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Feasibility Study of Closed Cavity Bag Moulding (CCBM) for Novel Mouldless Manufacturing of Carbon-Epoxy Composites

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M. Mahendran, S. Pant
Graduate Students, Carleton University
P. V. Straznicky, J. Laliberté
Professors, Carleton University

Carleton UNIVERSITY
Canada's Capital University

Outline

- Project Overview
- Project Objectives
- Mouldless Manufacturing Techniques
  - Vacuum Assisted Resin Transfer Moulding (VARTM)
  - Closed Cavity Bag Moulding (CCBM)
- VARTM vs. CCBM
- Permeability Evaluation and Results
- Conclusion / Future Work

Project Overview

- Manufacturing GeoSurv II, an all composite Unmanned Aerial Vehicle (UAV) for geophysical survey missions
- Industry partner: Sander Geophysics Ltd. (SGL)
  - Specializes in high resolution airborne surveys for petroleum and mineral exploration, and environmental mapping worldwide
- Research partner: National Research Council (NRC)

Wing Span: 16 ft
Length: 14 ft
Height: 3 ft
Target Weight: 200 lbs
Power Plant: 2 cylinder, 2-stroke, 30 hp engine

GeoSurv II UAV

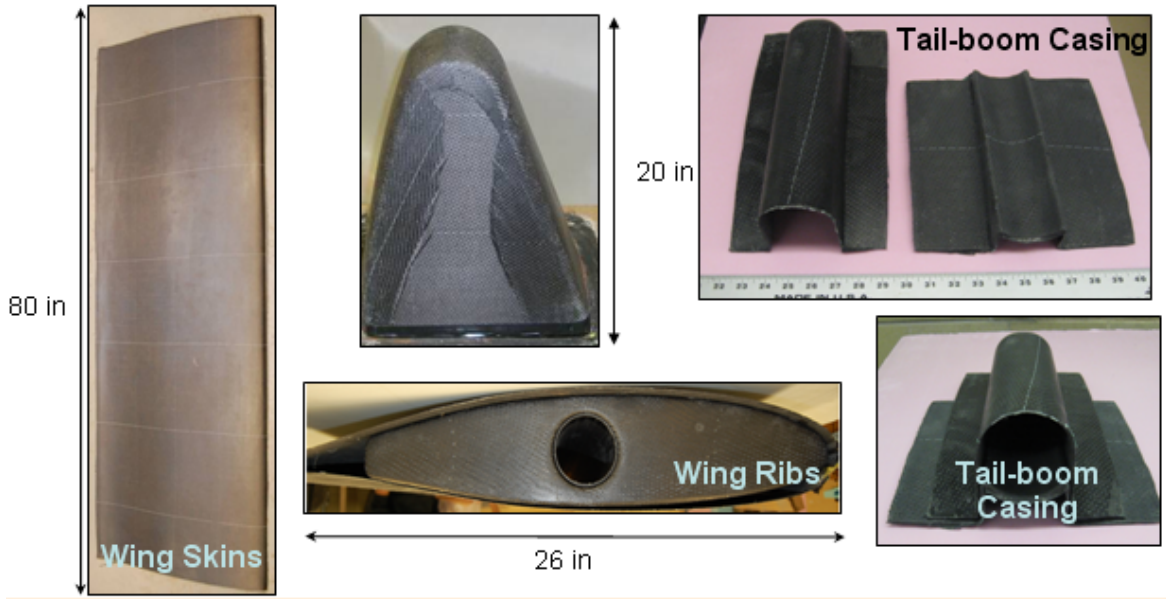
Project Objectives

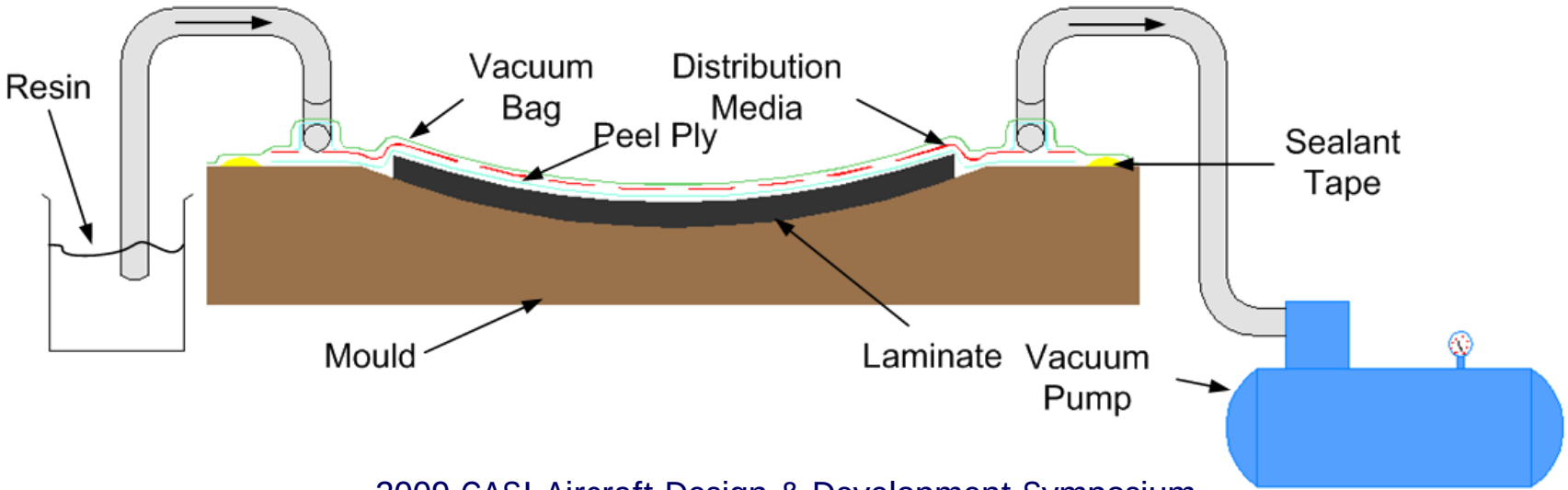
- Develop low cost composite manufacturing processes that are suitable for producing UAV components of varying complexity
  - Vacuum Assisted Resin Transfer Moulding (VARTM)
  - Closed Cavity Bag Moulding (CCBM)

- Apply flow simulation techniques to predict and optimize resin infusion
  - Permeability evaluation
  - Liquid Injection Moulding Simulation (LIMS)

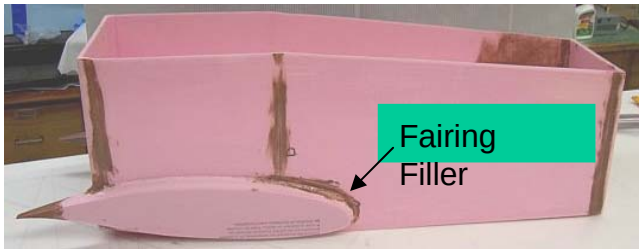
Conventional VARTM Methods

- Low cost
- Disposable materials
- Closed moulding process
- Good part quality
- Good mechanical properties



