

Environmentally Friendly Wax for Corrosion Protection

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ABSTRACT

A new wax has been developed for the prevention of corrosion in flanges, which are frequently points of origin for corrosion, in order to attempt to ensure 12-year protection against corrosion perforation of the exterior panels employed on vehicle bodies. The wax has been applied to new models. The wax displays reliable penetration into flanges, and hardens by means of oxidative polymerization, enabling the wax film to control corrosion. The properties of the wax help prevent flowing after application. Following application, the vehicle body is heated to enable the wax to penetrate the flanges. When the vehicle body returns to normal temperature, the wax becomes viscous, which helps prevent the material from flowing. In addition, to respond to environmental considerations, no solvents have been used in the wax.

1. Introduction

The increasing use of chemical agents to help prevent ice forming on roads in winter⁽¹⁾ has increased the severity of the threat of corrosion faced by automobiles, necessitating the development of more advanced anti-corrosion technologies.

The Canada Code⁽²⁾ (1.5 years free from exterior corrosion and 5 years free from corrosion perforation) was formulated in 1976 to protect consumers. In 2000, Northern European consumer advocate groups formulated a more stringent set of conditions (5 years free from exterior corrosion and 10 years free from corrosion perforation)⁽³⁾, and there are an increasing number of cases in which the warranty period for corrosion perforation of the vehicle body is set at 12 years in the European market.

The side sills and rear wheel arches of the standard automotive body configuration (the monocoque body) enable the achievement of a balance between low weight and stiffness. Given their effectiveness, the configuration of these parts has become progressively more complex over time. It is challenging to achieve an adequate anti-corrosion coating on the side sills and rear wheel arches, but salt water can easily infiltrate and become trapped in them. These areas should be sufficiently degreased, phosphate treated (pre-treatment) and e-coated to protect them from corrosion.

However, the complexity of the structures prevents the achievement of a sufficient level of flow of the treatment agents, etc. Salt water is prone to be retained and hasten corrosion in the flanges in particular, and this can result in perforation after several years. Guaranteeing corrosion prevention in the flanges is therefore a technological issue.

Responses to corrosion in the areas indicated above should be prioritized. The development of further methods to be used in addition to conventional anti-corrosion coatings is necessary, including increasing the corrosion resistance of the materials used in automotive panels (by employing alloy galvanized steel sheets, etc.) and using sealers and waxes to help prevent water infiltration.

Anti-corrosion waxes shield the vehicle from water and other corrosion-inducing factors, and are able to control corrosion in the flanges, where corrosion resistance cannot be guaranteed by coatings. Automakers employ a variety of different methods to apply wax to the vehicle body following e-coating, including continuous flow nozzles, mist sprays, and immersion of the lower section of the body⁽⁴⁾. In the 1970s, when the automotive industry commenced its battle against corrosion, anti-corrosion wax first made its appearance in liquid form as a vaseline-like agent dissolved in a solvent. The waxes took their present form, a thin film able to effectively prevent corrosion, in the 1980s. The waxes are easy to use and increase corrosion resistance by penetrating into the interior of

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complex body shapes, but issues remain in terms of ensuring corrosion prevention in flanges. The research focused on in this paper therefore attempted to develop a wax with stable anti-corrosion properties that would effectively penetrate the flanges, which function as points of origin for corrosion. The research focused on a non-solvent-type wax in order to reduce emissions of volatile organic compounds (VOC). This paper will discuss the details of this research.

2. Development Targets

If the solvent is simply removed from a wax as an environmental measure, the viscosity of the wax will increase, resulting in a decline in its level of penetration into the flanges. In order to ensure corrosion resistance performance, it is therefore important to set the viscosity conditions of the wax to enable penetration.

If a low-viscosity wax is employed to ensure penetration, the wax will tend to flow and, accumulating on the floor of the assembly line, etc., will affect work conditions and safety in the workplace. This would necessitate a mechanism to help prevent wax from flowing after application, thus resulting in increased costs.

In addition, there is the possibility that wax flow will affect the commercial appeal of the vehicle by, for example, causing swelling of the plastic components and affecting the appearance of the coating, and it is also necessary to take measures to help prevent wax flow in hot climates. In order to respond to wax flow in the short-term, the research discussed here examined methods of setting and actively controlling the point at which the wax flows. From the perspective of the prevention of wax flow over the longer term, the project examined the potential for the exploitation of the oxidative polymerization reactions of vegetable oils and the formation of a film on the surface of the wax.

