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Development of Zn-Mg-alloy-coated Anti-corrosion Steel Plate for Oil Storage Tank

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Abstract

New corrosion resistant Zn-Mg alloy coated (thermal sprayed or hot dip galvanized) steel, which is used for bottom plate or roof plate of oil storage tanks, was developed. Coated Zn-Mg alloy inhibits formation of Zn-Fe alloy layer and Zn oxide in melding, and it also enables reduction of coating thickness. Because of these superior properties, developed Zn-Mg alloy coated steel reserves good workability in welding providing superior corrosion resistance.

1. Introduction

Anti-corrosion measures of oil storage tanks are focused on localized corrosion of bottom plates by sand, sea salt corrosion of the outer surface of roof plates and inner surface corrosion caused by stored oil.

While the localized corrosion behavior of the bottom plates, which are faced to the ground, was not altogether clear, it was found that there were sometimes gaps between the bottom plates and tank foundations, and that localized condensation corrosion took place in the gaps with grains of sand and the like on the plate surface. They also found that a similar situation took place in the case of an asphalt bed in nearly the same severity as the case of a sand bed. The authors used for the bottom plates thermal sprayed Zn-coated steel plates, which are cathodic protection plates having a sacrifice metal coating a base metal and are effective even in the cases of the gaps and condensation therein, and as a result, confirmed their excellent corrosion protection performance[1]. Welding heat input limitations are imposed on thermal spray-coated plates with simple Zn coating for avoiding deterioration of corrosion resistance at welded joints. For the purpose of relaxing the limitation and reducing the time (or the coating thickness) of the thermal spray work, the suitability of thermal sprayed Zn-Mg-coated steel plates for the oil storage tanks, based on experiences of the above and similar cases was studied.

Hot-rolled steel sheets have been used for tank roofs, in most cases with paint coating on the outer surface and without it on the inner surface. In the past, the authors had used hot dip Zn galvanized steel sheets for the roof plates[2] for the purpose of extending the service life on the inner surface and eliminating initial painting on the outer surface side, and based on this, studied measures for extending the service life. Increase in coating weight is effective for extending service life. However, since roof plates have to be welded together, there is a problem that the coating layers are greatly damaged at heat affected zones on the inner surface side when the coating weight is 225 g/m^2 or more per side. In view of this, the possibility of applying hot-dip Zn-Mg-coated steel plates to the roofs as a material having excellent corrosion resistance with a smaller coating weight was studied.

2. Methods of Tests and Investigations

2.1 Bottom Plates

A 2,000 kl ambient temperature oil storage tank was constructed on an asphalt bed using thermal sprayed Zn-coated steel plates (9 mm in initial thickness, 0 negative tolerance, 400 μm in coating thickness) for the bottom, and their thickness was measured 10 years thereafter[3]. During construction, the plates were welded by overlap fillet welding and the welding heat input was limited to 0.6 kJ/mm for preventing damage to the thermal sprayed Zn layers.

Another corrosion test was carried out in a laboratory wherein test pieces of JIS SS400 steel plates with thermally sprayed Zn coat-

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Table 1 Spray corrosion test condition

(ppm)

	Cl^-	SO_4^{2-}
Test condition	1,000	300
Maximum concentration in real environment	487	287

ing 400 μm in thickness were prepared and buried in the same sand as used for tank foundations. Here, the temperature was kept at 20°C and the water content ratio at 12 wt %, which condition had been found most corrosive to localized corrosion through separate studies. This testing method has been confirmed to quantitatively correspond to the localized corrosion rate of bottom plates of real tanks[1)].

In addition, test pieces 9 mm in thickness, some having thermal sprayed Zn coating and others having thermal sprayed Zn-0.5%Mg coating, 60 to 400 μm in coating thickness, were subjected to overlap fillet welding with a heat input of 1.2 kJ/mm. Then, the test pieces were subjected to an EPMA line analysis of the thermal sprayed layers at heat affected zones and a spray corrosion test at 30°C using a solution shown in **Table 1**.

