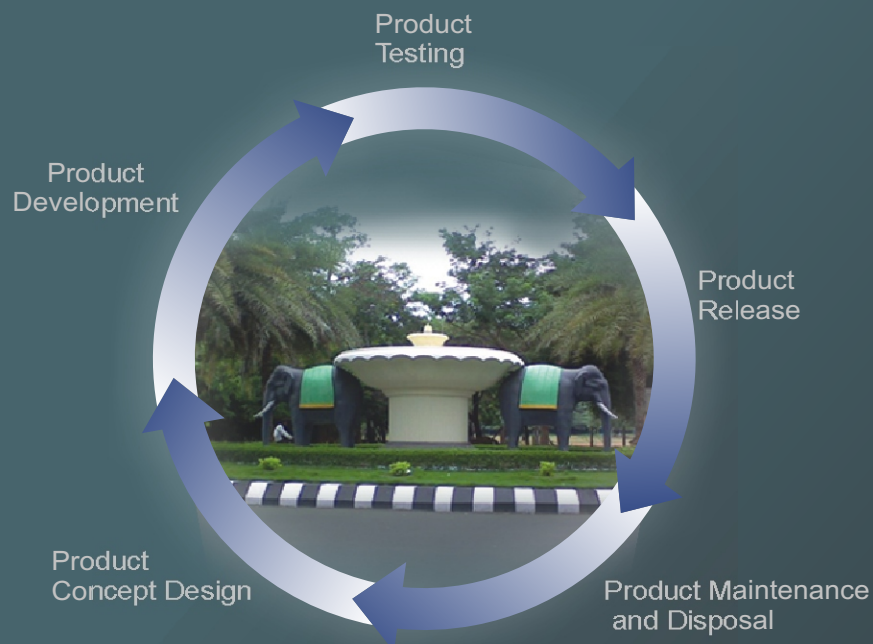


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NPDC 2009

New Product Development : Challenges in Meltdown Times



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L.S.Ganesh
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PREFACE

The International Conference on *New Product Development :Challenges in Meltdown Times* (NPDC 09) is being organized at a time when the world is wondering whether it has gone past the worst of the economic slowdown experienced by most countries, particularly by those in its developed parts. In our wisdom we have observed that it is in such meltdown times that NPD ought to be given prime importance to kindle hopes of economic recovery and stabilized prosperity. Such economically stressful times also pose the greatest challenge to NPD professionals to expand their creative capabilities to bring forth new products that push the limits of balancing the requirements of Design for X, Cost Optimization, Eco- friendly design and realizing customer delight. It is necessary to motivate and improve the effectiveness of NPD professionals by introducing them to the state of art in New Product Development covering the changing role of People, Process and Technology and the best practices in Product Innovation.

The Proceedings of this Conference contains keynote speeches and papers presented by distinguished researchers and practitioners working in institutions and industrial/business organizations all over the world. The papers reflect the current experiences, challenges, concerns, methodologies and solution approaches in regards NPD. The selection covers the theory, models, frameworks, concepts, contexts, cases, tools and techniques pertaining to NPD. Hopefully, an integrated understanding of their contributions to both intellectual as well as practical aspects would lead to significantly furthering the cause of NPDC 09 in these meltdown times.

We place on record our sincere thanks to our Advisory Committee members for their advice and to all the reviewers of the conference papers. Thanks are due to the sponsors, facility providers and those who were directly or indirectly involved with NPDC09 activities.

We also thank the IIT Madras authorities for their support in organizing this conference.

N. Sivaprasad

L. S. Ganesh

Message from the Chief Guest

In a truly globalized world with ever increasing competition, there is no doubt that excellence in Products and Services can make all the difference between success and failure. Global competition in Product Design has meant that on the one hand we see a very rapid convergence of ideas, technologies and tools. Yet, in this convergence, manufacturers and designers are compelled to seek out unique differences that may form the basis of sustainable competitive advantage. Hence, the motivation to sustain product innovation and uniqueness, while employing similar tools, methods and resources can form the recipe for business success. Numerous case studies have indicated how diverse factors such as culture, exposure and needs can shape the evolution of Product Design. As India's Product Design capabilities of this era begin to grow, we would be well advised to seek unique paths to achieve product differentiation and excellence.

