that a light-weight structure made with carbon fibres is still more expensive today, mainly due to the high material prices.

We expect, however, that the price for advanced composites will become more competitive in the next decade, partly due to the higher purchase quantities of the cooperating airframe industries. Furthermore we may assume that material waste will be minimized by means of better nesting programs for computer-controlled cutting machines, batch manufacturing of cuttings, modular cutting, structured Mylar films etc.

There is still the question of the portion of the recurring cost, which is a challenge for the mfr. engineer. By this I mean the cost potentials in the composite shop or the manhour potentials. (Fig. 10)

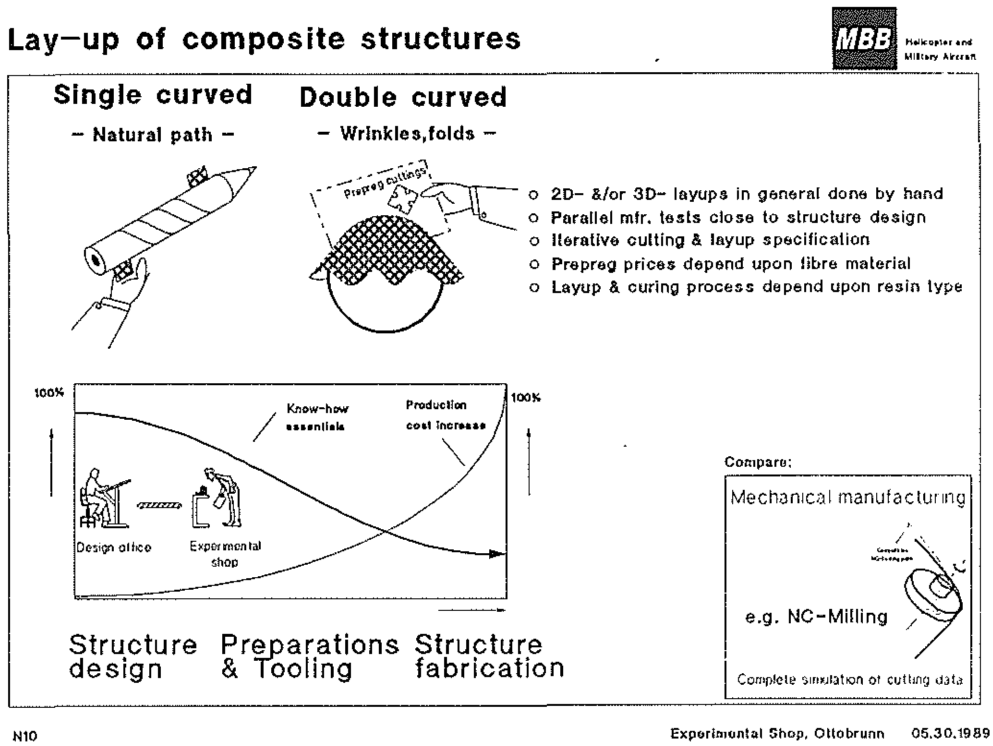


fig. 10

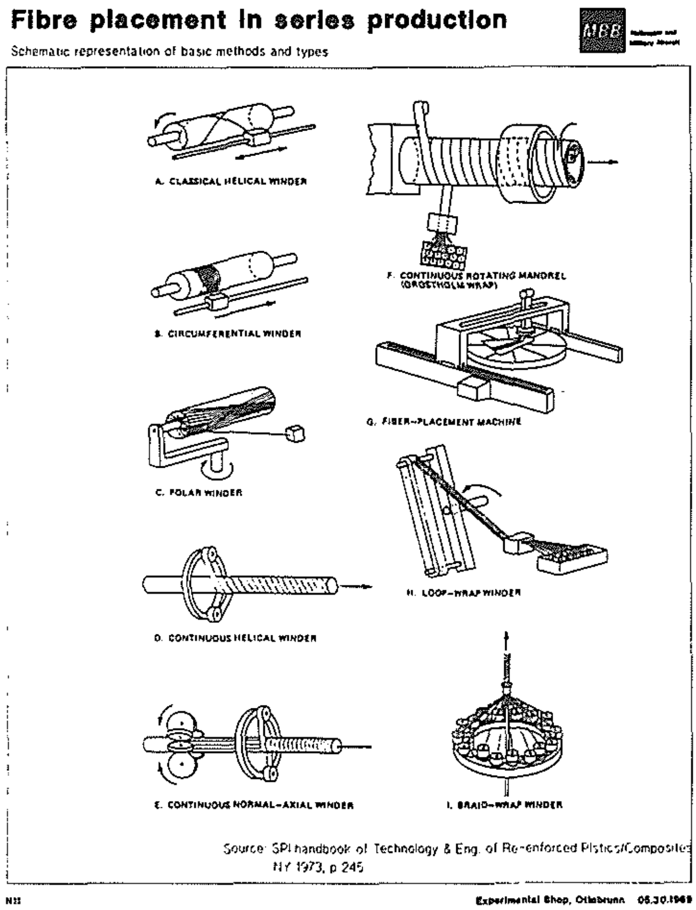
The core operation of composites manufacturing is very similar to an assembly process, where different parts have to be positioned and fixed in a given orientation.
As you probably remember, this lay-up of fabric-cuttings cannot be completely simulated on drawing boards or design screens if the loft or surface of the composite parts is curved.
Furthermore, the draping of a flat cutting on a curved surface will follow a natural path and will eventually fall in folds.

