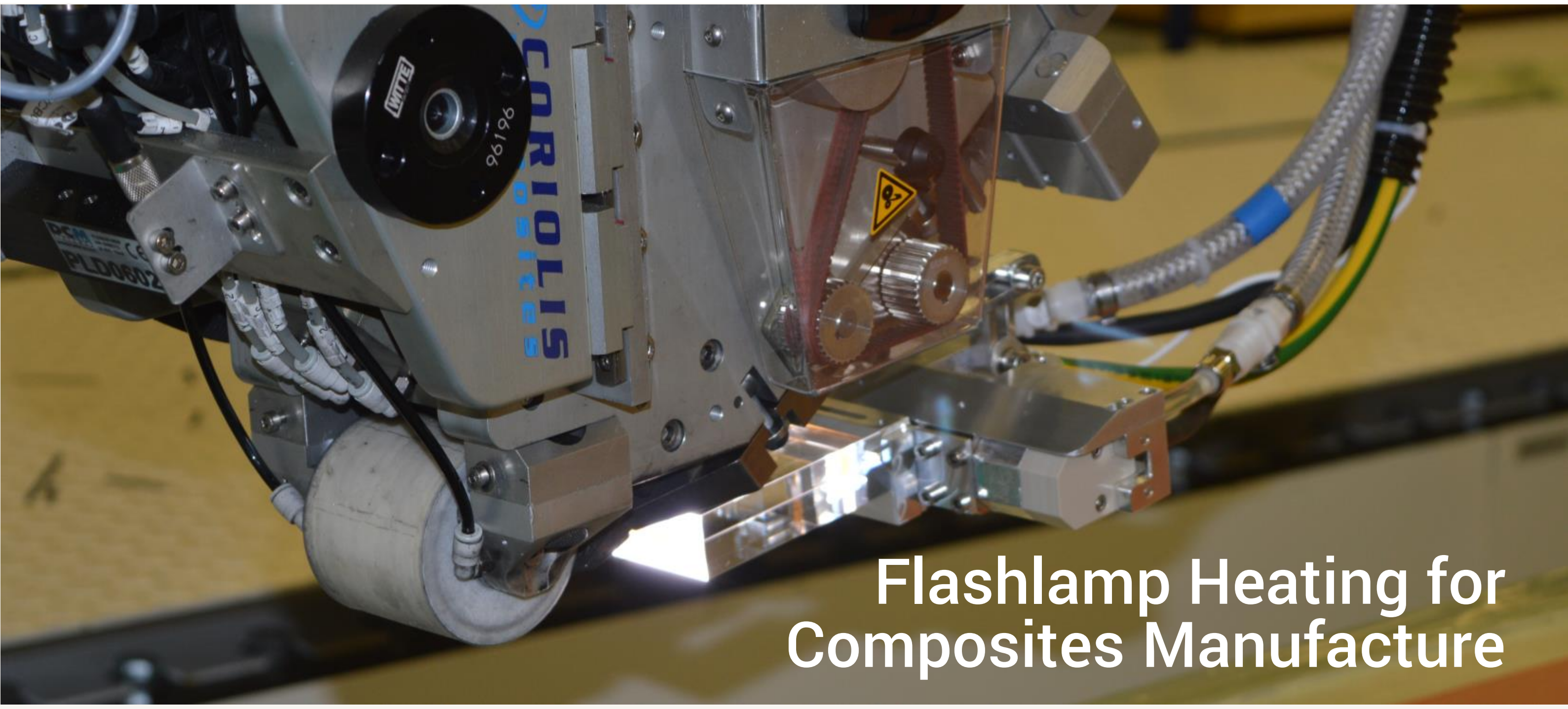
NCC Case Study

March 2016



Flashlamp Heating for Composites Manufacture

Flashlamp heating for composites manufacture has been demonstrated in a collaboration between the National Composites Centre and Heraeus Noblelight Ltd.

Heraeus Noblelight is a market leader in speciality lighting and heating applications, offering lamps and complete systems with wavelengths from ultraviolet (UV) to infrared (IR). They have an established market for their IR emitters and Xenon flashlamps in a range of sectors.

