

**Title of the Invention: Hot Dipping 5 Weight % Al-Zn Alloy
Coating on Steel**

Background of the Invention

Field of the Invention

5 The present invention relates to the technology of hot dipping aluminum(Al) - zinc(Zn) alloy coating on steel, in particular to, after a hot dip galvanizing treatment of the steel, the use of a reduction in thickness of a galvanized coating on the steel, followed by hot dipping 5 weight % Al-Zn alloy coating to produce durable and corrosion resistant steel having 5
10 weight % Al-Zn alloy coating.

Description of the Prior Art

Hot dip galvanizing is contributory to the corrosion resistance of steel in a normal atmosphere. The protection mechanism provided by pure zinc coating on steel substrate is divided into two types: the first utilizes the
15 formation of a zinc oxide film to prevent the invasion of corrosion factors, and the second features zinc that acts as a sacrificial anode.

However, the durability of galvanized steel in specific corrosive circumstances, such as exposure to air high in salt content, industrial waste and high moisture, is reduced by one-fifth or more than under normal
20 conditions. Therefore, it is important to develop a durable and economic coating for steel used in areas with a high concentration of salt and/or poison gas.

Coating of other metals is also used in industry, for example hot dipping aluminum. The main reason for hot dipping aluminum is to form a strong
25 corrosion resistant alumina coating film. The corrosion resistant effect of hot dipping aluminum is significantly better than that of hot dip galvanizing,

particularly in a warm wet environment with high concentrations of salts or sulfides. Nevertheless, hot dipping aluminum is undesirable as a coating because aluminum acts as a poor sacrificial anode and is usually cathodic to steel. When a leakage occurs in the aluminum coating, it will cause corrosion. The cathodic protection of alumina film is notably reduced, and sometimes is even completely lost.

In addition, small amounts of aluminum is added to pure molten zinc to diminish the γ -phase iron-zinc alloy layer of the zinc-iron interface and to enhance the processing of hot dip galvanizing. The corrosion resistance of such a coating is not improved because the additional amount of aluminum is small. Minor amounts of aluminum is added to diminish the brittle γ -phase iron-zinc alloy layer so that aluminum is distributed only in the zinc-iron interface.

It has been found that when more aluminum is added to the hot dip galvanizing process enhancement of the corrosion resistance of coating on steel occurs. When the coating function and preparation procedures of a Al-Zn combination with various ratios of Al and Zn are taken into consideration, 5 weight % Al-Zn alloy coating is discovered to possess the corrosion resistance of pure zinc coating as well as that of pure aluminum coating. The excellent corrosion resistance of 5 weight % Al-Zn alloy coating is demonstrated particularly in a normal atmosphere and environment with high concentrations of salts or sulfides.

In a warm climate with air with a high moisture and high salt content (such as Taiwan located in subtropical zone and surrounded by ocean) the corrosion problem for steel construction is very serious. Particularly, galvanized steel cannot meet the use requirements in seashore area and offshore oil drilling platform. If 5 weight % Al-Zn alloy coating is used, the coated steel can have longer durability and an enhanced corrosion resistance.

Since 1983, the commercial product "Galfan" (steel with 5 weight % Al-Zn alloy coating) is developed, and further research and efforts focus on 5 weight % Al-Zn alloy coating on steel. The immersing technology in the past was limited to the experimental scale only and could not be applied in
5 a large commercial scale. The preparation process of commercial Galfan can only be applied to steel sheets and steel coils. Successful technology for batchwise hot dipping has not been found. In order to solve these problems and to improve the corrosion resistance and mechanical properties of the coated steel, the present invention provides a new process
10 of hot dipping 5 weight % Al-Zn alloy coating on steel in a large scale manner. The immersing technology of the present invention can be used not only to steel sheets and steel coils but also to numerous steel constructions, such as bolts, nuts and steel beams.

