

DESCRIPTION

TITLE: WASHING MACHINE

5 TECHNICAL FIELD

[0001]

The embodiments of the present invention relate to a washing machine.

10 BACKGROUND

[0002]

It has been conventionally conceived to provide various types of functional films on a water tub of a washing machine. For example, patent document 1 discloses a technology of providing a thermally insulative coating film along an inner surface of a water tub in attempt to reduce power consumption during a dry operation. Patent document 1 further discloses that power consumption can be reduced even more effectively by spreading and vaporizing film of water attached to the surface of the water-repellant thermally insulative coating film containing hollow hydrophilic beads.

[0003]

Coatings providing antifouling features through hydrophilic properties have been developed in recent years. It is possible to keep the inner surface of the water tub clean by antifouling features when such coatings are applied over the inner surface of a washing machine water tub. The inner surface of the water tub, however, is subjected to contact with water

stored in the water tub during the wash and rinse operations as well as with water thrown off from the rotary tub disposed inside the water tub during the dehydrate operation. It is thus, possible to keep the inner surface of the water tub relatively clean
5 without applying the coating having such antifouling features. Hence, it is not possible to utilize the antifouling features even if such features are provided on the inner surface of the water tub.

10 PRIOR ART DOCUMENTS

PATENT DOCUMENT

[0004]

PATENT DOCUMENT 1: JP 2010-172436 A

15 SUMMARY OF THE INVENTION

PROBLEMS TO BE OVERCOME

[0005]

Thus, embodiments of the present invention seek to provide a washing machine in which an antifouling feature is applied to
20 a portion where the antifouling feature is exerted most effectively.

MEANS TO OVERCOME THE PROBLEM

[0006]

A washing machine according to a first aspect of the present invention comprises:

a water tub;

a rotary tub made of stainless steel provided rotatably in
5 the water tub; and

a hydrophilic portion provided by coating a hydrophilic material on the outer surface of the rotary tub,

wherein hydrophilicity is present on a surface of the hydrophilic portion before coming in contact with water and
10 contaminant is lifted off by intrusion of water between the surface of the hydrophilic portion and contaminant attached to the hydrophilic portion.

A washing machine according to a second aspect of the present invention comprises:
15

a water tub;

a rotary tub made of stainless steel provided rotatably in the water tub; and

a hydrophilic coating inhibiting propagation of mold
20 coated on the outer surface of the rotary tub,

wherein hydrophilicity is present on a surface of the coating before coming in contact with water and contaminant is lifted off by intrusion of water between the surface of the coating and contaminant attached to the coating.

[0007]

A washing machine according to a third aspect of the present
5 invention comprises:

a water tub;

a rotary tub made of stainless steel provided rotatably
in the water tub; and

a hydrophilic coating inhibiting attachment of
10 contaminant coated on the outer surface of the rotary tub,

wherein hydrophilicity is present on a surface of the
coating before coming in contact with water and contaminant is
lifted off by intrusion of water between the surface of the
coating and contaminant attached to the coating.

15

A washing machine according to a fourth aspect of the
present invention comprises:

a water tub;

a rotary tub made of stainless steel provided rotatably
20 in the water tub; and

a hydrophilic coating inhibiting attachment of detergent coated on the outer surface of the rotary tub,

wherein hydrophilicity is present on a surface of the coating before coming in contact with water and contaminant is
5 lifted off by intrusion of water between the surface of the coating and contaminant attached to the coating.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

10 [FIG.1] FIG.1 is a vertical cross-sectional view schematically illustrating one example of a structure of a drum-type washing machine of a first embodiment.

[FIG.2] FIG.2 is a vertical cross-sectional side view schematically illustrating one example of a structure of a
15 vertical-axis washing machine of a first embodiment.

[FIG.3] FIG.3 is a development view of a rotary tub.

[FIG.4] FIG.4 indicates test conditions and the test results of the operational suitability test.

[FIG.5] FIG.5 provides a visual representation of the test
20 results of the operational suitability test.

[FIG.6] FIG.6 indicates the test results of a simulated contaminant wash test.

[FIG.7] FIG.7 provides a visual representation of the test

results of a simulated contaminant wash test.

[FIG.8] FIG.8 corresponds to FIG.3 and illustrates one example of a portion being tested in the mold attachment and growth inhibition verification test.

5 [FIG.9] FIG.9 indicates the test results of the mold attachment and growth inhibition verification test.

[FIG.10] FIG.10 pertains to a second embodiment and corresponds to FIG.1.

[FIG.11] FIG.11 pertains to the second embodiment and
10 corresponds to FIG.2.

[FIG.12] FIG.12 pertains to a third embodiment and corresponds to FIG.1.

[FIG.13] FIG.13 pertains to the third embodiment and corresponds to FIG.2.

15 [FIG.14] FIG.14 pertains to a modified embodiment and corresponds to FIG.1 (Part 1).

[FIG.15] FIG.15 pertains to a modified embodiment and corresponds to FIG.1 (Part 1).

[FIG.16] FIG.16 pertains to a modified embodiment and
20 corresponds to FIG.2.

[FIG.17] FIG.17 pertains to a modified embodiment where: (a) is an enlarged view of the periphery of a hole in one example of a structure in which a hydrophilic capacity is not provided on an end surface of the hole, and (b) is an enlarged view of the
25 periphery of a hole in one example of a structure in which a hydrophilic capacity is provided on an end surface of the hole.

EMBODIMENTS OF THE INVENTION

[0009]

A description will be given on multiple embodiments of a washing machine with reference to the drawings. The elements that are substantially identical across the embodiments are identified with an identical reference symbol and are not re-described.

