COMPOSITE IN AEROSPACE MANUFACTURING INDUSTRY

“Mini Project during PhD”

at Universiti Putra Malaysia,

Studi Banding di:
Composites Technology Research Malaysia

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JURUSAN TEKNIK INDUSTRI
FAKULTAS TEKNIK – UNIVERSITAS MALIKUSSALEH
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CONTENTS

- Objectives
- Introduction:
  A. History & Development of aircrafts
  B. Aircraft structure & assembly
  C. Aircraft materials & processes
- Background of Malaysia Aerospace industry
- Aerospace companies in Malaysia
- CTRM
- CTRM production flow
- Conclusion
OBJECTIVES

1. To discuss the general process, parts and components of aircraft production.
2. To discuss about the Malaysian aircraft industry and introduce about the CTRM process
3. To elaborate on the aircraft composite production process
First airplane to fly successfully was invented by Orville and Wilbur Wright in December 17th 1903 after 2 earlier unsuccessful attempts.

[Source: History of Aeroplane (Anon, 2006) ]
T O D A Y

MILITARY AIRCRAFT

COMMERCIAL AIRCRAFT

FIGHTER JETS

COMMERCIAL AIRCRAFT

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IMPORTANCE OF AIRCRAFTS:

- One of the fastest transportation method
- Facilitate international trade
- Provision of security & for distributing supplies during
- Aviation industry provides more job opportunities
- Facilitate rescue missions.
AIRCRAFT SECTIONS

[Source: Boeing presentation (Anon, 2006)]
MAIN ASSEMBLY SECTIONS

FUSELAGE SECTION

LANDING GEARS

WINGS

ENGINES

TAIL SECTION

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Aircraft components such as engine parts, fly wheels etc are produced via Advanced manufacturing processes such as casting, powder metallurgy, Drilling, machining. This components can be produced by highly specialized Producers in order to obtain high level of quality. For example, Boeing aircrafts got its parts or components from countries such as Japan and Italy. However the final assembly is done in US.
AIRCRAFT FINAL ASSEMBLY PROCESS

1. WINGS
   - CONNECT
   - CENTRE FUSELAGE

2. FORWARD FUSELAGE
   - FINAL BODY ASSEMBLY
   - PAINTING

3. TAIL SECTION
   - ENGINE

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EXAMPLE

Boeing 777 commercial aircraft assembly process in progress.

[Source: Boeing presentation (Anon, 2006)]
AIRCRAFT MATERIALS

1. Aluminium alloys
2. Steel alloys
3. Titanium alloys
4. Composites
5. Plastics
6. Glass
ALUMINIUM ALLOYS

APPLICATION
- Airframes
- Skins
- Stressed components
- Fuselage structure

FACTORS CONSIDERED
- Strength
- Ductility
- Ease of manufacture e.g. extrusion and forging.
- Resistance to corrosion
- Fatigue strength
- Freedom from sudden crack

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<table>
<thead>
<tr>
<th>No.</th>
<th>Alloy</th>
<th>Advantage</th>
<th>Disadvantage</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aluminum-Zinc-magnesium</td>
<td>High static strength</td>
<td>Sudden crack in unloading condition. Reason <strong>forging</strong> and <strong>heat treatment</strong></td>
<td>Forging, Extrusion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(retention of internal stress.)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Aluminum-copper(4%)</td>
<td>High strength, good fatigue, crack growth resistance,</td>
<td>Slightly high cost</td>
<td>Casting, Machining</td>
</tr>
<tr>
<td></td>
<td></td>
<td>toughness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Aluminium-magnesium-silicon</td>
<td>Cheaper than (2), Weldable, high fracture toughness</td>
<td>Ductility decreases as result of heat treatment (segregation of Si at grain</td>
<td>Casting, Machining</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resistance to crack</td>
<td>boundary) Solution add chromium</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Aluminium-Lithium alloys</td>
<td>Increase fatigue life, Reduction in weight</td>
<td>Reduced ductility and fracture toughness in short transverse direction.</td>
<td>-</td>
</tr>
</tbody>
</table>
STEEL ALLOYS

