Enhancing composite curing with high-temperature heat flux sensors

Swinburne University of Technology and Boeing successfully developed an AI-driven framework to optimise composites manufacturing. Reliable heat flux measurements were essential for real-time production monitoring. Therefore, Hukseflux's FHF06 high-temperature heat flux sensor was selected for its accuracy, fast response time, and proven reliability in demanding industrial environments.

Introduction

Composite materials are crucial for high-performance sectors such as aerospace and automotive. However, their production quality relies heavily on thermal conditions, making real-time monitoring essential. To address this, Swinburne University of Technology and Boeing collaborated to create an AI-driven framework for real-time monitoring and forecasting using Hukseflux's FHF06 heat flux sensors.

Composite manufacturing basics

Composites are formed by combining reinforcing fibres with a matrix material that binds them together. This results in strong, durable materials which are widely applied in many industries.

One commonly used manufacturing method is Liquid Composite Moulding (LCM), which involves four stages (see Figure 1):

- **preforming:** reinforcement fibres are placed into a mould to form the desired shape
- **resin injection:** the mould is filled with hot liquid resin. A constant temperature is maintained to ensure effective resin flow through the fibre layers
- **curing:** the composite is heated until the optimal degree of cure is reached. Curing conditions are critical to final composite quality
- **demoulding:** after curing, the composite is removed from the mould and is ready for use

The manufacturing conditions during LCM significantly affect the final composite properties. Swinburne University researchers developed an AI-based framework to accurately monitor and forecast these conditions, enhancing process control by allowing timely adjustments of production parameters. For this, the researchers used FHF06 heat flux sensors, selected for their accuracy and short response time.

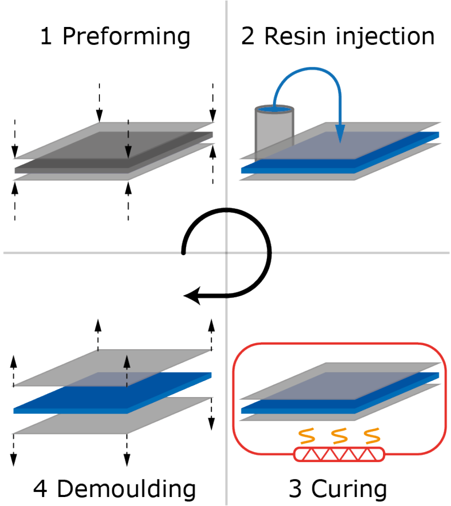

Figure 1 *Liquid Composite Moulding (LCM) involves (1) preforming, (2) resin injection, (3) curing and (4) demoulding.*

Using heat flux sensors in thermal monitoring of composites

Heat flux measurements provide valuable insights into the LCM process. Therefore, heat flux sensors are gaining traction in the composite industry. They are mainly utilised during the resin injection and curing stages.

Heat flux sensors can monitor the resin flow front during the injection stage. This enables early defect detection and allows fine-tuning of injection parameters, such as pressure and flow rate, which can reduce production costs. Since changes in heat flux precede temperature changes, heat flux sensors yield more accurate and faster flow front detection than temperature sensors.

Heat flux also plays a key role in the curing stage. Most curing processes are exothermic, meaning that they release heat. Therefore, curing progress can be monitored by measuring the resin's heat production, which can be determined through combined heat flux and temperature measurements.

Explaining the AI-driven monitoring framework

Researchers at Swinburne University collaborated with Boeing to streamline LCM manufacturing methods using AI-driven predictions.

The AI-driven framework consists of three core components:

- **specialised sensors** measure critical parameters such as temperature, heat flux, and resin flow progression
- **an Internet of Things (IoT) platform** enables real-time data acquisition, processing, and cloud storage
- **an AI model** predicts future process states, such as the resin curing progress and temperature profiles

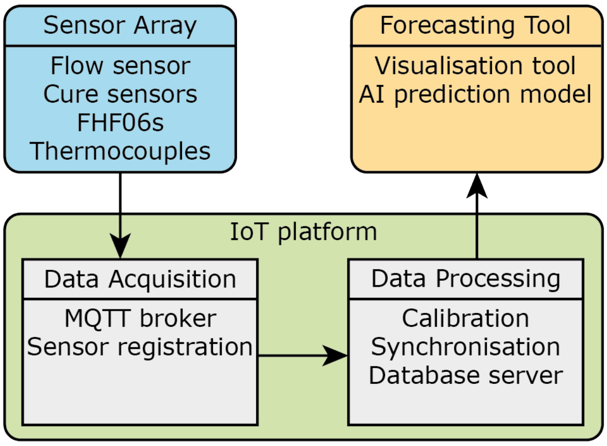

Figure 2 *The specialised sensors provide data to a central IoT platform, which processes and sends the data to the AI prediction model.*

The researchers tested the framework in a real-world manufacturing case study. The results demonstrate that this framework is a promising candidate for digitalised composite manufacturing.

FHF06 high-temperature heat flux sensors

For reliable forecasting, the researchers required accurate and sensitive sensors. Therefore, they selected Hukseflux's FHF06 heat flux sensors. The sensor can withstand temperatures up to 250 °C, while maintaining excellent accuracy and fast response times. These properties make the FHF06 ideal for high-precision composite curing applications.

Additionally, the sensitivity of the FHF06 ensures that even small changes in the heat flux can be measured. Combined with fast response times, this allows for timely detection of resin flow fronts during the injection stage. Therefore, the FHF06 also provides a solution for resin flow front monitoring.

Figure 3 *Hukseflux's FHF06 high-temperature foil heat flux sensor. Its unique design enables measurements up to 250 °C and includes a T-type thermocouple for temperature readings.*

In summary, the FHF06 heat flux sensor has proven to be a valuable tool in the composite manufacturing industry. It is suitable for critical process stages such as the resin injection and curing stages. The innovative study conducted by Swinburne University and Boeing highlights the applicability of the FHF06 in high-accuracy composite manufacturing and research.

About Hukseflux

Hukseflux is the leading expert in measurement of energy transfer. We design and manufacture sensors and measuring systems that support the energy transition. We are market leaders in solar radiation- and heat flux measurement. Customers are served through the main office in the Netherlands, and locally owned representative sales offices in the USA, Brazil, India, China, Southeast Asia and Japan.

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