(FIRST EMBODIMENT)

Washing machine 100 illustrated in FIG.1 is a so-called lateral axis drum-type washing machine in which the central axis of rotation of the rotary tub is horizontal or is slightly inclined. The exterior housing 101 serving as the outer shell of the washing machine 100 is formed of a base 102 made of synthetic resin and a housing body 103 coupled to the base 102. A laundry inlet/outlet 104 is provided so as to be located substantially at the central portion of the front face of the housing body 103. In FIG.1, the front face of the housing body 103 is located on the left side. A door 105 is further provided on the front face of the housing body 103 for opening and closing the laundry inlet/outlet 104. A control panel 106 is provided on the upper portion of the front face of the housing body 103. A controller 107 configured to control the overall operation of the washing machine 100 is provided on the underside of the control panel 106. A water tub 108 shaped like an enclosed bottom cylinder is provided inside the exterior housing 101. The bottom portion of the water tub 108 is located in the rear side as viewed in the drawings. The water tub 108 is elastically supported by a suspension 109 so that its central axis lies on an axis declining slightly in the rearward direction which is the rightward

direction as viewed in FIG.1.

[0010]

A motor 110 is provided on the outer side of the rear surface portion of the water tub 108. The motor 110 comprises a direct
5 current brushless motor of an outer rotor type for example which is provided with a stator 111 and a rotor 112. The stator 111 is fixed in the outer side of the rear surface portion of the water tub 108. A rotational shaft 113 is provided on the central portion of the rotor 112. The rotational shaft 113, being
10 supported by a bearing bracket 114 by way of a bearing 115, is inserted into the water tub 108. A drum 116 shaped like an enclosed bottom cylinder is provided inside the water tub 108. The bottom portion of the drum 116 is located in the rear side as viewed in the drawings.

15 [0011]

The drum 116 is made of metal such as a stainless steel. The rear central portion of the drum 116 is fixed to the end portion of the rotational shaft 113 of the motor 110 so as to be rotatable about the rearwardly declined axis of the water tub
20 108. In this example, the motor 110 serves as a drive unit for rotating the drum 116. A reinforcement member 117 for adding strength to the rear surface portion of the drum 116 is provided at the bottom portion of the drum 116, in other words, the outer surface of the rear surface portion of the drum 116. The
25 reinforcement member 117 is made of metal such as an aluminum die cast. Multiplicity of holes 118 are formed throughout peripheral wall of the waist of the drum 116. The holes 118 extend through the peripheral wall of the drum 116 and allow passage

of water and air. Baffles 119 made of synthetic resin for lifting and turning the laundry is provided on the inner peripheral portion of the drum 116. The water tub 108 may be disposed so that its central axis lies on a horizontal axis without inclining,
5 in which case the drum 116 is capable of rotating about the horizontal axis.

[0012]

The front sides of both the drum 116 and the water tub 108 are opened to provide an opening 120 and an opening 121,
10 respectively. A balance ring 122 made of synthetic resin is provided around the opening 120 of the drum 116. A liquid such as salt water is sealed in the balance ring 122. The balance ring 122 is fastened to the drum 116 from the outer surface side of the drum 116 with a screw for example not shown made of metal
15 such as a stainless steel. The opening 121 of the water tub 108 is connected to the laundry inlet/outlet 104 by way of annular bellows 123 made of elastic material such as rubber. The laundry inlet/outlet 104 communicates into the drum 116 through the bellows 123, the opening 121 of the water tub 108, and the opening
20 120 of the drum 116.

[0013]

A drain port 124 is provided at the bottom portion of the water tub 108 located in the rear surface side in the figures. One end of a drain hose 125 provided in the machine interior is
25 connected to the drain port 124. The other end of the drain hose 125 provided in the machine interior is connected to a filter case 126 provided in the front portion of the base 102 of the exterior housing 101. A cap 127 is removably attached to the front

end portion of the filter case 126. A lint filter not illustrated being structurally integral with the cap 127 is stored in the filter case 126. A drain valve 128 is connected to the lower portion of the filter case 126. A drain pipe 129 is connected to the outlet of the drain valve 128. The end portion of the drain pipe 129 is lead out of the washing machine from the base 102 of the external housing 101 to be connected to the drain hose provided in the machine exterior.

[0014]

10 An air trap 130 is provided in the upper portion of the filter case 126. The air trap 130 and a water level sensor 131 disposed in the upper portion of the interior of the external housing 101 is connected to an air tube 132. The water level sensor 131 detects the water level inside the water tub 108 by way of the discharge hose 125, the filter case 126, the air trap 130, and the air tube 132 and produces an output to the controller 107.

[0015]

20 A water feed valve 133 and water feed case 134 are provided in the upper portion of the interior of the external housing 101. A water feed hose, disposed in the machine exterior and extending from the tap water faucet not illustrated, is connected to the inlet of the water feed valve 133. Further, the outlet of the water feed valve 133 is connected to one end of a connection pipe 135. The other end of the connection pipe 135 is connected to the water feed case 134. A detergent storage not illustrated is provided inside the water feed case 134. One end of a water feed hose 136 disposed in the machine interior is connected to the

water feed case 134. The other end of the water feed hose 136 disposed in the machine interior is connected to the upper portion of the water tub 108. The water fed from tap water through the water feed valve 133 is supplied into the water tub 108 through the connection pipe 135, the water feed case 134, and the water feed hose 136 disposed in the machine interior.

[0016]

A washing machine 200 illustrated in FIG.2 is a so called vertical-axis washing machine in which the rotational center of the rotary tub extends in the vertical direction. An exterior housing 201 serving as an outer shell of the washing machine contains a cylindrically shaped water tub 202 having an open top and an enclosed bottom. The water tub 102 is elastically supported by a suspension mechanism 203. A cylindrically shaped rotary tub 204 having an open top and an enclosed bottom is provided rotatably inside the water tub 202.

