

Development of Waterborne Conductive Primer for Motorcycles

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ABSTRACT

Most types of paint materials currently used for motorcycles contain large amounts of VOCs (Volatile Organic Compounds). VOCs are environmental load substances, and there is a demand to reduce emissions in recent years. Many of a motorcycle's exterior parts are made of ABS (Acrylonitrile-Butadiene-Styrene) plastics (henceforth ABS) or PA (Polyamid) plastics (henceforth PA). These two plastic materials have different film adhesion mechanisms and adhesion strength. Therefore it was necessary to use different conductive primers and that's was one of the factors which made time and material losses in the painting processes. We solved those two issues, the reduction of VOCs and the common use of the same conductive primer for different parts materials, by combining two kinds of resins originally designed as the conductive primers, i.e., urethane resins with carboxylic acid groups and acrylic resins with amide groups, which are different in properties. Many of the plastic parts used in motorcycles are painted manually because there are difficult portions to be painted by automated painting machines. The viscosity was adjusted to satisfy both the controllability of paint sagging and the surface smoothness to keep the efficiency of paint workers' operations.

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INTRODUCTION

Adoption of Waterborne Primer to Reduce VOCs

In these days, public concerns for the environment are growing considerably. Chemical substances that are hazardous to the environment and/or health have been recognized as environmental load substances, and are now regulated. VOCs are a kind of those environmental load substances and are contained in materials used in paint as well. "VOCs" is a general term for organic compounds which are easily evaporated and stay as gaseous body in the atmosphere, and is considered as one of the substances that causes photochemical smog through photochemical reactions in the atmosphere. In some countries regulations of VOCs have been enacted such as the Clean Air Act in the United States, TA-Luft in Germany and the Environmental Protection Act in the United Kingdom. In Japan, the Air Pollution Control Act was revised in April 2006 to include VOCs regulations. This prompted the Japan Automobile

Manufacturers Association (JAMA) to set stricter target, aiming to reduce VOCs by 40%, compared to 2000, until 2010. Japanese automobile manufacturers have developed various technologies [1-2] to meet this target. VOCs are contained in the solvents of painting materials and discharged during the painting processes in the automobile production lines. Before JAMA set their target, lots of efforts had been done in Honda factories towards the improvement in painting efficiency, the retrieval of paint thinner and the adoption of high-solid type solventborne paint. However, more efforts were needed to meet JAMA's target of 40% reduction. Therefore, we had made further step to adopt a waterborne primer to achieve even larger reduction of VOCs emissions.

Painting Materials to be Changed to Waterborne Materials

The parts of a motorcycle that are painted are tanks, frames and exterior parts such as cowls. Figure 1 shows proportions of VOCs emissions per square meter from each parts category in Honda's Kumamoto Factory. As can be seen

from the graph, the greatest VOCs emissions occur in the painting of the exterior parts which are made of plastic. To know the details on the sources of the emissions, the VOCs emissions for each layer of the painting materials were examined. The results are shown in [Figure 2](#). The paint layer structure has two layers composed of a primer and a top coat paint, which consists of a base coat and a clear coat, to give colored appearances. This primer is the reason that such high VOCs emissions occur during the painting of the exterior parts. The chart in [Figure 2](#) shows that the primer emits more VOCs than the base coat and top coat. This is because the primer is a one-composite material and it can not be made as a high-solid type. Based on those circumstances, it is expected that large reduction of VOCs can be achievable if the solventborne primers are substituted with waterborne primers to reduce VOCs rate from 70 % to a few % in primers.

That expectation motivated us to make challenges to alter the solventborne primers currently used with the newly developed waterborne primer applicable to the plastic exterior parts.

