CORROSION SCIENCE AND TECHNOLOGY, Vol.2, No.2(2003), pp.102~108

Surface Treatment of Automotive Cast Parts of Magnesium Alloy

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The surface treatments, Chrome/Manganese and Modified Chrome Pickle, that are treated to improve the anti-corrosion property which is needed to increased the probability of prototype product enabled the sand cast Magnesium test specimens to have better corrosion resistance than non-treated one.
Sand cast Magnesium specimens which was treated only with chemical conversion coating had same corrosion resistance with the Steel specimens plated by Zinc, and the another one that had the finishing treatment(painting) worked on the chemical surface treatment had the corrosion resistance property to meet to FPO-3 requirement. We also investigated the multiple finishing system(chemical surface treatment + 3 coating) to test the severe condition that magnesium should to endure.

Keywords *: magnesium alloy, surface preparation, modified chrome pickle, chrome-manganese*

1. Introduction

It has been well known that magnesium is among the lightest structural material which has the specific density of 1.8 g/cm^3. This light weight character has allowed the use of magnesium in many applications, especially in Automotive and Aerospace industry. But the extensive use of magnesium have been restricted by several demerits such as poor corrosion resistance, high cost and low mechanical properties at elevated temperatures.

The poor corrosion resistance of magnesium is deeply related to the active nature of magnesium element and the weakness of magnesium-oxide film naturally formed upon the bare metal surface when the magnesium surface is freely exposed to corrosive environments.

For the last few decades, many studies have been done to improve the corrosion properties of magnesium and also many kinds of surface treatments have been developed to make the life cycle of magnesium parts more endurable in their corrosive functional environments.

This paper examines the effects of chemical surface preparations that are now widely used at the magnesium industry to get the confirmation for the development process of using the magnesium for substituting the material of automotive parts and acquire the optimum solution for preparing the pretreatments that are needed for enhancing the corrosion resistance of magnesium in bare metal or surface finished conditions.

The test for examining the performance of a chemical surface preparation was SALT SPRAY(ASTM B117). SALT SPRAY detects any susceptibility to substrate corrosion and to the spread of corrosion from points where physical damage to the coating has exposed bare metal. Since surface preparation is very important to coating performance, the effects of two types of chemical surface preparation on the magnesium were examined. The one was Chrome-Manganese and the other was Modified Chrome Pickle(all etching) with Alkali and chromic rinses. In order to find out the best condition for forming the surface treated layers which show the highest performance for corrosion resistance and paint adhesion, several types of dipping conditions were conducted and tested.

2. Experimental and results

2.1 Test plates

The magnesium was in the form of high purity AZ91E 35×70 mm and 70×140 mm sand cast test plates. Test plates were categorized into three groups(non heat treated, heat treated - Solution Heat Treatment and Solution Heat Treated and Artificial Aging). Mechanical preparation was used to remove surface burrs and relieve sharp edges.

2.2 Chemical surface preparation

The base starting condition of all the magnesium plates can be described as "nominally clean", as achieved by hot alkaline soak cleaning. Alkaline cleaning removes light organic soils but may leave entrapped lube residues or other persistent soils. It would not remove any trace heavy metal contamination, or aluminum-rich segregation which could resist reaction with conversion coating baths. From this base, the following chemical treatments were evalua-

ted as preparation for painting.

The Modified Chrome Pickle and Chrome-Manganese surface treatments were selected for enhancing the corrosion resistance of sand cast magnesium among the currently used several kinds of treatments listed in Table1 considering the ease of obtaining chemicals and economical merits. The Modified Chrome Pickle is one of the popular chromic treatment which generally removed about 0.25 mil of surface, while simultaneously forming a chromate conversion coating. The Chrome Manganese is a non-etching treatment which forms a chromate conversion coating without any significant metal removal. With these two treatments, to get the optimum dipping conditions, nearly ninety sorts of each treatment, which were classified by dipping temperature and delay time at solution bath, was carried out and the detail conditions are indicated in Table 2.

