(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 166 124 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
24.03.2010 Bulletin 2010/12

(21) Application number: **08017991.4**

(22) Date of filing: **14.10.2008**

(51) Int Cl.:
C23C 2/00 *(2006.01)* ***C23C 2/16*** *(2006.01)*
C23C 2/18 *(2006.01)* ***C23C 2/20*** *(2006.01)*
C23C 2/40 *(2006.01)*

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

(30) Priority: **12.09.2008 US 96323**

(71) Applicant: **Linde AG**
80331 München (DE)

(72) Inventors:
- **Dwyer, John J. Jr.,**
  Easton PA 18045, (US)
- **Miller, Howard Robert**
  Tega Cay SC 29708, (US)
- **Chang, Edward K.,**
  Gilette NJ 07933, (US)
- **Olexa, Timothy D.,**
  Transfer PA 16154 (US)

(74) Representative: **Gellner, Bernd et al**
Linde Aktiengesellschaft
Patente und Marken
Dr. Carl-von-Linde-Strasse 6-14
82049 Höllriegelskreuth (DE)

(54) Method and apparatus for continuous hot-dip coating of metal strips

(57) The invention relates to a method for coating a metal product (1) wherein a molten coating (14, 15) is applied to a surface of said metal product (1) and wherein part of said molten coating (14, 15) is wiped off said metal product (1) by an gas flow (18, 19) wherein said gas flow (19) is heated (20) before being directed to said metal product.

EP 2 166 124 A1

Description

[0001] The invention relates to a method for coating a metal product wherein a molten coating is applied to a surface of said metal product and wherein part of said molten coating is wiped off said metal product by a gas flow directed to said metal product. Further, the invention relates to an apparatus for coating a metal product comprising a coating section wherein a molten coating is applied to a surface of said metal product and a control section wherein said control section comprises a gas knife for wiping off part of said molten coating from said metal product.

[0002] Continuous hot-dip galvanizing of metal sheets is a well-known technique. This method involves the application of a molten coating onto the surface of a metal sheet in a continuous process. The metal sheet is passed through a bath of a molten metal. In the bath the surface of the metal sheet reacts with the molten metal to bond the coating onto the sheet surface. When the metal sheets emerge from the metal bath excess liquid metal is bond to the surface, too.

[0003] In a subsequent control section the coating thickness is controlled. This thickness control is achieved by a gas wiping process. Gas nozzles deliver low-pressure, high-volume air streams on the surface of the metal sheet to wipe off surplus molten metal pulled from the molten metal bath. Since the gas nozzles "cut off' excess coating material they are often referred to as "gas knives".

[0004] In the following the term "gas knife" shall mean a device for delivering a gas onto or along the surface, in order to wipe off surplus coating material. The terms "air knife" and "nitrogen knife" accordingly refer to devices for delivering air or nitrogen for gas wiping purposes.

[0005] Some of the steel manufacturers use nitrogen instead of air as the wiping gas in the steel galvanizing process. The use of nitrogen has the advantage that a coating with improved surface quality is achieved due to the inertness of nitrogen.

[0006] It is an object of the invention to propose a method and an apparatus for improved gas-wiping.

[0007] This object is achieved by a method for coating a metal product wherein a molten coating is applied to a surface of said metal product and wherein part of said molten coating is wiped off said metal product by a gas flow directed to said metal product wherein said gas flow is heated before being directed to said metal product.

[0008] It has been found that a more consistent cooling rate can be achieved by using a heated gas flow for the wiping purposes. A more uniform edge-to-edge coating distribution and a smoother surface coating without ripples and heavy edges are achieved.

[0009] The term "heated" shall mean that the temperature of the gas flow is increased in any manner, in particular by direct or indirect heat exchange, by heating with a burner or another conventional heater or by blending with another warm or hot fluid.

[0010] It is preferred to use air and/or nitrogen as the wiping gas. The air and / or nitrogen flows are pre-heated and then directed to the metal product for wiping off excess molten coating. It is especially preferred to use nitrogen as wiping gas. Among the benefits of using nitrogen instead of air are reduced dross formation and improved surface quality.

[0011] According to a preferred embodiment an air flow and a nitrogen flow are directed to the metal product one after the other, with pre-heating of the air flow, of the nitrogen flow or of both gas flows wherein the alternative to pre-heat the nitrogen flow only is preferred most.

