Development of Environmentally Friendly Decorating Technology

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Abstract

Recently, there are many great opportunities to bring up environmental concerns. The revised Air Pollution Control Law that regulates VOCs linked with air pollution was enforced in April 2006. However, under current law, plants that have coating facilities of a given scale or larger are targeted, and domestic corporations' response to plastic parts is currently lagging. Under these conditions, even the design panels for Fujitsu Ten car audio equipment are manufactured using a coating process that gives off VOC. As a corporation that aims to manufacture "green" products, Fujitsu Ten has decided to take the lead in working to reduce environmental load.

In addition, our design panels are the "face" of Fujitsu Ten products, and key parts that are viewed and touched by our customers. However, it is difficult to maintain the quality of decoration coating processes such as coatings that affect appearance.

In this paper, "Development of Environmentally Friendly Decorating Technology", we report on the development of technology that reduces environmental load through the use of water-based coating while simultaneously improving the quality of Decorating processes.

A number of processes, including coating, printing, and marking, are required for the decoration coating of design panels. However, in this paper we focus primarily upon coating development, coating machines, and coating technology for coating processes.

1 Introduction

Recently, many environmental problems have been considered on a global scale. Air pollution caused by suspended particulate matter(1) and photochemical oxidants(2) is very serious, and has been indicated to have adverse effects on human health.

Within this context, a law to regulate volatile organic compounds (VOC), which are the source of such pollution, was promulgated in 2004 as the Revised Air Pollution Control Law (VOC Control Law), and implemented nationally beginning in April 2006. (See Table 1.)

Table 1 Trends in VOC regulations

1) Cabinet approval	March 9, 2004
2) Law enacted	Promulgated on May 24, 2004
3) Date government ordinance was promulgated	Promulgated on June 10, 2005 (Discharge rate standards determined)
4) Implementation date	April 1, 2006 ⇒ Discharge standard: 400 ppmC (Calculated as the volume of carbon per 1 m^3)
5) Moratorium	Moratorium on existing facilities set until the end of FY 2009

Within this situation, the design panels for Fujitsu Ten car audio products are manufactured through coating processes that discharge regulated solvents such as toluene and xylene, and response to these regulations is required. Compared with coatings for automotive bodies and construction, and so on. domestic response has been slow and remains at the experimental level, due to the small volume used and the moratorium on the implementation of the law (until March 2010).

In addition, design panels are directly viewed and touched by customers, and therefore the resin products have strict levels of quality control. For the decoration which is one of secondary processes, there are many cases of faults occurring during the manufacturing process as shown in Fig. 2, amounting to 70 to 80% of part manufacturing costs. (See coating, printing, and leather making in Fig. 1.)

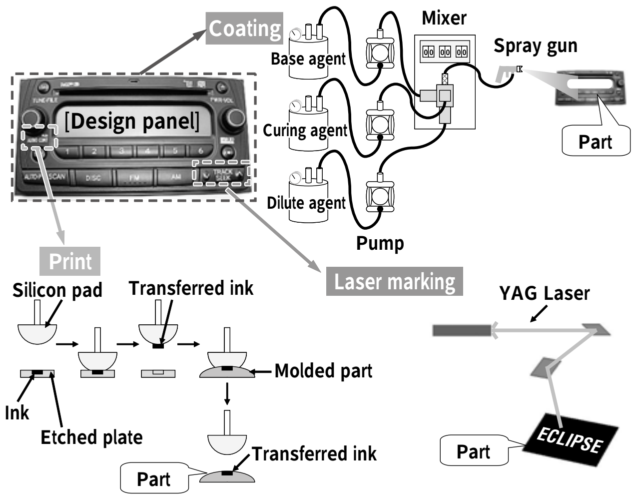

Fig.1 Details of the Decorating process

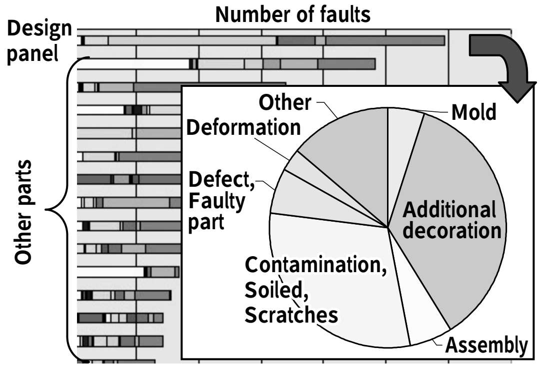

Fig.2 Number and analysis of faults in design panels

Since decorating is a process with many factors to be controlled, it requires daily adjustment by skilled, experienced personnel. Because of this, it is difficult to obtain stable quality even from specialty manufacturers. In addition, Fujitsu Ten lacks production technology for decorating, and improvements are not currently being made.

With this background, water-based coatings are used, reducing VOC emission volumes by 89% when compared with solvent-based coatings, and we pioneered the development of technology that achieves the standard values for emissions shown in Table 1. At the same time, we have improved the level of production technology for decorating processes, and achieved a template for technologies that allow stable manufacturing even at overseas locations.

