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(71) Applicant: **Tata Steel IJmuiden B.V.**
**1951 JZ Velsen-Noord (NL)**

(72) Inventors:
- **VAN VELDHUIZEN, Hendrik Bart**
  **1970 CA IJmuiden (NL)**
- **TOOSE, Edgar Matthijs**
  **1970 CA IJmuiden (NL)**
- **DUARTE ALVARENGA, Henrique**
  **1970 CA IJmuiden (NL)**

(74) Representative: **Herman de Groot, Johan Willem**
**Tata Steel Nederland Technology B.V.**
**Group Intellectual Property Services**
**P.O. Box 10000**
**1970 CA IJmuiden (NL)**

## (54) COATED METAL SHEET, METHOD TO PROVIDE SUCH A COATED METAL SHEET, AND HOT DIP GALVANIZING DEVICE TO MANUFACTURE SUCH A COATED METAL SHEET

(57) Method of providing a coating on a metal sheet, wherein a cold rolled metal sheet is subjected to a hot dip galvanizing operation to provide a metal coating on the metal sheet, which hot dip galvanizing operation comprises guiding the metal sheet through a liquid bath of the metal coating with at least one stabilization roll provided at a predefined depth ('Depth') below surface level of the liquid bath, and wiping the metal coating that is provided on the metal sheet with at least one gas knife having an outlet to project wiping gas on the metal coating on the metal sheet that passes along the gas knife, wherein a distance ('D') of the at least one gas knife to the passing metal sheet and a height ('H') of the at least one gas knife above the liquid bath of the metal coating are selected at values so as to satisfy a formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*In(H*Depth) and wherein Wsa is selected at a value representing a maximum allowable waviness.

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## Description

**[0001]** The invention relates primarily to a method of providing a coating on a metal sheet, wherein a cold rolled metal sheet is subjected to a hot dip galvanizing operation to provide a metal coating on the metal sheet, which hot dip galvanizing operation comprises guiding the metal sheet through a liquid bath of the metal coating with at least one stabilization roll provided at a predefined depth below surface level of the liquid bath, and wiping the metal coating that is provided on the metal sheet with at least one gas knife having an outlet to project wiping gas on the metal coating that is provided on the metal sheet that passes along the gas knife.

**[0002]** Such a method of providing a coating on a metal sheet is widely known throughout the iron and steel industry; an exemplary publication showing such a method is GB 2517622.

**[0003]** A problem also acknowledged in GB 2517622 is the waviness of the coated metal sheet, which causes that after providing the coated metal sheet with a film of paint its outer appearance can be less than optimal. One known problem is the appearance of orange skin which is particularly undesirable for outside body parts of automobiles.

**[0004]** GB 2517622 does not particularly provide a workable solution for this problem, for one thing since its disclosure is obscure in relation to the waviness measure it applies.

**[0005]** It is an object of the invention to solve this long existing problem and to provide a workable solution for it. In this connection throughout this application waviness of the coated metal sheet is defined by the measure Wsa as published by the Deutsche Industry Norm publication SEP 1941:2012-05 entitled (in German): Messung des Welligkeit-skennwertes Wsa (1-5) an kaltgewaltzten Flacherzeugnissen.

**[0006]** Accordingly the invention proposes a method to manufacture a coated metal sheet, such a coated metal sheet, a hot dip galvanizing device and its combination with a cold rolling mill in accordance with one or more of the appended claims.

**[0007]** In a first aspect of the invention the method of manufacturing a coated metal sheet has the feature that a distance ('D') of the at least one gas knife to the passing metal sheet and a height ('H') of the at least one gas knife above the liquid bath of the metal coating are selected at values so as to satisfy a formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth) and wherein Wsa is selected at a value representing a maximum allowable waviness, and wherein 'Depth' stands for the depth of the at least one stabilization roll below the surface level of the liquid bath. In this specification '<=' symbolizes "less than or equal".