APPLICATION
- Under carriage pivot brackets
- Wing root attachments
- Fasteners and tracks
- Aircraft arrester hooks
- Rocket motor cases
- Gears
- Ejector seats
- Other structural components

CONSIDERED FACTORS
- High tensile strength
- High stiffness
- High resistance to wear

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### STEEL ALLOYS CONT’D

<table>
<thead>
<tr>
<th>Type of steel</th>
<th>Advantage</th>
<th>Disadvantage</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional steel</td>
<td>Low cost</td>
<td>High carbon thus brittle &amp; distort (Machining, cold forming, welding difficulty)</td>
<td>Machining, Casting</td>
</tr>
<tr>
<td>Maraging steels (1961)</td>
<td>High fracture toughness, notched strength, simpler heat treatment, simple to weld, easier to machine, better resistance to corrosion</td>
<td>Cost is 3 times the cost involved in conventional steel</td>
<td>Machining</td>
</tr>
</tbody>
</table>
Usage increases in 1980s to 1990s and are common in Combat aircrafts

**PROPERTIES**
- Good Fatigue/ tensile strength ratio
- Retain considerable strength at 400 to 500 degrees Celsius
- Good Resistance to corrosion

**APPLICATIONS**
- Airframe
- Engine
- Wing Part
- Tail assembly
- Flap & slat tracks
- Undercarriage parts
- Access doors

**PROCESS INVOLVED**
Forging are common
TITANIUM ALLOYS

PROBLEMS

- Properties are adversely affected by exposure to temperature & stress in salty environment e.g. aircraft carriers
- Relatively high densities (weight)
- High fabrication cost (7x more than AL & steel alloys)

SOLUTION

- New fabrication process e.g. super plastic forming combined with diffusion bonding which allows large & complex components to be produced.
- Typical savings: 30% red in man hrs; 50% red in cost
PLASTICS
- Material is heavier than wood but much lighter than AL-alloys

Applications
- Windows
- Lightly stressed parts
- Electrical insulators

GLASS
- Material are normally heat strengthened for aircraft applications

Applications
- Windscreens
- windows
## COMPOSITE MATERIAL

Composite materials consist of strong fibre such as glass or carbon set in a matrix of plastic or epoxy resin, which is mechanically and chemically protective.

<table>
<thead>
<tr>
<th>Material &amp; Development</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Glass Reinforce Plastic (GRP)</td>
<td>Strength</td>
<td>Low stiffness</td>
</tr>
<tr>
<td>2 Kelva (1960)</td>
<td>Strength, Stiffness</td>
<td>Low Elasticity</td>
</tr>
<tr>
<td>3 Boron fibre composite</td>
<td>Strength, Stiffness, Elasticity</td>
<td>High Cost</td>
</tr>
<tr>
<td>4 Carbon Fibre Reinforced Plastic (CFRP)</td>
<td>Strength, Stiffness, Low cost</td>
<td>Brittle, not elastic to high stress area</td>
</tr>
<tr>
<td>5 Composite (fibre glass &amp; aluminum)</td>
<td>Used in main aircraft structures</td>
<td></td>
</tr>
</tbody>
</table>
### Application:
- Helicopter Blades
- Wings
- Tail plane
- Forward fuselage
- Panels
- Galley partitions
- Beam structure

### Problems
- Main material which is epoxy resin absorbs moisture which degrades its mechanical properties. Polyetheretherketone absorbs less moisture thus is new research area in composite materials for aircraft.
- Cost of composite structures are high due to labor intensive production. Thus max use so far is 15% composite.

[Source: (Megson, 1999)]

**COMPOSITE MATERIALS**
AIRCRAFT MATERIAL

TYPICAL EXAMPLE OF BOEING AIRCRAFTS

- Aluminum (2024T3) used in fuselage skin and aircraft structures
- Composites used on fuselage fairings, wings and panels
- Steel (AISI301) used on aircraft components
- Titanium (AMS4901) used on pylon & engines
- Miscellaneous used on minor areas

[Source: Boeing presentation (Anon, 2006)]
Prepreg

- specially formulated resin matrix systems
- reinforced with man-made fibers such as carbon, glass and aramid
- when cured at elevated temperatures and under pressure, the thermoset resin undergoes a chemical reaction that transforms the prepreg into a solid structural material
- the solid structural is highly durable, temperature resistant, exceptionally stiff and lightweight
- roll form, to be stored frozen and defrosted before use
- golf clubs, satellite arrays, wind turbine rotor blades and others
Direct Materials
Introduction

New aerospace industry in Malaysia, it offers opportunities of advanced technology transfer in engineering field, electric, electronic and composite materials and manufacturing and system integration.