2.3 Test and evaluation

Each shape of treated magnesium plate and detail surface morphologies are shown at Fig. 1 and Fig. 2. From the Figs., it could be analyzed that thickness and the amount of chrome was proportion to the dipping time and temperature and the indication of grain boundaries were more notable when the dipping process was more proceeded. Since the duty of pretreatment for making the bare metal to have a better corrosion resistance is also very important, the SALT SPRAY test was performed on the only surface prepared test plates according to the ASTM B117. After following the salt spray exposure for 168 hours, the plates were rinsed in warm water and evaluated according to the ASTM D1654. From the Fig. 3, we can see the effects of Modified Chrome Pickle and Chrome Manganese for diminishing the corrosive action of sand cast AZ91 bare magnesium alloy.

Table 1. Currently used surface preparations for magnesium

	PRETREATMENTS	
CONVER-SION	• Acid Chrome Pickle • Galvanic Dichromate • Chrome-Manganese • Parker Phosphate	• Modified Chrome Pickle • Dichromate, NH35 • Dilute Chromic Acid • Amchem Phosphate
ANODI-ZING	• H. A. E NO.17	

2.4 Painting

Painting is the principal finishing process having the purposes of helping the product get more attractive appearance and better corrosion resistance under the severe corrosive environments. In this study, confirming the durability of magnesium products such as ROAD WHEEL in intensely exposed corrosive circumstances as well as testing the tendency of joining between the film of surface preparation and paint system, the three kinds of paint system were introduced as listed in Table 3.

2.5 Test for paint adhesion with surface treated film

The effects of coatings which was formed by surface preparation are possibly divided into two major parts.

Table 2. Surface preparation precedures

		PROCEDURE	CONSTITUENTS	DIP TEMP (℃)	DIP TIME (min)	No.of PLATES
Cr-Mn	1	Alkali	NaOH	55	2	54
	2	Chemical Cleaning	CrO_3 : 100-200g H_2O : 1L $Na_2Cr_2O_7 \cdot 2H_2O$: 100g	Boiling	1-15	
	3	Conversion Coating	$MnSO_4 \cdot 5H_2O$: 50g $MgSO_4 \cdot 7H_2O$: 50g H_2O : 1L	35-55	5-20	
Cr Pickle	1	Alkali	NaOH	55		36
	2	Chemical Cleaning	CrO_3 : 100-200g H_2O : 1L $Na_2Cr_2O_7 \cdot 2H_2O$: 100g	Boiling	1-15	
	3	Conversion Coating	NaF : 15g $Na_2Cr_2O_7 \cdot 2H_2O$: 180g $Al_2(SO_4)_3 \cdot 14H_2O$: 10g HNO_3 70% 125 mL H_2O 1 L	35-55	1/2-2	

