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(54) **METHOD FOR COATING A STEEL SUBSTRATE, AND COATED STEEL SUBSTRATE**

VERFAHREN ZUR BESCHICHTUNG EINES STAHLSUBSTRATS UND BESCHICHTETES
STAHLSUBSTRAT

PROCÉDÉ DE REVÊTEMENT D'UN SUBSTRAT EN ACIER, ET SUBSTRAT EN ACIER RECOUVERT

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Description

[0001] The invention relates to a method for coating a steel substrate, wherein pickled hot rolled steel strip, cold rolled steel strip or zinc-coated steel strip - hereafter referred to as steel strip material, has been provided with a lubricant for corrosion protection before shipping and wherein the lubricated strip material is worked and/or formed to manufacture the steel substrate, and before and/or after the working and/or forming the steel substrate is coated with a paint system. The invention also relates to a coated steel substrate.

[0002] It is known in the art to produce pickled hot rolled steel strip, cold rolled steel strip or zinc-coated steel strip material and to coat the produced steel strip material with a lubricant directly after rolling. The lubricant, often oil, is applied to protect the steel against corrosion during shipping and storing the steel material, before a client of the steel producer uses the steel strip material. Instead of oil a dry film lubricant can be used, which provides at least the same corrosion resistance. In the industry a dry film lubricant can also be described as a hot melt product or film lubricant. These products are often used to improve the press performance during the forming of the steel into a steel substrate or product.

[0003] DE102007020552 relates to a method for coating a steel substrate, wherein steel strip material has been provided with a lubricant. The steel substrate is coated while the lubricant remains on the steel with a paint system comprising a solvent-free mixture from epoxy resin in bisphenol A and/or bisphenol F-base, glycidyl ether as reactive diluent, a curing agent based on an amine adduct (addition compound) from a polyamine and/or generic amines with primary, secondary and tertiary amino groups, fillers and additives on the surface, by filling, brushing, rolling or spraying; and treating the surface at 15 C.

[0004] EP0577486 relates to a method for the temporary corrosion protection of a metal substrate, by applying on the said metal substrate an emulsion obtained by dispersing in water an oily phase comprising a mineral oil, a surface-active agent and a corrosion inhibitor, and drying said coated metal substrate until a dry film is obtained.

[0005] Lubricants in general have to be removed by degreasing and the substrate has to be pre-treated, before a paint system can be applied to or on the substrate. When a lubricant has not been removed or the substrate has not been pre-treated, this results in a poor quality of the painted product, meaning that the paint adheres badly to the substrate. Such products are commercially unacceptable.

[0006] It is an object of the invention to provide a method for coating a steel substrate that is easier than the known method.

[0007] It is another object of the invention to provide a method for coating a steel substrate that has more value in use than the known method.

[0008] It is a further object of the invention to provide a method for coating a steel substrate that is more cost-effective for the paint system applicators than the known method.

[0009] According to the invention, one or more of these objects are reached by implementing a method for coating a steel substrate, wherein steel strip material has been provided with a lubricant for corrosion protection before shipping and/or storing, and wherein the lubricated strip material is worked and/or formed to manufacture the steel substrate, and before and/or after the working and/or forming the steel substrate is coated with a paint system, wherein the steel substrate is coated while the lubricant remains on the steel, and the lubricant that is used is a dry film lubricant, and the dry film lubricant contains ester-based polymers. It has been found that dry film lubricants can provide the adhesion that is necessary for the paint systems used.

[0010] Surprisingly, the inventors have found that it is possible to paint steel substrates without removing the lubricant, which is always applied as corrosion protection, when certain lubricants are used. The adhesion of the paint on the substrate is at least as good as when the lubricant has been removed. The standard procedure to remove the lubricant or to pre-treat the steel substrate by using hazardous degrease or pre-treatment chemicals can thus be omitted, which on the one hand makes the method both cheaper and faster, because the method is easier, and on the other hand improves the environmental position of the overall painting procedure.

