Proceedings of Meetings on Acoustics

Volume 19, 2013 http://acousticalsociety.org/

ICA 2013 Montreal
Montreal, Canada
2 - 7 June 2013

Biomedical Acoustics
Session 2aBA: Bubbles Bubbles Everywhere I

2aBA2. A new approach to ultrasonic cleaning

Timothy G. Leighton*, Peter Birkin and Doug Offin

***Corresponding author's address: Institute of Sound and Vibration Research, University of Southampton, Highfield, Southampton, SO51 6DD, Hants, United Kingdom, tgl@soton.ac.uk**

Traditional ultrasonic cleaning baths are limited in that they cannot clean objects that are too large to fit in the bath, and cannot be taken to objects with complex geometries in order to ' clean in place' . Furthermore the object to be cleaned sits in a ' soup' of contaminated liquid, and whilst cavitation fields can be set up under test conditions, immersion of the object to be cleaned can significantly degrade the bath' s performance by disrupting the sound field. An alternative technique, which does not use ultrasound is the commercial pressure- or power-washer, where high speed jets of water and cleaning agent are pumped onto a surface. Although these can ' clean in place' , they pump large volumes of water, and produce significant volumes of contaminated run-off and contaminated aerosol, both of which are hazards for secondary contamination of users and water supplies. The momentum of the water and pump requirements mean they are difficult to scale up. This paper specifies a low volume flow technique for ultrasonic cleaning in place, benefits being that it operates with low flow rates (1-2 litres per minute), and there is no need to expend energy on heating the water.

Published by the Acoustical Society of America through the American Institute of Physics

Received 10 Jan 2013; published 2 Jun 2013

INTRODUCTION

Society runs on its ability to clean. Ineffective cleaning leads to food poisoning; failure of manufactured products (from precision watches to microchips); and poor construction, since (from shipbuilding to space shuttles) dirty surfaces do not bond. The impact in healthcare is huge. The US Government has been successfully sued by veterans who acquired series infections from routine colonoscopies [1]. With increasing numbers of endoscopy procedures and limited time available to clean instruments between each, such cases are likely to increase worldwide if the technologies do not improve (particularly given the resistance of some microorganisms and prions such as those responsible for CJD).

Hand cleaning is a ubiquitous task but of vital importance in many key areas, including the health sector and food preparation industries. In the NHS, health associated infections cause an estimated 5000 deaths and costs £1 billion [2]. Indeed if the 'Clean Your Hands' campaign were adopted nationally it could save 450 lives and the NHS £140M per year.

Whilst the need for cleaning is inescapable in society, cleaning is very wasteful of water and energy. Even before it meets the contaminated material, usually the water is heated, and mixed with additives to assist the cleaning. This activity alone takes energy, increases the carbon footprint of the process, and makes the water unfit for drinking even before it comes into contact with the substrate, adding a processing burden to its use before it can re-enter the water supply.

The volumes of water used in cleaning are also very great. For example, it takes 100 tonnes of water to produce 1 tonne of clean wool after shearing. This not only constitutes excessive consumption of one of our rarest resources, but also generates large quantities of contaminated run-off. The water from hosing down an abattoir represents a real health risk, and must not be allowed to enter the water supply. Purifying run-off is costly: each cubic meter of water used for cleaning in the nuclear industry costs £10,000 to treat subsequently. Radioactive contamination is also typical for equipment used in the Earth's crust during oil exploration.