Summary of the Invention

15 One object of the invention is to provide a process of hot dipping 5 weight % Al-Zn alloy coating on steel comprising reducing the thickness of galvanized coating on steel between the steps of hot dip galvanizing and hot dipping 5 weight % Al-Zn alloy coating to produce durable and corrosion resistant steel having 5 weight % Al-Zn alloy coating.

20 Another object of the invention is to provide a process for either a batch type or a continuous type hot dipping 5 weight % Al-Zn alloy coating on steel which is suitable for the formation of 5 weight % Al-Zn alloy coating on various steel constructions and for the production in a large commercial scale.

25 A further object of the invention is to provide a steel construction containing 5 weight % Al-Zn alloy coating which possesses improved corrosion resistance and excellent mechanical properties and is suitable for the production of desirable steel constructions.

These and the other objects, advantages and features of the present invention will be more fully understood and appreciated by reference to the written specification and appended drawings.

Brief Description of the Drawings

5 The invention will be further described by the following drawings wherein:

Fig. 1 shows aluminum-zinc two-element phase diagram;

Fig. 2 shows iron-aluminum two-element phase diagram;

Fig. 3 shows iron-aluminum-zinc three-element phase diagram at a
10 temperature of 450 °C;

Fig. 4 shows a comparison between conventional galvanized steel and steel with 5 weight % Al-Zn coating in a salt spray test for 250 hours;

Fig. 5 shows a comparison between conventional galvanized steel and steel with 5 weight % Al-Zn coating in a salt spray test for 500 hours;

15 Fig. 6 shows a comparison between conventional galvanized steel and steel with 5 weight % Al-Zn coating in a salt spray test for 750 hours;

Fig. 7 shows a comparison between conventional galvanized steel and steel with 5 weight % Al-Zn coating in a salt spray test for 1000 hours;

Fig. 8 shows a comparison between conventional galvanized steel and
20 steel with 5 weight % Al-Zn coating in a salt spray test for 1250 hours;

Fig. 9 shows a comparison between conventional galvanized steel and steel with 5 weight % Al-Zn coating in a salt spray test for 1500 hours;

Fig. 10 shows a comparison between conventional galvanized steel and steel with 5 weight % Al-Zn coating in a salt spray test for 1750 hours;

25 Fig. 11 shows a comparison between conventional galvanized steel and steel with 5 weight % Al-Zn coating in a salt spray test for 2000 hours; and

Fig. 12 shows a golden phase construction of 5 weight % Al-Zn coating obtained in the present invention.

Detailed Description of the Invention

The present invention relates to a new technology for hot dipping 5 weight % Al-Zn alloy coating on steel by simple steps to produce a durable corrosion resistant coating on steel. The process of the present invention is suitable for the production of various steel construction products for different uses. In accordance with the present invention, the process of hot dipping 5 weight % Al-Zn alloy coating on steel comprises:

- (a) cleaning a steel material and then hot dip galvanizing the steel material; and
- 10 (b) reducing the thickness of a galvanized coating on the steel material, followed by hot dipping 5 weight % Al-Zn alloy coating.

In accordance with the step (a) of the process of the present invention, the cleaning treatment depends on the species and features of the steel material and can be conducted by any conventional method. For example, 15 the cleaning step of the present invention may include classifying the steel materials, degreasing, first washing the steel materials with water, pickling, second washing the steel materials with water, and neutralizing. Moreover, the process of the present invention optionally comprises cooling the steel material, after the hot dipping 5 weight % Al-Zn alloy coating of step (b).

