PROCESSING AND MECHANICAL PROPERTIES OF TEXTILE INSERT FOAMED INJECTION MOLDING

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Abstract

In this study, polypropylene knit/foamed polypropylene composites were fabricated by using the textile insert injection molding technique. Foamed materials can reduce the quantity of the consumed material by introducing air through the usage of foaming agents. The textile was knitted from polypropylene fibers and matrix was also foamed polypropylene. Since the textile and matrix are of similar materials, good interfacial properties can be achieved. In this paper, drop weight impact properties of specimens with and without textile inserts and effect of melting state of PP fiber on impact properties were examined. Drop-weight impact properties of PP knit/foamed PP specimens were superior to those without textile inserts.

1 Introduction

In recent years, the developments of the materials considering environment and the various molding methods to use new materials have been studied. In these circumstances, the concern with composite consisting of same material with different reinforcement and matrix shapes, such as fiber and pellet, has been growing. These composites are called one-unity composites. The concept of one-unity composites is mainly driven by the need to avoid physical deterioration due to interfacial problems and achieve improved interfacial, thermal, mechanical, economical and eco-logical benefits.

Studies about moldings method which used idea of one-unity composite have been carried out. For example, firm insert injection molding and textile insert injection molding have been investigated [1]. Many material systems have been applied to concept of one-unity composite such as polyethylene (PE) [2] and polypropylene (PP) [3]. In this study, concept of one-unity composites was applied to foamed materials. Foamed material can reduce quantity of consumed material by introducing air or bubbling with foaming agent in the material.

Textile fabrics were employed for the reinforcements and composites were molded with textile insert injection compression molding. The major textiles for composite reinforcements are woven, knitted and braided fabric. Figure 1 shows schematics of woven, knitted and braided fabric.

In this study knitted fabric was used for reinforcements in order to improve the impact properties. Knitted fabric is suitable for the manufacture of components with complex shape. Their excellent formability would allow them to be formed in a tool and infiltrated with an appropriate resin to produce the desired complex shape of a composite component. Figure 2 shows schematic of a plain knitted fabric used in this study and Figure 3 shows textile inserted injection moldings.

In this study, drop weight impact test was carried out for knitting fabric insert injection compression moldings. Two kinds of experiments were done. First, effect of textile inserting sequence on impact properties was investigated. Secondly effect of melting state of PP fiber on impact properties was investigated by changing the melting temperature of PP fiber.

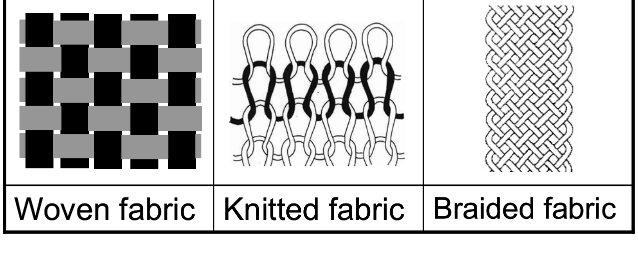

Fig.1 Types of textile configuration

2 Experimental Procedure

2.1 Materials and Specimens

The matrix used was PP (J-3000GP; Idemitsu Kosan Co. Ltd) and its melting temperature was 160℃. Two kinds of PP fiber with different melting temperature were used as reinforcement; their melting temperatures were 174°C and 167°C, respectively. In this study, plain knitted fabric was used as reinforcements. The stitch density was 8 stitches per cm in a course direction and 3.5 stitches per cm in a wale direction.

The specimens were molded by injection compression molding. Figure 4 shows molding method of a specimen. The resin temperature and mold temperature were maintained at 200°C /30°C during molding.

The specimens that had knitted fabric placed on top during impact were termed 'Knit face', while those with the knitted fabric below were termed 'PP face' and the specimen without fabric termed 'Foam'. Figure 5 shows schematic drawings of Foam, Knit face and PP face specimen. Moreover, PP fibers, of which melting temperature were 167°C and 174°C, were named Tm167°C and Tm 174°C.