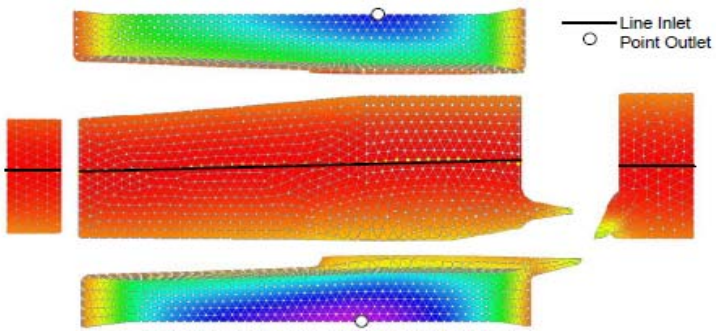


Mouldless VARTM Methodology

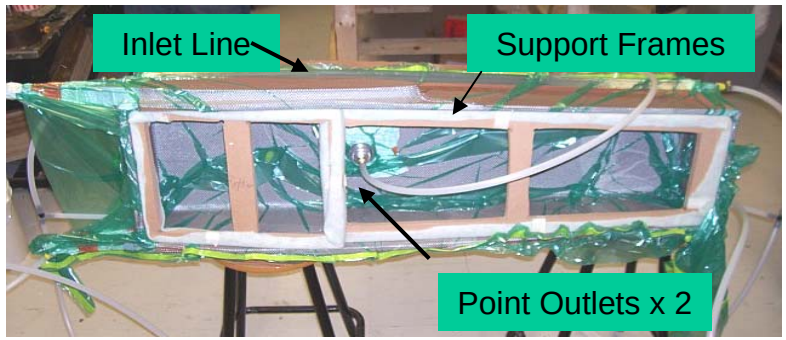


Core Preparation

Fabric Layup



Flow Simulation



Infusion Setup

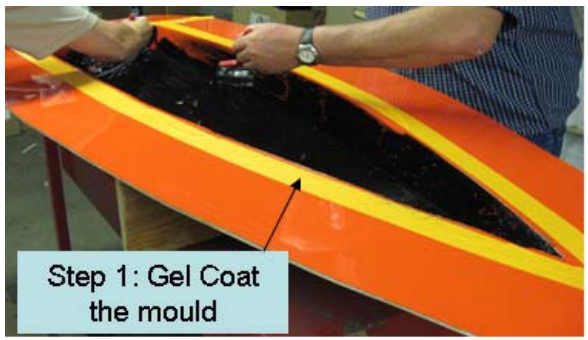
Mouldless VARTM Results

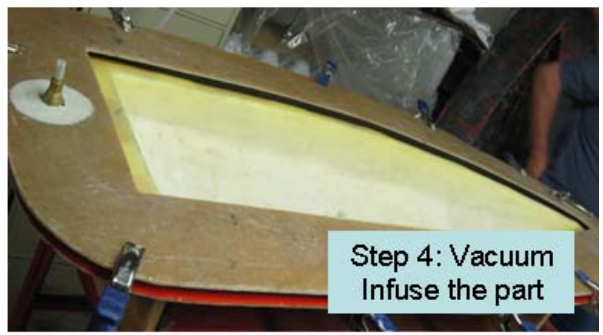
- Mouldless VARTM is a viable option for low cost airframe manufacturing
- Major Issues:
  - Vacuum leaks → air pockets
  - Dimensional tolerances
- Process robustness, repeatability and tolerances need to be improved

Fuselage main frame manufactured by mouldless VARTM

Closed Cavity Bag Moulding (CCBM)

- Relatively new process - popular in the marine industry
- Uses a silicone based elastomeric material to manufacture flexible vacuum bags that are form fitted to the shape of the mould





- Reusable
- Robust
- Less wastage of materials
- Integrated manufacturing

CCBM for Mouldless Manufacturing

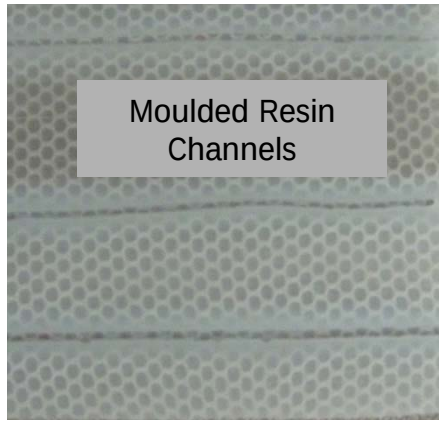
- Major Challenges
  - Relatively high initial costs
  - Need for a sealing mechanism
- Potential Benefits
  - Improved robustness
  - Repeatability
  - Improved dimensional tolerances
  - Tailorable infusion: embedded channels

CCBM Process Development

- Goal:
  - Make CCBM Feasible for mouldless manufacturing
- Approach: Process Value Analysis (PVA)
  - Identify and assess the feasibility of various CCBM techniques
  - Develop a PVA matrix including all process variations
  - PVA Analysis
- CCBM Systems
  - Available in sprayable or brushable forms
  - SWORL™, Sprayomer Elastomer, Airtech Multibag, Vacuspray and Arctek reusable vacuum bagging systems
  - Arctek reusable vacuum bagging systems was chosen for initial experiments

