

One-coat Paint for Motorcycle Engine Magnesium Cylinder Head Cover

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ABSTRACT

Two-coat painting is generally necessary to achieve both weather resistance and corrosion resistance in magnesium motorcycle cylinder head covers. A paint that enables the achievement of both weather resistance and corrosion resistance using one coat has been developed by adding epoxy resin to the main resin to promote modification, adding compounds to increase adhesiveness, and adding rust preventive pigments. The developed paint enables magnesium cylinder heads to be painted using one coat, and thus reduces the number of painting processes involved.

1. Introduction

Most motorcycle cylinder head covers are made of aluminum alloy (ADC12), but recently the need for magnesium alloy (AZ91D) cylinder head covers in order to reduce vehicle weight has been increasing. Figure 1 shows an example motorcycle cylinder head cover.

Cylinder head covers made from both types of materials are painted for rust prevention and decorative purposes, but aluminum alloy materials have relatively



Fig. 1 Cylinder head cover of CBR600RR

good corrosion resistance, so sufficient performance including corrosion resistance can be obtained with only one-coat of paint that has good weather resistance. In contrast, magnesium alloy materials have low corrosion resistance, so the paint used should have good corrosion resistance and adhesion properties. However, paint with such properties generally has low weather resistance, so magnesium alloys should be given two coats of paint, consisting of a primer coating using paint that has high corrosion resistance and then a top coating using paint that has good weather resistance. This increases the number of painting processes involved.

This study developed one-coat chromium-free paint that achieves both corrosion resistance and weather resistance in order to reduce the number of painting processes. This paint was developed by adding epoxy type primer resin to acrylic urethane resin to promote modification, and adding a polymer compound and rust preventive pigments to further enhance performance. This paper describes the paint design approach and results.

2. Paint Development

2.1. Development Points

In order to change the two-coat paint used for magnesium alloys to one-coat paint, the paint should simultaneously achieve the basic performances of

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Table 1 Points of development

Item		Purpose
Reduction of number of coats (2-coat to 1-coat)		Reduction of procedures
Basic performance	Adhesion	Satisfy all property of adhesion, corrosion resistance, and weather resistance requirement using 1-coat paint
	Weather resistance	
	Corrosion resistance	
Applicability to mass production	Re-coatability	Adhesion after re-coat
	Baking-temperature applicability	Applicability to mass production line

adhesion, corrosion resistance and weather resistance. In addition to these basic performance characteristics, recoatability for paint touch-up, a one-component paint, and adaptability to mass production lines that can flexibly support the paint conditions of multiple paint manufacturers are also important. Therefore, these performance characteristics were positioned as development points on the same level as those of basic performance characteristics. Table 1 lists the development points.

2.1.1. Paint design issues

The current paint configuration for magnesium alloy parts is generally a two-coat paint with primer paint applied first as a primer coating, followed by a top coating paint. When using this type of two-coat paint, the necessary functions can be divided between the primer and the top coating, so it is easy to obtain the various necessary performance characteristics. Primer paint is selected focusing on adhesion and corrosion resistance, so epoxy resin type paint is generally used. Epoxy resin has epoxy groups and hydroxy groups distributed at equal intervals throughout its molecular structure, so it features good material adhesion. In addition, the main chain of the molecular structure does not include an ester bond, so epoxy resin also has good water and chemical resistance characteristics⁽¹⁾. On the other hand, the weather resistance is quite low, and ultraviolet rays easily cause yellowing and chalking, so epoxy resin is considered unsuitable as a top coating paint.

In contrast, acrylic resin type paint, which has low adhesion and corrosion resistance but good weather resistance and appearance characteristics, is generally used as the top coating paint.

The issue when changing from two-coat paint to one-coat paint is to achieve both corrosion resistance and weather resistance. It is therefore necessary for the corrosion resistance and adhesion of epoxy resin to be assigned to acrylic resin, but it is challenging to achieve both performance characteristics simply by changing the resin. This paint development added a polymer compound that increases adhesion and functional pigments that increase corrosion resistance in order to simultaneously

enhance both performance characteristics. This resulted in the development of a one-coat paint that can manifest the roles of both a primer epoxy paint and top coating acrylic paint, which formerly necessitated a two-coat paint.

