ICLASS-2006
Aug.27-Sept.1, 2006, Kyoto, Japan

Paper ID ICLASS06-015

SPRAY CHARACTERISATION AND PERFORMANCE TESTS FOR AN ULTRASONIC ATOMIZER IN THE DECONTAMINATION PROCESS

M. Burby[1], G.G.Nasr[2], A.J.Yule[3], and T. Hughes [4]

[1, 2,3] Spray Research Group
Institute of Materials Research (IMR)
University of Salford
School of Computing Science and Engineering
Newton building
Manchester M5 4WT
UK

Tel: 01282 697086
Mobile: 07863 165 971
martinburby@fsmail.net

[4] Hughes Safety Showers Ltd
Managing Director
Stockport SK6 2SS
UK

ABSTRACT HSS Ltd has developed a handheld spray gun incorporating an ultrasonic atomizer that can be used for the decontamination of buildings, vehicles and personnel from 'super bugs' such as MRSA. The gun delivers a spray uniformly onto a surface, providing a 'mist like' coverage. Ideally there should be sufficient coverage of the decontaminant agent upon a surface without streaking and over wetting of the surface during or after spray application. The size of the droplets produced by the atomizer is important as it has a direct effect on the coating performance with regard to the delivery of the decontaminant agent and the evaporation times that can be achieved using the atomizer**.**

The HSS Ultrasonic handheld atomizer has been characterised using a Mastersizer-X laser instrument for droplet size at two-water pressures, 0.5 and 1 bar. The flow rates at these conditions were calculated at standard room temperature. An investigation into the coating performance of the atomizer was then carried out on four material samples that would be typically found in a hospital ward (metal, glass, wood and plastic). The surfaces were sprayed for varying spray durations, distances from the atomizer and water supply pressures. During the coating trials the gun was placed at two chosen distances relative to each corresponding surface in order to produce optimum coverage. From these results atomizer settings have been defined for the four materials in order to deliver a good transfer of decontaminant agent upon the surface and to prevent streaking and over wetting of the surface during the decontamination of a room or vehicle using the ultrasonic atomizer.

Keywords: Ultrasonic Atomizer, MRSA, Decontamination, Coating, Atomization.

1. INTRODUCTION

In recent years there has been being growing pressure on hospital trusts to combat MRSA [1], which is bacteria often carried on the skin or in the nose of healthy people and which has increasingly become resistant to antibiotics. Figures have shown that deaths linked to MRSA just in the North West of England have doubled between 2000 and 2004 [2]. It is estimated that one in ten patients acquire the infection during their hospital stay, and with approximately 100,000 hospital-acquired infections per annum, this costs the NHS an estimated £1 billion a year. [3]. One of the primary reasons for the rise in MRSA is ineffective hygiene control and the inability to provide clean hospitals.

In order to combat this growing problem, Hughes Safety Showers Ltd has developed a handheld spray gun with ultrasonic atomizer that can be used for decontamination, particularly for the MRSA 'super bug' found on hospital wards. To deliver the disinfectant the gun must be able to spray uniformly onto the surface, providing 'mist like' coverage and without causing any streaking patterns on the surface during or after spray application.

To determine optimum combinations of spray input conditions, distance(s) and the time(s) in order to uniformally 'mist' spray coat the surface(s) without producing streaking patterns. The gun was placed at two chosen distances relative to each corresponding surface. The material surfaces were chosen that would be commonly found on hospital wards (i.e. metal, plastic, glass and laminated wood).

2. APPARATUS

The atomizer is an ultrasonic Hartmann whistle type for which the air-liquid jet, from a supersonic nozzle, is impacted on a "resonator cup" on wire supports. In principle an ultrasonic vibration is set up to break up the liquid into a fine mist in a wide-angle spray.

As described in the Hughes operating manual [3], the atomizer unit consists of a hand held spray gun, a water/chemical supply cylinder, an air cylinder pressure regulator, a standard breathing air cylinder and a control panel, all mounted on a two wheeled hand trolley, as seen in Fig.1.

