## Description

This invention relates to spray type ultrasonic washing apparatus, and more particularly to such apparatus using deaerated washing liquid and provided with means for keeping such liquid in good deaerated condition while being sprayed towards a surface to be washed.

Ultrasonic washing apparatus is widely used for washing work surfaces, deflashing work surfaces, and the like. See, for example, US 4834124, which describes an ultrasonic washing apparatus having a washing liquid outlet nozzle shaped to improve washing efficiency. It is also known from DE 3916446 to use a jet of heavily aerated water for washing surfaces.

Cavitation has hitherto been supposed to be most easily formed in an ultrasonically treated liquid which is abundant in air bubbles. Experiments we have performed have however revealed that, on the contrary, cavitation can be more easily formed in a deaerated liquid. This is because air bubbles in a nondeaerated liquid absorb the energy of cavitation, thereby suppressing the formation of cavitation. In contrast, when ultrasonic radiation is applied to a deaerated liquid, a drastic pressure decrease will be caused under certain conditions, and when the pressure of the deaerated liquid is reduced below saturated vapour pressure, the liquid will be evaporated to form air bubbles, which will rapidly expand to form cavities. Then the cavities will be compressed to cause very high pressure, thereby expediting the formation of cavitation.

For this reason use is made of deaerated liquid in ultrasonic washing, and deaerated liquid in which cavitation has been formed is sprayed against a surface to be washed.

This ultrasonic washing has the effect of reducing the time involved in washing surfaces because, as explained above, the use of deaerated liquid permits effective formation of cavitation. Use of deaerated liquid in the form of a spray, however, tends to permit invasion of air into the deaerated liquid while it is being sprayed towards the surface to be washed. As a consequence the liquid does not remain deaerated, and the washing effect decreases with the resulting decrease of cavitation.

According to the present invention there is provided spray type ultrasonic washing apparatus in which ultrasonic radiation is applied to washing liquid to be sprayed on a surface to be washed, so as to cause cavitation in the washing liquid, the apparatus comprising a washing liquid nozzle assembly comprising an inner nozzle defining a passage for deaerated washing liquid, and an outer nozzle surrounding said inner nozzle to define an annular passage for nondeaerated washing liquid, so that nondeaerated washing liquid envelopes the deaerated washing liquid expelled from the nozzle in use, and a vibratory element for applying ultrasonic radiation to the deaerated washing liquid.

With such an arrangement the deaerated washing liquid ejected from the inner nozzle will be enclosed by nondeaerated liquid ejected from the annular space between the outer and inner nozzles.

An embodiment of the invention will now be described by way of example and with reference to the accompanying drawings, in which:-

Fig. 1 is a longitudinal axial cross-section of a spray type ultrasonic washing apparatus according to the invention; and

Fig. 2 is a cross-section taken along the line X-X' in Fig. 1.

As shown in Fig. 1, a spray type ultrasonic washing apparatus comprises a nozzle assembly 1 and a vibrating element 9.

The nozzle assembly 1 comprises an outer nozzle 2 and an inner nozzle 3, each in the form of a conical frustum. The inner nozzle 3 defines a passage 8 through which deaerated liquid is made to flow before being sprayed. An annular passage 7, through which nondeaerated liquid is made to flow, is formed between the outer and inner nozzles 2 and 3. The nozzle assembly 1 is tapered towards the nozzle tip 4.

The outer nozzle 2 is provided with an inlet 5 for nondeaerated liquid, whilst the inner nozzle 3 is provided with an inlet 6 for deaerated liquid. A vibrating element 9 for producing ultrasonic radiation has a vibrating piece 10 integrally connected thereto. The vibrating piece 10 is attached to the rear end of the nozzle assembly 1.

A vessel 16 contains washing liquid in nondeaerated form. The vessel 16 is connected to the inlet 5 of the nozzle assembly 1 via a pump 15a. Also, the vessel 16 is connected to the inlet 6 of the nozzle assembly 1 via deaerating means 17 and a pump 15b. Thus, nondeaerated washing liquid 12 is supplied to the inlet 5 of the nozzle assembly 1, and deaerated washing liquid 11 is supplied to the inlet 6. The deaerating means 17 may be constructed that the liquid may be boiled and deaerated.