2.1.2. Paint line adaptability conditions

Paint exerts its natural adhesion under conditions of properly treated materials, proper painting and proper baking. However, different painting line facilities use different baking oven temperature rise conditions. Considering its applicability to multiple painting lines, the paint should support a wide range of baking conditions. Based on temperature data obtained from actual painting lines, the standard temperature for the developed paint was set at 150°C, and the target was to achieve adhesion with the materials over the baking range of 140°C to 160°C for 20 to 30 minutes.

2.1.3. Recoatability

Paint should also consider recoatability. The recoat painting process is performed when paint trouble occurs such as the adherence of dirt or bits, and consists of a sanding procedure to help eliminate the trouble and then repainting. In this case the recoated paint film should exhibit the same level of adhesion by the same kind of processes as normal painting, so this feature was also set as a goal for the developed paint.

2.1.4. Environmental compliance

The conventional painting pretreatment for magnesium alloy parts generally used hexavalent chromium. However, the one-coat paint aimed for by this development also had the environmental goal of paint that does not contain hazardous substances. Therefore, in addition to making the paint itself lead-free and hexavalent chromium-free, this development also removed hexavalent chromium from the pretreatment process.

2.2. Paint Design

2.2.1. Resin Types

(1) Main resin

The important performance characteristics for one-coat paint resins are good adhesion with materials and equivalent weather resistance to that of the conventional top coating paint. Based on proven results of adhesion performance to nonferrous materials, epoxy resin and acrylic resin were selected as candidates for the main resin. In addition, the baking temperature was set at the general temperature of 150°C, so melamine resin and blocked isocyanate resin were selected as candidates for the hardener.

Table 2 shows the results of preliminary verification of the main resin candidates. Epoxy resin has better adhesion compared to acrylic resin, but weather resistance as a top coating paint should also be considered, so development of an epoxy resin type paint was abandoned.

Table 2 Study of resin types

Resin type / Characteristics	Water resistance/ secondary adhesion	Corrosion resistance	Weather resistance	Hardness
Acrylic / Melamine	Low	Low	High	High
Acrylic / Urethane	High	Low	High	High
Epoxy / Melamine	High	High	Low	Low
Epoxy / Urethane	High	High	Low	Low

In addition, melamine resin has issues with water and humidity resistance, so it was excluded from consideration as a hardener.

Therefore, acrylic resin with reactive hydroxy groups was selected as the main resin, and development focused on increasing the adhesion performance of this acrylic resin.

Acrylic resin was adopted because it has been proven to support a wide range of diverse applications⁽²⁾ due to its compatibility with various monomers, glass-transition temperature (Tg), the ability to control the molecular weight, etc. Figure 2 shows the Tg and main performance characteristics of acrylic resin.

The hardness and solvent resistance of acrylic resin increase together with the Tg, but adhesion tends to decrease⁽³⁾. Therefore, optimization design was performed taking into account the correlation between Tg and adhesion.

Resin with blocked isocyanate groups that undergo a dissociation reaction when heated was selected as the hardener. In consideration of paint workability, the temperature inside the oven and other factors, the dissociation temperature was set at 130°C, which is equivalent to that of the hardening conditions for general top coating. In addition, the hardener characteristics focused on adhesion, and the compounding amount was adjusted in consideration of adhesion.

(2) Modified resin and polymer compound

One method of enhancing paint performance is modification, which consists of compounding or polymerizing other resins into the main resin. One-coat paint with stable adhesion could not be obtained simply by optimizing the acrylic urethane (blocked isocyanate) main resin, so a modification promoting epoxy resin and a polymer compound were added to the main resin with

Tg	Low	← Fixed Tg →	High
Resistance to solvent	Low		High
Adhesion	High		Low

Fig. 2 Tg performance of acrylic resin

the aim of increasing adhesion. The epoxy resin added for modification was a bisphenol type because polyisocyanate can be used as a common hardener for both this resin and the acrylic resin. However, the paint performance varies greatly depending on the compounding ratio of the epoxy resin, so the compounding ratio was determined from the viewpoint of weather resistance and corrosion resistance in consideration of the operating environment. Figure 3 shows the relationship between the epoxy resin compounding ratio and the weather resistance and corrosion resistance.

