

Development of Magnetic Stiffener

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ABSTRACT

A magnetic stiffener was developed to enhance workability and increase the degree of freedom in its range of application. A tentative holding function that does not use release paper and does away with the need for a human-powered press-bonding process is needed to enhance workability. This feature was achieved by selecting non-sticky resin materials, and by mixing ferrite particles into and magnetizing the resin layer. In addition, the optimum magnetic force was ascertained in order to help prevent drop-out in the mass production process, and material design was performed to also simultaneously achieve conventional reinforcement performance.

1. Introduction

Stiffeners are materials that are applied to localized areas, at which the surface stiffness is insufficient with respect to outer parts of an automobile, as represented by the doors, hood, trunk, and the like, to provide necessary stiffness⁽¹⁾. Historically, technology for simulating the surface stiffness of the outer parts had not yet been developed, so detailed correlation between the predicted values and the measured values obtained using an actual vehicle could not be obtained. In addition, when structural measures could not be adopted, stiffeners were used. However, because of the need to lighten the body in recent years, the panel thickness of the parts has become increasingly thinner, and the number of parts where surface stiffness is called for has increased. Consequently, at present, stiffeners are often used from the initial design stage.

As shown in Fig. 1, a general stiffener is of a 3-layer construction consisting of a glass cloth, which has reinforcing performance and strain mitigation ability, a resin layer, which has reinforcing performance, temporary retentivity prior to curing, sticking power subsequent to

curing, and release paper. The stiffener is applied by peeling off the release paper, aligning the stiffener with the target location, bonding it to the mating surface while taking care to ascertain that there is no air inclusion, and then applying pressure to the stiffener with an application device that uses a roller, for example. From the perspective of the current environment and to reduce the working load (ergonomics), it is predicted that eliminating the pressure application, which entails working time, and the release paper to keep the factory clean and reduce garbage, and reducing the panel thickness of outer parts, other than that of the above-mentioned parts and their associated weight reduction, will be promoted in the future, so the quantity of stiffeners is tending to increase each year. Consequently, to reduce the workload, the development of stiffeners that meet the above needs is being demanded.

2. Setting the Development Targets

As shown in Fig. 2, stiffeners are applied at the weld shop where the outer parts are bonded to each other in an automobile manufacturing process, and are cured using a heat source at the paint shop where rust-proofing and painting are applied. A stiffener should of course satisfy the main function of reinforcing performance subsequent to the curing process, and prior to curing it should be in a condition such that it can be readily applied to the bonding surface and temporarily retained. In addition, it should be completely cured at the paint shop without



Fig. 1 Structure of stiffener

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dropping out. Accordingly, in the development of the stiffener, the following two items were set as the development targets.

- (1) To be able to eliminate the release paper.
- (2) The stiffener should not drop out from when it is applied in the welding section to when it is cured and baked in the painting section.

3. Philosophy Concerning Stiffener Design

Figure 3 shows the material formulation of the resin layer of the conventional stiffener. For the basic specifications, it was decided to study a blend based on the conventional resin and curing agent to enable the main function of reinforcing performance to be secured. Particularly, a study of stiffener design that could enable the targets to be achieved by adding functions to the filling agent that is used as an extender was performed.

3.1. Philosophy Concerning the Elimination of the Release Paper

The composition of the resin used in many of the conventional stiffeners consisted of epoxy resin and/or SBR or BR rubber, either as a mixture or a single material⁽²⁾, and full play was given to the stickiness power prior to curing, as well as the adhesiveness and reinforcing performance after curing, by using the physical properties of these materials. In order to eliminate the release paper, it is necessary to reduce the stickiness power, and thus it is necessary to select a material that realizes both adequate stickiness power prior to curing and adequate adhesiveness and reinforcing performance after curing. With the

conventional stiffeners, the adhesiveness generated prior to curing was large because liquid rubber was used. It is therefore considered that the stickiness power can be reduced by selecting solid rubber.