[0011] The dry film lubricant preferably contains ester-based polymers and/or ester-based organic molecules and/or saturated hydrocarbons and/or unsaturated hydrocarbons and/or viscosity modifiers and/or corrosion prevention additives. The dry film lubricants containing one or more of the above constituents have shown it is possible to use paint systems without removing the dry film lubricant.

[0012] According to a preferred embodiment, the dry film lubricant contains a mixture of aliphatic hydrocarbons and saturated esters. This mixture has shown to give an adhesion of the paint on the substrate while the dry film lubricants remains on the substrate, that is as good as when the lubricant has been removed.

[0013] Preferably, the steel substrate is used for purposes outside the automotive sector. Such purposes encompass all types of industrial products including furniture for office and household use, such as filing cabinets, shelving for outlets and drum manufacture.

[0014] According to a preferred embodiment the lubricant or dry film lubricant has been applied to the steel strip material at a coating weight of 0.3 - 3.0 g/m². With a coating weight lower than 0.3 g/m² the corrosion protection is too

low; with a coating weight above 3.0 g/m^2 the adhesion of the paint to the substrate is believed to diminish. Preferably, the coating weight is between 0.5 g/m^2 and 2.0 g/m^2 .

[0015] Preferably the lubricant or dry film lubricant has been applied at speeds between 20 and 600 m/min. Speeds lower than 20 m/min are not economical; speeds higher than 600 m/min are technically difficult to realise. A preferred range is a speed between 100 and 300 m/min, which is economically viable.

[0016] According to a preferred embodiment the lubricant or dry film lubricant has been applied using an electrostatic oiler or using hot melt application technology or through the use of a high speed coating technique such as a chemcoater or spray disk process. Such ways of application are especially suitable for dry film lubricants and are technically suitable for the coating weights and speeds contemplated herein.

[0017] The paint system that is used in the method described above preferably is in liquid form or in powder form, which paint system preferably is a derivate of phenolics, acrylics, esters, urethanes or epoxies, and mixtures thereof. Such paint (or lacquer) systems are in wide use for the coating of steel substrates, and these paint systems are perfectly suitable for coating steel substrates on the surface of which the lubricant remains present. An example of a mixture is a combination of a polyester and an epoxy phenolic.

[0018] According to a preferred embodiment the liquid paint is applied through roller coating, curtain coating, spray disk coating and derivatives thereof. Such application techniques are known in the art, and have proven to be suitable to apply the liquid paint systems mentioned above on a steel substrate on which the lubricant remains present.

[0019] According to another preferred embodiment the powder paint is a thermosetting paint or a thermoplastic paint, and is preferably applied through use of an electrostatic gun. Such powder paint systems are known in the art, and their application methods as well.

[0020] Preferably the lubricated steel substrate that has been coated with a paint system is cured, preferably within the temperature range of $140 - 250^\circ \text{C}$ for up to 1 - 15 minutes. It has been found that such curing temperatures and periods are suitable for paint systems as mentioned above that are applied on a steel substrate with the lubricant remaining on it.

[0021] The curing of the paint is preferably performed using a gas fired oven, an infra-red oven, a near infra-red oven, an electron beam unit or an induction oven. Such equipment is known in the art and all are suitable for a paint on a steel substrate with lubricant.

[0022] Usually, the paint before curing has a thickness between 30 and 120 microns, preferably between 50 and 90 microns. These are thicknesses for which the paint can accommodate the lubricant or dry film lubricant.

[0023] According to a further embodiment of the invention, there is provided a steel substrate produced in accordance with the method described above, wherein the substrate has been provided with a coating comprising a lubricant and a paint.

[0024] Such a steel product coated with lubricant and paint is not on the market, because for commercial products the lubricant always has been removed.

[0025] Preferably, the substrate has been worked/formed for purposes outside the automotive sector. Such purposes are for instance office furniture and shelving.

[0026] The invention will now be elucidated with reference to a number of trials performed using the method described above and the resulting coated steel substrates.