CCBM Process Development

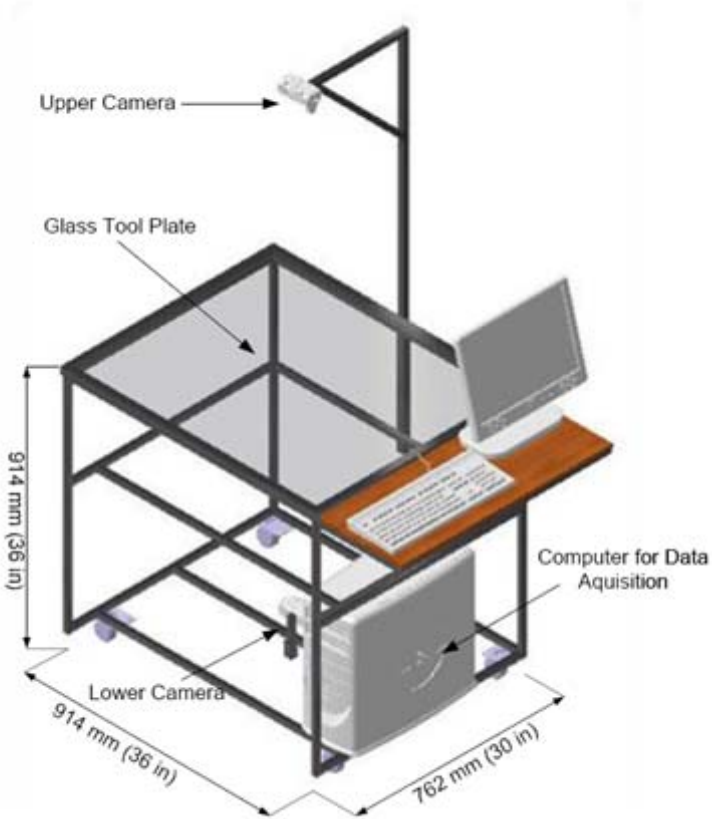
- Sealing mechanism
  - 2 part- extruded silicone seal
  - Using conventional tacky tape
- Channel In Bag (CIB) infusion
  - Can be optimized for faster and quality resin infusion
  - Less resin wastage
- Faster resin infusion with distribution medium