20 The process of hot dipping 5 weight % Al-Zn alloy coating on steel can be conducted either, preferably, in a batch type hot dipping or a continuous type hot dip for steel sheets, stripes, coils, wires, etc. The present invention is specifically useful to solve the difficulties of a batch type hot dipping. A minor amount of aluminum was generally added to hot dip 25 galvanizing in the past to enhance the flowability as well as glittering and to improve the processing. But when the content of aluminum is more than 0.03 weight %, it is impossible to coat such a mixture of molten metals on steel because a fluxing on the surface of steel tends to migrate into the aluminum contained in the surface of molten zinc. In other words, the

fluxing of the coated steel disappears and is incapable of forming an alloy with molten zinc. The surface of steel cannot be hot dip galvanized and shows its original appearance. In order to improve the function of a higher amount of aluminum in molten zinc, in addition to the improvement of the fluxing which keeps aluminum from being influenced by contacting molten zinc having the content of aluminum more than 0.03 weight % and of about 5 weight %, the fluxing should be used as a medium for bonding Al-Zn-Fe alloy on the surface of steel and the steel can be hot dipped when contacting a molten 5 weight % of Al-Zn liquid. The present invention is characterized by, after a hot dip galvanizing treatment of steel, the step of reducing the thickness of a galvanized coating on the steel, followed by hot dipping 5 weight % Al-Zn alloy coating.

A preferable embodiment of the present invention includes (1) classifying steel materials; (2) degreasing the steel materials comprising blasting with sand or washing with a NaOH solution which depends on the steel materials and the need; (3) first washing the steel materials with water, with the proviso that only when the steel materials are treated with a NaOH solution washing, first washing with water is necessary; (4) pickling the steel materials; (5) second washing the steel materials with water; (6) neutralizing the steel materials; (7) hot dip galvanizing the steel materials, (8) reducing the thickness of a galvanized coating on the steel materials; (9) hot dipping 5 weight % Al-Zn alloy coating on the steel materials; and (10) cooling the steel materials to produce the steel materials having 5 weight % Al-Zn alloy coating.

As shown from the above flowsheet, the most important difference between the process of hot dipping 5 weight % Al-Zn alloy coating on steel of the present invention and conventional hot dip galvanizing resides in that, after a hot dip galvanizing treatment of steel, the present invention makes use of reducing the thickness of a galvanized coating on the steel, and the

galvanized steel is then immersed in a molten 5 weight % Al-Zn for a hot dipping 5 weight % Al-Zn alloy coating on steel.

In accordance with the preferable embodiment of the present invention, the purpose of classifying the steel materials is to improve the efficacy and quality of hot dipping by handling similar steel materials. The steel articles can be classified as piping steel, section steel, structural carbon steel, forging steel, a bolt, a nut, casting steel, members of steel tower, etc. Similar sizes and thickness of the piping steel can be handled together. The section steel contains angles, channels, I beams, H beams, rule plates, and several light section steel. The structural carbon steel could be any welded steel constructions, such as H beam steel, bridges formed and welded from steel plates, and triangle brackets. The forging steel includes any iron parts used in shears and punches. Bolts and nuts include various types and basic shapes.

The degreasing step of the process of the present invention comprises blasting with sands or washing with a NaOH solution which depends on the steel materials and the need thereof. Blasting with sands can completely remove greases, paints, rusts adhered to the surface of steel and reach the desired porosity of steel. On the other hand, a NaOH solution at a concentration of 15 ± 5 weight % at a temperature of 80°C or more is used in degreasing. The degreasing is conducted for about 90 minutes and should be checked every 15 to 30 minutes to determine the cleaning results. If necessary, some portions can be further manually cleaned.

Only when steel is washed with a NaOH solution, it is necessary to be first washed with water. The steel treated with a NaOH solution is immersed in water at room temperature to remove residual NaOH from the surface of steel. Moreover, if the steel is blasted with sands, it is not necessary to be washed with water.

The steel of the present invention is subject to pickling which is

generally treated by an inorganic acid, such as hydrochloric acid and sulfuric acid. The concentration of hydrochloric acid for use in pickling is in the range of 7 to 14 % w/v and the pickling is conducted at room temperature for 15 to 60 minutes. When the content of ferrous ion of the acidic solution reaches from 80 to 100 g/l, the acidic solution should be refreshed for washing. The concentration of sulfuric acid for use in pickling is in the range of 6 to 14 % w/v and the pickling is conducted at a temperature of from 60 to 65 oC for 5 to 30 minutes. When the content of ferrous ion of the acidic solution reaches from 80 to 120 g/l, the acid solution should be refreshed. An inhibitor is optionally added in the acidic solution so that the steel would not be corroded by hydrochloric acid or sulfuric acid. Any conventional inhibitors can be used in the process of the present invention. The amount of inhibitor used in the present invention is 2 weight %.

