DEVLOPMENT OF TECHNIQUES TO MEASURE THE FACTORS WHICH INFLUENCE THE ADHESION OF FIBRES IN THE ROTATIONAL MOULDING PROCESS

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The manufacturing of rotationally moulded composites has been challenging due to many factors. Firstly, the intricate polymer-fibre interaction during the bi-axial rotation complicates the combination of different materials. Secondly, the addition of reinforcing fibres alters the normal sintering and densification mechanism involved in part formation. A number of methods have been developed here to measure how the moulding process is changed by the addition of reinforcement. Firstly, a new Fibre-Particle Interaction Test (FPIT) was developed to quantify the level of adherence produced between a polymeric particle and a reinforcing fibre bundle. Additionally, a new in-mould visual imaging system called RotoCam was developed to detect the fibre saturation point during the process using real-time images from the rotational moulding tool. The FPIT records the Angle of Contact (AOC) between fibre and particle so that the final angle measured can provide information about the adherence effectiveness. The work presents the effect of Peak Internal Air Temperature (IAT) and heating rate (HR) on the adhesion of polyethylene to glass fibres under similar thermal conditions to the rotational moulding cycle. Results showed that increasing the heating rate from 10 °C/min to 30 °C/min could increase the adhesion speed up to 360 %. The RotoCam system demonstrated the equipment's capability to detect the fibre saturation point during the process in real time.

01 Introduction

During the heating phase of the rotational moulding process the polymer particles tumble and soften, assisted by the rotation, to stick together to form a continuous film. This process is called sintering. The use of reinforcement media at this stage will contribute to a major improvement in part strength and stiffness. Foam reinforcement is commonly used to improve part strength and stiffness (Fig.1) However another very common method of reinforcement in other plastic processes is through the use of fibre reinforcement. Due to the different nature of this reinforcement, there are major limitations in the ability to develop multilayer technology in rotational moulding using fibre, such as material compatibility, fibre dispersion or polymer agglomeration. The idea of studying how fibre reinforcement can affect sintering is essential as it determines which materials can be combined in the process.

Fig. 1 Foam Reinforcement in Rotational Moulding

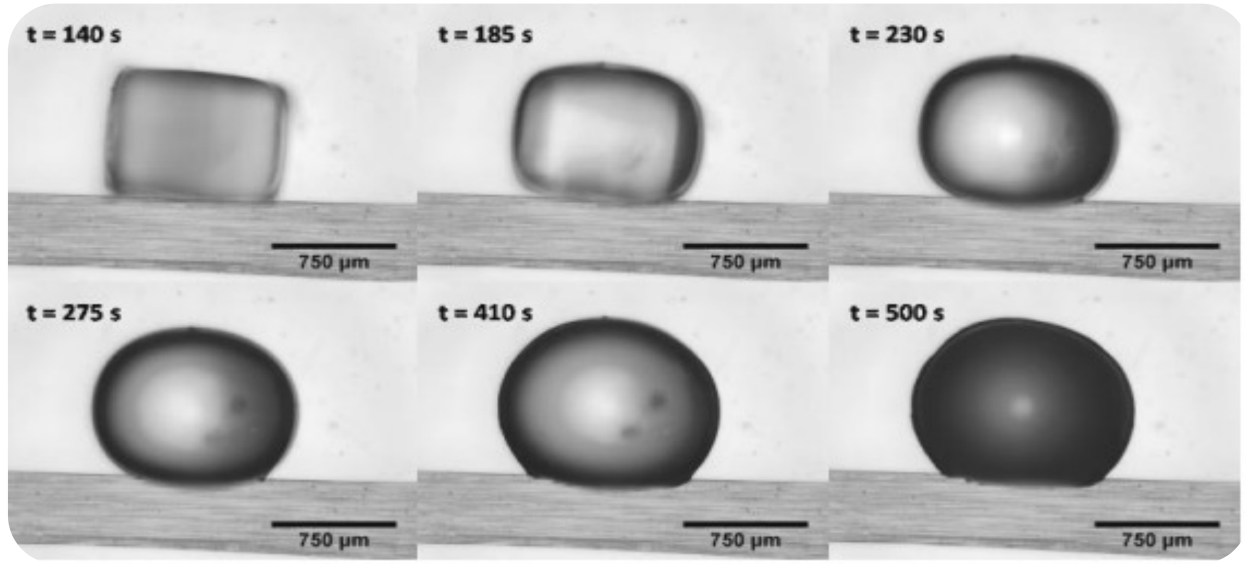

Fig. 3 Fibre-Particle Interaction Test Progression with Time

The **RotoCam** System is a in-mould visual imaging system attached to the AMS Robomould system (Fig.4) was developed to detect the fibre saturation point during the process using real-time images from the rotational moulding tool as shown below in Fig. 5 to give a series of real time images (Fig.6) that were then used for image processing.