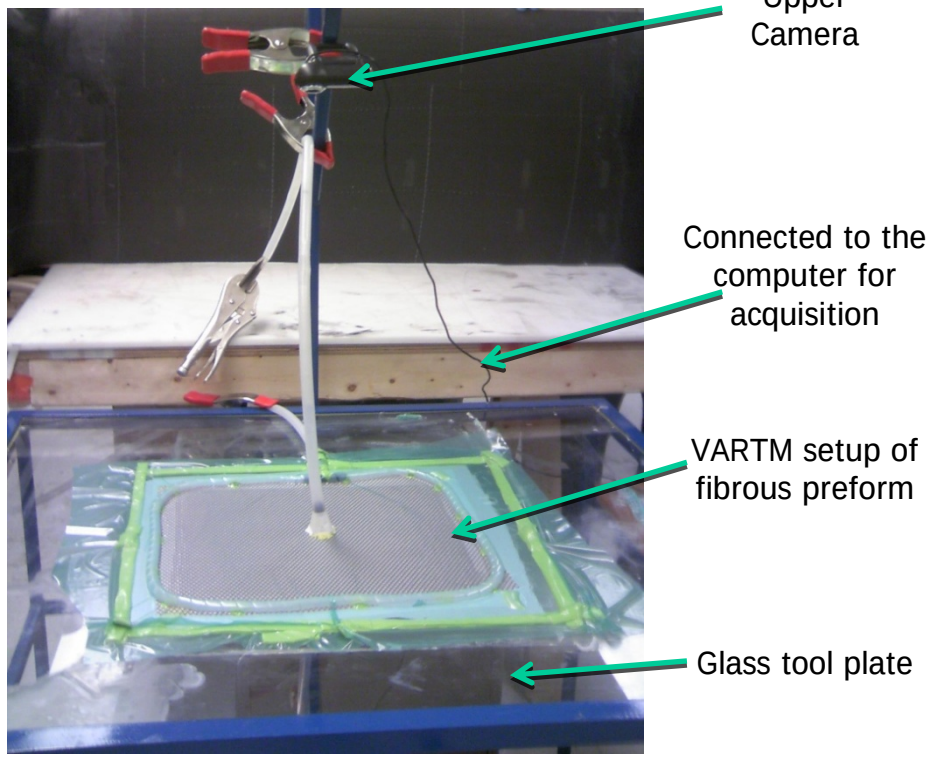


Sample CCBM bag-tacky tape seal

Permeability Evaluation

- Permeability (resistance to flow) is needed to simulate infusion during composite manufacturing





Permeability evaluation setup

Image Acquisition and Analysis

- An image acquisition graphical user interface (GUI) software was developed in Matlab 2007b
  - Acquisition software is capable of remotely controlling camera parameters, take time lapse pictures at desired intervals, and save it as images and/or create a video

- Acquired images are processed using image analysis GUI software also developed in Matlab 2007b
  - Analysis software is capable of processing the acquired images to detect and track the flow front using various algorithms

Image Acquisition Software

Register and select the device and its resolution

Preview live video taken by the selected device in color or in greyscale

Review and change device parameters such as: zoom, brightness, contrast, etc.