3.2. Philosophy Concerning Drop-out Guarantee Prior to Curing

3.2.1. Method of temporary retention

A method of realizing temporary retention instead of stickiness power was studied. As a method of temporary retention of a stiffener to a steel panel to which rustproofing oil or press oil, for example, adheres, the use of magnetic force instead of stickiness power was studied from the following two perspectives.

- (1) The fact that steel material is used for the greater part of an automobile body
- (2) The reduction of the working load (automation)

In general, the addition of ferrite particles is used as a method of generating magnetic force in the resin curing agent⁽³⁾, and it is considered that temporary retention, prior to curing, can be realized by substituting the abovementioned filling agent with ferrite.

3.2.2. Setting the magnetization force

Figure 4 shows the mechanism of magnetization. The ferrite particles dispersed in the resin layer are magnetized by orienting them by means of a magnetizer that uses a permanent magnet, for example. Because the ferrite raw material itself has a high specific gravity, a high magnetic force can be produced by increasing the amount of ferrite added. There is however a possibility that the weight of the ferrite may affect the impact resistance and reinforcing

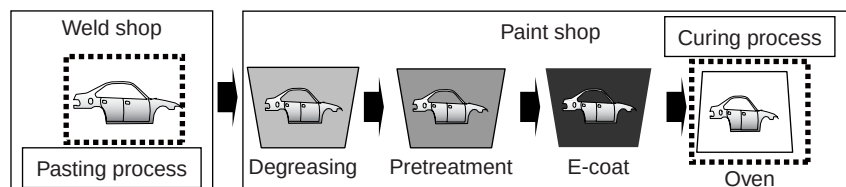


Fig. 2 Automotive product process

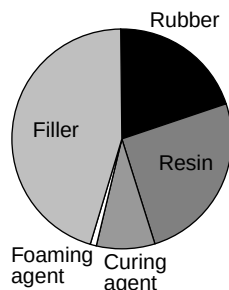


Fig. 3 Material formulation

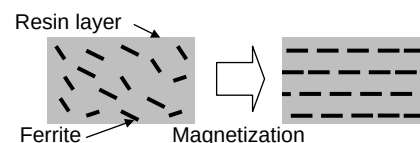


Fig. 4 Mechanism of generating magnetism

performance. It is considered that a high magnetic force can be produced with a relatively small amount of ferrite by either using ferrite of small particle diameter and large surface area, or by using a means of aligning the magnetization axes.

3.2.3. Demagnetization timing

It is considered that because the magnetic force is not needed after the resin has cured, the stiffener can be demagnetized by physically destroying the orientation of the ferrite particles after the resin has cured. Because drop-out will occur unless the adhesive strength is generated prior to demagnetization, the timing of demagnetization and adhesion after the resin has cured is important. It is considered that drop-outs can be avoided by prompting the resin to foam in order to destroy the orientation of the ferrite particles and thus bring about demagnetization, while ascertaining that foaming starts after the adhesive strength is generated.

4. Evaluation Method

4.1. Reinforcing Performance

As shown in Fig. 5, a three-point bending test is used to evaluate the reinforcing performance⁽⁴⁾. The reinforcing performance is defined as the load value for a 2 mm displacement obtained from the load-displacement curve shown in Fig. 6. Likewise, measurement after the environmental durability test is performed under the same condition. The conditions of the environmental durability test are shown in Table 1.