This project attempted to control wax flow by means of wax viscosity and temperature, with the following aims:

- (1) Penetration of wax into the flanges
- (2) Prevention of wax flow in later procedures
- (3) Film formation in the flanges

3. Basic Design of Wax and Responses to Environmental Issues

Conventional waxes use organic solvents (mineral spirits, etc.), as diluent solvents in order to achieve low viscosity. The waxes are applied in a spray form, which volatilizes the solvent, increasing viscosity and promoting film formation. Research has been conducted on the possibility of replacing the organic solvent added to reduce viscosity with a low-volatility, high-viscosity oil, but this increased the flow of the wax following application, with the result that the wax film could not be retained under the flow of water from the showers

Table 1 Components of former wax

Function	Main component
Composition of membrane	Calcium sulfonate
	Petrolatums
	Petroleum wax
Rust prevention additive	Metallic salt oxide wax
	Esters
	Sulfanilic acid salts
Solvent	Lubricating oil
	Mineral spirit

Table 2 Comparison of properties of former and developed wax

	Former wax	Developed wax
Appearance	Light brown liquid	Milky white
Density (g/cm ³)	0.85 ± 0.02	0.95 ± 0.03
Viscosity (mPa·s)	3000 ± 2500	900 ± 200
Flash point	35 °C and above	180 °C and above
NV (wt%)	35 – 70	95 and over

Table 3 Components of developed wax

Function	Main component
Composition of membrane	Sulfanilic acid salts
	Petrolatums
	Petroleum wax
Additive for thixotropy	Thixotropy additives
Hardening agent	Vegetable oil
Rust prevention additive	Metallic salt oxide wax
Filler	Calcium carbonate, etc.
Solvent	Low viscosity paraffin
	Vegetable oil

employed in the inspection procedure on the body assembly line. The fact that the waxes which were initially studied were removed in this way by physical force indicated issues in terms of film formation.

In order to develop a solvent-free and low-viscosity wax and to ensure penetration, the research discussed here therefore added low-viscosity lubricating oils (liquid paraffin, etc.) and a hardening agent to a diluent solvent.

Table 1 shows the main components of the former wax, while Table 2 compares the properties of the former and the developed wax. Table 3 and Fig. 1 show the main components of the developed wax.

The addition of the hardening agent promoted an oxidative polymerization reaction at the surface of the wax

(the area exposed to air), enabling the formation of a continuous film. In addition to controlling wax flow, this continuous film hardens, and can therefore also be expected to act as a barrier preventing the infiltration of oxygen, water, and electrolytic substances that promote rust.

Figure 2 shows the effect of the reduction of the solvent content of the developed wax. As a result of using the components discussed above, more than 95wt% of the content of the developed wax is non-volatile, contributing to a reduction in VOC.

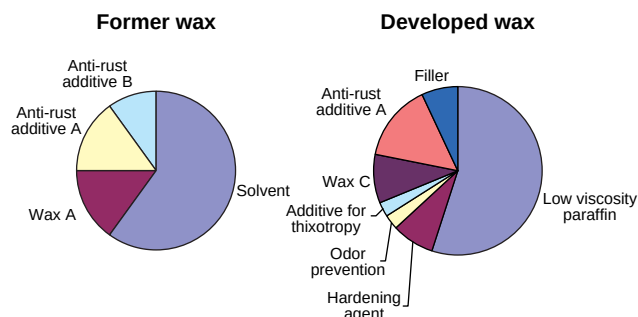


Fig. 1 Composition of former and developed wax

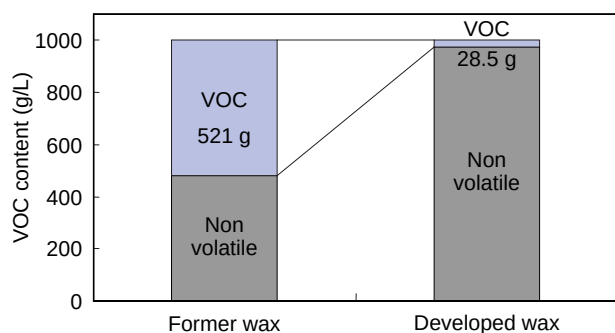


Fig. 2 Effect of reduction of VOC content

4. Characteristics and Basic Performance of Wax

4.1. Wax Viscosity Control: Considerations

There is a correlation between wax viscosity and temperature. Viscosity can also be controlled by the selection of the components of the wax. As a measure to help prevent short-term flow of the wax, the viscosity of the developed wax was controlled by the addition of a heat-activated thixotropic agent⁽⁵⁾ and a new wax component (modified wax).

