MALAYSIAN RUBBER COUNCIL

MRC INDUSTRY LINKAGE FUND

Prediction and Control of Humidity of Glove Former in Vulcanization Ovens

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PROJECT OUTPUT	MATLAB Software for Simulating Vulcanization Oven

Introduction

Drying and vulcanization are important processes in glove manufacturing. The quality of the final product depends on accurate control of the vulcanization oven, especially its temperature. This has a large effect on the moisture content of the gloves exiting the oven. To ease prediction and controller design, it is useful to have a simulation model of the oven. For this purpose, a software for simulating vulcanization ovens has been developed based on MATLAB, under the Malaysian Rubber Council Industry Linkage Fund. The software can be used to analyze the relative significance of different heat transfer mechanisms, investigate temperature profile changes due to parameters changes, compute the amount of water evaporation which can be achieved and investigate influence of various parameters on evaporation.

MATLAB Programme

In the software programme, the oven dimensions, material properties, burner settings and environmental temperature are user-defined. The oven is segmented in all three dimensions with the number of segments that can be specified by the user. The oven may be heated by several burners and these divide the oven lengthwise into zones. Each zone has a burner as shown as in Figure 1 and the segmentation into zones is illustrated in Figure 2. Computation of the oven temperature takes into account conductive, convective and radiative heat transfers, as well as heat transfer due to airflow. The humidity in the oven can be treated in three different ways. Firstly, it can

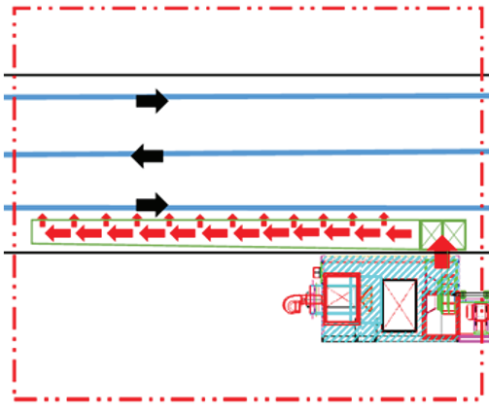

Figure 1: Example of a zone

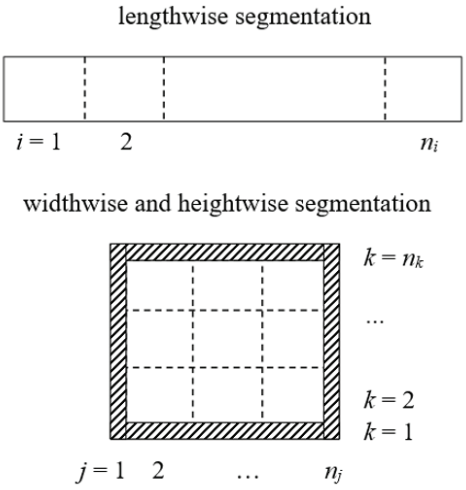

Figure 2: Segmentation of an oven

be set as a constant. Secondly, it can be computed without any system for moisture extraction; this means that the humidity will eventually increase to 100% due to the evaporation adding to the moisture content of the air. Thirdly, it can be computed with a predefined humidity entering the bottom of the oven through recirculation air.

An evaporation model is included where the amount of water evaporated from a single glove depends on the airflow rate, air density, number of gloves per segment, drying time constant, conveyor line speed and the surface area of the glove former. The drying time constant describes the rate of drying. It depends on the type of rubber used, such as natural rubber or nitrile rubber, the composition of the latex compound, as well as the glove thickness. The value of the drying time constant will need to be supplied by the glove manufacturer or estimated from experiments. The software programme outputs the amount of water evaporated per glove after passing through the oven.

Programme's Functions

By default, the software plots the temperature contour with a cross-section cutting across the oven at the centre widthwise as shown in Figure 3 and Figure 4. With minor modifications, the user can amend the plots to display different quantities such as the power loss due to conduction, convection, radiation and evaporation at different cross-sections. An example is displayed in Figure 5. These plots are very useful to aid visualization, analysis and subsequent decision-making.

