

Introduction

The technique of producing apron boards on high-speed rail equipment cabinet by composite material

Technology field

This invention relates to a kind of technique of producing apron boards on high-speed rail equipment cabinet by composite material with high strength and light weight.

Background technology

Apron board on high-speed rail equipment cabinet is an important part of the equipment cabinet from standard high speed train. In practical application, lamination design, material usage and technique design are considered since there are certain requirements on bearing ability, flame retardant ability and anti impact ability of apron board; along with the constant update of science and technology, light weight and smooth going design is used to effectively reducing the resistance of the train during operation, thereby reducing the continuous energy consumption. Under the condition of ensuring comprehensive performance, using of composite materials instead of aluminum alloy materials can reduce the weight of the overall train and enhance the level of light weight performance.

Invention Content

In view of the above questions, the main purpose of the present

invention is to provide a kind of technique to produce apron boards on high-speed rail equipment cabinet with high strength and light weight.

This invention is to solve the above technical problems by the following technical solution: one kind of technique to produce apron boards on high-speed rail equipment cabinet with composite material which includes:

Aramid fiber honeycomb, PET foam, 3K carbon fiber flame retardant prepreg, unidirectional carbon fiber flame retardant prepreg, glass fiber flame retardant prepreg, aramid flame retardant prepreg, 300g/m² of single medium temperature curing blue epoxy adhesive.

Following steps are included in this technique:

(1)、Making apron mainboard

(2)、Making apron board strip; and apron board strip includes two parts, two pieces by each with a total of four pieces

(3)、Apron board and four apron board strips altogether consist of the apron board assembly

Among the four apron board strips, two of which face with each other are the same kind, and all the apron board strips are stuck in apron board.

In a specific example of the present invention, the lamination design of the apron main board is in sequence from outside to inside as following:

1 layer of 198~200 g/m² 3K twill carbon fiber flame retardant prepreg

5~8 layers of 300 ~315 g/m² glass fiber flame retardant prepreg
2 layers of 235~240g/m² aramid flame retardant prepreg
2 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg

1 layer of 300g/m² of single medium temperature curing blue epoxy adhesive;

2 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg

1 piece of aramid honeycomb with thickness of 16.4mm

1 layer of 100~150 g/m² unidirectional carbon fiber flame retardant prepreg

1 layer of 300g/m² of single medium temperature curing blue epoxy adhesive;

2 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg

4 layers of 300 ~315 g/m² glass fiber flame retardant prepreg

1 layer of 198~200 g/m² 3K twill carbon fiber flame retardant prepreg

According to the lamination design, all layers are pasted in the mold cavity closely. Product is taken shape on hot press machine with temperature setting of 130-150 ° C, molding time of 3600-3800s and pressure setting of 4mpa-6mpa.

In a specific example of the present invention, the molding technique of the apron board strip is vacuum bagging: Apron board strips are

designed in lamination sequence from inside to outside:

1~2 layers of 300~315 g/m² glass fiber flame retardant prepreg

4~6 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg

1 layer of 235~240g/m² aramid flame retardant prepreg

2 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg

1 layer of 235~240g/m² aramid flame retardant prepreg

4~6 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg

1 layer of 198~200 g/m² 3K twill carbon fiber flame retardant prepreg

According to lamination design, all layers are pasted closely in the mould cavity. After installation of air duct, product is taken shape on hot press machine with temperature setting of 130-150° C, molding time of 3600-3800s, pressure setting of 4mpa-6mpa, and internal pressure of installed air duct is 1 MPa.

In a specific example of the present invention, the density of aramid fiber paper honeycomb is required to be 48~50kg/m³.

In a specific example of the present invention, the density of PET foam is required to be 59~61 kg/m³.

The positive progresses of this invention lie in:

This technique of producing apron boards on high-speed rail equipment cabinet with composite material has the following advantages:

1、By lamination design, the invention makes the apron board obtain very high strength at all angles, with aramid design gaining high impact resistance

2、Mould pressing technique is used on the apron board ,and vacuum bagging technique on the apron board strips which improves its strength. Different techniques are used on different product parts.