[0012] It is in particular preferred to first use an air flow for wiping off excess molten coating and to subsequently direct a nitrogen flow to said metal product. The idea is to first reduce the coating with an air flow to a particular level and then complete the wiping with nitrogen. Due to its inertness the nitrogen is used to finish the final molten metal coating in order to achieve the desired surface quality. Thus, without any loss of surface quality this method reduces the required nitrogen volume and the related gas consumption costs compared to the use of pure nitrogen knives.

[0013] Further, to achieve a maximum flexibility to change the surface properties of the coating it might also be helpful to apply the air flow and the nitrogen flow at the same time.

[0014] According to a preferred embodiment of the invention the nitrogen consumption is between 1% and 99%, preferably between 1% and 60%, more preferred between 30% and 60%, of the nitrogen consumption of a pure nitrogen knife system. The air to nitrogen ratio used in the inventive method is preferably between 1 to 99 and 99 to 1.

[0015] The heating of the gas flow may be obtained by conventional heaters, such as electrical heaters. However, due to the large flow required for the gas knives, a conventional heater would have to be a bulky equipment which is not always possible. Therefore, it is preferred to heat up the main gas flow which will be directed to the metal product by blending it with a second gas flow of higher temperature. A relatively smaller volume of a second gas flow of much higher temperature is mixed with the large main gas flow which is at lower temperature, for example ambient temperature, to obtain a resultant gas flow at the desired temperature. The temperature of the resulting gas flow can be controlled by the temperatures and relative amounts of the main gas flow and the second gas flow.

[0016] Said second gas flow is preferably obtained by means of a plasma generator. For example, a plasma torch is used to create a hot plasma gas which is then mixed with the main gas flow to create the desired gas flow for the gas knives. It is especially preferred to use a nitrogen plasma generator.

[0017] According to another preferred embodiment the second gas flow is obtained by combustion of a fuel gas and an oxygen-containing gas. The product of in-line

combustion of a liquid or gaseous fuel with an oxygen-containing gas, such as air or air enriched with oxygen, is added to the main gas flow in order to obtain the desired hot gas flow for wiping. This alternative is especially advantageous when small amounts of CO_2, H_2O and oxygen do not cause any adverse effects on coating quality.

[0018] If zinc vapour presents an environmental problem it is further advantageous to include small amounts of oxidants to the main gas flow or to the second gas flow.

[0019] Pre-heating of the wiping gas flow has the advantage of increased surface quality of the metal product. On the other hand, by increasing the temperature of the wiping gas flow the cooling rate is decreased since the temperature difference between the metal product and the wiping gas is lower. In this respect it has been found that the following temperature range is a good compromise: The gas flow is preferably heated to a temperature between 50°C to 10°C over the temperature of the coating metal bath (pot temperature), more preferably between 300°C and 600°C.

[0020] The invention is preferably aimed at coating elongated metal products, in particular metal strips, metal sheets or metal wires, for example steel sheets or steel strips, which are continuously passed through a coating section where a molten coating, in particular a metal coating, is applied to a surface of the metal product. The metal strip or metal sheet or in general the elongated metal product is transported through a coating bath where coating material from the coating bath is bond to the surface of the metal product. When the elongated metal product exits the bath it drags out more coating material than needed for the coating. Therefore, a heated gas flow is blown onto the surface to wipe off excess coating material and to achieve the desired thickness.

[0021] It is advantageous to pass the coated elongated metal product continuously along a gas knife which blows a heated gas flow onto or along the surface of the passing metal product.

[0022] Preferably a metal coating is applied to said metal product. Preferably the coating which is applied to the metal product comprises one or more metals or composites of the group of zinc, aluminium, silicon.

[0023] In particular, the invention is directed to galvanizing a metal product, and even more preferred to galvanizing metal sheets or metal strips, in particular steel sheets or steel strips. However, the inventive method can also be used for the application of other coating materials to a metal product by hot-dip coating, that is by dipping the metal product into a bath of coating material.

[0024] When coating an elongated product as described above the amount of excess coating material which is dragged out of the coating bath depends on the speed the metal product exits the bath. The higher the speed, the more coating material is dragged out of the bath. The inventive method works well at speeds of the metal product between 1 m/min and 300 m/min that is it fits quite well into the speed range of standard hot-dip coating systems.

[0025] The inventive apparatus for coating a metal product comprises a coating section wherein a molten coating is applied to a surface of said metal product and a control section wherein said control section comprises a gas knife for wiping off part of said molten coating from said metal product wherein a gas pre-heater is connected to said gas knife.

