Institution: Bournemouth University

Unit of Assessment: UOA15

Title of case study: Green Tribology – The Sustainable Design of Lifeboat Launch Systems.

1. Summary of the impact (indicative maximum 100 words)

Royal National Lifeboat Institution (RNLI) lifeboats attend over 15,000 incidents annually with an average of 22 people rescued daily. Previously friction and wear on launch slipways adversely impacted safe lifeboat launching, costing the RNLI up to £260k/year. Lifeboat crewmen would address this issue by applying a layer of grease along the slipway, but repeated use had both safety and environmental implications. In 2005 this prompted the RNLI to draw on Bournemouth University's (BU) extensive green tribology expertise to find a solution. Collaboration between BU and the RNLI led to the redesign of slipway panels to double their life-span and switch from grease to a water lubrication system. As well as safety and environmental benefits, this saves the charity £1 million over a 5 year term, allowing resources to be focused on life-saving.

2. Underpinning research (indicative maximum 500 words)

Green tribology provides answers to friction and wear problems within an ecological and environmentally sound context. BU's research in this area began in 1998 with a combined EPSRC and BP Castrol grant (G1) aimed at informing industry of optimal design and effective fluid viscosities for environmentally acceptable refrigerants (P1). This work received "tending towards outstanding" and "internationally leading" for three categories within the Grant Review. This original research provided the foundation for further research and impacts over the next 15 years, based on green tribology, which at the time was a new concept.

The body of green tribology research, including hermetic compressors; combining heat and power (CHP) systems; refrigerants; lubricants; cavitation erosion and sliding contact wear effects contributed to the growing knowledge base within the Sustainable Design Research Centre (SDRC) at BU (G6). Specifically, green tribology's role in reducing the environmental and economic impact within mechanical systems has received international acclaim (P3).

The purpose of the EPSRC CASE award in 2004–7 (G3) was to work with the RNLI to address increasing problems of wear on the slipways. Slipway linings were found to suffer high wear and friction, adversely impacting safe lifeboat launching and costing the RNLI up to £260,000/year. Following the introduction of the new heavier 'Tamar' class lifeboat in 2006, the problem worsened with slipway panels wearing out in as little as two weeks. Lifeboat crewmen would address this issue by applying a layer of grease along the slipway, but the repeated use of this had safety and environmental implications.

In 2004 Thomas (BU 2010 to present) undertook research, supervised by Hadfield (BU 1997 to present), as part of a CASE award studentship (G3). Thomas designed two novel test-rig contact conditions specifically for the slipway contact scenario. These incorporated real-world factors, such as dwell times and external contamination. BU invested in new analysis equipment to evaluate the results, including the Zygo profilometer and light microscope upgrades. Thomas applied wear modelling techniques using bespoke Finite Element software in order to link the implications of the lab tests to the real-world case, demonstrating good correlation with the observed real-world effects (P4–P6).

Specifically, Thomas analysed the contact conditions between the 15cm wide keel of a 35 tonne lifeboat during a 45kph launch. This required the development of a new multi-disciplinary approach using aspects of tribology, finite element analysis, life cycle analysis and real world data collection, with experimental results combined with real slipway experience and computer simulations.

The data collected indicated that the reliability of lifeboat slipways could be greatly increased by ensuring the slipway panels were well aligned along the length of the slipway. It also showed a small change to the panel geometry to incorporate a chamfer significantly reduced wear development and the adverse effects of panel misalignments on launch and recovery friction.

The project showed that it was feasible to substitute the currently used marine grease lubrication with biodegradable grease, which would reduce the effects of grease bioaccumulation at the base of the slipway. The research also proposed the use of a novel water lubrication system instead of grease directly applied to the slipway, with the potential to greatly reduce both the operational costs and the environmental impact of slipway launches.

Furthermore, the RNLI commissioned Hadfield and Thomas to undertake research into alternative slipway materials in 2009. Formal slipway panel design and fitting guidelines were published for use with the RNLI shoreworks team (R1).

The project has helped to establish on-going research collaboration between BU and the RNLI with a jointly funded PhD into marine engine condition monitoring completed in 2011 (G6).

