Long-Fiber-Glass-Reinforced Thermoplastic Composite "KP-SHEET"*

Tsuguo Takehara** Hidetaka Suginobe***

1 Introduction

In June 1991, the production equipment for stampable KP-SHEET with an annual capacity of 5 800 t by the papermaking process was completed at K-Plasheet Corporation. The manufacturing process is based on a special papermaking technique introduced from Arjo Wiggins Appleton of U.K., using an aqueous foam. The features of the manufacturing process and of KP-SHEET, and the applications of this stampable sheet are outlined.

2 Manufacturing Process

KP-SHEET is a long-fiber-glass-reinforced thermoplastic composite material made from polypropylene (PP) in powder form and chopped glass fibers (GF) of about 13 mm in length. An outline of the manufacturing process is shown in **Fig. 1**.

Chopped strands, bandled GF monofilaments, and PP are fed into a dispersion tank, where they are thoroughly dispersed in an aqueous foam containing a surfactant. In the dispersion process of papermaking, reagglomeration of the dispersed fibers into secondary bundles usually occurs in parallel with dispersion. To obtain uniform quality, suppression of this re-agglomeration is important; this phenomenon has so far been suppressed by lowering the concentration of fiber in the dispersion tank. This technique, however, has the disadvantage of reduced productivity. Because an aqueous foam is used in the manufacture of KP-SHEET, dispersed monofilaments are suspended in the foam by interfacial tension and re-agglomeration is unlikely to occur. For this reason, efficient production is possible with the concentration of fiber kept at a high level. Furthermore, because PP is also suspended in the foam, no separation of PP and GF occurs due to their different specific gravity values and uniform dispersion is obtained.

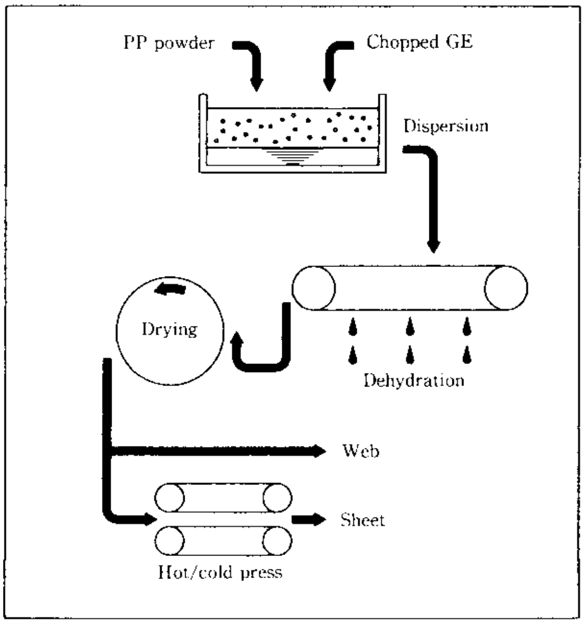

Fig. 1 Schematic flow of the KP-sheet process

The foam suspension containing PP and GF is pumped to the papermaking machine, and nonwoven fabric called a web is obtained after the dehydration and drying processes, as in the usual method for manufacturing paper. A web has voids of 50% to 75% and looks like a blanket. After heating to above the melting point of PP, the webs are pressed, while being cooled, to form KP-SHEET with a dense structure that does not contain voids.

After delivering to a customer, KP-SHEET is again heated to above the melting point of PP and then placed over a molding tool. The sheet is then pressed and flows to the ends of the mold cavity. At the same time, it is cooled and consolidates well. after it has thor-

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** General Manager, Plastics Dept., Chemical Div.

*** Dr. Ing., Staff Manager, Ironmaking Technology Sec., Ironmaking Dept., Chiba Works (Former Senior Researcher, Chemical Research Center, High-Technology Res. Labs.)

oughly cooled, the final product is removed from the mold.

Although this report is limited to a description of KP-SHEET composed of PP and GF, the features of the papermaking technique using an aqueous foam permit combinations of other resins in powder form and other fibers (for example, carbon or metallic fiber).

3 Features of KP-SHEET

Stampable KP-SHEET has the following general features:

(1) Press molding is possible, so that molding large parts is easier than by injection molding.

(2) Press forming minimizes damage to GF during the molding process, so that parts with good mechanical properties can be produced.

(3) Thermoplastic resin is used, so that the molding cycle is shorter than that with thermoset plastic which requires a certain reaction time.

Besides these features, KP-SHEET has other novel characteristics imparted by papermaking technology which are described next.

3.1 Mechanical Properties

The mechanical properties of KP-SHEET are shown in **Table 1**. The aspect ratio of GF, which is the ratio of the length to the diameter, is approximately 1 300, which is relatively high and almost equivalent to that of continuous fiber. For this reason, KP-SHEET has outstanding mechanical properties in spite of non-continuous fiber being used.

3.2 Product Size

Glass mat thermoplastics (GMT), which are manufactured by laminating PP and glass fiber mats, have so far been used as stampable sheet. The minimum thickness of a GMT-base stampable sheet is controlled by the thickness of the glass fiber mat.

The use of the papermaking process makes it possible to control the sheet thickness by changing the speed of the papermaking machine. Product thicknesses from 0.8 mm to 5.3 mm can be supplied, and the maximum width of the sheet is 1 500 mm. A wide range of customers' requirements can be met with this high degree of freedom for size.

