Overview of the Accelerated Insertion of Materials – Composites (AIM-C) Producibility Module Development

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Jointly accomplished by BOEING Led Team and the U.S. Government under the guidance of NAST

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**Report Documentation Page**

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Prescribed by ANSI Std Z39-18
Overall Program Plan

RDCS/DOME Framework
- Structure Models (Science Based)
- Material & Process Models (Science Based)
- Productivity Models (Science Based)

Heuristic Models

Data Bases

Methodology

RDCS – Robust Design Computational System
DOME – Distributed Object Oriented Modeling Environment

Architecture Example

Setup File Database
- IM7 Fiber Setup File
- 977-3 Resin Setup File
- 977-3IM7 Peeling Setup File

AIM GUI
- Select Material Types
- Select Probability Assessment
- Enter or Select Requirements

RDCS Project File
- Thickness Distribution

Initiate RDCS Project
- Calculate Laminate Level Variability
- Evaluate Output vs Requirements
Most aspects of producibility are very subjective and/or based on previous experience with very little existing software. Therefore, it is being proposed existing software capable of logical programming along with data bases that will contain pertinent information to be interrogated through SQL.

- **Heuristic and/or Rule Based Software**
  - (Java, Visual Basic, C++, etc.)

- **Knowledge/Data Bases**
  - (Access, Oracle, M-Vision, ...)

- **Science Based Objective Models**
  - (Fortran, C++, etc.)
  - **CACC** (Thickness, Voids/Porosity, Resin Flow Bagging, Debulking, Tooling, etc.)
**Definition:**

A Controller Module to Compare Requirements to Manufacturing Capabilities For Quality Components

**Corollaries:**

- Can I Make It?
- With What Degree of Success?
- How Can I Make It?
- By Which Manufacturing Sequence Should It Be Made?

- The Initial Envisioned Module Provides Heuristics Which Give Guidance Through Part Thermal Processing (Cure/Post Cure)
- Does Not Include Hole Drilling or Assembly in Basic Program

- **For purposes of Bookkeeping in the AIM-C CAT Program, It Also Includes What Hasn’t Been Addressed in Other Areas**
**Producibility Module Definitions**

**Additional Definitions:**

- **Manufacturing Capabilities**
  - Ability to Fabricate the Unassembled Components with Identified Materials and Manufacturing Methods

- **Quality Requirements/Parameters**
  - Meets Functional Requirements (Strength, Stiffness, Dimensions, Etc.)
  - Requirements/Parameters are Identifiable, Measurable, and Boundable

- **Manufacturing/Processing Steps/Areas**
  - Ply Cutting
  - Layup
  - Debunking
  - Bagging
  - Equipment
  - Tooling
  - Repairability

- **Component Quality Requirements/Parameters**
  - Dimensions
  - Voids
  - Porosity
  - Inclusions
  - Surface Waviness
  - Fiber Volume/Resin Content
  - In-Plane & Out of Plane Fiber Distortion
  - Surface Finish

- **In-Process Quality Requirements/Parameters**
  - Ply Angle
  - Ply Lap/Gap
  - Out Time
  - Freezer Time
  - Equipment
  - Certifications
  - Heat-up Rates
  - Cure Time, Temp, Pressure
  - Abort Conditions
  - Debulk Time, Temp, Pressure
## Knowledge/Data Bases

<table>
<thead>
<tr>
<th>Manufacturing/Processing Steps</th>
<th>Tooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Cutting</td>
<td>- Primary Tooling</td>
</tr>
<tr>
<td>- Layup</td>
<td>- Secondary Tooling</td>
</tr>
<tr>
<td>- Debunking</td>
<td>- Secondary Operations</td>
</tr>
<tr>
<td>- Cure</td>
<td>- Bonding</td>
</tr>
<tr>
<td>- NDE/Quality</td>
<td>- Painting</td>
</tr>
<tr>
<td>- Testing</td>
<td>- Coating</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Lessons Learned</th>
<th>Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Configuration/Type/Class (Parts)</td>
<td>- In-process</td>
</tr>
<tr>
<td>- Methodology</td>
<td>- Final Part (After Cure)</td>
</tr>
<tr>
<td>- Material(s) and Material Combinations</td>
<td>- Material Compatibility</td>
</tr>
<tr>
<td>- Manufacturing/Processing Steps</td>
<td>- Testing/Evaluations</td>
</tr>
<tr>
<td>- Tooling</td>
<td>- Secondary Operations</td>
</tr>
<tr>
<td>- Equipment</td>
<td>- Repair</td>
</tr>
<tr>
<td>- Quality (In-process and Final Part)</td>
<td>- RDT&amp;E Costs/Times?</td>
</tr>
<tr>
<td>- Testing/ Evaluations</td>
<td></td>
</tr>
<tr>
<td>- Secondary Operations</td>
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<tr>
<td>- Repair</td>
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<tr>
<td>- Other</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Health &amp; Safety</td>
<td>- ITAR</td>
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<tr>
<td>- Proprietary Info</td>
<td></td>
</tr>
</tbody>
</table>
Producibility Module Has Integrated Components That In Turn……..