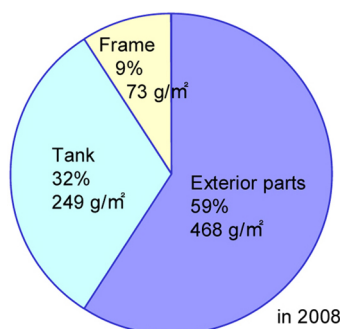
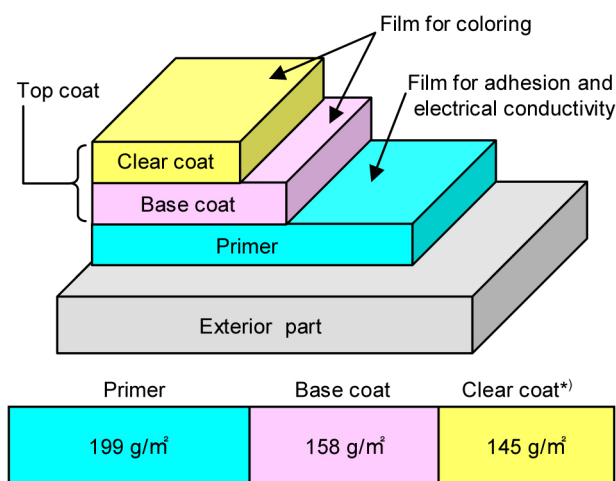


Figure 1. Proportions of VOCs emissions from each parts category



*) In case of a typical metallic color coat

Figure 2. Paint composition on exterior parts and VOCs emission amount

Functions of Primers and Creation of One Common Primer

The primer is a film applied between the parts and the top coat film, which is used for colored appearances. Its function is to apply conductivity for electrostatic spraying and to facilitate adhesion between the top coat film and the parts.

The transfer efficiency in paintings can be significantly improved by using the electrostatic spraying method in which large amount of paint material is carried on to the painting parts with the help of electrostatic forces generated by electrical fields which are created by voltage applied between the paint spray gun and the parts. Non electrostatic spraying has low transfer efficiency, as a large amount of the paint dose not reach the target parts ([Figure 3](#)). To apply the electrostatic spraying method, the target painting parts should have electrical conductivity. That is the reason why conductive primers should be painted on plastic parts, which are not conductive, when top coat painting is to be electrostatically spray painted.

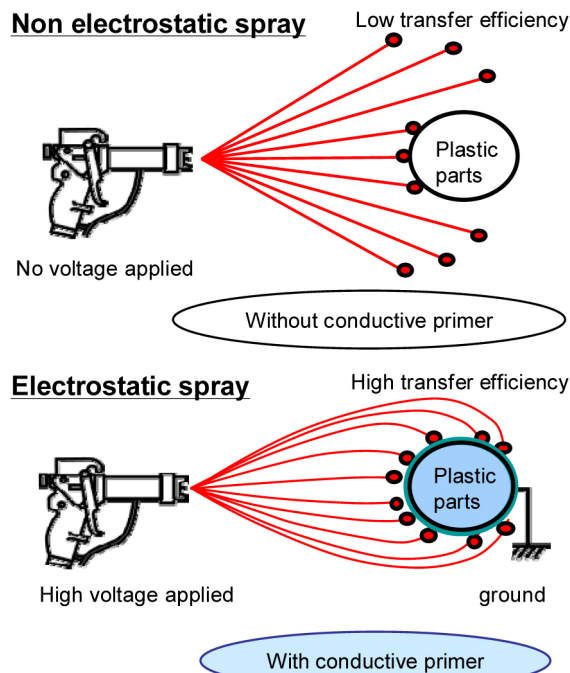


Figure 3. Difference between non electrostatic spray and electrostatic spray

Adhesion strength to a paint film varies from one plastic material to another. When the adhesion of the plastic is low a primer with good adhesion characteristics against plastic needs to be applied.

Figure 4 shows the examples of plastic exterior parts of a motorcycle. Three different types of plastics are used for the outer coverings of a motorcycle. Table 1 shows the features of the plastics to fulfill the requirements in motorcycle applications. The roles of the primers shall be outlined as follows. In the case of ABS and ABS+PE (Polyethylene) plastic (henceforth ABS+PE), the primer is used only to put on conductivity for electrostatic spraying, because two-package type urethane acrylic paint adheres well to these plastics without primer.



