plate thickness etc. The cap is low relative to a typical step of a lap joint, and the shape of the cap of a correctly made welding seam is normally smooth and round.

For applications where a particularly nice appearance is desired, e.g. above waterline of expensive superyachts and pleasure crafts, the cap of welding seams over the waterline is sometimes grinded until it is in level with the surface of the steel plates or the entire hull is plastered over the water line to cover surface irregularities. This process is purely for aesthetic reasons, and may be undesirable from a structural perspective.

The welding process, while providing a strong and simple way of joining plates, has certain disadvantages as compared to a non-heating assembly process such as riveting etc. Due to the intensive heat input, a heat affected zone (HAZ) is created on both sides of the seam. In this zone, the structure of the metal may have changed. Accordingly, it is an important aspect in vessel manufacturing to ensure suitable protection particularly at the welding seam and HAZ.

To ensure the layer thickness of the coating, the welding seams are often stripe coated by brush before the entire welded vessel structure is spray painted. This process is time consuming and expensive.

In addition to the aspects of the HAZ, fouling is sometimes experienced in connection with welding seams under the waterline. Without being bound by theory, it is believed that such fouling can be caused by anchor points formed by corners of the welding or flow conditions in the vicinity of the welding, and typically, the fouling can be experienced even when antifouling is applied with caution.

SUMMARY

According to a first aspect, the present disclosure refers to a method for improving a fluid dynamic profile of a marine vessel, the method comprising the

step of identifying at least one welding seam forming a cap protruding above an underwater surface of the vessel, and amending a profile of the vessel by applying a fairing to the underwater surface and to the welding seam, wherein the fairing is applied to the underwater surface and to the welding seam by applying unsolidified filler to the underwater surface and to the welding seam, shaping the filler, and solidifying the filler.

According to a second aspect, the present disclosure refers to a marine vessel having a hull forming a welding seam extending along an underwater surface and forming a cap projecting a seam-height in an outwards direction away from the underwater surface, the vessel further comprising a fairing extending in an axial direction and projecting a fairing-height in the outwards direction and covering at least a part of the welding seam and underwater surface.

According to a third aspect, the present disclosure refers to a coating system for an underwater surface of a vessel, the coating system comprising at least one layer of a primer applied to the underwater surface, a fairing configured to amend the profile of the under water-surface at a welding seam and applied in accordance with the second aspect, the fairing being applied to the primer, and a top coat applied to the fairing

To reduce drag and thereby to reduce fuel consumption, or potentially increase the speed of a vessel and/or to protect a welding seam and associated HAZ of a welded vessel hull, and/or to reduce the cost in coating of welded vessels and/or

to improve the coating quality, and/or to reduce fouling, the present disclosure provides a method according to the first aspect and a vessel according to the second aspect and a coating system according to the third aspect.

As mentioned previously, the welding seams form caps which are smoothly rounded and therefore already have a shape which is superior to a lap joint relative to fluid dynamic properties. According to the first aspect, a method is provided for amending a profile of the vessel at the welding seam by applying a fairing. This may reduce the drag further. Additionally, the amending of the profile changes the flow condition around the welding seam and can thereby reduce fouling.

Herein, the term fairing is considered to cover an element located against the welding seam and against the underwater surface thereby amending the profile of the vessel at that welding seam. Additionally, the fairing may protect the welding seam and the HAZ, particularly against ingress of water which could lead to corrosion at the welding seam. Additionally, the change of the profile may change the antifouling properties at the welding seam.

In a first group of examples, the fairing may be constituted by a pre-defined element which is attached to the welding seam, e.g. a rigid element or a soft bendable element, e.g. in the form of adhesive tape, an extruded profile, e.g. of a polymer material, or a rigid element, e.g. of composite material, metal, wood, or plastic. In this group of examples, the method comprises the step of attaching the fairing, e.g. adhesively to the underwater surface and/or to the welding seam, and optionally to prepare the surface by cleaning and/or primer coating the surface prior to the attaching of the fairing, and optionally by providing layers of coating on the fairing, e.g. a fouling control surface coating system.

The pre-defined element may be supplied e.g. on a roll, which is unrolled along the welding seam. It could be attached to the underwater surface by use of an adhesive. It could be applied to cover the welding seam completely, or it could be attached, such that only a part of the welding seam is covered. It could

extend along only one side of the welding seam, or it could extend along both sides of the welding seams.

The fairing could be solid, or it could be hollow or porous to reduce weight and material consumption.

Particularly, the fairing may be applied to the completely finished welding seam, i.e. after the welding process is completed, and preferably, the fairing is applied after the welded material has cooled down to a normal temperature.