[0026] Preferably the gas knife is connected to a first gas supply line supplying a large flow of a wiping gas at low temperature, for example ambient temperature, and to a second gas supply line for supplying a smaller gas flow at high temperature. The second gas supply line is provided with a gas pre-heater to heat up the gas.

[0027] The gas pre-heater can either comprise any means for heating the gas flow directed to the gas knife by indirect or direct heat exchange. According to a preferred embodiment the gas pre-heater comprises a plasma generator for heating at least part of said gas supplied to said gas knife. According to another preferred embodiment the gas pre-heater comprises a burner for heating at least part of said gas supplied to said gas knife.

[0028] The invention provides an apparatus and a method for economically heating large gas flows, in particular nitrogen flows, used for wiping excess molten coating, such as zinc, off a surface of a metal product. The invention further provides a simple control over temperature and concentrations of various oxidants of the atmosphere. In a particular preferred embodiment a heated nitrogen wiping gas flow is generated by mixing a minor flow of nitrogen at high temperature with a major flow of nitrogen at low temperature, for example ambient temperature.

[0029] The invention as well as further details of the invention will now be described with reference to the attached drawing. The figure schematically shows an arrangement for coating a steel sheet according to the invention.

[0030] The figure shows an apparatus for galvanizing a steel strip 1. The steel strip 1 is transported through a snout 2 into a coating or galvanising bath 3 of molten zinc. Within the bath 3 molten zinc is bond to the steel surface. The steel strip 1 is deflected by a sink roll 4 and exits the coating bath 3 in a vertical direction.

[0031] Above the coating bath 3 there is a control section which comprises a gas knife 6. The gas knife 6 comprises a chamber 8 with a slot opening 9. Chamber 8 is connected to a gas inlet 10.

[0032] In operation the steel strip 1 is passed at a high speed of for example about 150 m/min through the coating bath 3 and through the control section. In the control section any excess zinc 14 which has been dragged off the coating bath 3 is blown off the steel strip 1 by preheated gas as described below.

[0033] Gas knife 6 is supplied with pressurized gas which is then blown out through the slot opening 9 onto the surface of the coated steel strip 1. The resulting gas jet 18 acts as a knife and wipes off excess molten zinc from the surface of the steel strip 1. The molten zinc which

has been stripped off the steel strip 1 flows back into the coating bath 3.

[0034] Above the slot opening 9 of the gas knife 6 the coating thickness has been reduced to the desired thickness 15. As will be explained in more detail below the pressurised gas essentially consists of nitrogen. Since nitrogen is an inert gas a coating 15 with a high quality surface is produced.

[0035] Pressure and volume of the gas supplied to the gas knife 6 are controlled depending on the speed of the steel strip, the desired thickness and quality of the coating, and/or the type of coating material. Further parameters which might be used to control pressure and volume of the gas are the height of the gas knife 6 above the bath 3, the distance of the gas knife 6 from the passing steel strip 1, the angle of gas knife 6, or the size of slot opening 9.

[0036] According to the invention a pre-heated gas is supplied to the gas knives 6 and then directed to both sides of steel strip 1. The wiping process is preferably carried out with nitrogen as wiping gas. Therefore, pressurised nitrogen 19 is supplied via conduits 22, 23 to gas inlet 10.

[0037] Heating of the nitrogen stream 19 is achieved by mixing the main nitrogen stream 19 with a relatively smaller flow of a hot gas stream 20. The hot gas stream 20 is obtained by means of a nitrogen plasma torch 21. The nitrogen plasma is preferably produced within an annular enclosure 24. Annular enclosure 24 and nitrogen supply conduit 22 are concentrically arranged and both have a flow connection to supply conduit 23.

[0038] One or more plasma torches 21 produce a small volume of hot nitrogen plasma 20 which is then passed to the nitrogen supply conduit 23 and blended with a relative large flow of nitrogen gas 19 at ambient temperature. By controlling the ratio of gas streams 19 and 20 the temperature of the resulting pre-heated nitrogen gas stream can be set to the desired value.

[0039] Instead of producing the hot nitrogen gas stream 20 by means of a plasma generator 21 it is also possible to mix the main nitrogen gas stream 19 with the combustion product of air and fuel. In that case an air-fuel burner would be used instead of plasma torch 21. However, the resulting mixture of nitrogen stream 19 and the stream of combustion products 20 will contain small amounts of CO2, H_2O and oxygen. Therefore, this embodiment will only be used if the CO2, H_2O and oxygen do not adversely effect the coating quality. If zinc vapour presents an environmental problem the inventive pre-heating of the nitrogen gas stream by blending with air-fuel combustion products may even be a welcome feature.

