Automated Processing of Aerospace Composite Components

Don Evans
Manager, Composite Product Development
Automated Composites Processing

FIBER PLACEMENT

TAPE LAYING
Aerospace Programs Using Automated Composites Processing Systems

YESTERDAY
- F-117
- JSF
- CB-17
- 777
- C-17
- F-18 E/F
- ATR
- B-2

TODAY
- F-117
- JSF
- CB-17
- 777
- C-17
- F-18 E/F
- ATR
- B-2

TOMORROW
- F-117
- JSF
- CB-17
- 777
- C-17
- F-18 E/F
- ATR
- B-2

Companies and Programs:
- Airbus A400M
- BA609
- Global Express
- Ariane 5
- Premier I
- Premier II
- 787
- A320
- A330/340
- A380
- Eurofighter
- V-22
- ATR

Technology, Speed, Flexibility, Service
Aerospace Programs Using Automated Composites Processing

- Fuselage Components
- Empennage Structure
- Fighter Aircraft Intake Ducts
- Engine Nacelle Components
- Space Launch Vehicle Components
Fiber Placement Systems
What is Fiber Placement?

- Fiber Placement is a Hybrid of Filament Winding and Automated Tape Laying
  - Machine Configuration Similar to Filament Winder
  - Material Form Similar to Tape Layer
- Computer Controlled Process that Utilizes a Prepreg Tow or Slit Tape Material Form to Lay Up Non-Geodesic Shapes
  - Convex and Concave Surfaces
  - In-Process Compaction of Laminate
Large and Small VIPER Systems

Up to 32 Tows and 18.7 Feet Diameter

VIPER FPS-3000

VIPER FPS-1200

25 Large and Small VIPER Fiber Placement Systems for USA, Europe, and UK over the past 14 years.
Fiber Placement Components

- Fiber Placement Head, Mounted to a Roll-Bend-Roll Wrist
- Refrigerated Creel Containing Bi-directional Tensioners
- Headstock
- Tailstock

Reference: Compotes ASM Handbook
FIBER PLACEMENT MATERIALS

- TOW
- SLIT TAPE
Fiber Placement Head

Up to 32 Tow Capacity
Fiber Placement Systems
New Automation Technologies Continue to be Developed

- Patented Segmented Roller
- Patented Bi-directional Tensioners
- Patented Redirect Roller System
- Individual tow cut-clamp-restart head
- Backing film removal system
- Integration with a laser projection system

VIPER 1200

VIPER 3000
Fiber Placement Systems – VIPER 6000

- Less Y-axis arm motion to achieve position
- No Singularity
- Bi-directional Capability 0 and 45’s and up to 60 Deg. In Some Cases
- Fast Machine Axes motion
- Quick Tool Load/Unload system
- Verification plate on Tailstock

- Wide Variety of Parts
  - High dexterity
  - Accurate
  - High structural stiffness
- Operator Friendly
  - One sided Creel
Fiber Placement Advantages

- Variable bandwidth of Material “On The Fly”
  - Localized Build-ups and Cutouts
  - Constant Thickness on Tapered Shapes

- Change Ply Angle “On The Fly” (Tow Steering)
  - Maintain Constant Angle on Non-Geodesic Surface

- In-Process Compaction of Material

- No Limitation on Ply Orientations

- Low Material Scrap Rates (3% - 8%)
Designing for Fiber Placement

FPS Components Should be Designed Considering the Unique Process Capabilities - and Limitations
- Tailor Laminate Design to Meet Local Loads
- Minimum Course Length - 5"

Changing Design from Fabric Lay up to Fiber Placed Material Produces Positive Results
- Weight Reduction and Higher Performance Structure

Hybrid Material Forms “On The Fly” Are Possible
- Improved Damage Resistance / Damage Tolerance
Fiber Placement Tooling Options

**Single-Tool Option**
- Fiber Place Part on Mandrel (Male or Female)
- Remove Mandrel From Machine
- Cure Part on Fiber Placement Mandrel