[0027] In the trials, substrates have been provided with a dry film lubricant and these substrates have been coated with paint systems. The painted substrates have been tested to assess the adhesion performance.

[0028] The substrate used was a cold reduced, annealed and temper rolled steel strip having a gauge between 0.62 and 0.78 mm and a width between 902 and 1240 mm. The steel used for these trials was DC01 material. It will be understood by the person skilled in the art that other gauges and width can be used as well; it is known to supply strip in thicknesses in the range of 0.3 mm to 2.2 mm and width in the range of 500 to 2000 mm. The dry film lubricant has been heated to a maximum temperature of approximately 85°C before it has been applied, so it will have had a temperature of approximately 70°C when it was applied on the steel strip. The speed of the strip during application of the dry film lubricant has been up to 100 m/min. In another trial, the speed of the strip during the application of the dry film lubricant has been up to 250 m/min. The steel strip itself has had a temperature of approximately 15°C before the dry film lubricant has been applied. The dry film lubricant has been applied using an electrostatic oiler. The electrostatic oiler has run with a blade gap typically between 75-200 microns.

[0029] The dry film lubricant used is a hot melt containing, amongst other ingredients, ester based organic molecules, ester based polymers and unsaturated hydrocarbons

[0030] For the pilot line trials different thicknesses of dry film lubricant have been produced and tested:

Trial 1 : 0.1 to 1.0 g/m^2 dry film lubricant

Trial 2 : 0.4 to 0.8 g/m^2 dry film lubricant

Trial 3 : 0.5 to 2.5 g/m^2 dry film lubricant.

[0031] It has been found that the difference in performance between the various thicknesses of the dry film lubricant are small, but that a thickness of 1.0, 1.5 and 2.0 g/m² per side of the substrate generated better results in the laboratory adhesion tests compared to tests of the same paint on the same substrate when the dry film lubricant had been removed. It also became clear that a curing temperature of the paint coating of 180 - 200 °C for a dry film lubricant of 1.0 g/m² provided better adhesion test results compared to tests of the same paint on the same substrate when the dry film lubricant had been removed.

[0032] Apart from the laboratory paintability and adhesion tests, also some real life industrial production tests have been performed. Several finished industrial products have been manufactured using both liquid paint and powder paint lines, both with dry film lubricant remaining on the substrate and with dry film lubricant removed before painting. A layer of 1.0 g/m² had been applied on the substrate in accordance with the invention. The tests showed that the adhesion of the samples according to the invention was significantly better than for the samples where the dry film lubricant had been removed, for one of the powder paint systems used. For other powder paint systems and for liquid paint systems the results of the adhesion tests for coated substrates with and without dry film lubricants are approximately the same.

[0033] The result of the tests thus is that it is possible to use a dry film lubricant on a steel substrate that remains present on the substrate when coated with a paint system, without loss of quality of the adhesion of the coating.

[0034] Chemical mechanistic studies of the interaction between the dry film lubricant and selected powder paint systems have been undertaken to elucidate the paint adhesion mechanisms. Analysis techniques used have included differential scanning calorimetry (DSC) and optical microscopy.

[0035] For the DSC spectra of the different powder coatings (without dry film lubricant) the method used involved heating up the samples to 180°C at 10°C/min (to determine melting point), keeping at 180°C for 10 min (curing), subsequent quenching and reheating to 180°C at 10°C/min, to determine the glass transition temperature (T_g) of the cured coating.

Step	Rate of heating / cooling	Rationale
0 - 180°C	10°C/min	Determine melting point T _m
180°C	10 min isotherm	Curing
180 - 0°C	-100°C/min	Quenching
0°C	5 min isotherm	Equilibration
0 - 180°C	10°C/min	Determine T _g of cured coating

[0036] For pure (no paint present) dry film lubricant the method used was to heat up the sample from 0°C to 180°C at 10°C/min (to determine melting point).