POWER WASHERS AND ULTRASONIC CLEANING BATHS

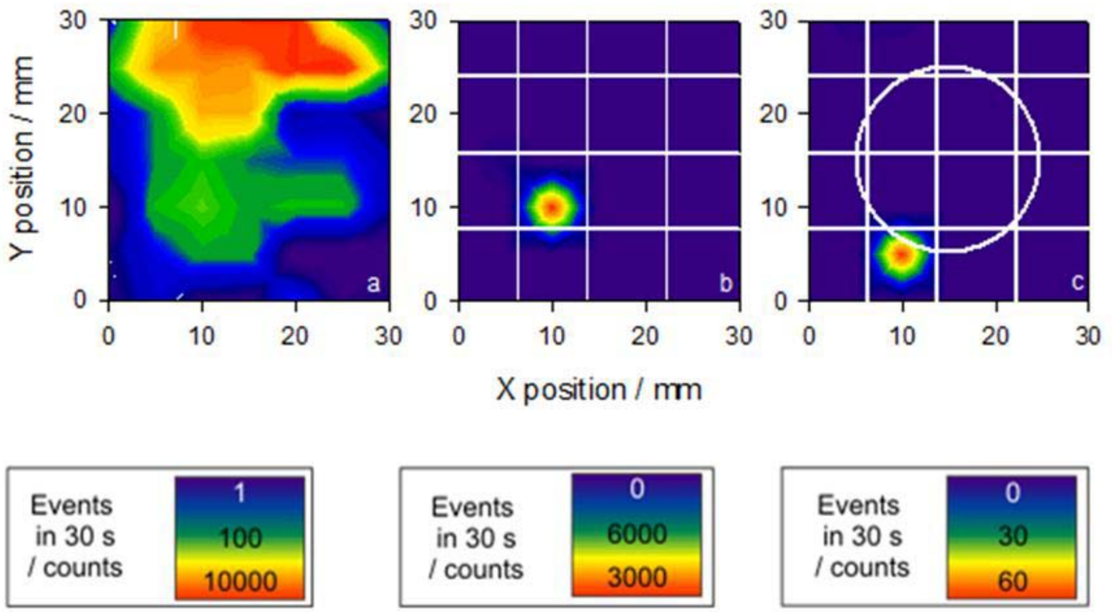
Power washers (also known as pressure washers) do not keep the object to be cleaned immersed in a 'soup' of contaminated liquid, but they do use large volumes of liquid (up to 20 liters per minute for a large pressure washer), and consequently lead to large volumes of contaminated run-off. They are difficult to scale up (in terms of using multiple nozzles or larger nozzles), both because of the pump requirements (in terms of power and water usage), and because they generate considerable back force when used, meaning that the structural support for scaled up versions must become increasingly robust. Power washers can be damaging to delicate surfaces, and they generate aerosols of contaminated liquid (the liquid droplets produced when pressure-washing, say, sewage lines represent a significant hazard & route to spread contamination).

One technology which does not generate large volumes of run-off, is the ultrasonic cleaning bath. Such baths represent an established global product, but have many limitations which prevent further market penetration: the bath is too small for some objects (e.g. they cannot be used for vehicle cleaning); the bath cannot get into complex geometries and clean them (e.g. it cannot be used to hose down inside an engine); the devices to be cleaned sit in a soup of contaminated liquid. This is not the only drawback when considering a procedure such as hand washing: the ultrasonic bath works by generating violent bubble collapse, which may be destructive to tissue such as skin. Moreover, immersion of the object to be cleaned into the bath can degrade the sound field and the cleaning action: In the example shown in figure 1, the cavitation-induced surface effects on the coin immersed in the bath (figure 1(c)) are at best 200 times less than when the cleaning bath has no solid objects immersed in it (figure 1(a)).

Furthermore, the characterization of the cleaning performance of such ultrasonic baths is rudimentary, much of industry favouring a check based on the insertion of domestic aluminium cooking foil into the bath to see whether the cavitation is capable of generating small erosion 'pits' and 'holes' within the foil [3, 4]. This has numerous disadvantages, the main one being that the effect on the foil may be very different from the effect on the object to be cleaned when it is inserted into the bath, because insertion of such an object can disturb the ultrasonic field which causes the cleaning (as was shown in figure 1).