Thus nondeaerated washing liquid 12 is made to flow to the nozzle tip 4 through the passage 7, whilst deaerated washing liquid 11 is made to flow to the nozzle tip 4 through the passage 8. As a result, and as shown in Fig. 2, the deaerated washing liquid 11 is encircled by nondeaerated washing liquid 12, and the deaerated and nondeaerated washing liquids are sprayed onto a surface 13 to be washed.

The temperature $T_A$ of the nondeaerated washing liquid is set to be substantially higher than the temperature $T_B$ of the deaerated washing liquid, by heating the nondeaerated liquid and cooling the

deaerated liquid. Also, the flow rate $V_A$ of the nondeaerated washing liquid is set to be substantially higher than the flow rate $V_B$ of the deaerated washing liquid.

At the time of spraying, the vibrating element 9 is connected to a power supply 18, thereby putting its vibrating piece 10 into operation. Thus, ultrasound is radiated through the deaerated washing liquid 11 in the inner passage 8 of the nozzle assembly 1. Cavitation is formed, and the surface 13 is washed efficiently.

After washing the surface 13, the washing liquid is collected in a vessel 14, which is placed below the surface to be washed. In the vessel 14, deaerated washing liquid and aerated washing liquid are mixed together, and also air becomes mixed therewith. Thus, nondeaerated washing liquid results, which is then returned to the vessel 16 via a pump 15c.

As described above, a spray type ultrasonic washing apparatus according to the present invention uses a coaxial nozzle structure 1 which is composed of inner and outer hollow conical frustums 3 and 2. These frustums are arranged to have nondeaerated washing liquid supplied to the annular passage formed between the outer and inner frustums, and deaerated washing liquid supplied to the inner hollow frustum, thus causing the deaerated washing liquid to be enclosed by nondeaerated washing liquid in being sprayed against a surface to be washed, and thereby isolating the deaerated washing liquid from the surrounding atmosphere to prevent invasion of air into the deaerated washing liquid on its way to the surface. Thus, cavitation can be formed effectively in the deaerated washing liquid, and washing can be performed with increased efficiency.

As mentioned above, the temperature of the nondeaerated washing liquid is set to be higher than that of the deaerated washing liquid. This temperature difference provides a further barrier against invasion of air from the surrounding nondeaerated washing liquid into the deaerated washing liquid, even if air enters the enclosing nondeaerated washing liquid from the surrounding atmosphere. This further enhances the effective formation of cavitation in the deaerated washing liquid by preventing invasion of air into the same.

Furthermore, the flow rate of the deaerated washing liquid 11 is set to be substantially lower than that of nondeaerated washing liquid 12. This is advantageous to the operation of spraying the deaerated and nondeaerated washing liquid in combination.

## Claims

1. Spray type ultrasonic washing apparatus in which ultrasonic radiation is applied to washing liquid to be sprayed on a surface to be washed, so as to cause cavitation in the washing liquid, the apparatus comprising a washing liquid nozzle assembly (1) comprising an inner nozzle (3) defining a passage (8) for deaerated washing liquid (11), and an outer nozzle (2) surrounding said inner nozzle to define an annular passage (7) for nondeaerated washing liquid (12), so that nondeaerated washing liquid envelopes the deaerated washing liquid expelled from the nozzle in use, and a vibratory element (9) for applying ultrasonic radiation to the deaerated washing liquid.

2. Apparatus as claimed in claim 1, further comprising means for cooling said deaerated washing liquid (11), and means for heating said nondeaerated washing liquid (12), so as to cause said deaerated washing liquid to be at a temperature substantially lower than that of said nondeaerated washing liquid.

3. Apparatus according to claim 1 or 2, further comprising means for causing the flow rate of said deaerated washing liquid (11) in said passage (8) to be substantially lower than that of said nondeaerated washing liquid (12) flowing in said passage (7).