[0017]

The waist of the rotary tub 204 is formed of a first member 204a made of for example metal such as a stainless steel. The bottom portion of the rotary tub 204 is formed of a second member 204b made of for example synthetic resin. A reinforcement member 204c configured to strengthen the second member 204b, i.e. the bottom portion of the rotary tub 204, is provided along the outer side of the second member 204b constituting the bottom portion of the rotary tub 204. The reinforcement member 204c is made of metal for example such as a stainless steel plate. The rotary tub 204 is configured to rotate about a vertical axis and is used as a wash tub in the wash step in which laundry is washed and

in the rinse step in which the laundry is rinsed. The rotary tub 204 is also used as a dehydrate tub in the dehydrate step in which laundry is dehydrated. The rotary tub 204 is provided with multiple holes 205 on its peripheral wall. The holes 205 extend
5 through the peripheral wall of the rotary tub 204 and allow water flow and airflow therethrough. Only some of the holes 205 are illustrated. A balance ring 206 made of synthetic resin is mounted on the upper portion of the rotary tub 204. A liquid such as salt water is sealed in the balance ring 206. The balance ring 206
10 is fastened to the rotary tub 204 from the outer surface side of the rotary tub 204 with a screw 206a for example made of metal such as a stainless steel. An agitator 207 made of synthetic resin is provided rotatably at the bottom portion of the rotary tub 204 interior.

15 [0018]

A drain passageway 208 is provided at the lower portion of the water tub 202. A drain valve 209 is provided in the drain passageway 208 and the water inside the water tub 202 is discharged outside the water tub 202 when the drain valve 209
20 is opened. An air trap 210 used for water level detection is provided at the bottom portion of the water tub 202. A water level sensor not illustrated is connected to the air trap 210 through an air tube 211. A pressure sensor is used as the water level sensor in this example. The pressure sensor is configured to
25 detect the water level inside the water tub 202 based on the pressure inside the air trap 210.

[0019]

A drive mechanism 213 is provided at the lower central

portion of the water tub 202. The drive mechanism 213 is provided with a motor capable of being driven at variable speed, a clutch mechanism, a deceleration unit, and a brake unit. In the wash step or the rinse step, the drive mechanism 213 decelerates the rotational force of the motor by the deceleration unit, and transmits the rotational force of the motor to the agitator 207 by way of the clutch mechanism. In the dehydrate step, the drive mechanism 213 transmits the rotational force of the motor to the rotary tub 204 and the agitator 207 at high speed by way of the clutch mechanism without decelerating the rotational force of the motor by deceleration unit.

[0020]

A top cover 214 is provided at the upper portion of the exterior housing 201. A two-fold lid 215 for example configured to open and close the laundry inlet/outlet is provided openably and closably at the top cover 214. A tub cover not illustrated is attached to the upper portion of the water tub 202. A control panel 217 is provided at the front portion of the top cover 214. A controller not illustrated configured to control the overall operation of the washing machine 200 is provided on the underside of the control panel 217. A water supply mechanism not illustrated is provided at the rear portion of the top cover 214. The water supply mechanism is configured to supply tap water into the water tub 202.

[0021]

In the washing machine 100 illustrated in FIG.1, hydrophilic film 300, being one example of a hydrophilic portion, is applied at least on the outer surface of the side section of

the drum 116. The hydrophilic film 300 serving as the hydrophilic portion constantly exerts hydrophilic capacity. In this example, the hydrophilic film 300 is applied throughout the entirety of the outer surface of the side section of the drum 116. In the washing machine 200 illustrated in FIG.2, hydrophilic film 300, being one example of a hydrophilic portion, is applied at least on the outer surface of the first member 204a serving as the side section of the rotary tub 204. In this example, the hydrophilic film 300 is applied throughout the entirety of the outer surface of the side section of the rotary tub 204. Next, a description will be given in further detail on an example in which the hydrophilic film 300 is implemented by a hydrophilic coating. The hydrophilic film 300 is formed by spraying a coating having hydrophilic capabilities such as a silica-system inorganic coating (hereinafter referred to as a "hydrophilic material") on the outer surface of the side section of the drum 116 or the outer surface of the side section of the rotary tub 204.

[0022]

In this example, both the drum 116 and the rotary tub 204 are made of metal. It is thus, possible to apply reinforced coating by baking the hydrophilic material sprayed onto the outer surface of the drum 116 or the rotary tub 204. The baking temperature of the hydrophilic material is preferably specified to 250 degrees Celsius or greater which is generally believed to be the temperature in which organic materials are decomposed and may preferably be specified to temperatures such as 300 degrees Celsius, 500 degrees Celsius, etc. By baking the hydrophilic material at such high temperatures, it is possible

to mostly or completely decompose the organic materials contained in the hydrophilic material and thereby form the hydrophilic film 300 in a mostly or completely inorganic state.
[0023]

5 When providing a coating of these types of materials, a degreasing treatment for degreasing the surface of the substrate is normally carried out prior to the spraying of the substrate. In the present embodiment, the drum 116 and the rotary tub 204 both serving as the base material are made of stainless steel.
10 It is thus, possible to carry out the degreasing treatment, prior to the spraying of the hydrophilic material, by using a strongly alkaline degreasing agent in the level of PH14 for example. Hence, it is possible to spray the hydrophilic material after degreasing most of or all oil components from the surface of the drum 116
15 and the rotary tub 204 serving as the substrate and allow the hydrophilic material to be in good attachment with the surface of the drum 116 and the surface of the rotary tub 204.

[0024]

 In the present embodiment, a hydrophilic material
20 exhibiting at least the following capacity is employed for forming the hydrophilic film 300 in the present embodiment. The hydrophilic film 300 of the present embodiment possesses a hydrophilicity in which contact angle of water on the hydrophilic film 300 is less than the lower limit value of the contact angle
25 of water on glass. The lower limit value of the contact angle of water on glass is generally considered to be 20 degrees. Thus, in the present embodiment, a hydrophilic material in which the contact angle of water is less than 20 degrees, for example, 13

degrees is used for forming the antifouling coating.

[0025]

In the present embodiment, a hydrophilic material containing a silicon oxide is employed for forming the hydrophilic film 300. The hydrophilic film 300 formed by such hydrophilic material has a hardness property which is at least equal to greater than 5H in pencil hardness. More specifically, the hydrophilic film 300 of the present embodiment is formed of a rigid structure of siloxane skeleton and alkali metal/alkali earth metal. As a result, the hydrophilic film 300 exhibits a rigid structure in which the pencil hardness is 5H or greater.

