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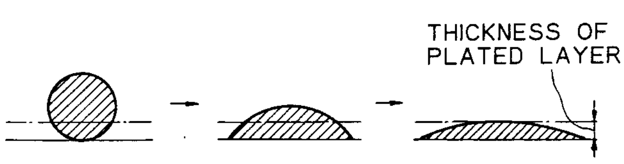
(54) Process for producing spray plated metal strip.

(57) A process for producing a spray-plated metal strip by spraying a molten metal on a metal strip, which comprises: spraying, on a metal strip, molten metal particles having a weight average particle diameter of not more than 15 times the thickness of a plated layer to be formed on the strip.

Fig. 1



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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a process for producing a spray-plated metal strip, sheet, or plate by spraying a molten metal on a metal strip.

2. Description of the Related Art

In a spray-plating process, i.e., a plating of a metal strip by spraying a molten metal thereon, the sprayed strip is necessarily subjected to a smoothing treatment of the sprayed metal layer, to obtain a smooth surface of a plated metal strip.

Japanese Unexamined Patent Publication (Kokai) No. 1-201456 discloses a process, which comprises cleaning a steel sheet surface, spraying the thus cleaned sheet with a molten metal atomized by a pressurized gas, and then blowing the sheet with a pressurized gas by a gas wiping nozzle.

Such a gas-wiping conditioning treatment of the sprayed sheet surface, however, cannot provide a well smoothed surface of a plated strip in comparison with those obtained by other plating processes such as electroplating, hot dipping, etc.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a process for producing a spray-plated metal strip, which provides a plated strip surface as smooth as a dip-plated strip surface.

To achieve the above object according to the present invention, there is provided a process for producing a spray-plated metal strip by spraying molten metal on a metal strip, which comprises:

spraying, on a metal strip, molten metal particles having a weight average particle diameter of not more than 15 times the thickness of a plated layer to be formed on the strip.

The term "weight average particle diameter" as herein used is defined as follows.

Assuming a non-globular molten metal particle of a volume Vp, a globe of the equivalent volume should have a diameter, d, which can be calculated from

$$Vp = (4\pi/3) \times (d/2)^3$$

The diameter "d" is referred to as "equivalent globe diameter". The weight average particle diameter, dm, is obtained by

$$0.5 = (1/M) \sum_{d=0}^{d=dm} (\rho Vp) Nd$$

where

- M: total weigh of particles, in kg,
- Vp: volume of a particle having a diameter of d in terms of the equivalent globe diameter, in m^3,
- ρ: specific gravity of a particle, in kg/m^3, and
- Nd: number of particles having a diameter of d in terms of the equivalent globe diameter.

Thus, the weight average particle diameter, dm, refers to a particle diameter in terms of the equivalent globe diameter which satisfies the above equation, i.e., a summation of the weight of particles having a diameter of dm or less amounts to 50% of the total weight M of particles having a distribution in diameter.

The term "metal strip" as herein referred to includes strips, sheets, and plates of metallic materials, such as steel, copper, copper alloys, aluminum, aluminum alloys, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a sectional view showing the deposition of a molten metal particle on a substrate;

Fig. 2 is a graph showing a percentage of non-plated area as a function of the ratio of the weight average particle diameter of a spray-plating molten metal particle to the thickness of a plated layer;

Fig. 3 is a graph showing the deposition efficiency of sprayed molten metal as a function of the molten metal spraying condition;

Fig. 4 schematically illustrates an arrangement for carrying out a process according to the present invention;

Fig. 5 is a graph showing the interrelationship between the weight deposit, the number of effective nozzle stages, and the speed of metal strip conveying line;

Fig. 6 is a graph showing the interrelationship between the heating temperature, the heating time, and the smoothness of a plated layer; and

Fig. 7 is a graph showing the weight loss by corrosion of a spray-plated steel sheet according to the present invention in comparison with the conventional hot-dip plated steel sheet.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present inventive process uses a spray of molten metal particles having a weight average particle diameter of not more than 15 times the thickness of a plated layer to be formed on a metal strip. Figure 1 shows that the molten metal particle of size larger than the plated layer thickness can be used in the present invention, because the molten metal particle size does not directly correspond to the plated layer thickness due to wetting between the molten metal and the substrate metal strip.

