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METHOD FOR FORMING PAINT COATING

BACKGROUND OF THE INVENTION

The present invention relates to a method for forming a substantially uniform paint coating on articles such as vessels, steel structures, etc., and more particularly to a method which can form a substantially uniform, anti-corrosive paint coating in an exact thickness even on regions such as interiors of vessels which are extremely difficult to be coated.

Articles such as vessels, steel structures, etc., which are likely subjected to severe corrosion, need be formed with thick, single-layer or multi-layer paint coatings, whose layer formed by a single coating step should be as thick as 100 μm or more to have sufficient resistance to rust and corrosion. To make sure that such a thick paint coating is formed, a wet gauge, an electromagnetic thickness meter, etc. are presently used. However, because articles such as vessels, steel structures, etc., have wide surfaces to be coated, and because some of such surfaces are not easily coated, it is practically difficult to measure the paint coating thickness by a wet gauge during painting and to check the entire regions of a dried paint coating completely by an electromagnetic thickness meter, etc. Under such circumstances, various attempts have been carried out to check whether or not paint coatings formed on articles such as vessels, steel structures, etc. have reached the predetermined thickness.

Japanese Patent Laid-Open No. 62-218459 discloses a coating composition comprising resins and coloring pigments, having a contrast ratio of 0.96 or more at a dry thickness of a μm, and 0.90 or less at a dry thickness of (a-30) μm or more and less than a μm,

wherein *a* is 50-120 μm. This coating composition makes it possible to observe the change of a contrast ratio (hiding ratio of an underlying black & white pattern) by the variation of a coating thickness within 30 μm or less, because this coating has much smaller hiding power than conventional paints due to a drastically reduced amount of coloring pigments. To determine the contrast ratio, however, a diffusion reflectance should be measured after the coated paint is dried, making the coating operation inefficient. Though this Japanese reference describes that the hiding power can be evaluated by the naked eye instead of calculating the contrast ratio, it is impossible to exactly control the thickness of a paint coating by the observation of the hiding power with the naked eye.

Japanese Patent Laid-Open No. 64-15181 discloses a method for forming a multi-layer pattern coating consisting of a plurality of coating layers such as an undercoat, an intermediate coat, a topcoat, etc. on a surface of building, etc., paints being colored and then coated such that there is enough color difference between the adjacent layers, thereby making it easy to confirm and notice the hiding and patterning with paints. However, this method simply utilizes a color difference between the adjacent coating layers, failing to exactly and substantially uniformly control a paint coating to a targeted dry thickness with a color difference between the paint coating and an article to be coated.

Japanese Patent Laid-Open No. 4-145979 discloses a painting method comprising forming an undercoat on an article, forming an intermediate coating layer on a surface of the undercoat, grinding the intermediate coating layer, and then forming a color coating layer on the ground intermediate coating layer, a color difference ΔE between the undercoat and the intermediate coating

layer, a standard thickness A μm of the color coating layer and a thickness B μm of the coloring paint hiding a black-and-white surface satisfying the following equation:

$$\Delta E \leq 100 \times (A/B)^4.$$

Though this method is suitable for forming a coating layer having a thickness of about 10-20 μm as coatings for automobiles, it is not usable for coatings of 100 μm or more for articles such as vessels, steel structures, etc. Also, since the above equation is complicated, it is difficult to calculate the equation in situ, failing to utilize it for coatings of articles such as vessels, steel structures, etc.

OBJECT AND SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a method for easily and exactly control a dry thickness of a paint coating to a target value even in regions such as interiors of vessels, etc. where painting is extremely difficult.

As a result of intense research in view of the above object, the inventors have found that when a paint containing a relatively small amount of coloring pigments is used as a thickness-determining paint, it is easily and exactly control a dry thickness of a paint coating formed on an article such as a vessel, a steel structure, etc. to a targeted dry thickness, by making each of (a) a color difference between the thickness-determining paint and the article, (b) a color difference between a paint coating of a targeted dry thickness and a paint coating thinner than the targeted dry thickness, and (c) a color difference between the paint coating of the targeted dry thickness and a paint coating thicker than the targeted dry thickness, within a predetermined range. The present invention is based on this finding.

According to one embodiment of the present invention, there is provided a method for forming a substantially uniform paint coating having a targeted dry thickness of 100 μm or more on a surface of an article, using a paint having a coloring pigment content of 0.01-3 volume % based on solid paint components as a thickness-determining paint, the coloring pigment content of the thickness-determining paint being adjusted to meet the following conditions:

(a) a color difference between the thickness-determining paint and the article is 20 or more,

(b) a color difference between a paint coating having the targeted dry thickness and a paint coating having a dry thickness less than (targeted dry thickness - 50) μm is 2 or more, and

(c) a color difference between a paint coating having the targeted dry thickness and a paint coating having a dry thickness more than (targeted dry thickness + 50) μm is less than 1.