[0026]

The hydrophilic film 300 of the present embodiment contains a silanol group and exhibits an extremely high hydrophilic capacity. For example, the hydrophilic film 300 has a hydrophilic capacity capable of removing an oil-based ink attached thereto merely by contact with water. Thus, the ink of an oil-based ink pen attached to the hydrophilic film 300 can be lifted off through contact with water.

[0027]

The hydrophilic film 300 of the present embodiment is extremely thin, being equal to or less than 10 μm in thickness. It is generally required to repeatedly apply the hydrophilic coating in order to improve hydrophilic capacity which tends to result in a thick hydrophilic coating. The present embodiment employs a hydrophilic material which forms the hydrophilic film 300 exhibiting extremely high hydrophilic capacity by only a single iteration of coating and baking. It is thus, possible to

form a hydrophilic film 300 having extremely high hydrophilic capacity without repeating the coating of hydrophilic material. As a result, it is possible to keep the thickness of the hydrophilic film 300 to 10 μm or less. The thickness of the hydrophilic film 300 is illustrated to be greater than the actual thickness of for convenience of explanation.

[0028]

Further, the hydrophilic film 300 of the present embodiment exhibits a surface roughness of 2 μm or less. In the present embodiment, a hydrophilic material is used which forms a hydrophilic film 300 having an extremely smooth surface as described above. Further, the hydrophilic material used in the present embodiment is opaque white before it is sprayed but becomes transparent after it is sprayed such that opaque whiteness is hardly recognizable and becomes mostly or completely transparent after it is baked.

[0029]

Next, a description will be given on the results of tests conducted to evaluate the antifouling capacity of the washing machine of the present embodiment. In this example, an "operational suitability test", a "simulated contaminant wash test", and a "mold attachment and growth inhibition verification test" were conducted as described in the following. Each of the tests were conducted, for example, by using a test washing machine provided with a test rotary tub T. A development view of the rotary tub T is schematically illustrated in FIG.3. The hydrophilic coating 300 is applied to a half perimeter portion Ra of the outer surface of the side section of the rotary tub T. The hydrophilic

coating 300 is not provided on the remaining half perimeter portion Rb. The portion Ra provided with the hydrophilic coating 300 is hereinafter referred to as a "coated portion Ra" and the portion Rb free of the hydrophilic coating 300 is hereinafter referred to as a "uncoated portion Rb".

[0030]

<<Operational Suitability Test>>

In the "operational suitability test", test washing machines were installed in home A and home B and were used under the following conditions. After the test washing machines were used, the surfaces of the coated portion Ra and uncoated portion Rb of the rotary tub were wiped off using different cloths. The increase in the weight of each cloth after wiping the surfaces were observed as the amount of contaminant attachment of the coated portion Ra and the amount of contaminant attachment of the uncoated portion Rb. The amount of contaminant attachment is indicated in the unit of "mg/25 cm²", that is, the weight per 25 square centimeters. The contaminant attached to the used rotary tub may include detergents used in the test operation, or more specifically, "slight detergent residue remaining after operation".

[0031]

•Home A

As illustrated in FIG.4 for example, 75 cycles of a normal wash operation, that is, "a general wash operation including a wash step, a rinse step, and a dehydrate step" and 30 cycles of a normal dry operation were carried out in home A using "liquid detergent a" and "softener a" generally available in the market.

In home A, the operation was executed using bath water.

[0032]

In this example, the amount of contaminant attachment in coated portion Ra was equal to or less than the detectable limit of "0.01 mg/25cm²". On the other hand, the amount of contaminant attachment in the uncoated portion Rb was 0.5 mg/25cm². Under the conditions of use in home A, it was verified that the coated portion Ra exerted significantly higher antifouling capacity compared to the uncoated portion Rb.

10 [0033]

•Home B

As illustrated in FIG.4 for example, 76 cycles of a normal wash operation, that is, "a general wash operation including a wash step, a rinse step, and a dehydrate step" and several cycles of a normal dry operation were carried out in home B using a "powder detergent b", "liquid detergent b", and "softener b" generally available in the market. In home B, the operation was executed using tap water.

[0034]

20 In this example, the amount of contaminant attachment in the coated portion Ra was equal to or less than the detectable limit of "0.01 mg/25 cm²". On the other hand, the amount of contaminant attachment in the uncoated portion Rb was 0.2 mg/25 cm². It was verified that the coated portion Ra exerted significantly higher antifouling capacity compared to the uncoated portion Rb under the conditions of use in home B as well. FIG.5 provides a visual representation of the results of the "operational suitability test" which is, in this example,

"amount of contaminant attachment".

[0035]

<<Simulated Contaminant Wash Test>>

In the "simulated contaminant wash test", laundry soiled
5 with simulated contaminant was placed in the rotary tub of the
test washing machine and a normal wash operation was executed
for a predetermined number of times. After executing the wash
operation for a predetermined number of times, a normal tub clean
operation was executed. The normal tub clean operation may be
10 defined as "an operation in which the rotary tub is rotated with
water stored in the water tub for cleaning the inside of the water
tub". In this example, laundry was soiled with approximately 2.8
g of dirt and approximately 1.2 g of lard amounting to
approximately 4.0 g of simulated contaminant. In the wash step,
15 powder detergent generally available in the market was used and
water having a hardness of 50 ppm was used as the wash water and
the rinse water.

[0036]

FIG.6 indicates the amount of contaminant attachment
20 observed in the coated portion Ra and the uncoated portion Rb
before and after the tub clean operation. The contaminant
attached to the used rotary tub may include detergents used in
the test operation, or more specifically, "slight detergent
residue remaining after operation".