The molten metal particle must have a weight average particle diameter of not more than 15 times the plated layer thickness for the following reason.

Figure 2 shows the percentage of a non-plated area as a function of the ratio of the weight average particle diameter (d µm) of a sprayed molten metal to the target thickness (t µm) of a plated layer. When the ratio (d/t) is greater than 15, a significant non-plated area unavoidably remains after the heating of a sprayed strip, even if the heating conditions are varied.

A greater particle size also requires a longer time for the smoothing treatment, a larger heating furnace, and increased equipment cost.

In a preferred embodiment of the present invention, the deposition efficiency of the sprayed molten metal on the strip surface is ensured to be 90% or more by using the distance "L" from a spraying apparatus to a strip to be sprayed in the range defined by the following formula:

$$L < (1.75/\theta) \times (\rho d V^2/\alpha)^{\frac{1}{4}}$$

where

- L: distance between spraying means and metal strip to be sprayed in m,
- θ: flare angle of molten metal spray in rad,
- ρ: specific gravity of molten metal spray in kgf/m^3,
- d: weight average particle diameter of molten metal spray in m,
- v: maximum speed of molten metal spray in m/sec, and
- α: surface tension of molten metal spray in kgf/m.

It is generally known that the distance (L) between a spray apparatus and a metal strip to be sprayed is expressed as:

$$L = (k/\theta) \times (\rho d V^2/\alpha)^{\frac{1}{4}}$$

Figure 3 shows the deposition efficiency as a function of the parameter "k". It is seen from Fig. 3 that, to obtain a deposition efficiency of 90% or more, the k-value should be less than 1.75, i.e., k<1.75, and in turn, the distance "L" should be in the range as defined by the above-stated inequality formula.

In a preferred embodiment of the present invention, the spraying of a molten metal is carried out in separate spraying steps by directing a metal strip through separate spraying means. This enables the plated thickness to be controlled in a wide range with respect to the strip conveying speed while ensuring an improved smoothness of a spray-plated strip surface.

The present inventive process preferably further comprises heating and holding a metal strip, which has been sprayed with a molten metal, at a temperature of T and for a time of S defined by the following formula, to provide a smoother surface of a metal strip;

$$S \geqq 0.095 \times (0.5 + d/200)/(T/T_m)$$

where T>Tm,

- S: holding time in second,
- d: weight average particle diameter in µm,
- T: holding temperature in °C, and
- T_m: melting point of spraying metal in °C.

The heating and holding of a sprayed strip at the specified temperature and for the specified time promotes wetting between the deposit metal and the substrate strip and further improves the smoothness of a spray-plated metal strip product.

When a strip of steel or iron alloy is sprayed according to the present invention, the strip is preferably electroplated with a precoating metal such as nickel before being sprayed, to further improve the smoothness of a spray-plated metal strip product.

EXAMPLE

Figure 4 shows an arrangement in which a steel sheet was plated with zinc by a process according to the present invention.

A continuous plating arrangement 1 is disposed on the outlet side of a not-shown continuous annealing furnace. A steel sheet "S", which was being conveyed in the direction denoted by an arrow, was annealed in a not-shown continuous annealing furnace, had a temperature of 450°C when passing a deflector roll 2, and was directed through a plating chamber in which spray nozzles 3 are arranged in two stages along the conveying direction and sprayed a molten metal on the steel sheet "S" being conveyed. The molten metal spray had a particle size of 25 µm in terms of the weight average particle diameter. This particle size was obtained by gas-atomizing with a non-oxidizing gas such as nitrogen, argon, etc. In a heating furnace 4 arranged in continuation with the plating chamber, the steel sheet "S" was heated by a heater element which can heat the sheet without being in contact therewith. Electrical heaters, high frequency heaters, radiant tube heaters or other non-contact type heaters may be used for this purpose. The heating atmosphere may be either oxidizing or non-oxidizing.