3、Hot mould pressing process requires low contents of resin that leads to light weight of the apron board.

4、The invention brings not only elegant and nice appearance also strong performance. Compared with aluminum alloy material, the weight of product in composite material is 35% ~ 40% lower which leads to a good prospect of application.

Description of figures

Figure 1 is the assembly resolution diagram of the apron board in this invention.

Figure 2 is the assembly diagram of apron board in this invention.

Figure 3-1 is a sectional view of the first kind of apron board strip in this invention

Figure 3-2 is a sectional view of the second kind of apron board strip in this invention

Figure 4 is sectional view of apron main board in this invention
Specific implementation

A preferred example is given together with following figures to

describe technical solution of this invention in detail.

Figure 1 is the overall structure diagram of this invention, as shown in Figure 1, the composite materials to make apron board on high-speed rail equipment cabinet includes: aramid fiber honeycomb, PET foam, 3K twill carbon fiber flame retardant prepreg, unidirectional carbon fiber flame retardant prepreg, glass fiber flame retardant prepreg, aramid flame retardant prepreg, 300g/m² of single medium temperature curing blue epoxy adhesive.

The technical solution to make apron board on high-speed rail equipment cabinet includes following steps:

- (1)、Making apron main board 3
- (2)、Making apron board strip 1,2; and apron board strip includes two kinds, two pieces of each kind and with a total of four pieces
- (3)、Apron main board 3 and apron board strips 1,2 altogether consist of the apron board assembly.

Among the four apron board strips, two of which face with each other are the same kind, and all the apron board strips are stuck in apron board.

The lamination design of the apron main board is in sequence from outside to inside as following:

- 1 layer of 198~200g/m² 3K twill carbon fiber flame retardant prepreg
- 5~8 layers of 300~315 g/m² glass fiber flame retardant prepreg
- 2 layers of 235~240g/m² aramid flame retardant prepreg
- 2 layers of 100~150g/m² unidirectional carbon fiber flame retardant

prepreg

1 layer of 300g/m² of single medium temperature curing blue epoxy adhesive;

2 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg

1 piece of aramid honeycomb with thickness of 16.4mm

1 layer of 100~150 g/m² unidirectional carbon fiber flame retardant prepreg

1 layer of 300g/m² of single medium temperature curing blue epoxy adhesive;

2 layers of 100 ~ 150 g/ m² unidirectional carbon fiber flame retardant prepreg

4 layers of 300~315 g/m² glass fiber flame retardant prepreg

1 layer of 198~200 g/m² 3K twill carbon fiber flame retardant

According to the lamination design, all layers are pasted in the mold cavity closely. Product is taken shape on hot press machine with temperature setting of 130-150 ° C, molding time of 3600-3800s and pressure setting of 4mpa-6mpa.

The molding technique of the apron board strips are vacuum bagging: Apron board strips are designed in lamination sequence from inside to outside:

1~2 layers of 300~315gsm glass fiber flame retardant prepreg

4 ~ 6 layers 100 ~ 150g/ m² unidirectional carbon fiber flame retardant prepreg

1 layer of 235~240 g/m² aramid flame retardant prepreg

2 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg

1 layer of 235~240g/m² aramid flame retardant prepreg

4 ~ 6 layers 100 ~ 150 g/ m² unidirectional carbon fiber flame retardant prepreg

1 layer of 198~200 g/m² 3K twill carbon fiber flame retardant prepreg

According to lamination design, all layers are pasted closely in the mould cavity. After installation of air duct, product is taken shape on hot press machine with temperature setting of 130-150° C, molding time of 3600-3800s, pressure setting of 4mpa-6mpa, and internal pressure of installed air duct is 1 MPa.