In this paper, we introduce the "Environmentally friendly decoration coating technology", with a focus upon the development of new coatings, coating equipment, and coating technologies.

2 Countermeasures for regulation

Regulated VOCs include all organic compounds dispersed as gas. All organic solvents included in coatings are subject to these regulations.

One countermeasure is a method for the combustion or absorption of VOCs emitted during coating. However, it can not be used due to an extremely high cost of equipment, and the fact that there is no solution for the fundamental problem with emissions of VOCs during coating and manufacturing.

Table 2 shows a comparison of the performance of solvent-based coatings that are currently used, and currently available coatings that comply with regulations (coatings with reduced volumes of solvents). Although powder-based coatings that contain no solvents are opti-

(1) Suspended particulate matter
Particulate matter suspended in the atmosphere; a common type of air pollution. Depending upon the size of particles, accumulation can build up in respiratory organs and become a detriment to human health.

(2) Photochemical oxidants
Pollution that occurs when Nox in the atmosphere reacts with sunlight .
The source of photochemical smog, which irritates the eyes and throat, causes headaches.

mal, these coatings are hardened by melting the powder at temperatures of 150 °C and higher, which is not suitable for design panels that use resins that deform at a temperature of 100 °C. In addition, high-solid coatings will not lead to a breakthrough reduction in volume of solvent. Based on this, we used water-based coatings that have no ignition or explosive hazards, and that have few ill effects on human health due to the use of solvents during coating processes. However, there are issues regarding operability and performance. These issues are described below.

Table 2 Comparison of performance of coatings that comply with regulations and solvent-based coatings

Item		Current solvent-based coatings	Regulated coatings		
			Water-based coatings	High-solid coatings	Poweder-based coatings
Coating film finishing (gloss, skin, ...)		○	△	○	△
Coating film performance (properties, durability, water resistance, ...)		○	△	○	○
Baking temperature		○	○	○	△
Storage quality (period, temperature dependency)		○	△	○	○
Operability		○	×	○	○
Safety (ignition, explosion)		×	○	×	△
Equipment (current usage suitability)		○	△	○	△
Recycling		△	×	×	○
Ratio of components	Solid content	50	50	70	100
	Solvent	50	8	30	0
	Water	0	42	0	0
Solvent reduction ratio (current solvent to coating ratio)		—	−84%	−40%	−100%

3 Current water-based coatings

There are no water-based coatings that satisfy all of the capabilities of coating surfaces for automotive resin parts. A comprehensive solution for coatings, coating equipment, and coating methods is required to overcome the disadvantages of water-based properties. Fujitsu Ten cooperated with the manufacturers of coatings and coating equipment to develop this technology.

3.1 Making water-based coatings

There are a variety of water-based coatings, depending upon for what they are being used, and currently progress is being made with those that are needed most on the market. Although changes to water-based coatings are occurring relatively earlier in construction- and building material-related fields, the main coating capabilities required in such fields are water resistance, humidity resistance, and weather resistance. There are few instances where a strict surface finish (for aesthetic purposes) without dripping or bubbling is required. In comparison, parts to be manufactured by Fujitsu Ten require a certain level of aesthetic beauty, and the items to which the coating is applied are made of resin rather than the metals used in automotive bodies. Therefore, the heat resistance of the material itself is low, it cannot be dried at high temperatures to increase hardness, and the coating requires a degree of hardness that is higher than that of the resin material. In addition, the resin material has poor wettability, and is difficult to use with coatings. Current water-based coatings for resins are primarily used for home electronics products with relatively low performance levels.

3.2 Performance of water-based coatings for resins

First, in order to understand the performance of current water-based coatings for resins, we examined commercial water-based coatings. The results of our evaluations based on Fujitsu Ten standards for use in automobiles are shown in Table 3. From the results, we can see that there are no water-based coatings that satisfy all performance needs for use in automobiles.

Table 3 Evaluation of performance of water-based coatings

	Company A	Company B	Company C	Company D	Company E	Company F	Sovent
Surface hardness	×	×	×	×	×	×	○
Adhesiveness	×	△	—	△	—	—	○
Transfer prevention	○	○	○	○	○	○	○
Humidity resistance	○	○	○	○	○	○	○
Water resistance	○	○	○	×	○	○	○
Acid resistance	○	○	○	×	○	○	○
Alkali resistance	○	○	○	×	×	○	○
Gasoline resistance	×	×	×	×	×	○	○
Oil resistance	×	×	○	×	×	×	○
Accelerated light resistance	○	○	×	○	○	○	○
Overall evaluation	×	×	×	×	×	×	○

3.3 Differences between water-based coatings and solvent-based coatings

For solvent-based coatings, thinners, with good operability and performance, can be selected from a large number of solvents. For water-based coatings, other measures are required since these are replaced simply with water. In addition, the physical properties of water itself interfere with the manufacture of coatings. The physical differences and problems associated with typical solvents and water are shown in Table 3.

