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Vehicle accelerated corrosion test procedures for automotive in Malaysia

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Abstract. An accelerated corrosion test, known as proving ground accelerated test, is commonly performed by automotive manufacturers to evaluate the corrosion performance of a vehicle. The test combines corrosion and durability inputs to detect potential failures that may occur during in-service conditions. Currently, the test is conducted at an external test center overseas. Such test is aimed to simulate the effects of one year accelerated corrosion in severe corrosive environment of the north-east and south east of America. However, the test results obtained do not correlate with the actual corrosion conditions observed in the Malaysian market, which is likely attributed to the different test environment of the tropical climate of vehicles in service. Therefore, a vehicle accelerated corrosion test procedure that suits the Malaysian market is proposed and benchmarked with other global car manufacturers that have their own dedicated corrosion test procedure. In the present work, a test track is used as the corrosion test ground and consists of various types of roads for structural durability exposures. Corrosion related facilities like salt trough, mud trough and gravel road are constructed as addition to the existing facilities. The establishment of accelerated corrosion test facilities has contributed to the development of initial accelerated corrosion test procedure for the national car manufacturer. The corrosion exposure is monitored by fitting test coupons at the underbody of test vehicle using mass loss technique so that the desired corrosion rate capable of simulating the real time corrosion effects for its target market.

1 Introduction

Vehicle accelerated corrosion or proving ground test is a method used by many car manufacturers to evaluate the overall corrosion performance [1, 5]. It is able to combine corrosion and durability inputs as shown in Figure 1. Proving ground is a large scale laboratory that consists of a variety of road surfaces and facilities for automotive testing and validation. Examples of proving grounds by car manufacturers are listed in Table 1.

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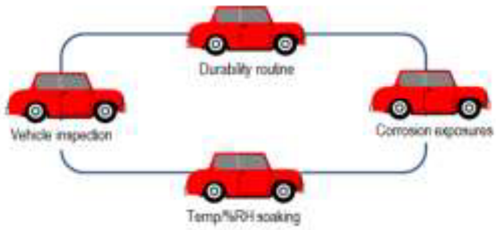

Fig. 1. General flow of proving ground accelerated corrosion test.

Table 1. Proving Grounds by car manufacturers.

Car Manufacturer	Proving Ground Location
General Motors	Milford, USA
Chrysler	Milford, USA
Volkswagen	Phoenix, USA
Ford	Kingman, USA
Navistar	Phoenix, USA
Mitsubishi	Japan

Corrosion test is important to ensure the lifespan of vehicles and relates with warranty periods [2]. It is used to predict potential failures that may occur during in-service conditions and which can be prevented. The national car manufacturer in Malaysia adopted the proving ground accelerated corrosion test, which is conducted at an external test centre overseas, to evaluate the corrosion performance of its products. This test simulates the effects of one year accelerated corrosion that mimics the severe corrosive environment of north-east and south east of America [3]. However, the test results obtained vary and do not correlate with the actual corrosion conditions observed in the Malaysia market. Because of this, the national car manufacturer is planning to establish corrosion facilities and design its own test procedure that suits the environment of the targeted market especially for tropical climate countries. Benchmarking the proposed test to other car manufacturers such as Volkswagen, General Motors and Ford is also one of the objectives in the development of this test [1].

2 Experimental setup

2.1 Test facilities

To replicate the proving ground test the required corrosion facilities should be available. A test track as shown in Figure 2 is used as the corrosion test ground [7] and consists of different types of roads for structural durability exposures. Corrosion related facilities like salt trough, mud trough and gravel road are constructed as additions to the existing facilities. A salt trough is designed to provide a corrosive environment to all vehicle surfaces – top, sides and bottom. The vehicle is driven through a shallow trough of salt water, which splashes the vehicle's underbody and sides. A mud trough is designed to introduce small particles into vehicle joints and crevices, primarily at the underbody, door lower hem flanges and engine compartment. The accumulated grit / poultice increases the time of wetness and may abrade coatings. A gravel road tests the physical integrity of protective coatings by introducing stone impact [4].

Fig. 2. Overall view of Test Track.

2.2 Test parameter

There are several important parameters that need to be considered in order to conduct the accelerated corrosion test. Table 2 describes these parameters [1-4].

Table 2. Corrosion test parameters.

No	Parameter	Details
1	Sodium Chloride (NaCl)	5% of NaCl solution as per ASTM B117 - Standard Practice for Operating Salt Spray (Fog) Apparatus. Purpose : Act as corrosive agent
2	Temperature and Humidity	Temperature of 50°C and 98% RH is widely used. Purpose : To create condition that will accelerate the natural corrosion
3	Gravel road	Aggregate from 25mm to dust is used. Purpose : To introduce stone chipping to vehicle body and components.
4	Mud	Water, sand and loam. Purpose : To build up deposits in related areas.

2.3 Test cycle

A test cycle is designed to suit the test track facilities lay-out and corrosion facilities. Figure 3 shows the corrosion driving cycle used in the present study. A vehicle is driven to achieve a target of 6 cycles per day to accumulate 140 km. the overall mileage targeted is 14000km that requires approximately 3 to 4 months of test duration.

2.4 Test Control and Monitoring

Control and monitoring of the test is conducted using test coupons made from recommended materials such as cold rolled mild steels ASTM C1008, AISI 1006-1010 [15] with the dimensions of 50 mm (H) x 25 mm (W) x 1.5 mm (T). The test coupons were installed on a coupon rack, which was then installed at under floor of the test vehicle. Each coupon rack contained 10 coupons. All materials used for the bolt, nut and washer were made from the plastic material of nylon. Figure 4 (a) and (b) show the installation of test coupon racks.

