Institution: Queen's University, Belfast

Unit of Assessment: 12

Title of case study: Catalytic Converter Research Leads to Major New Product for Motor Vehicles

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

Globally there are estimated to be 60 million cars produced each year. These all require catalysts that need testing to meet stringent emissions legislation. Catagen Ltd, a spin-out from Queen's University has developed a product for testing motor vehicle catalysts that is **85% cheaper to operate** than traditional methods and **represents a 98% reduction in CO_2 emission from testing and an 80% reduction in energy input.**

Major global customers including GM motors and Fiat have adopted this revolutionary patent protected technology and international sales growth has been recognised, winning an all-Ireland business award for **BEST High Growth Company 2012**

2. Underpinning research (indicative maximum 500 words)

Engine catalyst research at QUB has been led by Professor Roy Douglas since the late 1990's. Initial research focused on catalytic converters for two-stroke engines and addressed the catalytic substrate simply as an obstruction to the flow of exhaust gas, which hinders the progression of the main exhausted pulse, and in turn affects the performance of the engine [1]. This initial research led to a validated catalyst model for two-stroke applications that involved Douglas and McCullough [2].

A natural progression of the research was to understand the catalysis processes themselves, research driven by the automotive industry, which was coming under increasing pressure to reduce and monitor engine emissions. This work addressed the reaction rates associated with the storage process, for three-way automotive catalysts [3] and highlighted the need for precise understanding of the ageing process in catalysts. Ageing, in this context, refers to the fact that catalysts do not operate with the same efficiency over long periods (years in terms of required life-times in cars). Therefore test methods must be able to demonstrate that new designs will operate effectively (i.e. within engine emission targets) over sustained periods.

Later work by Douglas and McCullough describes a detailed mathematical model for oxygen storage, a crucial part of a complete kinetic model of a three-way automotive catalyst. This model consisted of two interdependent sub-models with the complex environment of a catalyst: one for the oxidation process and a second for the reduction process. In this study, O_2 and NO were used as oxidizing agents and CO, C_3H_6 and C_3H_8 were used as reducing agents [4].

The development of the new ***dynamic Catalyst Ageing System*** for testing motor vehicle catalysts dates back to the formation of CenTACat in 2003 [6]. CenTACat undertakes multidisciplinary research involving chemists, physicists and engineers with a common interest in understanding the fundamental principles that underpin clean energy production and environmental protection. Within this facility Douglas supervised PhD student Andrew Woods (now CEO of Catagen) and together they filed a patent relating to the IP that their research had developed for testing of catalyst materials [5].

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

1. McDowell, A.P.N., Carberry, B.P., Douglas, R. Effects of the catalytic converter on two-stroke engine performance , SAE Special Publications Volume 1294, September 1997, Pages 81-90. DOI: 10.4271/972741
2. *McCullough, G., Douglas, R., Cunningham, G., Foley, L. The validation of a two-dimensional transient catalyst model for direct injection two-stroke applications (2001) Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 215 (8) , pp. 935-955. DOI: 10.1243/0954407011528491
3. Khossusi, T., Douglas, R., McCullough, G. Measurement of oxygen storage capacity in automotive catalysts (2003) Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 217 (8), p 727-733. DOI: 10.1243/09544070360692113
4. *Khossusi, T., McCullough, G., Douglas, R. Modelling of oxygen storage in automotive catalysts. (2004) Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 218 (11) , pp. 1349-1362. DOI: 10.1243/0954407042580066
5. *Douglas R, A. Woods A. Method and Apparatus for Testing a Catalyst Material Douglas, R. & Woods, A. Sep 2011 EP2376754. Granted Patent (under examination in 4 jurisdictions: USA, China, India & Brazil)