Since 2012, Heraeus has worked with the National Composites Centre (NCC) to investigate the potential of the Xenon flashlamp system in composites manufacturing. In particular, the flashlamp has been targeted at Automated Fibre Placement (AFP), where it has shown potential to surpass the performance of current heating solutions.

The collaboration brought together technical experts, in composites manufacture from the NCC and flashlamp systems from Heraeus, to build a strong team that has rapidly taken the technology up the TRL scale, from initial proof of concept trials to a full demonstrator.

The NCC has been able to assist Heraeus in finding collaborative R&D funding through the National Aerospace Technology Exploitation Programme (NATEP), and has been instrumental in helping form a research consortium from its wide member base that has given appropriate guidance to the project.

A highlight of the collaboration was a technology demonstrator event held at the NCC to showcase the benefits of the flashlamp system to potential end users of the technology.

Main Image: the Xenon flashlamp system attached to an AFP head, laying up dry fibre composite material at the NCC

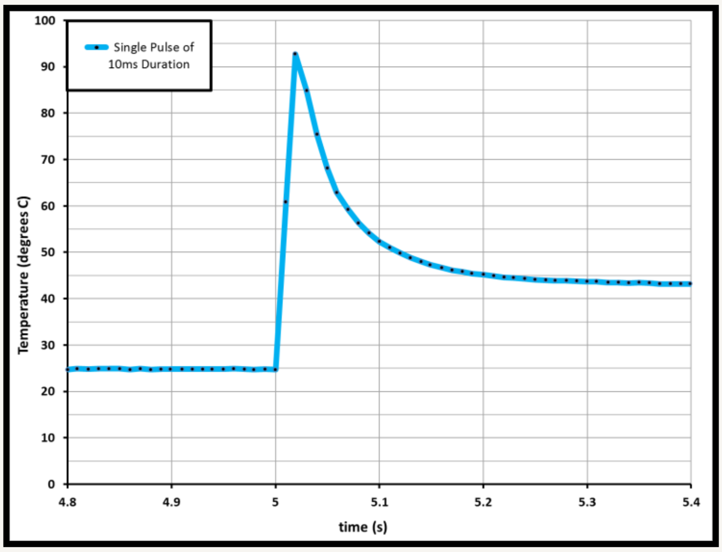


Figure 1: Temperature vs. Time results for a single 10ms Pulse

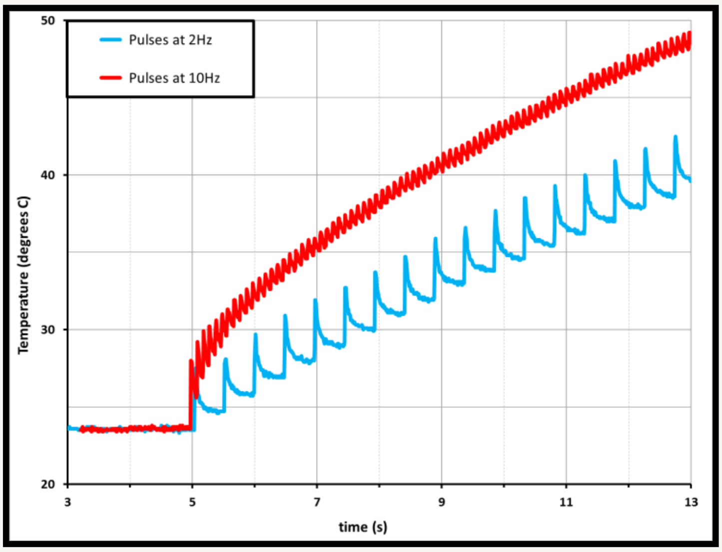


Figure 2: Temperature vs. Time results for multiple pulses - 2Hz and 10Hz

The initial investigation of the flashlamp technology for composites heating applications was made through the NCC Core Research programme – a collaborative research activity that brings together all of the NCC Tier 1 members to investigate common research interests.

The first fundamental trials were carried out using a basic flashlamp system at Heraeus' Cambridge research labs. Small pieces of composite prepreg material were exposed to single, short-duration pulses from the flashlamp and the surface temperature was measured with thermal imaging equipment.

These first trials revealed that the broadband radiation from the single flashlamp pulses was able to increase the surface temperature on the composite from ambient temperature to a temperature relevant to composites manufacture in a fraction of a second (Figure 1).