[0037] In order to study the potential interactions (miscibility and plasticising effects) between the dry film lubricant and powder coating systems, dry blends of lubricant and powder coating were prepared in-situ in the DSC sample pans. To this end, first a small amount of dry film lubricant (ca. 1 mg) was placed in the DSC sample pan and weighed. Then, the proper amount of powder coating was added to the sample to reach a total content of about 10% lubricant. The same DSC measuring method is used as with the powder coats.

[0038] The experimental results showed that most of the powders tested had a melting point in the range 55-65°C. A dry mixture of about 10% dry film lubricant with one powder gave, after curing, a T_g that was lowered by approximately 12°C compared to the pure system. Further to this, a drop in T_g of approximately 13°C was observed with a second powder. This indicates a notable 'plasticising' effect, which in turn means good mixing and specific interactions between dry film lubricant and coating resin. With a third powder no clear T_g was visible after mixing with the dry film lubricant, only a little indistinct peak around 48 - 50°C. This can be the T_g, in which case there would be a substantial plasticising versus the powders on their own (T_g of 61 - 65°C).

[0039] It is understood that dry film lubricant and powder coatings will mix in the liquid state during curing, due to a broad overlap in the temperature ranges over which they are in all the liquid phase. The dry film lubricants have a liquid state starting at approximately 40°C. The dry film lubricants are applied at temperatures around 60 - 80 °C.

[0040] Also, it has been shown using optical microscopy that the dry film lubricant is partially absorbed into the paint film during the curing process.

[0041] It is concluded that a number of processes contribute towards good adhesion of the paint to the steel, i.e. plasticisation of the paint by the dry film lubricant coating and solubilization of the dry film lubricant in the paint.

[0042] It is also possible that components of the dry film lubricant, for example, unsaturated molecules, undergo co-polymerisation reactions with the powder paint. The inventors think that this is happening because the esters from the dry film lubricant combine or are miscible with the esters within the powder. In addition it is possible that the unsaturated hydrocarbons in the dry film lubricant can co-polymerize with the powder.

Claims

1. Method for coating a steel substrate, wherein steel strip material has been provided with a lubricant for corrosion protection before shipping and/or storing, and wherein the lubricated strip material is worked and/or formed to manufacture the steel substrate, and before and/or after the working and/or forming the steel substrate is coated with a paint system, **characterised in that** the steel substrate is coated while the lubricant remains on the steel and the lubricant that is used is a dry film lubricant that contains ester-based polymers.
2. Method according to claim 1 wherein the dry film lubricant contains ester-based organic molecules and/or saturated hydrocarbons and/or unsaturated hydrocarbons and/or viscosity modifiers and/or corrosion preventive additives.
3. Method according to claim 1 or 2 wherein the dry film lubricant contains mixture of aliphatic hydrocarbons and saturated esters.
4. Method according to any one of the preceding claims, wherein the dry film lubricant has been applied to the steel strip material at a coating weight of 0.3 - 3.0 g/m².
5. Method according to claim 4, wherein the dry film lubricant has been applied at speeds between 20 and 600 m/min.
6. Method according to claim 4 or 5, wherein the dry film lubricant has been applied using an electrostatic oiler or using hot melt application technology or through the use of a high speed coating technique such as a chemcoater or spray disk process.
7. Method according to any one of the preceding claims, wherein the paint system is in liquid form or in powder form, which paint system preferably is a derivate of phenolics, acrylics, esters, urethanes or epoxies, and mixtures thereof.
8. Method according to claim 7, wherein the liquid paint is applied through roller coating, curtain coating, spray disk coating and derivatives thereof.
9. Method according to claim 7, wherein the powder paint is a thermosetting paint or a thermoplastic paint, and is preferably applied through use of an electrostatic gun.
10. Method according to any one of the claims 7-9, wherein the lubricated steel substrate that has been coated with a paint system is cured, preferably within the temperature range of 140 - 250° C for up to 1 - 15 minutes.
11. Method according to claim 10, wherein the curing of the paint is performed using a gas fired oven, an infra-red oven, a near infra-red oven, an electron beam unit or an induction oven.
12. Method according to any one of the preceding claims, wherein the paint before curing has a thickness between 30 and 120 microns, preferably between 50 and 90 microns.
13. Steel substrate produced in accordance with any one of the preceding claims, wherein the substrate has been provided with a coating comprising a dry film lubricant and a paint and wherein the dry film lubricant contains ester-based polymers.

