Institution: Queen's University, Belfast

Unit of Assessment: 12

Title of case study:
New Bottle Manufacturing Technology leads to Energy and Material Savings

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

Multinational companies *[text removed for publication]* **have saved more than 20,000 tonnes of plastic and $10M in less than 4 years, using QUB technology to develop their innovative lightweight plastic bottles**.

This has created both economic and environmental impact through the **savings** in material, transport and energy costs and a **reduction in CO_2 usage**. For example the *[text removed for publication]* showed savings per year of €3M and 1800 tonnes of plastic and a reduction of CO_2 of 800 tonnes/year.

A **spin-out company**, built on this technology, was created in 2012 and is actively selling process instrumentation (***THERMOscan***) to both USA and EU customers enabling them to make further reductions in material and energy usage. The product **won a *clean energy* award in 2011**.

2. Underpinning research (indicative maximum 500 words)

In 1993 Prof. C. Armstrong (CA) and Prof. R. Crawford (RC) were involved in prestigious **EPSRC funded** research into the feasibility of modelling the stretch blow moulding process. [G1]. This research continued in 1996 with a 4 year project sponsored by **InvestNI, Coca Cola and Boxmore Plastics**. Both of these projects focused on the development of a stretch blow moulding (SBM) manufacturing simulation **with the aim of removing the trial and error techniques from the process.** From this research a material model capable of modelling the nonlinear viscoelastic material behaviour of Polyethylene terephthalate (PET) at strain and thermal histories appropriate to SBM was implemented within a SBM simulation [P1]. A major output of this project was the development of a biaxial testing machine capable of duplicating the deformation behaviour of the SBM process [P2]. The machine enabled an appropriate dataset to be created and a corresponding mathematical model to capture the behaviour of PET and has since attracted interest from a **host of multinational companies** *[text removed for publication].* Additional work funded by InvestNI and Boxmore Plastics, led by the Boxmore chair Prof. Eileen Harkin-Jones [EHJ] and CA between 2001-2004 led to further advancement of the process simulation through industrial plant tests [P3].

The *[text removed for publication]* **from 2002 have invested £200k** [G2] to develop capability in SBM simulation. An aspect of this work corresponding to characterising of PET for SBM is highlighted in [P4]. The paper was the first to present a comprehensive set of experimental data suitable for modelling the behaviour of PET for SBM and led to collaboration with University of Paris Est.

Between 2005-2008, an **EU FP6 project** led by GM, CA and EHJ [G3], resulted in the **development of wireless instrumentation capable of recording process conditions on industrial machines** [P5]. The data provided for the first time, data on the behaviour of the

preform inside the mould and the corresponding process conditions and led to GM obtaining **EPSRC funding** [G4] which enabled a new fluid structure interaction approach to be incorporated into the manufacturing simulation. The novel instrumentation, new data, and modelling approach attracted further interest from industry with *[text removed for publication]* investing in projects led by GM and CA of £342k [G5] over the period 2008 to 2012. The research with *[text removed for publication]* has resulted in new experimental approaches for obtaining material data relevant to the SBM process and new mathematical models to accurately capture the material and air flow behaviour which they are currently using to optimise the design of their containers. A £100k project led by GM and funded from **InvestNI** in 2009, resulted in the transformation of a **research measurement tool developed** from [G3] in to a commercial product named ***THERMOscan*** that is now being sold via a **spin out company** and being used by industry to optimise process setup, energy usage and evaluate new materials. Intellectual property has been protected via filing of an associated patent [P6]. The product developed from the patent won the prize at the Invest Northern Ireland 25k awards for the technology with **the most promising commercial potential in the clean energies category** (2011).

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

Key Outputs

P1. *Menary G. H.; Armstrong C.G. ; Crawford R.J ; McEvoy J.P.; Modelling of poly(ethylene terephthalate) in injection stretch-blow moulding; Plastics, Rubber And Composites: Macromolecular Engineering, Vol. 29, no7, pp. 360-370, 2000, DOI:10.1179/146580100101541166

P2. Martin, P.J ; Tan, C.W.; Tshai, K.Y.; McCool, R. ; Menary, G.H. ; Armstrong, C.G. ; Harkin-Jones, E .M, "Biaxial Characterisation of Materials for Thermoforming and Blow Moulding." Plastics, Rubber And Composites: Macromolecular Engineering, Vol. 34, no. 5, pp. 276-282, 2005 [***won the James Walker award for the best paper in the field of Polymers from the Institute of Materials***]

P3. Yang, Z.J.; Harkin-Jones, E.M.; Menary, G.H; Armstrong, C.G.; "Finite Element modelling of stretch blow moulding of PET bottles using Buckley model: plant tests and effects of process conditions and material parameters." Proceedings of the Institution of Mechanical Engineers, Part E, Vol. 218(4), pp.237-250, 2004 [***award winning paper from IMECHE for the best paper published in the volume***]

P4. *Menary, G.H.; Tan C.W.; Harkin-Jones, E.M.; Armstrong, C.G.; Martin, P.J. , "Biaxial Deformation and Experimental Study of PET at Conditions Applicable to Stretch Blow Molding" Polymer Engineering and Science, Volume 52, No. 3, pp. 671–688, 2012, DOI: 10.1002/pen.22134

P5. *Salomeia Y.M.; Menary, GH; Armstrong, CG , "Experimental investigation of stretch blow molding Part II: Analysis of process variables, blowing kinematics and bottle properties." Advances in Polymer Technology, 2013, DOI: 10.1002/adv.21291