Aerospace manufacturing is a high technology industry that produces "aircraft, guided missiles, space vehicles, aircraft engines, propulsion units, and related parts.

The aerospace industry and manufacturers’ unrelenting passion to enhance the performance of commercial and military aircraft is constantly driving the development of improved high performance structural materials.

Composite materials are one such class of materials that play a significant role in current and future aerospace components. Composite materials are particularly attractive to aviation and aerospace applications because of their exceptional strength and stiffness-to-density ratios and superior physical properties.
Introduction

Malaysia's aerospace industry categorized to four subsector:

- Light aircraft installation
- Part and component manufacturing
- Maintenance / repair / reshuffle treat (MRO)
- Design and development
Introduction

- Currently, in Malaysia have two assembler company light aircraft, six parts produce and component, 30 company labour in MRO's activity and four companies involved in design and development field.

- Aerospace industry contribute 3.6 percent economy to country and near to 2015 will increased to 5-8 percent.
Company involve in Aerospace, Composites and Engineering at Malaysia

1. Composites Technology Research Malaysia Sdn Bhd (CTRM) at Batu Berendam, Melaka. CTRM supply chain composites aero structures for major commercial and military aircraft manufacturers in the world.

2. Asian Composites Manufacturing Sdn Bhd (ACM) at Bukit Kayu Hitam, Kedah, Malaysia. The primary business is the manufacture of composites material components and sub-assemblies for aircraft application.
Airbus A380
Design and manufacturing support for the Forward Leading Edge Access Panels. A total of 66 panels per aircraft that consists of both composites and metallic structures.

Nimrod Floor Panels
Complete composite floor panel design from cockpit to rear pressure bulkhead including structural support for panels.

Scottish Aviation Bulldog Military Trainer Aircraft
Development of the wing spar strengthening modification kit.

A400M
Design works packages on the A400M military airlifter.

Eagle Reconnaissance Vehicle
Responsible for the aircraft modification, system integration, ground vehicle integration, flight testing and joint system development with BAE SYSTEMS.
<table>
<thead>
<tr>
<th>Customer</th>
<th>Program</th>
<th>Contract Period</th>
<th>Value (RM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spirit Aerosystem</td>
<td>A300 FTE</td>
<td>2000-2010</td>
<td>20M</td>
</tr>
<tr>
<td>Spirit Aerosystem</td>
<td>A320 LTEP</td>
<td>2000-2010</td>
<td>78M</td>
</tr>
<tr>
<td>Spirit Aerosystem</td>
<td>A320 Ph I &amp; II</td>
<td>2000-2010</td>
<td>773M</td>
</tr>
<tr>
<td>Spirit Aerosystem</td>
<td>A380 IOFLE</td>
<td>2002-2012</td>
<td>145M</td>
</tr>
<tr>
<td>Airbus AUK</td>
<td>A380 FLELP</td>
<td>2002-2019</td>
<td>800M</td>
</tr>
<tr>
<td>Goodrich</td>
<td>V2500</td>
<td>2004-2007</td>
<td>101M</td>
</tr>
<tr>
<td>BAE Land System</td>
<td>LRAC</td>
<td>2000-2006</td>
<td>9M</td>
</tr>
<tr>
<td>GKN</td>
<td>A400M WTE</td>
<td>2005-2015</td>
<td>]</td>
</tr>
<tr>
<td>Airbus UK</td>
<td>A400M NEF</td>
<td>2005-2015</td>
<td>417M</td>
</tr>
<tr>
<td>Airbus UK</td>
<td>A400M FPF</td>
<td>2006-2015</td>
<td>]</td>
</tr>
<tr>
<td>CASA EADS</td>
<td>A400M VTP</td>
<td>2005-2015</td>
<td>356M</td>
</tr>
<tr>
<td>CASA EADS</td>
<td>A400M HTP</td>
<td>2005-2015</td>
<td>]</td>
</tr>
<tr>
<td>SONACA</td>
<td>A400M MLGD</td>
<td>2006-2015</td>
<td>61M</td>
</tr>
</tbody>
</table>
Composites Engineering