Dr. V. Sumantran

Executive Vice Chairman,
Hinduja Automotive Ltd.

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An Approach to Skin-Stringer Construction in Composites and Their Cost Benefit Analysis

S.K.Vinod Das¹ and V.Bindu^{*}

¹Engineering and R&D Services (Aerospace)

^{*}Energy Utility and Services

¹HCL Technologies Limited, Bangalore-560100, India

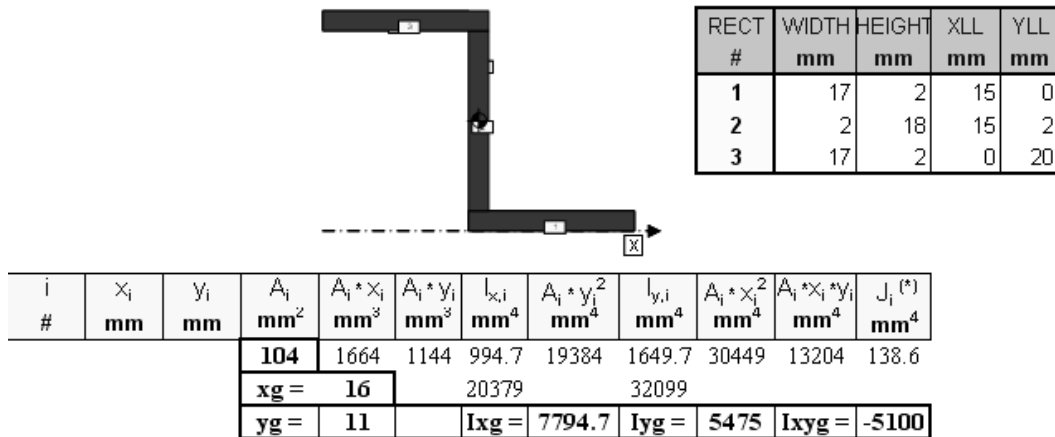
^{*}Infosys Technologies Limited, Bangalore-560100, India

Phone: +91-080-28523016, E-mail: vinoddhas@yahoo.co.in

Abstract

Skin-Stringer construction using composites are increasingly being used in the primary structures to provide structural integrity to the relatively weak skin structure. One of the major failure modes of the skin in an aircraft is buckling. Stringers are often bonded together to increase the buckling strength. Skin-stringer integration for the center fuselage of a military aircraft was carried out using CATIAV5R16-composite workbench and the effective cost variants are prepared. The skin panel in the form of rolled sheets along with conventional[^] and RMTF[^] affected extruded stringers (as per NTA44650 – ASO-EN-SD01)are sandwiched for an integrated construction.