Claims

1. Method for coating a metal product (1) wherein a molten coating (14, 15, 16) is applied to a surface of said metal product (1) and wherein part of said molten coating (14, 15) is wiped off said metal product (1) by a gas flow (18, 19) directed to said metal product (1), **characterized in that** said gas flow is heated before being directed to said metal product.

2. Method according to claim 1 **characterized in that** a nitrogen flow (18, 19) is directed to said metal product.

3. Method according to any of claims 1 or 2 **characterized in that** said gas flow is heated by addition of a second gas flow of higher temperature.

4. Method according to any of claims 1 to 3 **characterized in that** said second gas flow is obtained by means of a plasma generator, preferably by a nitrogen plasma generator.

5. Method according to any of claims 1 to 4 **characterized in that** said second gas flow is obtained by combustion of a fuel gas and an oxygen-containing gas.

6. Method according to any of claims 1 to 5 **characterized in that** said gas flow is heated to a temperature between 300 °C and 600 °C.

7. Method according to any of claims 1 to 6 **characterized in that** said metal product (1) is an elongated product, in particular a metal strip, metal sheet or metal wire, which is continuously passed through a coating section where a molten coating, in particular a metal coating, is applied to a surface of said metal product (1).

8. Method according to claim 7 **characterized in that** said elongated product (1) is continuously passed through a bath (3) of a molten coating material.

9. Method according to any of claims 1 to 8 **characterized in that** said metal product (1) is galvanized.

10. Method according to any of claims 1 to 9 **characterized in that** said metal product (1) is passed through said coating section at a speed between 1 m/min and 300 m/min.

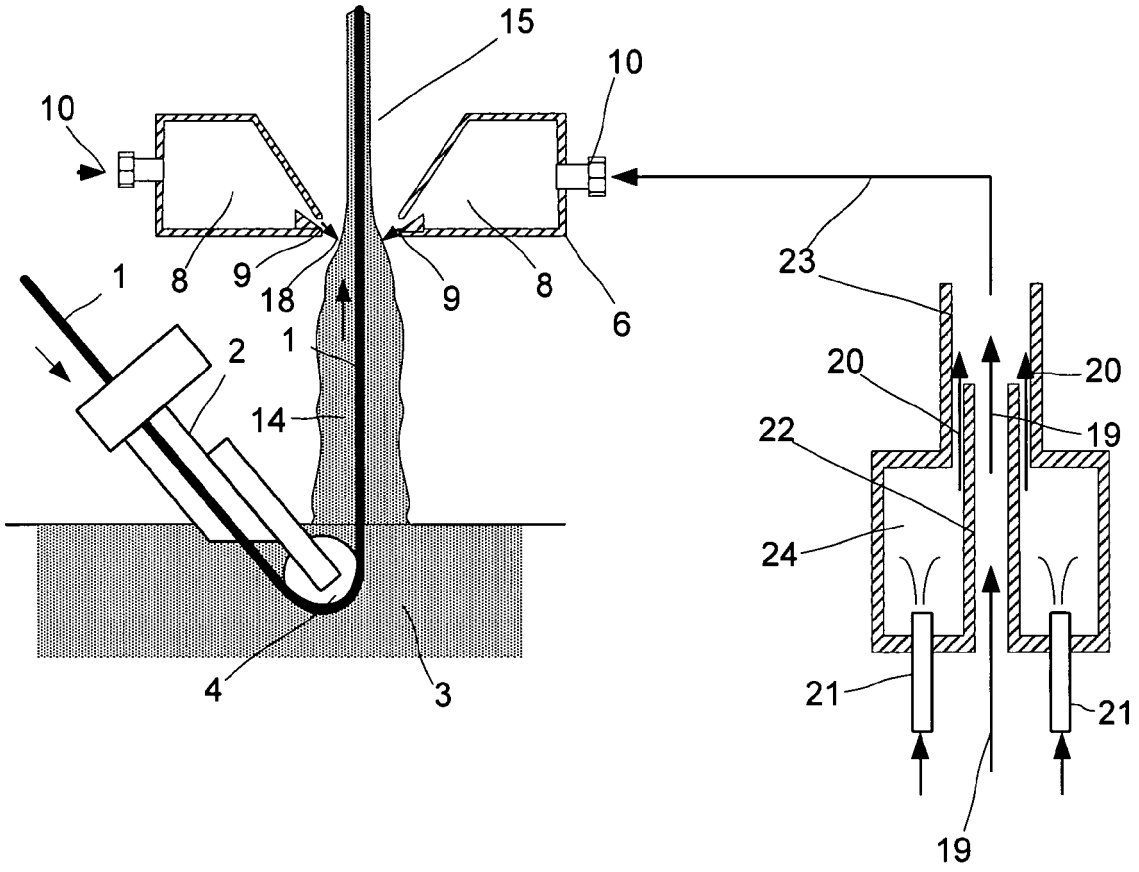
11. Apparatus for coating a metal product (1) comprising a coating section wherein a molten coating (14, 15, 16) is applied to a surface of said metal product (1) and a control section (5) wherein said control section (5) comprises a gas knife (6, 7) for wiping off part of said molten coating (14, 15) from said metal product (1), **characterized in that** a gas pre-heater is connected to said gas knife.