Figure 4. Plastic exterior parts of a motorcycle

Table 1. Plastic type and features for applications

Plastic type	Features for applications
ABS	Easiness for painting
ABS+PE	Resistance against chemical agents
PA	Heat resistance

In the case of PA plastic, on the other hand, the film does not adhere well. Therefore, a primer is required not only to give conductivity but to ensure adhesion of the film to the parts. Thus, in this case, the primer plays the major role in preventing the film from peeling.

ABS and PA have different mechanisms of adhesion to primers and two different primers have to be separately used. This is imposing on us the necessity of management of time and material losses at the painting processes in our factories. These situations motivated us to develop a waterborne primer that can be used on both ABS and PA plastics.

With those two objectives mentioned above in mind, we developed a waterborne conductive primer that could be used on different plastic materials of motorcycles, in order to reduce VOCs and simplify the painting process.

REQUIREMENTS IN DEVELOPMENT

The requirements for our development of a waterborne conductive primer that could be used on different plastic materials were as follows:

1. Organic solvent proportion (to whole primer quantity) : Less than 3% (which is the amount to satisfy VOCs emission regulations)
2. Surface electrical resistance: No more than 0.05 MΩcm (which is the value that fulfills the transfer efficiency requirement for electrostatic spraying)
3. Meeting requirements for products and manufacturing processes: Paint film performances (initial adhesion, water resistance, humidity resistance, etc.) and good handling and painting properties (sagging prevention management, surface smoothness of wet film, surface smoothness of dry film, etc.) when applied to ABS, ABS+PE and PA.

ISSUES AND TECHNICAL MEASURES

Adhesion to ABS and PA and Resin Design

ABS can be made adhesive to the paint film without difficulties, by adding functional groups with polarity to the primer resins, because ABS contains nitrile groups with high polarity. Meanwhile, PA can not be easily made adhesive because it has less polarity with its crystallized structure. Therefore, as for PA, the binding force for adhesion is mainly created by intermolecular force of the alkyl chains between the primer resin and PA and by hydrogen bonding between the polar functional groups of the primer resin and the amide groups of PA. Because of these differences in adhesion mechanisms to the primer, a primer resin must be individually designed for each plastic. In those circumstances, we made a challenge to select appropriate principal chains and side chains in resins that adhered to ABS and PA and examine the suitable combination and the right composition ratio. Table 2 shows the resins selected and their adhesion mechanisms. Figure 5 illustrates the adhesion mechanisms.

Moreover, in motorcycle applications, plastic parts are used even in high temperature locations such as in the vicinity of an engine or a exhaust pipe. For those parts used under the high temperature, PA is usually selected because of its high melting point and is reinforced with glass filler. Where the glass filler appears on the surface of the plastic the adhesion between the primer film and the plastic is further reduced. To resolve this issue, adhesion to the glass was improved by adding silica body pigment to the primer and a low-polarity component to the resin in the primer.

As for the adhesion strength between the top coat film and primer on ABS or PA, it does not become a concern due to the polar functional groups contained both in the resin of the top coat film and the resin of the primer film.

Table 2. Resin type and adhesion mechanisms

Resin type		Target of adhesion	Adhesion mechanisms
Principal chain	Urethane emulsion	ABS PA	Dipolar interactions and hydrogen bonds between: 1) ABS; urethane bonds of urethane resin and nitrile groups of ABS 2) PA; urethane bonds of urethane resin and amide bond of PA
	Acrylic emulsion	PA	Intermolecular force of the alkyl chains between acrylic resin and PA
Function group in side chain	Carboxylic acid groups	ABS PA	Dipolar interactions and hydrogen bonds between: 1)ABS; carboxylic acid groups and nitrile groups of ABS 2)PA; carboxylic acid groups and amide groups of PA
	Sulfonic acid groups	ABS PA	Dipolar interactions and hydrogen bonds between: 1)ABS; sulfonic acid groups and nitrile groups of ABS 2)PA; sulfonic acid groups and amide groups of PA
	Amide groups	PA	Dipolar interactions and hydrogen bonds between amide groups and amide groups of PA

