Institution: The University of Huddersfield

Unit of Assessment: 15 General Engineering

Title of case study: Optimal design of flow handling systems using computational fluid dynamics

1. Summary of the impact

University of Huddersfield research into the optimal design of flow-handling systems has been credited with "transforming" the development strategies and global market sales of an industrial partner. Weir Valves and Control Ltd has enjoyed a 75% saving in design lead time and a 1,800% increase in annual sales – from several thousand before its collaboration to millions in 2013 – through the structured integration of researchers' computational fluid dynamics expertise in its design process. The success of this collaboration, which has been described as an exemplar of a Knowledge Transfer Partnership, has also led to further research contracts.

2. Underpinning research

The innovative design of fluid systems is an important area of work for the University of Huddersfield's Energy, Emissions and the Environment Research Group (EEERG) which is a part of the Centre of Efficiency and Performance Engineering. Novel methods in this field can have a number of different yet related applications for a range of end-users. Professor Rakesh Mishra (Senior Lecturer, 2004-2009; Reader, 2009-2011; Professor of Engineering, 2011-present) has led EEERG's studies into flow through complex geometries, including research carried out on various fluid-handling systems.

In 2005, as part of an EPSRC New Academic CASE award in collaboration with Bentley Motors, Mishra began research to develop an inverse design code for brake discs for optimum flow and heat transfer characteristics. These discs have embedded pin and aerofoil-shaped structures within the flow passage to modify flow patterns and minimise judder and undesirable vibrations. A systematic computational fluid dynamic (CFD) analysis and experimental study resulted in the development of design equations correlating flow characteristics with the geometry of the disc. These equations were then embedded in the design methodology to develop an inverse design code. This work resulted in several publications, including two in the Proceedings of the Institute of Mechanical Engineers, Part D: Automobile Engineering [1, 2].

Weir Valves and Controls Ltd, which uses similar features in control valve applications, approached Mishra after becoming aware of his research through these publications. This resulted in a three-year Knowledge Transfer Partnership programme, approved by the Technology Strategy Board and EPSRC, to address the company's need to embed complex flow knowledge into its design, operation and sales teams. This research involved the following objectives:

- Improved scientific understanding of flow geometry of valve bodies in order to enhance valve performance and comply with IEC 60534 Part 2 sizing calculation standards
- Improved understanding of valve performance under compressible versus incompressible flows
- Understanding the effects of multiphase flow (e.g. oil/water, water/solids, oil/water/gas) and entrained solids on valve performance
- Understanding the effects of specific trim designs on flow recirculation, vortex shedding and cavitation.

The work involved detailed CFD and experimental studies on the standard valve trim to validate the CFD models. The strategy for CFD was based on the published works [1, 2] and resulted in accurate estimates of design parameters CV and K. It was apparent that the front-row cylinders were responsible for the majority of the pressure loss. Areas of negative pressure zone that were susceptible to cavitation were also identified (Figure 1).

By manipulating the geometry it was possible to achieve controlled reduction in pressure drop and minimise cavitation. The results obtained through CFD tests were matched with a purpose-built valve test rig at the University, and excellent matching between the two was observed. Outcomes from CFD were then embedded in the design process, and a new strategy was adopted (Figure 2). The work also included the development of special software to simplify design and analysis.

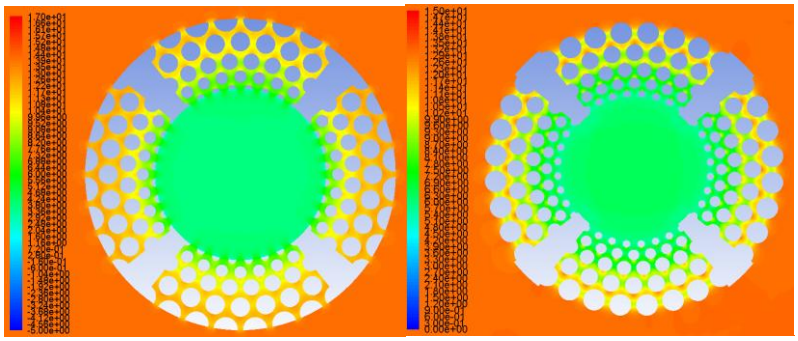

Figure 1: Effect of geometry modification on Pressure

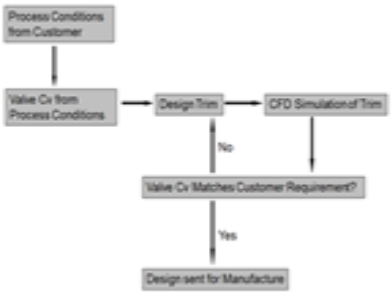

Figure 2: Modified design strategy

3. References to the research

Publications:

1. E Palmer, **R Mishra** and J Fieldhouse (2008): 'A Computational Analysis on the Effect of Front-Row Pin Geometry on the Aero-Thermodynamic Properties of a Pin-Vented Brake Disc', *IMechE Journal Part D*, Volume 222, 1231-1245. DOI: 10.1243/09544070JAUTO755 (Downloaded 60 times from the University Repository by users in 19 countries http://eprints.hud.ac.uk/4395/).