**Two-Tool Option**
- Fiber Place Part on Male Mandrel
- Remove Part From Mandrel - Transfer to Cure Tool
- Cure Part on Female Cure Tool
Fiber Placement Tooling

Two-Tool Approach Preferred for Parts That Have “Aerodynamic Smoothness Requirements” (Example - Engine Cowl Door)

Aluminum Mandrel

Invar Cure Tool
VIPER FPS-3000
VIPER FPS-1200
VIPER FPS-1200

- Entry level Fiber Placement System
- Newest CM Composite System
  - 4 Systems Installed
  - 2 Systems on Order
- Small Production Parts & Development Labs
- Part Diameters Up to 1.0 M
- Installation in Existing Facilities
  - Ceiling Height 3.5 m
  - Concrete Floor 10” Thick
VIPER Fiber Placement Systems
Worldwide Since 1990

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V-22 Osprey Tilt Rotor Application

- Aft Fuselage
- Fuselage Side Skins
- Sponsons
- Drag Angle

Cincinnati Lamb VIPER FPS-3000 System at Boeing (Philadelphia)
F-18 Super Hornet Application

Fiber Placement Process Provides Cost Savings on F/A-18 E/F Parts
- 25% - 38% savings
Northrop Grumman Fiber Places Fuselage Skins and Intake Duct
Fiber Placed Stabilator Skins

- 10 Inlet Duct Skins
- 12 Fuselage Skins
- 4 Stabilator Skins
Closed 360° Fuselage Sections (2 Sections)
- Fiber Placed Skins Over Nomex Core
  - 20% Lighter Than Aluminum
  - 30 Machine Hours to Fabricate Fuselage
- Design Reduces Number of Parts
  - 3000 Parts - to - 2 Parts
VIPER Fiber Placement Systems
A380 Aft Fuselage

All skin panels for Sections 19 & 19.1 made on VIPER FPS in Spain.
Nacelle Component Application

- Excellent Application for FPS
- 80% Labor Reduction (C-17)
- Low Material Scrap (3%)

Fiber Placement Implemented on C-17 and A340 Nacelle Fan Cowl Doors
Launch Vehicle Application

Ariane 5 Launch Vehicle Components

- 2.5 M dia Payload Adapters
- Thrust Frame 5.5 M dia
- Vehicle Equipment Bay

Technology, Speed, Flexibility, Service
Automated Tape Layers
Automated Tape Layers

- Cincinnati Machine is a World Leader in Automated Tape Layer Technology
  - Involved Since 1982
  - 41 Tape Layer Systems

- Two Tape Layer Machine Configurations
  - 4-axis Flat Tape Layer (FTL)
  - 5-axis Contour Tape Layer (CTL)
Contour Tape Layers

3”/6” and 6”/12” Tape for Global and Local Contours

36 Contour Tape Layers for USA, Europe, Japan, UK, and Indonesia over the past 21 years.
Flat Tape Layers

6"/12" Tape for Flat and Variable Thickness Laminates

5 Flat Tape Layers for USA, Europe, and UK over the past 11 years.

- Vought (2)
- Boeing
- Airbus
- Bombardier Shorts
Automated Tape Layer

Rail supports come in 3.6 m sections for flexibility in machine length.

10 axis machine
5 on gantry
5 on head

Z-axis stroke is adjustable for specific applications.

Rail height is configured for specific applications.

A-axis on tape head allows for contoured parts.

PC based control
Variable gantry width
200” std.

CINCINNATI LAMB
Technology, Speed, Flexibility, Service
# Tape Layer Customers

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Tape Laying Application

Boeing is aerospace leader in automated tape laying.