Subsequent tests investigated the effect of multiple pulses at a range of frequencies. Multiple pulses were able to raise the surface temperature incrementally, in a "staircase" type profile, up to even higher levels. Figure 2 shows the results from trials at 2 and 10 flashes per second.

These flashlamp results were compared with equivalent measurements using alternative heating sources such as infrared lamps, hot gas guns and induction coils. The flashlamp's rate of heating exceeded all other sources, and was found to be equivalent to a diode laser.

"The initial results were extremely promising, and opened up a range of interesting possibilities for the flashlamp in composites heating applications"

Dr. David Williams,
Research Engineer,
National Composites Centre

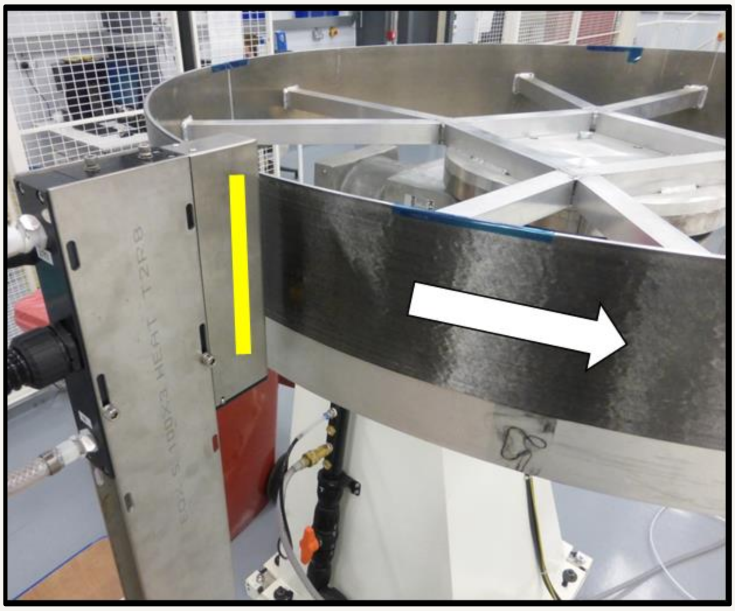


Figure 3: Image of the rotating drum experimental set-up

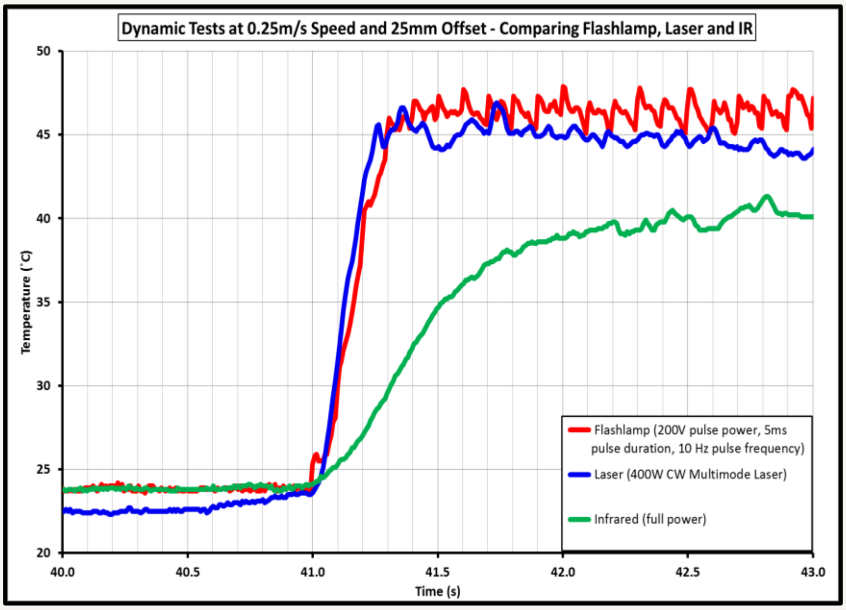


Figure 4: Temperature results for moving trials: Flashlamp, Laser and IR lamp

In order to test the flashlamp system in a more realistic context, an experimental rig was conceived at the NCC that was able to move composite materials past a stationary flashlamp at different speeds. This was realised by creating a large rotating drum, with composite materials attached to the circumference. By rotating the drum at a series of rotational speeds, a range of translational speeds relative to the flashlamp could be investigated.