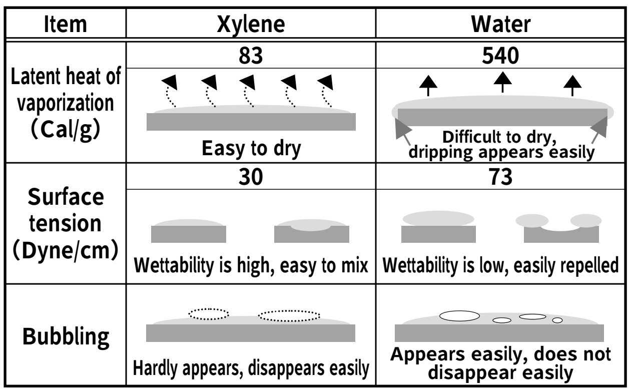

Fig.3 Comparison of physical characteristics of water and primary solvents

These do not volatilize during the coating process like solvents, and since drying is difficult the coatings produce a flow pattern. Since surface tension is high and wettability is low, coating does not take a detailed shape and the coating film does not form according to the shape. In addition, bubbling is formed on the surface and inside of the coating film.

There are also a variety of other problems, which are linked to issues with coating processes. In addition, the curing agent for water-based coatings used during the coating process greatly reduces the hardening time for the coating more so than with solvent-based coatings. (Sometimes hardening occurs in about 1/10 the time required for solvent-based coatings.) Therefore, changes in viscosity are quick, making stable coating difficult.

Since the disadvantages of water-based coatings cannot be resolved simply by improving the coating, we also developed coating equipment.

We report on the details of the development including that for coating equipment in the following sections.

4 Development of water-based coatings

In order to achieve the Fujitsu Ten standard of quality for automotive parts, we considered development capabilities, system, enthusiasm, and confidentiality when selecting development manufacturers for joint development.

4.1 Evaluation of performance

There are a variety of components in the resin materials used for coatings, and in some cases there are problems with the adhesive properties of coatings based on the combination of coating and material. In this evaluation, we used the following three types of resin materials for coating: ABS, polycarbonate ABS, and acryl.

Table 4 Evaluation of performance of water-based coatings

Evaluation item	Material		
	ABS	Polycarbonate ABS	Acryl
Resistance to wear	○	○	○
Adhesiveness	100/100	100/100	50/100
Pencil scratchinig	HB	F	F
Transfer prevention	○	○	○
Heat resistance	○	○	○
Resistance to thermal shock	○	○	○
Humidity resistance	○	○	○
Water resistance	○	○	○
Acid resistance	○	○	○
Alkali	○	○	○
Gasoline resistance	×	×	×
Oil resistance	○	○	○
Accelerated light resistance	○	○	○
Evaluation results	×	×	×

We performed 13 performance tests on samples based on the Fujitsu Ten "surface processing quality standards for design resin parts". The results are shown in Table 4.

Problems occurred with adhesiveness, scratching with pencil (hardness), and volatile solvent resistance. The test results are shown in Fig. 4.

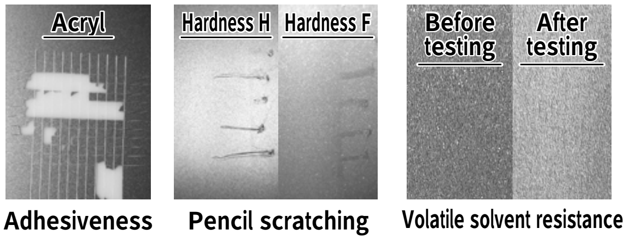

Fig.4 Coating performance test results

(1) Adhesiveness

Using a cutter, the sample materials were cut to create a grid on their surface. Cellophane tape was then applied and removed, resulting in peeling of 50 of 100 cells, which failed to satisfy standards. As mentioned above, this is a problem of combination with material. Adhesiveness was weak for acryl materials, but there were no problems with other materials.

(2) Pencil scratching (hardness)

Hardness was compared based on the scratches and breaks produced by scratching a pencil on the coating film. Coating samples have hardness of HB to F only, although the standard is H.

(3) Volatile solvent resistance

A flannelet soaked with ethanol was rubbed back and forth over the coating surface.

This test resulted in color changes that will not satisfy the standard. We have developed a coating that meets these standards.

4.2 Development of coating

In order to maintain the coating film performance mentioned above, we selected a number of resins that can be used as water-based coatings, used them to create coating prototypes, and evaluated their performance.

Table 5 Results of evaluation of resin for water-based coating

Resin	Resin composition	Adhesiveness	Hardness	Other performance
A	Acryl dispersion	×	△	○
B	Urethane acryl dispersion	○	×	Gasoline resistance×
C	Acryl emulsion	○	×	○
D	Urethane dispersion	×	—	—
E	Polyester dispersion	×	—	—

Of the materials selected, there were no coatings that satisfied all performance tests for any resin, including adhesiveness and hardness. Next, we attempted to combine the advantages of each resin to obtain the performance required. Specifically, we searched for the optimal values for resin composition in order to apply the adhesive properties of one resin along with the coating film properties of another resin. Further, we selected a resin with a high Tg (glass transition point)(3) for hardness. In addition, in order to improve the operability and water-based properties of coatings, a variety of additives were blended as shown in Table 6 to improve performance.

