Institution: University of Wales, Trinity Saint David

Unit of Assessment: 15 (General Engineering)

Title of case study: Scientific Advice to Belron Technical Ltd on Windscreen Impact Damage

1. Summary of the impact

Belron® is the world's largest dedicated vehicle glass repair and replacement company, operating in 35 countries and serving 10 million motorists each year. Annual turnover exceeds 2.7 billion Euros. In 2007, Prof Donne published the first ever peer-reviewed paper on vehicle glass repair, which demonstrated that the resin injection process significantly reduced the residual stress in a chipped windscreen. This research was significant in providing objective and independent evidence that the Belron® repair process generates strong repairs. This research work and other research projects undertaken by Prof Donne have been used to support the Belron® advertising message worldwide which has led to motorists' increased awareness of windscreen repairs. Annual repair jobs have consequently increased by 26% over the period 2008 to 2012.

2. Underpinning research

Modern vehicle windscreens are a lamination of two glass layers with a plastic interlayer. It is well known in the automotive industry that modern, thinner laminated windscreens exhibit star-shaped chips following stone impact in contrast to earlier, thicker laminated windscreens that exhibited 'bulls-eye' shaped chips. Donne has undertaken time-dependent finite element analysis of the initial impact to understand the effect of ambient temperature on the level of glass damage. This time dependent finite element analysis of stone impact on a laminated windscreen included a modified brittle damage model and the strain-rate behaviour of the plastic interlayer, whose stiffness varies dramatically with ambient temperature. The glass impact damage is therefore highly dependent on whether the windscreen glass layers are decoupled, which occurs at ambient temperatures above 30^{O}C due to the reduction in the stiffness of the plastic interlayer. This research was presented at the Belron® 2010 International Conference (Best of Belron®) that took place in Paris.

The Department's ballistic facility enabled projectiles to impact on laminated windscreens that were located in a temperature controlled target chamber. This facilitated the analysis of the effects of impact speed, projectile mass, material and ambient temperature. Photoelastic-based stress measurements were undertaken to confirm the computational model and provided consistent evidence of the reduction in residual stress due to the injection of the repair resin.

Further field experiments in climatic wind tunnels at Calsonic Kansei Ltd and MIRA in the UK provided further validation of the computer model. Following the extensive experimental programme in the climatic wind tunnel facility at MIRA, Donne and Thomas led experimental demonstration activities to approximately 1000 individuals from international automotive insurance and technical service businesses associated with Belron®. In these activities, live experiments were conducted, with thermally induced stress gradients on chipped windscreens. At a subsequent Best of Belron® International Conference in Paris, the same team conducted further live experiments to a similarly sized group from international companies, principally the senior executives of the insurance companies that form the major part of Belron's client base.

Further computational work using time-dependent F.E.A. on the 'chip to crack-off' problem was also undertaken. The research work has been used to support Belron® international advertising campaigns, especially the latest one "Every chip will eventually crack". This is based on a strong claim that was challenged by competitors and that Belron® successfully defended to the Advertising Standard Agency in the UK. The computational work undertaken by Prof Donne was key to this defence.

3. References to the research

Early work in photoelastic experimentation and computational modelling that demonstrated the significant reduction in residual stress following a resin-injected repair:

Donne K E, Thomas R D, Davies C and Calvert G 'Photoelastic Stress and thermographic measurements of automotive windscreen defects generated by projectile impact', International Journal of Quality, Reliability in Engineering (Wiley), Vol 24, 897-902, 2008.

Further work on time-dependent modelling of initial windscreen impact and the effect of ambient temperature on damage level :

Belron International Conference 2010, Paris. Presentation of computational modelling work at https://vimeo.com/user8581080/review/55524096/a54e0a89f5 (password to view: Belron)

Industrial research sponsorships by Belron Technical Ltd:

Over the period from 2008, audited investment for multiple projects that total over £113,000.

4. Details of the impact

The research impact achieved with Belron® is the result of a combined computational and experimental study into the impact creation of a windscreen 'chip' and how that chip will grow into a non-repairable crack if left untreated. This market-driven research has been influenced by environmental climate changes that alter the temperature gradients experienced by automotive windscreens on start-up in extreme ambient conditions. In this context the temperature controlled ballistics chamber used by the Unit is vital in validating the computational model. Our work for Belron® has developed for over twenty years and has provided objective scientific understanding of windscreen damage. This has kept Belron® at a competitive advantage in a service sector that typically provides little objective evidence. The contribution from the unit is based on computational modelling of the initial stone impact event and the subsequent chip-to-crack failure mode due to a windscreen experiencing thermal and mechanical stresses.

The peer-reviewed published research has provided independent evidence of the reduction in residual stress following a resin-injected repair to a windscreen. The computational modelling shown in the Paris conference video has clarified the critical role that the plastic interlayer plays in the stone impact event. In particular, the change in mechanical stiffness of this interlayer with ambient temperature has been shown to have a significant influence on the impact damage level.

Impact and benefit to Company:

Dr Chris Davies, Head of Technical Research & Innovation at Belron Technical Ltd:

- "The work carried out by Swansea Metropolitan University [now known as UWTSD] over the years has allowed us to assess some of our tools and equipment, support our advertising claims worldwide and in some cases fend off challenges from competitors. "

- "Professor Donne, Dean of Faculty of Applied Design and Engineering – computer modelling expert of Swansea Metropolitan University [now known as UWTSD], also features in one of our videos alongside Professor Conradt from Aachen University and Dr Fouvry from Ecole Centrale de Lyon, where he explains how his modelling work using finite element analysis (FEA) has helped Belron® understand and visualise complex physical behaviour. The video was first aired in Paris in 2010 during a Belron® event in front of over one thousand viewers that included most of Belron® insurance partners from over 30 different countries. The impact of the video was far-reaching and helped convince some of our partners of our 'repair first' strategy."

The experimental and modelling works undertaken at UWTSD, Swansea Metropolitan has provided independent scientific evidence to support Belron® successful international marketing campaign, which has contributed to a 26% increase in repair jobs over the period 2008-2012.

	fy2012	fy2011	fy2010	fy2009	fy2008
Turnover	€2727.2m	€2771.1m	€2804.6m	€2426.6m	€2159.2m
Repair jobs	2.9m	3.4m	3.5m	3.1m	2.3m

5. Sources to corroborate the impact

Point of contact: Head of Technical Research & Innovation, Belron Technical Ltd.