**[0008]** The method of the invention can suitably be executed by providing that the distance ('D') of the at least one gas knife to the passing metal sheet is equal or less than 9 mm, preferably equal or less than 8 mm, preferably equal or less than 7 mm, and the height ('H') of the at least one gas knife above the liquid bath of the metal coating is selected at a value so as to satisfy the formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth).

**[0009]** Alternatively the method of the invention can be executed by providing that the height ('H') of the at least one gas knife above the liquid bath of the metal coating is equal or less than 550 mm, preferably equal or less than 400 mm, more preferably equal or less than 200 mm, and the distance ('D') of the at least one gas knife to the passing metal sheet is selected at a value so as to satisfy the formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth).

**[0010]** Favourable results can be achieved by providing that the at least one stabilization roll is provided at a depth below surface level of the liquid bath of equal or less than a value of 150 mm, preferably at a value equal or less than 140 mm, more preferably at a value equal or less than 130 mm, most preferably at a value equal or less than 120 mm.

**[0011]** In a further aspect of the invention wherein working rolls of a cold rolling mill have a predefined roughness Ra, it is found beneficial that the at least one stabilization roll is provided at a depth below surface level of the liquid bath of the metal coating in dependence of the roughness Ra of working rolls of the cold rolling mill in order to provide a maximum allowable waviness Wsa of the coated metal sheet according to a formula Wsa <= - 1.245 + 0.016271 * X + 0.017416 * Ra, wherein X = D*ln(H*Depth) and wherein Ra is set at a value of equal or less than 4.5. More preferred is that Ra is set a value of equal or less than 1.5, preferably a value of 0.6 or less.

**[0012]** According to the invention a coated metal sheet can effectively be provided with a maximum waviness value Wsa equal or less than 0.41; preferably less than 0.35; more preferably less than 0.31; more preferably less than 0.26; most preferably less than 0.23.

**[0013]** The invention is also embodied in a hot dip galvanizing device to provide a metal coating on a moving metal sheet, which

according to the mentioned prior art comprises a liquid bath of metal coating to be provided on the metal sheet, wherein at least one stabilization roll is provided at a predefined depth below a surface level of the liquid bath to guide the moving metal sheet through the bath, wherein at least one gas knife is provided above the liquid bath, and wherein said gas knife has an outlet to project wiping gas such as air or nitrogen on the metal coating provided on the metal sheet that in use passes along the gas knife. According to the invention this hot dip galvanizing device has the feature a distance ('D') of the at least one gas knife to the passing metal sheet and a height ('H') of the at least one gas knife above the liquid bath of the metal coating are selected at values so as to satisfy a formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth) and wherein Wsa is selected at a value rep-resenting a maximum allowable waviness.

**[0014]** In one preferred embodiment of the hot dip galvanizing device the distance ('D') of the at least one gas knife to the passing metal sheet is set at a value of equal or less than 9 mm, preferably equal or less than 8 mm, more preferably equal or less than 7 mm, and the height ('H') of the at least one gas knife above the liquid bath of the metal coating is set at a value so as to satisfy the formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth).

**[0015]** In another preferred embodiment of the hot dip galvanizing device the height ('H') of the at least one gas knife above the liquid bath of the metal coating is set at a value of equal or less than 550 mm, preferably equal or less than 400 mm, more preferably equal or less than 200 mm, and the distance ('D') of the at least one gas knife to the passing metal sheet is selected at a value so as to satisfy the formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth).

**[0016]** Preferably the at least one stabilization roll of the hot dip galvanizing device is provided at a depth below surface level of the liquid bath of equal or less than a value of 150 mm, preferably at a value equal or less than 140 mm, more preferably at a value equal or less than 130 mm, most preferably at a value equal or less than 120 mm.