## Patentansprüche

1. Ultraschall-Sprühreinigungsvorrichtung, bei der eine Reinigungsflüssigkeit, die auf eine zu reinigende Fläche zu sprühen ist, Ultraschallstrahlung ausgesetzt wird, um in der Reinigungsflüssigkeit Kavitation zu bewirken, die Vorrichtung umfassend eine Reinigungsflüssigkeits-Düsenbaugruppe (1) mit einer inneren, einen Kanal (8) für entgaste Reinigungsflüssigkeit (11) begrenzenden Düse (3) und einer äußeren, die innere Düse zur Begrenzung eines Ringkanals (7) für nicht entgaste Reinigungsflüssigkeit (12) umschließenden Düse (2), so daß im Gebrauch nicht entgaste Reinigungsflüssigkeit die von der Düse ausgestoßene entgaste Reinigungsflüssigkeit umgibt, sowie ein Vibrationselement (9), um die entgaste Reinigungsflüssigkeit Ultraschallstrahlung auszusetzen.

2. Vorrichtung nach Anspruch 1, ferner umfassend Mittel zum Kühlen der entgasten Reinigungsflüssigkeit (11) sowie Mittel zum Erwärmen der nicht entgasten Reinigungsflüssigkeit

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deaerated liquid. Also, the flow rate $V_A$ of the nondeaerated washing liquid is set to be substantially higher than the flow rate $V_B$ of the deaerated washing liquid.

At the time of spraying, the vibrating element 9 is connected to a power supply 18, thereby putting its vibrating piece 10 into operation. Thus, ultrasound is radiated through the deaerated washing liquid 11 in the inner passage 8 of the nozzle assembly 1. Cavitation is formed, and the surface 13 is washed efficiently.

After washing the surface 13, the washing liquid is collected in a vessel 14, which is placed below the surface to be washed. In the vessel 14, deaerated washing liquid and aerated washing liquid are mixed together, and also air becomes mixed therewith. Thus, nondeaerated washing liquid results, which is then returned to the vessel 16 via a pump 15c.

As described above, a spray type ultrasonic washing apparatus according to the present invention uses a coaxial nozzle structure 1 which is composed of inner and outer hollow conical frustums 3 and 2. These frustums are arranged to have nondeaerated washing liquid supplied to the annular passage formed between the outer and inner frustums, and deaerated washing liquid supplied to the inner hollow frustum, thus causing the deaerated washing liquid to be enclosed by nondeaerated washing liquid in being sprayed against a surface to be washed, and thereby isolating the deaerated washing liquid from the surrounding atmosphere to prevent invasion of air into the deaerated washing liquid on its way to the surface. Thus, cavitation can be formed effectively in the deaerated washing liquid, and washing can be performed with increased efficiency.

As mentioned above, the temperature of the nondeaerated washing liquid is set to be higher than that of the deaerated washing liquid. This temperature difference provides a further barrier against invasion of air from the surrounding nondeaerated washing liquid into the deaerated washing liquid, even if air enters the enclosing nondeaerated washing liquid from the surrounding atmosphere. This further enhances the effective formation of cavitation in the deaerated washing liquid by preventing invasion of air into the same.

Furthermore, the flow rate of the deaerated washing liquid 11 is set to be substantially lower than that of nondeaerated washing liquid 12. This is advantageous to the operation of spraying the deaerated and nondeaerated washing liquid in combination.

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1. Spray type ultrasonic washing apparatus in which ultrasonic radiation is applied to washing liquid to be sprayed on a surface to be washed, so as to cause cavitation in the washing liquid, the apparatus comprising a washing liquid nozzle assembly (1) comprising an inner nozzle (3) defining a passage (8) for deaerated washing liquid (11), and an outer nozzle (2) surrounding said inner nozzle to define an annular passage (7) for nondeaerated washing liquid (12), so that nondeaerated washing liquid envelopes the deaerated washing liquid expelled from the nozzle in use, and a vibratory element (9) for applying ultrasonic radiation to the deaerated washing liquid.