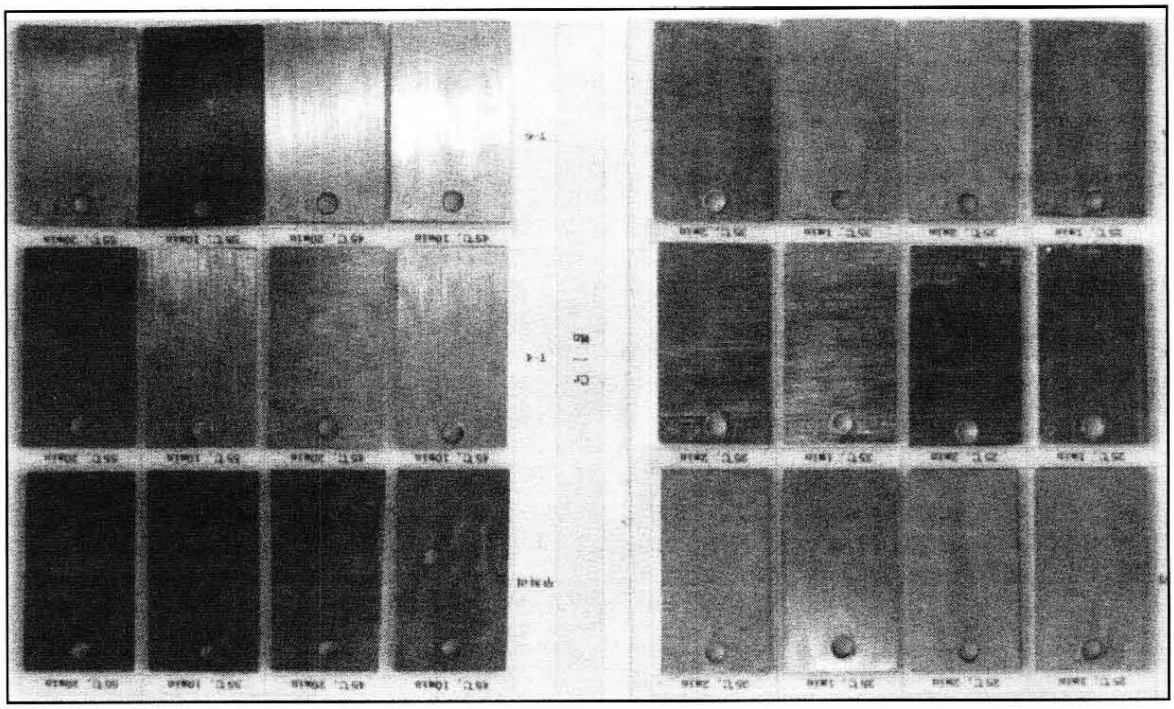

Fig. 1. Each shape of surface treated magnesium plates

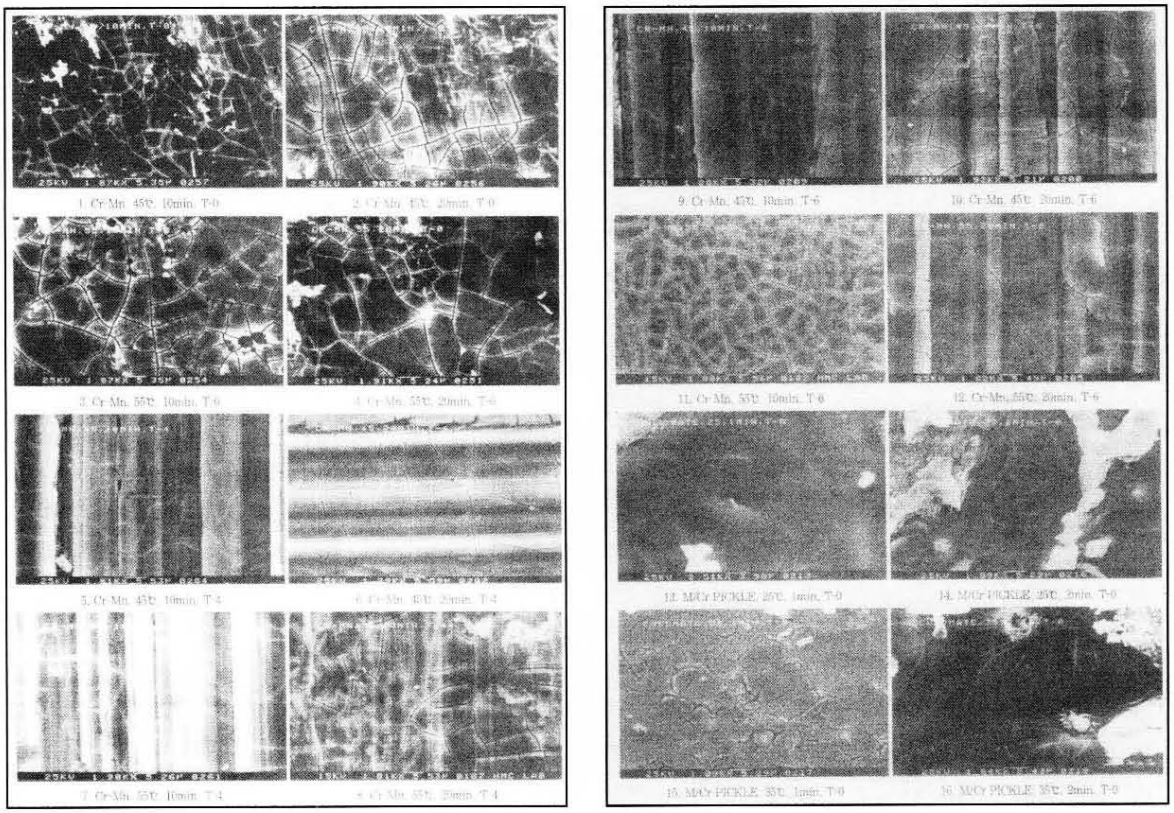

Fig. 2. Detail surface morphology of treated magnesium plate

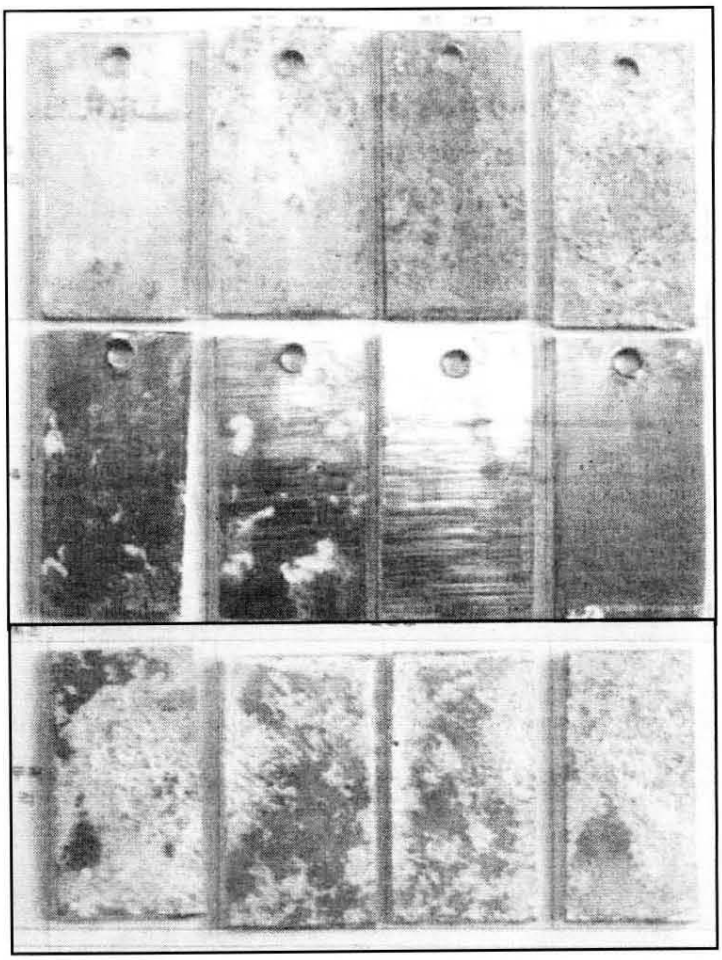

Fig. 3. The results of salt spray for magnesium plates

Table 3. Painting processes and composition

PAINTINGS			METHOD	FLOW OF PAINTING	COMPOSITION	REMARKS
1-COAT			BLACK PAINT	DIPPING	ACRYL	
SEVERAL COATING	2		SPRAY & BAKING	Color Base	T/S Acryl π 661	Baking Temperature 200℃
				Top Clear	T/S Acryl π 661	
	3-COATING	A		Primer	Epoxy-Polyester EX8816	
				Color Base	Polyester PX8576	
				Top Clear	Polyester PX8576	
		B		Primer	Epoxy EJ 2754	
				Color Base	T/S Acryl π 661	
				Top Clear	T/S Acryl π 661	
		C		Primer	Epoxy EJ 2754	
				Color Base	T/S Acryl π 661	
				Top Clear	T/S Acryl π 661	