However, depending on the percentage and volume of composition, a variety of problems occurred, such as the negative effects shown in Table 6. In addition, some additives interfered with or cancelled the effects of other additives, or were incompatible with water. Therefore, a variety of experiments were performed to find optimal conditions, resulting in the development of a water-based coating that satisfies the specifications required for use in automobiles.

Table 6 Types and hazards of primary additives

Type	Effect		Negative effects when there are large volumes
Surface adjusting agent	Leveling	Smoothes the surface of the coating	Bubbles are produced easily.
	Application	Makes materials easy to apply	
Anti-foaming agent	Reduces surface tension to remove bubbles from coating		Coating may peel off. Lowers wettability
Pigment agent	Allows pigments, resin, and water to mix easily. Allows fine pigment particles to exist in coating.		Lowers water resistance and humidity resistance
Thickening agent	Increases coating viscosity. Prevents sedimentation in pigments, and flowing during application.		Lowers water resistance and humidity resistance
Film forming agent	Dissolves particles in emulsions and dispersions during the drying process, and continuously produces a coating film.		Lowers hardness.
Neutralizing agent	Neutralizes acid functional groups in resins, so that the resin will dissolve in water.		Lowers water resistance, humidity resistance, and light resistance

This developed coating was used on the three types of resin. When performance testing was implemented again, surface hardness could not be maintained only when the coating was applied to the ABS resin.

The reason for this is that the ABS itself is soft and ABS under the coating film gives away during the pencil-scratching test. Next, we improved the coating by increasing the hardness of the coating film itself, to satisfy the pencil-scratching test even for the ABS resin. The concept is a change in the compositional ratio between the OH groups in the base agent in the coating and the NCO groups in the curing agent. For materials such as those used to create this coating film by mixing the base agent with curing agent, it is necessary to find the optimum composition ratio for reducing unreacted resin, in order to perform a hardening reaction that will produce a hard film. However, when a hardening reaction is fully performed, the hardening time becomes faster, and a new problem that the available time becomes shorter after mixing the base agent with the curing agent arises. Therefore, we decided to find a solution by developing coating equipment that fit the available time for the materials developed, and devising a new coating method.

The points for the development of the coating described above are shown in Fig. 5.

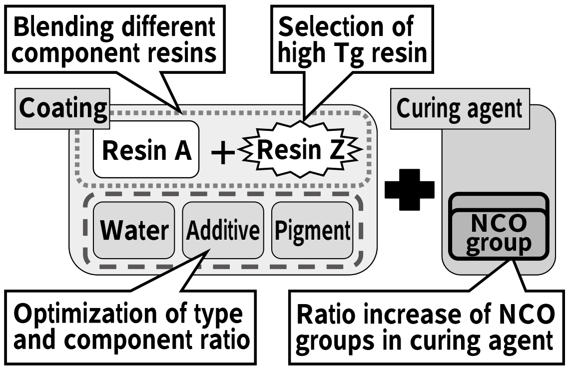

Fig.5 Points for coating development

As a result, we developed a coating that passes all Fujitsu Ten standards.

Since there was little need on the market for water-based coating for resin, there were few types of resins, pigments, aluminum particles, and additives, making it necessary to begin with an examination of required performance. In addition, several unexpected difficulties occurred in the blending processes, such as forming a gel due to the wrong procedure, and not developing a coating. Since several weeks were required for performance evaluation testing, fault prediction was thoroughly performed, and as a result, a coating was developed in a short period of time.

4.3 High-brightness metallic coating

A commonly used coating is a metallic coating composed of aluminum particles. However, changing this to a water-based coating results in the following two major problems:

①Variation in visual quality after the coating is finished
②No high-brightness color

These problems were solved by addressing additive composition and coating method, and the processing methods for the aluminum particles.

(1) Additive composition and coating method

A sense of brightness is created from the reflection of light off of the aluminum in the coating. However, since the amount of light reflected changes when the orientation of the aluminum changes, the brightness and visual quality also change. (See Fig. 6.)

Since the orientation changes depending upon the coating method, it is necessary to carefully consider the stability in the coating. Although the same trend exists with solvents, the water in water-based metallic coatings is more difficult to evaporate than for solvents, making

(3) Glass transition point
Glass transition refers to the change from hard glass like state to rubber state when high polymers are heated. The temperature at which glass transition occurs is called the glass transition point (temperature).

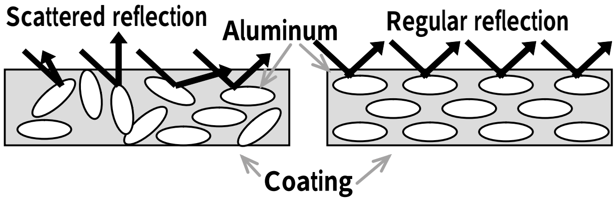

Fig.6 Reflection of light due to differences in orientation of aluminum

the drying of the coating film go slower. Therefore, the aluminum particles move easily, making stability difficult. As a measure for improvement in observed brightness and stable coating, optimal composition with a variety of additives and overcoating with thin layer were combined to ensure the uniform orientation of aluminum particles.