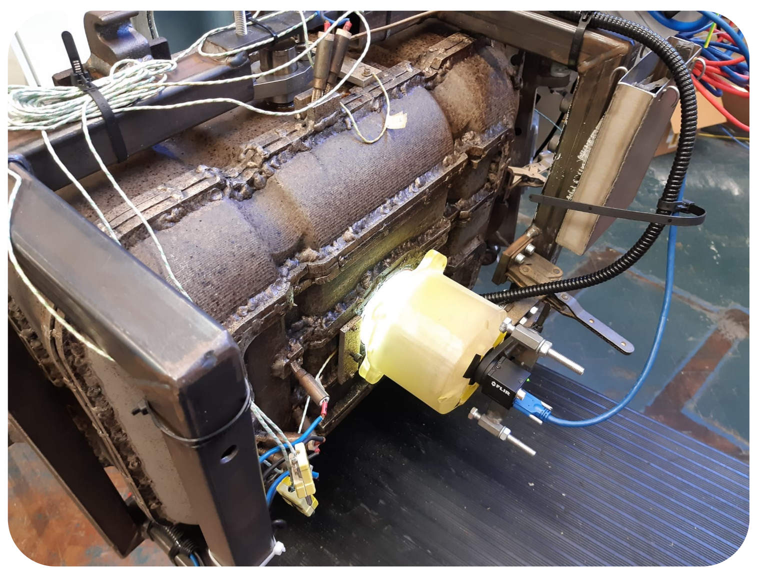

Fig.4 RotoCam™ mounted on the RoboMould tool

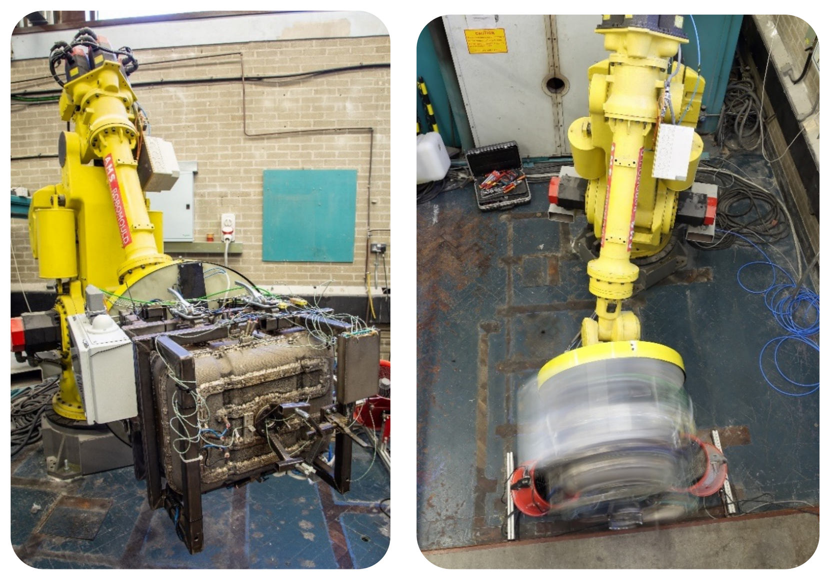

Fig. 5 AMS RoboMould System

02 Development of FPIT and RotoCam

The **Fibre-Particle Interaction Test (FPIT)** consists of a microscope with a heating stage, in which a sample made up of a resin particle and fibre to be tested is located as shown in Fig.2. The fibre-particle group is placed horizontally in the microscope while the cubic particle is located in the upper part of the fibre. The hot stage then warms up the combination while taking digital images to show how this polymer adheres to the fibres in a process similar to wetting (Fig.3). Finally, image processing software is used to manually measure the Angle of Contact (AoC) between the resin and the fibre to produce contact angle measurements.