Patentansprüche

1. Verfahren zur Beschichtung eines Stahlsubstrats, wobei Stahlstreifenmaterial vor dem Versand und/oder der Lagerung als Korrosionsschutz mit einem Schmiermittel versehen worden ist, und wobei das geschmierte Streifenmaterial bearbeitet und/oder geformt wird, um das Stahlsubstrat herzustellen, und das Stahlsubstrat vor und/oder nach der Bearbeitung und/oder dem Formen mit einem Lacksystem beschichtet wird, **dadurch gekennzeichnet, dass** das Stahlsubstrat beschichtet wird, während das Schmiermittel auf dem Stahl bleibt, und wobei das Schmiermittel dass verwendet wird ein Trockenfilmschmiermittel, das Polymere auf Esterbasis enthält, ist.
2. Verfahren nach Anspruch 1, wobei das Trockenfilmschmiermittel organische Moleküle auf Esterbasis und/oder gesättigte Kohlenwasserstoffe und/oder ungesättigte Kohlenwasserstoffe und/oder Viskositätsmodifikatoren und/oder Korrosionsschutzadditive enthält.

3. Verfahren nach Anspruch 1 oder 2, wobei das Trockenfilmschmiermittel ein Gemisch aus aliphatischen Kohlenwasserstoffen und gesättigten Estern enthält.
- 5 4. Verfahren nach einem der vorstehenden Ansprüche, wobei das Trockenfilmschmiermittel mit einem Beschichtungsgewicht von 0,3 bis 3,0 g/m² auf das Stahlstreifenmaterial aufgetragen worden ist.
5. Verfahren nach Anspruch 4, wobei das Trockenfilmschmiermittel mit Geschwindigkeiten zwischen 20 und 600 m/Min. aufgetragen worden ist.
- 10 6. Verfahren nach Anspruch 4 oder 5, wobei das Trockenfilmschmiermittel unter Verwendung eines elektrostatischen Ölers oder unter Verwendung einer Schmelzapplikationstechnologie oder unter Verwendung einer Hochgeschwindigkeitsbeschichtungstechnologie, wie etwa eines Chemcoaters oder eines Sprühscheibenverfahrens aufgetragen worden ist.
- 15 7. Verfahren nach einem der vorstehenden Ansprüche, wobei das Lacksystem in flüssiger Form oder in Pulverform vorgesehen ist, wobei das Lacksystem vorzugsweise ein Derivat von Phenolen, Acrylen, Estern, Urethanen oder Epoxiden und Gemischen davon ist.
- 20 8. Verfahren nach Anspruch 7, wobei der flüssige Lack aufgetragen wird durch Walzbeschichtung, Gießbeschichtung, Sprühscheibenbeschichtung und Derivate davon.
9. Verfahren nach Anspruch 7, wobei der Pulverlack ein wärmeaushärtender Lack oder ein thermoplastischer Lack ist, und wobei er vorzugsweise unter Verwendung einer elektrostatischen Pistole aufgetragen wird.
- 25 10. Verfahren nach einem der Ansprüche 7 bis 9, wobei das mit einem Lacksystem beschichtete geschmierte Stahlsubstrat gehärtet wird, vorzugsweise für 1 bis 15 Minuten auf einer Temperatur zwischen 140 bis 250 °C.
- 30 11. Verfahren nach Anspruch 10, wobei das Härten des Lacks unter Verwendung eines Gasofens, eines Infrarotofens, eines Ofens mit kurzweiliger Infrarotstrahlung, einer Elektronenstrahleinheit oder eines Induktionsofens durchgeführt wird.
12. Verfahren nach einem der vorstehenden Ansprüche, wobei der Lack vor dem Härten eine Dicke zwischen 30 und 120 Mikron aufweist, vorzugsweise zwischen 50 und 90 Mikron.
- 35 13. Stahlsubstrat, das gemäß einem der vorstehenden Ansprüche hergestellt worden ist, wobei das Substrat mit einer Beschichtung versehen ist, die ein Trockenfilmschmiermittel und einen Lack umfasst, und wobei das Trockenfilmschmiermittel Polymere auf Esterbasis enthält.