Table 1 Mechanical properties of KP-sheet

		Glass fiber content (wt%)	
		30	40
Specific gravity		1.1	1.2
Grammage	(g/m²)	4 000	4 000
Tensile strength	(MPa)	80	100
Tensile modulus	(GPa)	4.1	4.9
Bending strength	(MPa)	120	140
Bending modulus	(GPa)	4.4	5.4
Izod strength	(kJ/m²)	59	88

3.3 Uniform Flow of Glass Fiber

The GF filaments are uniformly distributed in the PP matrix. For this reason, both GF and PP flow uniformly together when KP-SHEET is press-molded after heating, with the result that the GF content is constant throughout the product; consequently, because the variation in mechanical properties at different points in the product is very small, it is possible to design products with a high level of reliability.

This uniform flowability also provides uniform GF filling of such features as ribs and bosses. In the case of KP-SHEET with 40% GF, for example, GF will uniformly fill a 3 mm wide rib up to a depth of 6 times the width with a variation of only about 2%. Accordingly, KP-SHEET is particularly suitable for parts that can benefit from increased stiffness or lower weight by a ribbed structure.

3.4 Expanded Molding

Although voids contained in the web are eliminated by the press-molding process during the manufacture of KP-SHEET, a web-like structure containing voids is reinstated when the sheet is heated again. This is because, when PP is heated and melted, the relief of stress in the GF filaments causes the sheet to return to the original state of the web.

Porous expanded parts can be obtained when press molding is conducted with an appropriate setting of the mold gap so that the sheet remains in an expanded condition and does not flow. Although the absolute values for the strength and modulus of elasticity of expanded parts are lower than those of the original sheet, their specific strength and specific modulus of rigidity are higher. Therefore, KP-SHEET is ideally suited as a material for saving weight.

The fact that porous expanded parts can be obtained without the addition of a foaming agent is a feature of the papermaking process.

4 Applications of KP-SHEET

Conventional GMT-based materials have already been extensively used for such automotive parts as battery trays and bumper beams, and have also been applied to produce building materials such as form panels for concrete. The basic concept for selecting applications based on the foregoing features peculiar to KP-SHEET are next described.

The weight ratio of various materials with respect to steel of the same rigidity is shown in **Fig. 2**. It is apparent that KP-SHEET permits a 50% weight saving even

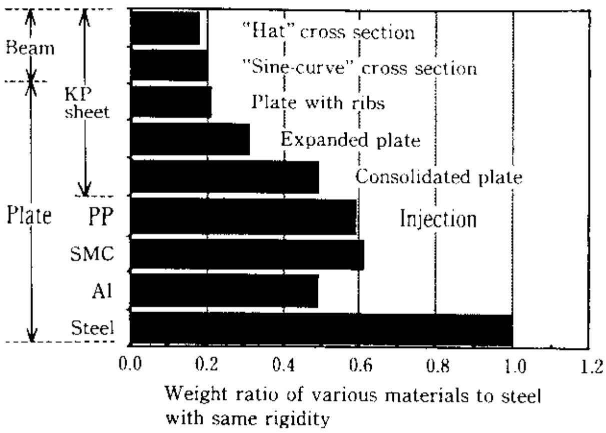

Fig. 2 Weight saving potential of KP-sheet

when it is used in the form of a flat plate. The required weight decreases further in the case of an expanded plate. Therefore, expanded molding is advantageous for parts with a relatively simple form that permit this process. When designing parts, the thickness necessary to achieve the target rigidity value is first calculated. The appropriate thickness can be selected from the wide range of thickness in which KP-SHEET is available.

As shown in Fig. 2, further weight saving can be achieved by designing parts with ribs and various cross sections. When unidirectional rigidity is required, the "hat" cross section is advantageous for beams, and the "sine-curve" cross section is recommended for plates. When two-directional rigidity is required of a plate, combinations of ribs permit wide design scope. The selection of the size and thickness of a plate on which the design of such parts is based and the uniform GF filling in ribs are conferred by the size range and flow characteristics of KP-SHEET.

Photo 1 shows an automobile molding of a fold-down seat back that can act as a load floor. This was made as an example of a ribbed part, and demonstrates that ribs 3.8 mm in width and 34 mm in height can be molded.

5 Concluding Remarks

KP-SHEET manufacturing equipment has been operating smoothly since July 1991. The company plans to produce further products that meet customers' requirements and further improve the performance of KP-SHEET.

For Further Information, Please Contact to:
K-Plasheet Corporation
1, Kawasaki-cho, Chuo-ku, Chiba 260, Japan
FAX 043–262–2370
TEL 043–262–2837

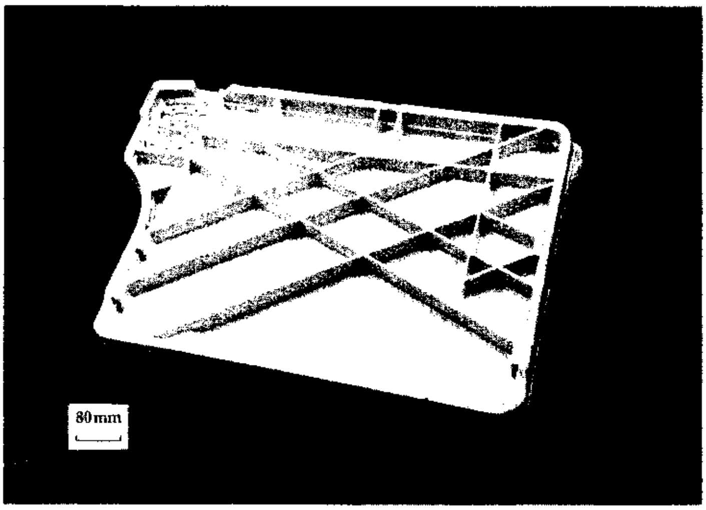

Photo 1 Seat back load floor