Two consequences may be derived from this complex operation:

1) Cutting and lay-up drawings for composite mfr. can only be optimized by parallel mfr. tests in a nearby experimental shop. This is also valid in spite of improved 3D-computer aided design tools.

2) Even with optimal design data, the lay-up process of broadgood cuttings on double curved surfaces or along restricted corners will not be completely mastered by usual automatization approaches in series production. Unfortunately this lay-up work might have to be primarily performed by hand in the near future !

fig. 11

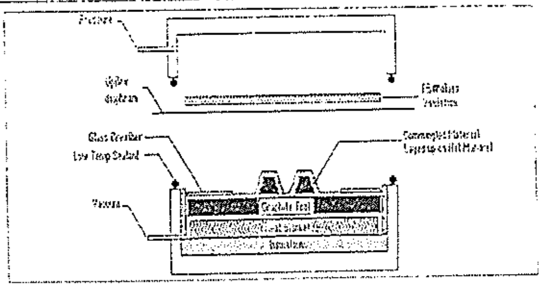


This figure shows well known methods and types of mechanical fibre placement in composites manufacturing. What all these kinematic solutions have in common is that we have a continous lay-up process with endless rovings or tapes and that they can be profitably used to manufacture flat or convex parts with closed surfaces.

The support of machines, however, for the fabrication of concave lay-ups in negative-moulds, double curved structures full of corners as well as highly integrated sandwich structures is extremely limited.
In my opinion, the lay-up work will continue to be performed by hand for most of these parts unless we succeed in developing reproducible forming processes for flat lay-ups such as hot-forming, bag moulding etc. (Fig. 12)

Heat forming

Heat mandrel :



Flexible diaphragm:

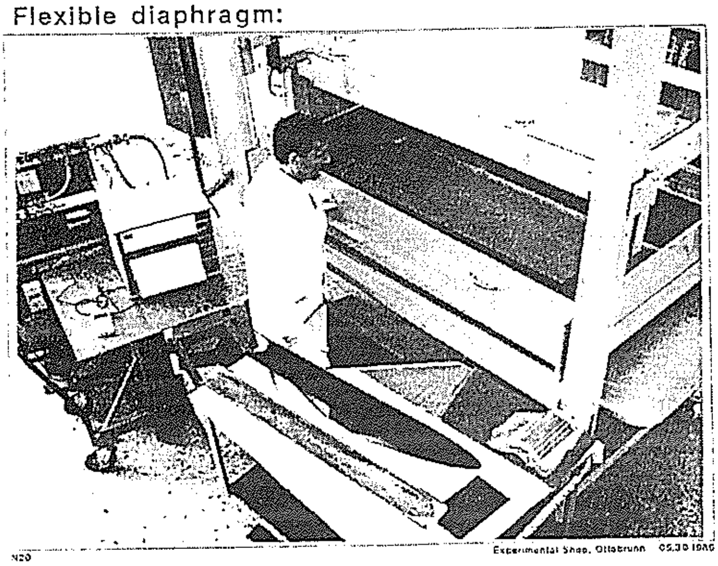


fig. 12

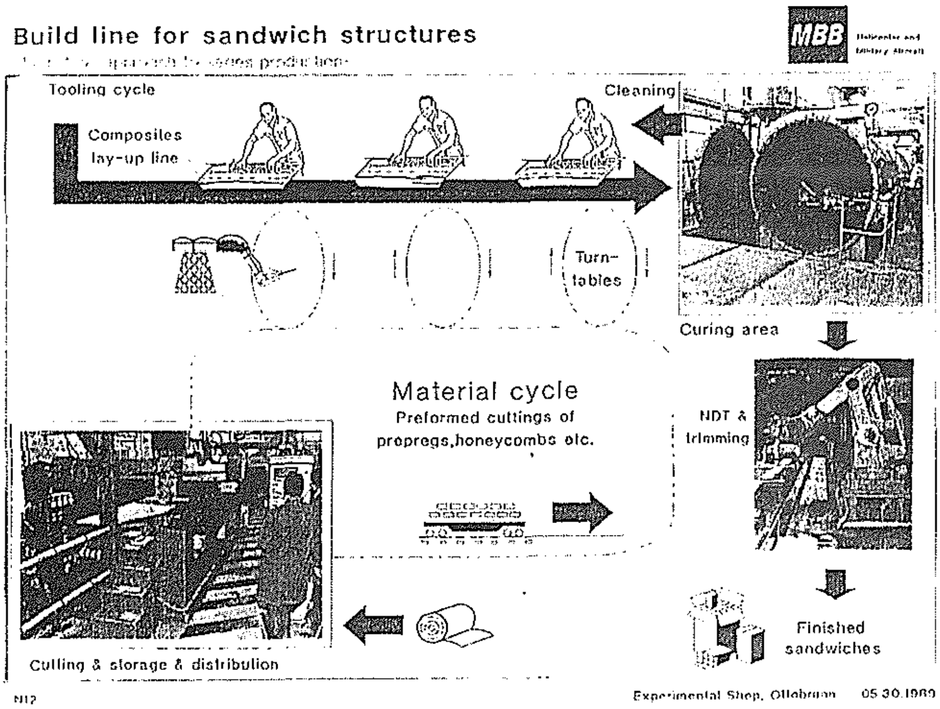
In contrast to forming and deep-drawing processes used on (isotropic-) sheet metal, tne nature of remoulding flat composite lay-ups is based on a fibre-displacement process in the softened matrix. This explains why short fibre lay-ups can easily be deep-drawn into complex surface shapes. It also explains why remoulding of long-fibre reinforced thermoset lay-ups is generally limited to a preforming operation used to gain a rough formed, bi-stage part.

Endshape forming and final curing still need the autoclave process or solid mouldings with complex pressure tools.

I am afraid that this process chain will stay the usual technology for the reproducible manufacturing of composite structures based on long-fibre reinforced thermosets.

But even for this conventional process chain we can streamline our shop organization with respect to the many provisioning and distribution operations involved or in general in respect to indirect times. (Fig. 13)

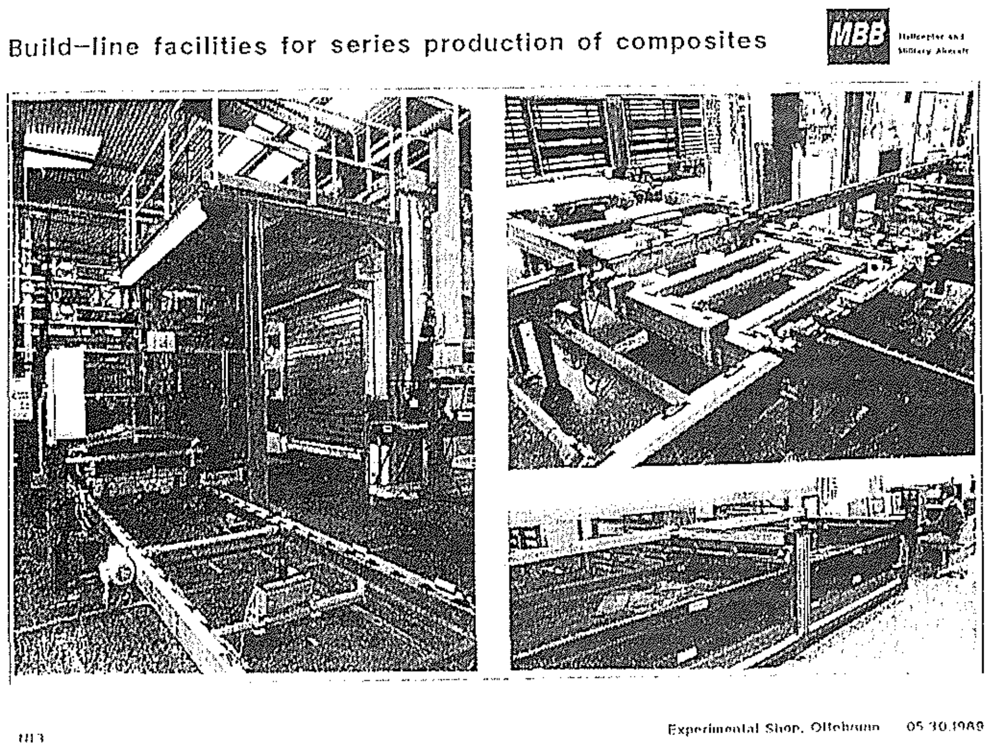
fig. 13



Here a schematic representation of a build-line for sandwich structures is shown, which allows a high division of labor and sufficient flexibility in the case of frequently changing batches. Cutting and preforming honeycombs and prepregs is done in batches in specific mfr. areas, which are then stored, ready to be available on order call.