The spray nozzles 3 had a maximum spray amount of 160 g/sec/m(width) and a controllable range of from 160 to 80 g/sec/m(width).

An annealed steel sheet having a temperature of 450°C was sprayed with zinc-0.2% aluminum in the plating chamber provided with two stages of spray nozzles 3 having a spray amount of 160 g/sec/m(width) per stage. The temperature of the molten zinc spray was 460°C. The thus sprayed steel sheet was heated at 450°C for 0.5 sec by being held in an atmosphere of 100% nitrogen gas held at 450°C.

To obtain a deposition efficiency of 90% or more, the spraying distance "L" or the distance between the spray nozzles 3 and the steel sheet "S" was determined with respect to the particle size, the initial speed, and the flare angle of the molten metal spray, as expressed by the following relationship:

$$L < (1.75/\theta) \times (\rho d V^2/\alpha)^{\frac{1}{4}}$$

where the symbols have the same meanings as herein previously defined.

A spray-plating test of a steel sheet was carried out by using an arrangement provided with seven stages of spray nozzles.

Figure 5 shows the interrelationship between the number of nozzle stages actually used, the weight deposit on the sheet surface per unit area of one sheet side, and the speed of a steel sheet conveying line. The abscissa represents the line speed in m/min, the left ordinate the weight deposit, and the right ordinate the total spray amount from the spray nozzles. It is seen from Fig. 5 that the more the nozzle stages used, the wider the controllable ranges of both the weight deposit and the line speed. When the spray amount per stage is increased, the total number of nozzle stages can be reduced, but the uncontrollable range denoted by "A" becomes wider. When the spray amount per stage is too small, the number of nozzle stages should be increased and the equipment cost is raised. It is, then, important that the number of nozzle stages be reasonably determined in accordance with the line speed and the maximum weight deposit for specific cases.

Figure 6 shows the interrelationship between the residence time "S" in the heating furnace 5, a parameter "X" as defined below, and the surface smoothness of a spray-plated metal strip product.

$$X = (0.5 + d/200)/(T/T_m)$$

where $T > T_m$,

d: weight average particle diameter in μm,
T: holding temperature in °C, and
T_m: melting point of spray metal in °C.

In Fig. 6, the blank circles, the solid circles, and the "X"-marks mean that the surface of a spray-plated steel sheet product is perfectly smooth, has few defects, and is significantly defective, respectively. The perfect smoothness region of "A" can be defined by a line S = 0.095X and the residence time "S" required for obtaining a good smoothness should be in the range specified as:

$$S \geqq 0.095 \times (0.5 + d/200)/(T/T_m)$$

A spray-plated steel sheet was produced by using two stages of spray nozzles at a weight deposit zinc of 80 g/m^2 per one sheet side, under the same condition as mentioned above. The product sheet was subjected to a salt water spray test to estimate the corrosion resistance of the steel sheet.

For comparison, a conventional hot-dip plated steel sheet was also tested under the same testing condition. The hot-dipping was carried out under the condition of a zinc plating bath temperature of 450°C, a pre-dip steel sheet temperature of 453°C, a zinc plating bath composition of 99.8% zinc and 0.2% aluminum.

Figure 7 shows the plots of the thus obtained results in terms of the weight loss by corrosion as a function of the duration of salt water spray. The result proves that the present inventive spray-plated steel sheet has a good corrosion resistance comparable with that of the conventional hot-dip plated steel sheet.

To summarize the advantages of the present inventive process:

(1) It produces a spray-plated metal strip having a good surface smoothness comparable with that obtained by the conventional hot-dip process;

(2) It makes it possible to accelerate the spray-plating process;

(3) Either both sides or one side of a metal strip can be plated; and

(4) Different metals can be plated on either sides of a metal strip.

