

DEVELOPMENT OF A DIELECTRIC SENSOR FOR THE FLOW MONITORING OF RESIN TRANSFER MOULDING PROCESS

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Introduction

This research project focuses on online flow monitoring in the Resin Transfer Moulding (RTM) process, which is one of the most promising and cost-effective technologies used for production of large complex three-dimensional composite components [1, 2]. The main steps of the RTM process for the manufacture of a simple part are the preform preparation, the draping of the preform inside the mould cavity, the closing of the mould, the resin injection and finally the curing phase.

The manufacturing techniques that are used for composite materials and the variability of the material introduce faults during the manufacturing process. Numerical simulations are useful process design tools when accurate parameters' data are used to describe the problem [3]. However, the collection of the parameters that are used by these models is lacking and for that reason, online monitoring of the process is suggested to enhance the understanding of resin's flow and cure.

This paper describes the development of a dielectric sensor system for flow monitoring, which is to be embedded on a pilot RTM tool. The optimum sensor geometry and materials were analysed through Finite Element Method (FEM).

Electrostatic modelling

The modelling of the sensor enhances the understanding of the electric field response due to differences in materials conductivity. The electrostatic behaviour of the proposed sensor has been analysed. The Partial Differential Equations (PDE) toolbox in the MATLAB software was used for the electrostatic analysis, which can be used to solve electrostatic field equations. The equations used for the analysis are as follows:

$$\nabla \cdot \vec{D} = -\rho_v \xrightarrow{\vec{D}=\epsilon \cdot \vec{E}} \nabla \cdot (\epsilon \cdot \vec{E}) = -\rho_v \quad (1)$$

$$\vec{E} = -\nabla V \quad (2)$$

where, ϵ is the coefficient of dielectricity, ρ_v is the space charge density, V is the scalar potential, \vec{E} is the vector of the electric field and \vec{D} is the electric displacement field.

The boundary conditions were applied onto the curves of the electrodes and the materials, where the areas of interest are located. In this case study, the grounded areas have zero potential. The electrode to which voltage is applied has a potential equal to 1 Volts. Dirichlet is the selected boundary condition because of the known variable, which is the potential of the driving electrode. Table 1 includes the dielectric coefficients used in the model.

Table 1: Dielectric coefficients of the materials used for the electrostatic study. [4]

Material Name	Dielectric Coefficient	Domain
Copper	0	A
PET	2.1	B
Air	1.00059	C
Resin	3.6	C
Carbon fibres	0	D

Results and discussion

The main variables for the modelling of the sensor response are the dielectric thickness, the distance between the electrodes, and the selected materials. The distance between the electrodes is correlated to the thickness of the measuring material, which in this case study is the impregnated carbon fibre fabric. The designed sensor is 4 mm wide and the overall thickness is 0.5 mm. The simulation includes two case studies, which are linked to the presence or not of resin. The sensitivity and the voltage drop on the sensing electrode are the criteria for the selection of sensor's final geometry. It can be observed that the sensitivity of the sensor is increased with the addition of a dielectric layer. Figure 1 presents the sensitivity analysis and the voltage drop with regards electrodes' distance.

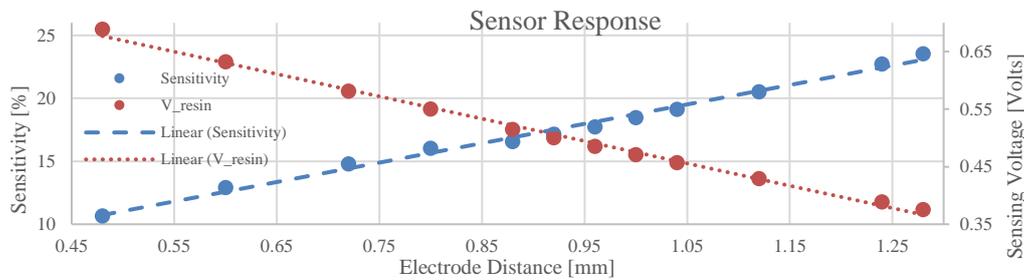


Figure 1: The sensitivity and voltage drop of the sensor as a function of electrodes distance.

Figure 2.a illustrates a 2D section of the sensor geometry and its domains (Table 1), which are used for the simulation. Figure 2.b shows the voltage distribution of the selected sensor. The voltage across the sensing electrode is 0.52 Volts. Also, the electric field is interrupted at the level of the carbon fibre tows as expected, because of the conductivity of the carbon fibre. This is an inevitable limitation with the carbon fibre. Thus, the sensitivity of sensor is crucial for detecting the resin impregnation.

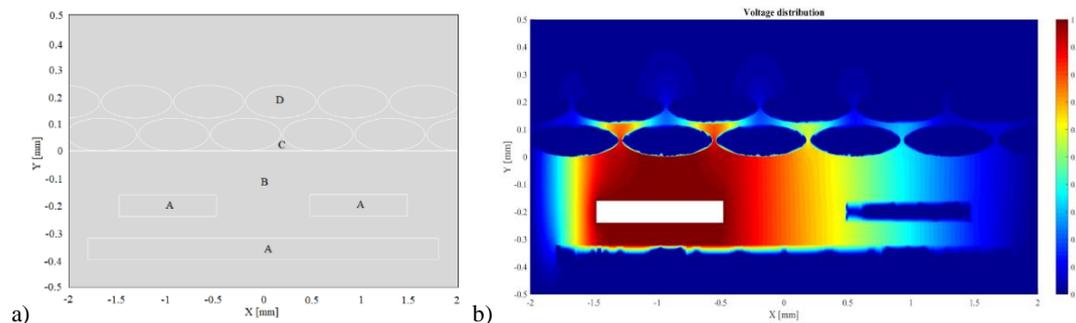


Figure 2: a) The geometry of the sensor with the domains for the simulation and b) the voltage distribution.

Electrostatic analysis can provide information on the sensor response and is a useful tool during the design stage. The material properties were considered during the design and simulation of the sensor. The main contribution to the changes in the sensor response comes from the impregnation of resin to the reinforcement. Then, the sensor signal correlates to the resin location [5] and provides information about the frontal flow position.

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