2. E Palmer, **R Mishra** and J Fieldhouse (2009): 'An Optimisation Study of a Multiple-Row Pin-Vented Brake Disc to Promote Brake Cooling Using CFD', *IMechE Journal Part D*, Volume 223, Number 7, 865-875. DOI: 10.1243/09544070JAUTO1053 (Downloaded 76 times from the University Repository by users in 20 countries http://eprints.hud.ac.uk/4392/)

Grants:

EPSRC CASE award for New Academics, University of Huddersfield and Bentley Motors, September 2005 to September 2009 – £78,000. PI Rakesh Mishra.

Technology Strategy Board/EPSRC KTP award to University of Huddersfield in association with Weir Valves and Controls Ltd, January 2011 to January 2014 – £120,000. PI Rakesh Mishra.

4. Details of the impact

EEERG's innovative work on fluid systems has been credited with "transforming" the design, operating and sales strategies of one of the University of Huddersfield's industrial partners. The successful application of research, which has resulted in 18-fold increase in sales for the company and further contracts for the University, has been described as an exemplar of a Knowledge Transfer Partnership.

The inverse design methodology that was first developed for Bentley Motors led to immediate success when incorporated into Weir Valves and Controls Ltd's X-Stream valve trim. In its product literature the company, based in Elland, West Yorkshire, describes X-Stream as "the first [valve] of its kind to provide complete 3D-flow control", adding: "The result of an extensive research programme, this method of design uses a combination of proven computational fluid dynamics (CFD) and actual flow visualisation techniques to eliminate local areas of excessive turbulence and

velocity (the main source of noise and erosion problems) and areas of recirculating flow (a significant cause of cavitation)." [a] Modifications in design strategy brought about by EEERG's research resulted in an immediate improvement in design lead times – specifically, a reduction of 75% – and led to growth in demand for and sales of X-Stream. In addition, enhanced knowledge of the pressure field and the velocity field inside valve internals enabled the company's design and sales employees to handle clients' queries far more efficiently. [b, c]

The resulting success of this collaboration has led to more investment in the company's R&D and sales strategies, including the establishing of a team specifically tasked with handling X-Stream matters. The industrial supervisor of the KTP was given responsibility for leading further research and development in this area, with Mishra's team and the University's facilities remaining integral to the work. The growth in sales since the partnership was first established is reflected in the figures below.

Year:	2010	2011	2012	2013
Sales:*	£X	£4X	£ 11 X	£ 18 X

(Actual numbers cannot be given because of confidentiality)

This progression shows how embedding the knowledge through the KTP programme, along with initiatives taken by the company to fully utilise the support available, has resulted in a 18-fold increase in sales in the space of less than four years. [c] The figure for 2012-2013 is expected to show a 25 fold increase by the end of this year. Weir's Senior Design Engineer has remarked: "The impact of embedding outcomes of computational fluid dynamics into the design strategy, as well as operation and sales, transformed the market for X-Stream worldwide." [c] Speaking at a local management committee meeting in September 2013, the KTP adviser described the programme as an example of an ideal Knowledge Transfer Partnership in which academic expertise had been embedded through a structured process in the company's work system to deliver benefits to all parties. [d]

The strengthening of the partnership between the University and Weir as a result of the success of EEERG's research has delivered further advantages. In the past two years four graduates have been employed by the company as full-time engineers, and every year Weir has employed two placement students, which has further contributed to the partnership's sustainability. Although the current KTP is due to end in January 2014, both parties have already agreed to extend collaboration via another KTP – one focused on extending the work carried out so far to develop the design of wear-resistive valves for application in the oil and gas industry.

The influence of the research conducted with both Bentley and Weir has also been be evidenced by the securing of further contracts by Mishra and his team. Two PhD studentships are being sponsored by Blackhall Engineering Ltd, of Brighouse, West Yorkshire, to embed the team's knowledge base into the company's design and development activities in order to optimise Blackhall's product range. [e]

5. Sources to corroborate the impact

a. Product description of X-Stream, Weir Valves and Controls Ltd
http://www.weirpowerindustrial.com/products__services/valve_products/control_valves/severe_service_control_valve-1.aspx

b. Support letter from Managing Director, Weir Valves and Controls Ltd

c. Support letter from Research and Development Lead Engineer, Weir Valves and Controls Ltd

d. Support letter from the KTP Adviser, Technology Strategy Board

e. Studentship agreements signed by Managing Director, Blackhall Engineering Ltd