Select time interval and start logging

Save acquired images for further analysis and create a video

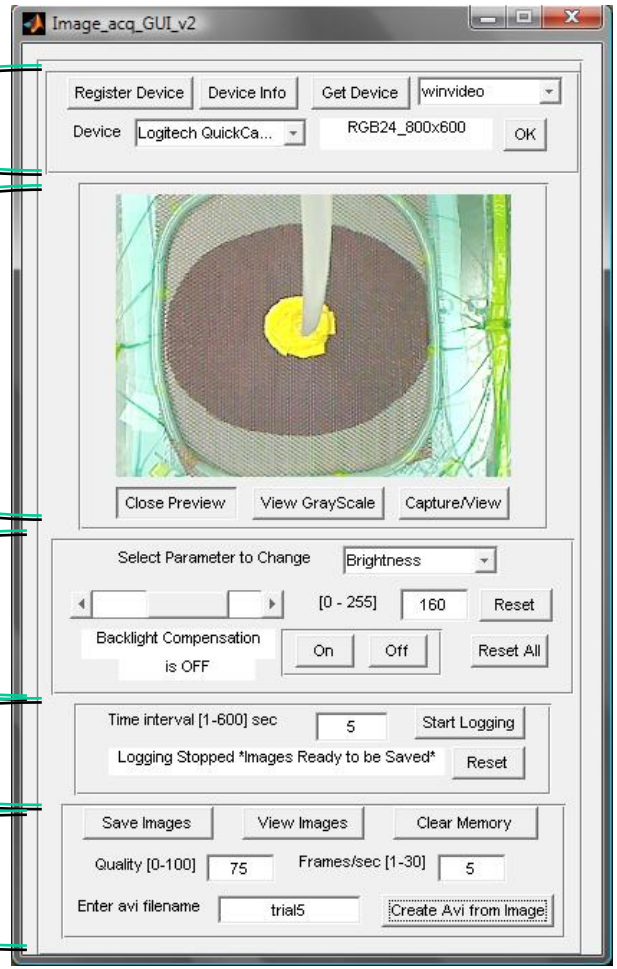
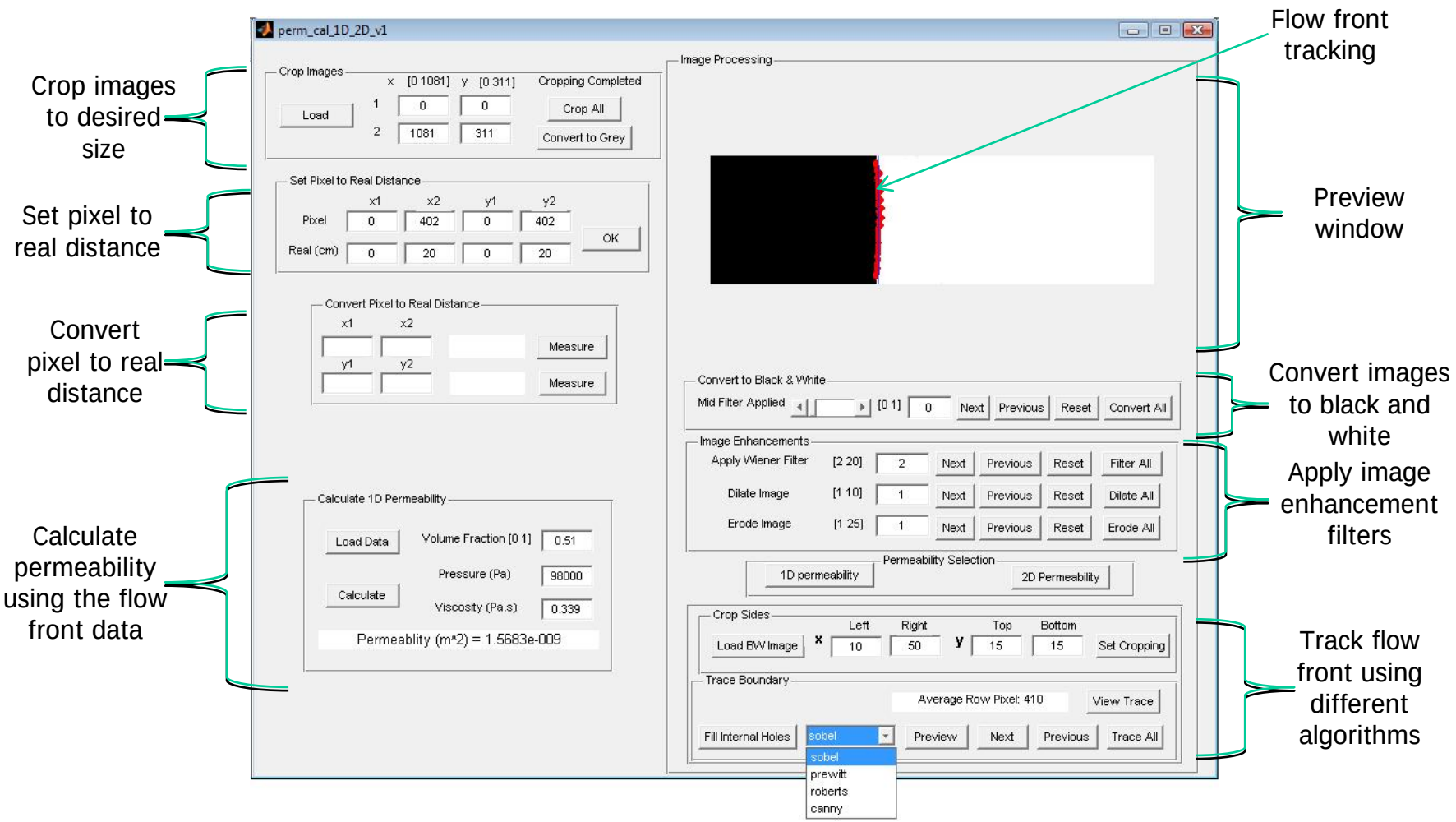
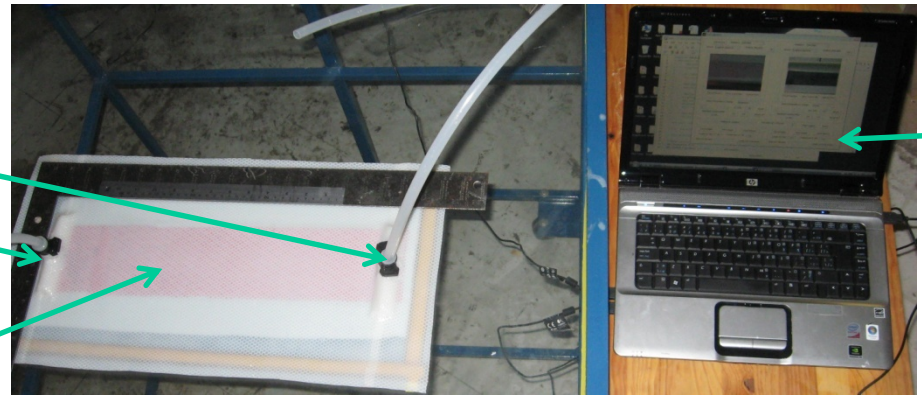