According to another embodiment of the present invention, there is provided a method for forming a substantially uniform, multi-layer paint coating comprising a topcoat having a targeted dry thickness of 100 μm or more and an undercoat immediately below the topcoat, the topcoat being formed from a first thickness-determining paint having a coloring pigment content of 0.01-3 volume % based on solid paint components, and the undercoat being formed from a shop primer and/or a second thickness-determining paint having a coloring pigment content of 0.01-3 volume % based on solid paint components, the first thickness-determining paint having a different color from that of the second thickness-determining paint, the coloring pigment content of the first thickness-determining paint being adjusted to meet the following conditions:

(a) a color difference between the topcoat and the undercoat is 20 or more,

(b) a color difference between a paint coating having a targeted dry thickness and a paint coating having a dry thickness less than (targeted dry thickness - 50) μm is 2 or more, and

(c) a color difference between a paint coating having a targeted dry thickness and a paint coating having a dry thickness more than (targeted dry thickness + 50) μm is less than 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be explained in detail below.

[1] Thickness-determining paint

(A) Binder resins

The binder resins for the thickness-determining paint are preferably (1) epoxy resins, and/or (2) epoxy resins modified with coal tar, pitch or petroleum resins. In addition, alkyd resins, acrylic resins, vinyl chloride resins, chlorinated olefin resins, chlorinated rubbers, vinyl acetate resins, etc. may also be used as binder resins.

(1) Epoxy resins

The epoxy resins may be in a solid type or a liquid type which has conventionally been used, and their examples include bisphenol-type epoxy resins, which are resins based on condensation units of bisphenol compounds such as bisphenol A, F, B or halogen derivatives thereof and epihalohydrin. Particularly preferable are diglycidyl ethers of bisphenol A, diglycidyl ethers of bisphenol F, phenol-novolak type epoxy resins, adducts of bisphenol compounds and alkylene oxides, etc. Also, epoxy resins modified with carboxylic acids described in Japanese Patent Laid-Open No. 63-30569, epoxy

resins modified with amines described in Japanese Patent Laid-Open No. 63-30568, epoxy resins modified with phosphoric acid described in Japanese Patent Laid-Open No. 61-91217 may be used.

(1) Modified epoxy resins

In place of or together with the epoxy resins, epoxy resins modified with coal tar, pitch or petroleum resins may also be used.

(a) Coal tar or pitch

The coal tar or pitch preferably contains large amounts of polycyclic aromatic polymer substances soluble in organic solvents in addition to free carbon. The coal tar or pitch preferably has a softening point of 50-150°C. When the softening point is less than 50°C, the resulting coating is likely to be sticky. Oh the other hand, when the softening point is higher than 150°C, the modified epoxy resins are solidified. Those satisfying such conditions include α-bitumen, β-bitumen, γ-bitumen, etc. The coal tar or pitch may be used, if necessary, in a state dissolved in small amounts of organic solvents (aromatic solvents such as xylene, toluene, etc., ester solvents such as ethyl acetate, butyl acetate, etc.).

(b) Petroleum resins

The petroleum resins are products obtained by polymerizing diolefins or monoolefins by-produced in the cracking of petroleum oil without isolation. The petroleum resins are classified into C_5 petroleum resins, C_9 petroleum resins, etc.

(c) Modification

The modification of the epoxy resins can be achieved by a method of mixing the epoxy resins with coal tar, pitch or petroleum resins at room temperature, or a method of reacting them at 80-150°C so that part of epoxy groups are opened. The amount of coal tar, pitch

or petroleum resins in the modified epoxy resins may generally be 10-500 parts by weight per 100 parts by weight of the epoxy resins.

(B) Curing agents

The curing agents for the epoxy resins or the modified epoxy resins are preferably amines, polyamides or polyisocyanate compounds, which may be combined.

(1) Amine curing agents

Preferred examples of the amine curing agents include linear aliphatic polyamines such as diethylenetriamine, triethylenetetramine, ethylaminopropylamine, etc.; alicyclic polyamines; aliphatic polyamine adducts; ketimines; modified aliphatic polyamines; polyamide amines; aromatic amines; modified aromatic amines; aromatic polyamines such as diaminodiphenylmethane, etc.; modified aromatic polyamines; etc.

(2) Polyamide curing agents

Preferred examples of the polyamide curing agents include aliphatic polyamides formed by the polycondensation of polycarboxylic acids and polyamines; aromatic polyamides formed by introducing aromatic rings into the above aliphatic polyamides; aliphatic polyamide adducts; aromatic polyamide adducts; etc.

(3) Polyisocyanate compound curing agents

Preferred examples of the polyisocyanate compound curing agents include aliphatic polyfunctional isocyanates such as hexamethylene diisocyanate (HMDI); alicyclic polyfunctional isocyanates such as isophorone diisocyanate (IPDI); polyisocyanate compounds such as diphenylmethane-4,4′-diisocyanate (MDI) and hydrogenated MDI, etc.; and blocked polyisocyanate compounds formed

by partially or completely blocking functional groups of these polyisocyanate compounds.

