July 30, 2021

Xenon flashlamp heating simulation support thermoplastic fibre placement.

Clean Sky 2 FRAMES project advances simulation of processing temperatures during thermoplastic fibre placement with Humm3 system.

FRAMES, which begun in July 2020, has the main objective is to validate a manufacturing approach being used to produce a mid-scale advanced rear end demonstrator manufactured by the Deutsches Zentrum für Luft- und Raumfahrt (DLR), as part of a Clean Sky 2 technology platform for large passenger aircrafts. The demonstrator expects to bring reliable and competitive solutions for simulation of heating during fibre placement, high rate manufacturing of thermoplastic stiffeners and self-heated tooling to support co-consolidation of a skin-stiffener assembly.

Optical thermal modelling of flash lamp heating system

Besides conventional laser heating, a new technology has emerged that is based on a pulsing Xenon flashlamp. Highly energetic short duration pulses delivered by a powerful pulsed broadband heat source are collected and delivered by a quartz light guide. In fibre placement, the end of the light guide is shaped and positioned near the nip point to heat the substrate and incoming tows before consolidation is achieved under a compaction roller. The Xenon Flashlamp system has been shown to match the rapid response time of a laser and reach the temperatures required to process thermoplastic composites. Pulse parameters of energy, duration and frequency are varied during lay-up to account for changes in speed and geometry and maintain a target temperature.

In order to optimise these parameters, an opto-thermal simulation model has been created that utilises optical ray tracing techniques to characterise the flashlamp source and finite element analysis (FEA) to predict the resultant processing temperature. Using these simulation tools, pulse parameters can be chosen to achieve a desired processing temperature without the need for expensive and time-consuming physical trials.

Heraeus Noblelight (Cambridge, UK) is leading the development of the optical thermal model applied to its flashlamp system the humm3®. The process to create a reliable simulation involves the optical characterisation of the Xenon flashlamp source, using goniometric and spectral irradiance measurements which are then used to determine the spectral energy levels, spatial distribution, and electrical-to-radiative energy efficiency of the source.

To determine the energy emission of a flashlamp with respect to wavelength via spectral irradiance measurements, the experimental setup shown in Figure 1 has been devised. For this system the light from a source goes into a detector a pre-set distance away, typically 0.5 to 1 m, and the light is transported via an optical cable into a double-monochromator system. The double-monochromator then determines the light intensity at a specific wavelength. This results in a detailed spectral irradiance plot of the light source – in this case the entire emission curve of the Xenon plasma is measured.

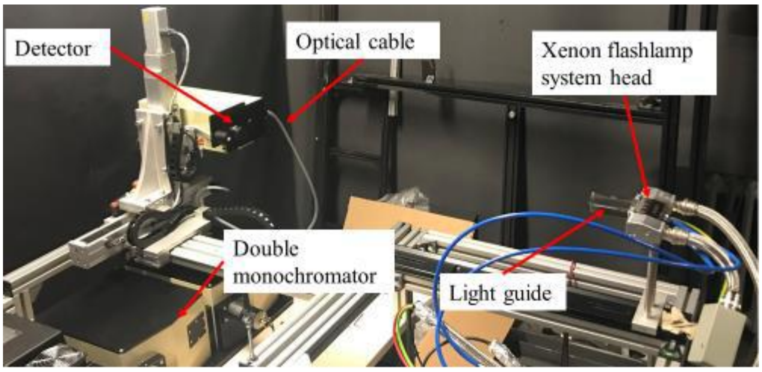

Figure 1 : Double monochromator test setup used for spectral irradiance measurements