2. Apparatus as claimed in claim 1, further comprising means for cooling said deaerated washing liquid (11), and means for heating said nondeaerated washing liquid (12), so as to cause said deaerated washing liquid to be at a temperature substantially lower than that of said nondeaerated washing liquid.

3. Apparatus according to claim 1 or 2, further comprising means for causing the flow rate of said deaerated washing liquid (11) in said passage (8) to be substantially lower than that of said nondeaerated washing liquid (12) flowing in said passage (7).

## Patentansprüche

1. Ultraschall-Sprühreinigungsvorrichtung, bei der eine Reinigungsflüssigkeit, die auf eine zu reinigende Fläche zu sprühen ist, Ultraschallstrahlung ausgesetzt wird, um in der Reinigungsflüssigkeit Kavitation zu bewirken, die Vorrichtung umfassend eine Reinigungsflüssigkeits-Düsenbaugruppe (1) mit einer inneren, einen Kanal (8) für entgaste Reinigungsflüssigkeit (11) begrenzenden Düse (3) und einer äußeren, die innere Düse zur Begrenzung eines Ringkanals (7) für nicht entgaste Reinigungsflüssigkeit (12) umschließenden Düse (2), so daß im Gebrauch nicht entgaste Reinigungsflüssigkeit die von der Düse ausgestoßene entgaste Reinigungsflüssigkeit umgibt, sowie ein Vibrationselement (9), um die entgaste Reinigungsflüssigkeit Ultraschallstrahlung auszusetzen.

2. Vorrichtung nach Anspruch 1, ferner umfassend Mittel zum Kühlen der entgasten Reinigungsflüssigkeit (11) sowie Mittel zum Erwärmen der nicht entgasten Reinigungsflüssigkeit

(12), um zu bewirken, daß sich die entgaste Reinigungsflüssigkeit auf einer Temperatur befindet, die wesentlich niedriger als diejenige der nicht entgasten Reinigungsflüssigkeit ist.

3. Vorrichtung nach Anspruch 1 oder 2, ferner umfassend Mittel, um zu bewirken, daß die Strömungsrate der entgasten Reinigungsflüssigkeit (11) in dem Kanal (8) wesentlich geringer als diejenige der in dem Kanal (7) strömenden nicht entgasten Reinigungsflüssigkeit (12) ist.

**Revendications**

1. Dispositif de nettoyage ultrasonique du type pulvérisateur dans lequel une radiation ultrasonique est appliquée au liquide de nettoyage à pulvériser sur une surface à laver, de sorte de provoquer une cavitation dans le liquide de nettoyage, le dispositif comprenant un assemblage de buses de liquide de nettoyage (1) comprenant une buse intérieure (3) définissant un passage (8) destiné au liquide de nettoyage dégazé (11), et une buse extérieure (2) entourant ladite buse intérieure pour définir un passage annulaire (7) destiné au liquide de nettoyage non dégazé (12), de sorte que le liquide de nettoyage non dégazé enveloppe le liquide de nettoyage dégazé expulsé de la buse en service, et un élément vibratoire (9) pour appliquer l'émission ultrasonique au liquide de nettoyage dégazé.

2. Dispositif selon la revendication 1, caractérisé en ce qu'il comprend en outre des moyens pour refroidir ledit liquide de nettoyage dégazé (11), et des moyens pour chauffer ledit liquide de nettoyage non dégazé (12), de sorte d'amener ledit liquide de nettoyage dégazé à une température sensiblement inférieure à celle du liquide de nettoyage non dégazé.

3. Dispositif selon la revendication 1 ou 2, caractérisé en outre en ce qu'il comprend des moyens pour amener la vitesse d'écoulement dudit liquide de nettoyage dégazé (11) dans ledit passage (8) à être sensiblement inférieure à celle dudit liquide de nettoyage non dégazé (12) circulant dans ledit passage (7).