Institution: University of Bath

Unit of Assessment:12: Aeronautical, Mechanical, Chemical and Manufacturing Engineering

Title of case study: Reducing CO_2 emissions and saving drivers' fuel costs from the Ford fleet of vehicles

1. Summary of the impact

Impact on the environment

- The adoption of cost effective CO_2 reduction technologies across a range of Ford vehicles reduced CO_2 emissions by an estimated 40,000 tonnes in 2012. This reduction applies pro rata for 2013 and becomes cumulative year on year.

Economic impact

- Improvements to vehicle engines have saved over €25M in fuel costs to the owners of Ford vehicles in 2012.
- Research has led to improvements that have been made to Ford products and processes; these improvements have been used to address upcoming legislation on CO_2 in a cost effective manner. Future penalties of up to €0.5bn have been avoided by these improved products and processes.

Impact on practitioners

- Improved monitoring processes, reducing variability in measurement of CO_2 from vehicles within Ford by 50%, facilitating the adoption of a range of new fuel saving technologies, which helped to justify a $50M investment in the Ford UK facilities.

2. Underpinning research

Key researchers

Members of the Powertrain and Vehicle Research Centre (PVRC): Dr S Akehurst (Research Officer 2000-2004, EPSRC Advanced Fellow 2005-2010, Lecturer since 2010); Dr CJ Brace (Research Officer 1992-2000, Lecturer 2000-2006, Senior Lecturer 2006-2012, Reader since 2012); Professor JG Hawley (Lecturer 1995-1997, Senior Lecturer 1997-2001, Reader 2002-2004, Professor since 2004); and Dr RD Burke (Postgraduate 2008-2011, Research Officer 2011-2012, Prize Research Fellow since 2012).

The underpinning research was focused on reducing engine parasitic losses, thereby making the engine more efficient and reducing the CO_2 emitted. In order to achieve this, a greater understanding of the factors limiting precision in the measurement of CO_2 produced by vehicles was required. This also gave a greater precision in determining fuel consumption as it is calculated from the CO_2 measurement. Research aimed at improving measurement precision was funded by Ford from 2001, initially to assess the instantaneous vehicle emissions on a second by second basis and to understand how errors in measurement would affect the final result over a standard driving cycle [1]. This work was carried out on the newly commissioned, state-of-the-art chassis dynamometer facility at Bath. The expertise gained from this research led to a collaborative project with BP in 2004-2005 to undertake a fundamental study of the effect of experimental disturbances on the precision of CO_2 measurements [2, 3]. The key insight arising from this research was that techniques developed for controlling manufacturing processes of mass produced components could be used in an experimental environment. The work quantified for the first time the influence of changes in experimental conditions on measurement precision; this allowed the effects on fuel efficiency due to incremental improvements in technology to be measured reliably.

These experimental techniques were critical to the success of the research into parasitic loss reduction. This experimentally intensive research was carried out on a Ford production engine using an advanced engine test research platform. A formal systematic method was developed to characterise and robustly model the complex interactions between the engine systems, i.e. heat exchange mechanisms, hydraulic systems, mechanical and electrical subsystems, control strategies and combustion processes. Among the technologies investigated by Bath were variable flow oil pumping, an improved engine cooling system and improved lubricant specifications, first through a joint project led by Ford and BP (DTI project TP/2/5/10036, 2005-2007) and followed by a project adding Mahle Powertrain to the existing consortium (TSB project TP/9/LCV/6/I/S0052K, 2008-2011). The research demonstrated that, with the right control strategy, variable flow oil pumps are able to deliver precisely the right amount of oil needed to protect the engine at any particular time thereby saving energy, fuel and reducing CO_2 [4]. Improving the cooling system allows faster warm up of the engine, again reducing fuel use [5]. The improved lubricant blends demonstrated similar improvements by reducing friction and pumping work within the engine [6].

Key findings from this research demonstrated that:

1. A novel design of an engine cooling and lubrication system, including a variable displacement oil pump, provided a 4% fuel economy benefit [4, 5].
2. Novel engine and transmission lubricant formulations each demonstrated a 1% fuel economy saving [6].