Figure: 1

The breathing air cylinder pressure regulator is set at 5 bar.g and feeds air to the atomizer nozzle and to the chemical cylinder via the control panel.

The water/chemical cylinder is filled with decontamination/ disinfection fluid, and then charged with compressed air via the control panel to feed the fluid to the atomizer nozzle

3. DROPLET SIZE TESTS

Droplet sizing for the atomizer was undertaken using a non-intrusive device, the Malvern Mastersizer X Particle sizer. This allows the global characteristics of the spray to be obtained, with regard to the size and range of the droplets produced by the ultrasonic atomizer.

The droplet measurement technique is based on the Fraunhofer diffraction of a parallel beam of monochrome light by a cloud of drops. The schematic of the technique is shown in Fig. 2.

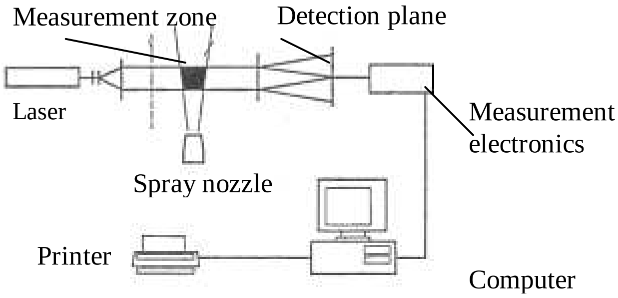

Figure 2: Laser diffraction equipment

The lens focuses the diffraction pattern onto a multi element photodetector consisting of semicircular photo-sensitive rings, each of which is most sensitive to a particular range of drop size. The light energy distribution is measured as a function of angle and the software in the PC converts this into a droplet size distribution. Each measurement consists of an averaged size distribution for all droplets that have passed through the 10mm diameter laser beam. Two spray cases were chosen, as shown in Table 1:

Table 1: Spray cases

Water pressure (bar)	Air pressure (bar)
0.5	3
1.0	3

4. COATING TESTS

The coating tests were performed in a room that could be controlled to simulate the desired temperature and humidity experienced on a normal day. The temperature, pressure and humidity were recoded for each period of testing. The experimental apparatus is shown in Fig. 3.

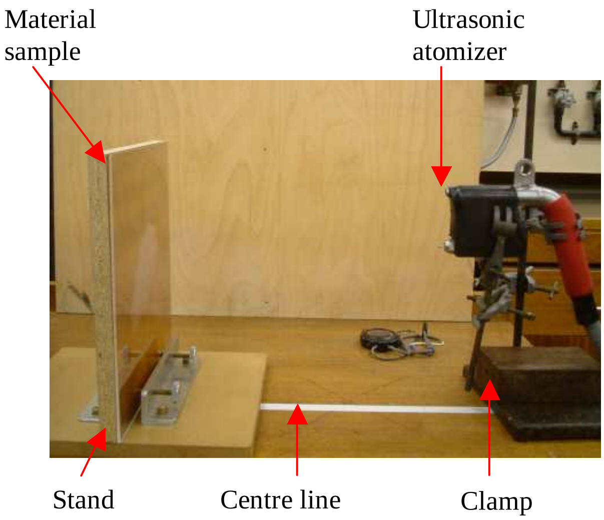

Figure 3: Coating performance apparatus.

The ultrasonic atomizer was held upright with the use of a clamp. A centreline was marked out at distances downstream from the tip of the atomizer. A stand was used to hold the 30cm x 30cm material specimens upright. A stopwatch was used to record the spray duration.

During commercial operation the fluid supplied will be a solution of decontamination agent, Sterichelle and water. The recommended concentration for this solution is 65 parts water to 1 part Sterichelle. At these small concentrations it was sufficient for only water to be used in the testing of the atomizer for droplet size and coating performance.