(C) Pigments

The coloring components affecting the hue and brightness of the thickness-determining paint are mainly coloring pigments. Body pigments and anti-corrosive pigments also affect the hue and brightness of the thickness-determining paint, and the anti-corrosive pigments are preferable because of anti-corrosive effects on vessels, etc.

(1) Coloring pigments

The coloring pigments which may be used in the present invention include carbon black, titanium dioxide, basic lead carbonate, graphite, zinc sulfide, zinc oxide, chromium oxide, yellow nickel titanium, yellow chromium titanium, yellow iron oxide, red iron oxide, black iron oxide, phthalocyanine blue, phthalocyanine green, ultramarine blue, quinacridone, red or yellow azo pigments. Because titanium dioxide greatly affects the hue and brightness of the thickness-determining paint and turns a paint coating into a pale color, titanium dioxide is preferable for use alone or in combination with other pigments.

(2) Body pigments

The body pigments which may be used in the present invention include talc, clay, calcium carbonate, magnesium carbonate, barium sulfate, silicic acid, silicate, aluminum oxide hydrate, calcium sulfate, etc. Among them, talc is preferable.

(3) Anti-corrosive pigments

The anti-corrosive pigments are preferably those used for heavy duty protective coatings, and preferred examples of such anti-

corrosive pigments are metal compounds such as zinc phosphate, trilead tetroxide, basic lead sulfate, lead suboxide, lead cyanamide, calcium zinc cyanamide, zinc molybdate, aluminum molybdate, basic lead chromate, zinc chromate, strontium chromate, barium chromate, etc.

(D) Amounts of components

(1) Binder resin and curing agent

The amount of the curing agent is preferably 5-200 parts by weight on a solid basis per 100 parts by weight of the binder resin. When the amount of the curing agent is less than 5 parts by weight, the resultant paint coating has a low cross-linking density, thus being poor in hardness, weather resistance, corrosion resistance, heat resistance, water resistance, etc. Oh the other hand, when the amount of the curing agent exceeds 200 parts by weight, the resultant paint coating becomes brittle. The preferred weight ratio of the curing agent to the binder resin is 20/100-60/100.

(2) Pigments

The total amount of the pigments is within a range of 10-60 volume % based on solid paint components. The preferred total amount of the pigments is 15-45 volume %. Since some binder resins have slight color, the total amount of the pigments is adjusted depending on the types of the binder resins.

(a) Coloring pigment

Since the thickness-determining paint should have a relatively small power of hiding an underlying surface, the thickness-determining paint should contain a small amount of coloring pigments. Specifically, the total amount of the coloring pigments is 0.01-3 volume % based on solid paint components. When the total amount of the

coloring pigments is less than 0.01 volume %, the thickness-determining paint provides so small hiding power that there arises substantially no color difference between the paint coating and the article even in a thickness of about 100 μm, failing to carry out the determination of the thickness of the resultant paint coating. Oh the other hand, when the total amount of the coloring pigments exceeds 3 volume %, the thickness-determining paint shows too much hiding power, resulting in disappearance of color difference before reaching the targeted dry thickness. In a case where titanium dioxide is used as a coloring pigment alone or in combination with other coloring pigments, the total amount of the coloring pigments is preferably within a range of 0.1-3 volume %.

(b) Body pigment, anti-corrosive pigment

The amount of the body pigment is preferably 0-59.99 volume % based on solid paint components. When the amount of the body pigment exceeds 59.99 volume %, the thickness-determining paint loses film-forming properties. The amount of the anti-corrosive pigment is preferably 0-10 volume % based on solid paint components. Even though the amount of the anti-corrosive pigment exceeds 10 volume %, further improvement in anti-corrosive effects cannot be achieved, resulting in decrease in the amount of the body pigment accordingly, which undesirably leads to increase in paint cost. When the body pigment and/or the anti-corrosive pigment is added, the coloring pigment is preferably within a range of 0.3-7 volume % per 100 volume % of all pigments.

(E) Other components

The thickness-determining paint of the present invention may contain organic solvents, additives, etc. in addition to the binder resins, curing agents and pigments.

(1) Organic solvents

Organic solvents or mixtures thereof which are widely used for paints may be used in the present invention. Preferred examples of the organic solvents include aromatic hydrocarbons such as toluene, xylene, etc.; aliphatic hydrocarbons such as n-hexane, heptane, etc.; petroleum fractions having various boiling points containing mainly aliphatic hydrocarbons and slightly aromatic hydrocarbons; esters such as butyl acetate, acetylene glycol diacetate, 2-ethoxyethyl acetate; ketones such as methyl isobutyl ketone, etc.; alcohols such as butyl alcohol, etc.; ethers such as ethylene glycol monobutyl ether, etc.

(2) Additives

The thickness-determining paint may further contain usual ultraviolet absorbers, surface adjusters, viscosity modifiers, anti-sagging agents, leveling agents, pigment dispersants, plasticizers, defoamers, etc.