The following examples are provided for further explanation of the invention

Example one

Step one: The production of apron boards with mould pressing technique:

According to lamination design, 1 layer of 200g/m² 3K twill carbon fiber flame retardant prepreg/ 6 layers of 300 g/m² glass fiber flame retardant prepreg/ 3 layers of 235g/m² aramid flame retardant prepreg/ 2 layers of 150g/m² unidirectional carbon fiber flame retardant prepreg/ 1 layer of 300g/m² single medium temperature curing blue epoxy adhesive/2

layers of $100 \sim 150\text{g}/\text{m}^2$ unidirectional carbon fiber flame retardant prepreg/1 piece of aramid honeycomb with thickness of 16.4mm / 1 layer of $300\text{ g}/\text{m}^2$ of single medium temperature curing blue epoxy adhesive/2 layers of $100 \sim 150\text{g}/\text{m}^2$ unidirectional carbon fiber flame retardant prepreg/ 4 layers of $300\text{ g}/\text{m}^2$ glass fiber flame retardant prepreg/1 layer of $200\text{g}/\text{m}^2$ 3K twill carbon fiber flame retardant prepreg, all layers are pasted in the mould cavity closely, with temperature setting of 130°C , molding time of 3600s and the pressure setting of 4mpa.

Step two: The molding technique of the apron board strip is vacuum bagging: Apron board strips are designed in lamination sequence from inside to outside: 1 layer of $300\text{ g}/\text{m}^2$ glass fiber flame retardant prepreg/ 6 layers of $150\text{g}/\text{m}^2$ unidirectional carbon fiber flame retardant prepreg/ 1 layer of $235\text{g}/\text{m}^2$ aramid flame retardant prepreg/2 layers of $150\text{g}/\text{m}^2$ unidirectional carbon fiber flame retardant prepreg/1 layer of $235\text{g}/\text{m}^2$ aramid flame retardant prepreg/6 layers of $150\text{g}/\text{m}^2$ unidirectional carbon fiber flame retardant prepreg/1 layer of $200\text{g}/\text{m}^2$ 3K twill carbon fiber flame retardant prepreg, all layers are pasted closely in the mould cavity. After installation of air duct, product is taken shape on hot press machine with temperature setting of 130°C , molding time of 3600s, pressure setting of 4mpa, and internal pressure of installed air duct is 1 MPa.

Step three: parts to be CNC processed, and all parts to be glued together.

Step four: Comparing with the weight of apron board on real high speed

rail with aluminum alloy material, the weight of apron board in composite material is less 51% than it. Loading capacity has been over 2500pa per unit area.

Example two

Step one: The production of apron boards with mould pressing technique:

According to lamination design, 1 layer of 200g/m² 3K twill carbon fiber flame retardant prepreg / 7 layers of 300g/m² glass fiber flame retardant prepreg / 2 layers of 235g/m² aramid retardant prepreg / 2 layers of 150g/m² unidirectional carbon fiber flame retardant prepreg / 1 layer of 300g/m² of single medium temperature curing blue epoxy adhesive / 2 layers of 150g/m² unidirectional carbon fiber flame retardant prepreg / 1 piece of aramid honeycomb with thickness of 16.4mm / 1 layer of 300g/m² of single medium temperature curing blue epoxy adhesive / 2 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg / 4 layers of 300g/m² glass fiber flame retardant prepreg / 1 layer of 200g/m² 3K twill carbon fiber flame retardant prepreg, all layers are pasted in the mould cavity closely, with temperature setting of 140° C, molding time of 3600s and the pressure setting of 4mpa.

Step two: The molding technique of the apron board strip is vacuum bagging: Apron board strips are designed in lamination sequence from inside to outside: 2 layers of 300g/m² glass fiber flame retardant prepreg / 4 layers of 150g/m² unidirectional carbon fiber flame retardant

prepreg/ 1 layer of 235g/m² aramid flame retardant prepreg/2 layers of 150g/m² unidirectional carbon fiber flame retardant prepreg/1 layer of 235g/ m² aramid flame retardant prepreg/6 layers of 150g/ m² unidirectional carbon fiber flame retardant prepreg/1 layer of 200g/ m² 3K twill carbon fiber flame retardant prepreg, all layers are pasted closely in the mould cavity. After installation of air duct, product is taken shape on hot press machine with temperature setting of 140° C, molding time of 3600s, pressure setting of 5mpa, and internal pressure of installed air duct is 1 MPa.