The addition of the modified wax contributed to the ability to adjust the change in wax viscosity occurring due to changes in temperature. As a result of the addition of the heat-activated thixotropic agent, when the wax is given a thermal history, heat energy causes dislocation of the crystal structure, which forms a reticulated structure

following cooling, increasing the viscosity of the wax. The viscosity of the wax is therefore higher following cooling than it was prior to heating. Control of the viscosity of the wax following application has enabled wax flow to be prevented.

4.2. Wax Viscosity and Penetration

Figure 3 shows the relationship between viscosity and penetration in the former wax. The depth of penetration shown on the vertical axis was measured using the test apparatus shown in Fig. 4, which reproduced a flange. A spacer was used to set a gap of 0.1 mm in the flange. Wax was dripped into the flange, and the depth of penetration was measured visually. The results show that the greatest depth of penetration is achieved at lower viscosity, and that penetration depth decreases with increasing viscosity. The wax to be employed in the flanges needed to penetrate deeply, and to achieve this penetration without the use of solvents. This necessitated study of issues in relation to wax flow.

4.3. Achievement of Penetration and Prevention of Flow by means of Viscosity

This section will discuss the characteristics of the wax to which the heat-activated thixotropic agent had been added to control viscosity. Because the viscosity of the wax differs when measurements are conducted as its temperature increases and as its temperature declines,

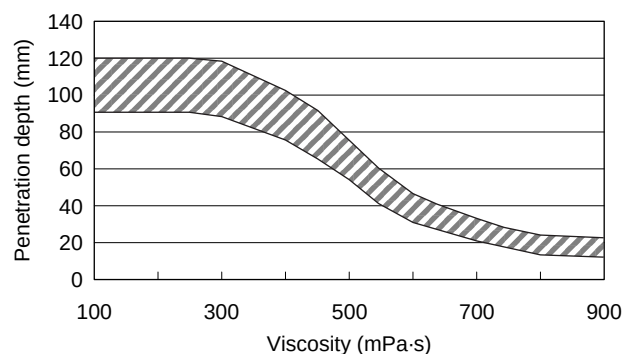


Fig. 3 Relationship between penetration depth and viscosity of former wax

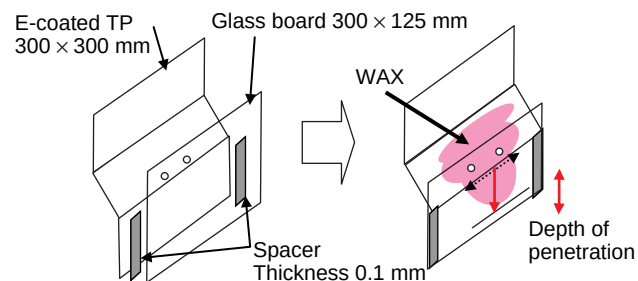


Fig. 4 Reproduced flange for wax penetration test

measurements were conducted under both sets of conditions. The results of viscosity measurements conducted during heating of the wax and during cooling following heating to 70°C are shown in Figs. 5 and 6. Figures 5 and 6 respectively show viscosity measurements prior to and following the addition of the thixotropic agent. The increase in viscosity during cooling following the heating of the wax to 70°C in accordance with the projected heating conditions for the developed wax shows that the target characteristic, an increase in viscosity due to thermal history, has been achieved.

Exploitation of this characteristic to control the viscosity of the developed wax enables wax flow in the short term to be controlled by means of the temperature of the vehicle body.

4.4. Wax Film Properties and Durability

Table 4 shows the basic properties of the former and the developed wax. Penetration was measured using the test apparatus shown in Fig. 4.