When hydrochloric acid is used for pickling, a larger space is needed because of more treatment tanks and the washing velocity is slower. Hydrochloric acid vapor is easy to spatter and influence air quality but the treated steel will not become fragile due to hydrogen adhesion. However, when sulfuric acid is used, the necessary space needed is smaller because the treatment tanks full of sulfuric acid become fewer, and the washing velocity is faster than that of hydrochloric acid. The sulfuric acid vapor is not easy to spatter but hydrogen will adhere on steel and result in fragile steel.

After being pickled, the steel is put into water to remove any residual acid solution by shaking it forward and backward. This is the second washing of the steel with water.

The function of neutralizing the steel is to form a fluxing on the surface of steel. The fluxing can facilitate Fe-Zn-Al interfacial metal coating on the surface of steel for hot dip galvanizing. The chemicals used for

neutralizing include sodium chloride, phosphate, ammonium zinc chloride, etc. Take ammonium zinc chloride as an example, its concentration is in the range of 30 - 35 w/v %. Preferably, the pH value of a solution of ammonium zinc chloride for neutralizing is controlled at 3.0 to 4.5 at a temperature of 65 to 80 °C. If necessary, 2 weight % of surfactant may be added in the neutralizing step. On the other hand, the content of ferrous ion can be used as an indicator. When the content of ferrous ion is more than 7 w/v % and the solution becomes brown, the equipment should be cleaned. For instance, the capacity of filtrating equipment can filtrate the treatment tanks in about 2 to 4 hours.

According to the process of hot dipping 5 weight % Al-Zn alloy coating on steel of the present invention, the hot dip galvanizing is conducted by any known method. Generally speaking, the temperature of hot dip galvanizing is controlled at 445 ± 5 °C for most of steel materials and at 480 ± 5 °C for steel bolts and nuts. The operation time should also be monitored. The operation time for hot dip galvanizing section steel, structural steel and piping steel is shown in the following Table 1.

Table 1

Type	Thickness (m/m)	Time (sec)
section steel & structural steel	3 ~ 4.5	30 ~ 75
	5 ~ 6	75 ~ 150
	9 ~ 12	150 ~ 180
	over 15	over 180
piping steel	below 3	45 ~ 120
	3 ~ 6	120 ~ 150
	over 6	150 ~ 180

The process of the present invention can be conducted either

continuously or, preferably, batchwise. The classification of steel is important, particularly when the steel can be treated together for 15 to 600 seconds, preferably 30 to 300 seconds in accordance with the size and thickness of steel constructions. The thicker the steel is, the longer the time
5 for hot dip galvanizing needs.

The present invention is characterized by reducing the thickness of a galvanized coating on steel after hot dip galvanizing so that the thickness of hot dip galvanized coating is controlled for the following hot dipping 5 weight % Al-Zn alloy coating on steel. In other words, after hot dip
10 galvanizing and before hot dipping 5 weight % Al-Zn alloy coating, the step of reducing the thickness of a galvanized coating on steel is conducted by retaining the content of aluminum close to 0.03 weight % in hot dip galvanizing and keeping the molten metal flowing quickly. When the steel is taken from the molten metal, air or ammonium chloride is used to spray
15 the surface of steel and to reduce the thickness of the galvanized coating.