25 [0037]

The amount of contaminant attachment observed in the coated
portion Ra before the tub clean operation was equal to or less
than the detectable limit of "0.01 mg/25 cm²" and equal to or

less than the detectable limit of "0.01 mg/25 cm²" after the tub clean operation as well. The amount of contaminant attachment in the uncoated portion Rb on the other hand was 0.3 mg/25 cm² before the tub clean operation and 0.1 mg/25 cm² after the tub
5 clean operation. While 0.1 mg/25 cm² of contaminant remains in the uncoated portion Rb even if the tub clean operation is executed, it is possible to keep the amount of contaminant attachment to the detection limit or less in the coated portion Ra even without executing the tub clean operation. It was thus,
10 verified that the coated portion Ra exerted significantly higher antifouling capacity compared to the uncoated portion Rb. FIG.7(a) provides a visual representation of the test results when 30 cycles of a normal wash operation is executed which is, in this example, "amount of contaminant attachment".

15 [0038]

For example, when 90 cycles of normal wash operation was executed, the amount of contaminant attachment in the coated portion Ra was equal to or less than the detectable limit of "0.01 mg/25 cm²" and equal to or less than the detectable limit of "0.01
20 mg/25cm²" after the tub clean operation as well. The amount of contaminant attachment in the uncoated portion Rb, on the other hand was 0.7 mg/25 cm² before the tub clean operation and 0.3 mg/25 cm² after the tub clean operation. While 0.3 mg/25 cm² of contaminant remains in the uncoated portion Rb even if the tub
25 clean operation is executed, it is possible to keep the amount of contaminant attachment to the detection limit or less in the coated portion Ra even without executing the tub clean operation. It was thus, verified that the coated portion Ra exerted

significantly higher antifouling capacity compared to the uncoated portion Rb. FIG.7(b) provides a visual representation of the results of the test results when 90 cycles of a normal wash operation is executed which is, in this example, "amount
5 of contaminant attachment".

[0039]

<<Mold Attachment and Growth Inhibition Verification Test>>

The "mold attachment and growth inhibition verification
10 test" is conducted in the following manner.

•Tested Portions

As illustrated in FIG.8, 12 locations of the coated portion Ra, indicated as a matrix of 3 columns x 4 rows in broken lines as well as 12 locations of the uncoated portion Rb, indicated
15 as a matrix of 3 columns x 4 rows in broken lines were tested. Each of the tested portions are sized to have an area of 80 mm x 32 mm corresponding to 25 cm².

[0040]

•Operating Conditions

20 A wash operation including the following steps are executed.

Wash operation: wash Step → first intermediate dehydrate step → first rinse step → second intermediate dehydrate step → second rinse step → final dehydrate step.

25 •Mold used in the test

The following mold was used in the test.

Exophiala Dermatitidis NBRC 6421

[0041]

Test Method (Overview)

A liquid of mold spores, that is, "a liquid containing spores of the above described mold" were coated on the coated portion Ra and uncoated portion Rb of the rotary tub T using the above described test washing machine. The portions coated with the liquid of mold spores were wiped off after they were set aside for 24 hours. Then, the above described wash operation was executed, whereafter the above described tested portions were wiped off in a similar manner. The above described tested portions were further wiped off in a similar manner after being set aside for 3 days. The above described tested portions were further wiped off in a similar manner after being set aside for 7 days. The mold wiped off in the each of the above described timings were cultured by known methods and counted. The removing effect and the growth inhibition effect resulting from the presence and absence of the hydrophilic coating were evaluated based on the obtained count. The test is described in detail hereinafter.

[0042]

(1) Contamination of Rotary Tub

Laundry carrying simulated contaminant was placed in the rotary tub and 25 cycles of the above described wash operation was executed to cause contamination of the rotary tub.

[0043]

(2) Coating of Liquid Containing Mold Spores

Approximately 10^7 CFU/ml (CFU: Colony Forming Unit) of liquid containing mold spores were applied in drops of 10 μ l on 20 given unique locations (10 μ l $\times$ 20 locations) on the tested portions of the coated portion Ra and dried for approximately

3 hours. Approximately 10^8 CFU/ml of liquid containing mold spores were applied in drops of 20 μ l on the tested portions of the uncoated portions Rb and stirred with a bacteria spreader.
[0044]

5 The coated portion Ra is given a significantly high hydrophilic capacity by the coating, whereas the uncoated portion Rb does not possess hydrophilic capacity. Because the surface properties of the two portions differ, it is difficult to use the same method in applying the liquid containing mold
10 spores on the two portions. Thus, the test was conducted by applying the liquid containing mold spores on the tested portions of the coated portion Ra and the uncoated portion Rb using different methods of coating. The amount of liquid containing mold spores coated on the two portions is the same though coated
15 in different methods.

[0045]

(3) Test Operation

After the liquid containing mold spores are coated on the tested portions and dried in the above described manner, the
20 washing machine door is closed and the tested portions are set aside for 24 hours. The temperature inside the washing machine ranged approximately between 21.5 to 25.8 degrees Celsius and the relative humidity (RH) ranged approximately between 65 to 87% while the tested portions were being set aside. After being
25 set aside for 24 hours and before executing the above described wash operation, 3 given locations (indicated as n1, n2, and n3 in FIG.9) in the tested portions of the coated portion Ra and 3 given locations (indicated as n1, n2, and n3 in FIG.9) in the

tested portions of the uncoated portion Rb were wiped off by a sterilization pouce, i.e. "a gauze for wiping off fungus". Then the above described wash operation was performed, whereafter the tested portions were similarly wiped off and set aside after
5 closing the door. The temperature inside the washing machine ranged approximately between 22.8 to 26.6 degrees Celsius and the relative humidity (RH) was mostly equal to or greater than 90% while the tested portions were being set aside. The tested portions were further wiped off in a similar manner after being
10 set aside for 3 days. The above described portions were further wiped off in a similar manner after being set aside for 7 days. The sterilization pouces used in the wiping were each placed in sterilization bag with culture medium. Mold was extracted using stomacher processing which may be described as "a processing for
15 extracting fungi after homogenizing the samples by grinding".
[0046]