The flashlamp pulses were directed in a perpendicular sense on to the material surface and the surface temperature “down stream” of the lamp, at a position equivalent to the AFP nip point, was measured using a thermal imaging camera (Figure 3).

The superposition of the individual flashlamp pulses generated a very regular, constant surface temperature over the time of each experiment. It was possible to compare the flashlamp-generated temperature profile with the equivalent profile from an infrared lamp and a diode laser. Figure 4 shows a comparison, with the flashlamp and laser reaching a temperature of 45^{o}C in approximately 0.3 seconds, and the infrared lamp reaching 40^{o}C in approximately 1.2 seconds.

Subsequent tests at higher flashlamp powers showed temperatures of over 200^{o}C at a speed of 0.5 metres per second.

> “Working with the NCC enabled us to engage with the most up-to-date technologies used in the composites industry. Key expertise was deployed on the project, meaning the research progressed quickly, and gave clear access to the composites supply chain.”
>
> Martin Brown
> Applications Manager
> Heraeus Noblelight Ltd.

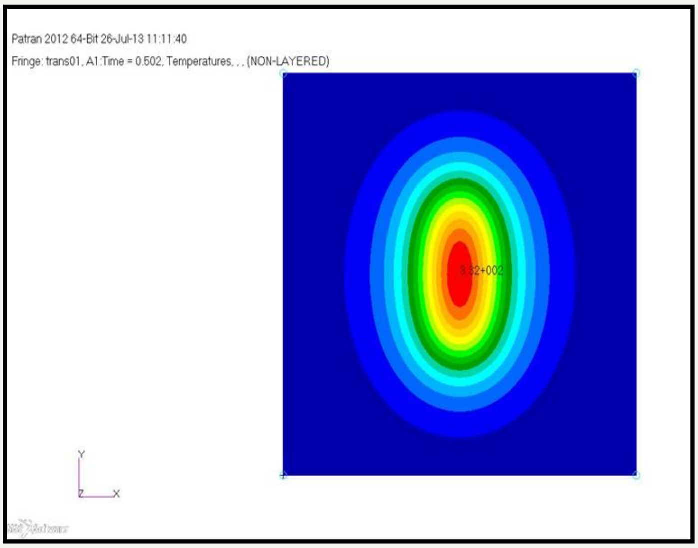


Figure 5: Simulation results: Static target

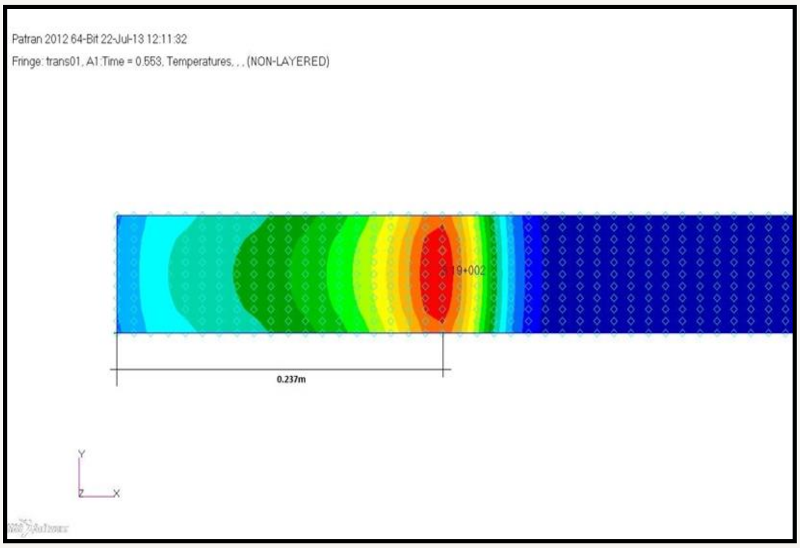


Figure 6: Simulation results: Moving target

The NCC was able to offer Heraeus their expertise in computer simulation to predict the temperature profiles generated by the flashlamp under various pulse conditions.

Surface temperatures from static and moving target experiments were predicted as well as the through-thickness thermal profile.