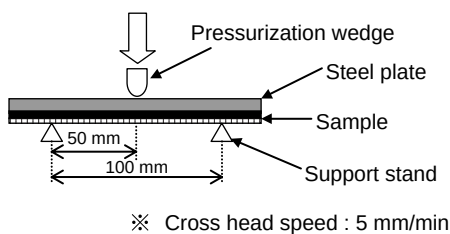


Fig. 5 Three-point bending test

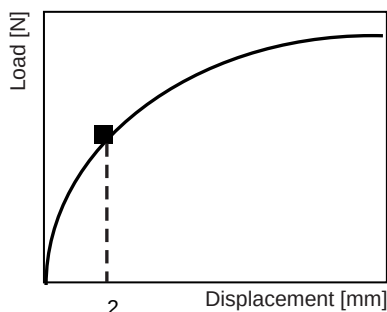


Fig. 6 Load-displacement curve

Table 1 Test conditions

Durability item	Conditions
Heat resistance	100 °C
Water resistance	50 °C warm water
Humidity resistance	50 °C 95%Rh

4.2. Impact Resistance Performance

The impact resistance test used was a slamming test⁽⁵⁾, a general test method employing the tester shown in Fig. 7. The test piece is placed on the slamming tester, and an impact is applied to it from an angle of 10 degrees. If separation or misalignment does not occur, the impact is applied repeatedly at the same angle to a total of 10 times. If neither of the above phenomena occurs during this time, the angle is increased 10 degrees at a time and the same test performed. The impact angle and the number of test cycles at which separation or misalignment occur were defined as the impact values.

4.3. Magnetic Force Measurement

The magnetic force was measured using a gauss meter [T-301 (main body GM-301) made by Denshijiki Industry Co., Ltd., or equivalent). The gauss meter probe was drawn along the line on the magnetizing face of the stiffener in the horizontal magnetization direction, in close proximity to it but without actually touching it, and the maximum magnetic force at this time was measured.

4.4. VOC Measurement

Regarding measurement of VOCs (Volatile Organic Compounds), a measurement method based on the method of the Japan Automobile Manufacturers Association, Inc.^{(6), (7)} was decided upon and implemented.

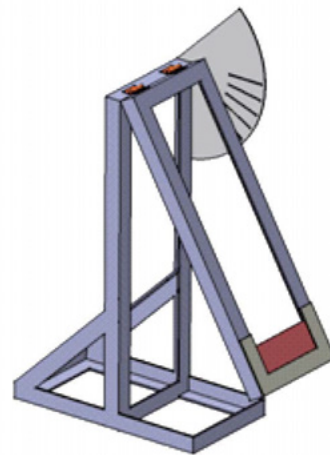


Fig. 7 Slamming test machine

5. Results and Examination

5.1. Design of Resin Layer that has no Stickiness Power, and Reinforcing Performance

As mentioned above, a resin layer that had no stickiness power was realized by changing the rubber component from a liquid type to a solid type. Also, it was decided to continue to use butadiene rubber for the rubber component in order to minimize the reduction of reinforcing performance after the durability test. The blend composition of the developed stiffener is shown in Fig. 8, and the results of performing a comparative reinforcement test of the conventional stiffener and that of the developed stiffener are shown in Fig. 9. It was found that compared to the conventional stiffener the developed stiffener showed no reduction of performance, including that of the durability test items. It is thought that this is because the absolute quantity of the composition of the resin layer that is affected by a reduction of the reinforcing performance is less in the case of the developed stiffener, making the developed stiffener less affected by the passage of time while the durability test is taking place.

5.2. Setting the Magnetic Force

Figure 10 shows the results of studying the ferrite content. The results show that it is necessary to increase the amount of ferrite in order to generate a high magnetic force, but that as the amount of ferrite is increased, the relative resin content decreases, leading to reduced