[2] Color difference

The thickness-determining paint should meet the following conditions:

(a) a color difference between the thickness-determining paint and the article is 20 or more,

(b) a color difference between a paint coating having a targeted dry thickness and a paint coating having a dry thickness less than (targeted dry thickness - 50) μm is 2 or more, and

(c) a color difference between a paint coating having the targeted dry thickness and a paint coating having a dry thickness more than (targeted dry thickness + 50) μm is less than 1.

In the case of a multi-layer paint coating, the above conditions are modified to read the article as "undercoat." The measurement of color difference is carried out by a generally know method using a colorimeter such as an SM color computer (SM-7CH, manufactured by Suga Test Instruments Co., Ltd.).

(1) Color difference from article

When the color difference between the thickness-determining paint and the article to be coated is less than 20, it becomes difficult to observe the change of color difference from the article by the naked eye as the thickness of the thickness-determining paint coating nears the targeted thickness. To make easy the observation of the change of color difference by the naked eye, it is preferable that the color difference between the thickness-determining paint and the article is 35 or more.

(2) Color difference from paint coating of dry thickness less than (targeted dry thickness - 50) μm

Because the paint coating of a dry thickness less than (targeted dry thickness - 50) μm is a paint coating before completion, it would be impossible to check whether or not the paint coating has reached the targeted thickness, unless there is at least slight color difference between the paint coating being formed and a paint coating of the targeted dry thickness. Accordingly, it is necessary that the color difference between a paint coating having the targeted dry thickness and a paint coating having a dry thickness less than (targeted dry thickness - 50) μm is 2 or more. If the color difference is too large

at a time immediately before the completion of painting, however, the article would not be fully hidden even by a paint coating of the targeted dry thickness, leaving remarkable mottle on the painted surface. Thus, the upper limit of the color difference is preferably 10, more preferably 5.

(2) Color difference from paint coating of dry thickness more than (targeted dry thickness + 50) μm

Because the paint coating of a dry thickness more than (targeted dry thickness + 50) μm is a paint coating having a thickness exceeding the targeted thickness, the color difference from the paint coating of the targeted dry thickness should be as small as possible. Accordingly, it is necessary that the color difference between a paint coating having the targeted dry thickness and a paint coating having a dry thickness more than (targeted dry thickness + 50) μm is less than 1. The preferred color difference is less than 0.5.

[3] Coating method

The thickness-determining paint of the present invention may be coated by (1) a method of directly applying the thickness-determining paint to a surface of the article, (2) a method of applying the thickness-determining paint to a surface of the article after application of a shop primer and/or a thickness-determining paint of a different color, etc. In any case, the application of the thickness-determining paint is carried out while observing the change of color difference between the paint coating being formed and the article until the resultant paint coating reaches the targeted thickness. Specifically, the change of color difference between the paint coating being formed and the article or an undercoat (a shop primer layer or a paint coating of a different color) is observed by the naked eye while the resultant

thickness-determining paint coating is still wet, in order to check whether or not the resultant thickness-determining paint coating has reached the targeted thickness. Because the change of color difference does not depend on the state (wet or dry) of the paint coating, the results of observation in a wet state are applicable to a dry paint coating without modification.

(1) Direct coating

The articles usable in the present invention may be untreated steel, blasted steel, acid-treated steel, zinc-plated steel, stainless steel, aluminum or its alloy, copper or its alloy, etc. These steel or nonferrous articles may have weld lines.

(2) Coating of shop primer and/or thickness-determining paint of different color

Shop primers which may be used in the present invention include:

(a) a primary anti-corrosive paint composition comprising an initial condensate of a hydrolyzate of tetraalkoxy silicate, a solvent-dispersed, acidic colloidal silica, and zinc powder (Japanese Patent Laid-Open No. 60-235871);

(b) an anti-corrosive paint composition comprising zinc alloy powder having a melting point higher than that of zinc and an electric potential lower than that of iron (Japanese Patent Laid-Open No. 60-235872);

(c) a primary anti-corrosive paint composition comprising a binder and spherical zinc powder having an average diameter of 5-10 μm measured by a light transmission sedimentation method, zinc powder of 2 μm or more being 95 volume % or more per the total amount of the zinc powder, the amount of

zinc powder being 20-60 parts by volume per 100 parts by volume of the resultant dry paint coating, and the paint coating having a heat resistance of 600°C or higher (Japanese Patent Laid-Open No. 62-141075), or

(d) an anti-corrosive paint composition having a similar formulation to those of the above anti-corrosive paint compositions.

When a shop primer and/or a thickness-determining paint of a different color is coated, a multi-layer paint coating is formed. In this case, the first requirement (a) concerning the color difference the paint coating and the article is altered to a color difference between an upper thickness-determining paint coating (topcoat) and a lower shop primer or thickness-determining paint coating (undercoat). Namely, the topcoat should meet the conditions:

(a) a color difference between the topcoat and the undercoat is 20 or more,

(b) a color difference between a paint coating having a targeted dry thickness and a paint coating having a dry thickness less than (targeted dry thickness - 50) μm is 2 or more, and

(c) a color difference between a paint coating having a targeted dry thickness and a paint coating having a dry thickness more than (targeted dry thickness + 50) μm is less than 1.

