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Invention title	THE SPINNING PINS NOZZLE ; A NEW CONTROLLED DROPLET APPLICATOR FOR AIRCRAFT

The following statement is a full description of this invention, including the best method of performing it known to me

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THE “SPINNING PINS” NOZZLE

A NEW CONTROLLED DROPLET APPLICATOR FOR AIRCRAFT

This information relates to improvements in devices for delivery of spray droplets from aircraft or ground vehicle.

The application of pesticide using aircraft remains a vital part of modern agricultural systems, but the problem of associated off-target transport or spray drift is receiving increasing attention. Research carried out by Craig et al 1998a has demonstrated that spray drift depends upon the size of droplets in the spray and also the width of the droplet size distribution or spectrum. Buffer distances of several hundred metres are often required to reduce aircraft spray drift deposition to acceptable levels. Such large distances are inconvenient and uneconomical in most cropping situations.

The present approach is to significantly reduce spray drift by developing a new nozzle which utilises large droplet Controlled Droplet Application (CDA) technology. This would produce a spray with a narrow droplet size distribution and reduce the number of driftable fines, and also the number of excessively coarse droplets which constitute waste.

The aim with the present invention is to produce near monosized droplets, with a Volume Median Diameter or D[v.0.5] of approximately 250µm (micron or 1/1000th of a mm), and with a relative SPAN or {D[v,0.9] – D[v,0.1]} / D[v,0.5] of 0.5 or less. At present, existing hydraulic nozzles generally produce sprays with a relative SPAN substantially greater than 1.0. The research work of Craig 1991 and Craig et al 1998b has demonstrated that a spray with a relative SPAN of 0.5 would significantly reduce spray drift whilst minimising waste and maintaining high efficacy of the spray droplets.

Controlled Droplet Applicators consisting of a spinning disc with sharp teeth are capable of producing a spray with a relative width SPAN of about 0.75 to 1.0. This results in intermediate rather than significantly reduced spray drift levels. The droplets are formed via the breakup of fluid ligaments generated from each tooth. Fluid ligaments are formed when the flowrate per tooth is greater than about 0.2 ml/min.

The present design features very large number of issuing points which will lead to flowrates per per issuing point of less than 0.1 ml/min. This will enable fluid atomisation by means of Direct Droplet formation, necessary for the relative SPAN to be 0.5 or less. The “monosized” droplets will form directly at the tip (2) of the pins (1).

The present design allows for a very large number of fluid emission points (3600 per cm length of the rotating element (3). Assuming, the length of the rotating element is 13.88cm, the total number of teeth will be 50000. With a total atomiser flowrate of 5 L/min, the flowrate per tooth will be approximately 0.1 ml/min per tooth.

The present invention will result in a substantial reduction in spray drift buffer distances required (Craig et al 1998), particularly useful for the aerial application of herbicides in forestry, for example.

To assist with understanding the invention, reference will now be made to the accompanying drawings which show one example. All given dimensions are approximate and may be varied.

The most novel feature of the invention are the pins (1) which have sharp fluid issuing points or tips (2). Spray fluid, after being distributed evenly via the various other components of the nozzle (3-16) is directed under the influence of centrifugal force along the length of the pins. After progressing to the tip (2) of each pin (1), the fluid detaches into the air forming droplets of near uniform size. The uniformity of the drops produced was shown by Craig 1991 to be dependent upon the flowrate of the fluid per tooth and also the sharpness of the tooth.

The present design has a total pin (1) length of 10mm and a diameter at the base of each pin of 0.5mm. The pin is retained in the 5mm thick outer sleeve of the rotating element (3) using the first 5mm of its length. For the remaining 5mm progressing outwards to the tip (2), the pin is tapered with an angle (tooth sharpness) of 6°. Additionally, to reduce flowrate per tooth to a minimum, the number of teeth has been maximised as follows :-

The pins (2) are set radially at 2° intervals in rows containing 180 pins each.
In the first, third, fifth rows etc, the pins are set at 2°, 4°, 6° ….360° etc radial positions.
In the second, fourth, sixth rows etc , the pins are set at 1°, 3°, 5° ….259° etc radial positions.
Assuming a diameter to the base of the tips (2) of 57.3mm, the radial spacing between the tooth centres here is 1mm. Each row of 180 pins is spaced at 0.5mm intervals along the length of the rotating element (3). This arrangement will enable a very large number of fluid emission points (2 per mm², or 3600 per cm length of the atomising element).

The teeth are fed by adjacent feed holes (4) of 0.5mm diameter. The fluid exiting from a feed hole will supply the tip immediately behind it, relative to the direction of rotation.