**[0017]** The invention is further embodied in a combination of a hot dip galvanizing device as just mentioned, with working rolls of a cold rolling mill that have a predefined roughness Ra, wherein the at least one stabilization roll is provided at a depth below surface level of the liquid bath of the metal coating in dependence of the roughness Ra of the working rolls of the cold rolling mill in order to provide a maximum allowable waviness Wsa of the coated metal sheet according to a formula

Wsa <= - 1.245 + 0.016271 * X + 0.017416*Ra, wherein Ra is set at a value of equal or less than 4.5. The objects of the invention can be further promoted when the roughness Ra is set a value of equal or less than 1.5, preferably a value of 0.6 or less.

**[0018]** The invention will hereinafter be further elucidated with reference to the drawing of an exemplary embodiment of an apparatus according to the invention that is not limiting as to the appended claims.

**[0019]** In the drawing:

- figure 1 shows a typical manufacturing sequence of a coated metal sheet according to the invention; and
- figure 2 schematically shows a hot dip galvanizing device.

**[0020]** Whenever in the figures the same reference numerals are applied, these numerals refer to the same parts.

**[0021]** Making first reference to figure 1 a typical flow of manufacturing steps is shown leading to a coated metal sheet according to the invention, as well as some sequential steps to convert the coated metal sheet of the invention into a press formed and painted automobile body part. In this figure 1 it is shown that casting 1 of a metal slab is followed by hot rolling in a hot strip mill 2 to provide a metal strip, processing in a pickling line 3, cold rolling in a cold rolling mill 4, annealing in a continuous annealing line 5, providing a metal coating on the annealed strip in a hot dip galvanizing line 6 , temper rolling in a temper mill 7, shipping 8 of the product to customers, press forming 9 and painting 10. Some of these operations can be dispensed with, while it is also possible that some other operations are added to this sequence of events. The skilled person further knows that many operations precede the casting step.

**[0022]** Relevant to the invention is particularly what occurs in the hot dip galvanizing line 6, although of course the surface quality of the steel that arrives at the cold rolling mill also plays a decisive role in the resulting waviness of the final product. It is therefore expressly pointed out that albeit that the disclosure of the instant invention concentrates on the process of hot dip galvanizing, the other processing steps are not without importance and should be maintained at their normal high quality standard. A particular desirable relation between the hot dip galvanizing operation and a prior processing step will accordingly be discussed hereinafter.

**[0023]** Turning now to figure 2 it shows a hot dip galvanizing device 11 to provide a metal coating on one surface 12 or both surfaces 12, 13 of a moving metal sheet 14, comprising a tank 15 that holds a liquid bath of the metal coating 16 that is to be provided on the moving metal sheet 14.

**[0024]** Figure 2 shows the application of a stabilization roll 17 and a sink roll 21 to guide the moving metal sheet 14 through the bath, wherein the stabilization roll 17 is provided at a predefined depth ('Depth') below a surface level 18 of the liquid bath. This 'Depth' is defined as the distance between the surface level 18 of the liquid bath and an upper edge of the stabilization roll 17. It is remarked that the application of plural stabilization rolls is also possible, wherein then the 'Depth'-parameter relates to the uppermost stabilization roll.

**[0025]** Above the liquid bath at least one gas knife 19 is provided, which has an outlet 20 to project -in known way- wiping gas on the metal coating provided on the surface or surfaces 12, 13 of the metal sheet 15 that passes along the gas knife 19. Figure 2 shows both the height H of the gas knife or knives 19 above the liquid bath with reference to its surface level 18, and the distance D of the shown two air knives 19 with reference to the metal sheet 14.

**[0026]** According to the invention the distance D of the at least one gas knife 19 with reference to the passing metal sheet 14 and the height H of the at least one gas knife 19 above the liquid bath of the metal coating 16 are selected at values so as to satisfy a formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth) and wherein Wsa is selected at a value rep-resenting a maximum allowable waviness, and wherein 'Depth' stands for the depth of the at least one stabilization roll 17 below the surface level 18 of the liquid bath.