The upper thickness-determining paint is preferably near a complimentary color to the shop primer or the underlying thickness-determining paint coating, having a hue range from -20 to - 50 or from + 50 to + 20, assuming that the shop primer or the underlying thickness-determining paint coating has a hue of 0 on a Munsell 100-hue cycle which represents 0 to + 50 counterclockwise and 0 to - 50

clockwise. The closer the colors of the upper and lower thickness-determining paint coatings are to a complimentary color relation, the larger color difference exists between the upper and lower thickness-determining paint coatings. Accordingly, the thickness-determining paint for the upper layer preferably has a hue range of -40 to -50 or +50 to +40 relative to the lower layer.

(3) Coating of topcoat

A topcoat may further by formed on the thickness-determining paint coating of the present invention. Usable for the topcoat are epoxy resin paints, chlorinated rubber paints, vinyl chloride resin paints, alkyd resin paints, silicone alkyd resin paints, acrylic resin paints, urethane resin paints, fluorine resin paints, polyester resin paints, epoxy acrylic resin paints, etc.

The present invention will be explained in further detail by way of the following Examples without intention of restricting the scope of the present invention.

Examples 1-10, Comparative Examples 1, 2

Thickness-determining paints (Paints 1-6) having formulations shown in Table 1 below were prepared. The thickness-determining paints 1-4 were for Examples, and the thickness-determining paints 5 and 6 were for Comparative Examples.

Table 1

Formulation of Thickness-Determining Paint

Components (volume %)	Paint 1	Paint 2	Paint 3
Hue	Gray	Yellow	Blue
Talc	13.81	13.43	13.58
Anti-Corrosive Pigment(1)	2.34	2.34	2.34
Coloring Pigments			
Titanium Oxide(2)	0.25	0.57	0.44
Yellow Iron Oxide(2)	-	0.08	-
Red Iron Oxide(2)	-	-	-
Phthalocyanine Blue(2)	-	-	0.06
Carbon Black(2)	0.02	-	-
Percentage of Coloring Pigments			
Based on SPC(3)	0.47	1.14	0.87
Based on All Pigments	1.64	3.96	3.05
Anti-Sagging Agent(4)	8.14	8.14	8.14
Synthetic Petroleum Resin(5)	14.78	14.78	14.78
EPOXY Varnish(6)	22.73	22.73	22.73
Mixed Solvent (7)	23.17	23.17	23.17
Curing Agent(8)	14.76	14.76	14.76
Total	100.00	100.00	100.00

Note: (1) Zinc molybdate.

(2) Volume % based on the entire volume of the paint.

(3) Solid paint components (nonvolatile components).

(4) Solid component: 20 volume %, volume % including a solvent.

(5) Solid component: 99 volume %, volume % including a solvent.

(6) Bisphenol A epoxy resin varnish (solid component: 75 volume %, volume % including a solvent).

(7) Aromatic hydrocarbon solvent + ketone solvent (weight ratio: 1/1).

(8) Polyamide resin varnish (solid component: 65 volume %, volume % including a solvent).

Table 1 (Continued)

Formulation of Thickness-Determining Paint

Components (volume %)	Paint 4	Paint 5	Paint 6
Hue	Pink	Gray	Yellow
Talc	13.45	12.11	12.17
Anti-Corrosive Pigment(1)	2.34	2.34	2.34
Coloring Pigments			
Titanium Oxide(2)	0.57	1.90	1.90
Yellow Iron Oxide(2)	-	-	0.01
Red Iron Oxide(2)	0.06	-	-
Phthalocyanine Blue(2)	-	-	-
Carbon Black(2)	-	0.07	-
Percentage of Coloring Pigments			
Based on SPC(3)	1.10	3.44	3.34
Based on All Pigments	3.84	12.00	11.60
Anti-Sagging Agent(4)	8.14	8.14	8.14
Synthetic Petroleum Resin(5)	14.78	14.78	14.78
EPOXY Varnish(6)	22.73	22.73	22.73
Mixed Solvent (7)	23.17	23.17	23.17
Curing Agent(8)	14.76	14.76	14.76
Total	100.00	100.00	100.00

Note: (1)-(8) Same as under Table 1.

Using as an article a sand-blasted steel plate coated with 15 μm of a shop primer ("Nippeceramo," manufactured by Nippon Paint Co., Ltd.) and a sand-blasted steel plate without a primer, airless spraying of thickness-determining paints (Paints 1-6) was carried out on each article with a targeted thickness of 200 μm and a targeted dry thickness of 125 μm, and left to stand at room temperature for 24 hours. The resultant six thickness-determining paint coatings were as thick as 50 μm, 75 μm, 100 μm, 125 μm, 150 μm and 175 μm, respectively in terms of dry thickness. Incidentally, a wet thickness was 1.6 times a dry thickness in each thickness-determining paint coating.