Step three: parts to be CNC processed, and all parts to be glued together.

Step four: Comparing with the weight of apron board on real high speed rail with aluminum alloy material, the weight of apron board in composite material is less 52% than it. Loading capacity has been over 2500pa per unit area.

Example three

Step one: The production of apron boards with mould pressing technique:

According to lamination design, 1 layer of 200g/m² 3K twill carbon fiber flame retardant prepreg /6 layers of 300g/m² glass fiber flame retardant prepreg/ 3 layers of 235g/m² aramid flame retardant prepreg/2 layers of 150g/m² unidirectional carbon fiber flame retardant prepreg/1 layer of 300g/m² of single medium temperature curing blue epoxy adhesive

/2 layers of 150g/m² unidirectional carbon fiber flame retardant prepreg /1 piece of aramid honeycomb with thickness of 16.4mm / 1 layer of 300g/m² of single medium temperature curing blue epoxy adhesive /2 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg/ 4 layers of 300g/m² glass fiber flame retardant prepreg /1 layer of 200g/m² 3K twill carbon fiber flame retardant prepreg, all layers are pasted in the mould cavity closely, with temperature setting of 150° C, molding time of 3600s and the pressure setting of 4mpa.

Step two: The molding technique of the apron board strip is vacuum bagging:

Apron board strips are designed in lamination sequence from inside to outside: 1 layer of 300g/m² glass fiber flame retardant prepreg/ 4 layers of 150g/m² unidirectional carbon fiber flame retardant prepreg/ 1 layer of 235g/m² aramid flame retardant prepreg/2 layers of 150g/m² unidirectional carbon fiber flame retardant prepreg/1 layer of 235g/m² aramid flame retardant prepreg/8 layers of 150g/m² unidirectional carbon fiber flame retardant prepreg/1 layer of 200g/m² 3K twill carbon fiber flame retardant prepreg, all layers are pasted closely in the mould cavity. After installation of air duct, product is taken shape on hot press machine with temperature setting in 150 ° C, molding time of 3600s, pressure setting of 6mpa, and internal pressure of installed air duct is 1 MPa.

Step three: parts to be CNC processed, and all parts to be glued together.

Step four: Comparing with the weight of apron board on real high speed rail with aluminum alloy material, the weight of apron board in composite material is less 51% than it. Loading capacity has been over 2500pa per unit area.

All the above information is used to show and describe the basic principles, main features and advantages of this invention. The technician of this field should understand that the invention is not restricted to the examples above. The above examples and the specification are just used to describe the principle of the invention. Based on the principle and scope of this invention, various changes and improvement can be done, and these changes and improvements are included in the scope of the present invention. The scope of this invention which requires to be protected is defined in the Claim of Rights attached and its equivalent definition.

Claims

1. A method of producing an apron board on high-speed rail equipment cabinet with a composite material, the characteristic lies in:

the composite material comprising:

aramid fiber honeycomb, PET foam, 3K carbon fiber flame retardant prepreg, unidirectional carbon fiber flame retardant prepreg, glass fiber flame retardant prepreg, aramid flame retardant prepreg, 300g/m² of single component blue epoxy adhesive; and

the method of producing an apron board on high-speed rail equipment cabinet with the composite material comprises the following steps:

(1) making an apron main board;

(2) making an apron board strip; wherein the apron board strip includes two kinds, two pieces of each kind and with a total of four pieces;

(3) assembling the apron main board and the four pieces of apron board strips to make the apron board;

wherein among the four pieces of apron board strips, two of which face with each other are of the same kind, and all the pieces of apron board strips are stuck to the apron main board, and

wherein the apron main board is made of the composite material in a lamination design.