*Best 3 outputs

Grants

6. General Motors R&D, R Douglas (funded A Woods PhD), 2005-2008 , direct industrial funding, $60,000
7. Centre for the Theory and Application of Catalysis (CenTACat), Douglas R., McCullough G. (2 of 20 Co-investigators), 2003-2008, Support Programme for University Research *SPUR2*, £5,000,000.
8. EPSRC Studentship, R Douglas, Catalyst Modelling, 2008-2012, £100,000

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

The data from catalyst aging tests are required in the commercialisation of any new formulation in the automotive industry. **Traditional methods to achieve this are not only expensive in terms of fuel consumption but have secondary negative impacts including CO_2 emissions.** The realisation that exhaust gas recirculation could be applied to improve such issues was a significant advance and led to the development of the patented *dynamic Catalyst Ageing System*. This technique **currently out performs all published ageing procedures** in terms of the balance of overall cost.

It was research into the ageing of catalysts within CenTACat that resulted in a QUB spinout company **Catagen Ltd**, which was formed in May 2011. Catagen produce a range of such ageing systems for the automotive industry including ***Labcat***. Each system has been trialled by industry to advance commercialisation of catalytic technologies. The first system was manufactured by FAST Technologies Ltd in Derry City with product launch in January 2012. This brought much needed jobs to a region with the highest youth unemployment in N Ireland. Catagen will have their own Belfast-based manufacturing facility in 2013, with FAST involved as a component supplier.

The Catagen technology is regarded as a revolutionary innovation in laboratory based ageing. The

technique which uses the patented *dynamic Catalyst Ageing System* costs just over $3 USD per hour to run which translates to lower running costs than competitors and faster return on investment. **This low carbon technology also outputs 50 times less CO_2 compared to engine ageing of equivalent catalyst volumes and space velocities**, therefore representing an **environment-friendly technology**. Catagen delivered the first machine to Fiat CRF, Italy in June 2012 and, at that time, quotations were sent to 6 automotive companies. Turnover for the year 2012 was £200k and the company is projecting sales of £1m for 2013, with a company valuation of about £5m at that time.

In January 2012 Arlene Foster MLA (N Ireland Minster for Trade) described Catagen as a ***"Northern Ireland success story"*** that followed a great tradition of local manufacturing excellence in the industry. This is backed up by former **Director of Ford Motors in the USA** (Rose Mary Stalker) who stated "The automotive industry is built on innovation and *Labcat* is a significant and welcome development … ***it will find international success***". Rose Mary Stalker's strong belief in Catagen resulted in her accepting the position of its Chair in January 2013.

That international success is now being demonstrated with global sales to **Fiat** and **General Motors Company** (both iconic names and world leaders in motoring) and a new major deal with Mahle Powertrain, the second largest company in the world producing engine components. As well as bringing economic rewards to Catagen this has been acknowledged by the **Best High Growth Company Award at InterTradeIreland's 2012 all-island Seedcorn Business Competition**.

The **global market size is estimated at 15,000 test machines** (just within the automotive sector) translating to a required production capacity of 150 machines per year (current Catagen capacity is 4 machines per year). Further markets will be coming on-stream, such as small off-road engines (SORE), which will require catalysts. This will occur over the next 10 years due to the introduction of new emissions legislation. Currently 100 million SORE are produced each year.

In summary the technology, developed at QUB, brings economic growth to the region with global reach in terms of product sales and environmental impact. Professor Douglas is Chief Technical Officer and shareholder within Catagen.

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

1. Catagen CEO
2. Catagen company literature acknowledging QUB input: http://www.catagen.co.uk/research.html
3. Intertrade Ireland Business Awards http://www.dcppr.co.uk/catagen-triumphs-intertradeireland-seedcorn-business-awards/
4. NI Minister for trade speech at Catagen Product Launch Jan 2012 http://www.catagen.co.uk/videos.html
5. Belfast Telegraph article on Catagen Product Launch (Jan 2012) http://www.belfasttelegraph.co.uk/news/local-national/northern-ireland/derry-hosts-launch-of-major-new-car-product-28704662.html