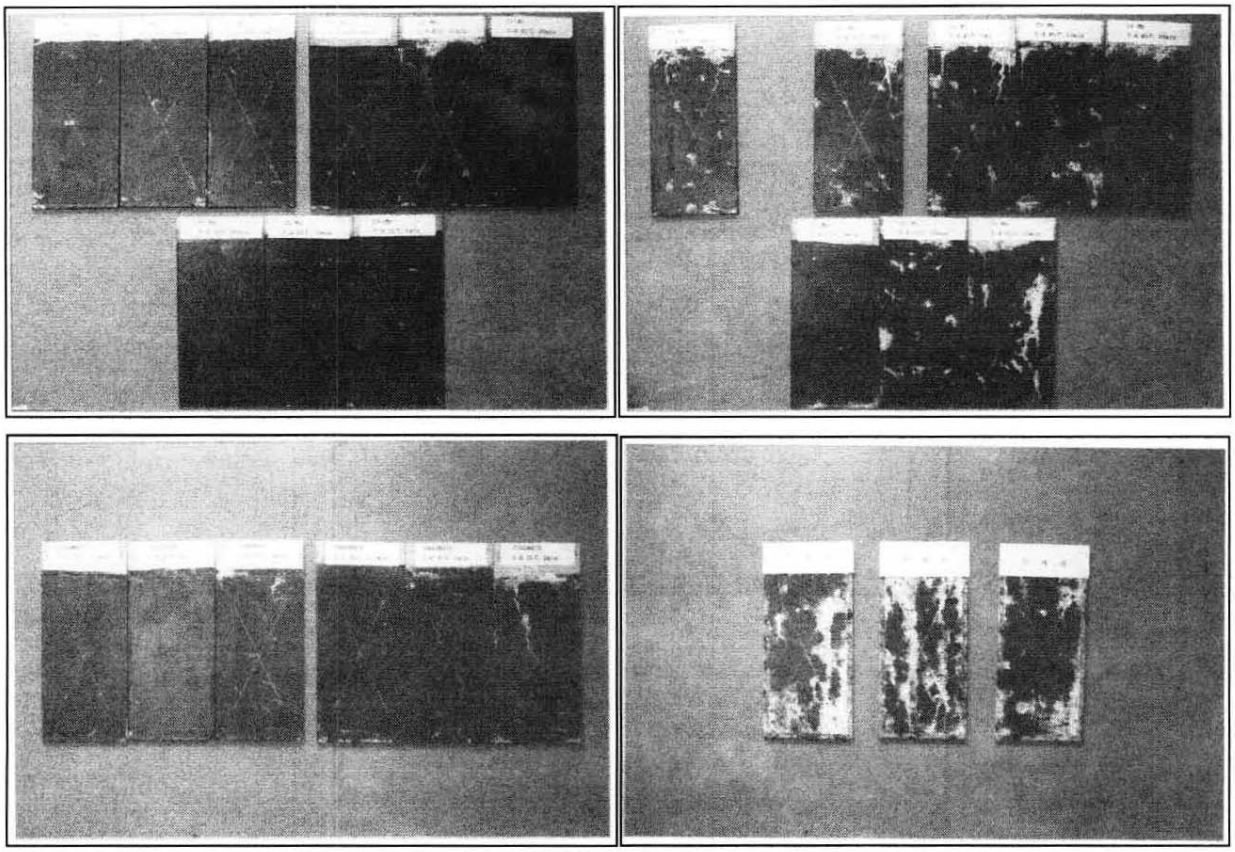

Fig. 4. Test results of salt spray for 1-coating finished plates

The first effect is enlargement of the contacted area between bare metal and painted layer which could strengthen the adhesion of the two layers.