• Conventional stringer section



[^]Figure: 1 - CONVENTIONAL STRINGER

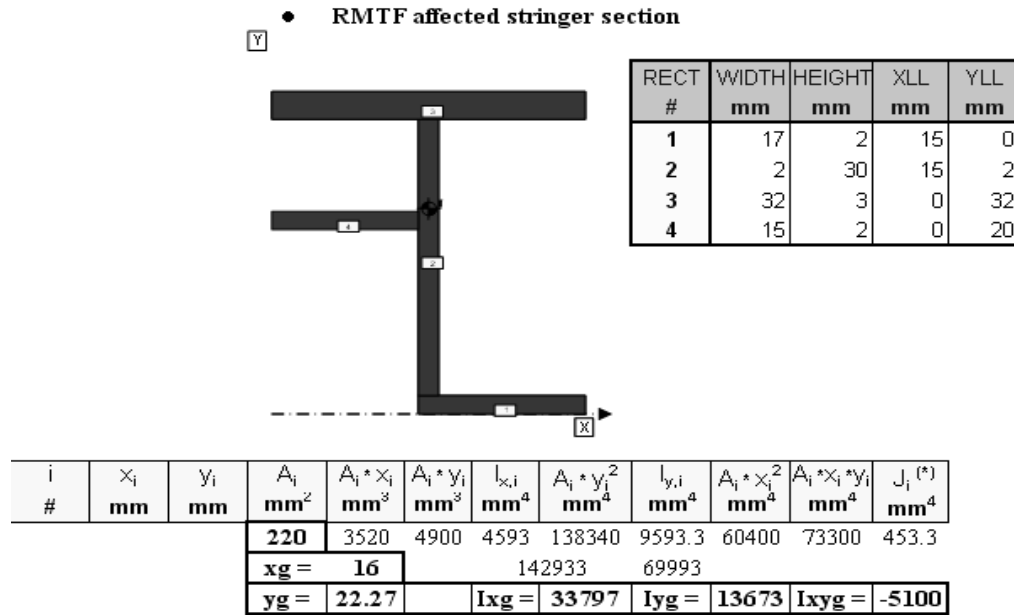


Figure: 2 – RMTF AFFECTED STRINGER

The material cost analysis for the composite center fuselage structure is carried out in comparison with the aluminium alloys and their results are compared using a tool called Cost Analysis for Fuselage (CAF).

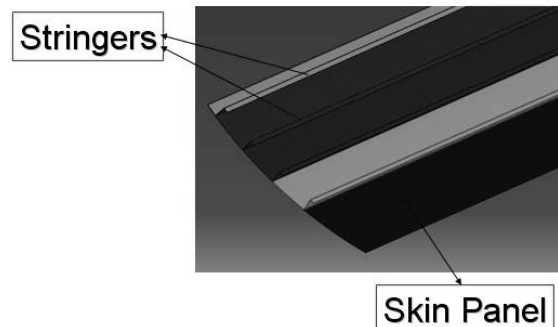


Figure: 3 – Colored zones representing the Skin-Stringer bonding

The CAF tool gets some preliminary inputs and provides an optimal cost matrix, this helps in choosing between metal and composites as affordability plays a key role in our current global scenario.

Keywords: Skin, Stringer, Composite, Center fuselage, RMTF, CAF, volume fraction.

1. Introduction

The aerospace industry's unrelenting quest to enhance the performance of its products has constantly driven to the development of improved structural materials which embarked the protrusion of composites.

[1]Airbus introduced the use of composites in 1972, in secondary structures such as the fin leading edges on the A300B. In 1982, Airbus was the first to use carbon fiber composites to make the spoilers, airbrakes, elevators and rudder on the A310-200. It was also the first manufacturer to use composites in primary structures, namely for the vertical fin of the A310-300 and the horizontal tail plane and flaps on the A320 in 1987. Several key innovations followed, including the development of a carbon- fibre keel beam for the A340-500/-600 and a composite panel on

the same aircraft. A composites text stated that, in aircraft, "composite secondary structures might save 10% [weight], but primary that composite primary structures might save more than 30%." These figures might be optimistic. Another text stated that applying composites to an existing design might save 15% weight while redesigning an aircraft around composites might save 25%.

Composites are attractive structural materials classified by the composition of the reinforcing because they provide a high strength-to-weight ratio and offer design flexibility (i.e.) change from metal to composite (multiple) materials where each individual fiber can be tuned to a particular functional requirement.

The function of a composite is to replace heavy/dense metals with stronger, lighter weight structural components, allowing lightweight aircraft to carry payloads using less fuel. Since the fibers provide the bulk of the strength and stiffness to the part, the higher volume fraction (V_f) of fibers, the lighter the part. In contrast to traditional materials of construction, these materials can be adjusted to match more efficiently to the requirements of specific applications.