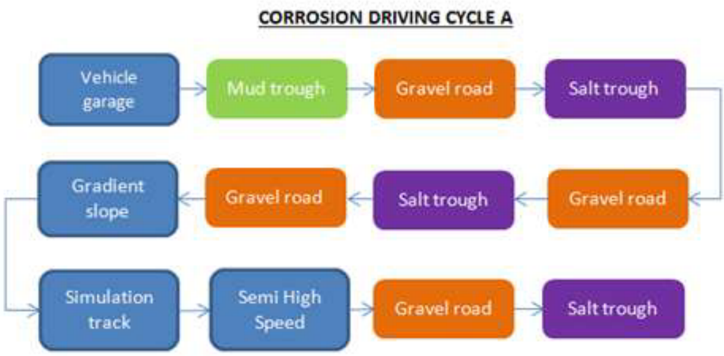

Fig. 3. Corrosion Driving cycle A.

Fig. 4 (a) and (b) Test coupon racks at under floor of vehicle**.**

After each specified corrosion exposure interval, the test coupon was removed from the rack and analysed using the mass loss technique. The corrosion rate was calculated according to ASTM G1-03 standard using the formula in Equation 1.

$$\text{Corrosion Rate} = (K \times W) / (A \times T \times D) \qquad (1)$$

where;
K = a constant
T = time of exposure in hours
A = area in cm^2
W = mass loss in grams
D = density in g/cm^3

2.5 Cosmetic Corrosion

Cosmetic corrosion inspection is conducted during the corrosion exposure interval. Cosmetic corrosion is characterized by blistering and/or rusting that is aesthetically displeasing, but may not result in catastrophic failure of the item [8]. The test driver will conduct inspection and provide cosmetic corrosion rating as shown in Table 3. The corrosion rating data is important and is used to correlate with the customer's acceptance towards corrosion [3].

Table 3. Cosmetic corrosion rating.

Scale	Rating	Customer's Perception
10	No visible corrosion	No Problem
9	Trace of corrosion	Not quite perfect
8	Slight corrosion	Readily visible but acceptable
7	Light corrosion	Almost acceptable : Critical customer would object
6	Moderate corrosion	Objectionable areas of corrosion
5	Medium corrosion	Very obvious corrosion : Everyone would object
4	Mostly corroded	Unacceptable but not totally imperfect
3	Totally corroded	Totally objectionable
2	Severe corrosion	Metal loss
1	Perforation	Hole in a panel/component

3 Results and discussion

3.1 Corrosion rate

The results of corrosion rate of the test vehicle calculated from the test coupon using the mass loss technique is plotted as shown in Figure 5. As can be seen in this figure the corrosion rate of the test vehicle is monitored against the target corrosion exposure line [10].

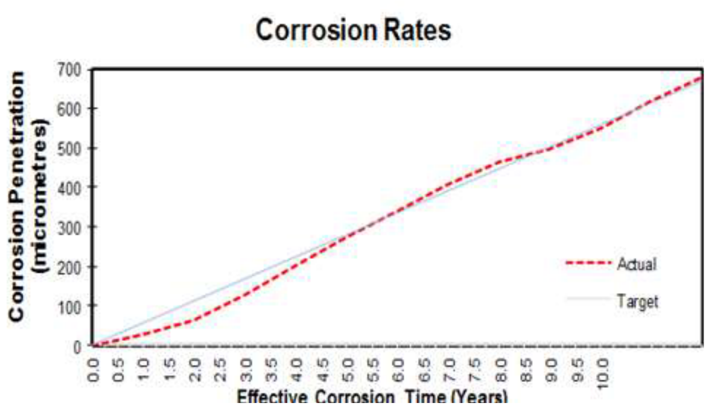

Fig. 5. Example of corrosion rate data

From Figure 5 it can be seen that the actual corrosion exposure rate has not reach the targeted exposure line during at the start of the effective corrosion years. It is during this period of exposure that the corrosion test cycles can be modified to provide additional corrosion exposure and durability inputs [9].

3.2 Corrosion cosmetic ratings

The overall cosmetic corrosion ratings are categorized into 6 observation areas as outlined in Table 4. It is a good indicator to evaluate the corrosion exposure given to the vehicle in relation with the corrosion rates obtained from the test coupons. Based on the ratings, it is shown that the test vehicles experienced medium to moderate corrosion behavior. Analysis on specific corroded components is also necessary so that proper assessment of the corrosion level is predicted. If too severe corrosion exposure is given to the test vehicle, it can be detrimental to the overall vehicle performance like breakdown and components malfunction.

Table 4. Cosmetic corrosion rating.

No	Area of vehicle	Requirement	Rating
1	Exterior	Rating 6 or better	6
2	Under hood		5
3	Underbody		6
4	Interior	Rating 7 or better	8
5	Perforation	No perforation	No perforation
6	Functional	No loss of function within 10 years exposure	Few functional issues

The combination of corrosion rate and cosmetic ratings obtained can be used as a guideline to improve the corrosion test procedures designed for Malaysia market [12].

4 Conclusions

The establishment of vehicle accelerated corrosion test in Malaysia is targeted to achieve the best correlation of the product performance with the local tropical climate. In vehicle and components development for the Malaysia's market, real time corrosion prediction can be done. Suitable material selection, coating application, product design and specification can be considered to meet the intended market. This can prevent an under-designed or over-designed component or vehicle and leads to a cost effective, durable and reliable products and higher overall performance. In addition, the test procedure can also be used in the test track for more product development and fast evaluation instead of outsourcing the test form overseas.

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