The rotating element (3) containing the pins (1) has a central cylinder with raised internal lips (5) and (3) and (5) revolve with respect to a central stainless steel shaft with raised lips (6). This constitutes essentially a plain bearing which will be of low friction and resistant to corrosion – a problem particularly with pesticide formulations and bearings of the ballrace type.

The stainless steel shaft (6), together with the rotating element (3 and 5) mounted upon it, are attached via a suitable screw thread (7) to the central (non rotating) nozzle body (8). The rotating element (3 and 5) is retained on the shaft (6) by means of the plain bearing, and also a ball bearing (9) between the rotating element front plate (10) and the fluid supply tube (11). The supply tube contains a filter (13) and extends to the central nozzle body (8).

The inside of the rotating element is fed with fluid from 6 rows of 12 nozzles (12) each situated on the central nozzle body (8) giving 72 nozzles in total, although this may vary. The nozzles are of the flat fan type in order to achieve an even distribution of fluid to the inside of the rotating element outer wall (3). The flat fan angle (~110°) is generated by a “V” (~20° included angle) notch (14) milled across each hole with an orientation parallel to the axis of rotation.

Attached to the rotating element front plate (10) is a slotted drive wheel (15) containing 12 air slots (16) arranged radially at 30° intervals. The sides of the airslots are machined to a face which is at 30° to the uninterrupted airflow.

SPINNING PIN NOZZLE COMPONENTS

1) pin
2) tip of pin
3) outer wall of rotating element containing pins
4) feed hole
5) central cylinder of rotating element with raised internal lips
6) steel shaft with raised lips
7) shaft screw thread
8) central (non rotating) nozzle body
9) main bearing
10) front plate of rotating element
11) supply tube
12) flat fan nozzles
13) fine mesh filter
14) V notch forming flat fan nozzle
15) slotted drive wheel
16) angled air slots

NON ROTATING NOZZLE POSITIONS

Non rotating nozzle positions (degrees from datum) are as follows :-

Radial positon	1	2	3	4	5	6	7	8	9	10	11	12
Row 1	0	30	60	90	120	150	180	210	240	270	300	330
Row 3	5	35	65	95	125	155	185	215	245	275	305	335
Row 5	10	40	70	100	130	160	190	220	250	280	310	340
Row 2	15	45	75	105	135	165	195	225	255	285	315	345
Row 4	20	50	80	110	140	170	200	230	260	290	320	350
Row 6	25	55	85	115	145	175	205	235	265	295	325	355

TABLE DESCRIBING HOW THIS INVENTION IS DIFFERENT FROM PRIOR ART

Patent	**Number**	**Novel feature**	**Mechanism**
Bals (1979)	GB2026904A	sideways advancing (<) groove ending in pyramidal tooth	droplet formation via medium flowrate ligament breakup
Spillman (1989)	GB233918A	sideways advancing (∠) groove with vertical wall, or tube§, ending in pyramidal tooth	droplet formation via high flowrate ligament breakup
Spillman (2000)	AU200048892	forward advancing (V) groove ending in pyramidal tooth	droplet formation via very high flowrate ligament breakup
Spillman (2001)	AU200160474	forward advancing (V) groove ending in pyramidal tooth	droplet formation via very high flowrate ligament breakup
Craig (2001)	*AU2001 63597/01*	*conical tooth (pin) ending in very sharp point, no groove*	*extremely uniform droplet formation via low flowrate direct droplet formation Ψ*

Notes

direction of advancement of groove is vertically up the page with respect to orientation of symbol used

§ as a matter of interest, both sideways advancing groove with vertical wall and tube invented and designed by myself as part of my PhD studies 1987-1990

Ψ supporting reference is Walton and Prewitt (1949)

KEY STATEMENT

The pins used in this invention (63597/01) are intended for the production of large (250µm) monosized droplets which are generated using the direct droplet mode of atomisation. This atomisational mode is made possible by evenly feeding sharp pins rotating at low speeds (~ 2000 RPM) with a low flowrate of fluid. The spinning pins are intrinsically different to the teeth/groove arrangements of existing spinning disc/dish/drum designs (GB2026904A, GB233918A, AU200048892, AU200160474) because droplet formation is now possible via a fundamentally different mechanism, namely direct droplet formation rather than ligament formation. Droplets generated via the ligament mode generally have a bimodal (wide) droplet size distribution with a relative span of 0.75 or greater, whereas, droplets generated via direct droplet production are extremely uniform in size with a relative span less 0.5 or less. The purpose of having such a narrow droplet size distribution is to enable drift free spraying of liquid pesticides.