**[0027]** Table 1 shows the influence of the height H of the gas knife 19 above the liquid bath, and the influence of the distance D from sheet 14 to knife 19 in relation to the waviness Wsa of the coated metal sheet 14.

Table 1

| Height H | D | Depth | -X- | Best Wsa | Worst Wsa | Typical Wsa |
|---|---|---|---|---|---|---|
| 400 | 7 | 117,5 | 75,30532 | 0,27 | 0,3 | 0,275 |
| 400 | 9 | 117,5 | 96,82113 | 0,28 | 0,33 | 0,29 |
| 200 | 7 | 117,5 | 70,45329 | 0,25 | 0,27 | 0,265 |
| 200 | 9 | 117,5 | 90,5828 | 0,28 | 0,31 | 0,295 |
| 400 | 12 | 117,5 | 129,0948 | 0,35 | 0,41 | 0,375 |
| 400 | 9 | 117,5 | 96,82113 | 0,29 | 0,34 | 0,3 |

**[0028]** Table 2 shows the influence of the height H of the gas knife 19 above the liquid bath and the Depth of the at least one stabilizing roll 17 below the surface level 18 of the liquid bath.

Table 2

| Height H | D | Depth | -X- | Wsa |
|---|---|---|---|---|
| 550 | 8 | 120 | 88,77928 | 0,278 |
| 500 | 8 | 130 | 88,65714 | 0,28 |
| 550 | 8 | 130,3 | 89,43806 | 0,29 |
| 550 | 8 | 134,8 | 89,70968 | 0,29 |
| 505 | 8 | 140 | 89,32961 | 0,282 |
| 550 | 8 | 150 | 90,56443 | 0,311 |

**[0029]** It follows from table 1 and table 2 that preferably the distance D of the at least one gas knife 19 to the passing metal sheet 14 is equal or less than 9 mm, more preferably equal or less than 8 mm, even more preferable equal or less than 7 mm, and the height H of the at least one gas knife above the liquid bath of the metal coating is then selected at a value so as to satisfy the formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth).

**[0030]** Alternatively it follows from table 1 and table 2 that the height H of the at least one gas knife 19 above the liquid bath of the metal coating 16 is preferably equal or less than 550 mm, preferably equal or less than 400 mm, more preferably equal or less than 200 mm, and the distance D of the at least one gas knife 19 to the passing metal sheet 14 is selected at a value so as to satisfy the formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth).

**[0031]** Table 3 shows the influence of the roughness Ra of the last working rolls in the cold rolling mill in relation to X (the parameter D*ln(H*Depth)) and their impact on the waviness of the product.

Table 3

| Ra | Wsa-meas. | Height H | D | Depth | -X- | Wsa-calc |
|---|---|---|---|---|---|---|
| 1,5 | 0,23 | 500 | 8 | 150 | 89,80195 | 0,242313 |
| 1,5 | 0,26 | 500 | 8 | 150 | 89,80195 | 0,242313 |
| 1,5 | 0,23 | 500 | 8 | 150 | 89,80195 | 0,242313 |
| 0,6 | 0,227 | 550 | 8 | 135 | 89,72154 | 0,225331 |
| 0,6 | 0,229 | 550 | 8 | 135 | 89,72154 | 0,225331 |
| 4,5 | 0,311 | 550 | 8 | 150 | 90,56443 | 0,306968 |
| 4,5 | 0,278 | 550 | 8 | 120 | 88,77928 | 0,277921 |
| 4,5 | 0,28 | 500 | 8 | 130 | 88,65714 | 0,275934 |
| 4,5 | 0,29 | 550 | 8 | 130,3 | 89,43806 | 0,28864 |

(continued)

| Ra | Wsa-meas. | Height H | D | Depth | -X- | Wsa-calc |
|---|---|---|---|---|---|---|
| 4,5 | 0,29 | 550 | 8 | 134,8 | 89,70968 | 0,29306 |
| 4,5 | 0,282 | 505 | 8 | 140 | 89,32961 | 0,286876 |

**[0032]** According to the results of Tables 2 and 3 the at least one stabilization roll 17 is preferably provided at a depth D below surface level 18 of the liquid bath at a value of equal or less than 150 mm, preferably at a value equal or less than 140 mm, more preferably at a value equal or less than 130 mm, most preferably at a value equal or less than 120 mm.