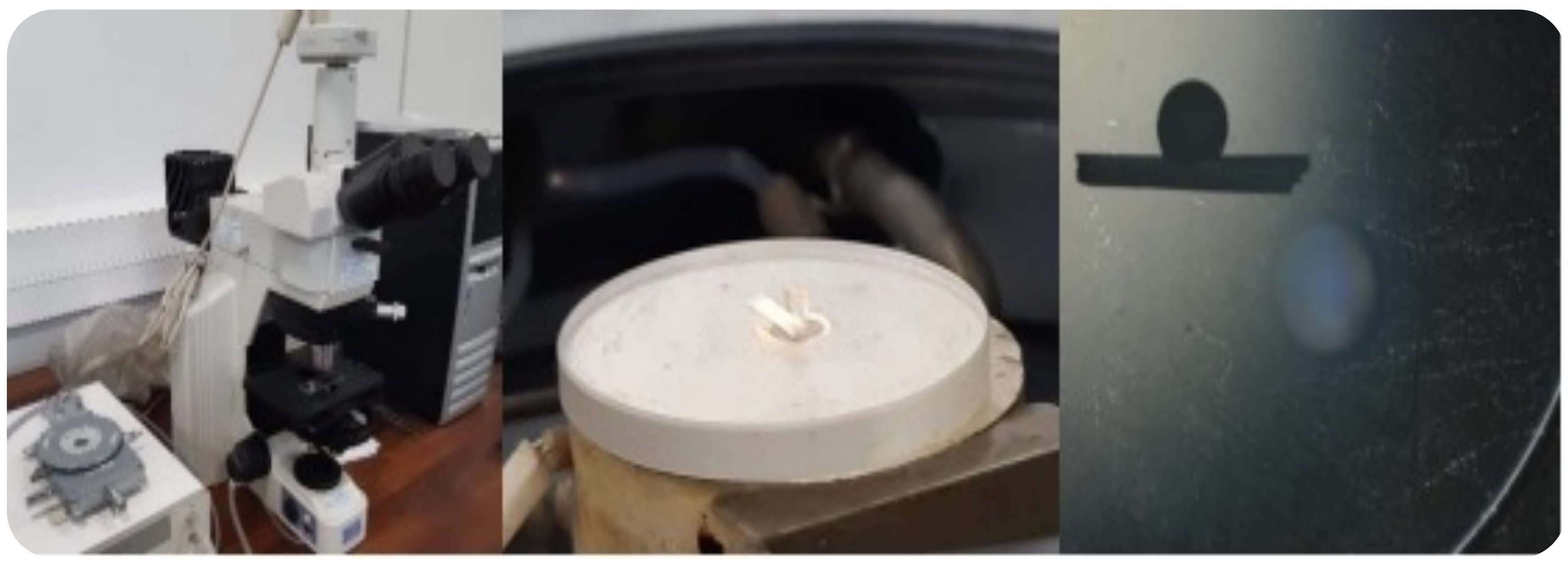

Fig. 2 Fibre-Particle Interaction Test (FPIT)