3. References to the research (* references that best indicate quality)

1. JG Hawley, CD Bannister, CJ Brace, A Cox, D Ketcher and R Stark. Vehicle modal emissions measurement – techniques and issues, 2004, Proceedings IMechE, Part D, Journal of Automobile Engineering, **218**, 859-873. DOI: 10.1243/0954407041581057

2*. CJ Brace, RD Burke and J Moffa. Increasing accuracy and repeatability of fuel consumption measurement in chassis dynamometer testing, 2009, Proceedings IMechE, Part D, Journal of Automobile Engineering, **223**, 1163-1177. DOI: 10.1243/09544070JAUTO1084

3. E Chappell, CJ Brace and C Ritchie. The control of chassis dynamometer fuel consumption testing noise factors and the use of response modelling for validation of test repeatability, 2013, Proceedings IMechE, Part D, Journal of Automobile Engineering, **227**, 853-865. DOI: 10.1177/0954407012469557 [Ref 2]

4*. RD Burke, AJG Lewis, S Akehurst, CJ Brace, I Pegg and R Stark. Systems optimisation of an active thermal management system during engine warm-up, 2012, Proceedings IMechE, Part D, Journal of Automobile Engineering, **226**,1365-1379. DOI: 10.1177/0954407012441883

5. CJ Brace, JG Hawley, S Akehurst, M Piddock and I Pegg. Cooling system improvements – assessing the effects on emissions and fuel economy, 2008, Proceedings IMechE, Part D, Journal of Automobile Engineering, **222**, 579-591. DOI: 10.1243/09544070JAUTO685 [Ref 2]

6*. JG Hawley, CD Bannister, CJ Brace, S Akehurst, I Pegg, and MR Avery. The effect of engine and transmission oil viscometrics on vehicle fuel consumption, 2010, Proceedings IMechE, Part D, Journal of Automobile Engineering, **224**, 1213-1228. DOI: 10.1243/09544070JAUTO1534 [Ref 2]

4. Details of the impact

The Ford Motor Company sold 1.4 million cars in Europe in 2012. It builds the 1st and 3rd best selling cars in the UK. The upcoming EU fleet average CO_2 emissions legislation will impose a levy of €95 per gCO_2/km above a fleet average of 95gCO_2/km by 2020. This challenging requirement would cost a company the size of Ford €5.3bn if no improvement were evident from 2011 fleet average emissions levels. Clearly this is commercially untenable hence every car manufacturer has had to put into place a process to develop technologies and enhancements to meet these requirements by improving fuel efficiency incrementally each year. Crucially, though, these technologies must be commercially affordable if car manufacturers are to be in a position to maintain profitability.

The technological and commercial needs have resulted in a powerful research imperative to develop and assess cost effective technologies that can effect measurable reductions in CO_2. The need for improved products is self-evident. The need for improved processes arises because the level of CO_2 saving offered by individual enhancements is typically small and often masked by the measurement imprecision typical of industrial laboratories. Improved precision is needed if product enhancements are to be demonstrated to be cost effective. The research at Bath has been uniquely able to contribute to improvements in both product and process. It was conducted in partnership with the Ford Technical Collaborations Group, which commissions and manages research on behalf of engineering teams within the whole Ford structure. The findings of the research are then passed directly to those groups and feed into current practice and future model development programmes.

Improving the precision of CO_2 measurements

A project in partnership with Ford and co-funded by the Bath KTA (2010-2012) developed and extended the techniques demonstrated by the research at Bath [3] in such a way that they could be adopted in the commercial setting of the Ford vehicle emissions laboratories at the Dunton Technical Centre. Ford engineers, assisted by Bath researchers, incorporated the findings of the high precision CO_2 measurement research into everyday practice for the benefit of fuel consumption evaluation. The target was to double the level of precision, thereby allowing engineers to rapidly establish the benefits of increasingly small design changes to the vehicles. This target has been successfully achieved and has been instrumental in the development of the Transit and the Econetic range of vehicles. The Econetic range sold 550,000 vehicles in Europe in 2012, representing nearly half of Ford's European sales [A].