12. Apparatus according to claim 11 **characterized in that** said gas pre-heater comprises a plasma gen-

erator for heating at least part of said gas supplied to said gas knife.

13. Apparatus according to any of claims 11 or 12 **characterized in that** said gas pre-heater comprises a burner for heating at least part of said gas supplied to said gas knife.

Fig.



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 08 01 7991

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 0 039 422 A (BETHLEHEM STEEL CORP [US]) 11 November 1981 (1981-11-11) * page 1, line 4 - page 3, line 28 * * page 8, line 20 - line 25 * * page 18, line 15 - line 33 * * page 27, line 19 - page 28, line 6 * * page 40, line 26 - page 41, line 30 * * claims 1,14,18,20,21,24,25; figures 1,9,11 *	1,2, 6-11,13	INV. C23C2/00 C23C2/16 C23C2/18 C23C2/20 C23C2/40
X	US 4 612 215 A (HENNECHART JEAN-PAUL [FR] ET AL) 16 September 1986 (1986-09-16) * column 1, line 34 - column 2, line 52 * * column 3, line 14 - column 4, line 17 * * column 5, line 20 - column 5, line 55 * * column 6, line 39 - line 51 * * claims 1,3-5,9,10,12,15-17; figures 1,5 *	1,2,5-11	
X	US 4 083 323 A (ROTE EVERETT ARTHUR) 11 April 1978 (1978-04-11) * column 1, line 5 - line 17 * * column 2, line 9 - line 43 * * column 5, line 5 - line 40 * * column 6, line 12 - line 34 * * claim 1; figure 1 *	1,6-9,11	TECHNICAL FIELDS SEARCHED (IPC) C23C
X	US 6 562 412 B1 (FONTAINE PASCAL [DE]) 13 May 2003 (2003-05-13) * column 3, line 17 - line 29 * * column 5, line 1 - line 35; figure 1 *	1,2,6-11	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	27 January 2009	Ovejero, Elena

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
.....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 08 01 7991

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

27-01-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0039422 A	11-11-1981	AU 544277 B2	23-05-1985
		AU 6939581 A	15-10-1981
		CA 1158484 A1	13-12-1983
		DE 3166905 D1	06-12-1984
		JP 56156747 A	03-12-1981
		US 4310572 A	12-01-1982
		ZA 8102370 A	28-04-1982
US 4612215 A	16-09-1986	CA 1251364 A1	21-03-1989
		DE 3471691 D1	07-07-1988
		DE 122856 T1	23-05-1985
		EP 0122856 A1	24-10-1984
		ES 8501805 A1	01-03-1985
		FR 2544337 A1	19-10-1984
		JP 1826875 C	28-02-1994
		JP 5034424 B	24-05-1993
		JP 59205463 A	21-11-1984
US 4083323 A	11-04-1978	CA 1057134 A1	26-06-1979
		GB 1562236 A	05-03-1980
		JP 1342350 C	14-10-1986
		JP 52021239 A	17-02-1977
		JP 61008146 B	12-03-1986
US 6562412 B1	13-05-2003	AU 742312 B2	20-12-2001
		AU 3800399 A	02-11-2000
		BR 9902711 A	06-03-2001
		CA 2277456 A1	28-10-2000
		CN 1271625 A	01-11-2000
		DE 19919234 A1	16-11-2000
		EP 1048361 A2	02-11-2000
		JP 3357318 B2	16-12-2002
		JP 2000328219 A	28-11-2000
		RU 2199603 C2	27-02-2003
		ZA 9904522 A	25-02-2000

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82