After the galvanized coating on the surface of steel has been reduced, the steel is subject to hot dipping 5 weight % Al-Zn alloy coating. The reduced galvanized steel is directly dipping in a molten 5 weight % Al-Zn liquid at a temperature of 440 ± 20 °C, preferably 440 ± 10 °C for a hot
20 dipping 5 weight % Al-Zn alloy coating on most of steel materials, and of 470 ± 20 °C, preferably 470 ± 10 °C for a hot dipping 5 weight % Al-Zn alloy coating on steel bolts and nuts. The operation time for hot dipping 5 weight % Al-Zn alloy coating is controlled within 15 to 600 seconds, preferably 30 to 300 seconds, as shown in Table 2, which depends on the
25 types and sizes of steel. Before the beginning of hot dipping 5 weight % Al-Zn alloy coating on steel and, when the steel is taken out from the molten 5 weight % Al-Zn liquid after hot dipping 5 weight % Al-Zn alloy coating, the surface of molten 5 weight % Al-Zn liquid should maintain clean and avoid any oxides or impurities from contaminating the steel.

Table 2

Type	Thickness (m/m)	Time (sec)
section steel & structural steel	3 ~ 4.5	30 ~ 75
	5 ~ 6	75 ~ 120
	9 ~ 12	120 ~ 150
	over 15	over 150
piping steel	below 3	45 ~ 120
	3 ~ 6	120 ~ 150
	over 6	150 ~ 180

After hot dipping 5 weight % Al-Zn alloy coating in the step (b) of the process of the subject invention, the steel may optionally be cooled. That is, the steel hot dipped with 5 weight % Al-Zn alloy coating is put in
5 flowing water at a temperature of 40 - 70 °C for 30 - 90 seconds. The cooling time for different types of steel is listed in the following Table 3.

Table 3

Type	Thickness (m/m)	Time (sec)
section steel & structural steel	3 ~ 4.5	30 ~ 45
	5 ~ 6	30 ~ 60
	9 ~ 12	45 ~ 60
	over 15	over 60
piping steel	below 3	30 ~ 60
	3 ~ 6	30 ~ 60 and more
	over 6	over 60

The steel, after hot dipping 5 weight % Al-Zn alloy coating and cooling, is subject to a visible inspection for quality control. If necessary, the
10 thickness of the coated steel is measured by instruments for the desired

requirement.

The process of the present invention, particularly the combination of step (a) cleaning a steel material and then hot dip galvanizing the steel material; and step (b) reducing the thickness of a galvanized coating on the steel material, followed by hot dipping 5 weight % Al-Zn alloy coating, can produce durable and corrosion resistant steel having 5 weight % Al-Zn alloy coating. After analysis, it is found that the distribution of aluminum in the resultant 5 weight % Al-Zn alloy coating layer is very complicated. The aluminum-zinc two-element phase diagram is shown in Fig. 1, wherein an eutectic structure of 5 weight % Al-Zn is formed at a suitable temperature. Thus, most of the 5 weight % Al-Zn alloy coating on steel is eutectic. An interfacial metal compound layer is formed, as shown in the iron-aluminum two-element phase diagram of Fig. 2, because the affinity between Al and Fe is better than that between Al and Zn. When a further reaction between Fe and Zn occurs, Fe-Zn-Al three-element intermetallic layer is formed as shown the iron-aluminum-zinc three-element phase diagram of Fig. 3. The thickness and corrosion resistance of the galvanized coating on steel depend on the growth of the intermetallic layer.

In order to measure the mechanical properties and corrosion resistance of the resultant coating on steel, the steel having 5 weight % Al-Zn alloy coating is measured by several tests, such as slat spray test, exposure test, electrochemical test, golden phase test, hardness test, stretchability test. It is noted that the time to find rust occurring on the steel having 5 weight % Al-Zn alloy coating of the present invention in a salt spray environment is 2 to 3 times of that of general hot dip galvanizing. Other mechanical properties of the resultant steel in the present invention all meet the industrial requirements. Therefore, the process of hot dipping 5 weight % Al-Zn alloy coating on steel of the present invention is useful to enhance the corrosion resistance and mechanical properties of the obtained steel.

The following examples are offered by way of illustration. The examples are not intended to limit the scope of the invention in any respect and should not be so construed.