**[0033]** Table 3 shows a calculation of the waviness Wsa which is depicted by the parameter Wsa-calc, whereas it also shows the measured waviness Wsa-meas. Wsa-calc is determined with the formula Wsa = - 1.245 + 0.016271 * X + 0.017416 * Ra, wherein X = D*ln(H*Depth), and Ra stands for the roughness of the working rolls in the last stand of the cold rolling mill. From these data it can be derived that the at least one stabilization roll 17 is preferably provided at a depth D below surface level 18 of the liquid bath of the metal coating 16 in dependence of the roughness Ra of the final working rolls of the cold rolling mill in order to provide a maximum allowable waviness Wsa of the coated metal sheet according to a formula Wsa <= - 1.245 + 0.016271 * X + 0.017416 * Ra, wherein X = D*ln(H*Depth) and wherein Ra is set at a value of equal or less than 4.5. Further preferred values of the roughness Ra are that Ra is set a value of equal or less than 1.5, and more preferably at a value of 0.6 or less.

**[0034]** The method of coating a metal sheet according to the invention results into a coated metal sheet with a waviness value Wsa equal or less than 0.41; preferably less than 0.35; more preferably less than 0.31; more preferably less than 0.26; most preferably less than 0.23.

**[0035]** Although the invention has been discussed in the foregoing with reference to exemplary embodiments of the method and devices of the invention, the invention is not restricted to these particular embodiments which can be varied in many ways without departing from the invention. The discussed exemplary embodiments shall therefore not be used to construe the appended claims strictly in accordance therewith. On the contrary the embodiments are merely intended to explain the wording of the appended claims without intent to limit the claims to these exemplary embodiments. The scope of protection of the invention shall therefore be construed in accordance with the appended claims only, wherein a possible ambiguity in the wording of the claims shall be resolved using these exemplary embodiments.

## Claims

1. Method of providing a coating on a metal sheet, wherein a cold rolled metal sheet is subjected to a hot dip galvanizing operation to provide a metal coating on the metal sheet, which hot dip galvanizing operation comprises guiding the metal sheet through a liquid bath of the metal coating with at least one stabilization roll provided at a predefined depth ('Depth') below surface level of the liquid bath, and wiping the metal coating that is provided on the metal sheet with at least one gas knife having an outlet to project wiping gas on the metal coating on the metal sheet that passes along the gas knife, **characterized in that** a distance ('D') of the at least one gas knife to the passing metal sheet and a height ('H') of the at least one gas knife above the liquid bath of the metal coating are selected at values so as to satisfy a formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth) and wherein Wsa is selected at a value representing a maximum allowable waviness.

2. Method according to claim 1, **characterized by** providing that the distance ('D') of the at least one gas knife to the passing metal sheet is equal or less than 9 mm, preferably equal or less than 8 mm, preferably equal or less than 7 mm, and the height ('H') of the at least one gas knife above the liquid bath of the metal coating is selected at a value so as to satisfy the formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth).

3. Method according to claim 1, **characterized by** providing that the height ('H') of the at least one gas knife above the liquid bath of the metal coating is equal or less than 550 mm, preferably equal or less than 400 mm, more preferably equal or less than 200 mm, and the distance ('D') of the at least one gas knife to the passing metal sheet is selected at a value so as to satisfy the formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth).

4. Method according to any one of claims 1 - 3, **characterized by** providing that the at least one stabilization roll is provided at a depth below surface level of the liquid bath of equal or less than a value of 150 mm, preferably at a value equal or less than 140 mm, more preferably at a value equal or less than 130 mm, most preferably at a value equal or less than 120 mm.