The second is getting rid of the reaction between the alkali magnesium bare metal and the acidic paint which would shorten the life of paint. To test these effects, the salt spray test was performed according to the ASTM B117. Before salt spray testing, the paint films were subjected to a form of deliberate damage, two vertical scribes to expose bare metal. The duration was 168, 240 and 268 hours. The results is shown in Figs. 4 for modified chrome pickle and chrome-manganese prepared plates. From the Figures, it can be concluded that the coatings prepared by dipping the plates into the solution bath were very effective to corrosion protection by enhancing the adhesion between bare metal and finished layer.

2.6 Analyzing the optimum surface preparation condition

From the viewpoint of cost savings, the optimum conditions for surface pretreatment are very important. Therefore, the analyzing processes were carried out to get the best solution. Firstly, the only one-coating(black paint) plates were concerned to select the best conditions measuring width and the ratio of areas of blisters taken

Table 4. Test results of salt spray for painted plates

TREAT-MENTS	HEAT TREAT	DIPPING CONDITION		WIDTH OF BLISTER (mm)	RATIO OF BLISTER(%)
		TEMP (℃)	HOUR		
CHROME - MANGANESE	T-0	35	5, 10, 20	6, 6, 1.5	0.7, 0.5, 0.2
		45	5, 10, 20	2.6, 0.4, 1.6	0.3, 0.3, 0.0
		55	5, 10, 20	2.6, 0.4, 1.6	0.3, 0.3, 0.0
	T-4	35	5, 10, 20	6.2, 9.5	2.6, 4.1
		45	5, 10, 20	4.6, 8.6	3.6, 3.1, 1.0
		55	5, 10, 20	0.5, 4, 14	0.1, 3.5, 11.8
	T-6	35	5, 10, 20	17, 4, 2	8.6, 3.6, 0.4
		45	5, 10, 20	9, 3, 6	16.2, 13.1, 2.6
		55	5, 10, 20	7.5, 4, 18	8.2, 1.4, 9.3
MODIFIED CHROME PICKLE	T-0	25	1/2, 1, 2	3.5, 1, 6.5	0.2, 0.2, 0.6
		35	1/2, 1, 2	3, 5, 8	0.0, 0.2, 1.2
	T-4	25	1/2, 1, 2	11.5, 25, 4	11.2, 9.1, 1.9
		35	1/2, 1, 2	7, 4, 10	1.5, 5.1, 3.3
	T-6	25	2, 5, 5	1/2, 1, 2	0.5, 1.7, 0.4
		35	1/2, 1, 2	8, 4, 4	1.9, 1.4, 1.3