Particularly, the fairing may be maintained on the surface throughout the lifetime of the vessel and particularly it remains on the underwater surface of the vessel while the vessel is operated such that it can reduce the fuel consumption by improving the hydrodynamic properties of the vessel.

In a second group of examples, the fairing is constituted by filler and the method comprises the step of applying the filler in an unsolidified condition to the underwater surface, shaping the filler on the welding seam, and solidifying the filler to define a fairing.

Also relative to the second group of examples, the fairing is applied to the completely finished welding seam, e.g. after the welded material has cooled down to a normal temperature, and maintained during operated of the vessel to improve the hydrodynamic properties of the vessel.

In the following, the invention will be described by reference to the first and the second group of examples, some features are, however, relevant only for one of the first and second groups of examples, and in that case, the disclosure applies for the relevant group. Generally, whenever reference is made to fairing, the feature is relevant for both groups of examples, and when reference is made to filler, the feature is relevant to the second group of examples.

In one example, the fairing is arranged symmetrical about the welding seam.

In one example, the welding seam is completely encapsulated in the fairing, and in one example, the fairing has a width transverse to the longitudinal direction in the range of at least 10 cm or even 20 cm corresponding to at least 10 or 20 times the height of a 1 cm high welding seam.

The fairing could be arranged directly on the uncoated welding seam, and may it-self have primer properties. The fairing may also be attached to a primed surface, i.e. the welding seam and/or the underwater surface could be coated with a primer before the fairing is applied.

In the second group of examples, the filler could be applied directly to the uncoated surface of the welding seam or on the surface of a primer, and the filler may be selected such that it has protective characteristics itself and thereby protect the welding seam and the surrounding area. If the filler is applied on primer, the primer may effectively bind to the steel surface and to the filler. The primer may be more low viscous than the filler to therefore allow the primer to fill out irregularities in the steel surface and smoothen the surface prior to the application of a thicker and more viscous filler.

The fairing could be covered with a coating, e.g. an antifouling surface coating system, e.g. a multilayer antifouling coating system.

The fairing may be made from a material providing antifouling properties and thereby constitute a part of a fouling control surface coating system.

The fairing may, irrespective of any antifouling property, reduce fouling by amending the flow conditions at the welding seam.

Welding seams on the underwater surface may have different impact on the drag resistance depending on the location and direction of the welding seam relative to the sailing direction. In the following, the term “longitudinal direction”

The application of a fairing only to selected welding seams has a further advantage of allowing unhindered inspection of those welding seams not being covered.

In this process, the fairing may subsequently be covered with the same fouling control surface coating system as that used for covering the welding seams extending in the sailing direction.

In one example, the fairing will be applied on top of a primer, e.g. an anticorrosive primer. The anticorrosive primer will be applied on the entire hull directly to the underwater surface. The surface of the hull could be a steel surface, e.g. treated by abrasive blasting or the existing surface could be an aged paint surface of an old hull. Following the application of the anticorrosive primer, the fairing will be applied at the welding seam area as described above. On top of the fairing, a top coat may be applied. The top coat could comprise one or more layers of a fouling control surface coating system. Additionally, one or more layers of a tie-coat could be applied below the top coat.

In one example, the anticorrosive primer system is an epoxy-type anticorrosive primer, and the fairing is made from an epoxy-containing material, e.g. from an epoxy based filler. The tie-coat will be an epoxy, silicone, or polyurethane based tie-coat, and the fouling control surface coating system comprises one or more antifouling coats as described below, or a silicone system, where the silicone system can comprise similar or different layers of silicone coatings. An example of a suitable top coat for fouling control can be found inter alia in the patent publication WO2011076856

In another examples, the fairing will be applied directly to the existing surface of the ship hull. The existing surface could be either an aged coating system or bare steel from e.g. abrasive blasting pre-treatment. On top of the fairing, a layer of anticorrosive primer will be applied, followed by a top coat, e.g. comprising one or more layers of tie-coat and a fouling control surface coating system as described above.

In one examples, the fairing has elastic properties allowing it to deform elastically to thereby improve the ability to adapt to the shape of the hull and to deflect when the hull deflects, e.g. in high waves.

The method of the first aspect may particularly apply to welding seams where two bottom skin panels are joined in a butt joint.

The method may form part of a method for making a hull of a marine vessel, the method comprising the step of arranging edges of at least two bottom skin panels in a butt joint to form adjacent edges, joining the adjacent edges by at least one welding seam forming a cap protruding above an underwater surface of the vessel, and amending a profile of the hull by applying a fairing to the underwater surface and to the welding seam, particularly it may be applied after the welding seam is completely finished and cooled down.

In an example, the invention provides a marine vessel with a welding seam extending on an underwater surface. The welding seam forms a cap projecting a seam-height in an outwards direction away from the underwater surface.