2. The method according to claim 1, wherein the apron main board is designed in a lamination sequence from outside to inside:

- 1 layer of 198~200 g/m² 3K carbon fiber flame retardant prepreg;
- 5~8 layers of 300~315 g/m² glass fiber flame retardant prepreg;
- 2 layers of 235~240g/m² aramid flame retardant prepreg;
- 2 layers of 100~150g/m² unidirectional carbon fiber flame retardant prepreg;
- 1 layer of 300g/m² of single component blue epoxy adhesive;
- 2 layers of 100 ~ 150 g/m² unidirectional carbon fiber flame retardant prepreg;
- 1 piece of aramid honeycomb with thickness of 16.4mm;
- 1 layer of 100~150 g/m² unidirectional carbon fiber flame retardant prepreg;
- 1 layer of 300 g/m² of single component blue epoxy adhesive;
- 2 layers of 100 ~ 150 g/m² unidirectional carbon fiber flame retardant prepreg;
- 4 layers of 300 ~315 g/m² glass fiber flame retardant prepreg;
- 1 layer of 198~200 g/m² 3K carbon fiber flame retardant prepreg;

wherein according to the lamination sequence, all the layers are pasted in a mold cavity closely and taken shape in a hot press machine with temperature setting of 130-150°C, molding time of 3600-3800s, pressure setting of 4mpa-6mpa.

3. The method according to claim 1, wherein the apron main board is designed in a lamination sequence from outside to inside:

- 1 layer of 200 g/m² 3K carbon fiber flame retardant prepreg;
- 6 layers of 300 g/m² glass fiber flame retardant prepreg;
- 3 layers of 235 g/m² aramid flame retardant prepreg;

2 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;
1 layer of 300 g/m^2 of single component blue epoxy adhesive;
2 layers of $100 \sim 150 \text{ g/m}^2$ unidirectional carbon fiber flame retardant prepreg;
1 piece of aramid honeycomb with thickness of 16.4mm;
1 layer of 300 g/m^2 of single component blue epoxy adhesive;
2 layers of $100 \sim 150 \text{ g/m}^2$ unidirectional carbon fiber flame retardant prepreg;
4 layers of 300 g/m^2 of glass fiber flame retardant prepreg;
1 layer of 200 g/m^2 3K carbon fiber flame retardant prepreg;

wherein according to the lamination sequence, all the layers are pasted in a mold cavity closely and taken shape in a hot press machine with temperature setting of 130°C , molding time of 3600s, pressure setting of 4mpa.

4. The method according to claim 1, wherein the apron main board is designed in a lamination sequence from outside to inside:

1 layer of 200 g/m^2 3K carbon fiber flame retardant prepreg;
7 layers of 300 g/m^2 glass fiber flame retardant prepreg;
2 layers of 235 g/m^2 aramid flame retardant prepreg;
2 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;
1 layer of 300 g/m^2 of single component blue epoxy adhesive;
2 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;
1 piece of aramid honeycomb with thickness of 16.4mm;
1 layer of 300 g/m^2 of single component blue epoxy adhesive;
2 layers of $100 \sim 150 \text{ g/m}^2$ unidirectional carbon fiber flame retardant prepreg;

4 layers of 300 g/m² of glass fiber flame retardant prepreg;

1 layer of 200 g/m² 3K carbon fiber flame retardant prepreg;

wherein according to the lamination sequence, all the layers are pasted in a mold cavity closely and taken shape in a hot press machine with temperature setting of 140°C, molding time of 3600s, pressure setting of 4mpa.

5. The method according to claim 1, wherein the apron main board is designed in a lamination sequence from outside to inside:

1 layer of 200 g/m² 3K carbon fiber flame retardant prepreg;

6 layers of 300 g/m² glass fiber flame retardant prepreg;

3 layers of 235 g/m² aramid flame retardant prepreg;

2 layers of 150 g/m² unidirectional carbon fiber flame retardant prepreg;

1 layer of 300g/m² of single component blue epoxy adhesive;

2 layers of 150 g/m² unidirectional carbon fiber flame retardant prepreg;

1 piece of aramid honeycomb with thickness of 16.4mm;

1 layer of 300g/m² of single component blue epoxy adhesive;

2 layers of 100~150 g/m² unidirectional carbon fiber flame retardant prepreg;

4 layers of 300 g/m² of glass fiber flame retardant prepreg;

1 layer of 200 g/m² 3K carbon fiber flame retardant prepreg;

wherein according to the lamination sequence, all the layers are pasted in a mold cavity closely and taken shape in a hot press machine with temperature setting of 150°C, molding time of 3600s, pressure setting of 4mpa.