3. References to the research (indicative maximum of six references)

Publications

P1. Ciantar, C., Hadfield, M., Smith, A.M. and Swallow, A. (1999). The influence of lubricant viscosity on the wear of hermetic compressor components in HFC-134a environments. *Wear*, 236(1–2), 1–8. DOI: 10.1016/S0043-1648(99)00267-7.
P2. Howarth, G. and Hadfield, M.A. (2006). Sustainable product design model. *Materials and Design*, 27(10), 1128–1133. DOI: 10.1016/j.matdes.2005.03.016.
P3. Tzanakis, I., Hadfield, M., Thomas, B., Noya, S.M., Henshaw, I. and Austen, S. (2012). Future perspectives on sustainable tribology. *Renewable and Sustainable Energy Reviews*, 16(6), 4126–4140. DOI: 10.1016/j.rser.2012.02.064.
P4. Thomas, B., Hadfield, M. and Austen, S. (2010). Wear and Friction Modeling on Lifeboat Launch Systems. *Tribology Transactions*, 53(4), 584–599. DOI: 10.1080/10402001003602779
P5. Thomas, B., Hadfield, M. and Austen, S. (2009). Experimental Wear Modelling of Lifeboat Slipway Launches. *Tribology International*, 42(11–12), 1706–1714. DOI: 10.1016/j.triboint.2009.04.043.
P6. Thomas, B., Hadfield, M. and Austen, S. (2009). Wear observations applied to lifeboat slipway launches. *Wear*, 267(11), 2062–2069. DOI: 10.1016/j.wear.2009.08.008.

Grants

G1. 1998–2001: Hadfield, M. (Award Holder and PI) (DAK Z28X), EPSRC (GR/L74972/01), Managed Programme 'Design for Whole Life Cycle'. *Sustainable Development of Mechanical Systems using replacement environmental acceptable refrigerants* (three-year post-doc.). £108K (£120K).
G2. 2000–2005: Hadfield, M. (Award Holder) (DAJZ15), Royal Academy of Engineering. *Sustainable development education* – visiting professor scheme. £97K.
G3. 2004–2007: Hadfield, M. (Award Holder and PI) (DAK Z71), EPSRC and RNLI CASE award. *Sustainable design of lifeboat launching systems*. £64K.
G4. 2007–2010: Hadfield, M. (Award Holder and PI) (DAK G19X), Energetix Group. *Tribological study of new micro-generation system*. £16K.
G5. 2001–2004: Hadfield, M. (Award Holder and PI), EPSRC (Quota Award for Grant GR/L74972/01). *Sustainable design of sliding contact durability*. Fully funded studentship, estimated value of £45k for fees and bursary.
G6. 2008–2-11: Hadfield, M. (Award Holder and PI) (DAE G03X), EPSRC and RNLI (CASE). *Durability of Hydraulic Components in Marine Launching Equipment under Extreme Operating Conditions*. £104K.

4. Details of the impact (indicative maximum 750 words)

RNLI lifeboats attend over 15,000 incidents annually, with an average of 22 people rescued daily. As time is of the essence in life-threatening incidents in the sea, an immediate response with minimum reaction time is imperative.

In 2008 BU prepared a slipway Guidance Design Documentation for the RNLI, resulting from the EPSRC CASE award (R1). The document was a good practice design guide for implementation by RNLI technical staff. The new water-based slipway system identified has been implemented across 38% of RNLI lifeboat stations since 2008. The research has led to improvements in crew safety and RNLI launch reliability, as well as reducing maintenance down-time and machine failure. An increased number of standby lifeboats are now ready to interfere/engage, with the ultimate goal of ending the preventable loss of life at sea. All this has been achieved alongside the considerable cost savings of ~£200k per year as detailed below. The RNLI's head of engineering support (R2) is an author on publications P3–6, which corroborate the impact claims.

Financial Impact

Once fully implemented across the slipway network, the combined effects of the research allows the RNLI to save up to £52k in lubricant costs and a further £143k in material replacement costs (P3). This equates to a saving of almost £1 million over a 5 year term. With a 2011 combined budget of just £140m (R3) across the entire UK lifeboat operations solely provided by charitable donations, this systemic saving is crucial to the RNLI.