(2) Processing aluminum particles

Since the aluminum particles in the coating react to water to produce hydrogen gas, which has a bad effect on the coating film, the aluminum particles are processed to prevent this. However, this process reduces the brightness of the coating.

In order to obtain the same high brightness available with current mass-produced, solvent-based coatings, we created a prototype coating that used the brightest aluminum. However, the brightness was still less than that of the mass-produced parts.

Next, we improved the aluminum surface processing method, changed the processing method for resin film, and made the particles uniform in order to create a smooth surface and uniform thickness in the aluminum particles. This resulted in a brightness and color that were the same as the solvent-based coating. because the alkali resistance performance dropped below the standard further improvement is required, it is now clear what we need to do to improve brightness.

The points for improving brightness are shown in Fig. 7.

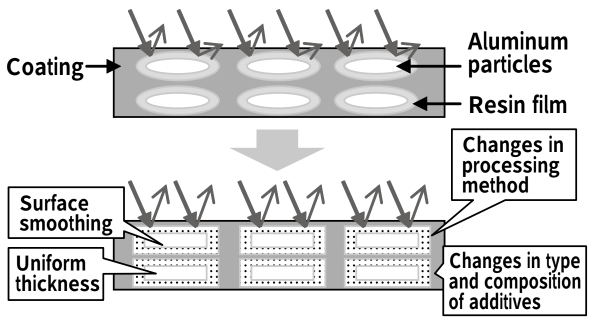

Fig.7 Points for producing high brightness

5 Development of coating technology applicable to water-based coating

With water-based coatings, there are issues regarding coating use time, coating replacement, ensuring a stable discharge rate, and bad coatings. However, since these issues cannot be resolved through the creation of coating, we overcame the issues through the design of coating equipment and the development of coating technology.

5.1 Problems with water-based coating, and the development of coating equipment

Based on fundamental drawbacks of water-based coating discussed above and the issues involved with the creation of coating, the following issues need to be resolved when actually performing a coating.

①The time when a coating can be used after mixture is too short.
②Hard to be washed due to the fact that the coating is not easily dissolved.
③The coating has a high viscosity, and the discharge rate is difficult to stabilize.

These issues were addressed by designing a new structure for coating equipment.

From the results of a coating test on several different types of coating equipment using a water-based coating, we selected the coating equipment that was most suitable with water-based coating.

Since the drying time for water-based coating varies due to temperature and humidity, and therefore effects quality, we created an environment in a coating room that allows the precision control of a set temperature and humidity that are suitable for water-based coating. In addition, in order to create a template for the technology, we developed a system that allows the control of all values for conditions such as the discharge rate of coating and pressure while spraying.

With respect to the mixing machine that has main functions of mixing, conveyance, and washing of coatings, we developed a new blending machines with a vigorous effort. Fig. 8 shows the outline for the initially developed coating equipment. The broken line shows the newly developed blending machine.

The points for development are as follows:

1. Three liquids (coating, curing agent, dilution agent (water)) can be simultaneously mixed at the last position near the gun.
2. Channel design to allow easy washing with high-pressure
3. Water-based coating with a high viscosity can be discharged with high precision even at low discharge rates.

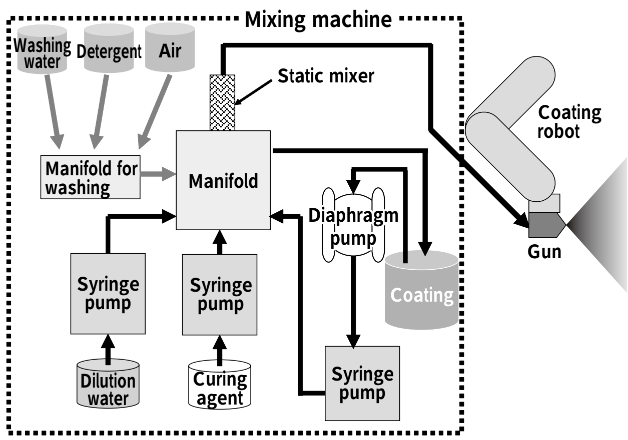

Fig.8 Initial development facility outline

(1) Coating mixture at final process in the equipment

To address the problem of a short coating use time, we designed the equipment so that the three liquids are mixed simultaneously near the spray gun. After the coating is mixed, only a small amount remains in the hose. Since the coating is replaced after only one or two applications, no coating remains in the equipment, resulting in a structure that is not affected by the use time for the coating. The mixing method is performed via a manifold(4) using a static mixer(5), in a compact structure. In addition, the layout was optimized so that the base agent, water, and curing agent do not react inside the manifold, in a configuration that avoids dead space. An image of the manifold is shown in Fig. 9.

