CReATE:

Carbon Reducing Advanced Thermal Engineering

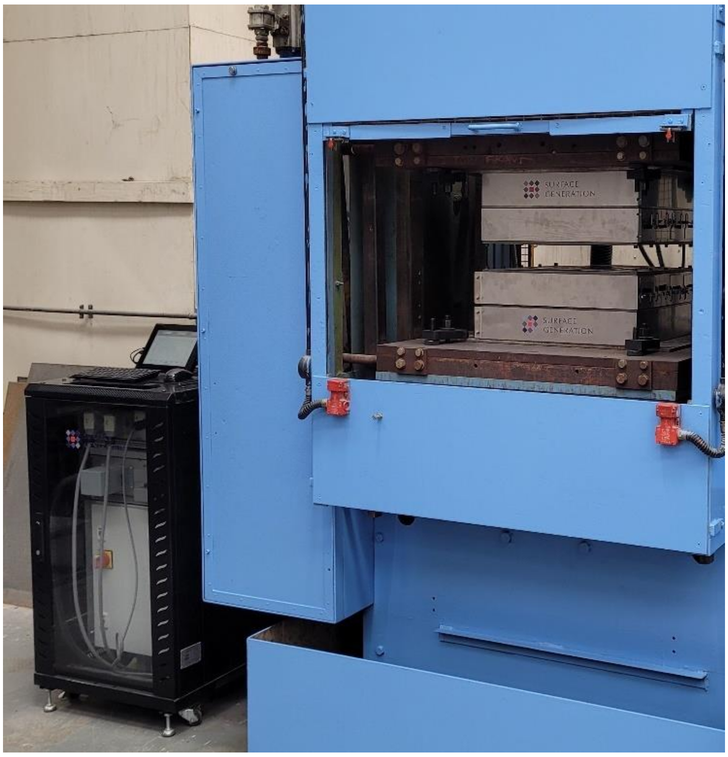

Fig.1, System installed on Press at demonstration site

The Industrial Energy Efficiency Accelerator (IEEA)

The IEEA programme supports the development of innovative technologies that will help industry reduce energy consumption and cut carbon emissions. It focuses on innovations with large potential cross-sector energy and carbon reduction impact - either new technologies or established technologies applied to new sectors. Over £15 million in public and private funding has been committed to develop solutions through partnerships between technology developers and industrial companies willing to test technologies on-site. The programme is funded by the UK government (BEIS) and managed by the Carbon Trust, with support from Jacobs.

Summary

The CReATE project was undertaken by Surface Generation, a process technology developer and Tiflex, a moulding company based in Cornwall. Tiflex were using high energy inefficient steam heated tooling to vulcanise their rubber mouldings, whilst Surface Generation had developed aerospace grade technology which was too expensive for the lower margin moulding trade. The opportunity was for Surface Generation to take that aerospace pedigree and develop a lower cost system for Tiflex, enabling them to significantly reduce their energy bills.

A demonstration site was set up at Tiflex with energy savings of 87% and over 43,000kgs of CO_2 saved from a single site per annum by the end of the project.

This technology can be adopted by the moulding sector for general industrial, automotive, consumer goods and less critical aerospace component manufacture to name but a few.

Introduction

The CReATE project, funded under the IEEA programme which is managed by the Carbon Trust with support from Jacobs, took Surface Generations successful underlying aerospace technology and designed and developed a lower cost system more applicable to the general moulding industry.

At Tiflex, the demonstration site, solid platens are heated by steam through conduit channels on which picture frame tools are placed. They use basic proportional based control systems (PID) to slowly cure the plastic & rubber components. The tooling is slow to heat up and has a long cooldown period, limited thermal control is available across the platen leading to long cycles, quality issues and extremely high energy use.

The project replaced the steam heated platens with lightweight tool faces attached to a novel, low-cost Production to a Functional Specification (PtFS) system specifically designed to meet the needs of Tiflex's type of energy intensive, low margin, larger area, high volume applications.

About the innovation

Surface Generation's underlying technology is a "pixelated" low mass closed loop thermal control system call, which can be heated and cooled extremely accurately and rapidly using forced air and resistance heating. Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) refinement of the tool faces allows removal of 80% of a billet without adversely affecting part quality. This is then heated or cooled by multiple jets of air all controlled in real-time by bespoke software to produce superior quality components using substantially less energy in reduced cycle times.

The technology comprises three elements; Controller (& software), Mould Bases (upper & lower) and Zoned Tool Faces (core & cavity tools).

By applying a new and novel version of this technology, designed specifically for this application, the partners can reduce energy consumption by lowering the heated and cooled mould tool mass by 75-85%, generating the heat energy at the point of use (rather than centrally with associated transmission losses), reducing cycle times from 4 hours to 0.5 hour (a 82% saving) and using multi-zone thermal control with active thermal management to reduce scrap from 30% to 5%.