6. The method according to claim 1, wherein the apron board strip is molded by vacuum bagging; the apron board strips are designed in a lamination sequence from inside to outside:

1~2 layers of $300 \sim 315 \text{ g/m}^2$ glass fiber flame retardant prepreg;

4~6 layers of $100 \sim 150 \text{ g/m}^2$ unidirectional carbon fiber flame retardant prepreg;

1 layer of $235 \sim 240 \text{ g/m}^2$ aramid flame retardant prepreg;

2 layers of $100 \sim 150 \text{ g/m}^2$ unidirectional carbon fiber flame retardant prepreg;

1 layer of $235 \sim 240 \text{ g/m}^2$ aramid flame retardant prepreg;

4~6 layers of $100 \sim 150 \text{ g/m}^2$ unidirectional carbon fiber flame retardant prepreg;

1 layer of $198 \sim 200 \text{ g/m}^2$ 3K carbon fiber flame retardant prepreg;

wherein according to the lamination sequence, all the layers are pasted closely in a mold cavity and taken shape after air duct installation on a hot press machine with temperature setting of $130 \sim 150^\circ\text{C}$, molding time of 3600-3800s, pressure setting of 4mpa-6mpa, and internal pressure of the air duct is 1 MPa.

7. The method according to claim 1, wherein the apron board strip is molded by vacuum bagging; the apron board strips are designed in a lamination sequence from inside to outside:

1 layer of 300 g/m^2 glass fiber flame retardant prepreg;

6 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;

1 layer of 235 g/m^2 aramid flame retardant prepreg;

2 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;

1 layer of 235 g/m^2 aramid flame retardant prepreg;

6 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;

1 layer of 200 g/m^2 3K carbon fiber flame retardant prepreg;

wherein according to the lamination sequence, all the layers are pasted closely in a mold cavity and taken shape after air duct installation on a hot press machine with temperature setting of 130°C , molding time of 3600s, pressure setting of 4mpa, and internal pressure of the air duct is 1 MPa.

8. The method according to claim 1, wherein the apron board strip is molded by vacuum bagging; the apron board strips are designed in a lamination sequence from inside to outside:

2 layers of 300 g/m^2 glass fiber flame retardant prepreg;

4 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;

1 layer of 235 g/m^2 aramid flame retardant prepreg;

2 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;

1 layer of 235 g/m^2 aramid flame retardant prepreg;

6 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;

1 layer of 200 g/m^2 3K carbon fiber flame retardant prepreg;

wherein according to the lamination sequence, all the layers are pasted closely in a mold cavity and taken shape after air duct installation on a hot press machine with temperature setting of 140°C , molding time of 3600s, pressure setting of 5mpa, and internal pressure of the air duct is 1 MPa.

9. The method according to claim 1, wherein the apron board strip is molded by vacuum bagging; the apron board strips are designed in a lamination sequence from inside to outside:

1 layer of 300 g/m^2 glass fiber flame retardant prepreg;

4 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;

1 layer of 235 g/m^2 aramid flame retardant prepreg;

2 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;

1 layer of 235 g/m^2 aramid flame retardant prepreg;

8 layers of 150 g/m^2 unidirectional carbon fiber flame retardant prepreg;

1 layer of 200 g/m^2 3K carbon fiber flame retardant prepreg;

wherein according to the lamination sequence, all the layers are pasted closely in a mold cavity and taken shape after air duct installation on a hot press machine with temperature setting of 150°C , molding time of 3600s, pressure setting of 6mpa, and internal pressure of the air duct is 1 MPa.

10. The method according to claim 1, wherein the density of the aramid fiber honeycomb is required to be $48\sim 50 \text{ kg/m}^3$.

11. The method according to claim 1, wherein the density of the PET foam is required to be $59\sim 61 \text{ kg/m}^3$.