Examples

- 5 The samples were SS41 steel coated by two manners: one was hot dipping 5 weight % Al-Zn alloy coating and the other was hot dip galvanizing. The former was proceeded in accordance with the process of hot dipping 5 weight % Al-Zn alloy coating on steel of the present invention and the latter was conducted by any conventional method.
- 10 In the process of the present invention, SS41 steel was degreased by treating the steel with a 15 ± 5 weight % of a NaOH solution at a temperature of 80 °C for 90 minutes and then was first washed with water. 10% w/v of hydrochloric acid solution was used to pickle the steel for 45 minutes. When the content of ferrous ion of the acidic solution reaches
- 15 about 80 to 100 g/l, the acid solution was refreshed for further washing. The steel was subsequently second washed again for the second time with water. Ammonium zinc chloride was used as a neutralizing agent to treat the steel at a temperature of 70 °C, wherein the concentration of ammonium zinc chloride was about 35 w/v % and the pH value was controlled at 4.0.
- 20 The steel was then hot dip galvanized at a temperature of 445 °C. When the steel was taken out from the molten zinc, the molten metal was kept quickly flowing and air was used to spray the surface of steel to reduce the thickness of the galvanized coating on the steel. The steel with reduced galvanized coating was directly put in a molten 5 weight % Al-Zn liquid
- 25 for a hot dipping 5 weight % Al-Zn alloy coating on steel, and then cooled in flowing water at a temperature of 70 °C for about 60 seconds. Steel with durable and corrosion resistant 5 weight % Al-Zn alloy coating was obtained.

Corrosion Resistance and Mechanical Properties Tests

The corrosion resistance and mechanical properties of the steel with hot dipping 5 weight % Al-Zn alloy coating obtained by the process of the present invention were measured by several tests including: 1) salt spray
5 test, 2) exposure test, 3) electrochemical test, 4) stretchability test, 5) hardness test, and 6) golden phase test. After testing, it was found that the steel with hot dipping 5 weight % Al-Zn alloy coating produced by the present invention showed excellent corrosion resistance and mechanical properties.

10 1) salt spray test

As shown in Figs. 4 to 11 and Table 4, the time needed to initial red rusting on the steel with hot dipping 5 weight % Al-Zn alloy coating obtained from the present invention in a salt spray environment was found to be 2 to 3 times of that for conventional hot dip galvanized steel.

Table 4: test time and rusting area % of the surface of the samples in salt spray test

test time (hour)			250	500	750	1000	1250	1500	1750	2000
rusting area	conventional test	5%Al-Zn	-	-	-	-	-	2.6%	6.3%	10.3%
		hot dip galvanizing	-	-	5.2%	8.3%	18.7%	25.5%	31.4%	33.1%
	accelerated test	5%Al-Zn	-	-	--	-	1.4%	3.7%	4.2%	8.5%
		hot dip galvanizing	-	-	8.6%	9.1%	21.4%	26.8%	31.9%	42.6%

2) exposure test:

Conventional General hot dip galvanized steel and the steel with hot dipping 5 weight % Al-Zn alloy coating produced by the present invention were immersed in a 3 weight % NaCl oxygen saturated solution for Galvanic coupling immersion test. The change of galvanic coupling potential and Galvanic electric current were recorded. From the result of Galvanic electric current, it was found that the steel with hot dipping 5 weight % Al-Zn alloy coating of the present invention was better than conventional hot dip galvanized steel. From Galvanic coupling potential, it was found that hot dip galvanized steel was good at the beginning but the steel with hot dipping 5 weight % Al-Zn alloy coating of the present invention was better than hot dip galvanized steel for the long term. Considering the action of chlorine salt, the corrosion potential of three

samples in the tests of three different concentrations were shown in Table 5.