The length of the flanges in the side sill, etc., is approximately 15 mm, making it necessary for the wax to achieve a penetration of 20 mm or more. The developed wax meets this requirement.

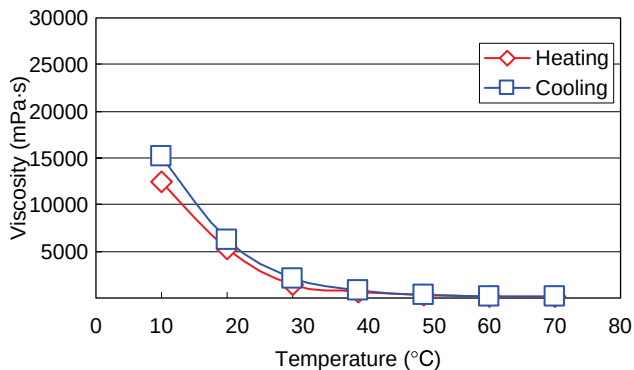


Fig. 5 Heating / Cooling viscosity of developed wax (without thixotropic additive)

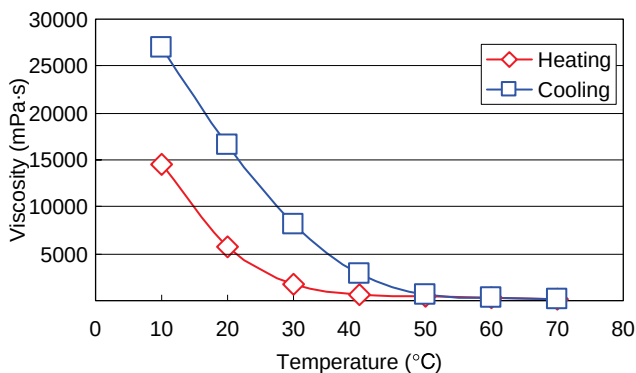


Fig. 6 Heating / Cooling viscosity of developed wax (with thixotropic additive)

Table 4 Basic properties of developed wax

	Conventional wax	Developed wax
Salt spray test	720 Hr red rust area max 10%	Equal to conventional
Cycle corrosion test	No rust from cross cut	Equal to conventional
Humidity	No irregularity	Equal to conventional
Pollution	Lubrication, and expansion	Equal to conventional
Odor	Low odor (no pungent odor)	Strong oil odor (no solvent odor)
Penetration	Good (15mm)	Good (35mm)
Correctivity	Easy to correct	Equal to conventional

Table 5 Endurance test results

Items	Results	
	Former wax	Developed wax
Water resistance 40 °C × 120 Hr DIP	No irregularity	No irregularity
Humidity resistance 50 °C, 95%RH × 120 Hr	No irregularity	No irregularity
Cold bending resistance	No irregularity	No irregularity
Removability	Easily removable	Easily removable
Cyclic heating and cooling resistance	No irregularity	No irregularity
Circulation stability	No change	No change
Stability of storage 40 °C (4 Hr) to -20 °C (4 Hr) Cycle on 240 Hr	Allowable viscosity increase	No problem on visual inspection, Allowable viscosity increase

Table 5 shows the durability of the developed wax. Given the requirement for a stable spray when the wax is employed on the vehicle production line, the test mode assumed circulation of the wax between the wax tank and the spray gun, i.e., a continuous flow between the tank and the spray gun. Looking at viscosity, the results show that application at a stable viscosity has been enabled by the fact that the heat generated during the flow of the wax causes the thixotropic agent to react, ensuring no increase in viscosity. In addition, tests using repeated thermal cycles within the range of temperatures assumed for storage over extended holidays, etc., showed no increase in viscosity.

The effect of application of the developed wax to the left and right side sills of the endurance test vehicle was also tested. Comprehensive durability tests were conducted in a corrosion-promoting environment on a proving ground⁽⁶⁾. Following the running tests the side sills were dismantled and checked for corrosion. Figure 7 shows the inner side of a dismantled outer side sill of the durability test vehicle following testing. The holes represent areas in which the spot welds have been removed to enable the status of corrosion in the flange to be seen. The effect of using wax as compared to using no wax is clearly visible from the status of corrosion. Figure 8 shows a