AIM-C Producibility Module

Other AIM-C Modules

Producibility Integration Layer

Components

……Are Integrated With Other AIM-C Modules
Producibility Module Demo Overview

Design User Inputs
- Primary Matl’s
- Size/Thickness
- Features
- Tolerances
- Quality Requirements

Producibility Item(s) Evaluation
- Thickness
- Voids/Porosity
- Cutting
- Indirect Matl’s
- Primary Matl’s
- Size/Thickness
- Features
- Tolerances
- Quality Requirements

Knowledge/Data Bases
- Lessons Learned
- Indirect Materials
- Testing/Specs
- Referenced/Required Information

Producibility Evaluation Outputs
- Knowledge/Data Bases
- Referenced/Required Information
- Indirect Materials
- Testing/Specs
- Lessons Learned
• Control of Users
• Multiple User Types
• Administration Control for Data Bases
• Design User Variables for Producibility
• Producibility Evaluations From a Design User Standpoint
• Producibility Evaluations From a Producibility User Standpoint
Design User Inputs

- Design User Sets Problem/Requirements For Producibility Evaluations
- Ties to Other Design User Items
- Allows Individual Producibility Item Evaluations or All Items

Producibility Evaluations/Outputs According to User Inputs/Requirements
Producibility – Quality Thickness

Ties to Resin, Fiber, and Prepreg Modules
Producibility – Quality: Thickness

Testing

Multiple Output Options and Information

Specifications

Identification of Potential Problems

Thickness for Producibility Evaluation

Testing

Multiple Output Options and Information

Specifications

Identification of Potential Problems
Producibility – Quality: Voids
Producibility – Quality: Voids

Voids and Porosity:
- Prepreg Material
- Part Length
  - Fabricate Productivity Part PP1 (view)
  - Standard for Length
- Part Width
  - Fabricate Productivity Part PP1 (view)
- Part Thickness
  - Fabricate Productivity Part PP1T1 (view)
  - Thin test panel [0.0] inches thick.
  - Standard for Width
- Part Feature Ramps
  - Fabricate Productivity panel PP2T1-2R1 (view)
  - Fabricate Productivity panel PP2T(0.0 or 1) - (0.0 or 2)R(0.0 or 1) (view)

Part Quantity - Voids
- NDE Standards (Effect of Defect)
  - Fabricate NDE standard part PP_NDE2 (view) with [0.0 %] voids.
  - Fabricate NDE standard part PP_NDE2 (view) with 2X[0.0 %] voids.
  - Fabricate NDE standard part PP_NDE2 (view) with 3X[0.0 %] voids.
- Mechanical Property Panels (Effect of Defect)
  - Fabricate Compression test Panel(s) CTP1 (view) with [0.0 %] voids.
  - Fabricate Compression test Panel(s) CTP1 (view) with 2X[0.0 %] voids.
  - Fabricate Compression test Panel(s) CTP1 (view) with 3X[0.0 %] voids.

Output Recommendations Based on User Inputs, Std Produce Tests, and Lessons Learned
Producibility – Method: Cutting

Methods Take Into Account Facilities/Capabilities, Direct Materials, Indirect Materials, Part Quality, In-Process Quality, and Interactions With Other Items
Producibility – Method: Cutting

Results for Cutting - Hand

Prepreg Material - Indirect Materials
- Backing Paper
  - Product A associated with Prepreg
  - Evaluate prepreg backing paper per???: Specification for NDE detectability and contamination.
- Product A associated with NDE Compatibility
- Evaluate prepreg backing paper per???: Specification for contamination.

Separator Material
- Evaluate prepreg separator per???: Specification for prepreg usage.
- Product A associated with ResinID 1
- Product A associated with NDE Compatibility
- Evaluate prepreg separator per???: Specification for prepreg usage, NDE detectability, and contamination.

Prepreg Material - Spool Requirements
- Cutting Capability
  - There is a conflict between cutting capabilities and prepreg spool ???: Needs investigation.
- Resin Environment Requirements
  - TBD.

Part Quality - Inclusion
- Indirect Materials - Cutting
  - Product A associated with Cutting
  - Evaluate cutting separator per???: Specification for prepreg usage.
  - Product A associated with NDE Compatibility
  - Evaluate cutting separator per???: Specification for prepreg usage, NDE detectability, and contamination.

In-process Quality - Angle Accuracy
- Angle accuracy capability (total layup angle accuracy/repeatability) can not meet quality requirements of [angle accuracy] because cutting accuracy/repeatability is ??.

Secondary Operations
- Tgest per ??? Specification

Part Dimensions
Producibility User
Producibility – Quality: Thickness

The Module Is Flexible So Different Users Can Use It For Their Needs Later In a Development Cycle
Producibility User
Producibility – Quality:
Thickness

Output According To Needs
Administrator User Database Management

Maintainability and Information Updating Is Critical....
Collaboration User Messenger
Summary

• **Demonstrated:**
  – Design User Interface for Producibility
  – Producibility Quality Areas of Thickness and Voids
  – Producibility Operation/Processing Area of Cutting and Indirect Materials
  – Recommendations Based on Inputs and Lessons Learned
  – Integration of Producibility Module Multiple Component Pieces

• **Approach Is Viable As Module Has Evolved**