A finite element model was created of the lamp and the target materials. To run the analysis, a temperature pulse was imposed on the elements representing the flashlamp of prescribed duration; radiation boundary conditions were imposed between the lamp and the top surface of the composite materials. Heat was dissipated through the composite using conducting elements and known thermal properties of the materials.

A very fine finite element mesh, both in the plane of the material and in the through-thickness direction, was required to give meaningful results, and a number of trials were required before convergence was achieved.

The simulations were able to show many of the features of the temperature profiles observed with thermal imaging cameras, and provide an understanding of the effects of lamp orientation, offset from the material and average pulse power. In particular, the heat conduction through the material was well described.

Figure 7: The redesigned Flashlamp mounted to the AFP robotic system

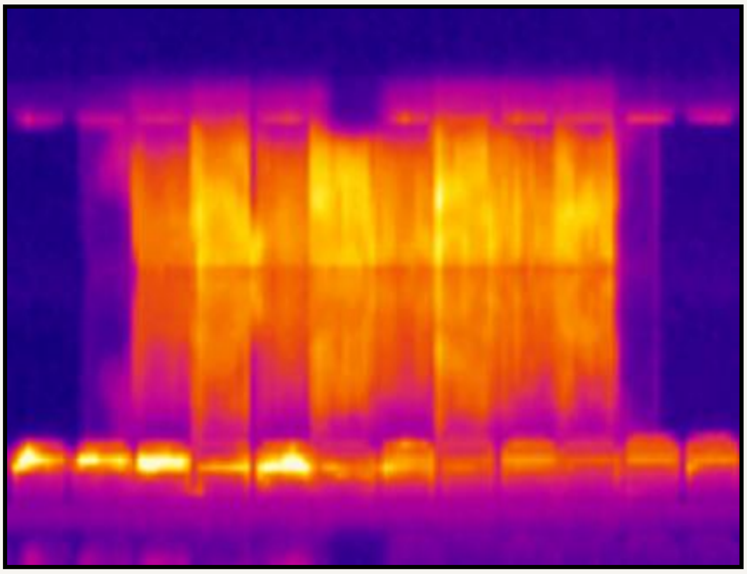


Figure 8: Thermal Image showing the heating of 8 parallel tows

The next phase of the flashlamp development for AFP was to redesign the flashlamp head to fit onto an AFP robotic system. The NCC was able to provide access to their Coriolis Composites robotic AFP system to facilitate initial resizing and mounting of the new flashlamp.

The overall volume of the flashlamp head was reduced by over 50%, and holding brackets were designed so that the angle and offset of the lamp could be varied.

Once the new design was ready, the very first trials on a real AFP system were initiated, with very positive results. In trials at both the NCC and Coriolis Composites, France, the flashlamp enabled AFP was able to lay up composite dry fibre materials, achieving a surface temperature of approximately 180^{o}C. Lay up speeds up to 1 metre per second were achieved.

Thermal images taken during the testing showed that although the incoming tows were heated consistently (as shown in Figure 8), the flashlamp energy was heating an area wider than the target. This meant that trials on thermoplastic materials were limited to low temperature materials and relatively low lay up speeds.

As a result of these investigations, a more efficient focusing mechanism was designed to focus all of the flashlamp energy onto the required target area.