The flow rates for the atomizer at the two water pressures tested, 0.5 and 1bar and at a constant air pressure of 3bar were calculated by collecting the water from the atomizer at the aforementioned conditions over a period of 1 minute. This was carried out using plastic tubing over the atomizer which collected all of the spray on its interior walls and led the water to a container. The fluid was then weighed and a flow rate obtained, as shown in Table 2.2.

Table 2: Ultrasonic nozzle flow rate.

Water pressure [bar]	Air pressure [bar]	Flow rate [l/min]
0.5	3	0.213
1	3	0.285

5. DATA ACQUISITION

Images of the coatings produced by the atomizer at the various spray coatings were captured with the use of an EOS 350D Cannon digital camera with 1 Gigabytes of memory. A Canon compact macro lens EF 50mm 1:2.5 extension was used with the camera Each image captured was set to a picture definition of 2496 x 1664 pixels and the pictures were taken 140mm from the material surface.

Six images of the coated surfaces were taken for each condition, and the locations of these are shown in Fig 4. For images b-f a view-finder was used, with marking in increments of 5mm.

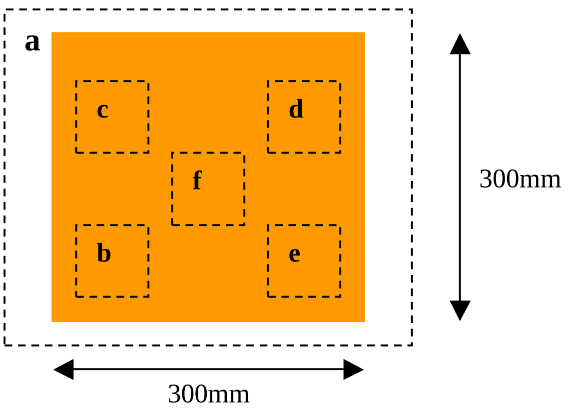

Figure 4: Image identification (NB, “a” represents an image of the complet surface).

The four material surfaces measuring 300x300mm were used in the spray coating tests:

1. wood, varnished hardwood.
2. glass,
3. metal, steel
4. Plastic, Perspex

6. SPRAY DURATION

Three spray durations, 1,2 and 3 seconds were chosen to identify the limits at which streaking would occur on the surface of the four test pieces. A spray duration of less than 1 second was not chosen as to control the spray to this duration would not be practical in an operational sense.

7. SPRAY DISTANCES

Initial tests were undertaken to determine the distances downstream from the nozzle at which the surfaces should be sprayed. The atomizer was set to 1 bar water pressure and 3 bar air pressure. The plastic sample piece was sprayed for 1 and 2 seconds at a number of axial distances downstream of the atomizer.

Initial observations showed that severe streaking took place at a distance of 25cm downstream of the atomizer, as the distance was increased to 65cm this streaking was greatly reduced. The area covered by the majority of the spray was 210x190 mm. The coverage remained the same up until an axial distance of 450 mm downstream, thereafter the majority of the sample size, 300x300 mm was covered by the spray.

The main source of error in the surface coating experiments was the accurate timing of the spray duration, due to a lag in the activation of the spray and the turning off of the spray. To ensure that consistent timings were achieved for all spray cases, a constant methodology was adopted for the timing. The methodology for this was activating the spray at the same time as the stopwatch and turning the spray off when the elapsed time had been reached. It is estimated that the timings are within ± 0.1 seconds for the stated spray duration.

8. DROPLET SIZE RESULTS

The results tabulated in Tables 3 and 4 show the droplet sizes for a number of runs at the two water pressures of 0.5 and 1 bar water pressure. The spray can be characterised by a number of parameters as detailed below;

Table 3: Droplet size at 0.5 bar water pressure.

D_{32} [μm]	D (v,0.5) [μm]	D (v,0.1) [μm]	D (v,0.9) [μm]	Span
11.59	20.62	4.60	44.99	1.96
11.83	21.69	4.61	47.19	1.96
11.15	21.00	4.70	44.07	1.88
11.18	21.14	4.79	45.76	1.94
11.27	22.61	4.87	50.33	2.01

Table 4 Droplet size at 1 bar water pressure.