The corrosion potential of the steel with hot dipping 5 weight % Al-Zn alloy coating of the present invention was the best, that of hot dip

galvanized steel was the second, and that of 5 % Al-Zn mother material

5 was poor. In the action of sulfide, shown in Table 5, the steel with hot dipping 5 weight % Al-Zn alloy coating of the present invention was found to be excellent in a condition with a low sulfur content. But conventional hot dip galvanized steel exhibited better in a condition with high sulfur content.

10 Table 5: corrosion potential (E_{corr} (V)) of three samples in different corrosive solutions

corrosive solutions sample	NaCl				Na ₂ S ₂ O ₃		
	0.5 M		2M	sat.	0.5M	2M	sat.
	non- deoxygen	deoxygen					
hot dipping 5%Al-Zn	-1.316	-1.340	-1.312	-1.285	-1.014	-1.021	-1.020
hot dip galvanizing	-1.340	-1.348	-1.358	-1.341	-1.068	-0.811	-1.012
5%Al-Zn mother material	-1.460	-1.446	-1.433	-1.427	-1.380	-1.305	-1.444

Unit : Voltage (V)

sat.: saturated

3) stretchability test

15 The result of stretchability test was shown in Table 6. The minimum stress for deforming general hot dip galvanized steel significantly increased.

In other words, the force against deformation was remarkably increased. But the change of destroyed stress was not as great as that of deformed stress. That is, the destroyed strength was not greatly improved. The change of the steel with hot dipping 5 weight % Al-Zn alloy coating of the present invention was higher than that of general hot dip galvanized steel.

Zinc *per se* is a metal with low strength. In hot dip galvanizing system, the strength of steel increased not because of zinc adhered on steel but because of the strength of Fe-Zn alloy layer. In 5 weight % Al-Zn alloy coating system, it is known from the Al-Zn phase diagram that no Al-Zn intermetallic compound was formed but only a layer rich in zinc and a layer rich in aluminum were formed. In addition, the formation of Al-Fe intermetallic compound was believed to increase the strength of the steel.

Table 6: the result of stretchability test

	yield strength		tensile strength		elongation	
	kg/mm ²	change %	kg/mm ²	change %	%	change %
SS41	26.53	-	35.04	-	146.8	-
hot dip galvanizing	29.87	12.6%	36.46	4.1%	140.2	-4.5%
hot dipping 5%Al-Zn	31.23	17.7%	37.18	6.1%	136.1	-7.3%

* Change % means the change between samples with coating and SS41 steel.

$$\text{Change \%} = (P_{\text{coating}} - P_{\text{SS41}}) / P_{\text{SS41}} \times 100\%$$

wherein P represents each test property.

4) hardness test

The hardness results on the front face of each sample are shown in Table 7. Because the thickness of coating was smaller than the length of pressed trace in the hardness test, it was impossible to obtain the hardness and its

distribution of the cross section of the coating on steel. In hot dip galvanizing, the hardness of pure galvanized layer (η) was 70 Hv on record. The hardness was found to be the contribution of the coating of steel. As to the steel with hot dipping 5 weight % Al-Zn alloy coating, Al dissolved
5 in Zn base and had an enforced effect of solid solution. Therefore, the hardness of hot dipping 5 weight % Al-Zn alloy coating of the present invention was found to be higher than that of galvanized coating.

Table 7

	SS41	hot dip galvanizing	hot dipping 5%Al-Zn
1	145.1	66.4	83.9
2	146.0	67.4	90.1
3	154.0	67.6	91.9
4	157.4	70.0	106.4
5	159.4	71.0	107.5
average*(Hv)	152.5	68.3	96.1

* Average value means, in addition to the maximum and minimum, the
10 average of three middle numbers.

According to a golden phase construction of 5 weight % Al-Zn coating obtained in the present invention in Fig. 12, the chemical composition is illustrated in Table 8.