DESIGN SPECIFICATION

The design specification for an improved cleaning system is that it should clean by subjecting the object to be cleaned to a flow of water, such that the contaminant is removed by the flow away from the object. However the flow should be significantly less than that of a power washers, say 2 liters per minute. The device should be based on a nozzle which can fit on the end of a tap or hose and thereby deliver ultrasonically assisted cleaning without the need to pre-heat the water. This should use less power than the equivalent pressure washer (<200 W compared to 2 kW), and be less damaging (since the stream pressure is less than ~1/100th that of a pressure washer), and generate much less runoff and aerosol (thereby reducing the risk of secondary contamination).



(a) (b) (c)

FIGURE 1. Plan view contour maps of the cavitation-induced surface erosion/corrosion activity over the same 30 mm by 30 mm region of a commercial ultrasonic cleaning bath (a) before the mesh is inserted, i.e. in an unperturbed ultrasonic bath; (b) during immersion in the bath of the wire mesh support basket (that is normally used to hold the objects to be cleaned, but here empty of any such objects); and (c) during immersion of the wire mesh support basket when it contains a UK 1 pence coin. Bright areas show regions where there have been high counts of surface erosion/corrosion cavitation (note that the scale shown below each map changes from (a) to (b) to (c)). The erosion/corrosion events are recorded on a 250 μm diameter Al electrode held at 0 V vs. a stainless steel counter/reference electrode using the Multi Channel Analyser collecting over 30 seconds with a threshold of 0.85 μA. The bath contained 2 dm^3 of 0.1 M Na_2SO_4. From Vian [5].

CONCLUSIONS

Whilst most of society's activities depend on effective cleaning, current techniques use too much water, power and additives, and can generate significantly secondary contamination through run-off and aerosols unless mitigating measures (which themselves introduce cost in terms of power and additives) are used. Furthermore both pressure washers and ultrasonic cleaning baths have drawbacks in terms of significant energy and water usage as well as having the potential to cause damage to delicate structures

The ability to clean effectively and quickly, without damaging the surface in question, underpins manufacturing, the health sector, food production, lab work, and the maintenance of infrastructure from a domestic to a national scale. Current techniques are not sufficiently effective (as evidenced by the incidence of hospital acquired infections, food poisoning, failure rate in manufactured products etc.). Furthermore, the large volumes of contaminated water produced by many cleaning operations generate a follow-on hazard to crops, water supplies, etc.

ACKNOWLEDGMENTS

The authors are grateful to the Royal Society Brian Mercer Award for Innovation for funding this study.

REFERENCES

1. Military_news.com. *Vet Wins $1.25M in Hep C Case Against VA Hospital* (Nov 23, 2012) http://www.military.com/daily-news/2012/11/23/vet-wins-125m-in-hep-c-case-against-va-hospital.html (Last viewed 10 Jan. 2013).
2. Design Council. *Clean your hands: poster campaign goes national.* (2011), http://www.designcouncil.org.uk/case-studies/clean-your-hands/ (Last viewed 6 Jan. 2013).
3. T. G. Leighton, P. R. Birkin, M. Hodnett, B. Zeqiri, J. F. Power, G. J. Price,, T. Mason, M. Plattes, N. Dezhkunov and A. J. Coleman, "Characterisation of measures of reference acoustic cavitation (COMORAC): An experimental feasibility trial," in *Bubble and Particle Dynamics in Acoustic Fields: Modern Trends and Applications,* edited by A. A. Doinikov (Research Signpost, Kerala, Research Signpost, 2005), pp. 37-94,
4. B. Zeqiri, M. Hodnett and T. G**.** Leighton *A* strategy for the development and standardisation of measurement methods for high power/cavitating ultrasonic fields-final project report, NPL Report CIRA (EXT) 016 for National Measurement System Policy Unit (Department of Trade and Industry, London, 1997).
5. C. J. B. Vian, *A comparison of measurement techniques for acoustic cavitation* (Ph.D. dissertation, University of Southampton, UK, 2007).