D_{32} [μm]	D (v,0.5) [μm]	D (v,0.1) [μm]	D (v,0.9) [μm]	Span
13.51	25.57	6.04	50.79	1.75
13.83	26.90	6.13	55.72	1.84
13.54	25.57	5.72	50.84	1.77
11.53	25.47	5.66	54.71	1.93
13.63	28.67	7.27	57.25	1.74
10.76	23.04	5.23	46.44	1.79
15.48	33.46	9.66	60.82	1.53

From the Table 3 it can be seen that the results are consistent for the 0.5 bar water pressure case. The atomizer at this condition produces droplets with a n average Sauter Mean Diameter (SMD, $D_{3,2}$) of 11.4μm, an average volume median diameter of 21.5 μm, with the majority of the spray within a range of 4.6 and 46 μm.

Table 4, showing the droplet sizes for the 1 bar water pressure case, consistently shows the atomizer to produce larger droplets at this increased water pressure. One reason for this could be due to droplets coalescing in the vicinity of the nozzle, as the spray angle decreases as the water pressure increases, despite the added benefit of the increased water injection pressure.

The SMD for the spray at this condition is 13 μm, with a volume median droplet diameter of 25 μm and a range in particle size of between 6 and 54 μm. The last entry shows a droplet SMD of 15 μm, which is higher than for the previous runs. One explanation for this increased size could be due to the location at which the sample was taken. If it had been taken in the location of the support struts, at the end of the nozzle, it could be expected that larger droplets would be created in this region.

The size of the droplets produced by the atomizer is important as it has a direct affect on the coating performance with regard to the delivery of the decontaminant agent and the evaporation times that can result when using the atomizer.

9. SPRAY COVERAGE RESULTS

The environmental test conditions in which the spray coating tets were undertaken are shown in Table 5. These are representative of a standard room on a standard day. As can be seen the conditions were similar for each test day.

Table 5: Environmental test conditions.

Temperature [ºC]	Dew point [ºC]	Humidity [%]	Pressure [mmHg]
16	9.4	31	757.6
18	10.3	33	762.5
18	11	32	763.2

Streaking occurs when a large droplet is deposited upon the surface of a material with sufficient mass to cause the drop under the influence of gravity to overcome the friction coefficient of the material and then move down the wall of the surface. In doing so the drop interacts with other droplets produced by the spray and gains in both mass and momentum, thus creating a streak line, as shown in Fig. 5. It is desired that the number of streaklines be kept to a minimum, to prevent wetting of the floor and over wetting the surface of the material.

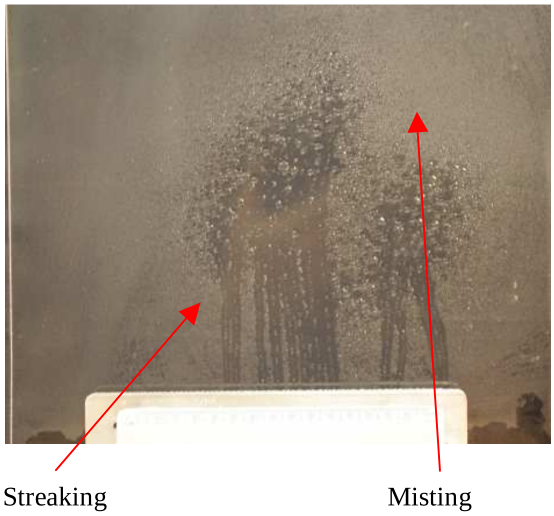

Figure 5: Plastic, 25cm downstream, 1bar/ 2 second.

Over wetting of the surface occurs when a significant amount of large droplets form on the surface but have insufficient mass to start to streak. The desired surface finish would be one with a mist like coating.

10. DISCUSSION

Pressure effects

Altering the water pressure from 0.5 to 1bar causes, the spray angle to decrease, creating a more concentrated spray with reduced spacing between droplets and a greater spray force. The affect of this is to produce a number of large droplets on the surface at a distance of 25cm from the atomizer resulting in severe streaking, as shown to be the case for all the samples tested.

