Optimization of the Infusion Process using Adaptive control coupled with genetic algorithm In Resin Transfer Molding

Pooria Kashani*, Alejandro Rodriguez, Bob Minaie

Department of Mechanical Engineering, College of Engineering

Abstract. To account for the irregularities in the filling pattern during Resin Transfer Molding (RTM), adaptive control can be used to regulate the filling pattern such that the last point to fill coincides with the preset exit vent location to avoid dry spot formation. In this work, Genetic Algorithm (GA) was selected as a robust search method to optimize the location of the gates and the sensors. Results obtained show that GA was able to use less than 5% of all possible arrangements to find the optimal solutions. In addition, the solutions found by GA were always in the top 0.4% of all possible combinations. These results could provide useful information for optimum arrangements and they could lead to more efficient and intelligent processing.

1. Introduction

Resin Transform Molding (RTM) process has became one of the most popular methods in fabrication of advanced composite materials. This process is attractive since it enables manufacturing of geometrically complicated parts with high quality and good strength to weight ratio. RTM process has four main stages: 1) cutting and placing of the fiber mats (preform) inside a mold, 2) resin injection, 3) curing of the part, and 4) demolding of the hardened part.

The formation of the flow front in resin injection process will affect the quality of the finished in terms of the void formation. Here in this work we minimize the void formation using adaptive control. In addition, by using an evolutionary optimization method, the gate-sensor location was optimized in order to increase the success of the resin injection control system.

2. Methodology

In this study, the filling process of a rectangular mold with three gates and one vent was simulated using a Control Volume Finite Element Method (CVFEM) code. A set of spinal sensors starting at each gate and ending at the vent were used to monitor the process (Fig 1). To calculate the next time step gate flow rate configuration, the position of the flow front along each spine line connecting a gate to the vent was used as control feedback. A control algorithm designed for adaptive flow control was used for flow control and Genetic Algorithm (GA) optimization method [1] was applied in order to find the optimal gate-sensors configuration.

Figure 1 a rectangular mold with three gates and one vent

In this work, a control algorithm designed for adaptive flow control using spinal sensor configuration described in [2, 3 and 4] was used.

$$\dot{Q}_i = \dot{Q}_{inj} \cdot \left( \frac{d_i}{\sum_{j=1}^{n} d_j} \right)^2$$  \hspace{1cm} (1)

where $\dot{Q}$ is the flow rate, $i$ represents each inlet gate, $t$ is the current time, $\Delta t$ is the time step, $d$ is the distance
between the flow front and the vent and $\sum_{j=1}^{3} d_j$ is the summation of the distances between the flow front and the vent for all sensor paths. The objective function used as the fitness function by GA, is defined based on the percentage of void formation, and the filling time required to fill the part. Accordingly:

$$\Gamma_j^k = \frac{MAV - PV_j^k}{MAT} - \frac{MAT - T_j^k}{PPOV} - \frac{MAT-OV}{MAT} * VW_j^k * TW$$

(2)

where MAV is the Maximum Allowable Void, PV is the Percentage of Void corresponding to the $j$th arrangement, $k$ is the case to be calculated, PPOV is the Percentage of Optimal void, MAT is the Maximum Allowable Time, $T$ is the Filling Time for the $j$th arrangement, OT is the Optimal Time, VW is the Void Weight constant, and TW is the Time Weight constant. This objective function is capable of distinguishing the acceptable cases from the non-acceptable ones. If the calculated value is positive, the arrangement is acceptable under the given parameters MAV and MAT. If the value is negative the arrangement is not acceptable under the given parameters.

### 3. Case Study

A rectangular geometry was chosen to apply our implementation of GA to the optimization of the RTM processes. The simulations were run for a 365x185x5 mm³ mold cavity. In this study, we chose 24 boundary nodes to be combined amongst them in arrangements of 3 gates and 1 fixed vent. In this case, 2024 possible combinations of 3 gate-sensor configurations exist.

### 4. Results and Discussion

Figure 1 shows the results obtained using the objective function to analyze the simulation filling outcome for different combinations of Gates-Sensors. The order of analysis of the Gates-Sensors configurations was chosen using the Selective Exhaustive Search (SES) method described in [4] for the same mold filling problem. This graph contains all the possible combinations available for gates-sensor. It is obvious that different arrangements cause a non-linear trend in objective function (Eq. 2). Also, only 2.3% of all possible configurations is positive and acceptable for RTM process.

### 5. Conclusions

Finding the optimal location of the gates-sensors to prevent dry spot formation and to minimize filling time during RTM composite manufacturing is a nonlinear problem and requires extensive trial and error experimentation that can be successfully substituted by filling simulations. Nevertheless, tremendous computational time is required to search for gate-sensor configurations yielding acceptable filling results. This study confirmed that GA constitutes a useful and efficient searching method that can be easily coupled with filling simulations and adaptive control with spinal sensor configurations to find gates-sensors arrangements that provide optimal filling results.

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