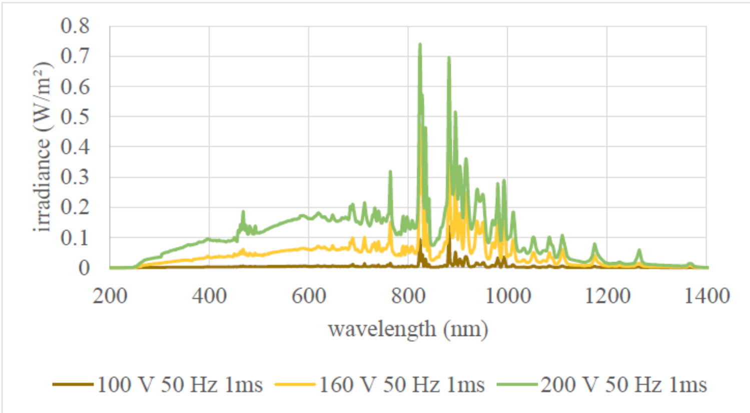

Figure 2 : Spectral irradiance measurements of light exiting the Humm3 head.

System efficiency has been also evaluated using an Integrating Sphere at a Heraeus Laboratory (Hanau, Germany) that accurately determined the spectral energy exiting the humm3® light guide at different voltage levels. The sphere surface is a highly reflective diffuse surface that directs virtually all the optical energy exiting the system head to a double monochromator detector. By modulating the pulse energy for a given pulse duration and frequency, the average optical power exiting the Humm3 head is measured as a function of wavelength for a range of flashlamp voltages.

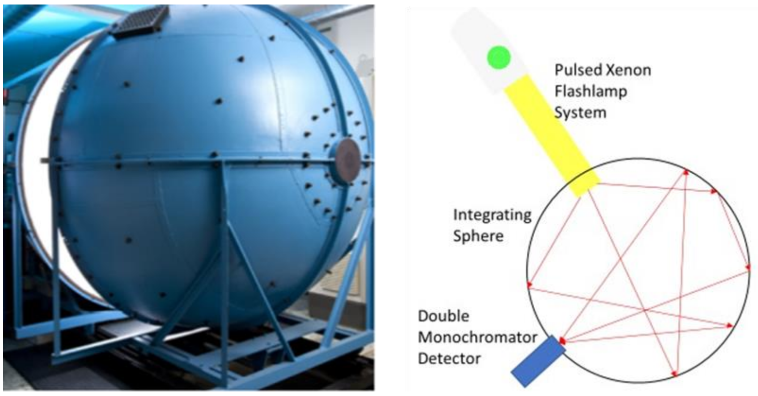

Figure 3 : Schematic of the Integrating Sphere at Measurement Lab in Hanau for spectral radiant power measurements

The position of the flashlamp head relative to the nip point is also a critical aspect for layup. In parallel to measurements of output power, the variation in intensity with respect to the angle from the source has been measured. All measurements were normalised to investigate angular energy distribution rather than absolute power output at this point. Those results were used to validate a ray tracing simulation of flashlamp to predict how the energy of pulses is distributed between the substrate, the nip point and incoming tows. The optical ray tracing analysis is then detailed, which calculates surface irradiance profiles on the composite tow and substrate that are used as input boundary conditions to the thermal simulation. Optical and thermal behaviour of carbon fibre reinforced LM-PAEK tapes has been characterized as well, to feed the model at the relevant processing temperatures.

Figure 4 : Modelling flash lamp position according to actual fibre placement configuration

