Institution:
University of Cambridge

Unit of Assessment:
UoA10

Title of case study:
Dissolved air flotation

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

By modelling the formation of micro-bubbles and the flows induced by them, researchers at the University of Cambridge Department of Applied Mathematics and Theoretical Physics developed a new, low-cost nozzle design that could be retrofitted to existing Dissolved Air Flotation (DAF) systems. This new design dramatically improved the performance of DAF systems, used by the water industry for the production of drinking water. Specifically, this research has enabled a substantial increase in throughput and effectiveness of the flotation process, whilst simultaneously providing a dramatic decrease in the energy requirement.

2. Underpinning research (indicative maximum 500 words)

The principle behind Dissolved Air Flotation is to generate very small bubbles that attach to flocculated particles in the water, making them buoyant enough to rise to the surface of the water and form a foam that can be removed. Such devices are in widespread use within the water industry for the purification of drinking water, and the research described here focuses on improving the efficiency of the process. This research was predicated by the concern within the water industry of the decreasing quality of the water sources (especially from upland areas where the decrease in ‘acid rain’ has led to an increase in the ‘colour’ of the runoff) at the same time as regulations are driving towards increased quality and safety. Additionally, privatisation of the water industry has brought into sharp conflict the rapidly increasing overall demand for potable water and the capital investment requirement to secure new water sources and/or increase the capacity of treatment works. Increasingly, societal concerns over land and the environment introduce further factors.

Research at the University of Cambridge Department of Applied Mathematics and Theoretical Physics (DAMTP) into the fluid mechanics of dissolved air flotation tanks commenced during the mid-1990s with funding from Yorkshire Water plc. Initially, DAMTP staff members Stuart Dalziel (DAMTP researcher from 1989, Assistant Director of Research from 1994, Lecturer from 2000, Senior Lecturer from 2001 and Reader from 2012 to present) and Paul Linden (DAMTP researcher from 1972, Reader from 1991-1998, Professor from 2010-present), along with postdoctoral researcher David Leppinen (DAMTP Research Associate 1997-2004), concentrated on the mean dynamics within flotation tanks induced by the combination of a through flow and the buoyancy introduced through bubble formation. This work identified the key rate-limiting factors governing the flotation process. In a follow-on project in 2002, Dalziel and Leppinen developed methods for in-situ field measurements of the bubbles and flocs involved in the flotation, and found that not only was most of the dissolved air being wasted through the generation of relatively large bubbles, but also that the manner in which it was being introduced was damaging the flocs and reducing the probability of successful floc-bubble interactions. Consequently, they turned their attention to the bubble formation process and used a simple model for bubble growth to analyse the conflicting requirements for energy dissipation and pressure reduction for the introduction of dissolved air into the system. Using theoretical and laboratory modelling, they developed a ‘ventilated shrouded’ nozzle through which water saturated with air at high pressure is injected into the flotation tank. The final phase of work was a field study in conjunction with Yanmin Zhang (Yorkshire Water). This field study (2004) saw prototype nozzles of the new design installed in one of Yorkshire Water’s dissolved air flotation tanks, thus allowing Dalziel and Leppinen to confirm their modelling with in-situ field measurements, and convince Yorkshire Water of the value of these new nozzles.

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

Leppinen, D.M. & Dalziel, S.B. 2001 A light attenuation technique for void fraction measurement of microbubbles; Experiments in Fluids 30, 214-220, DOI: 10.1007/s003480000158

Leppinen, D.M., Dalziel, S.B. & Linden, P.F. 2001 Modelling the global efficiency of dissolved air flotation. Water Science and Technology 43 (8), 159-166, URL: http://www.iwaponline.com/wst/04308/wst043080159.htm.

Leppinen, D.M. & Dalziel, S.B. 2004 Bubble size distribution in dissolved air flotation tanks. Journal of Water Supply Research and Technology – Aqua 53, 531-543, URL: http://www.iwaponline.com/jws/053/jws0530531.htm.

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

The new nozzle design is capable of producing much smaller bubbles of a more uniform size that (a) increased the effectiveness of the air introduced, (b) allowed the air to be introduced at a lower pressure, and (c) substantially reduced the breakup of the flocculated particles in the water supply. The indirect benefits of this include reductions in the energy requirements for the production of dissolved air, a reduction in the concentration of chemical additives required to achieve flocculation, an improvement in the quality of the treated water, and an increase in the throughput of existing dissolved air flotation systems. Additionally, as an indirect consequence of the improved water quality produced by the DAF system, the costs of subsequent filtration and maintenance/cleaning requirements of downstream systems were reduced.

Such was the success of this new nozzle design that Yorkshire Water immediately instigated plans to roll it out across its dissolved air flotation. This roll out has be prioritised on water works that (with their original nozzles) would not meet water quality requirements if operated at designed throughput. As of December 2012, Yorkshire Water have retrofitted the nozzles at six sites, with installation at four further sites operated by their sister company, Kelda Water Services. These nozzles have also been installed at two new treatment works, the more recent commissioned at the end of 2012.

The initial field trials suggested that 20% more raw water could be treated whilst maintaining an improved water quality (Zhang *et al.* 2009). The potential saving in capital investment through avoiding the need to construct new or additional flotation systems is substantial.
Earlier work had shown that reducing the pressure at which water was saturated with dissolved gases led to fewer, larger bubbles, thus requiring very high saturation pressures to be used. The energy cost in achieving this is substantial. However, the new nozzle is able to operate successfully at significantly lower saturation pressures. Yorkshire Water estimates energy savings at pumping sites in the region of 10-15% due to nozzle use (more accurate disaggregation of benefit is difficult since nozzle installation has been part of a refurbishment programme.) (Commercial Optimisation Manager, Yorkshire Water)

Patent protection in the UK and USA has been gained for these nozzles with Dalziel, Leppinen and Zhang listed as inventors and the rights assigned to Yorkshire Water Services. Under this Yorkshire Water have licensed the use of the new nozzles to three further water companies: United Utilities, Anglian Water and Northern Ireland Water.

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

Yorkshire Water Services Limited (incorporated in the United Kingdom)
Inventors: Dalziel, Stuart B; Leppinen, David M; Zhang, Yanmin
Dissolved gas flotation system and nozzle assembly
UKC Headings: B2F B2H Int Cl B05B
1/00(2006.01) B03B 5/28(2006.01)
B03D 1/02(2006.01) B03D
1/14(2006.01) B03D 1/16(2006.01)

US Patent: US 2008/0277329 A1
Jet nozzle arrangements for optimising gas bubble size in flotation
Inventors: Yanmin Zhang (Leeds, GB), Stuart B. Dalziel (Cambridge, G.B), David Leppinen

(Staffordshire, G.B.)

Zhang, Y., Leppinen, D.M. & Dalziel, S.B. 2009 A new nozzle for dissolved air flotation. Water Science and Technology: Water Supply 9 (6), 611-617. doi:10.2166/ws.2009.229

Email from R, D & I Project Manager at Yorkshire Water confirming use of Dissolved Air Floatation Nozzles

Email From Commercial Optimisation Manager at Yorkshire Water confirming energy savings resulting from use of new nozzles