The next figure shows some plant photos with details of the tooling circle and material distribution area next to the cold-storage depot of prepreg cuttings. (Fig. 14)

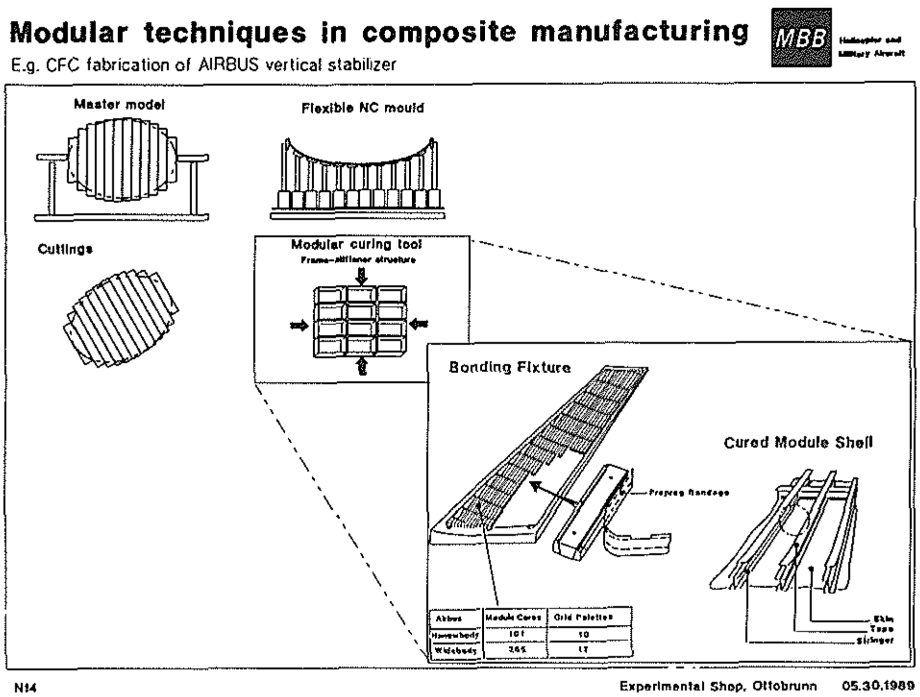
fig. 14



I should emphasize that this kind of investment only pays off if a reasonable series production of composites components is taken as a basis. New shop lay-outs, however, can be planned according to the expected logistical demands.

The last cost potential I would like to mention here concerns the aspect of standardization or specification of part families as well as functional modules. (Fig. 15)

fig. 15



I assume that we all know the modular or unit construction principle very well from many designs of structures and equipment both in aerospace products as well as in tooling. Regarding the variety of composite structures and toolings, however, I feel that this idea should be taken up again by the production engineers.
A consistent translation of this principle into a composites structure is, for instance, the carbon fibre structure of the Airbus vertical stabilizer.

In this case, the frame-stringer structure was divided into modular structural boxes, which can be manufactured separately and then bonded together in one shot. The economic benefits are mainly due to the limitation of cutting shapes, tool-modules, shop operations etc. while the production lead-time can be reduced by the high degree of parallel pre-fabrication of structural modules.

Before I run out of time, let me briefly come back to the opening question of the future employee in the composite shop. Advanced composite materials represent nearly unlimited possibilities in the design of lightweight structures.
The variety and complexity of today's aerospace structures is a reflection of the many degrees of freedom in design that the airframe engineers have been offered by these materials.

Even the hard-line advocates of standardization won't argue about the benefits of individual lightweight and functional designs. They may, however, suggest that, if possible, a minor cut in performance or weight can be profitable for the series production in the sense that the limitation to 90 % of the technical optimum may eventually save 20 up 25 % of the manufacturing cost.

In any case, in the near future, composites shop work will remain a skilled manual-craft, at least in the core operation, that is to say, the lay-up of broadgood cuttings.
The peripheral areas, however, ranging from cutting to non-destructive testing, will be consistently streamlined and automated. Hopefully, new materials will allow us to throw away the protective gloves and substitute manual draping with forming processes based on flat lay-ups, or even with consolidated profiles and semi products.

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