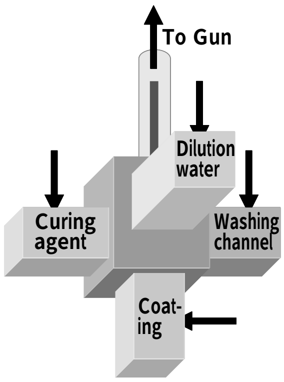

Fig.9 Manifold image

When coating is actually performed, the coating is initially discharged from the tip of the gun at a non-uniform rate. Therefore, the timing at which the manifold and gun open/close during mixing and spraying is turned on/off for each pump was optimized, and other measures were taken. As a result, both stability in the discharge of coating and sufficient mixing performance have been achieved.

(2) Washing coating

In order to resolve the issues on washing coatings, the channel was designed as simple as possible. In addition, a pressuring tank was included to allow washing with high-pressure water while optimizing the washing order and channel via a washing manifold.

As shown in Fig. 8, the initial design included a diaphragm pump(6) for the conveyance of coating. However, since coating sediment is easily produced from water-based coating, this pump was removed and a syringe pump(7) was used for direct conveyance of coating. To make it easy to wash, the system was designed to allow the interchange of containers that hold the coating. During washing, the containers are replaced with washing equipment, and pressurized water is used for washing. The same pressurized water is used to wash the coating after mixing.

If the curing agent is washed through the normal channel, it will react with the coating and water in the pipes and manifold. Therefore, we have created specially designed piping.

Since the wash channel includes some important information, we omit the details.

(3) Coating viscosity

In response to high coating viscosity, we did not use a pump that utilizes the air pressure used for normal coating. Instead, we selected a syringe pump that uses a motor, for a system that can provide a stable supply of water-based coating with a high viscosity. In addition, by calculating backwards from the volume used during coating and using the optimal size for the base agent, dilution agent, and curing agent, high-precision spraying is possible at even minute volumes. The dial can be used for high-precision control for each use ratio.

As a result of the implementation of a variety of other improvements, we developed equipment for the use of water-based coatings.

When compared with similar equipment, spraying precision improved from ±5 cc to ±1 cc, and the precision for mixing ratios of the three liquids improved from ±20% to ±5%. Washing time improved from an initial time of 40 minutes to 10 minutes.

5.2 Development of coating technology

Drawbacks in water-based coatings that cannot be resolved with coating equipment include coating faults such as dripping and bubbling. In order to resolve these issues, we developed coating technology that allows the digital control and management of the application methods and all conditions for water-based coating, and aims for the stabilization of coating film thickness and coating surface conditions.

A variety of coating patterns can be assumed based on shape of the target coating object, the conditions of the surface, and the operation of the 5-axis robot. To find the basic conditions for water-based coatings, coating testing was performed for the control of gun travel speed, distance, atomization pressure, pattern pressure, and discharge rate.

Fig. 10 shows the main control items.

Interrelationships are understood from the results of the coating test, and classification was performed by variable control items and fixed control items. The basic conditions suitable for water-based coatings can be identified by optimizing these items. An example of interrelationships is shown in Fig. 11.

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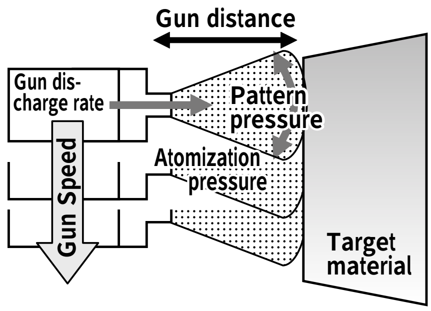
(4) Manifold
A collecting duct. In this paper, an instrument that uses valves to control the flow of coating, curing agent, and detergent.

(5) Static mixer
System that mixes multiple fluids. Uses a spiral route inside piping to partition, reverse, switch, and mix fluids. Also used by mayonnaise manufacturers.

(6) Diaphragm pump
A portion of the pump room is formed into a diaphragm of elastic rubber. This diaphragm is inflated and deflated with compressed air to increase/decrease the capacity of the pump room and pump fluids.

(7) Syringe pump
Uses pistons that move like syringes to pump fluids.



Control items	
Discharge rate	Volume of coating discharged from the gun
Atomization pressure (kPa)	Pressure used to atomize coatings
Pattern pressure (kPa)	Pressure used to disperse coatings
Gun speed (mm/sec)	Travel speed of the gun
Gun distance (mm)	Distance from gun to target material

Fig.10 Main control items

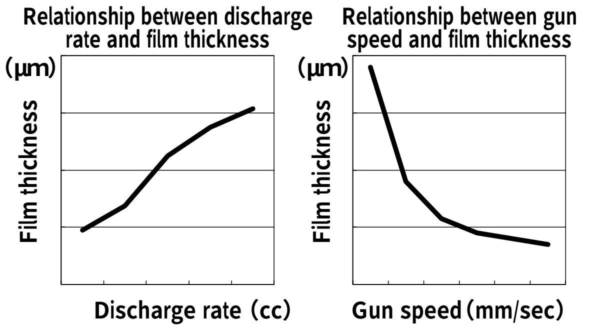


Fig.11 Relationship between discharge rate, gun speed, and film thickness

By identifying the basic conditions based on the test results, we were able to establish a method for adjusting conditions and maintaining film thickness at a high precision, while calculating a discharge rate and gun speed that fit the required film thickness, and improving surface conditions.