A polymer compound was also added to increase adhesion. Here, a silane coupling agent with functional groups that react with the hydroxy groups on the magnesium surface was used. Figure 4 shows the mechanism for increasing adhesion with the silane coupling agent, and Fig. 5 shows the relationship between the compounding amount and adhesion.

2.2.2. Pigment compounding

Color pigment was used to give the paint good appearance, body pigment to increase the paint strength,

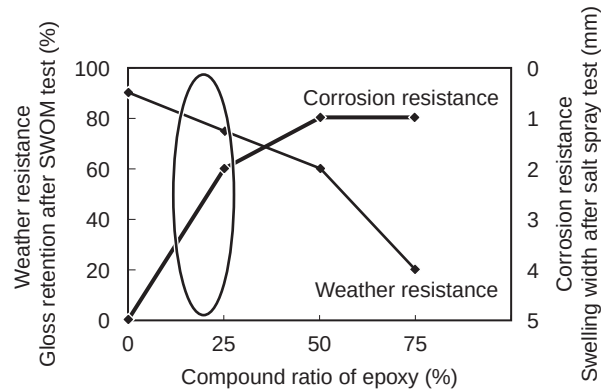


Fig. 3 Epoxy compound ratio versus weather resistance and corrosion resistance

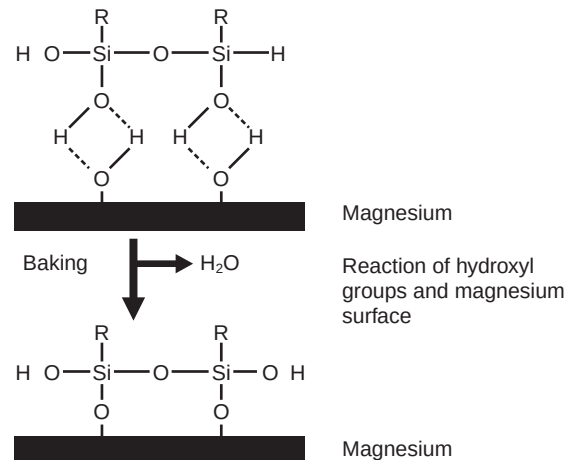


Fig. 4 Mechanism of adhesion to magnesium

and rust preventive pigment to provide corrosion resistance. Rust preventive pigment is not normally compounded with two-coat paint, but it was added to the developed paint to provide corrosion resistance. Chromium type rust-preventive pigment can generally be expected to provide rust preventive effects based on past results, but chromium-free type rust preventive pigment with good corrosion resistance was selected and compounded in consideration of environmental measures. Figure 6 shows the relationship between rust-preventive pigment type and corrosion resistance. Figure 7 shows that appearance diminishes when too much rust-preventive