(4) Mold Counting

The liquid extracted from the sterilization pouce was used as sample liquid which was diluted into 10 different
20 concentration levels by physiological saline. The sample liquid and the diluted liquid were coated on the PDA culture medium in the amount of 0.1 ml each. Further, 1 ml of the sample liquid was filtered using a membrane filter and the membrane filter was attached to the surface of another PDA culture medium. The culture
25 medium was cultured for 7 days at approximately 28 degrees Celsius (28 degrees Celsius $\pm$ 1 degrees Celsius). Then, the number of grown colonies was counted to obtain the count of mold per 25 cm².
[0047]

(5) Calculation of Mold Removal Rate

The mold removal rate (%) was calculated using the following equation.

$$\text{removal rate} = (1 - (B/A)) \times 100$$

5 A: mold count before wash operation

 B: mold count after wash operation

[0048]

•Test Result

The test results are indicated in FIG.9. That is, the mold
10 removal rate at 0th day after the completion of the wash operation
is approximately 99.92% in the coated portion Ra and
approximately 94.3% in the uncoated portion Rb. Mold did not
propagate in the period of the 3rd day to the 7th day after the
completion of the wash operation. This is believed to be caused
15 by the nutrient coated with the mold being washed away by the
wash operation.

[0049]

According to the above described test results, it has been
observed that mold is removed at significantly high percentage
20 close to 100% in this example in the coated portion Ra. It was
thus, possible to verify that the coated portion Ra exerted
significantly higher antifouling capacity compared to the
uncoated portion Rb.

[0050]

25 In the washing machines 100 and 200 of the present
embodiment, hydrophilic film 300 having extremely high
hydrophilic capacity is provided on the outer surfaces of the
side sections of the rotary tubs 116 and 204 provided rotatably

in the water tubs 108 and 202, respectively. It is thus, possible to keep clean the outer surfaces of the side sections of the rotary tubs 116 and 204, being unreachable by hand and thus, being difficult to perform maintenance work such as cleaning, by the
5 antifouling function of the hydrophilic film 300. The antifouling function is thus, utilized most effectively the washing machines 100 and 200.

[0051]

The washing machines 100 and 200 are provided with the
10 hydrophilic film 300 on the outer surfaces of the side sections of the rotary tubs 116 and 204 configured to rotate. The removal of contaminants detached from the surfaces of the rotary tubs 104 and 216 is facilitated by centrifugal force during the rotation of the rotary tubs 116 and 204. It is thus, possible
15 to keep clean the surfaces of the rotary tubs 116 and 204 even more effectively.

[0052]

In the washing machines 100 and 200, the hydrophilic film 300 is provided substantially throughout the outer surfaces of
20 the side sections of the rotary tubs 116 and 204. It is thus, possible to keep clean almost the entirety of the outer surfaces of the side sections of the rotary tubs 116 and 204 by the antifouling function of the hydrophilic film 300. In the washing machines 100 and 200, it is further possible to coat the
25 hydrophilic material on the outer surface of the metal portions of the rotary tubs 116 and 204 by spraying since the rotary tubs 116 and 204 are made of metal and not of synthetic resin. It is thus, possible to form a hydrophilic film 300 which is highly

inorganic, rigid, and durable.

[0053]

In the washing machines 100 and 200, the contact angle of water on the hydrophilic film 300 is less than the lower limit value of the contact angle of water on glass. The hydrophilic film 300 further has a silanol group. Thus, the hydrophilic film 300 exerts extremely high hydrophilic capacity. As a result, water is easily introduced between the surface of the hydrophilic film 300 and the contaminant attached to the hydrophilic film 300 to allow the contaminant attached to the hydrophilic film 300 to be removed so as to be lifted off.

[0054]

In the washing machines 100 and 200, the hydrophilic film 300 contains a silicon oxide and has a hardness property which is at least equal to greater than 5H in pencil hardness. It is thus, possible to inhibit damaging of the hydrophilic film 300 and peeling of the hydrophilic film 300. Further, in the washing machines 100 and 200, extremely thin hydrophilic film 300 is achieved which is equal to or less than 10 μm thick. Still further in the washing machines 100 and 200, extremely smooth hydrophilic film 300 is achieved which is equal to or less than 2 μm in surface roughness.

[0055]

In the washing machine 100, the hydrophilic film 300 may be provided on the metal screws provided on the drum 116 or on the inner surface of the drum 116. In the washing machine 200, the hydrophilic film 300 may be provided on the metal screws 206a provided on the rotary tub 204 or on the inner surface of the

rotary tub 204. Thus, in the present embodiment, the location for forming the hydrophilic film 300 is not limited to the outer surface of the side section of the drum 116 and the outer surface of the side section of the rotary tub 204. When forming the hydrophilic film 300 on the metal screw, it is not necessary to form the hydrophilic film 300 on the entirety of the screw. It suffices to form the hydrophilic film 300 on the surface of the screw head serving as the outer surface of the screw. When forming the hydrophilic film 300 on the inner surfaces of the drum 116 rotary tub 204, the hydrophilic film 300 may be formed on the entirety of the inner surfaces. Alternatively, the hydrophilic capacity portion 300 may be formed on portions of the inner surfaces.

[0056]

The hydrophilic film 300 may be colored. The hydrophilic film 300 may be formed of a hydrophilic material which maintains its color after being sprayed and baked onto the substrate. It is thus, possible to visibly spot any unevenness in the hydrophilic film 300 with ease. For example, a rotary tub in which the hydrophilic film 300 is not evenly formed may be identified as a defective product.

[0057]

In washing machines 100 and 200, a cleaning step may be executed after or during a wash course including steps such as a wash step, a rinse step, and a dehydrate step. In the cleaning step, the drum 116 and the rotary tub 204 are rotated with water stored in the water tubs 108 and 202. In the cleaning step, it is possible to remove the contaminants attached to the

hydrophilic film 300 by subjecting the hydrophilic film 300 in contact with water. In the cleaning step, amount of water stored in the water tubs 108 and 202 is preferably increased compared to the wash course and the speed of rotation of the drum 216 and
5 the rotary tub 104 may be increased as compared to the wash step or the rinse step.