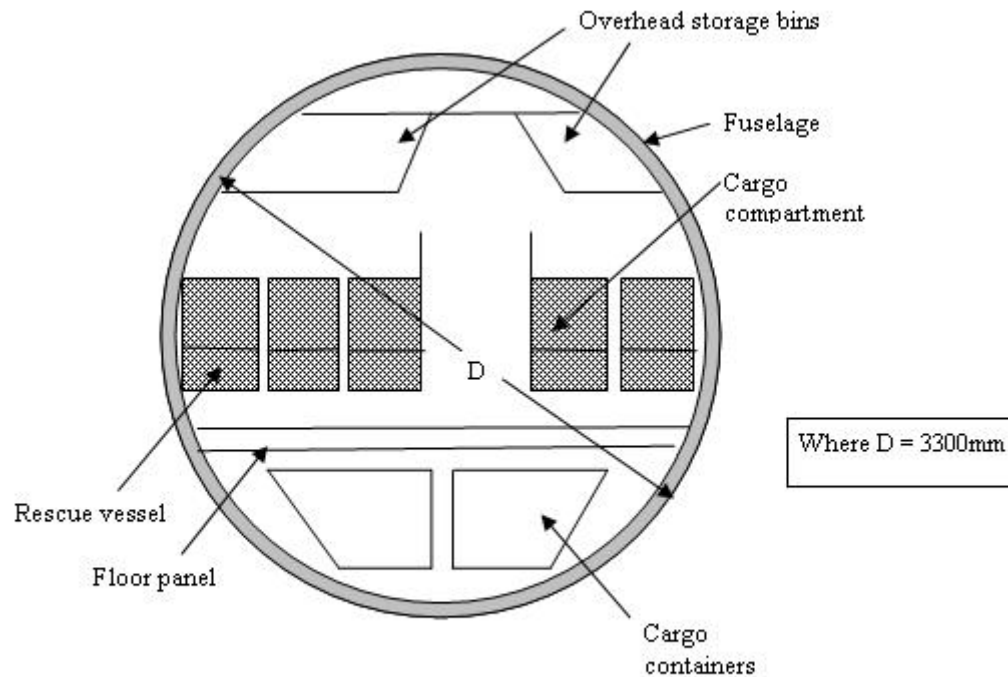


Fig.1.1 Schematic diagram of a typical fuselage cross-section

The figure 1.1 shows the line diagram of the center fuselage of a military aircraft which is taken under study.

The effect of small changes in the design can have a dramatic effect on the manufacturing cost. [3] In particular, increasing the complexity of highly repetitious operations could result in a dramatic increase in the overall time. This is the so called 'knock-on effect'. An example of this is the draping of a laminate's plies over surfaces with complex geometry.

1.1 Comparison Metrics:

Stress-Strain Curves

The stress strain curves of Carbon Fiber Reinforced Polymer (CFRP) have been experimentally shown which depends on the fibers and matrix of the composite, the interaction between the two, the direction of the load relative to the principal axes of the composite and environmental conditions. They also depend on the orientation of the fibers. The figure below shows an example of a stress-strain curve for a fiber composite, where the force was applied in the longitudinal direction (in the direction of the fibers):