Claims

1. A process for producing a spray-plated metal strip by spraying a molten metal on a metal strip, which comprises:

spraying, on a metal strip, molten metal particles having a weight average particle diameter of not more than 15 times the thickness of a plated layer to be formed on the strip.

2. A process according to claim 1, which further comprises:

heating and holding said metal strip, which has been sprayed with said molten metal, at a temperature of T and for a time of S defined by the following formula, to smooth the surface of said metal strip;

$$S \geqq 0.095 \times (0.5 + d/2000)/(T/T_m)$$

where T>Tm,

- S: holding time in second,
- d: weight average particle diameter in μm,
- T: holding temperature in °C, and
- T_m: melting point of spraying metal in °C.

3. A process according to claim 1, wherein said spraying is carried out in separate spraying steps by directing said metal strip though separate spraying means.

4. A process according to claim 1, wherein said metal strip is a steel strip which has been electroplated with nickel.

5. A process according to claim 1, wherein said spraying is carried out by a spraying means disposed at a distance of L from said metal strip, the distance L being defined by the following formula;

$$L < (1.75/\theta)\ \chi\ (\rho d V^2/\alpha)^{\frac{1}{4}}$$

where

- L: distance between spraying means and metal strip to be sprayed in m,
- θ: flare angle of molten metal spray in rad,
- ρ: specific gravity of molten metal spray in kgf/m^3,
- d: weight average particle diameter of molten metal spray in m,
- v: maximum speed of molten metal spray in m/sec, and
- α: surface tension of molten metal spray in kgf/m.

