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ASSESSING ON-OFF CONTROL FOR REGULATING TEMPERATURE ON A RESIN TRANSFER MOULDING PROCESS

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1. INTRODUCTION

In this work we present the assessment of digital control [1] strategies for regulating the temperature in a resin transfer moulding [RTM] based manufacturing process. This came from the design process of an industrial equipment currently under development, for producing mechanical components made of fibre reinforced polymers. The RTM equipment consists of two main parts, the injection mechanism and the mould system. The injection mechanism is a made of a cylinder and a servo controlled piston (very similar to a syringe), which drives a controlled flow of liquid resin to a mould that shapes the component. Both the injection system and the mould need to be under controlled temperature, according to the resin curing specifications.

Heat can be applied to the system either by electrical resistances or hot water. For simplicity and much lower system cost, this heat can be regulated by using a relay, for switching electrical resistances, or using an electromechanically-operated valve for driving hot water, thus employing a simple on-off control strategy [2]. The objective of the present work is assessing this possibility using computer simulation.

The process thermal responses are simulated by simple finite element 1D models of the injection system and the mould. The controller and the corresponding feedback system are computationally modelled.

2. ASSESSING CONTROL STRATEGIES

A Siemens S7-1500 programmable logic controller [PLC] is the device selected to run the

RTM equipment. Like any microprocessor, this PLC is continually executing a program in memory. At each run cycle, besides many other possible tasks, reads the sensor, filters the readings noise, determines the control action and issues an output signal to the actuator. The control algorithm will be implemented by this controller, so this sequential process is also considered in the computer simulations.

The following control strategies are examined, taking as example the case of an electrical resistance switched with a relay.

1. On-off control with hysteresis [2]. The relay turns on if the sensor reading is below the setpoint minus a tolerance and turns off if the reading is above the setpoint plus a tolerance. The relay only switches if a minimum required duration has elapsed since the last transition. This is a requirement introduced to limit relay contact failure due to fast switching. With a solid state relay, or switched mode power supply, this requirement could be removed, but involving a much higher system cost.
2. On-off control with prediction of the switch time duration. Similar to the previous strategy but using the error signal trend to predict the following necessary transition for the relay.
3. PID control [2]. This is probably the most used continuous actuation control algorithm, and is considered here for comparison. Note that only the heat provided to the system is controlled, the heat removed from the system is assumed to happen only by convection with the environment. This limits the control action to be positive only. A standard PID control approach is not applicable.
4. Siemens S7-1500 PLC library temperature control algorithms. Industrial grade auto-tuned temperature control algorithms assessed using an experimental test bench involving the S7-1500 PLC, an electrically heated plate, a thermocouple, a relay and a reference data logger.

The experimental test bench is used to measure the performance of the simulated on-off control strategies, including the noise levels in sensor readings and external perturbations coming from the convection with the environment. This system also provides accurate information for the reading sample frequencies, and controller update cycle frequencies, which are fundamental parameters for tuning any digital controller.

3. CONCLUSIONS

The effectiveness of on-off control strategies is strongly dependent on the magnitude of the system actuation (in this case the heat power) and the relation between the rate of response of the process and the controller update frequency. The simulations enabled a procedure for defining parameter values providing an effective on-off feedback control for the equipment, limiting the system response oscillations around the intended setpoint curves.

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