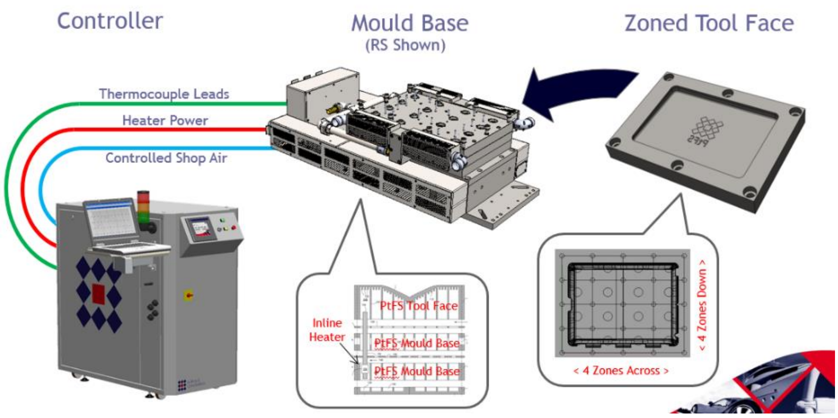

Fig.2, System principles

The demonstration

Current Process

Vulcanisation of rubber takes place when heat and pressure are applied to uncured compounds. Several methods of vulcanisation exist, including compression moulding, autoclaving, rotacuring, microwave curing and heated salt bath vulcanisation. Typical vulcanising temperatures range from 130°C to 180°C, with the heat generated through such means as direct electrical heating, gas heating and oil heating. Transfer media like steam or oil are often used in these processes.

Fig.3, Existing process, compression moulding

Tiflex Ltd has traditionally followed two methods of vulcanisation, namely compression moulding with steam heated steel platens (presses) and rota-curing.

Key Developments

The primary focus of the project was for a commercially viable system for the general moulding industry. This had to be lower cost, but retain some of that aerospace pedigree, which Surface Generation has developed. To that end we identified the key drivers to success, which formed our major developments;

- Stand-alone system generating its own air from electrically driven fans for the heaters (no shop compressed air)
- Manufacture of our own more robust heaters at shorter length for easier packaging, operating at low air flows and contributing to the cost reduction of mould bases
- Development and manufacture of a low-cost software and hardware control system
- Development of low-cost thermal control strategy and methodology
- Designing the system with significant reduction in machined parts
- Develop low-cost mould bases using off-the-shelf square steel section

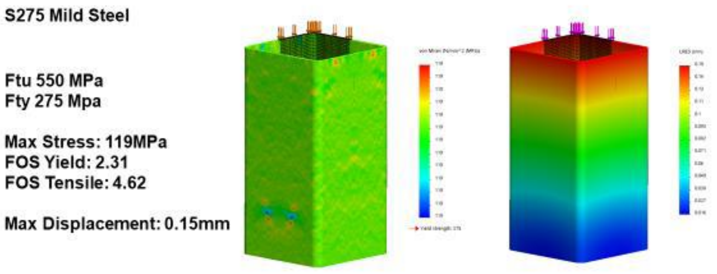

Fig.4, Stress analysis of box section

Manufacture, Assembly and Installation

Initial Build & Design

To realise our key developments, we had to change our way of thinking, from high specification, high tolerance aerospace standard, to design rules which would allow the manufacture of a lower cost system;

- Sympathetic to low-cost fabrication methods, minimal CNC machining if any
- Relaxation of part geometric tolerances to enable low-cost fabrication techniques
- Reduced part count
- Simplification of assembly to significantly reduce assembly time
- Use of low-cost stock items where possible

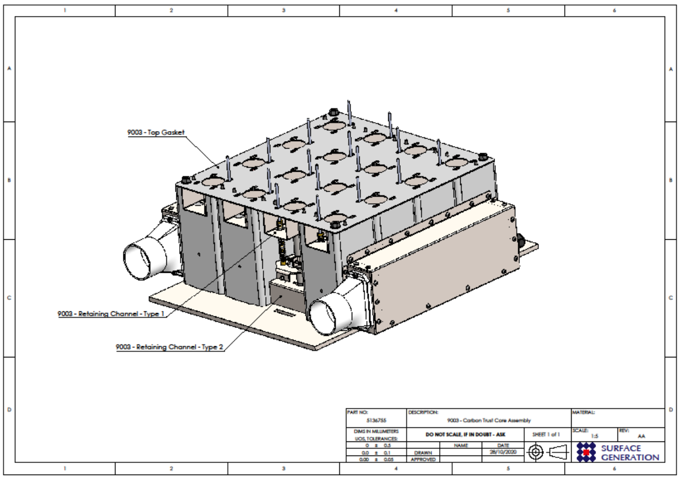

Fig.5, Initial design

The first design iteration of the mould base is shown as an assembly in schematic form.

Fig.6, V1 design build

Once the initial design and build was settled on, early versions of the control, air system and heater were developed as shown in the pictures below. The relaxation of conventional aerospace tolerances allowed us to deploy simplified versions, as shown by the Pi microprocessor controller interface.

The parts for the new micro-controller were thermally soaked to ensure long term reliability, whilst the heaters had to be tested at higher temperatures and low air flow to validate their predicted performance. Once we were happy with the component parts of the system, final versions of each were built and assembled into a complete system at Surface Generation, the air generator in the centre of the picture. Thermal trials were run to evaluate the satisfactory performance of the system, prior to deployment to Tiflex.