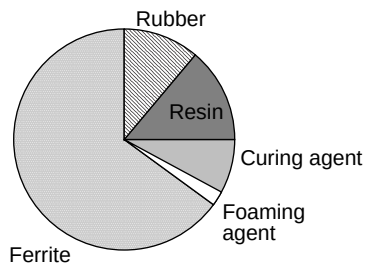


Fig. 8 Material formulation

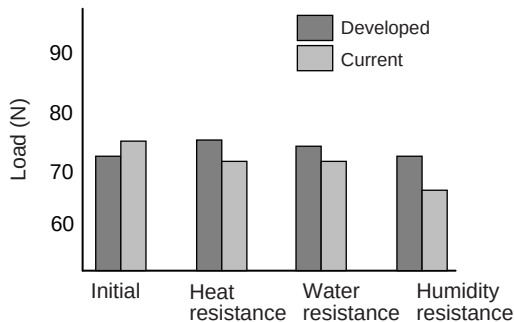


Fig. 9 Reinforcement performance

Table 2 Influence of ferrite particle diameter

Particle diameter (μm)	Magnetism (mT)	Impact resistance
1.0	13	30 deg, 1 time
1.2	13	30 deg, 1 time
2.8	13	30 deg, 1 time

Table 3 Influence of ferrite kind

Ferrite kind	Magnetism (mT)	Impact resistance
Isotropy	13	30 deg, 1 time
Anisotropy	13	30 deg, 1 time

reinforcement performance. It was also found that the magnetic force obtained by substituting the filling agent of the conventional blended material with the same amount of ferrite (45 wt%) did not provide satisfactory impact resistance. Consequently, a study of various types of ferrite was performed with the objective of obtaining high magnetic force through the addition of a relatively small amount of ferrite. The results are shown in Tables 2 and 3. It was predicted that small particle diameter material, which produced a larger magnetization area overall, would result in a larger magnetic force, and that large particle diameter material would result in a smaller magnetic force, but the results obtained in both cases were the same. The reason for this is thought to be that because only the maximum value of the magnetic force is measured, there is no change in the maximum value of the magnetic force, so as long as equal quantities of ferrite are added. Regarding the difference due to the grade of ferrite used, it is said that generally the magnetic force increases by using aeolotropic ferrite and magnetizing it from the magnetization axes⁽⁸⁾. An attempt was made to generate a high magnetic force by aligning the magnetization axes by rolling the ferrite dispersed in the resin material several times, though no difference with respect to isotropic ferrite was obtained. It is thought that

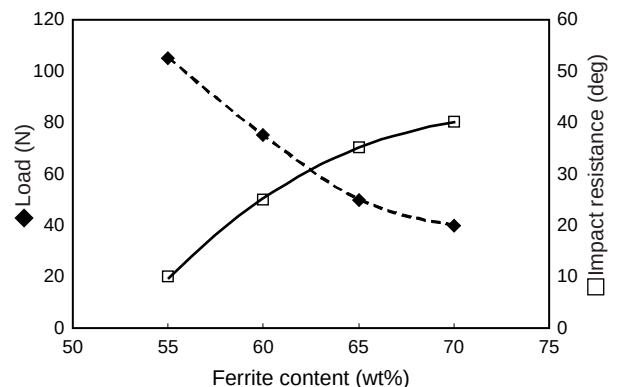


Fig. 10 Influence of ferrite content

this was because the resin layer is a rigid body, which suppresses the orientation movement of the ferrite particle in the resin layer from occurring freely. Based on the above, isotropic ferrite that had a particle diameter of 1.2 μm was selected from the viewpoint of versatility, and the blending ratio of the ferrite was made at least 65% in order to help ensure sufficient impact resistance. A study of how to increase the reinforcing performance in the region where the impact resistance performance is satisfied was performed.

5.3. Increasing the Reinforcing Performance

As a method of increasing the reinforcing performance, a study for increasing the thickness subsequent to curing was performed. Figure 11 shows the results of a study concerning the foaming rate. It was expected that by enhancing the foaming rate the thickness subsequent to curing would be increased, thus increasing the reinforcing performance. It was confirmed that the reinforcing performance increased as the foaming rate was increased, and that the impact resistance performance was satisfactory at all levels. However, drop-out was found to occur during baking. It is thought that this is due to the abovementioned difference in the timing between demagnetization and the generation of adhesive strength during baking. A foaming agent that resulted in a suitable timing difference was selected. Figure 12 shows the