Distance effects

The distance of the atomizer from the surface to be sprayed is a major factor as to whether streaking will occur. At 1bar water pressure and at a distance of 25cm and for all spray durations, all samples tested had streaklines shown on the surface. By increasing the distance to 65cm downstream of the atomizer and maintaining 1bar water pressure all the samples, except glass avoided streaking, provided the spray duration is less than 2 seconds. At 0.5bar water pressure for most cases the spray was diffuse enough to avoid streaking at both 25 and 65 cm downstream of the atomizer and for spray durations of up to 2 seconds.

Spray duration

Altering the duration for which the atomizer is sprayed can control streaking. At a distance of 25cm downstream and 1 bar water pressure it is not possible to alter the spray duration to practical operational levels to prevent streaking on the surface of the material.

At 0.5bar and at a distance of 25cm, plastic and metal can be coated with a 2 second spray duration. At 65cm downstream plastic and metal surfaces can be sprayed for up to 1 second without streaking at 1bar water pressure. For metal and plastic at 0.5bar and 65cm, the spray duration can be increased to 3 seconds before streaking occurs.

Material effects

The spray duration and distance from the surface of the sample has to be varied in accordance to the material that is being coated in order to prevent streaking. One of the reasons for this is due to the friction coefficient (surface roughness) of the material. Materials with low friction coefficients, for example glass are more prone to streaking as there is not sufficient friction to prevent the droplet from moving down the surface and interacting with other droplets, thus causing streaking. In addition the "friction" that acts against streaking is influenced by the surface tension of the liquid for the surface being sprayed. This surface tension can be greatly influenced by the cleanliness of the surface and factors as polish on the surface (all of these tests were conducted with carefully cleaned surfaces). The result of this is that the atomizer has to be operated within a tighter performance band with regard to water pressure and duration of spray for materials with low skin friction coefficients.

11. CONCLUSIONS

The main findings of the work are:

1. At 0.5 bar water supply pressure the atomizer produces droplet sizes of 11.4µm SMD.
2. At 0.5 bar water supply pressure the atomizer produces droplet sizes of 13 µm SMD.
3. The flow rate at 3 bar air pressure, 0.5 bar water pressure is 0.213 l/min.
4. The flow rate at 3 bar air pressure, 1 bar water pressure is 0.285 l/min.
5. At a distance of 25cm downstream from the atomizer and 1 bar water pressure, and for all surfaces, severe streaking occurs. By decreasing the flow rate to 0.5 bar and reducing the spray duration to 1 second, for materials with high surface coefficients, for example metal, streaking can be prevented.
6. At a distance of 65cm from the atomizer, metal, wood and plastic can be coated without streaking with a 2 second spray duration providing the water pressure is reduced to 0.5bar.
7. Decreasing the water pressure creates a wider spray and reduces the impact force of the spray.
8. At the lower pressure the droplets on the surface of the material are not as densely packed.

12. FURTHER WORK

Streaking as illustrated in the tests is a function of spray duration, distance, water supply pressure and material properties. There are however other factors that could be investigated that would also affect streaking, that being room temperature, material surface temperature and humidity. Furthermore if the disinfectant additive changes the surface tension of the liquid, this could affect drop size, streaking and ideal coating conditions.

A study into droplet evaporation times for different droplet sizes and ambient temperatures could be undertaken to show drying times for a range of surfaces and environmental conditions, for example in warm, dry environments for which significant evaporation of the spray might occur prior to surface deposition. Under these conditions reduction of atomising air pressure might be beneficial, in order to increase drop size and thus reduce evaporation rate.

13. REFERENCES

1. Manchester Metro News, March 17th 2006.
2. Smith, B., Britain: rise in "superbug" cases linked to decrease in hospital cleaning staff, www.wsws.org, 22nd Jan 2005
3. Manchester Metro News, March 10th 2006.
4. Hughes Safety Showers Ltd, Ultrasonic handheld atomizer operating manual.