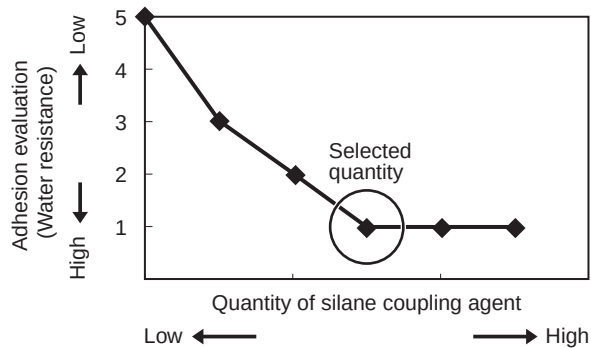


Fig. 5 Effect of silane coupling agent on water resistance

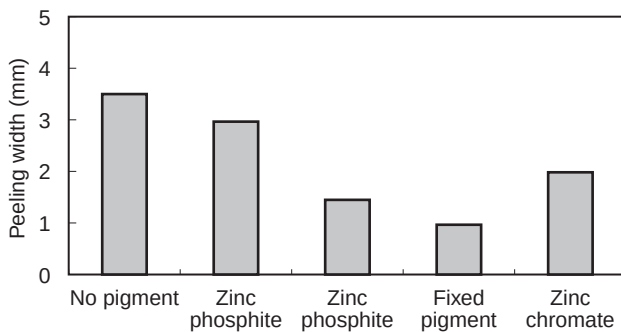


Fig. 6 Change in corrosion resistance by pigment

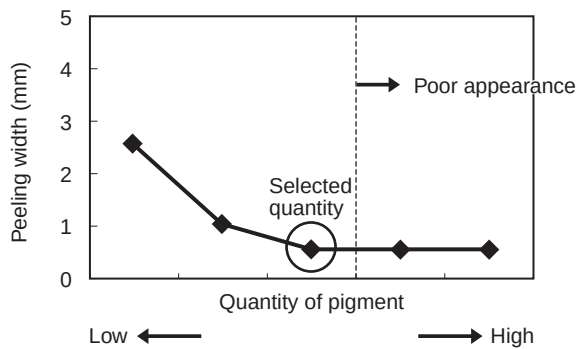


Fig. 7 Change in corrosion resistance and appearance by quantity of pigment

agent is added, so a quantity that achieves both corrosion resistance and appearance was determined and compounded.

3. One-coat Paint for Magnesium Alloy and Paint Film Performance

3.1. Basic Performance characteristics

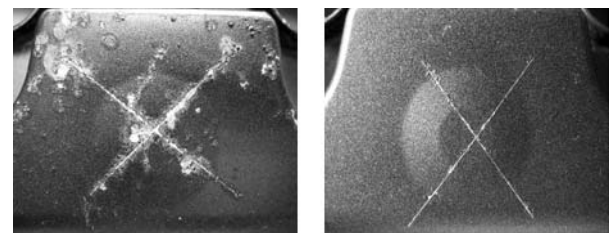
The developed paint made it possible to achieve the necessary performance characteristics of magnesium cylinder head cover paint with chromium-free type pretreatment plus one-coat paint instead of the conventional chromate type pretreatment plus two-coat paint.

3.1.1. Corrosion resistance

Corrosion resistance was increased, compared to conventional one-coat paint for magnesium surfaces, and the same corrosion resistance could be obtained as that of two-coat paint that uses primer. Figure 8 shows the appearance after the corrosion resistance test, and Fig. 9 shows the paint peeling width.

3.1.2. Weather resistance

The developed paint provides a level of weather resistance close to that of current paints, which poses no issues for practical use. Figure 10 shows the color difference and gloss residual ratio after the weather resistance test.



Conventional 1-coat paint
(acrylic resin type paint)

Developed 1-coat paint

Fig. 8 Corrosion resistance (salt spray test)

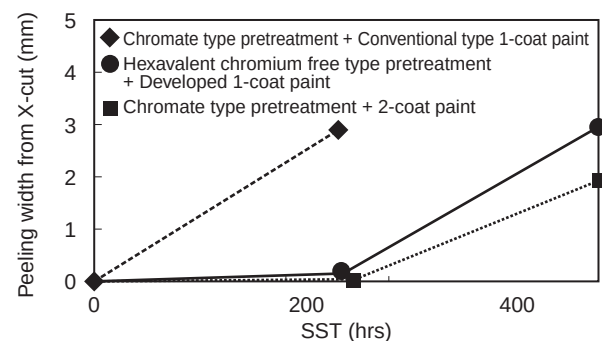


Fig. 9 Corrosion resistance (Salt spray test)

3.1.3. Galvanic corrosion resistance

Figure 11 shows the corrosion resistance test results in the actual mounted condition.

The influence of galvanic corrosion with the bolts used was confirmed to be the equivalent level to that for current mass-produced two-coat paints.

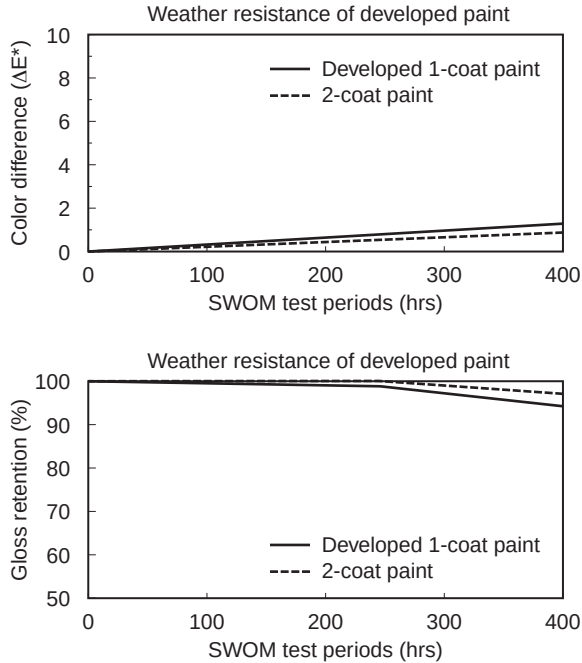


Fig. 10 Weather resistance

CCT cycle		30 cycle	100 cycle
Developed Hexavalent chromium free type pretreatment + 1-coat paint	Aluminum case		
	Bolt with Zn plating		
Current Chromate type pretreatment + 2-coat paint	Aluminum case		
	Bolt with Zn plating		