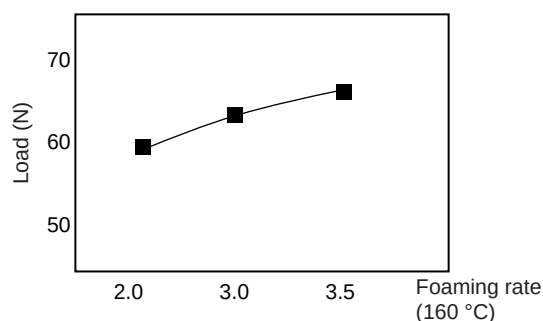


Fig. 11 Influence of foaming rate

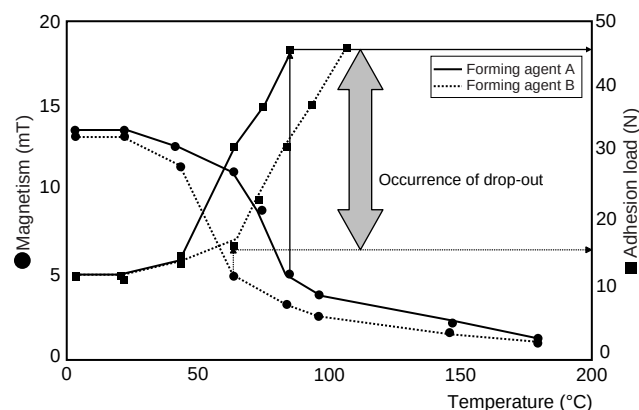


Fig. 12 Magnetism-load curve

Table 4 Impact resistance test

Process	Magnetism (mT)	Impact resistance
Degreasing	13	30 deg, 1 time
Pretreatment	13	30 deg, 1 time
E-coat	13	30 deg, 1 time

relationship between the disappearance of magnetic force and the occurrence of adhesiveness when foaming agents A and B were used. The minimum magnetic force for supporting the weight of the stiffener is 5 mT. From the figure, it can be seen that in the case where low temperature foaming type foaming agent B is used, foaming starts to occur early, speeding up demagnetization so that it occurs faster than adhesion to the steel sheet, which results in the stiffener dropping out. In the case where high temperature foaming type foaming agent A is used, adequate adhesive strength is generated by the time that the magnetic force reaches 5 mT. Consequently, it was decided to use foaming agent A and increase the thickness of the stiffener material prior to curing as the method of enhancing the reinforcing performance. Figure 13 shows the results of studying the thickness of the material prior to curing. It was found that the minimum thickness of the resin layer necessary for obtaining satisfactory reinforcing performance was 0.8 mm, so the thickness was set to 0.8 mm.

5.4. Effect of Paint Shop Zone Flow on the Magnetic Force

In mass-production, a stiffener is subjected to various chemical and physical factors such as warm-water washing (40°C) and pre-treatment by chemical liquids, and electric current due to electrodeposition, prior to being cured, so there are concerns about the effect of these factors on the magnetic force. Table 4 shows the results of the impact resistance test performed on the developed material. It was found that no demagnetization occurred due to the paint shop zone flow. Regarding temperature, demagnetization starts from the vicinity of 50°C, so it is considered that demagnetization did not occur in the

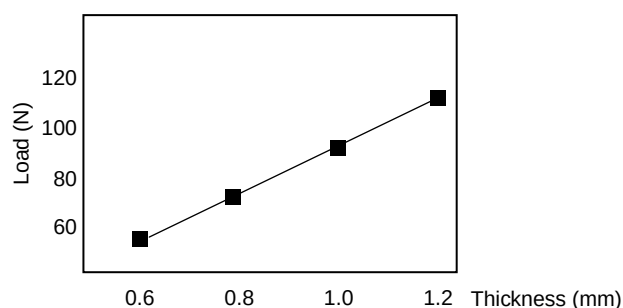


Fig. 13 Relation between thickness and load

vicinity of 40°C. Also, it is considered that the reason why no reduction of magnetic force due to acids, alkalis or other chemical liquids, or electric current was found is because, as mentioned in the sub-section concerning the mechanism of magnetization, the generation of magnetic force takes place as a result of the orientation movement of the ferrite particles, and there is no disappearance of magnetic force other than that due to the physical destruction of the orientation of the ferrite particles due to the foaming that occurs subsequent to curing.