These savings are used to contribute to the on-going process of modernising the RNLI network as a whole. The RNLI's head of engineering support, Steve Austin, states: "The findings of the specific research are extremely valuable to the RNLI as they outline improvements that can be made to produce more efficient, durable and cost-effective slipways from which to launch and recover the lifeboats" (P3, R4 & R2).

Operational Impact

The research has also shown that the improved fitting criteria and a modified panel design can reduce the high wear and friction effects. This philosophy is now codified in three related volumes of slipway panel design and fitting guidelines. These were published in 2008 and are used by the RNLI (R1). Slipway lining panels' lifespan increased by over 100% through better panel fitting criteria and modified panel geometry (P4 & P5). The RNLI has adopted these panel redesigns and fitting criteria on all their new slipways. Since 2008 the new slipway lining material identified in the research has been fitted to the new and newly refurbished slipway stations. This includes Tenby, Padstow and Sennen Cove among others (R2).

The recommended slipway lining materials are being phased in across the UK slipway station network over the next few years, coinciding with the simultaneous roll-out of the new Tamar lifeboat. Currently around 38% of RNLI slipway stations use the new water lubrication system. Durability of the panels is increased while service and maintenance time is significantly reduced.

Environmental Impact

In response to the research results the RNLI have stopped using grease to lubricate the slipways. Instead they have adopted the automated water-based system BU advised. Since 2010 the RNLI has applied this across their slipway network, preventing the release of grease from the slipway into the surrounding marine environment. Once fully adopted this will result in the removal of 500+ litres of marine grease per annum from the local marine environment with a consequent saving in carbon emissions of ~740kg CO_2 p.a.

Further environmental benefits include the reduction of carbon emissions from material wear by 45% alongside with other useful environmental savings due to reduced maintenance costs (P3).

Crewman Safety Impact

The automated water-based system has removed the need for a crewman to descend the slipway during lifeboat operations and has correspondingly improved crew safety on lifeboat slipways. The reliability of slipway launches has also increased.

Additionally, testimonials from individual lifeboat personnel confirm that the use of the automated water based system reduced the risk exposure of the volunteer lifeboat crew at each slipway station. This allows the safe continuation the RNLI's crucial role in preserving life along the coast of the UK and Ireland (R5).

Further societal benefits include the continued on-going reliability and security of vital life-saving services through the reduction in maintenance down-time and machine failure.

Wider Research Impact

The research was presented at a number of international conferences including at the House of Commons as part of the 'Reception for Younger Engineers at the House of Commons' (R6) and was short-listed at the Times Higher Education (THE) Awards 2010 in the category of 'Outstanding Contribution to Innovation and Technology'. This award specifically highlighted BU's role in reducing environmental impact and costs (R7).

The research methodology developed during this project has many potential uses in other tribological contact situations, including oil rig rescue craft, overseas slipway lifeboats and cradle-launched beach rescue craft. The research is also relevant to applications involving sliding contacts along any tiled or grooved surfaces, including tyre friction along paved roads and spacecraft heat shields.

The application of the research within the RNLI has already had significant economical, operational and environmental benefits, as well as facilitating improvements to crewman safety. The £1 million saved over a five year period frees up resources to be used in the 15,000 incidents and rescues the charity attends each year.

5. Sources to corroborate the impact (indicative maximum of 10 references)

R1. RNLI: Guidance Design Documentation resulting from EPSRC CASE project. BU account reference DAK K43.
R2. RNLI's head of engineering support. Contact details available.
R3. *RNLI Annual Report and Accounts 2011*. Available from: http://rnli.org/SiteCollectionDocuments/2011%20Annual%20Report%20and%20Accounts%202011%20LR.pdf.
R4. BBC Radio article: *RNLI Slipway Research*. Available from: http://www.bbc.co.uk/cornwall/content/articles/2009/04/27/places_slipway_feature.shtml.
R5. RNLI news story: *Lifeboat project ready for awards splash*.
R6. Reception for Younger Engineers at the House of Commons at Portcullis House, Westminster, 2005.
R7. THE Awards shortlist in the category of 'Outstanding Contribution to Innovation and Technology', 2010.