FIg. 1

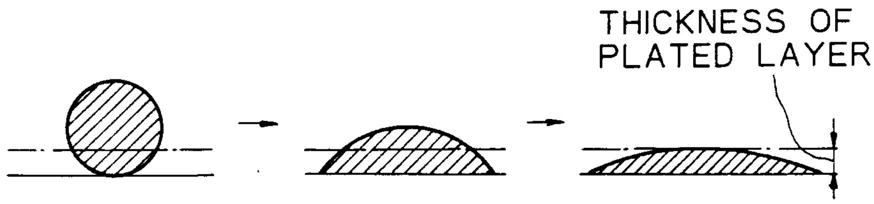

THICKNESS OF
PLATED LAYER

FIg. 3

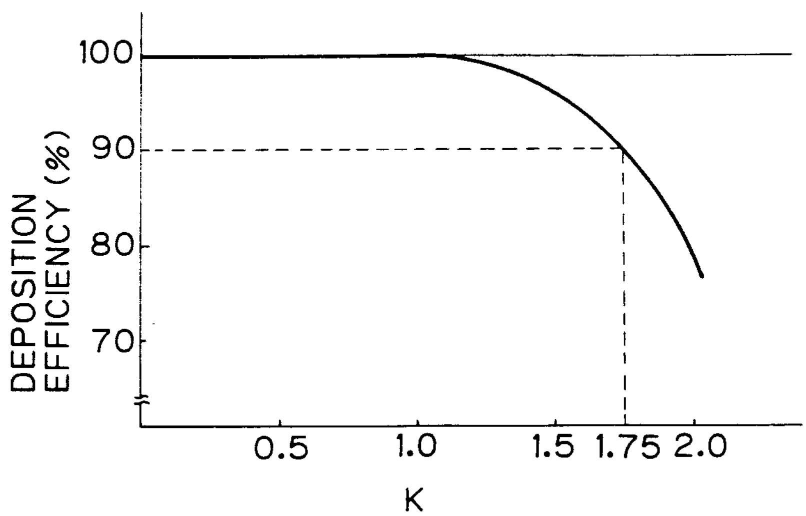

DEPOSITION
EFFICIENCY (%)
100
90
80
70
0.5
1.0
1.5
1.75
2.0
K

Fig. 2

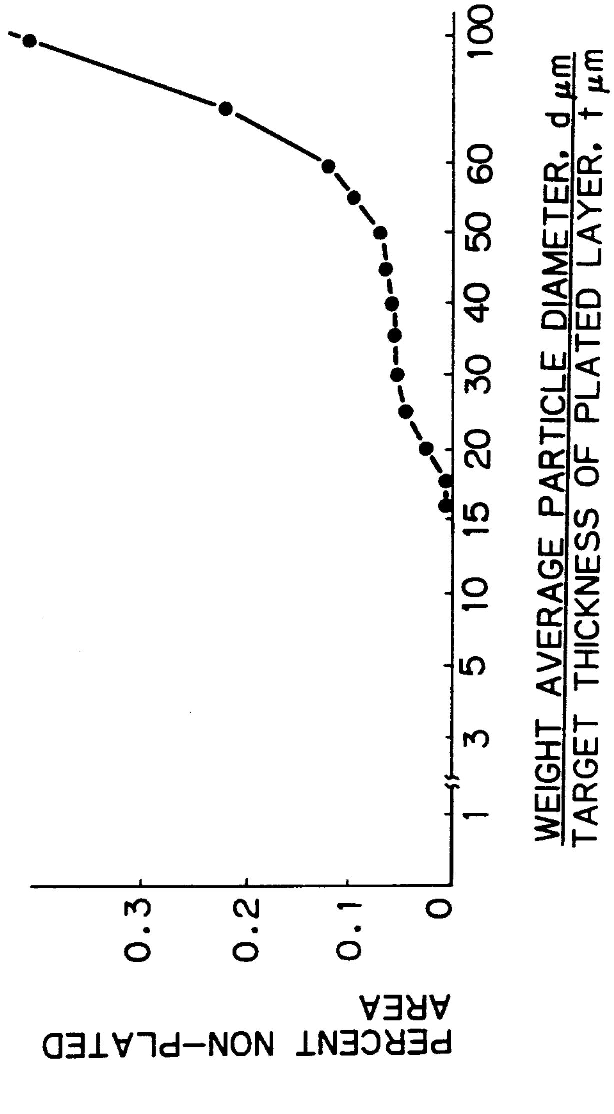

PERCENT NON-PLATED AREA
0.3
0.2
0.1
0
1
3
5
10
15
20
30
40
50
60
100
WEIGHT AVERAGE PARTICLE DIAMETER, d µm
TARGET THICKNESS OF PLATED LAYER, t µm