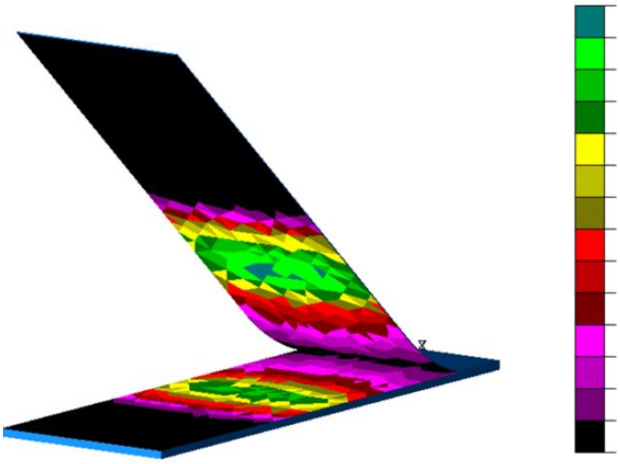

Figure 5 : Result from optical model with TracePro software

As a validation step, physical AFP trials have been performed at Compositadour (Bayonne, France) on heated tooling to show the ability of the simulation to predict temperature values seen in actual AFP lay-up. Processing temperatures have been collected using infrared thermography and embedded thin thermocouples inside preforms. Measurements appear to show reasonable agreement with predicted temperatures profiles in the region to close the nip point and through thickness; and highlights the influence of tooling on the thermal management for the first few plies.

The simulation model is now being adapted to the final heating system and tooling configuration that will ultimately manufacture the thermoplastic rear end demonstrator.

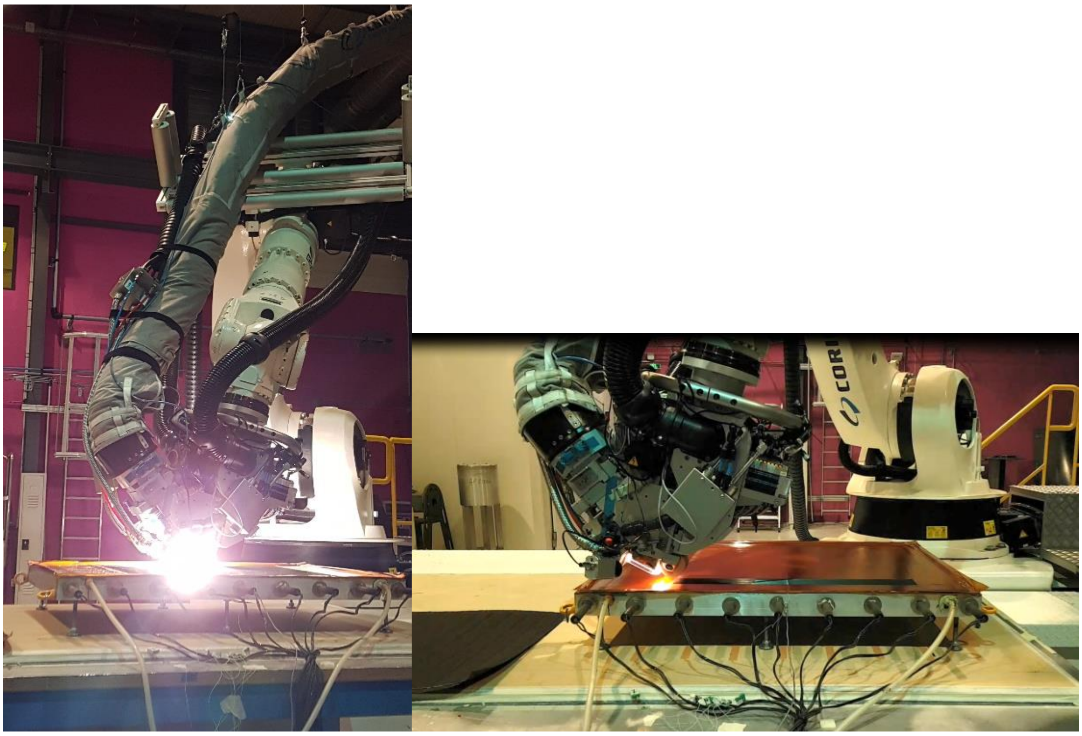

Figure 6 : Thermoplastic lay up trials with humm3 heating system at Compositadour

This project has received funding from the Clean Sky 2 Joint Undertaking (JU) under grant agreement No 886549. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Clean Sky 2 JU members other than the Union.

For more information, you can contact Guillaume Fourage, g.fourage@estia.fr