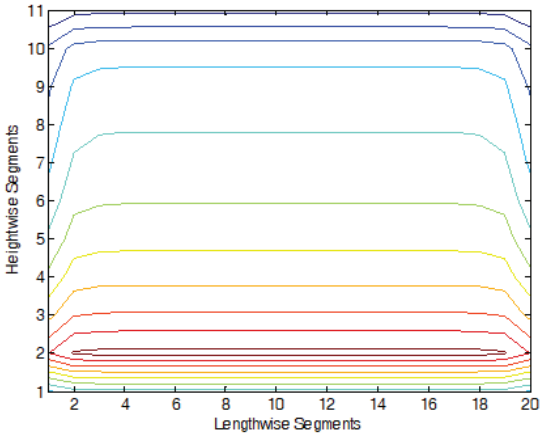

Figure 3: Simulation of oven's temperature contour in case of using indirect heating.

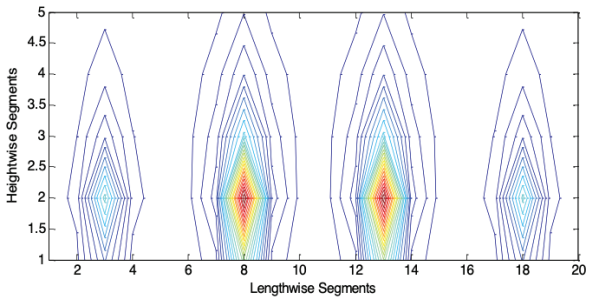

Figure 4: Simulation of oven's temperature contour in case of direct heating.

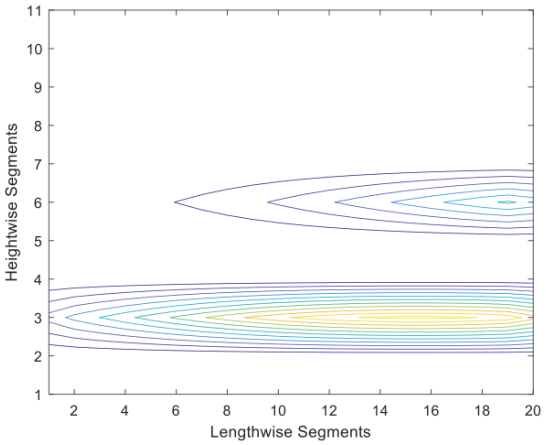

Figure 5: Simulation of power loss profile due to evaporation.

The software can be further utilized together with the MATLAB System Identification Toolbox as shown in Figure 6 to allow detailed system identification to be carried out on the simulated oven. This eases controller design; for example, the model predictive controller requires an accurate process model to function effectively. Further to this, the software can be employed along with the MATLAB Optimization Toolbox to perform optimization of the burner power.

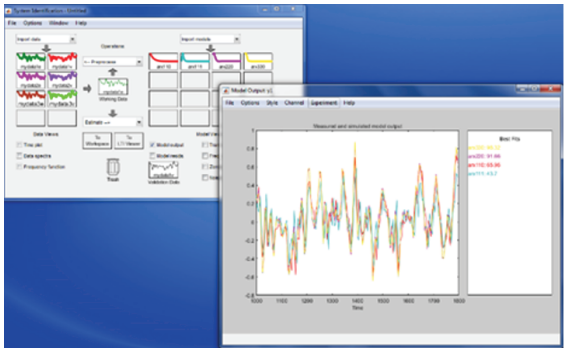

Figure 6: Modelling using MATLAB System Identification Toolbox

Programme's Benefits

The use of the software can lead to important benefits of lower energy consumption, lower percentage defects and a safer working environment for the factory personnel. However, the software also has several limitations. The airflow in the oven is more complicated than just vertical or horizontal directions as captured by the programme. The programme uses laminar flow although some parts may be turbulent flow. Different ovens have different shapes of the entrance and exit openings as well as the positioning of the air ducts. This means that additional effort will be needed to customize the software to a particular oven before it can be used.

Industry members are invited to test the developed MATLAB programme at the company's glove manufacturing facility for us to get the industry's feedback on the practicality and improvements that can be made to the software.

Interested company may contact the emails below for further discussion on the project or to view the project's complete report and the software programme's coding (complete report consists of 54 pages).

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