



DATA MINING OF PROCESS INFORMATION FOR VACUUM-ASSISTED RESIN TRANSFER MOLDING (VARTM)



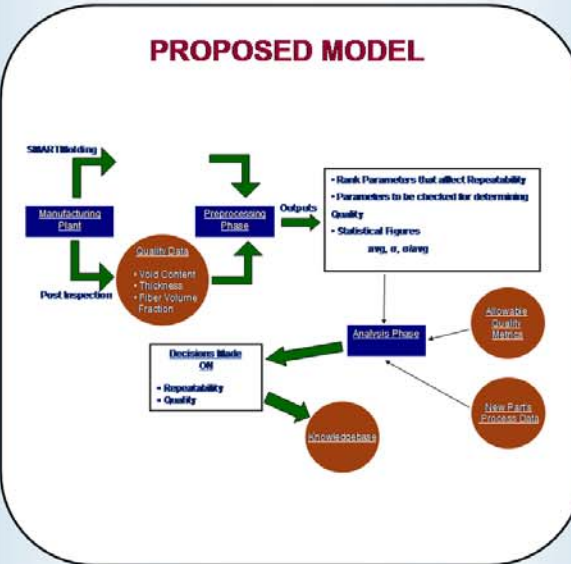
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OBJECTIVE

- **Analyze Repeatability of VARTM Process**
 - Identify parameters that affect process repeatability
 - Detect outliers based on the part's values for these parameters
- **Analyze Quality**
 - Identify Quality requirements
 - Relate process variables to quality requirements
 - Explore methods to determine if a new part manufactured is within acceptable quality limits
- **Identify Defects**
 - Develop methods to recognize a defective part based on its process values
- **Increase Knowledge**
 - Store process values, results of any analyses/post-inspection, and decisions about quality made for each part

PROPOSED MODEL



PARAMETERS FOR REPEATABILITY

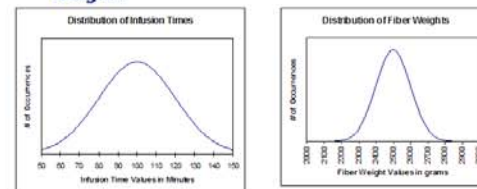
Process Parameter	Comments
Fiber Weight	
Final Part Weight	Fiber + Resin Weight
Fiber Volume Fraction	Calculated from Resin Density and Part Weight
Vacuum Check Time	Time taken to set up complete vacuum before Infusion
Infusion Time	
Vacuum Loss During Check	Should be below a threshold
Resin Weight Infused	Collected at periodic intervals during Infusion
SMART Molding	Indicates resin gelation. Collected at periodic intervals during Infusion and Dwell
Minimum Vacuum during Infusion	Should be above a threshold
Resin Flow Behavior	Time recorded by successive sensors when resin flow reaches the sensor

EQUATIONS

- **Process Repeatability**
 - Rank Parameters using $R = \sigma/avg$.
 - Relatively small deviation => Smaller R => High Repeatability of Parameter value
 - High R recommends preferred parameter for process improvement
- **Outlier Detection**
 - Sensitivity parameter
 - $T = |avg - newpartvalue| / \sigma$
 - Gives a feel for the amount of deviation of new part's value from the average
 - High T recommends preferred part for post-inspection

PROCESS REPEATABILITY R

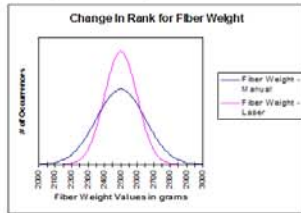
- **Fiber Weight vs Infusion Time**
 Infusion time is affected by many factors. Values are not as repeatable compared to Fiber Weight.



Parameter	Average	σ	R = σ/avg	Rank
Fiber Weight	2500	100	0.04	1
Infusion Time	100	20	0.2	2

PROCESS IMPROVEMENT

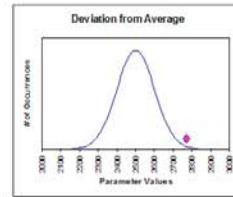
- **Improving Fiber Cutting**
 - Comparison of Hand-cut vs Laser-Cut Values. Rank of 'Fiber Weight' improves (becomes more repeatable) when layers are cut with laser.



Parameter	Average	σ	$R = \sigma/\text{avg}$	Rank
Fiber Weight (Hand Cut)	2500	150	0.06	Low
Fiber Weight (Laser Cut)	2500	100	0.04	High

OUTLIER STATISTICS T

- **Detecting Potential Outliers**
 - High Deviation from Average Value => Potential Outlier



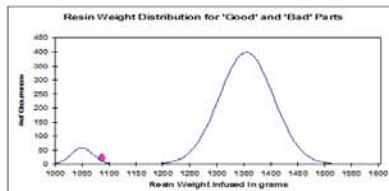
Fiber Weight Value	# of Layers	T - Avg value/ σ	Rank of Part based on T
2450	10	0.95346259	4
2580	10	1.52554814	5
2490	10	0.19069252	1
2460	10	0.78277007	3
2520	10	0.58138504	2
2880 (New Part)	11	1.59625213	5

PREPROCESSING PHASE - QUALITY

- **Process Variables Vs Quality Parameters**
 - Quality Parameter are dependent on one or more Process Variables
 - Example - Void Content of a part depends on the Vacuum Loss during Infusion and/or resin amount infused.
 - Quality Data collected through post inspection plays an important role in identifying these relationships
- **Relations between Process Variables**
 - Several Process Variables, which affect different/same Quality Parameters might be dependent on each other
- **Allowable Limits**
 - Based on the allowable Quality metrics, decide on the allowable values for those variables that relate to Quality Parameters.

DEFECT DETECTION

- **Quality Data**
 - Quality database gives information about which parts are good and which are bad, based on the acceptable values for quality parameters.
- **Example**
 - Insufficient Resin Infusion => Higher Void Content
 - If a new part's Resin Infused value is closer to the bad Parts' average than the good ones', then highly probable that the part is defective



SUMMARY

- **Identify Relationships**
 - Data mining on the SMARTMolding database reveals many hidden relationships between
 - Process data and Repeatability
 - Process data and Part Quality.
- **Rank Parameters**
 - based on Repeatability
- **Reduce post-inspection**
 - based on outlier detection algorithm

ACKNOWLEDGEMENTS

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