Composites Manufacturing and Assemblies

- Structural Carbon Fibre Composites Assemblies
- Major Structural Assemblies – Composites and Metallic
- Structural Carbon Fibre Bonding
- Non-Destructive Testing for Composites Components
- Machining Capabilities For Composites Components
- Manufacturing and Assemblies of Composites Components for Aerospace, Non-Aerospace and Defence Industries

Composites Engineering and Designs

- Structural Designs
- Structural Stress Analysis
- Weights Engineering
- Structural and Material Testing
- CTRM and its Group of Companies also possess CAD/CAM/CAE Capabilities:
  - CATIA 4.2.2, CATIA V5R14, Solid Works
  - MSC Nastran/Patran
  - Laminate Analysis Programme (LAP)
Composites Research & Development

CTRM also conducts Composites R&D Programme:

- 2D Honeycomb Chamfering Process Development
- Out of Autoclave (OOA) Prepreg Processing
- Resin Infusion
- Resin Transfer Moulding (RTM)

Aircraft Services

CTRM through CTRM Aviation provides Aircraft Services for General Aviation Industry:

- Aircraft Leasing Services
- Aircraft Schedule and Unscheduled Maintenance
- Aircraft Avionics Upgrade and Modifications
- Aircraft Structural Modifications Handling and Hangar Services
- Aircraft Maintenance, Repair & Overhaul Services
Airbus A320 Series
Aerospace Products and Services

Airbus 320 series

moveable fairing
over wing panels
a320 spoilers
spoiler
under wing
falsework
a320 fix fairing
a321 fix fairing
Products and Services

Aerospace

Airbus 380

- Inboard outward fixed leading edge
- Fixed leading edge lower panel
- Flielp (ip)
- Upper panel 2
- Flielp (mp)
- Flielp (op)
- Upper panels
- Seal panel - 4LH
- Seal panel - 3RH
Products and Services

Non-Aerospace

Lotus Europa S body shell

RADOME

Western Hill RADOME

Bukit Kubong RADOME

RADOME

Alvis Bridging
**Products and Services**

**Capabilities**

- Autoclave 1
- Autoclave 2
- Autoclave 3
- Autoclave Burner
- CMM Machine
- CMM Machine 2
- CMM Controller
- Control Panel & Chart Recorder for Core Oven
- Core Drying Oven
- Drilling Machine
- Dry Sanding Area
- FPF Mould 1
Products and Services

FPF Mould 2
Gantry Crane
Gantry Crane Side View
Fuselage Mould
Fume Hood
Gerber1 Digitizer
Gerber1 Data Entry Machine
Gerber1 Plotter
Gerber Cutter1a
Gerber Cutter1b
Gerber Cutter1c
Gerber Cutter2
Products and Services

Gerber Cutter 2b
Lab Refrigerator
Lathe Machine
Milling Machine
Mould Release Oven
NDT 2
NDT 3
NDT FlatBed
NDT FlatBed 1
NDT Vertical (Multi Axis 1)
NDT Vertical (Multi Axis)
New Paint Shop
Production Flow

- Warehouse (Raw Material) @ Freezer
- Thawing Room
- Kitting Department
- Clean Room (Layered Process)
- Demould
- Cure Process
- Painting Department
- Inspection
Warehouse (Raw Material)
Thawing Room  Kitting Department
Kitting Department

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Clean Room
(Layered Process)

Demould
Demould

Cure Process
Storage

General
Storage area : 11,395 sq.ft
FIFO system
3 freezers for cold storage
Walk in industrial freezer