To reduce drag and thus potentially increase speed or reduce fuel consumption, the vessel further comprises a fairing extending in the longitudinal direction and projecting a fairing-height in the outwards direction. The fairing is arranged such that it covers at least a part of the welding seam and preferably completely encapsulates the welding seam. Further, the fairing extends on both sides of the welding seam and thereby covers at least a part of the underwater surface.

Particularly, the fairing may be arranged to at least partly cover welding seams assembling skin panels of the hull in a butt joint.

Preferably, the fairing-height decreases in a width direction along the underwater surface away from the welding seam such that the fairing becomes triangular when seen in a cross-section perpendicular to the longitudinal direction.

The fairing-height may be between 90 and 110 percent of the seam-height such that the welding seam is either completely covered, or such that at most 10 percent of the height of the welding seam is uncovered.

The fairing may terminate in two side edges extending in the longitudinal direction on opposite sides of the welding seam. Preferably, these side edges are parallel to the welding seam, and at least one of the side edges may extend at a distance of at least 5 times the fairing-height from the welding seam, e.g. 6, 7, 8, 9, or 10 times the fairing-height.

The distance from one side edge to the welding seam may equal the distance from the other side edge to the welding seam.

In one examples, the fairing has an outer surface facing away from the underwater surface, the outer surface being convex in a cross-section transverse to the longitudinal direction.

Any of the aspects mentioned relative to the method for improving the fluid dynamic profile may be applied also to the vessel, e.g. the aspect of covering the welding seams at most in the forward half of the vessel with a fairing and leaving the remaining welding seams without fairing.

In an example, the disclosure relates to a coating system for an underwater surface of a vessel, the coating system comprises, in the mentioned order, at least one layer of a primer, e.g. an anticorrosive primer, e.g. based on epoxy and arranged towards the underwater surface, a fairing of the kind described relative to the first aspect of the invention, and a top coat. The top coat could comprise at least one layer of a fouling control surface coating system.

The fairing may particularly be made from a filler, e.g. applied on the primer.

The primer may particularly be an epoxy based primer, it may be low tar, or tar-less, it may have a viscosity below that of the filler, and it may particularly be applied in at least two separate layers.

The filler could particularly be an epoxy based filler, and it may particularly be in a colour different from the colour of the primer and the top coat.

In one example, the top coat comprises one or more layers of a silicone or epoxy based coating, e.g. a fouling control surface coating system as described elsewhere herein.

The fouling control surface coating system may particularly be a self-polishing antifouling binder system, like hydrolysable acrylic binders although not restricted to such. Examples of a particular relevant system include: non-aqueous dispersion binder systems. Such non-aqueous dispersion-type resins and method for their preparation are described in, e.g., US 3,607,821, US 4,147,688, US 4,493,914 and US 4,960,828, Japanese Patent Publication No. 29,551/1973 and Japanese Laid-open Patent Application No. 177,068/1982; specifically, as the shell component constituting the non-aqueous dispersion-type resin, various high-molecular substances soluble in a low-polarity solvent which are described in, e.g., US 4,960,828 (Japanese Laid- open Patent Application No. 43374/1989), can be used.; silylated acrylate binder system, such as those described in EP 0 297 505 B1; metal acrylate binder system, such as those described in e.g. EP 0 471 204 B1, EP 0 342 276 B1, EP 0 779 304 A1, EP 0 204 456 B1 or Japanese Patent Kokai No. 16809/1989; hybrids of silylated acrylate and metal acrylate binder system, such as those described in KR 20140117986; polyoxalate binder system, e.g. as disclosed in WO 2015/114091; zwitterion binder system, e.g. as disclosed in WO 2004/018533 and WO 2016/066567; polyester binder, e.g. as disclosed in WO 2014/010702; hybrids of silylated acrylate, zwitterion binder system, polyester binder system, (natural) rosin, rosin derivatives, disproportionated rosin, partly polymerised rosin, hydrogenated rosin, gum rosin, disproportionated gum rosin, acrylic resins, polyvinyl methyl ether, and vinyl acetate-vinylchloride-ethylene terpolymers. Particularly in combination with a self-polishing fouling control coating system, the fairing may provide improved flow conditions and thus improved self-polishing effect and thus reduced fouling problems.

Among these, it is believed that rosin binder systems, non-aqueous dispersion binder systems, silylated acrylate binder systems, metal acrylate binder systems, hybrids of silylated acrylate and metal acrylate binder systems, polyoxalate binder systems, zwitterion binder systems, hybrids of silylated acrylate, zwitterion binder systems and polyester binder systems, are especially interesting.

In one example, a tie-coat is applied between the fairing and the top coat, e.g. an epoxy, silicone, or polyurethane based tie-coat. The tie-coat could be applied in one or more layers.