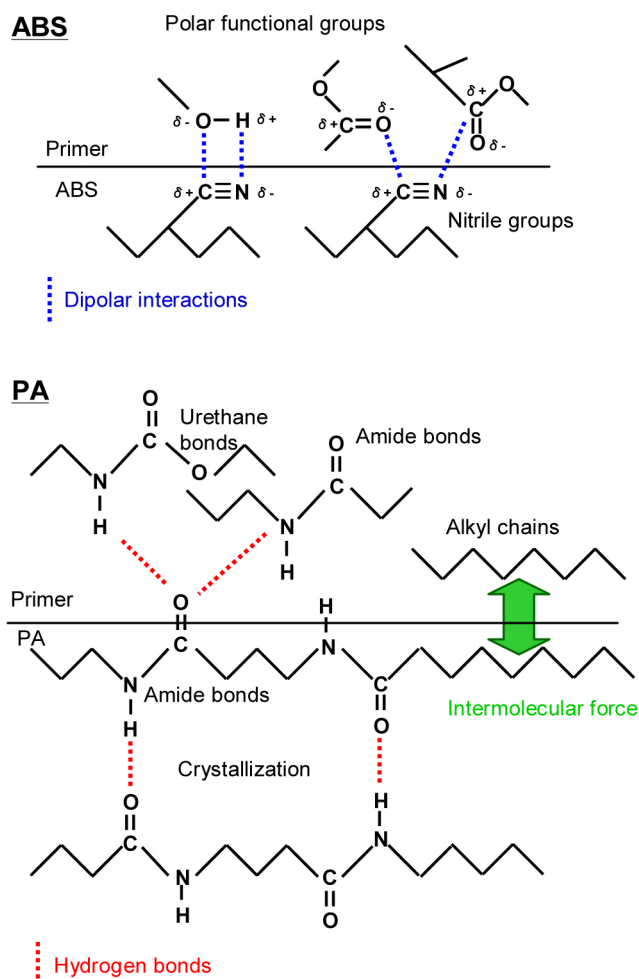


Figure 5. The adhesion mechanism of primers to ABS and PA

Decrease of Film Performance Due to Remaining Water and Increment of Solid Content Ratio (*1)

A film of two-package type urethane acrylic paint is formed by the reaction between the hydroxyl groups in the acrylic resin, the base resin, and the isocyanate groups in the isocyanate resin, the hardening agent, forming urethane bonds and creating a cross-linking reaction between them (Figure 6). The hardening agent in the top coat paint also reacts with the hydroxyl groups in the primer resin, creating adhesion between the top coat film and the primer film.

Waterborne primer contains water as the solvent and water is less volatile and that makes more water to be remained in the primer film for a long time after it has been applied. If the top coat paint is applied while the primer still contains a large amount of water, the water from the primer will seep into the top coat paint. As the isocyanate groups in the hardening agent preferentially react with water than with the hydroxyl groups in the base resin. This intervenes the cross-linking reactions between the base resin and hardening agent, resulting in softening of the top coat film and the poor adhesion between the top coat film and the primer film (Figure 7). Additionally bake-finishing after painting over primer containing water causes deteriorations in appearance such as blisters in the film caused by vaporized water.

To avoid these defects, we added a preheating process between applications of the primer and the top coat paint to release the water and increase the solid content ratio.

(*1) Solid Content: The solid component containing no vaporizing substances such as water or solvent. In the case of painting materials, the solid content is the resin, body pigment, color pigment and additives. The solid content ratio is the ratio of the weight of the solid content to the overall weight, and is used both for a paint material before painting and for a wet film after painting.