

## MICRO-FLOW VACUUM CONTROL (MIVACON) VARTM AND MULTI-STEP PROCESSING OF COMPOSITE ARMORS.

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### Comparison of VARTM with RTM and Hand Lay-Up

- Reduces lay-up time
- Reduces voids
- Contains fewer defects/product variation
- Lower tooling costs than RTM
- Less dependent on operator skill
- Room temperature processing
- Higher fiber volume fraction
- Scalability to large structures
- Higher strength and modulus than RTM
- More environmentally friendly

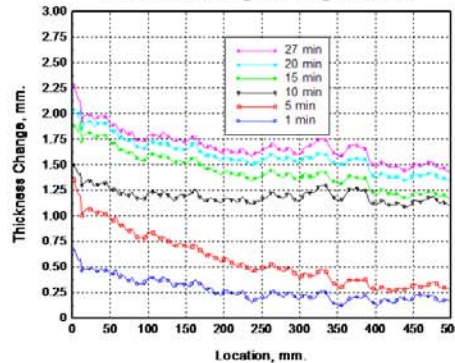


(Fawaz, p. 1), (Mahamed, 2001, p. 1)

### Disadvantages

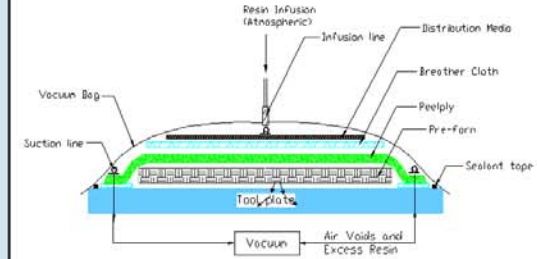
Pressure gradient - Thickness gradient - Limits on applications

#### Thickness Change During Infusion



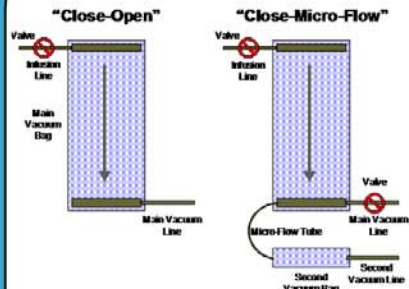
From Bazle A. Gama, Hongyun Li, Wei Li, Antonio Paesano, Dirk Heider, and J.W. Gillespie, Jr. Improvement of Dimensional Tolerances During VARTM Processing

### Lay-Up Sequence



Cross-section of Typical Lay-up Sequence

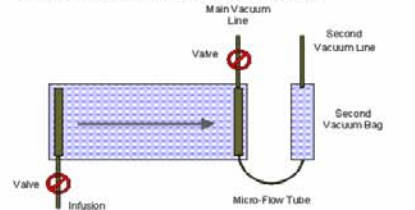
### Processing Scenarios: Issues



From Bazle A. Gama, Hongyun Li, Wei Li, Antonio Paesano, Dirk Heider, and J.W. Gillespie, Jr. Improvement of Dimensional Tolerances During VARTM Processing

### Typical Micro-flow Procedure

- The infusion stage of the process must be carefully monitored.
- As the resin begins to flow through the micro-tubes, the infusion line and the main vacuum line should be closed.
- Immediately before the resin gets (apparent by highly viscous resin), the main vacuum line must be re-opened to allow the excess resin to be suctioned out of the system.



Bazle A. Gama, Hongyun Li, Wei Li, Antonio Paesano, Dirk Heider, and J.W. Gillespie, Jr. Improvement of Dimensional Tolerances During VARTM Processing

### Variables

- Resin temperature
- Viscosity
- Fiber thickness
- Fiber orientation
- Vacuum pressure
- Fiber Type



### Single and Multi-Step Processing for Armor Panels

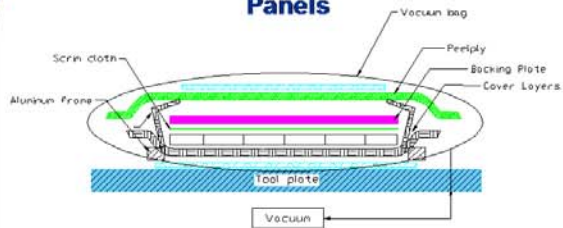
- **Single-step** is the preferred method to making a composite armor panel. The backing plate is formed within the lay-up sequence and uses the VARTM process.
- **Multi-step** is a process that requires experiments and hand lay-up. The backing plate is made prior to the final armor panel lay-up.



Single Step

Multi-Step

### Lay-up Sequence for Multi-Step Armor Panels



Cross-section of Typical Armor Panel Lay-up Sequence

\*Note: Hand Lay-up was used to apply SC31 resin.



### Armor Panel Procedure



Cutting fabrics



Preparing backing plate

### Armor Panel Procedure



Preparing the resin



Mixing the resin

### Armor Panel Procedure



Lay-up sequence



### Armor Panel Procedure



Lay-up sequence



### Armor Panel Procedure



Finished panel



Panel after ballistic testing

### Conclusions

- Composites are being used over other materials due to their stiffness, strength, and lighter weight.
- VARTM is used because of its advantages in making large-scale components, its lower costs, and fewer defects. There are a wide variety of applications ranging from sporting equipment and aircraft components to infrastructure repair and bridges.
- The multi-step composite armor panels have many military applications including lightweight shields for military vehicles.

### Acknowledgements

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