5.5. VOC Measurement Results

Although stiffeners are used on outer parts, measurement was performed and countermeasures devised with a view to widening the range of applications in the future. Figure 14 shows the VOC measurement results for the developed stiffener and the conventional stiffener. These results indicate that, with the exception of formaldehyde, the developed stiffener produces roughly the same measured values of VOC as those of the conventional stiffener. It is thought that this is due to the fact that there was no change in the organic contents of the resin layer, and thus the developed stiffener did not contribute to an increase or decrease of the associated volatile matter. Regarding formaldehyde, the conventional stiffener uses melamin resin during the glass cloth molding process, and it was found that residual formaldehyde from the melamin resin manufacturing process remains in the product. With the developed material, the generation of formaldehyde is suppressed as a result of the change from melamin resin to acrylic resin.

6. Results of Confirmation on an Actual Vehicle

The developed material was applied to an actual vehicle, and a validation, which included the impact when parts are being bonded in the weld zone and when the body is being transferred from the suspension hanger

while moving from the weld zone to the paint zone, and the water shower during the pre-treatment process in the paint zone, was performed. Figure 15 shows the parts to which stiffeners are applied and the application positions. As a result, it was found that no deviation or drop-out occurred due to the curing process and there was no loss of quality in terms of appearance, so it was judged that there was no problem with the developed material. Also, it was confirmed that the rigidity of the outer panel satisfied the constraints of an actual vehicle, and that the developed stiffener, which satisfies the target reinforcing performance and impact resistance performance, is suitable for mass-production conditions.

7. Conclusion

A new stiffener that does not have release paper, nor needs to have pressure applied, and has enhanced workability was developed, and the following results were obtained.

- (1) The butadiene rubber in the resin layer was changed from a liquid to a solid type in order to reduce the sticking



Fig. 15 Application part and position

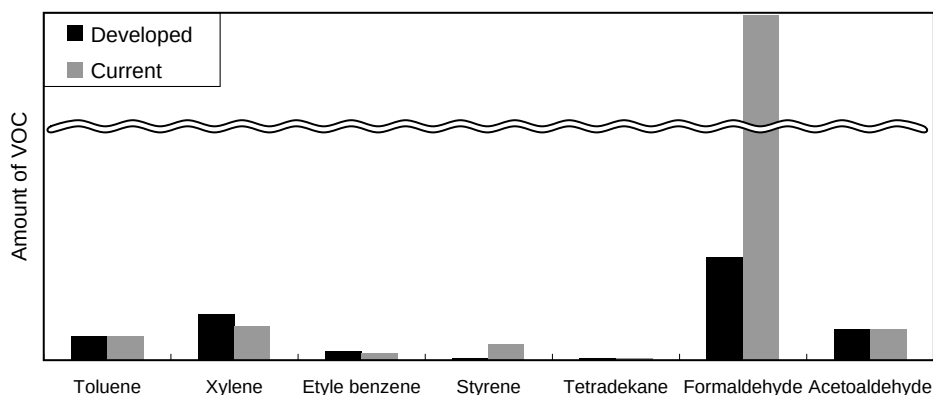


Fig. 14 VOC measurement result

power, thus enabling the release paper to be eliminated.

- (2) The ferrite blending ratio was studied and a foaming agent adopted, thus permitting material design that simultaneously realized high impact resistance and reinforcing performance.

The newly developed magnetic stiffener is used in the manufacture of the hood of the European ACCORD, which went on sale in 2008.

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