Table 8: chemical composition of 5 weight % Al-Zn coating (wt%)

	Al	Zn	Fe	O	Al/Fe atomic ratio
surface	6.2	70.2	1.8	21.8	-
1	5.3	83.1	-	11.6	-
2	2.6	85.9	-	11.5	-
3	30.4	53.8	8.3	7.5	7.6
4	42.4	36.0	10.0	11.6	8.8
5	13.5	71.7	3.3	11.5	8.5
6	36.6	39.1	11.8	12.5	6.4

Up to now, hot dipping 5 weight % Al-Zn alloy coating is only applied to steel sheets and steel coils in a continuous process and cannot be applied in a large scale. The present invention overcomes the difficulties in the art and provides a process of hot dipping 5 weight % Al-Zn alloy coating on steel either batchwise or continuously. The steel hot dipped with a durable and corrosion resistant 5 weight % Al-Zn alloy coating has good corrosion resistance and mechanical properties.



We Claim:

1. A process of hot dipping 5 weight % Al-Zn alloy coating on steel comprising:
 - (a) cleaning a steel material and then hot dip galvanizing the steel material; and
 - (b) reducing the thickness of a galvanized coating on the steel material, followed by hot dipping 5 weight % Al-Zn alloy coating.
2. The process according to Claim 1, wherein the steel material of step (a) is hot dip galvanized for 15 to 600 seconds.
3. The process according to Claim 2, wherein the steel material of step (a) is hot dip galvanized for 30 to 300 seconds.
4. The process according to Claim 1, wherein the thickness of a galvanized coating on the steel material of step (b) is reduced by spraying the surface of steel with gas so as to reduce the thickness of the galvanized coating.
5. The process according to Claim 4, wherein the gas is air or ammonium chloride.
6. The process according to Claim 1, wherein the steel is hot dipped with 5 weight % Al-Zn alloy coating at a temperature in the range of 440 ± 20 °C for 15 to 600 seconds.
7. The process according to Claim 6, wherein the steel is hot dipped at a temperature in the range of 440 ± 10 °C for 30 to 300 seconds.
8. The process according to Claim 1, wherein the steel is hot dipped with 5 weight % Al-Zn alloy coating at a temperature in the range of $470 \pm$



20 °C for 15 to 600 seconds, and the steel is a steel bolt or a steel nut.

9. The process according to Claim 8, wherein the steel is hot dipped at a temperature in the range of 470 ± 10 °C for 30 to 300 seconds.
10. The process according to Claim 1, wherein the cleaning step includes
5 classifying the steel material, degreasing, first washing the steel material by water, pickling, second washing the steel material by water, and neutralizing.
11. The process according to Claim 1 further comprising cooling the steel material, after hot dipping 5 weight % Al-Zn alloy coating of step (b).
- 10 12. The process according to Claim 10, wherein the degreasing the steel material is conducted by blasting with sand.
13. The process according to Claim 10, wherein the degreasing the steel material is conducted by washing with a NaOH solution.
14. The process according to Claim 13, wherein after being treated with a
15 NaOH solution washing, the steel material is washed with water.
15. The process according to Claim 10, wherein an inorganic acid is used in the pickling.
16. The process according to Claim 15, wherein the inorganic acid is hydrochloric acid.
- 20 17. The process according to Claim 15, wherein the inorganic acid is sulfuric acid.
18. The process according to Claim 1 being conducted batchwise.
19. The process according to Claim 1 being conducted continuously.



20. A batch type process of hot dipping 5 weight % Al-Zn alloy coating on steel comprising:

- 5 (1) classifying a steel material; (2) degreasing the steel material comprising blasting with sand or washing with a NaOH solution which depends on the steel material and the need; (3) first washing the steel material with water, with the proviso that only when the steel material is treated with a NaOH solution washing, first washing with water is necessary; (4) pickling the steel material; (5) second washing the steel material with water; (6) neutralizing the steel material; (7) hot dip
- 10 galvanizing the steel material, (8) reducing the thickness of a galvanized coating on the steel material; (9) hot dipping 5 weight % Al-Zn alloy coating on the steel material; and (10) cooling the steel material to produce the steel material having 5 weight % Al-Zn alloy coating.