5. Method according to any one of claims 1 - 4, wherein working rolls of a cold rolling mill have a predefined roughness Ra, **characterized by** providing that the at least one stabilization roll is provided at a depth below surface level of the liquid bath of the metal coating in dependence of the roughness Ra of working rolls of the cold rolling mill in order to provide a maximum allowable waviness Wsa of the coated metal sheet according to a formula Wsa <= - 1.245 + 0.016271 * X + 0.017416 * Ra, wherein X = D*ln(H*Depth) and wherein Ra is set at a value of equal or less than 4.5.

6. Method according to claim 5, **characterized by** providing that Ra is set a value of equal or less than 1.5, preferably a value of 0.6 or less.

7. Coated metal sheet manufactured in accordance with the method of any one of the previous claims 1 - 6, with a waviness value Wsa equal or less than 0.41; preferably less than 0.35; more preferably less than 0.31; more preferably less than 0.26; most preferably less than 0.23.

8. Hot dip galvanizing device to provide a metal coating on a moving metal sheet, comprising a liquid bath of metal coating to be provided on the metal sheet, wherein at least one stabilization roll is provided at a predefined depth ('Depth') below surface level of the liquid bath to guide the moving metal sheet through the bath, and at least one gas knife is provided above the liquid bath, said gas knife having an outlet to project wiping gas on the metal coating provided on the metal sheet that in use passes along the gas knife, **characterized in that** a distance ('D') of the at least one gas knife to the passing metal sheet and a height ('H') of the at least one gas knife above the liquid bath of the metal coating are selected at values so as to satisfy a formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth) and wherein Wsa is selected at a value representing a maximum allowable waviness.

9. Hot dip galvanizing device according to claim 8, **characterized in that** the distance ('D') of the at least one gas knife to the passing metal sheet is set at a value of equal or less than 9 mm, preferably equal or less than 8 mm, more preferably equal or less than 7 mm, and the height ('H') of the at least one gas knife above the liquid bath of the metal coating is set at a value so as to satisfy the formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth).

10. Hot dip galvanizing device according to claim 8, **characterized in that** the height ('H') of the at least one gas knife above the liquid bath of the metal coating is set at a value of equal or less than 550 mm, preferably equal or less than 400 mm, more preferably equal or less than 200 mm, and the distance ('D') of the at least one gas knife to the passing metal sheet is selected at a value so as to satisfy the formula Wsa <= 0.0016 * X + 0.1395, wherein X = D*ln(H*Depth).

11. Hot dip galvanizing device according to any one of claims 8 - 10, **characterized in that** the at least one stabilization roll is provided at a depth below surface level of the liquid bath of equal or less than a value of 150 mm, preferably at a value equal or less than 140 mm, more preferably at a value equal or less than 130 mm, most preferably at a value equal or less than 120 mm.

12. Combination of a hot dip galvanizing device according to any one of claims 8 - 11, with working rolls of a cold rolling mill have a predefined roughness Ra, **characterized in that** the at least one stabilization roll is provided at a depth below surface level of the liquid bath of the metal coating in dependence of the roughness Ra of the working rolls of the cold rolling mill in order to provide a maximum allowable waviness Wsa of the coated metal sheet according to a formula Wsa <= - 1.245 + 0.016271 * X + 0.017416*Ra, wherein Ra is set at a value of equal or less than 4.5.

13. Combination of a hot dip galvanizing device with working rolls of a cold rolling mill according to claim 12, **characterized in that** Ra is set a value of equal or less than 1.5, preferably a value of 0.6 or less.