Dry
Material:
Breather cloth
Honeycomb core
Peel Ply cloth
Carbon cloth
Glass cloth
Perforated sheet
Bagging sheet
Kevlar cloth
Cold

Freezer capability:
- Min. temperature: minus 25°C (-12.6°F)
- Size freezer 1 & 2: 36 ft x 36 ft x 10 ft
- Size freezer 3: 42’9”x31’10”x10’
- Temp chart recorder
- Automatic restart – Zero interruption generator back-up
- Alarm system (when temp. drop at below set temp)

Material:
- Glass Prepreg
- Carbon Prepreg
- Uni-carbon Prepreg
- Lightning Mesh (Al) Prepreg
- Film Adhesive
- Core splice
Thawing Room

- the material been kept for several hours to warm up the material until it reach room temperature before proceed to next process.
Cutting Process

- CNC Gerber Cutter
  - Cut material
    - Carbon cloth
    - Glass cloth
    - Kevlar cloth
    - Glass prepreg
    - Carbon prepreg
    - Kevlar phenolic prepreg

- Operation
  - Blade speed between 210 to 4300 rpm
  - Axis speed between 1 to 15 (Selected type)
    - Min Speed: 2600/min
    - Max Speed: 3800/min
  - Table size 36 ft x 6 ft
  - Max. turning angle 45°
  - 2 tables to support continuous cutting
  - Automatic & manual pattern nesting program to achieve optimum material utilization
  - Use Accumark Software for digitizing

- Manual
  - Glass Prepreg/ dry
  - Carbon Prepreg/ dry
From Programming to Gerber Cutter

The nesting design are upload to the machine
Max 7 plies
Material is held to its position on the table by vacuum suction from under the cutting bed.

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Before & after segregation kit

After cutting before segregate

Segregate by set
Packing the kit prepreg

Ready kit
Lay-Up Process

- The prepreg that had been cut are lay-up one by one according to the requirement
- Debulk process is required to consolidate the lay up of prepreg and to remove entrapped air
- Trim excess plies using knife
- Monolithic panel only contain prepreg but sandwich panel contain honeycomb and prepreg
Lay-up Board

Trim Template
Lay-up Manual Consolidate

Push the air out of the layers by using spatula with specific direction (0 degree, 45 degrees)
Indirect Materials

- Breather cloth
- Honeycomb core
- Peel Ply cloth
- Carbon cloth
- Glass cloth
- Perforated sheet
- Bagging sheet
- Kevlar cloth
Indirect materials Regulator
Debulking Process

Debulking Process

Air Pressure Monitoring
Final Bagging Process

Flip/Tuck

Thermo Couple
Curing Process

• The panel are cure according to types of materials and panel thickness.
• The important factor in curing is the air temperature, pressure and the time duration.
• Normally one panel would take around 8-10 hours to cure.
Autoclave

Vacuum port

Thermo couple
Mould Staging In Autoclave
Demould Process

- remove out the indirect material at the panels and separate it from mould

- Debag
- Bagging
- Remove Silicon Intensifier
- Release Thermocouple
- Remove Teflon Pin
- Mold Prep
- Part Marking
- Take Panel Out
- Remove Edge Member
Demould Process

Remove the panel from the mould and the mold are clean with solvent for next process.
Mechanical Assembly

Trimming Process

Countersunk Drill
NDT Station

- The Non Destructive Test (NDT) is for inspection process.
- To detect defect such as delaminating and dis bond on the panels by using Ultrasonic Test where water is used as a medium.
- using ultrasonic pulse-waves with frequency of 1MHz or 2.5 MHz

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NDT Main Machine

C-scan 7 axis

Horizontal C-scan 3 axis
NDT Main Machine

A and B-Scan

A-Scan Bond Tester
Painting Process

- "undercoat spray" to all panels
- There are 2 stages, light coat and primer
- In between the stages, the panels must be dry out by using oven
- Normally the time taken is 4 hours for the whole process
Painting Process

Dry sanding process  Painting process in progress
Set before & after painting

Before painting

After Painting
Packaging

One Box For One Set
Conclusion

Composite technology are developed rapidly form day to day, we had to learn about the technology if don’t want to be left behind.
REFERENCE