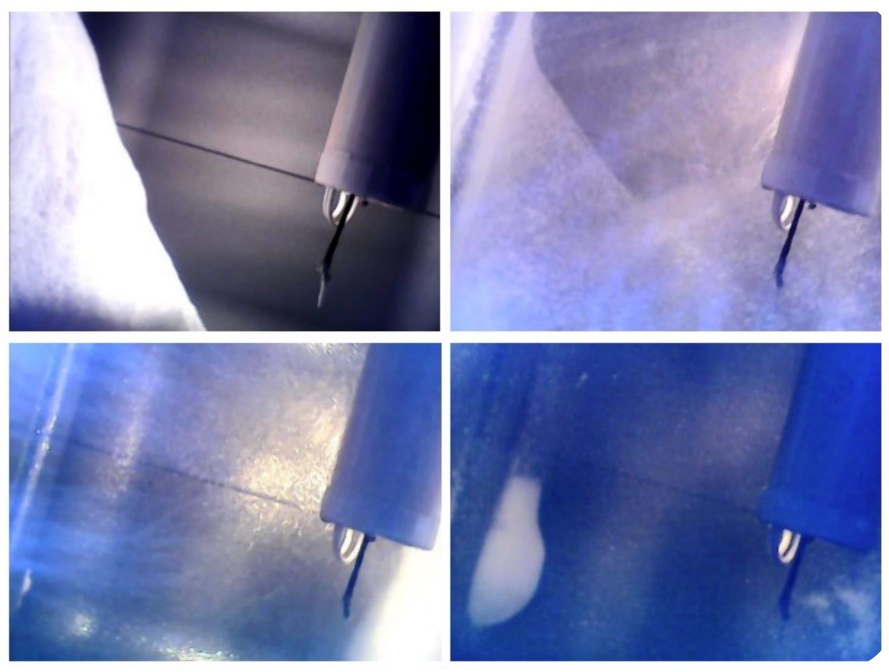

Fig 6 Sequence of images corresponding to a rotomoulding cycling

03 Results

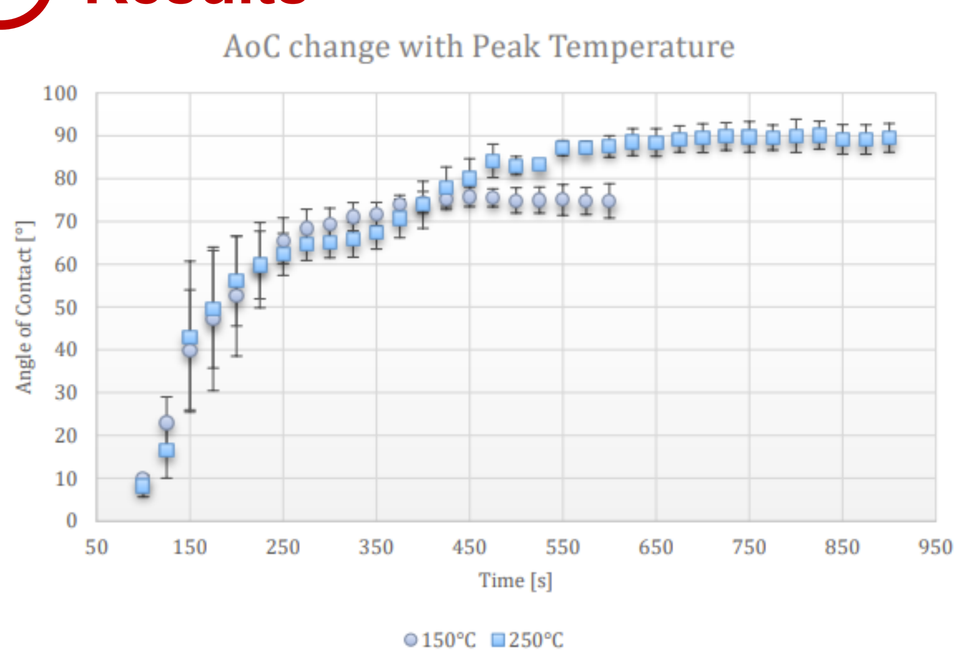

Fig.7 Comparison of High and Low Peak Temperature

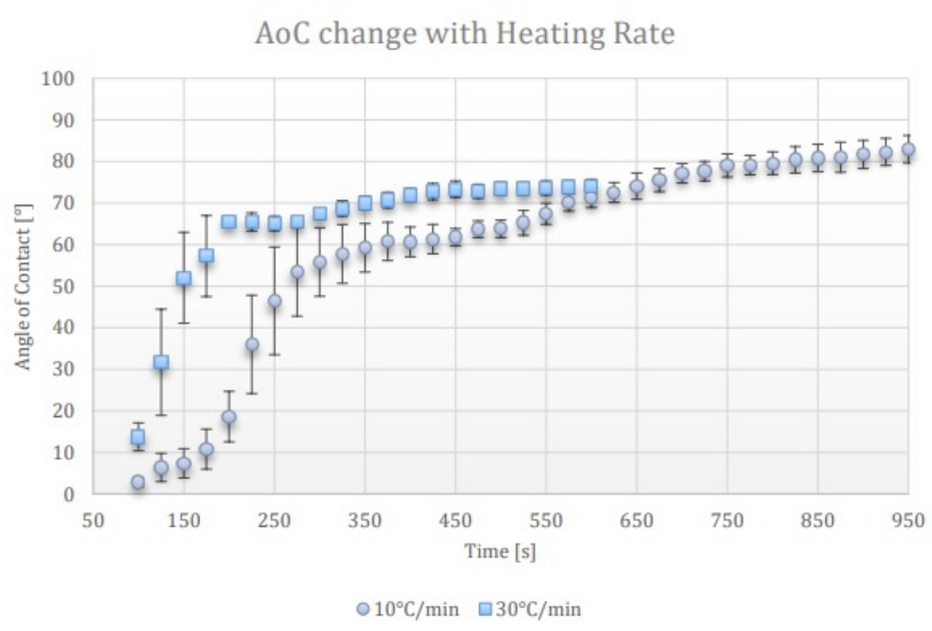

Fig.8 Angle of Contact change with Heating Rate

Fig. 7 shows a comparison between a low and a high peak temperature that was obtained using the Fibre-Particle Interaction Test (FPIT). As can be seen, the initial adhesion speeds are very similar, 0.362°/s for the 150°C sample and 0.374°/s for the 250°C samples. These results suggest that a variation in the peak temperature mainly impacts the final angle and does not seem to affect the adhesion speed to a great extent.

Also from the FTIP work, Fig. 8 shows the variation of the contact angle when the heating rate is varied. The graph shows a minor difference in the final angle and a much more significant difference in the initial slopes. Therefore, it can be concluded that a change in heating rate does not affect the final angle as much as it affects the initial slope.