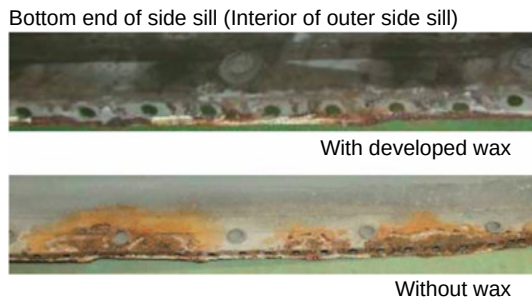


Fig. 7 Dismantled side sill from test vehicle side sill interior

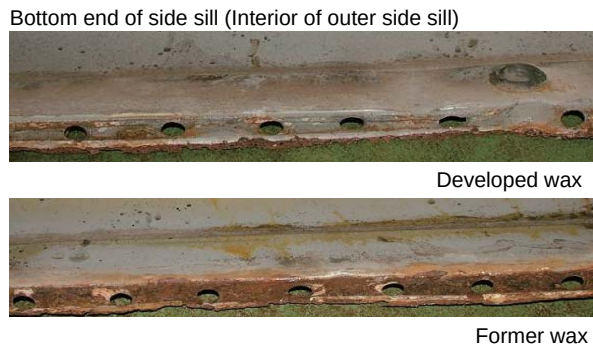


Fig. 8 Results for test vehicle side sill interior (compared to former wax)

comparison of the effect of the developed wax and the former wax. The results indicate that the developed non-solvent, post-heated, high-penetration wax achieves a level of performance equivalent or superior to that of the former wax.

5. Effect on Production Process and Cost

One issue of the developed wax was the fact that it was necessary to heat the vehicle body to a sufficient temperature to enable penetration to be controlled by the temperature of the interior wax. A wrap is therefore used to protect the coating in the drying oven. This has reduced the degree of change required to the conventional assembly line, enabling viscosity control to be used as a measure to help prevent wax flow with only minimal modification of facilities. Figure 9 shows an overview of the line layout. The wax is highly viscous directly after application and does not flow out in the processes between application and baking in the drying oven. Penetration of the wax occurs in the drying oven. A wax catcher is employed to collect the wax that flows out in the drying oven. When the vehicle body returns to a normal temperature, the viscosity of the wax increases, and it ceases to flow. Therefore, there is no need to take measures for wax flow-out in the later procedures. The range of procedures in which the wax flows is determined

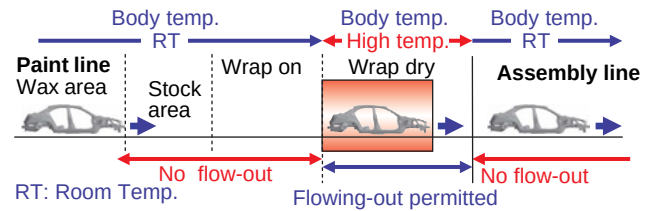


Fig. 9 Line layout (and countermeasures in car paint line)

by the temperature of the vehicle body. The use of the new wax has made the need for measures against wax flow-out such as the use of sealers and drip collectors attached to the bottom of the vehicle unnecessary. This will reduce the labor involved in their removal and the cost of their disposal by dealers, thus reducing expenses.

In addition, the fact that the wax does not employ a solvent reduces its odor and gives it a high flash point, enabling it to be used in environments of 180°C and above (e-coat drying ovens, for example, reach 180°C). The new wax is also not subject to regulations for the prevention of organic solvent poisoning on the production line.

6. Conclusion

- (1) Replacing the former solvent-type wax with a non-solvent type to respond to environmental issues has enabled reduction of VOC.
- (2) In vehicle endurance tests in a corrosion-promoting environment, the developed wax displayed increased corrosion resistance, and showed no functional issues.
- (3) While using no solvent, the developed wax achieves penetration at a low viscosity. As a measure to respond to wax flow, viscosity control is applied to increase the viscosity of the wax after application.
- (4) With only a minor investment in facilities, the use of the developed wax has made the wax flow measures employed when using the former wax unnecessary.

In addition to responding to the demands of the present environmentally-aware era for a reduction in the use of polluting substances, the development discussed here enables Honda to present its customers worldwide with vehicles displaying reliable corrosion resistance. This new post-heated high-penetration wax is being introduced to Honda paint lines around the world, and has already been applied to the 2008 year model in Europe.

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