[0058]

The washing machines 100 and 200 are further expected to exert anti-rust effects by the hydrophilic film 300.

10 (SECOND EMBODIMENT)

In the present embodiment, the hydrophilic film 300 is provided partially on the outer surface of the side section of the drum 116 and partially on the outer surface of the side section of the rotary tub 204 instead of being provided throughout the
15 outer surface of the side section of the drum 116 and throughout the outer surface of the side section of rotary tub 204.

[0059]

As illustrated in FIGS.10 and 11, water stored in the water tub 108 and the water tub 202 contact the portions lower than
20 the water level L indicated by a single-dot chain line in the side section of the drum 116 of the washing machine 100 and the side section of the rotary tub 204 during the wash operation and the rinse operation. Thus, it is possible to keep the portions lower than the water level L in the outer surface of the side
25 section of the drum 116 and in the outer surface of the side section of the rotary tub 204 to be relatively clean without providing the hydrophilic film 300. However, it is difficult for water stored in the water tub 108 and the water tub 202 to contact

the portions in the outer surface of the side section of the drum 116 and in the outer surface of the side section of the rotary tub 204 located higher than the specified water level L during the wash operation and the rinse operation and thus, contaminants
5 tend to remain in such portions.

[0060]

Thus, in the present embodiment, the hydrophilic film 300 is provided in portions located higher than the water level L in the outer surface of the side section of the drum 116 and the
10 outer surface of the side section of the rotary tub 204 as illustrated in FIG.10 and FIG.11. As a result, it is possible for hydrophilic capacity to be given in a concentrated manner especially in portions in the outer surface of the side section of the drum 116 and the outer surface of the side section of the
15 rotary tub 204 where contaminants tend to remain. It is thus, possible to effectively utilize the antifouling function achieved by the hydrophilic capacity and further reduce the amount of hydrophilic material being used. The water level L is variable and thus, the regions for forming the hydrophilic film
20 300 are preferably adjusted depending upon the expected water level. In such case, the region for forming the hydrophilic film 300 is preferably specified to be greater than what is actually required so as to encompass the lowest specifiable water levels in the washing machines 100 and 200 and the possible variations
25 in the water levels.

[0061]

(THIRD EMBODIMENT)

The present embodiment also provides the hydrophilic film

300 partially on the outer surface of the side section of the drum 116 and partially on the outer surface of the side section of the rotary tub 204 instead of providing the hydrophilic film 300 throughout the outer surface of the side section of the drum 116 and throughout the outer surface of the side section of rotary tub 204.

[0062]

The portions lower than the water level L in the outer surface of the side section of the drum 116 and the outer surface of the side section of the rotary tub 204 are kept relatively clean as water easily contacts these portions. However, this does not mean that these portions are constantly free of contaminants. Especially the portions lower than the water level L in the outer surface of the side section of the drum 116 and the outer surface of the side section of the rotary tub 204 are subjected to contact with water during the washing operation and the rinse operation. Thus, contaminants remaining in these portions may transform over time and eventually transfer to laundry during the wash operation or the rinse operation.

[0063]

Thus, in the present embodiment, hydrophilic film 300 is provided in portions lower than the water level L in the outer surface of the side section of the drum 116 and the outer surface of the side section of the rotary tub 204 as illustrated in FIGS. 12 and 13. As a result, it is possible to give hydrophilic capacity in a concentrated manner in portions where contaminants may remain, though kept relatively clean, in the outer surface of the side section of the drum 116 and the outer surface of the

side section of the rotary tub 204. As a result, it is possible to prevent transfer of transformed contaminant to laundry during the wash operation and the rinse operation. It is further possible to reduce the amount of hydrophilic material being used. The water level L is variable and thus, the regions for forming the hydrophilic film 300 are preferably adjusted depending upon the expected water level. In such case, the region for forming the hydrophilic film 300 is preferably specified to be greater than what is actually required so as to encompass the lowest specifiable water levels in the washing machines 100 and 200 and the possible variations in the water levels for example.

[0064]

(OTHER EMBODIMENTS)

The present embodiment is not limited to the foregoing embodiments but may be expanded or modified for example as follows.

Further, in the washing machine 100, the hydrophilic film 300 may be provided on the outer surface of the bottom portion of the drum 116 serving as the rear surface portion of the drum 116 as illustrated for example in FIG.14. In such case, the hydrophilic film 300 may be provided on the entire outer surface of the rear surface portion of the drum 116 or partially on the outer surface of the rear surface portion of the drum 116. Though not illustrated, the second member 204b serving as the bottom portion of the washing machine 200 may be made of metal such as stainless steel. In such case, the hydrophilic film 300 may be provided on the outer surface of the bottom portion formed of the second member 204b made of metal. For example, the hydrophilic

film 300 may be provided on the entire outer surface of the bottom portion made of metal or partially on the outer surface of the bottom portion made of metal.

[0065]

5 Further, in the washing machine 100, the hydrophilic film 300 may be provided on the reinforcement member 117 strengthening the bottom portion of the drum 116 serving as the rear surface portion of the drum 116 as illustrated for example in FIG.15. In such case, the hydrophilic film 300 may be provided on the
10 entire surface of the reinforcement member 117 or partially on the surface of the reinforcement member 117. Further, in the washing machine 200, the hydrophilic film 300 may be provided on the reinforcement member 204c strengthening the bottom portion of the rotary tub 204 as illustrated for example in FIG.16.
15 In such case, the hydrophilic film 300 may be provided on the entire surface of the reinforcement member 204c or partially on the surface of the reinforcement member 204c. The hydrophilic film 300 may be provided on both the upper surface and the lower surface of the reinforcement member 204c or either of the upper
20 surface and the lower surface of the reinforcement member 204c.