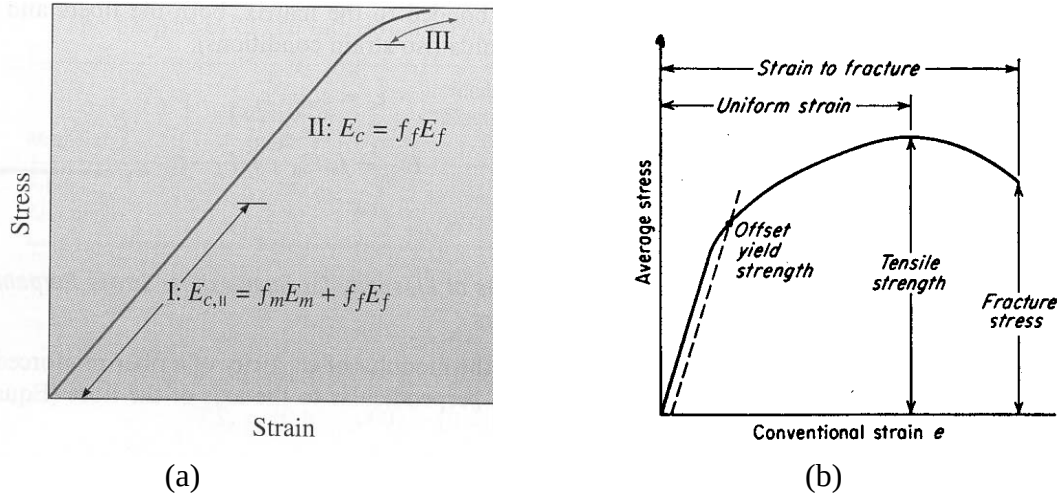


Figure 1.2: (a) Stress-Strain curves for Composite, (b) Stress-Strain curve for a Metal.
(Courtesy: Askeland, 2006, <http://www.key-to-steel.com>)

The stress-strain curve for a composite looks different from the stress-strain curve for an ordinary metal. The major difference being that the composites do not deform plastically they deform only elastically and have a higher ultimate strength than metals.

Figure 1.2 (a) divides the stress-strain curve for a fiber composite into three different regions. The first region corresponds to a linear region where the stresses are low. The second region corresponds to an area of higher stresses leading finally to the third region of fracture. If we assume that the fibers in the matrix are continuous and unidirectional, then the longitudinal modulus of elasticity of the composite (along the direction of the fibers) can be predicted using the rule of mixtures (Askeland & Phule, 2006), shown in Equation 1.1 below:

$$E_{c,||} = E_m V_m + E_f V_f \quad (1)$$

where $E_{c,||}$ is the longitudinal modulus of elasticity, E_m is the modulus of elasticity of the matrix, V_m is the volume fraction of the matrix, V_f is the volume fraction of the fibers and E_f is the modulus of elasticity of the fibers.

The volume fraction of a certain part of the composite is defined as the volume of that part divided by the total volume of the composite. Therefore, the volume fraction of the matrix is the volume of the matrix divided by the total volume of composite. However, if we assume that the composite, matrix and fiber phase lengths are all equal (Callister, 2004), then Equation 1.2 shown below holds.

$$V_m = \frac{A_m}{A_c}, V_f = \frac{A_f}{A_c} \quad (2)$$

where E_m is the modulus of elasticity of the matrix, A_m is the area of the matrix, A_c is the area of the composite, E_f is the modulus of elasticity of the fibers and A_f is the area of the fibers.

This modulus of elasticity can also be determined experimentally from the first region of Figure 1.2 (a) and is equivalent to the modulus defined in Equation 1.2. Another important parameter that can be obtained from the stress-strain curve of composites is the ultimate tensile strength. The ultimate tensile strength is the highest point on the stress-strain curve and corresponds to the point of failure. Analytically, Askeland and Phulé (2006) describe the use of the rule of mixtures to approximate the tensile strength by using Equation 1.3 below:

$$\sigma_c = \sigma_f V_f + \sigma_m V_m \quad (3)$$

where σ_c is the tensile strength of the composite, σ_f is the tensile strength of the fibers, V_f is the volume fraction of the fibers, σ_m is the tensile strength of the matrix and V_m is the volume fraction of the matrix.

2. Objective and its practical significance

Fuselage is probably most complex structure (shapes, systems, pressurization) and therefore most costly to convert to composites. An observation is done to the skin-stringer in metal and their inherent advantages in comparison to composites. The center fuselage construction is modeled in CATIA V5R16 in both Aluminium and composite for their producibility and cost factors.