It is useful to describe the term “droplet size” according to the following table :

Droplets	**Size range**	**Atomisational mode**	**Movement process**	**Applications**
Small	less than 100µm	ligament formation	move with the air (droplets have a high drag to weight ratio)	Ultra Low Volume (ULV) spraying of agricultural pesticides, combustion processes
Medium	100-250µm	ligament formation	mixture of moving and falling through the air	Most agricultural spraying purposes
Large	greater than 250µm	direct droplet formation	fall through the air (droplets have a low drag to weight ratio)	Large Droplet Placement (LDP) spraying for drift free application of agricultural pesticides

Table 1 Simple classification of droplet size according to generation, behaviour and purpose

Invention 63597/01 is novel and unique because a very large number of pins are used to generate large 250µm droplets using direct droplet mode (low RPM and flowrate) which will be drift free for the purposes of agricultural spraying of pesticides.

CLAIMS

The claims defining the invention are as follows :

1. The production of large (250µm diameter) liquid droplets for drift free application of agricultural pesticide sprays, by means of direct droplet formation from a multiplicity of rotating sharp pins, which under conditions of low rotational speed and low flowrate produce droplets of extremely uniform size, defined here as having a relative span of less than 0.5.
2. The spinning pins of claim (1), due to their narrow diameter (ie. approximately 300µm), are able to be spaced at approximately 0.5mm centres which generates a very large number of emitting points per square cm of atomiser surface (ie. 400 points per square centimetre). The emitting points are therefore large in number which enables a very low fluid flowrate per pin and droplets to be formed directly under the action of centrifugal force.
3. The spinning pins of claim (1) are cylindrical for the first half of their length, and then reduce in diameter (say 6° angle cone) towards the tip, ending with a radius of curvature at the very tip of say 10µm (or several orders of magnitude less than this if carbon/tungsten electrochemical etching manufacturing techniques are used).
4. The spinning pins of claim (1) are fed evenly with fluid emitted from adjacent feed holes which are in turn fed by fluid emitted from a series of flat fan nozzles machined into the central core of the nozzle.
5. The spinning pins of claim (1) produce spray droplets which are protected from airstream disruption by means of a slotted drive wheel (aircraft only).
6. The spinning pins of claim (1) are able to rotate freely by means of a low friction plain bearing which will be resistant to corrosion and stiffening due to ingress of dirt and pesticide formulations.
7. The spinning pins of claim (1) are substantially as herein described with reference to the accompanying drawings.

ABSTRACT

The Spinning Pins nozzle generates a spray with a 250µm monosized droplet size distribution, useful for applying pesticides with low drift and high efficacy. The design features a large number of rotating sharp pins which act as issuing points for the spray fluid emitted under the action of centrifugal force. The flowrate at each pin is sufficiently low enough for droplets to be formed directly. The design also features an upstream plate with angled slots which causes rotation of the pins and protects the fluid emitting from them. The design also features a plain bearing which will resist stiffening and corrosion due to ingress of pesticide formulations associated with other types of bearing.

RELEVANT PUBLICATIONS

Craig I.P. 1999 Address entitled “Spray Drift Research” presented to the *Aerial Agricultural Association of Australia at the AAAA Queensland Annual Conference, Twin Waters Resort, Maroochydore (unpublished)*

Craig I.P., Woods N, Dorr, G., 1998a Craig I.P., 1998. A simple guide to predicting aircraft spray drift. *Crop Protection* 17 (6) 475-482.

Craig I.P., Woods N, Dorr, G., 1998b Aircraft spraydrift and the requirement for improved atomiser design. *pp 65-69, ILASS Americas 11th Annual Conference on Liquid Atomisation and Spray Systems, Sacramento, CA, May 1998*

Craig I.P., Parkin C.S. 1992. Herbicide application using a fluid driven rotary atomiser, *Tropical Pest Management 38 (2) 164-166*

Parkin C.S., Kinnersley R.P., Craig I.P., Spillman J.J. 1991. The design of atomisers operating in the ligament mode of drop formation. *Proc. Sprays and Aerosols, University of Surrey, 188-193*

Parkin C.S., Craig I.P., Spillman J.J. 1991. A fluid driven rotary atomiser for controlled droplet application of herbicides by knapsack sprayers. *Agricultural Engineer 126-127 (Winter issue)*

Craig I.P., 1991 Fluid driven rotary atomiser for the controlled droplet application of herbicides. *PhD thesis (unpublished) - Department of Agricultural and Environmental Engineering, Silsoe College, Cranfield University, Beds, UK*

Walton, W.H. and Prewitt, W.C (1949) The production of sprays and mists of uniform size by means of spinning disc sprayers. Proc. of the Physical Society Sec B Vol 62 Part 6 pp 341-350