Each of the resultant thickness-determining paint coatings was measured with respect to a color difference from the shop primer and a color difference ΔE from a paint coating of the targeted dry thickness by the above colorimeter. Also, the conditions of the resultant thickness-determining paint coatings were observed by the naked eye in a wet state as well as in a dry state. The results are shown in Table 2.

Table 2

Properties	Example 1		Example 2		Example 3	
Shop Primer						
Hue	Gray		Green		Brown	
Munsell Value(1)	7.1GY 5.9/0.5		9.3GY 4.5/1.0		0.3YR 4.6/3.5	
Thickness-Determining Paint						
Type	Paint 1		Paint 1		Paint 1	
Hue	Gray		Gray		Gray	
Munsell Value(1)	4.4G 7.1/0		4.4G 7.1/0		4.4G 7.1/0	
Color Difference(2)	23		30		36	
Difference in Munsell(3)	0 to -10		0 to -10		-30 to -40	
Thickness(4)	ΔE	Obs.(5)	ΔE	Obs.(5)	ΔE	Obs.(5)
80/50 μm	4.6	○	5.0	○	5.1	○
120/75 μm	2.0	□	2.1	□	2.1	□
160/100 μm	1.2	△	1.3	△	1.3	△
200/125 μm	0.0	×	0.0	×	0.0	×
240/150 μm	0.5	×	0.5	×	0.4	×
280/175 μm	0.7	×	0.7	×	0.7	×

Note: (1) Munsell notation (hue, brightness/chromaticness).

(2) Color difference between the shop primer and the thickness-determining paint.

(3) Difference in a Munsell hue cycle between the shop primer and the thickness-determining paint.

(4) Wet thickness/dry thickness.

(5) Observation by the naked eye on both wet coating and dry coating. The conditions of each coating were evaluated by the following standards:

◎: The shop primer layer was entirely visible through the thickness-determining paint coating.

○: The shop primer layer was considerably visible through the thickness-determining paint coating.

□: The shop primer layer was slightly visible through the thickness-determining paint coating.

△: The shop primer layer was substantially hidden by the thickness-determining paint coating except for limited visibility.

×: The shop primer layer was completely hidden by the thickness-determining paint coating.

Table 2 (Continued)

Properties	Example 4		Example 5		Example 6	
Shop Primer						
Hue	Gray		Green		Brown	
Munsell Value(1)	7.1GY 5.9/0.5		9.3GY 4.5/1.0		0.3YR 4.6/3.5	
Thickness-Determining Paint						
Type	Paint 2		Paint 2		Paint 2	
Hue	Yellow		Yellow		Yellow	
Munsell Value(1)	2Y 7.3/8.0		2Y 7.3/8.0		2Y 7.3/8.0	
Color Difference(2)	38		46		45	
Difference in Munsell(3)	+10 to +20		+10 to +20		-10 to -20	
Thickness(4)	ΔE	Obs.(5)	ΔE	Obs.(5)	ΔE	Obs.(5)
80/50 μm	5.0	◎	7.0	◎	7.0	◎
120/75 μm	2.8	○	2.3	○	2.3	○
160/100 μm	1.4	△	1.4	△	1.4	△
200/125 μm	0.0	×	0.0	×	0.0	×

240/150 μm	0.2	×	0.2	×	0.3	×
280/175 μm	0.5	×	0.5	×	0.6	×

Note: (1)-(5) Same as under Table 2.

Table 2 (Continued)

Properties	Example 7		Example 8		Example 9	
Shop Primer						
Hue	Gray		Gray		-(6)	
Munsell Value(1)	7.1GY 5.9/0.5		7.1GY 5.9/0.5		7.5Y 5.6/0.1	
Thickness-Determining Paint						
Type	Paint 3		Paint 4		Paint 1	
Hue	Blue		Pink		Gray	
Munsell Value(1)	7.7B 6.1/6.6		9.4R 6.4/5.0		4.4G 7.1/0	
Color Difference(2)	31		25		23	
Difference in Munsell(3)	-30 to -40		+20 to +30		-10 to -20	
Thickness(4)	ΔE	Obs.(5)	ΔE	Obs.(5)	ΔE	Obs.(5)
80/50 μm	4.5	◎	4.7	◎	4.8	○
120/75 μm	2.1	□	2.3	□	2.2	□
160/100 μm	1.1	△	1.3	△	1.2	△
200/125 μm	0.0	×	0.0	×	0.0	×
240/150 μm	0.3	×	0.3	×	0.5	×
280/175 μm	0.6	×	0.5	×	0.8	×

Note: (1)-(5) Same as under Table 2.

(6) Uncoated steel plate. The Munsell value of the article was derived from the color of the sand-blasted steel plate.