2.2 Roof Plates

Hot-rolled and hot-dip galvanized steel sheets 3.2 mm in thickness, some with Zn-0.5%Mg coating (A) and others with Zn coating (B), were used as test pieces. The coating weight was 150 g/m^2 per side in either of the cases.

The test pieces were exposed at three locations: one location in an environment equivalent to inside of a tank and two locations in an environment equivalent to an outer surface. Salt concentration of rainwater and the amount of suspended salt particles in the air from the sea were also measured as environmental data.

3. Results of Tests and Investigations and Discussion

3.1 Bottom Plates

Fig. 1 shows the thickness measurement of steel plates with thermal sprayed Zn coating used for bottom plates of a real oil tank after 10 years of construction. The smallest thickness value actually measured was 9.0 mm against the initial thickness of 9.0 mm (0 negative tolerance), evidencing good corrosion protection of the base metal. Other test pieces having thermally sprayed Zn coating 400 μm in thickness were buried into the foundations at the time of construction, and after 10 years, their Zn coating layers were found to have disappeared locally. As a conclusion of a close examination[1)], the service life of the thermally sprayed Zn coating layer 400 μm in thickness was judged to be about 10 years.

Photo 1 shows appearances of some of the thermal-spray-coated plates after the spray corrosion test. The test pieces include the heat affected zones of overlap fillet welding. Whereas rusting resulting from base metal corrosion is seen with the Zn-coated plates, no such rusting is seen with the Zn-Mg-coated plates. While Zn-coated plates having layers 100 μm in thickness began to corrode after 3 months of the spray test, Zn-Mg-coated plates having the same coating thickness withstood 18 months or more of testing without corrosion; the corrosion resistance of the Zn-Mg-coated plates is at least 6 times that of the Zn-coated plates.

Fig. 2 shows the result of the EPMA line analysis of the heat affected zones of Zn-coated and Zn-Mg-coated plates having a coating thickness of 150 μm. Whereas, in the conventional Zn-coated plates, an Fe-Zn alloy layer about 50 μm in thickness was formed at the interface with the base metal, and an oxide layer of zinc about 50 μm in thickness on the outer surface, such layers were little seen in the newly developed Zn-Mg-coated plates, evidencing excellent corrosion resistance of the Zn-Mg-coated plates at heat affected zones.

Based on the test results and detail examination thereof[1)], **Fig. 3** shows service life estimation of steel plates having thermally sprayed Zn-Mg coating layers 400 μm in thickness when applied to the bottom plates of oil storage tanks, under the assumption of a severe corrosion condition expected of only one tank among a hundred. The figure, which is drawn assuming a safety factor of 2, shows that the newly developed Zn-Mg coating has a corrosion resistance 6 times as good as that of the conventional Zn coating or better. Even under

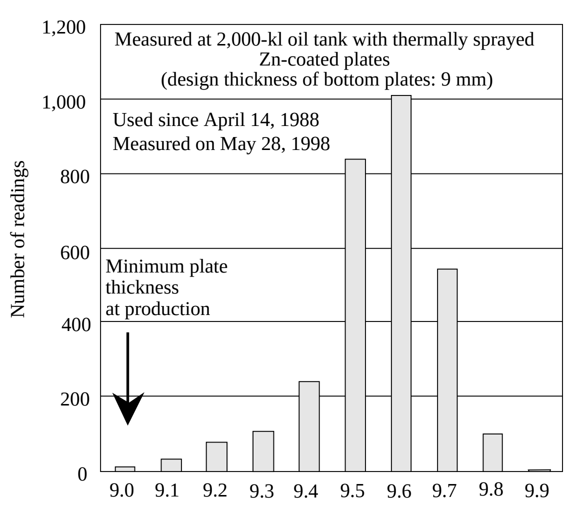
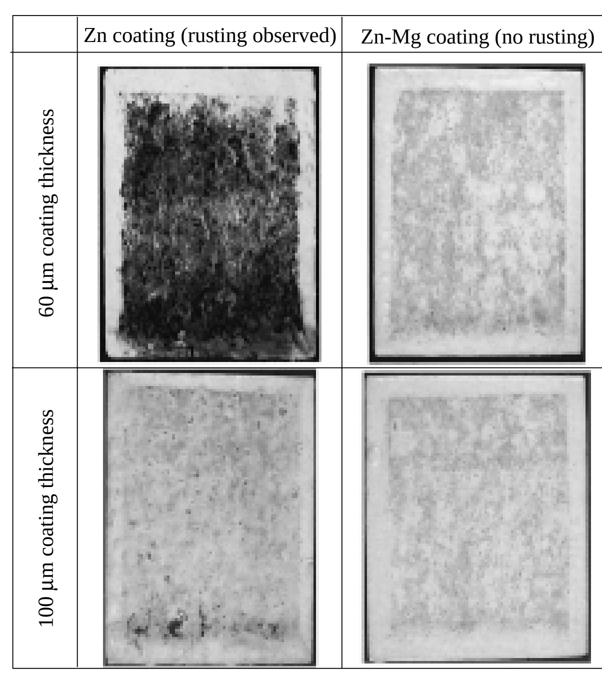