Fig. 4

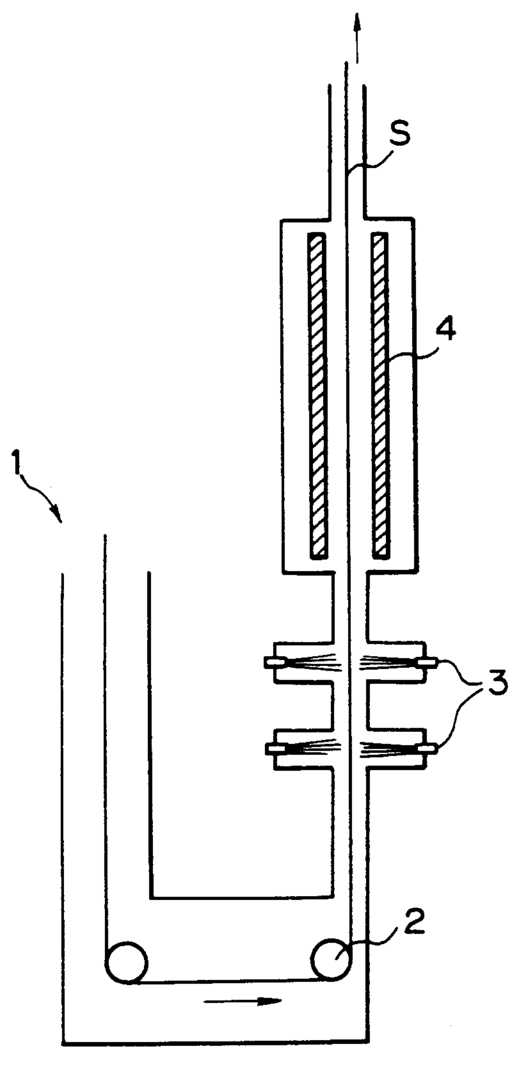


Fig. 5

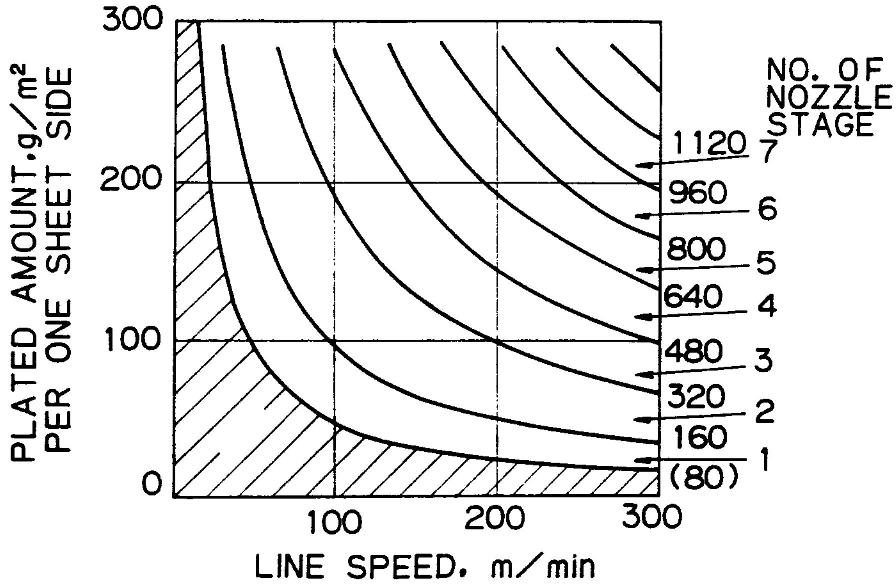

300
200
100
0
100
200
300
PLATED AMOUNT, g/m²
PER ONE SHEET SIDE
LINE SPEED, m/min
NO. OF
NOZZLE
STAGE
1120 7
960 6
800 5
640 4
480 3
320 2
160
(80) 1