Table 2 (Continued)

Properties	Example 10		Com. Ex. 1		Com. Ex. 2	
Shop Primer						
Hue	-(6)		Gray		Gray	
Munsell Value(1)	7.5Y 5.6/0.1		7.1GY 5.9/0.5		7.1GY 5.9/0.5	
Thickness-Determining Paint						
Type	Paint 2		Paint 5		Paint 6	
Hue	Yellow		Gray		Yellow	
Munsell Value(1)	2Y 7.3/8.0		5.5BG 5.7/0.1		2.7Y 7.8/9.2	
Color Difference(2)	39		5		39	
Difference in Munsell(3)	0 to +10		-10 to -20		+10 to +20	
Thickness(4)	ΔE	Obs.(5)	ΔE	Obs.(5)	ΔE	Obs.(5)
80/50 μm	5.1	◎	0.3	×	0.3	×
120/75 μm	2.9	○	0.2	×	0.2	×
160/100 μm	1.4	△	0.1	×	0.1	×
200/125 μm	0.0	×	0.0	×	0.0	×
240/150 μm	0.2	×	0.1	×	0.1	×
280/175 μm	0.6	×	0.1	×	0.1	×

Note: (1)-(6) Same as under Table 2 (Continued).

Examples 11-16, Comparative Example 3

Combining thickness-determining paints of different colors obtained in the above Examples and Comparative Examples, an undercoat and a topcoat were formed by an airless spraying method and left to stand at room temperature for 24 hours. The dry thickness of the undercoat was 125 μm, and the targeted dry thickness of the topcoat was 125 μm. The thickness of the topcoat immediately after painting and the dry thickness of the topcoat were 80/50 μm, 120/75

μm, 160/100 μm, 200/125 μm, 240/150 μm, and 280/175 μm, respectively.

Each of the resultant topcoats was measured with respect to a color difference from the undercoat and a color difference ΔE from a paint coating of the targeted dry thickness by the above colorimeter. Also, the conditions of the resultant topcoats were observed by the naked eye. The results are shown in Table 3.

Table 3

Properties	Example 11		Example 12		Example 13	
Undercoat(1)						
Type	Paint 1		Paint 2		Paint 2	
Hue	Gray		Yellow		Yellow	
Munsell Value(2)	4.4G 7.1/0		2Y 7.3/8.0		2Y 7.3/8.0	
Topcoat(3)						
Type	Paint 2		Paint 1		Paint 3	
Hue	Yellow		Gray		Blue	
Munsell Value(2)	2Y 7.3/8.0		4.4G 7.1/0		7.7B 6.1/6.6	
Color difference(4)	35		35		61	
Difference in Munsell(5)	+20 to +30		-20 to -30		-40 to -50	
Thickness(6)	ΔE	Obs.(7)	ΔE	Obs.(7)	ΔE	Obs.(7)
80/50 μm	5.0	◎	4.7	◎	7.1	◎
120/75 μm	2.8	□	2.5	□	2.9	○
160/100 μm	1.4	△	1.1	△	1.6	△
200/125 μm	0.0	×	0.0	×	0.0	×
240/150 μm	0.2	×	0.3	×	0.4	×
280/175 μm	0.5	×	0.6	×	0.6	×

Note: (1) Thickness-determining paint coating having a dry thickness

of 125 μm.

(2) Munsell notation (hue, brightness/chromaticness).

(3) Thickness-determining paint coating having a dry thickness of 50-175 μm

(4) Color difference between the undercoat and the topcoat.

(5) Difference in a Munsell hue cycle between the undercoat and the topcoat.

(6) Wet thickness/dry thickness.

(7) Observation by the naked eye by the same standards as under Table 3.

Table 3 (Continued)

Properties	Example 14		Example 15		Example 16	
Undercoat(1)						
Type	Paint 3		Paint 2		Paint 4	
Hue	Blue		Yellow		Pink	
Munsell Value(2)	7.7B 6.1/6.6		2Y 7.3/8.0		9.4R 6.4/5.0	
Topcoat(3)						
Type	Paint 2		Paint 4		Paint 3	
Hue	Yellow		Pink		Blue	
Munsell Value(2)	2Y 7.3/8.0		9.4R 6.4/5.0		7.7B 6.1/6.6	
Color difference(4)	61		26		46	
Difference in Munsell(5)	+40 to +50		+10 to +20		+40 to +50	
Thickness(6)	ΔE	Obs.(7)	ΔE	Obs.(7)	ΔE	Obs.(7)
80/50 μm	7.5	◎	4.6	◎	7.1	◎
120/75 μm	3.0	○	2.2	□	2.4	□
160/100 μm	1.7	△	1.3	△	1.4	△
200/125 μm	0.0	×	0.0	×	0.0	×

240/150 μm	0.4	×	0.3	×	0.3	×
280/175 μm	0.7	×	0.4	×	0.5	×

Note: (1)-(7) Same as under Table 3.

Table 3 (Continued)

Properties	Com. Ex. 3	
Undercoat(1)		
Type	Paint 5	
Hue	Gray	
Munsell Value(2)	5.5BG 5.7/0.1	
Topcoat(3)		
Type	Paint 6	
Hue	Yellow	
Munsell Value(2)	2.7Y 7.8/9.2	
Color difference(4)	33	
Difference in Munsell(5)	+30 to +40	
Thickness(6)	ΔE	Obs.(7)
80/50 μm	0.5	×
120/75 μm	0.3	×
160/100 μm	0.1	×
200/125 μm	0.0	×
240/150 μm	0.1	×
280/175 μm	0.1	×

Note: (1)-(7) Same as under Table 3.