[0066]

Further, end surfaces 118a and 205a serving as the inner peripheral surfaces of the holes 118 and 205 of the washing machines 100 and 200 may not be provided with the hydrophilic
25 film 300 as illustrated for example in FIG.17(a). Alternatively, the end surfaces 118a and 205a of the holes 118 and 205 of the washing machines 100 and 200 may be provided with the hydrophilic film 300 as illustrated for example in FIG.17(b).

[0067]

It is assumed that the test results similar to those presented in the first embodiment can be obtained when similar tests are conducted in the washing machines of other embodiments.

5 The embodiments and modified embodiments described above may be combined as required.

[0068]

The washing machine of the foregoing embodiments is provided with a hydrophilic portion at the rotary tub provided
10 rotatably in the water tub. According to such structure, it is possible to keep clean portions of the rotary tub, being unreachable by hand and thus, being difficult to perform maintenance work such as cleaning. The antifouling function achieved by the hydrophilicity is thus, utilized most
15 effectively.

[0069]

As clearly indicated by the test results described above, the washing machine of the foregoing embodiments provides excellent effects such as inhibiting the propagation of mold,
20 inhibiting attachment of contaminants, and inhibiting attachment of detergents by providing a hydrophilic coating on the rotary tub.

[0070]

An ordinary rotary tub made of stainless steel being free
25 of the hydrophilic coating will accumulate small amounts of contaminants even when a tub clean operation is performed once a month using chlorine based tub clean detergent. It has been verified by the above described test results that contaminant

hardly accumulates on the rotary tub even when the wash operation is repeated, by coating the rotary tub with a hydrophilic material. It is thus, possible to reduce the number of tub clean operations or eliminate the tub clean operation to reduce the running cost of the tub clean operation which may include reduction in the amount of tub clean detergents, water, and electricity used and costs incurred.

[0071]

While certain embodiments have been described, these
10 embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may
15 be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

CLAIMS

What is claimed is:

1. A washing machine comprising:
a water tub;
a rotary tub made of stainless steel provided rotatably in the water tub; and
a hydrophilic portion provided by coating a hydrophilic material on the outer surface of the rotary tub,
wherein hydrophilicity is present on a surface of the hydrophilic portion before coming in contact with water and contaminant is lifted off by intrusion of water between the surface of the hydrophilic portion and contaminant attached to the hydrophilic portion.
2. The washing machine according to claim 1, wherein the hydrophilic portion is provided on an outer surface of a side section of the rotary tub.
3. The washing machine according to claim 2, wherein the hydrophilic portion is provided throughout the outer surface of the side section of the rotary tub.
4. The washing machine according to claim 2, wherein the hydrophilic portion is provided on a portion of the outer surface of the side section of the rotary tub.
5. The washing machine according to any one of claims 1 to 4, wherein the hydrophilic portion is provided on an outer surface of a bottom portion of the rotary tub.

6. The washing machine according to claim 5, wherein the hydrophilic portion is provided throughout the outer surface of the bottom portion of the rotary tub.

7. The washing machine according to claim 5, wherein the hydrophilic portion is provided on a portion of the outer surface of the bottom portion of the rotary tub.

8. The washing machine according to any one of claims 1 to 7, wherein the hydrophilic portion is provided on a screw mounted on the rotary tub.

9. The washing machine according to any one of claims 1 to 8, wherein the hydrophilic portion is provided on an inner surface of the rotary tub.

10. The washing machine according to any one of claims 1 to 9, wherein multiple holes are provided on the rotary tub, the hydrophilic portion being provided on end surfaces of the holes.

11. The washing machine according to any one of claims 1 to 10, wherein the rotary tub is made of metal and the hydrophilic portion is coated by baking the hydrophilic material on the outer surface of the rotary tub.

12. The washing machine according to any one of claims 1 to 11, wherein the hydrophilic portion has a thickness equal to or less than 10 μm .

13. The washing machine according to any one of claims 1 to 12, wherein the hydrophilic portion has a surface roughness equal to or less than 2 μm .

14. The washing machine according to any one of claims 1 to 13, wherein the hydrophilic portion is colored.

15. The washing machine according to any one of claims 1 to 14, wherein the hydrophilic portion includes a silicon oxide and has a pencil hardness equal to or greater than 5H.

16. The washing machine according to any one of claims 1 to 15, wherein a contact angle of water on the hydrophilic portion is less than a lower limit of contact angle of water on glass.

17. The washing machine according to any one of claims 1 to 16, wherein the rotary tub is a drum configured to rotate about a horizontal axis or a rearwardly declining axis.

18. The washing machine according to claim 17, wherein the hydrophilic portion is provided on a reinforcement member configured to strengthen a bottom portion of the drum.

19. The washing machine according to any one of claims 1 to 16, wherein the rotary tub is configured to rotate about a vertical axis.

20. The washing machine according to claim 19, wherein the hydrophilic portion is provided on a reinforcement member configured to strengthen a bottom portion of the rotary tub.

21. The washing machine according to any one of claims 1 to 20, wherein the hydrophilic portion constantly exerts hydrophilicity.

22. A washing machine comprising:

a water tub;

a rotary tub made of stainless steel provided rotatably in the water tub; and

a hydrophilic coating inhibiting propagation of mold coated on the outer surface of the rotary tub,

wherein hydrophilicity is present on a surface of the coating before coming in contact with water and contaminant is lifted off by intrusion of water between the surface of the coating and contaminant attached to the coating.

23. A washing machine comprising:

a water tub;

a rotary tub made of stainless steel provided rotatably in the water tub; and

a hydrophilic coating inhibiting attachment of contaminant coated on the outer surface of the rotary tub,

wherein hydrophilicity is present on a surface of the coating before coming in contact with water and contaminant is lifted off by intrusion of water between the surface of the coating and contaminant attached to the coating.

24. A washing machine comprising:

a water tub;

a rotary tub made of stainless steel provided rotatably in the water tub; and

a hydrophilic coating inhibiting attachment of detergent coated on the outer surface of the rotary tub,

wherein hydrophilicity is present on a surface of the coating before coming in contact with water and contaminant is lifted off by intrusion of water between the surface of the coating and contaminant attached to the coating.