Fig. 11 Galvanic corrosion

3.2. Mass Production Characteristics

3.2.1. Adhesion stability

The adhesion at different baking temperatures and times was confirmed to evaluate baking temperature applicability. Figure 12 shows these results. Sufficient adhesion performance could be obtained over the wide temperature range of 140°C to 180°C, which is twice the target setting temperature range of 140°C to 160°C.

3.2.2. Corrosion resistance

Manganese phosphate type pretreatment, which is a type of hexavalent chromium-free treatment, was used as an environmental measure. However, the coating weight influences the corrosion resistance, so the optimum coating weight was determined. Figure 13 shows the relationship between the coating weight and corrosion resistance.

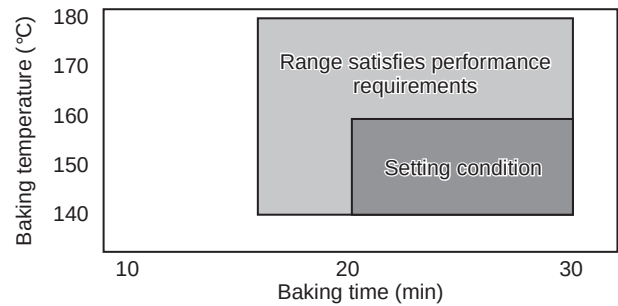


Fig. 12 Baking temperature applicability

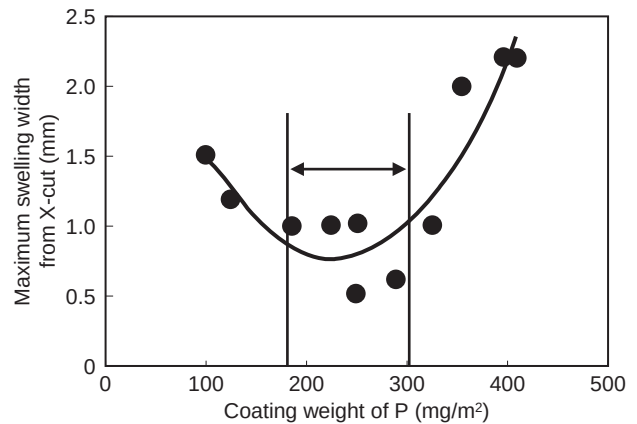


Fig. 13 Pre-treatment coating weight versus corrosion resistance

4. Conclusion

Two-coat painting is conventionally applied to magnesium cylinder head covers. The following items enabled use of one-coat paint, which reduced the number of painting processes by 30% or more.



Fig. 14 CBR600RR which applied developed paint

- (1) Corrosion resistance was increased by adding an appropriate amount of epoxy resin to the main resin to promote modification.
- (2) Adhesion was increased by adding a silane coupling agent that reacts with magnesium.
- (3) Rust prevention performance was increased by using chromium-free pigments in consideration of environmental compliance.

The developed paint was applied to the CBR600RR (Fig. 14).

References

- (1) Japan Paint Manufactures Association: Toryou Gairon, Toryou Bunrui, Koujou Tosou Rain ni Okeru Tosou Toryou Kanri Handobukku, Tokyo, p. 38-41 (2000) (in Japanese)
- (2) Sato, K.: Tomaku no Nendansei, Hashikakegata Tomaku no Nendansei, Gaisetsu Toryou Bussei Kougaku, Tokyo, p. 85-94 (1973) (in Japanese)
- (3) Sato, K.: Tomaku no Fuchaku, Tomaku no Sosei to Fuchakusei, Gaisetsu Toryou Bussei Kougaku, Tokyo, p. 197-208 (1973) (in Japanese)

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