40 Revendications

1. Procédé de revêtement d'un substrat en acier, un matériau de bande d'acier ayant reçu un lubrifiant de protection contre la corrosion avant expédition et/ou stockage, et le matériau de bande lubrifié étant usiné et/ou façonné pour fabriquer le substrat en acier, et avant et/ou après l'usinage et/ou le façonnage le substrat en acier étant recouvert à l'aide d'un système à peinture, **caractérisé en ce que** le substrat en acier est recouvert alors que le lubrifiant reste sur l'acier et le lubrifiant qui est utilisé est un lubrifiant à film sec qui contient des polymères à base d'ester.
- 45 2. Procédé selon la revendication 1, le lubrifiant à film sec contenant des molécules organiques à base d'ester et/ou des hydrocarbures saturés et/ou des hydrocarbures insaturés et/ou des modificateurs de viscosité et/ou des additifs préventifs de corrosion.
- 50 3. Procédé selon la revendication 1 ou 2, le lubrifiant à film sec contenant un mélange d'hydrocarbures aliphatiques et d'esters saturés.
- 55 4. Procédé selon l'une quelconque des revendications précédentes, le lubrifiant à film sec ayant été appliqué au matériau de bande d'acier à un poids de revêtement compris entre 0,3 et 3,0 g/m².
5. Procédé selon la revendication 4, le lubrifiant à film sec ayant été appliqué à des vitesses comprises entre 20 et

600 m/min.

- 5 6. Procédé selon la revendication 4 ou 5, le lubrifiant à film sec ayant été appliqué à l'aide d'un graisseur électrostatique ou à l'aide de la technologie d'application par fusion à chaud ou par l'utilisation d'une technique de revêtement haute vitesse telle qu'un dispositif de revêtement chimique ou un processus à disque de pulvérisation.
- 10 7. Procédé selon l'une quelconque des revendications précédentes, le système à peinture étant sous forme liquide ou sous forme de poudre, lequel système à peinture étant de préférence un dérivé de composés phénoliques, acryliques, esters, uréthanes ou résines époxydes, et mélanges de ceux-ci.
- 15 8. Procédé selon la revendication 7, la peinture liquide étant appliquée par application au rouleau, application à la machine à rideau, application au disque de pulvérisation et dérivés de ceux-ci.
- 20 9. Procédé selon la revendication 7, la peinture en poudre étant une peinture thermodurcissable ou une peinture thermoplastique, et étant de préférence appliquée par l'utilisation d'un pistolet électrostatique.
- 25 10. Procédé selon l'une quelconque des revendications 7 à 9, le substrat en acier lubrifié qui a été revêtu d'un système à peinture étant durci, de préférence dans la plage de températures comprise entre 140 et 250 °C entre 1 et 15 minutes.
- 30 11. Procédé selon la revendication 10, le durcissement de la peinture étant réalisé à l'aide d'un four à gaz, d'un four à infra-rouge, d'un four à proche infra-rouge, d'une unité à faisceau d'électrons ou d'un four à induction.
- 35 12. Procédé selon l'une quelconque des revendications précédentes, la peinture avant le durcissement ayant une épaisseur comprise entre 30 et 120 microns, de préférence entre 50 et 90 microns.
- 40 13. Substrat en acier produit selon l'une quelconque des revendications précédentes, le substrat ayant reçu un revêtement composé d'un lubrifiant à film sec et d'une peinture et le lubrifiant à film sec contenant des polymères à base d'ester.

REFERENCES CITED IN THE DESCRIPTION

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