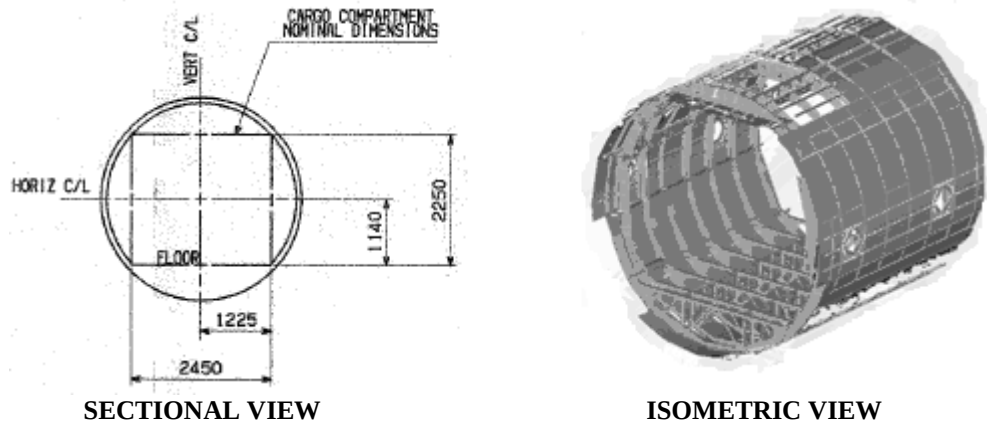


Figure: 2.1 Shows the two views of the center fuselage

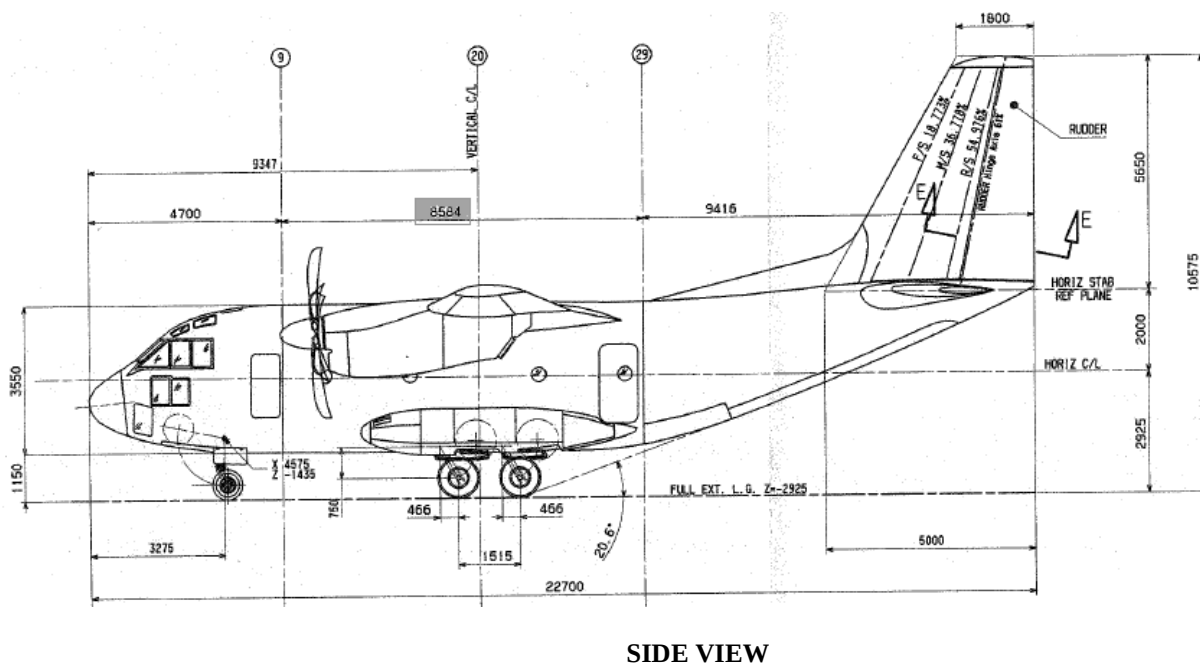


Figure: 2.2 Side view of the military aircraft with sketching dimensions.