The RotoCam system was used to observe in real time the fibres adhering to the polymer to form a composite During the moulding process, the system provided real time images (as shown in Fig. 9. which examines different fibre loadings) that showed the fibres attaching to the film in a similar way to the observations from the FPIT. Subsequently, an algorithm for image processing software was developed to extract quantitative information. Fig. 10 shows an example of an analysed frame from the video. The curves from Fig. 11 uses the image processed data to show how sintering starts at around minutes 3-4 and continues until approximately minute 8 when a relatively constant Region of Interest (ROI) area is achieved with the final ROI Area around 50 mm² smaller, suggesting fewer fibres were bonded to the melt.

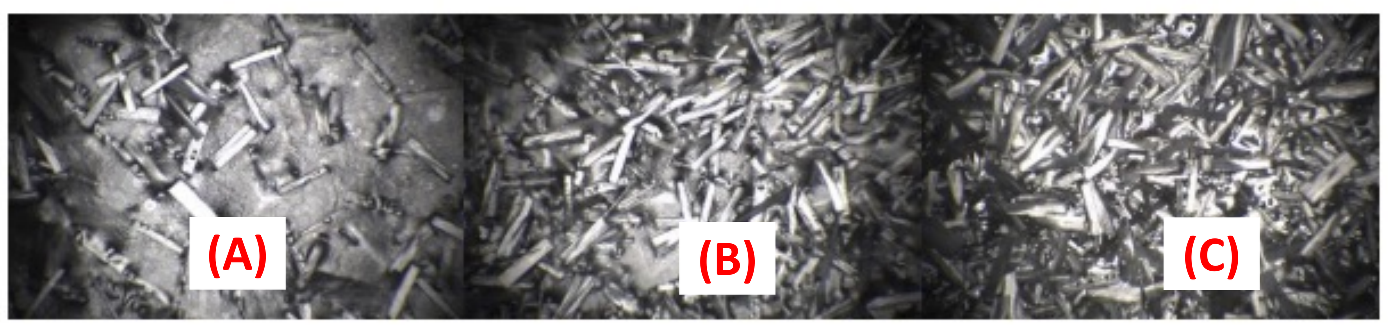

Fig.9 Image Processing Software used to identify fibre 10% (A), 20% (B), and 30% (C)

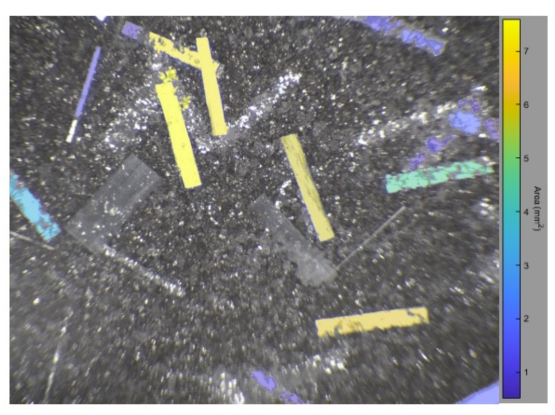

Fig.10 Image Processing Software used to identify fibre

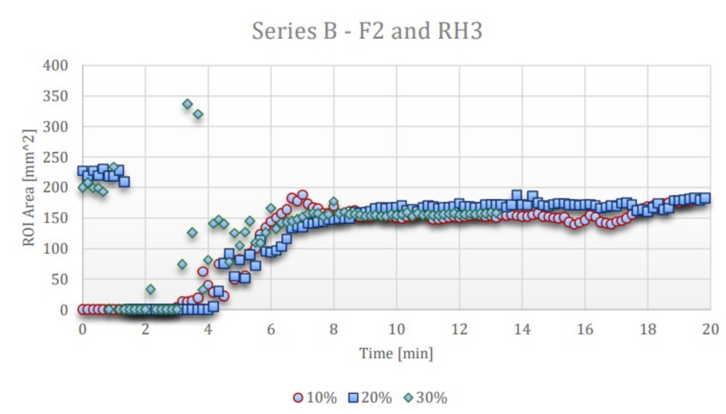

Fig.11 Results of ROI Detected

04 Conclusions

Two new methods of measuring fibre - polymer interactions are presented here. FPTI and Rotocam. FPIT demonstrated how the final angle measured can provide information about the adherence effectiveness. The in-mould visual imaging system RotoCam was developed to measure fibre content in real-time. When the fibres saturated the polymer film, no more polymer surface was available for further fibre to adhere demonstrating the equipment's capability to detect the fibre saturation point.

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