The Director of Vehicle Evaluation & Verification at Ford commented [B]:

> '*The* [Bath research] *project has accelerated the improvements to reduce variability in test measurements of fuel consumption and emissions. As consumption and emissions fall, any benefits become increasingly difficult to measure, which is why this project has been so useful. By making our test procedures more discriminating, it allows our development engineers to make best use of our facilities. Some of these improvements have been carried over to other labs, particularly in Germany and the United States.*'

In 2012 Ford committed to a multi-million $ investment in the vehicle emissions laboratories at its Dunton Technical Centre. The findings of the Bath research on improving CO_2 measurement precision were used to justify this investment [D].

Product improvement

The research findings from the parasitic losses research gave Ford the information needed to utilise variable flow oil pump technology, giving a 3% reduction in CO_2, in a production engine for the first time. This engine, the 1.0L EcoBoost, was launched in 2012 and was the winner of both the 2012 and 2013 International Engine of the Year award [C], judged by an international panel of automotive journalists. In addition, the high precision measurements made possible by Bath research were able to demonstrate that a custom oil formulation further improved the efficiency of this engine, giving an additional 1% improvement in efficiency [6].

The 1.0L EcoBoost engine achieved sales of over 100,000 in 2012, its first year of production, with an increasing sales trajectory. This engine is fitted to most of the Ford range from the Fiesta to the C-Max and will go into the Mondeo in 2013. The Fiesta and Focus achieved UK sales that made them the first (109,665 cars) and third (83,115 cars) best selling cars in 2012 [A].

Describing the mechanism by which the impact has been generated, the Director of Vehicle Evaluation & Verification at Ford commented in January 2013 [B]:

> '*Over the last ten years the relationship between Ford Motor Company and the University has grown into one that is of significant benefit to Ford…With the help of the EPSRC and the TSB,*

we have been able to develop powertrain technologies and processes that are now influencing our products. Work at [the University of Bath] gave us a head start in developing a specific engine oil for our 1.0L EcoBoost engine which is now "International Engine of the Year".'

The 2.2L Duratorq diesel engine, fitted to the Ranger and the Transit, which was the International Van of the Year 2013, also benefitted from improvements demonstrated in the research at Bath. The improved thermal management techniques and designs aimed at reducing friction have contributed to the creation of this engine. Transit sales alone totalled 129,200 in Europe in 2012 and sales of this engine will soon reach 300,000 per year. These engines are built at the Ford plant in Dagenham.

In summary, the impact of these improvements on the emissions generated and the fuel economy seen by the vehicle owners is substantial. The 4% improvement in fuel economy due to the variable flow oil pump and new engine oil formulation reduced CO_2 emissions by approximately 40,000 tonnes in 2012 based on 30,000 km per annum for trucks and 20,000 km for passenger cars. Based on €1.70 per litre, the reduction in fuel used saved the owners nearly €25M across Europe with further savings due to the vehicle classification into lower tax brackets [A].

Returning to the primary motivation for the research programme, the fact that research at Bath has allowed Ford to implement cost effective changes to its production vehicles reducing CO_2 emissions by 4% has significant commercial impact for Ford. The improvement in fleet average CO_2 performance is a key factor to the strategic imperative of achieving the EU set target of 95 gCO_2/km. The savings achieved by implementing the findings of the Bath research allow Ford to make progress towards avoiding an EU CO_2 penalty. The value of this contribution may be estimated by considering the number of vehicles affected (estimated to be at least 600,000); the grams of CO_2/km saved by the measures described (4% of current fleet average represents a saving of approximately 5 gCO_2/km); the levy per gCO_2/km over the 95 gCO_2/km threshold (€95/gCO_2/km). This results in a contribution valued at approximately €0.29bn per year in avoided penalties.

5. Sources to corroborate the impact

A. Corroborative statement from Director of ADS Collaborations Ltd, 3 October 2013.

B. Corroborative statement from Director - Global Vehicle Evaluation & Verification, Ford Europe, 7 January 2013.

C. International Engine of the Year 2013 (http://www.ukipme.com/engineoftheyear/ieoty.php).

D. Corroborative statement Supervisor - Advanced and Emissions Engineering, Ford UK, 30 October 2013.