The Figure: 2.1 section view provides an illustration of the cargo nominal sketching dimensions and the isometric view is a sample of the modeled structure in composite workbench. The highlighted portion shown in figure: 2.2 provide the dimension for the center fuselage across the horizontal axis. (i.e.) the center fuselage extends from STA (station) 9 to STA (station) 29.

2.1 Design Considerations:

Before designing the following objectives are kept as reference:

TABLE: 1

Economic Repair Life	25,000 flight hours
Crack free life	12,500 flight hours
Full stop landings	15,000 flight hours
Maximum take-off weight (MTOW)	30,500 kg
Maximum landing weight (MLW)	27,500 kg

The superiority of composites is seen when their inherent advantages are used, such as their very low assembly costs (due to the high potential for parts consolidation), and their significantly lower life-cycle costs. It is found that the cost incurred using composites are higher but when considering the “life-cycle-cost”, i.e., the cost/benefit ratio on the long run composites dominate by their higher performance commitment. With the affordability in mind a tool was developed for estimating the cost. The tool has a look and feel feature which helps in solving the possibility of converting the structure to composites in its initial phase itself.

2.2 Cost Analysis:

The fuselage carries the whole of the payload and is stressed under tension, compression, torsion, bending and pressurization forces. Most of these forces place the fuselage under tension. Thus to minimise weight and in turn cost it requires high ratios of stiffness to density and strength to density. It also requires good corrosion resistant material, high fatigue strength and low fatigue crack growth rates. The weight of the structure is important from a cost point of view, as is the aerodynamic drag, which also impacts on costs of operation. The overall shape and dimensions very much dictates the effectiveness of the design and these are in turn influenced the cost. With these prerequisite conditions the fiber and the matrix are selected. Due to the skin stringer complexity, it might require specialized manufacturing methods and hence the cost estimated might be higher. However, the skin-stringer cost can not be accurately estimated (due to choice of manufacturer, manufacturing method, etc) a rough comparison between the estimated cost for the composite skin-stringer and metal alloy skin-stringer is projected below:

Estimated cost for the Composite Center Fuselage

Approximate cost of Fiber IM7	:	23 USD*/square meter
Cost of Fiber IM7 (raw material for ~ 250 square meters)	:	5750 USD
Cost of Matrix 977-3	:	250 USD
Total Cost of Composite materials	:	5750 + 250 = 6000USD

6000 USD is the total cost for the composite skin stringer including the Fiber IM7 and Matrix 977-3.

Cost of Aluminum bars:

Approximate price of Aluminium	:	22 USD/ square meter
Cost of Aluminum (raw material for ~ 250 square meters)	:	5500 USD
Estimated Cost difference	:	$(6000 - 5500) / 5500 = 0.091 \sim 9\%$.

Though there is an approximate 10% extra cost for composites, in long run, the benefits of using composites are more convincing than metal.

3. Conclusion

The modeled skin-stringer parts for the center fuselage in metal and using composites are compared and the cost of constructing the skin-stringer for an ongoing military aircraft was studied. The comparative study between aluminium alloys and composite clearly specifies the high cost involved in the manufacture of composites.

A switch from metal to composites can make parts up to 30% lighter. The weight savings, which have a positive effect on both fuel consumption and the aircraft's payload, are particularly important in a market environment which is characterized by high fuel prices and more stringent aircraft emission standards. Besides being lighter than traditional materials, composites offer significant advantages in terms of operational reliability, leading to lower in-service operating costs. A Cost Analysis for Fuselage tool (CAF) for assessing the material selection has been developed and an example evaluation of both composite and aluminium was provided. By invoking some prerequisite parameters, the approximate cost estimated by CAF tool is evident.

The usages of composites for pressure differential area as of the external skin are undergoing developments, with an effort to contribute towards reduction in cost by selecting the apt material will have considerable cost saving and can provide new dimension in the field of research .