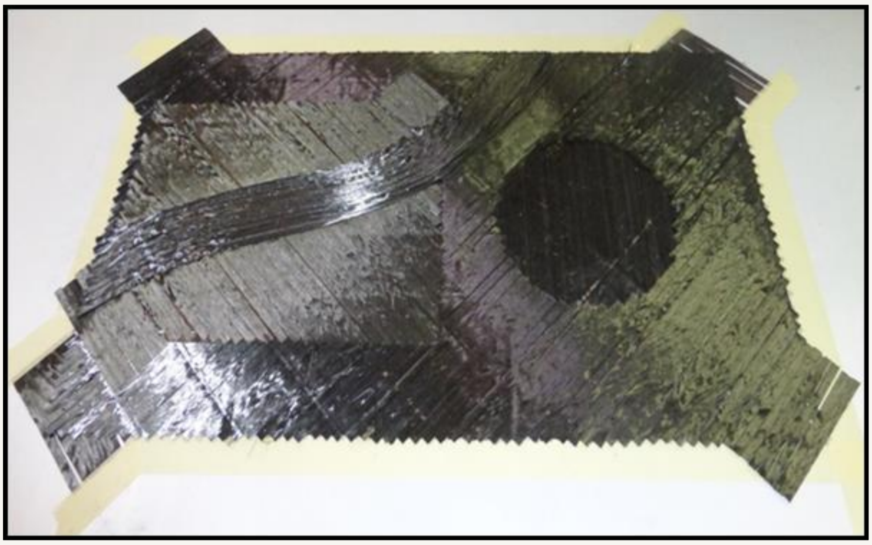


Figure 9: Flat dry fibre preform, including steered tow, laid up with flashlamp

Figure 10: Convex corner (spar) laid up with flashlamp

Further developments to the flashlamp, which were assessed under laboratory conditions at the NCC and at Heraeus in Cambridge, produced a flashlamp system that was able to focus energy to the nip point, giving higher achievable temperatures and greater consistency of lay up.

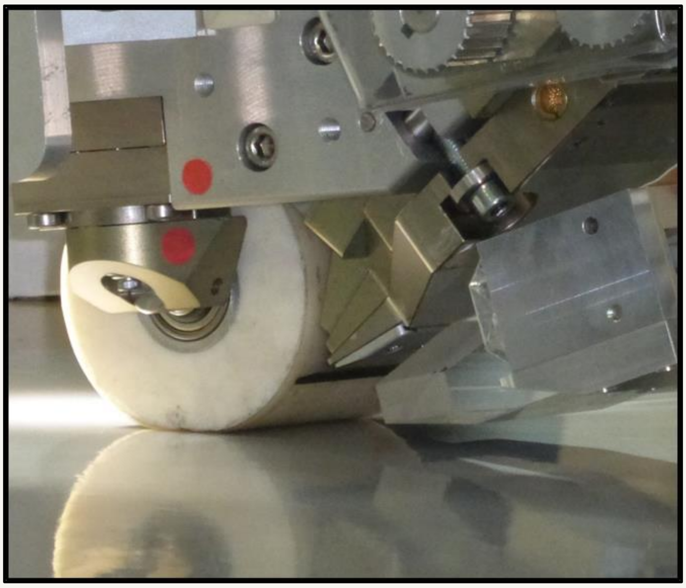
Enhancements included perfecting a dynamic flashlamp control system that was able to read the head speed output signal from the robotic system during lay up, and translate it immediately into the required flashlamp parameters to maintain a given surface temperature.

A range of dry fibre preforms, including multiple plies and tow steering, were manufactured using the latest flashlamp design. Figures 9 and 10 show a flat preform and a convex corner typical of a spar, respectively. A high level of lay up quality and consistency was achieved.

The current phase of flashlamp development culminated in a Technology Demonstrator Day, held at the NCC, in February 2016, where the flashlamp was demonstrated to 40 representatives from interested companies. The audience ranged from large OEMs to smaller high-tech firms, many of whom were NCC member companies. The very positive and specific feedback from attendees has allowed Heraeus to make important contacts in potential end user companies, and develop a detailed, industry-focused strategy for the next phase of flashlamp development.

NCC Case Study

March 2016



SUMMARY

- The partnership between the National Composites Centre (NCC) and Heraeus Noblelight Ltd. has given the framework for accelerated development of a highly innovative and potentially disruptive technology for the composites industry.
- The NCC Core Programme provided the initial opportunity to investigate alternative heat sources for AFP manufacture and led researchers to understand the relevance to industrial stakeholders.
- The Intellectual Property policy of the NCC was used to protect the inventions generated by the project.
- Through NATEP, research funding was gained to allow the rapid development of a more mature system, capable of being deployed in a full industrial context.
- The network of companies and contacts developed through the project, from both the NCC member and non-member organisations, has been vital in guiding the progress and providing Heraeus with potential customers ready to help take the flashlamp into the market.

"The National Composites Centre supplied valuable capabilities, expertise and excellent networking opportunities from all tiers of the Composites supply chain."

Jeremy Woffendin,
Technical Director,
Heraeus Noblelight Ltd.