Fig. 1 Thickness measurement of thermally sprayed steel plates use for bottom of 2,000-kl oil tank after 10 years of use



Time before rusting of thermally sprayed plates with 100-μm coating layers
Zn coating: 3 months, Zn-Mg coating: 18 months or more

Photo 1 Evaluation of corrosion resistance of thermally sprayed coated surfaces including heat affected zones

the severest condition, a service life about 5 times that of conventionally used materials can be realized with steel plates having the thermal sprayed Zn-Mg coating.

3.2 Roof Plates

Table 2 shows the result of the exposure test at Aichi Refinery of Idemitsu Kousan Co., Ltd. The Zn-coated plates (B) tested in a waste water treatment plant environment, where salt damage is considered to be the severest, lost as much as 137 g/m^2 of their coating layers in 6 months, and rusting was seen on the surfaces. In contrast, the Zn-Mg-coated plates (A) lost only 36 g/m^2 of their coating layers in the same environment in the same period, and no rusting was seen (see **Fig. 4**). As for the test pieces exposed inside a tank, only very slight corrosion occurred after 12 months and, as a consequence, it is understood that what is mostly responsible for the service life of roof plates is the corrosion on the outer surface.

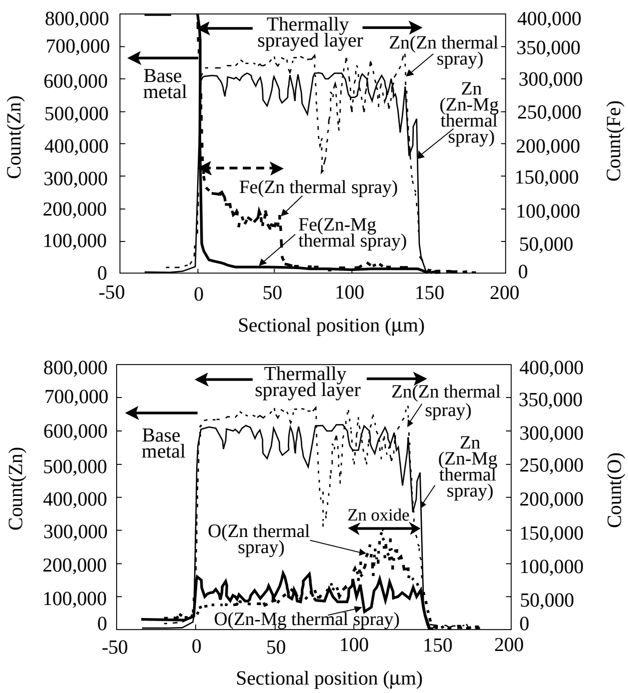


Fig. 2 Sectional EPMA line analysis of heat affected zones (welding heat input: 1.2 kJ/mm)