Boeing 777 Horizontal Stabilizer Skin Panel Lay up

- 19 tape layers
- Military aircraft
- Commercial aircraft
- Current & planned programs
Empennage Skin Panels Application

Boeing 777
- 564 ordered
- 332 delivered
- 1992 large skin panels completed with ATL process

Boeing uses tape layers for the horizontal and vertical stabilizer on the 777 aircraft

Tape Layers at Seattle Plant

Technology, Speed, Flexibility, Service
A330/A340 Empennage Skins Application

- 687 aircraft ordered
- 378 delivered
- 1512 large skin panels fabricated with ATL processes

Skin length - 9 m
Skin width - 2 m
Skin weight - 200 kg

Airbus Spain uses Flat and Contour Layers for A330 and A340 Empennage
Wing Outer Flaps Application

Airbus A330 / A340 Wing Outer Flaps

- 38 ft long 4 ft wide
- 12” tape
- Flat laminate is kitted and post-formed
- Co-cured stiffeners
- 800 lb monocoque structure

30 lbs / hr rate
70% reduction in man/hrs

Aerostructures Corp (Nashville, TN)
Horizontal Stabilizer Skins Application

- Full span upper skin
  - 7 m long, 1.1 m chord
  - 3 meter sweep

SABCA uses tape layer for horizontal stabilizer skins on Dassault Business Jets

- Falcon 50, 900, 2000

SABCA LIMBURG N.V. Belgium
Benefits of Composite Process Automation

- Reduce the cost of composite products
  - Component designs optimized by simulation
  - Reduced weight & assembly cost
  - Reduced labor hours per component
  - Reduced in-process inspection costs
  - Reduction in material scrap
  - Higher quality, repeatable quality products
  - Fewer QA rejections of components
  - Reduced Rework
  - Faster Part Throughput
Why Should the Depots Automate Composite Processing?

Primary objectives for investment in automated composites processing for the Depots to consider:

- Faster Part Throughput
- Repeatable quality components
- Full spec compliance
- Full replacement parts versus patchwork

Automating production provides the competitive edge required to ensure business growth.
Off-Line Programming Systems

- ACRAPATH Tape Laying
- ACRAPLACE Fiber Placement
- Create Machine Program
  - Cycle Time Estimates
  - Material Usage Data
Programming System - ACES

Design: Catia V5

ACES (Advanced Composites Environment Software)

- Catia V5 Translator
- Path Generation
- Post Processor
- Simulation Module
- Communication Module
- Productibility Module

Programming System - ACES

Design: Catia V5
Programming System - ACES

- Runs on a PC
- Windows Based System
- Processes Supported
  - Tape Laying
  - Fiber Placement
  - Hybrid Process
- Catia V5
- 4 Types of Path Generation
- Ships Q4, 2004
Programming System - ACES

ACES
Catia V5 Translator → Path Generation

Natural path

Multiple Types of Path Coverage for Tape Laying, Fiber Placement, and Hybrid Process
Programming System - ACES

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For Help, press F1

ACES - ACES
Programming System – ACES
Service and Support

- One Week User Training
- Online Help Screens
- Phone Support
- Email Support

Supporting 46 seat licenses at 26 different customers, in 8 different countries, for over 18 years
Machine Control – CM100

* Tool Path is Coordination of up to 7 axes of Motion
* Compaction Force Controlled
* 47 servo axes
* Programs in 10 X Mbytes

- Open Architecture Design
- Only Control Developed Specifically for Composites Equipment
- No Front End Processor PC Required
- Approved by Boeing Control Standards Committee
- CE Marked

FAST, SMOOTH & ACCURATE MOTION
- Pentium 4, 2.4G Hz
- Digital Drives
- S Curve Acc/Dec
Machine Control – CM100

- Large 18” color touchscreen monitor
- Industrial keyboard and pointing device
- Multi-level password access
- Camera monitors
- Multiple display pages and menus provide easy access to control functions and data
Machine Control – CM100

- Ply Displayed as It’s Being Laid
  - Colored coded, direction indicated & numbered
DEPOTS – What are the future needs?

- Hand Layups – repairs of small sections and basic shaped parts
- Small parts – automate for rapid replacement capability
- Support Production readiness to assure part compliance and rapid response