Image Analysis Software



Permeability (VARTM vs. CCBM)

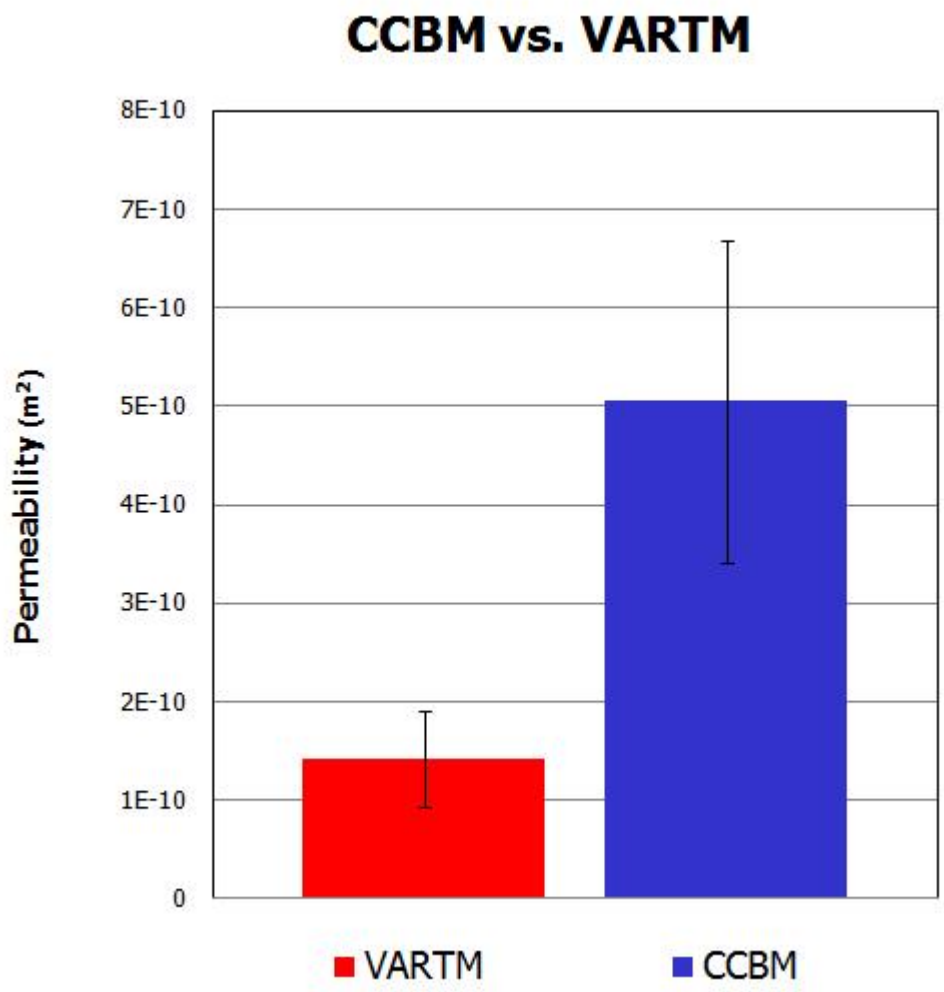


CCBM setup

VARTM setup

Permeability Results

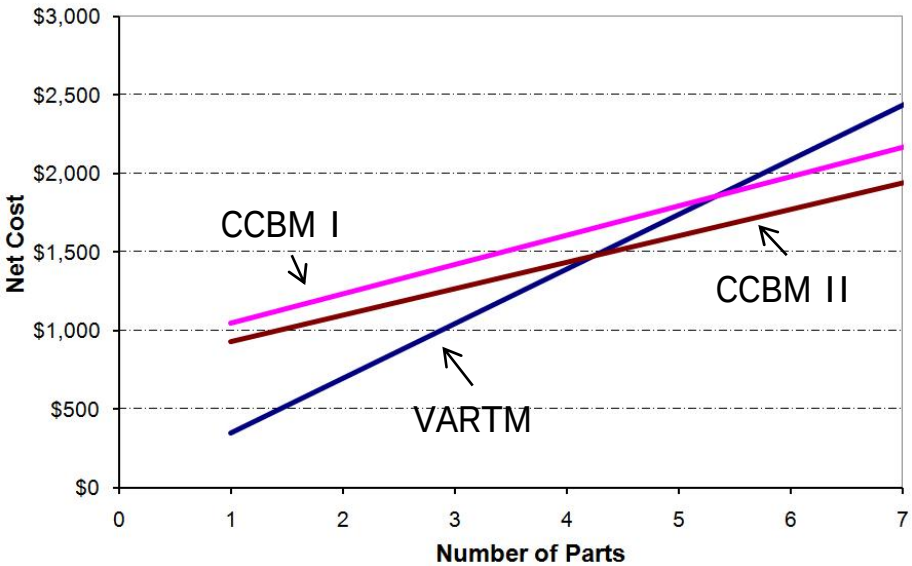
- Reinforcement:
  - AGP 370-5HS
- Layup:
  - [(0/90)˚, (±45)˚]
- Resin:
  - SC 780 Toughened Epoxy
- Vacuum Pressure:
  - 94800 Pa
- Fibre Volume Fraction:
  - 0.55
- Viscosity:
  - 0.339 Pa.s



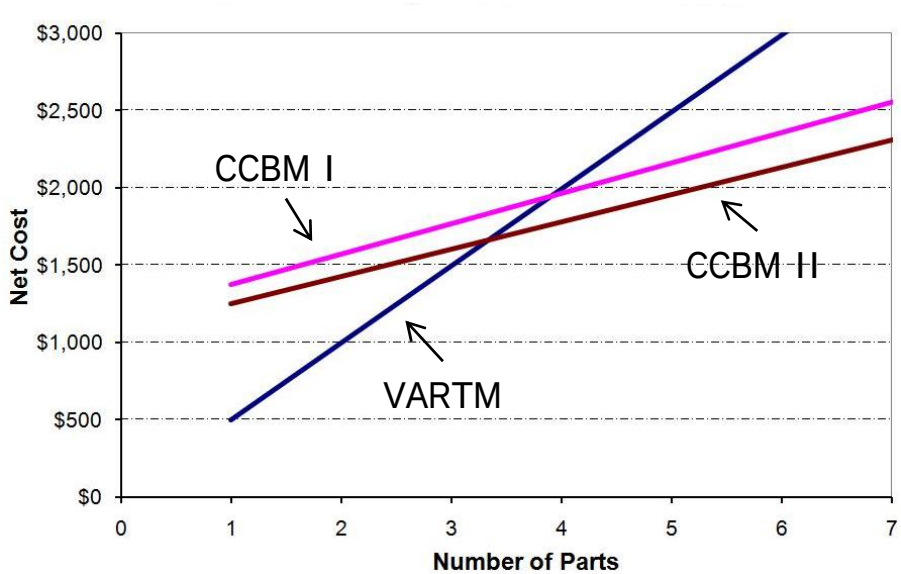
CCBM Process Value Analysis

Process Variation	Description
CCBM I	CCBM with extruded silicone seal and distribution medium
CCBM II	CCBM with tacky tape and resin distribution channels embedded in the bag
VARTM	Traditional VARTM with disposable materials

- All costs were estimates based on actual cost of the materials incurred
- All process parameters were converted to labour hours and then assigned a monetary value using the labour rate



PVA comparison at labour cost of $20/hr



PVA comparison: Sensitivity to labour cost ($40/hr)

Conclusions & Future Work

- CCBM with channel in bag infusion would be most feasible alternative to conventional VARTM for mouldless manufacturing of the fuselage and other complex components

- Future Work:
  - Optimize resin channels for minimum resin consumption and improve infusion quality
  - Manufacture a demonstrator fuselage main frame to illustrate the process capabilities

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QUESTIONS ???