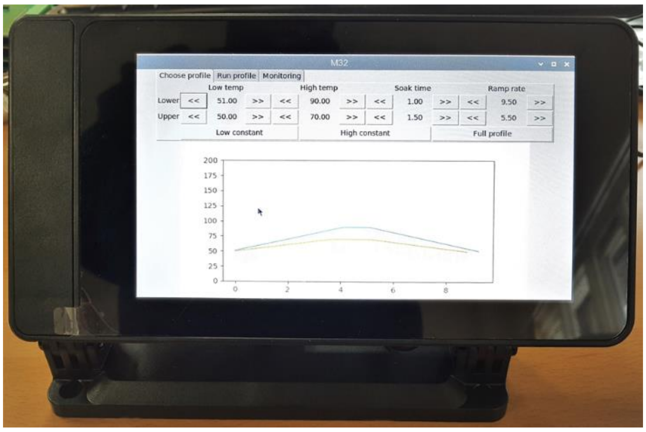

Fig.7, Much simplified CReATE controller interface

Fig.8, Completed system ready for deployment to Tiflex

Commissioning and Monitoring

Our thanks go to Tiflex for hosting the demonstration of the equipment and running the thermal trials for energy measurement. With help from the Tiflex team the equipment was very easy to install on Press 23 at Tiflex. It had previously been built and bench trialled at Surface Generation to de-bug the system prior to installation, hence a very straightforward commissioning process. The demonstrator system was very easy to monitor as it only uses electrical power.

The power being supplied by two industrial 5-pin plugs, each lead was linked to a meter to measure the power used.

Tiflex installed devices on their press, to measure steam and cooling water when manufacturing parts using their conventional technology. Manufacturing trials were completed using both techniques when extensive energy measurements were undertaken and realistic energy comparisons made.

Fig.9, Commissioned PtFS tool installed on press 23

Results

The results achieved were better than the 82% predicted energy saving. As shown in the table below we actually achieved just over 87%, saving 43.7 tonnes of CO_2 from a single installation.

Overall				
Total Energy saved kWh	**Total Energy saved %**	**Total CO2 Saved kg per lift**	**Total CO2 Saved per 20,000parts single installation / kg**	**Total kWh Saved per 20,000parts single installation**
48.7	**87.3**	8.7	**43,698**	**243,520.00**

Fig.10, Summary of Energy and CO_2 Savings

If we monetise the saving based on £0.15/kWh, the cost of energy saved is £36,528. If we then assume the press is only 60% utilised on this application and by maximising its usage to 100%, there is the potential to save a further £24,352, totalling £60,880. Against an installation price of £120,000 the pay back is under two years. We believe however that quality will be enhanced and scrap rates reduced. With better quality and capacity planning, payback could be further reduced to 18 months or less.

Future impact

The overall UK market size for carbon reinforced composites is currently valued at £3.6bn (£30bn globally) but with increasing use of injection over moulding (100,000 machines sold annually in the northern hemisphere alone) and tightening environmental legislation driving transportation electrification / light weighting the demand for high volume, low-cost composites is set to soar. Key to the success of this programme is the ability to be used as a turnkey or retrofit solution across the entire closed moulding space to help process the 60,000 tonnes of carbon fibre produced globally in 2018.

Given the long-term nature of many aerospace, automotive and medical type programmes, the proportion of applications that might realistically switch / implement the technology/process over the next 10 years will be limited to ~29% of the supply base. However, this number still equates to a UK demand of 389GWh using current state-of-the-art presses / autoclaves and so gives a saving using PtFS of 106GWh per year in the UK alone. Scaled globally, the UK's 11.9% market share gives a saving opportunity of 967GWh per year by year 10.

Innovation lessons

The collaboration between Surface Generation and Tiflex has been very successful, as we form a small but discrete supply chain. Surface Generation being the innovator and developer, Tiflex in effect being our customer drawing the novel technology through to successful application. We have learnt that this supply chain relationship can be key to a successful project. Through our developments we have raised the TRL level to 7/8, nearer 8, from an original level of 5. We have certainly learned other lessons through the project in our drive to develop a lower cost system. Such as, substituting highly engineered elements to pre-fabricated parts, such as the box sections that form the modules and the subsequent reduction in strength. Other lessons included going a little too low quality on the new microprocessor control screen and having some initial failures. Our initial designs of heaters turned out not to be cost effective in relation to the existing heaters, the 'lower' cost design actually adding cost.

These lessons will be addressed by specifying slightly higher specification materials, where available to improve performance and quality and to think twice about 'better' designs. We will look to 'harden' and improve the system through potential customer's feedback. This will be achieved through either additional public funding or direct investment by ourselves. Replication will depend not solely on the systems technical success, but on commercial advantage. The developed system must be competitive and provide the user benefits, including flexibility and an innovative approach.

Contact information

Andrew Sharpe
Surface Generation Ltd
+44 (0) 1572 737011

sales@surface-generation.com

www.surface-generation.com

Steve Ward
Tiflex Ltd
+44 (0) 1579 320808

sales@tiflex.com

www.tiflex.co.uk

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