In addition to coating faults such as dripping and bubbling, water-based coatings have the same coating properties as solvent-based coatings, but the surface conditions of the coating film vary greatly depending on the application method, affecting the appearance quality. The following points for adjustments in addition to the basic conditions are used to resolve these faults:

1. Change the discharge rate from the start of coating until the end, to control the surface conditions (quality) of the coating film.
2. Repeatedly apply layers to form the coating film, to prevent dripping and bubbling and adjust the film thickness.
3. Adjust the drying level of the coating after application.

These points are shown in Fig. 12.

Other refinements were performed on the gun angle, the robot teaching method, jig shape, and the directions for fixing parts, to ensure the coating of a high-precision film thickness with stable quality.

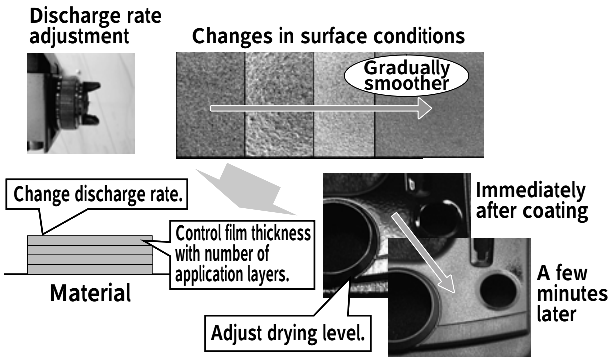


Fig.12 Points for applying water-based coating

Fig. 13 shows a graph that indicates the measured changes in film thickness and color during the application of a matte black water-based coating on a workpiece.

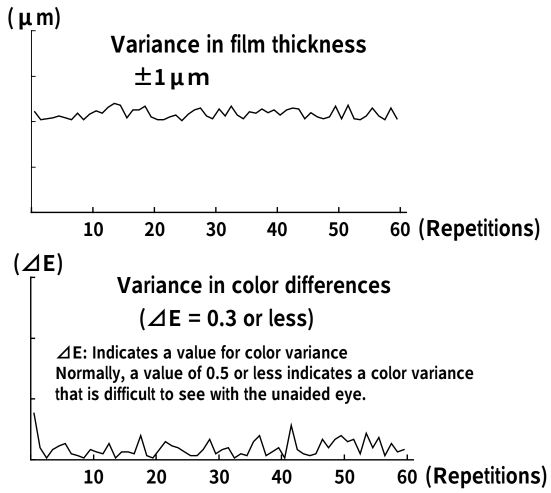


Fig.13 Variance in film thickness and color due to continuous coating

As discussed above, the aluminum particles in metallic coating move easily, requiring a change in the application method. As explained above, a method involving the repeated application of several thin coatings is used to achieve a stable coating without reduction in brightness for even metallic coatings. Fig. 14 shows the results from improvements in coating and application method.

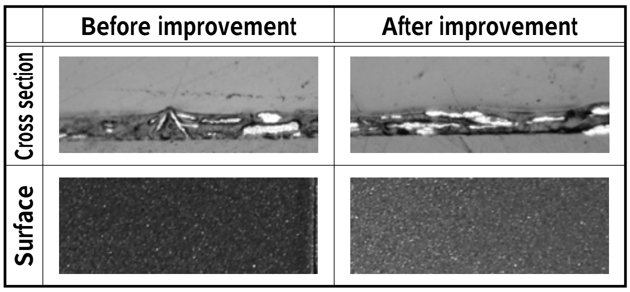


Fig.14 Results due to improvements in metallic coating and coating methods

These developments in coating equipment and coating technology have allowed the achievement of a high-quality appearance the same as with solvent-based coatings and a film thickness precision of ±2μm, with water-based coatings.

6 Manufacturing design panels

In addition to the coatings discussed above, the printing of text and logos using lasers is necessary to complete the development of design panels. Other development activities were performed for each process during the development discussed above, to achieve processes suitable for water-based coatings. The relevant points are introduced briefly below.

6.1 Laser marking process

Since the principle of laser processing involves the conversion of light energy emitted from a laser into heat energy to instantly vaporize the coating surface, there is a close relationship among the coating properties (laser absorption factor, reflection factor, color, boiling point, thermal conductivity, hardness, etc.), making it necessary to improve the coating itself to make any improvements in laser processing.

Therefore, to conduct laser processing, first it is necessary to understand laser power and processing conditions, and evaluate coating process properties. In addition, when setting the conditions for processing, it is necessary to optimize the conditions in response to variations in the film thickness of the coating.

As shown in Fig. 15, we created several processing conditions, and evaluated coating process performance. Improvements are required to the coating in instances where a high power is required or some portions remain. For the coating we developed this time, we considered the laser processing performance and also adjusted the volume of carbon, to achieve processing performance that is the same as for solvent-based coatings.