As described above in detail, the method for forming a paint coating of the present invention makes it possible for a painting operator to determine by the naked eye during painting operation such

as airless spraying whether or not a paint coating has reached a targeted dry thickness, thereby forming a paint coating having a targeted dry thickness surely and easily. Also, because the observation of the resultant paint coating can be carried out by the naked eye while the paint coating is still wet, it is possible for a painting operator to make quick determination in situ on whether or not the paint coating has reached a targeted dry thickness, contributing to improvement in efficiency of painting operation.

Because troublesome measurement of a paint coating thickness is not necessary in the method of the present invention, drastic decrease in the number of painting steps can be achieved, and it is possible to avoid the formation of a too thick paint coating, leading to the reduction of paint consumption. Further, the method of the present invention can provide a substantially uniform, anti-corrosive paint coating in an exact thickness even on regions such as interiors of vessels which are extremely difficult to be coated.

WHAT IS CLAIMED IS:

1. A method for forming a substantially uniform paint coating having a targeted dry thickness of 100 μm or more on a surface of an article, using a paint having a coloring pigment content of 0.01-3 volume % based on solid paint components as a thickness-determining paint, the coloring pigment content of said thickness-determining paint being adjusted to meet the following conditions:

(a) a color difference between said thickness-determining paint and said article is 20 or more,

(b) a color difference between a paint coating having said targeted dry thickness and a paint coating having a dry thickness less than (targeted dry thickness - 50) μm is 2 or more, and

(c) a color difference between a paint coating having said targeted dry thickness and a paint coating having a dry thickness more than (targeted dry thickness + 50) μm is less than 1.

2. The method for forming a substantially uniform paint coating according to claim 1, wherein said coloring pigment in said thickness-determining paint comprises titanium oxide and at least one other coloring pigment, the total amount of said titanium oxide and said at least one other coloring pigment being 0.1-3 volume % based on solid paint components.

3. The method for forming a substantially uniform paint coating according to claim 1 or 2, wherein said article is coated with a shop primer and/or a thickness-determining paint of a different color as an undercoat.

4. The method for forming a substantially uniform paint coating according to claim 3, wherein said thickness-determining paint coated on said undercoat has a hue range from +20 to + 50 or from - 50

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to - 20, assuming that said undercoat has a hue of 0 on a Munsell 100-hue cycle which represents 0 to + 50 counterclockwise and 0 to - 50 clockwise.

5. The method for forming a substantially uniform paint coating according to claim 4, wherein said thickness-determining paint coated on said undercoat has a hue range from +40 to + 50 or from - 40 to - 50.

6. The method for forming a substantially uniform paint coating according to any one of claims 1-5, wherein said article is a steel plate.

7. The method for forming a substantially uniform paint coating according to claim 6, wherein said steel plate has a weld line.

8. The method for forming a substantially uniform paint coating according to any one of claims 1-7, wherein said thickness-determining paint comprises at least one binder resin selected from the group consisting of epoxy resins and epoxy resins modified with coal tar, pitch or petroleum resins, and at least one curing agent selected from the group consisting of amines, polyamides and polyisocyanate compounds.

9. The method for forming a substantially uniform paint coating according to any one of claims 1-8, wherein the color difference between said thickness-determining paint and said article is 35 or more.

10. The method for forming a substantially uniform paint coating according to any one of claims 1-9, further satisfying the following conditions:



(b) a color difference between a paint coating having said targeted dry thickness and a paint coating having a dry thickness less than (targeted dry thickness - 50) μm is 3 or more, and

(c) a color difference between a paint coating having said targeted dry thickness and a paint coating having a dry thickness more than (targeted dry thickness + 50) μm is less than 0.5.

11. The method for forming a substantially uniform paint coating according to any one of claims 1-10, wherein the change of color difference is observed while said thickness-determining paint coating being formed is still wet, to determine whether or not said thickness-determining paint coating has reached a predetermined thickness.

12. A method for forming a substantially uniform, multi-layer paint coating comprising a topcoat having a targeted dry thickness of 100 μm or more and an undercoat immediately below said topcoat, said topcoat being formed from a first thickness-determining paint having a coloring pigment content of 0.01-3 volume % based on solid paint components, and said undercoat being formed from a shop primer and/or a second thickness-determining paint having a coloring pigment content of 0.01-3 volume % based on solid paint components, said first thickness-determining paint having a different color from that of said second thickness-determining paint, said coloring pigment content of said first thickness-determining paint being adjusted to meet the following conditions:

(a) a color difference between said topcoat and said undercoat is 20 or more,



(b) a color difference between a paint coating having a targeted dry thickness and a paint coating having a dry thickness less than (targeted dry thickness - 50) μm is 2 or more, and

(c) a color difference between a paint coating having a targeted dry thickness and a paint coating having a dry thickness more than (targeted dry thickness + 50) μm is less than 1.

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