LIST OF DRAWINGS

Figs. 1-3 illustrate cross-sectional views of a steel plate under the waterline of a vessel;

Figs. 4-6 illustrate top views of the steel plates;

Fig. 7 illustrates a top view of a bottom surface of a vessel;

Figs. 8a-8e illustrate different profiles of fairings;

Figs. 9-13 illustrate results of different tests, and

Figs. 14-16 illustrate aspects related to CFD simulation.

DESCRIPTION OF EMBODIMENTS

Fig. 1 illustrates steel plate forming an underwater surface of a marine vessel. The outer surface 1, which is in contact with water, is illustrated upwards, and the inner surface 2 faces inwards, e.g. towards ballast tanks etc. The plate is constituted by two separate sheets 3, 4 of metal which are joined by welding. The welding joint forms a cap 5 projecting a seam-height in an outwards

CLAIMS

1. A method for improving a fluid dynamic profile of a marine vessel, the method comprising the step of identifying at least one welding seam forming a cap protruding above an underwater surface of the vessel, and amending a profile of the vessel by applying a fairing to the underwater surface and to the welding seam, wherein the fairing is applied to the underwater surface and to the welding seam by applying unsolidified filler to the underwater surface and to the welding seam, shaping the filler, and solidifying the filler.

2. A method according to claim 1, wherein the filler is applied from a pump into an application tool configured to be moved over the underwater surface and configured to define a shape of the fairing.

3. The method of any of the preceding claims, comprising the step of applying a fairing having a triangular shape forming a lower surface against the underwater surface and two top surfaces extending from a top point above the welding seam and sloping from that top point downwards towards the lower surface.

4. The method of claim 3, comprising the step of applying a fairing having the shape of an isosceles triangle.

5. A method according to any of the preceding claims, wherein the fairing is applied to cover the welding seam and a heat affected zone (HAZ) of the welding seam.

6. A method according to any of the preceding claims, wherein the fairing is applied symmetrically about the welding seam.

7. A method according to any of the preceding claims, wherein the fairing is applied over the welding seam between a primer layer and a topcoat.

8. A method according to any of the preceding claims, wherein the fairing is covered with a fouling control surface coating system.

9. A method according to any of the preceding claims, comprising identifying at least one longitudinal welding seam extending on the underwater surface in a longitudinal direction in which the vessel is designed to sail, identifying at least one transverse welding seam extending on the underwater surface in a transverse direction being transverse to the longitudinal direction, and applying the fairing to the transverse welding seam without applying a fairing to the longitudinal welding seam.

10. A method according to claim 9, wherein the fairing is applied exclusively to welding seams extending in a direction being perpendicular to a longitudinal direction.

11. A method according to any of the preceding claims, wherein the fairing is applied only on a downstream side of the welding seam facing backwards relative to a sailing direction of the vessel.

12. A method according to any of the preceding claims, wherein the fairing is applied at most on welding seams in a forward half part of the underwater surface of the vessel, the forward half part of the underwater surface extending from a front end pointing forward the sailing direction and half the way towards a rear end of the vessel.

13. A method according to any of the preceding claims, wherein the vessel is operated with a speed through water with the fairing applied to the underwater surface and welding seam.

14. A marine vessel having a hull forming a welding seam extending along an underwater surface and forming a cap projecting a seam-height in an outwards direction away from the underwater surface, the vessel further comprising a fairing extending in an axial direction and projecting a fairing-height in the outwards direction and covering at least a part of the welding seam and underwater surface.

15. A vessel according to claim 14, wherein the fairing-height decreases in a width direction along the underwater surface away from the welding seam.

16. A vessel according to claim 14 or 15, wherein the fairing-height is between 90 and 110 percent of the seam-height.

17. A vessel according to any of claims 14-16, wherein the fairing terminates in two side edges extending in the axial direction on opposite sides of the welding seam.

18. A vessel according to claim 17, wherein at least one of the side edges extends at a distance of at least 5 times the fairing-height from the welding seam.

19. A vessel according to claim 17 or 18, wherein the distance from one side edge to the welding seam equals the distance from the other side edge to the welding seam.

20. A vessel according to any of claims 14-19, wherein the fairing has an outer surface facing away from the underwater surface, the outer surface being convex in a cross-section transverse to the axial direction.

21. A coating system for an underwater surface of a vessel, the coating system comprising at least one layer of a primer applied to the underwater surface, a fairing configured to amend the profile of the under water-surface at a welding seam and applied in accordance with any of claims 1-14, the fairing being applied to the primer, and a top coat applied to the fairing.

22. A coating system according to claim 21, further comprising a layer of a tie-coat applied between the fairing and the top coat.

23. A coating system according to claim 21 or 22, wherein the top coat comprises at least one layer of a fouling control surface coating system.