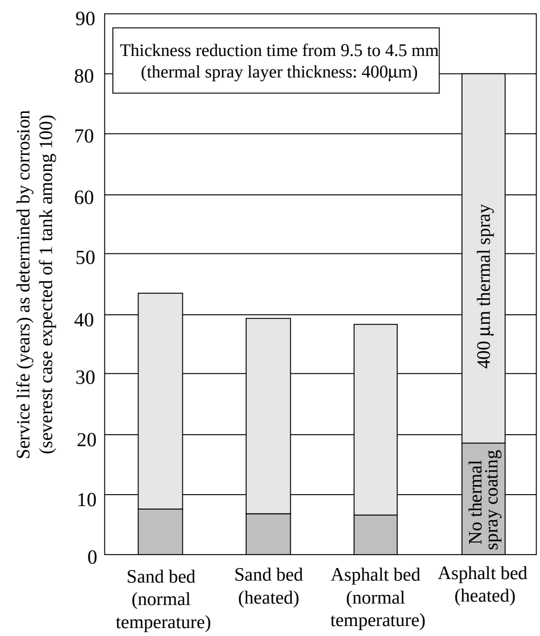


Fig. 3 Estimation of corrosion service life of tank bottom plates with and without thermal spray Zn-Mg coating

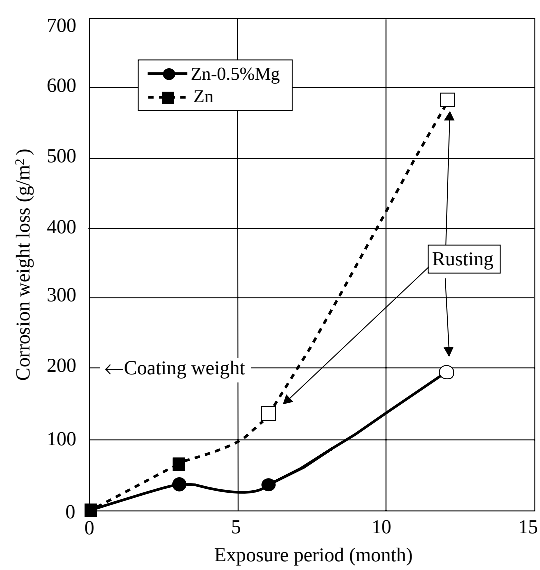


Fig. 4 Exposure test of Zn-Mg-coated roof material (waste water treatment plant environment)

Table 2 Environmental condition and result of exposure test of oil tank roof plates

	Exposure location	(1) Waste water treatment plant			(2) Tank roof		(3) Inside tank
Environmental condition	Salt concentration in rainwater	5,000 ppm			200 ppm		Dilute sulfuric acid gas
	Concentration of suspended salt particles from sea	2,000 mg / h·m^3			200 mg / h·m^3		
	Test period	3 months	6 months	12 months	3 months	12 months	12 months
A	Zn-0.5%Mg	36.5	36.4	193.3	8.3	39.3	2 or less
B	Zn	65.0	137.8	585.6	11.4	50.0	2 or less
	Appearance	White rust, clear difference between A and B	Red rust in B	Red rust in A and B	Early stage rust, clear difference between A and B		Slight corrosion

4. Closing

Past studies have made it clear that when there is a gap between bottom plates and the foundations of an oil tank and humidity is high in the gap, an unexpected extent of corrosion may occur to the bottom plates, even when countermeasures such as use of asphalt bed and cathodic protection are provided[1]. A thermally sprayed Zn-Mg-coated steel plate is a cathodic protection steel plate having a sacrifice metal coating the steel substrate and capable of achieving a sufficient corrosion protection effect even in the above mentioned severe conditions. The newly developed Zn-Mg-coated steel plate demonstrates excellent corrosion resistance and sacrifice protection capacity[4] , and at the same time, has good welding workability. The plate was applied to the bottom of a 30,000-kl oil storage tank in 2001 already.

Based on the excellent corrosion protection performance of the Zn-Mg coating explained above, hot-dip Zn-Mg-coated steel sheets have also already been used for the roof of about 60 oil storage tanks, exhibiting excellent corrosion resistance on both outer and inner surfaces.

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