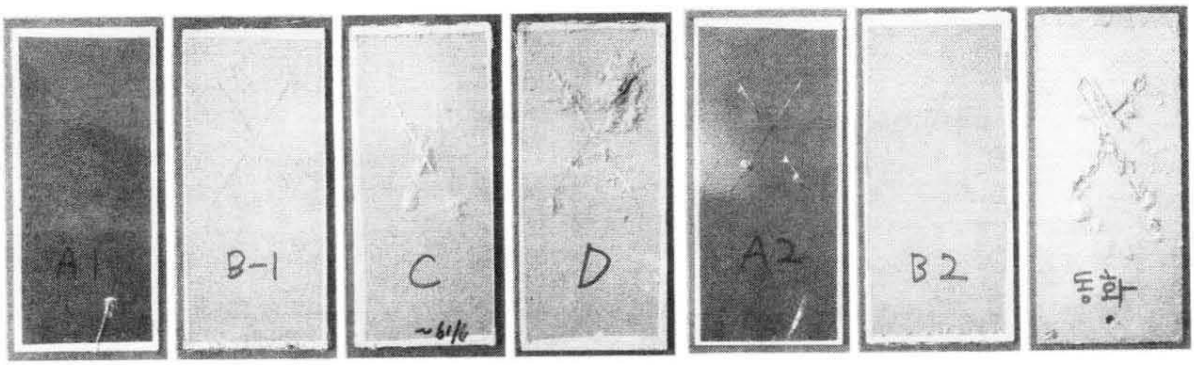

Fig. 5. Test results of salt spray for several coating finished plates

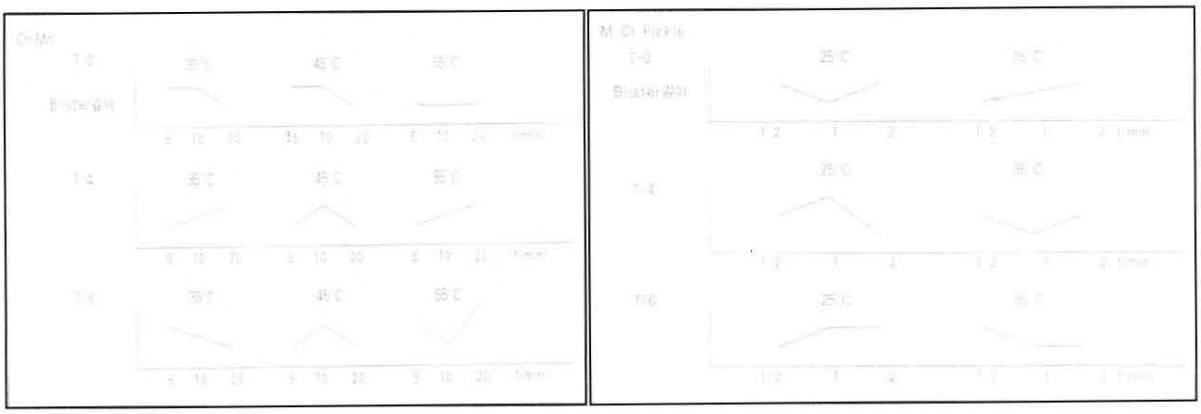

Fig. 6. The optimum conditions for surface treatments

place at the salt spray test. On the basis of this measurement, the results of Table 4 and Figs. 4, 6 were acquired. Then, the completely finished plates made by 3-coating and 3-baking process were tested to confirm the corrosion protection ability under severe corrosive environment. The results were very good as shown at Fig. 5.

2.7 Evaluating the anti-corrosion properties of magnesium treated by complete finishing system

To get the confirmation for the secure operations of the magnesium automotive parts in real driving system, the acquired data was compared with the standard value which could determine the possibility of magnesium components. The criteria was the FPO-3 which is often used for judging the corrosion protection ability of engine room components. The results were acceptable as shown at Table 5.

Table 5. The corrosion protection ability of concerned finishing system

TREATMENTS	HEAT TREAT CONDITION	DIPPING CONDITION		WIDTH OF BLISTER (mm)	FPO-3 (WIDTH OF BLISTER)
		TEMP (C)	HOUR		
Chrome - Manganese	T-0	35	20	1.5	3
		45	20	2.4	
		55	10, 20	1.2	
	T-4	55	5	1	
		35	20	2	
Modified Chrome Pickle	T-0	25	1	1	
		35	1/2	3	
	T-6	25	1/2	2.5	

3. Conclusions

Following conclusions are achieved from the analyses of surface preparations for sand cast magnesium.

1) The Modified Chrome Pickle and Chrome-Manganese surface treatments were very effective to corrosion protection of magnesium sand cast bare metal.

2) The Modified Chrome Pickle and Chrome-Manga-

nese surface treatments were very effective to enhance the adhesion between bare magnesium sand cast surface and black painted 1-coat finished layer.

3) The completely finished corrosion protection system which was made by 3-coating and 3-baking on the chrome-manganese and modified chrome pickle pretreated surfaces was so effective that the magnesium automotive parts could endure the severe corrosion environments nearly comparable to FPO-3 regulation.

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