P6. Method and apparatus for providing an internal surface temperature profile of a thermoplastic preform during a stretch blow moulding process. Inventors: Gary Menary, Cecil Armstrong, Yannis Mugurel Salomeia , Patent application number: 20110062611, Published March 2011

*Best three outputs

Key Grants

G1. Computer-Aided Design of Preforms for Injection Blow Moulded Containers, EPSRC, 1991-1995, **£73,000**

G2. Modelling the behaviour of PET for stretch blow moulding, *[text removed for publication]*,

2002-2010, **£200,000**

G3. Advanced Knowledge of Polymer Deformation for Tomorrow's Packaging (Aptpack) (STRP 505204-1) , 2005-2008, **£217,186**

G4. Fluid Structure Interaction in Injection Stretch Blow Moulding, EPSRC, (EP/H020756/1), 2010, **£101,354**

G5. Modelling and instrumentation of stretch blow moulding, *[text removed for publication]*, 2008-2012 **£342,000**

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

Since 2008 the research in Stretch Blow Moulding has made a significant impact on a number of multinational companies. The global presence of these companies and the volume of products they produce ensure that both the reach and significance of the impact is felt on a **global scale**. The impact of **the underpinning research has resulted in new technology, software and knowledge being integrated into the design process of containers** thus enabling them to lightweight them. This has direct savings to the companies through the usage of less material as well as impact on the environment through less use of petroleum based plastic and the transportation of lighter containers.

Economic Impact

Between 2003 and 2012, the *[text removed for publication]* invested ~£200,000 of funding to develop mathematical models of the behaviour of PET during processing and of the stretch blow moulding process. The research has had a significant impact within *[text removed for publication]* and beyond. A letter of support from *[text removed for publication]* **Head of modelling & simulation** *[text removed for publication]* (2002-2012) has confirmed that the know-how generated contributed to the launch of:

- **Several innovative packaging formats in 20 countries covering almost all continents of the world** *[text removed for publication]*
- **Several lightweight containers, including all sizes of the famous** *[text removed for publication]* **brand (from 33cl to 1.5L),** *[text removed for publication].*

As an example on the savings to the business, the reduction of ~3g from a 1.5l *[text removed for publication]*PET bottle lead to more than 1800 tonnes of PET saved per year (basis: 600 million bottles production on average). The average cost of PET since 2009 is ~ €1700, equating to an **economic saving of ~€3M per year since 2009**. The research work with QUB enabled *[text removed for publication]* to make decisions about the effect of processing on material properties as well as numerical simulation prediction, and thus made a significant and direct impact to these savings. The research has also enabled *[text removed for publication]* to develop a new methodology for evaluating new materials for stretch blow moulding, **including non-oil based and eco-friendly materials which is a key challenge for them in the future.** The investment in research has also contributed to the professional development of the *[text removed for publication]*packaging team including increasing the expertise of technicians, engineers and *[text removed for publication]* managers in the field of stretch blow moulding technology and the recruitment of 2 former PhD students of GM, CA, EHJ and PM.

Between 2008 and 2012, the *[text removed for publication]* have invested £342,000 in research with QUB with the aim of developing an accurate validated simulation of the stretch blow moulding process. **They use this process to make over 20% of the 5 billion containers they sell all over the world every year.** They currently use the simulation software package as part of their virtual design process for their new and existing products. The stretch blow moulding model is an integral component of their virtual package design system. A quote from *[text removed for*

publication] use of tools related to Queen's program has delivered, in the last year alone, at least $3 million in savings. Moving forward [text removed for publication] expects these models to deliver $25 million in annual savings"

THERMOscan

A new spin out company **Blow Moulding Technologies** was created in 2012. The product the company is selling (***THERMOscan***) is based on patent pending technology and the research assistant who worked on these projects is now the CEO of BMT. The company has already sold 7 units [**EU and USA**] and turned over £140,000 in 6 countries. The technology is enabling **multinational companies such as Logoplaste, Amcor and Procter & Gamble** to optimise their process setup, saving them time, energy and money and provides them with new information that enables a better understanding of their process and a more efficient production of bespoke products. **Paulo Correia, the Director of Logoplaste Innovation lab** which is the R&D centre for Logoplaste's 63 manufacturing plants based across the world, highlights the impact the new technology has on the business **"*THERMOscan enables us to setup our processes easier and faster. With a new insight on how preform design and materials are influencing the heating process we are now able to take upon even more ambitious projects.*"** Whilst *[text removed for publication]* has said "Temperature measurements from THERMOscan have enabled more accurate blow moulding simulations, improving our package design process". A major machine manufacturer, SOPLAR, based in Switzerland have purchased the THERMOscan device. On THERMOscan they quote "**THERMOscan has been an invaluable tool in helping us optimize and develop our IR-technology**."

Environmental Impact

The research also has an environmental impact through **less use of petroleum based plastic** and the **transportation of lighter containers**. Taking the case study of the 1.5l *[text removed for publication]* PET bottle *[text removed for publication]* the **1800 tonnes of PET saved per year** on this container can be translated in to **a reduction of CO_2 of ~ 800 tonnes/year**. Considering the savings of material made on other leading global brands as highlighted in the economic impact it is clear that the environmental impact has both reach and significance.

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

	Position	Company
1	CEO	Blow Moulding Technologies
2	Director	*[text removed for publication]*
3	Senior Engineer	*[text removed for publication]*
4	Director	Logoplaste Innovation Lab.
5	Innovation Management Head of Department	Soplar SA

6. Technology profiled in Packaging Europe News, 2011: http://www.packagingeurope.com/Packaging-Europe-News/40995/THERMOscan-Innovative-Technology-in-ISBM.html