Fig. 6

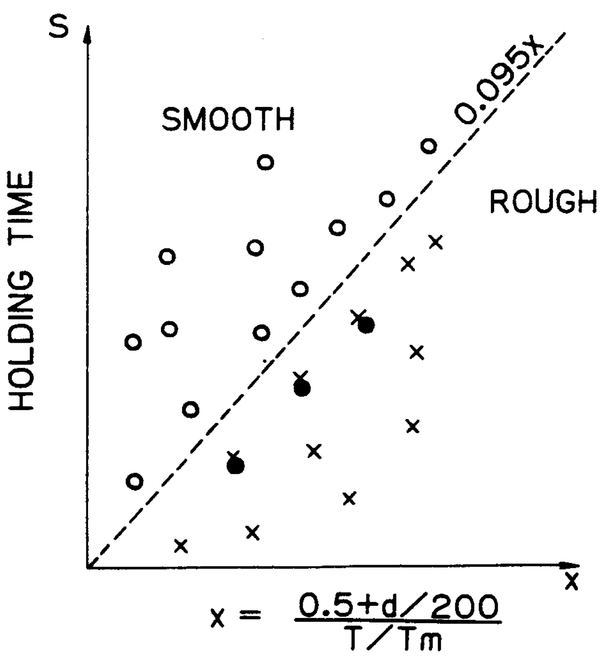
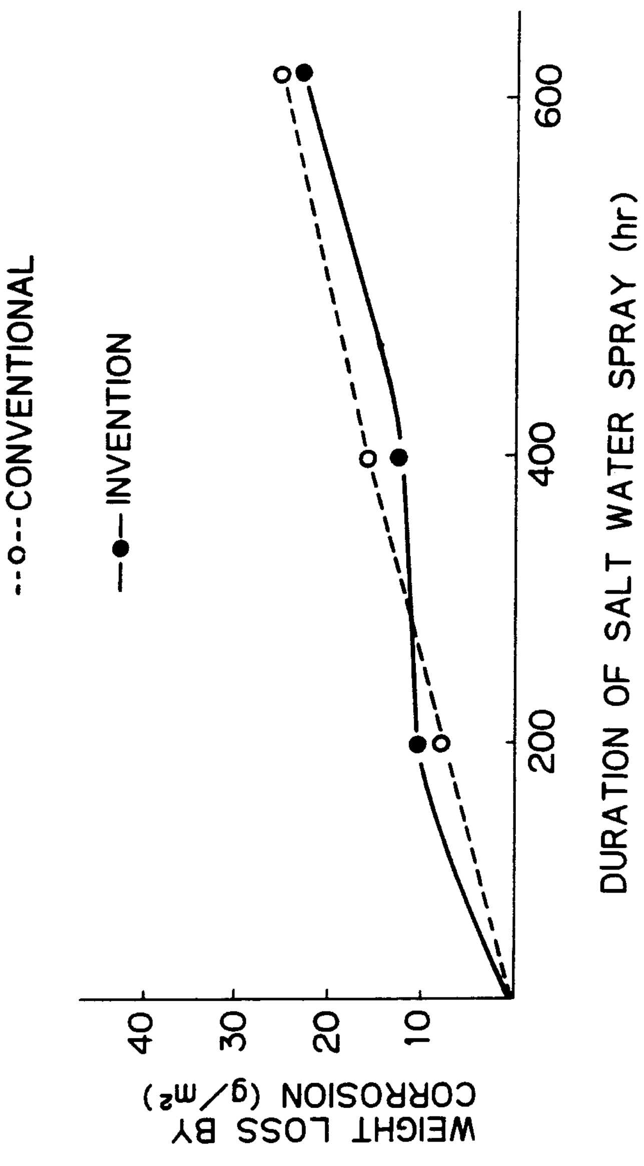

S
SMOOTH
ROUGH
0.095x
HOLDING TIME
x
x = 0.5+d/200 / T/Tm

Fig. 7


--o--CONVENTIONAL
—●—INVENTION
WEIGHT LOSS BY CORROSION (g/m²)
40
30
20
10
200
400
600
DURATION OF SALT WATER SPRAY (hr)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 11 0198

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	FR-A-2 558 850 (CLECIM S.A.) * page 4, line 14 - line 18 * – – –	1	C 23 C 4/12
A	EP-A-0 119 036 (NATIONAL RESEARCH DEVELOPMENT CORP.) * page 3, line 24 - line 28 * – – –	1	
A	US-A-2 873 219 (J.B. BRENNAN) * column 1, line 66 - line 71 * * column 2, line 18 - line 25 * – – –	1	
A	JOURNAL OF METAL vol. 41, no. 10, October 1989, WARRENDALE, USA pages 23 - 28; P. MATHUR ET AL: 'PROCESS CONTROL, MODELING AND APPLICATIONS OF SPRAY CASTING ' – – –		
A	METTALLURGICAL TRANSACTIONS /A vol. 20A, no. 1, January 1989, WARRENDALE, USA pages 71 - 85; E. GUTIERREZ-MIRAVETE: 'A MATHEMATICAL MODEL OF THE SPRAY DEPOSITION PROCESS ' – – – – –		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			C 23 C

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	19 September 91	JOFFREAU P.O.

CATEGORY OF CITED DOCUMENTS

- X : particularly relevant if taken alone
- Y : particularly relevant if combined with another document of the same catagory
- A : technological background
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- D : document cited in the application
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