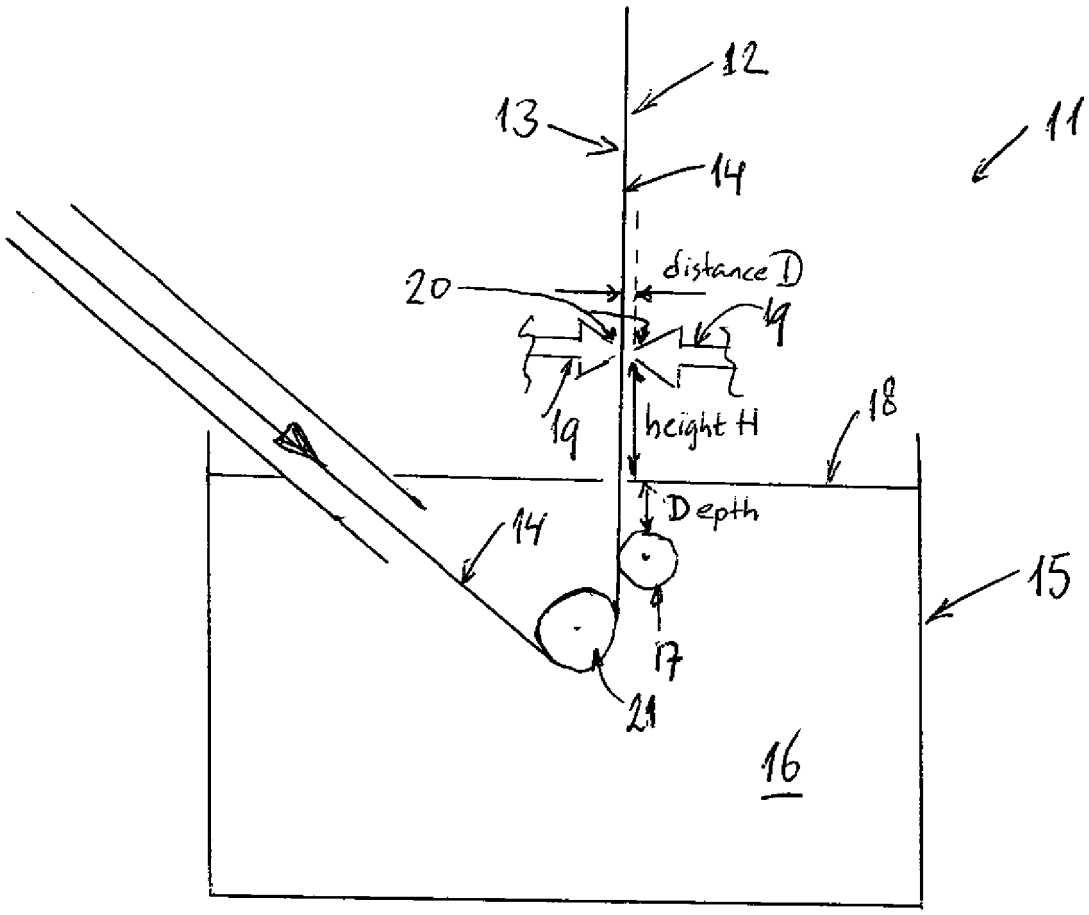


FIG. 2

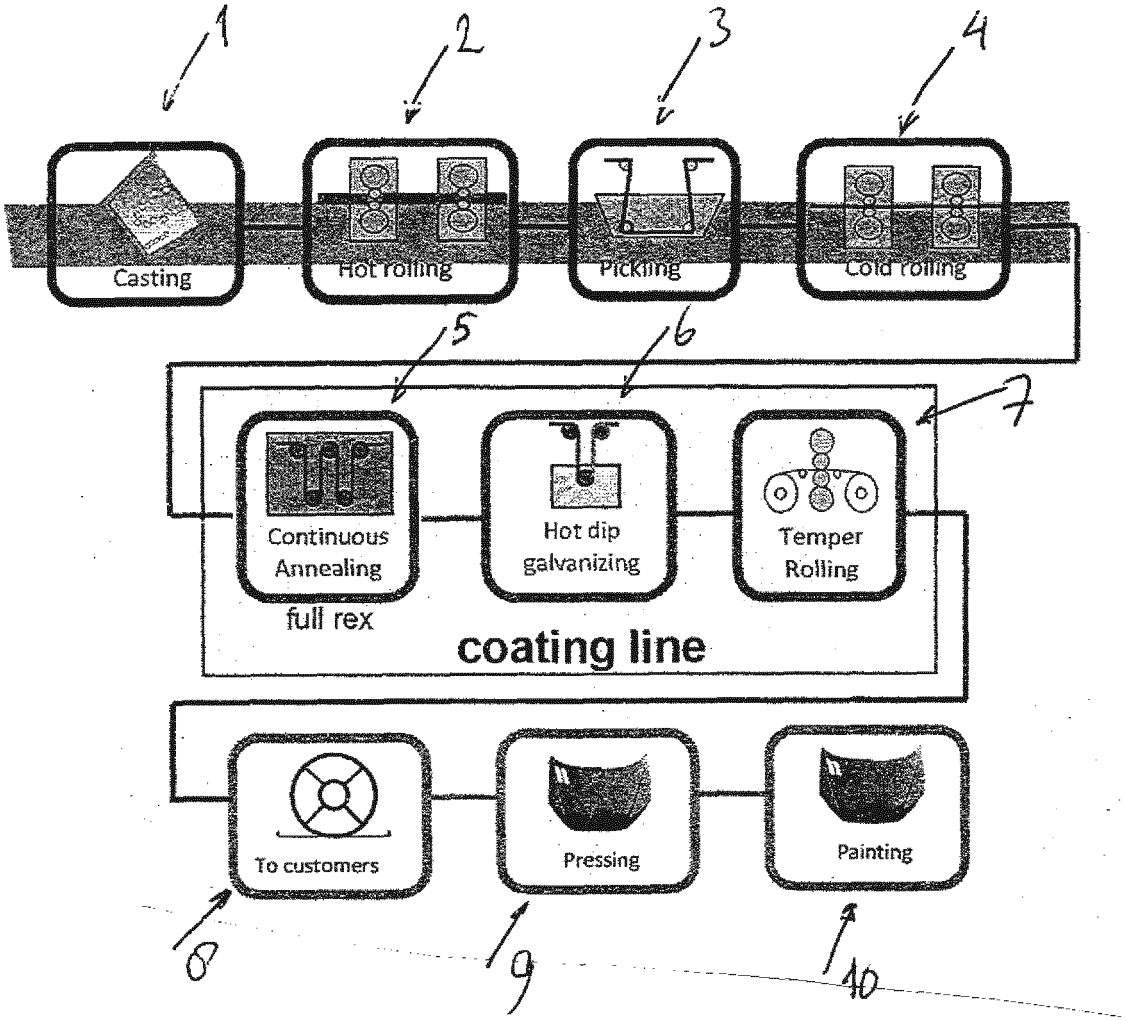
1
2
3
4
Casting
Hot rolling
Pickling
Cold rolling
5
6
7
Continuous Annealing
full rex
Hot dip galvanizing
Temper Rolling
coating line
To customers
Pressing
Painting
8
9
10

FIG. 1

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# EUROPEAN SEARCH REPORT

Application Number
EP 17 16 3994

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
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| A | WO 94/02658 A1 (DUMA MASCH ANLAGENBAU [DE]; PANNENBECKER H [DE]; JABS RONALD [DE]) 3 February 1994 (1994-02-03)<br>* claim 21; figures *<br>----- | 1-13 | INV.<br>C23C2/18<br>C23C2/20<br>C23C2/02<br>C23C2/00 |
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| | -/-- | | |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 7 September 2017 | Brisson, Olivier |

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## EUROPEAN SEARCH REPORT

Application Number
EP 17 16 3994

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TECHNICAL FIELDS SEARCHED (IPC)

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