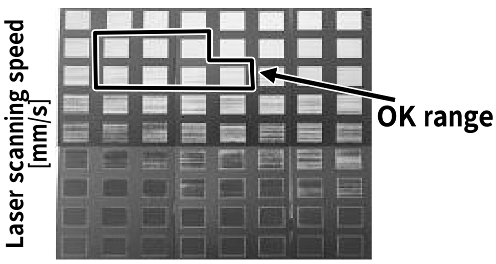


Fig.15 Relationship between process conditions and processing performance

We performed optimization based on the conditions examined above, and used a combination of scanning patterns and times of laser that matches the design to achieve optimal processing.

The film thickness of the coating has a major effect on laser processing performance, requiring strict control of film thickness in the coating. As discussed above, although application at a precision of ±2μm or less has been achieved, this laser marking is also possible under the same conditions and at greater film thickness variance with laser processing, with conditions that allow a margin for safety.

6.2 Pad printing process

With printing as well, there is an issue regarding adhesion with the coating. The features of this process are:

①Ink that is adhered to the water-based coating and is environmentally friendly was choosen.

②Process was made so as to be adjustment-free from the beginning of the process to the end

(1) Ink selection

The printing process uses a pad to transfer ink from the plate. Only a small amount of ink is used, but it contains solvents. Although there is little VOC discharged, ink and a detergent that do not contain PRTR(8) controlled substances, such as toluene and xylene, were selected to achieve decorating that is friendly to the environment. In addition, printing involves the same relationship as between the coatings and materials to be coated; since the compatibility between ink and the resin components in coatings has a major effect, we implemented performance tests, made evaluations, and prepared an ink mixture that compensated for performance that was lacking. As a result, we were able to develop an ink that satisfies all performance standards.

(2) Printing process

With this process, since there are a number of process setting conditions, such as ink dilute concentration, amount of pad compression, and compression position, it is normal to adjust these conditions during the process. We have achieved a stable process without the need to readjust conditions from the beginning of the process until the end, with equipment selection for removing these parameters, the addition of standards, and the optimization of conditions with a margin of safety for each condition item.

7 Results

The manufacture of design panels that are friendly to the environment is now possible through the development of decorating technology for the processes discussed above. (See Fig. 16.) PRTR controlled substances, including detergents, are not used in manufacturing processes.

In addition, this technology passes the 500 cycle testing required for thermal shock testing to evaluate durability, and we have also confirmed that there are no problems in 3,000 cycle operation.

(8) PRTR (Pollutant Release and Transfer Register)
System for registering the release and transfer of chemical substances.
Mechanism for understanding, compilation, and publication of the release and transfer volumes for a wide variety of toxic chemicals. There are 354 types of chemicals targeted, including coatings and ink that contain large volumes of toluene and xylene.

Fig.16 Design panel manufactured by Fujitsu Ten using water-based coating

With the application process, we have achieved an 89% reduction in VOCs compared with conventional methods, as shown in Fig. 17. Although the discharge rate varies according to the application details, the current average VOC discharge rate of 720 ppmC (calculated as the volume of carbon per $1m^3$) becomes approximately 80 ppmC when using our new developed coating, which satisfies the standard value of 400 ppmC by a wide margin.

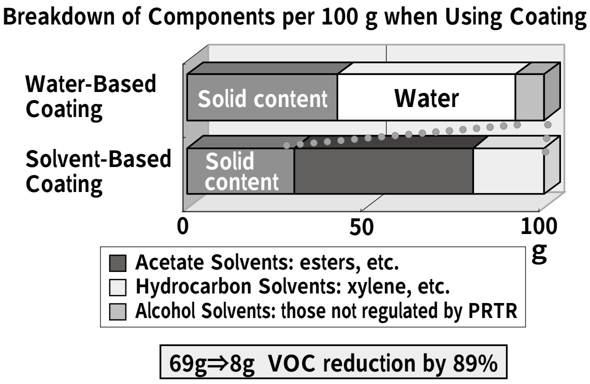


Fig.17 Comparison of solvent volume for developed coating and solvent-based coating

As a result of mass-production trials based on the development of this technology, it was confirmed a yield rate of more than 95% for primary targets. In the future, we will perform detailed investigations of faults that occur, and make further improvements.

8 Summary

In this paper, we have explained the main points for design panel decorating. With the current information we have obtained, only this developed water-based coating for plastic has satisfied the Fujitsu Ten standards in Japan.

With the development of this coating, the development items for improving the adhesive properties against materials will be the base for responding to changed in resin materials, making development possible in a relatively short period of time.

The development of this technology allows the digitalization of conditions in all processes to avoid reliance upon the skills of experienced workers. Therefore, by using the same equipment and environments, the manufacture of parts of uniform quality is now possible on a global scale.

In the future, we plan to make further improvements in yield rate, and perform more research and development.

Profiles of Writers

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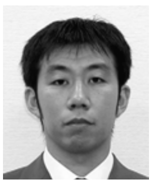

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