4. Acknowledgement

The work portrayed in this manuscript was carried-out in Engineering, Research and development Services (ERS), Bangalore. The authors express their sincere thanks to Mr. Mantha Venkataramana – Head Aero structures for being a great inspiration in coining this work. We have immense pleasure in expressing our thanks to Mr. Raghupathy.R – GPM, Aero structures for his concrete suggestions and encouragement. The author cannot forget the expert guidance, concrete suggestions and informative talks provided by Mr. Srinivasa Rao T.V. – APM, Aero structures.

5. Nomenclature

RMTF	–	Redesign Modification Task Force
CAF	–	Cost Analysis for Fuselage.
V_f	-	Volume Fraction of the fibers
V_m	-	Volume fraction of the matrix
V_c	-	Volume fraction of the composite
CFRP	-	Carbon Fiber Reinforced Plastic
STA	–	STAtion Planes
PSE	–	Product Structure Editor
$E_{c, }$	-	Longitudinal modulus of elasticity
A_m	-	Area of the matrix
A_f	-	Area of the fibers
A_c	-	Area of the composite
E_m	-	Modulus of elasticity of the matrix

6. References

- [1] <http://www.eads.net/800/en/madebyeads/possibilities/composites.html>
- [2] <http://ses.library.usyd.edu.au/bitstream/2123/857/12/adt-NU20020703.20410506chapter5.pdf>
- [3] Advisory council for Aeronautics Research in Europe, Strategic Research Agenda, Vol.1, Vol.2, and executive summary, October 2004. URL: <http://www.acare4europe.org/html/background.shtml>
- [4] The Science and Technology Sub-Group, Air Travel – Greener by Design, Mitigating the Environmental Impact of Aviation: Opportunities and Priorities, Royal Aeronautical Society, UK, July 2005.
- [5] Bailey, J.E., Chapter 1: Origin of composite materials in Aircraft structures (Ed. D.H. Middleton), Longman Scientific and Technical, Essex, UK, 1990, pp, 1-8.
- [6] MIL-HDBK-17-5 Volume 5 of 5 17th June 2002, Department of Defense, Composite Materials Handbook

7. Appendices

7.1 CAF tool

The development of a new tool named CAF tool to perform the cost analysis for the composite materials. Below screenshots show the screens of the CAF tool, developed for performing the above mentioned cost analysis.

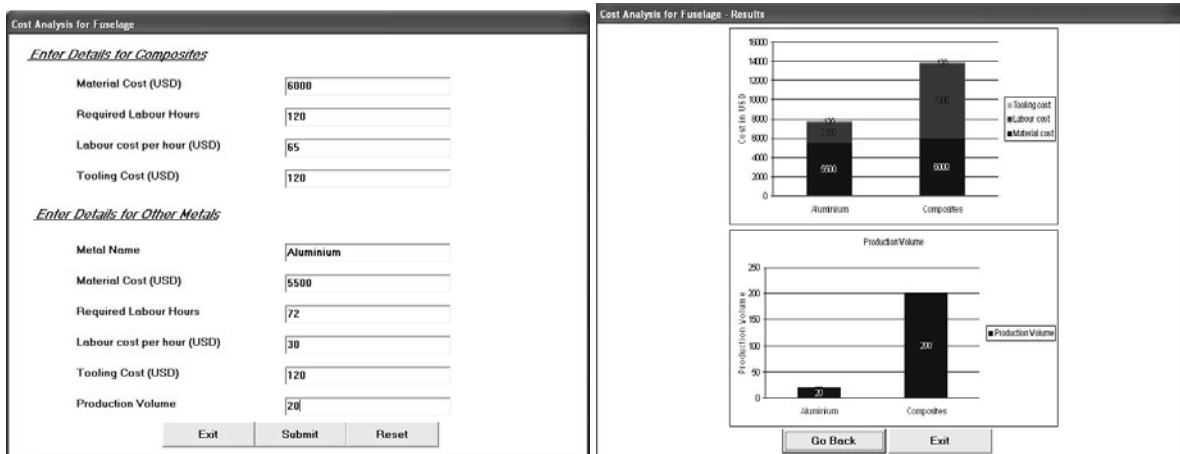


Fig.7.1 Screenshots from CAF tool