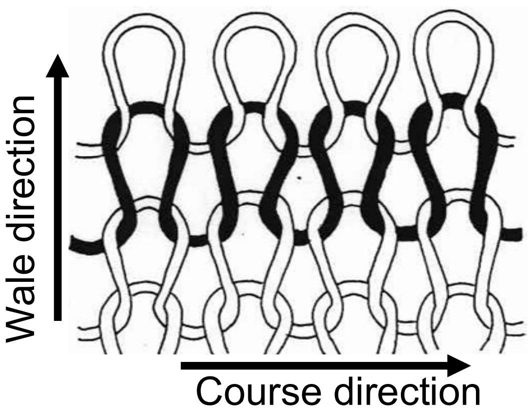

Fig.2 Schematics of plain knitted fabric

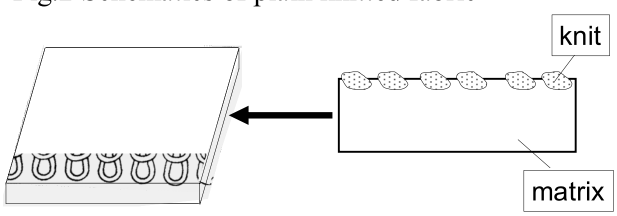

Fig.3 textile inserted injection moldings

Figure 6 shows SEM images of cross section for Foam and PP/PP specimen. From these images, it was found that there were solid parts in the both surface of all specimens. The cell shape of Foam was looked like oval shape, and size of cell became bigger from both surfaces to core of specimen. On the other hand, in case of PP/PP specimen, the cell shape was not oval shape and size of cell was irregular.

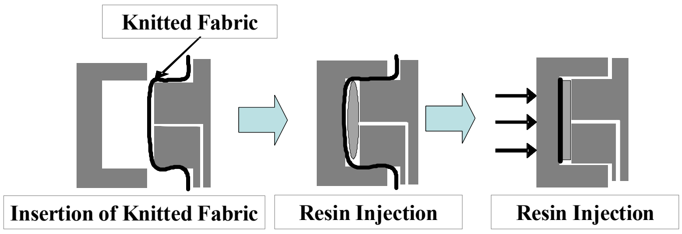

Fig.4 Process of textile inserted by injection compression molding

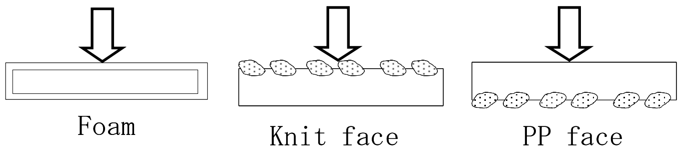

Fig.5 Schematics of Foam, Knit face and PP face

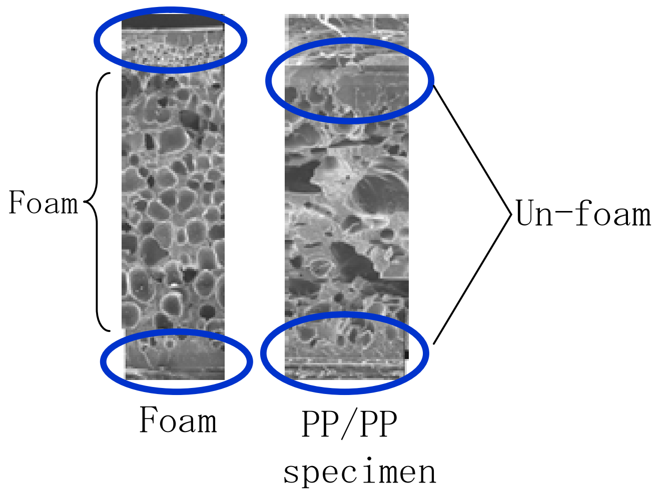

Fig.6 SEM images of cross section for Foam and PP/PP specimen

2.2 Test Methods

The impact tests were conducted with a drop weight impact testing machine (Instron Dynatup 9250HV). Figure 7 shows a schematic of drop weight impact test. The specimens were clamped on all sides by a rectangular steel plate with 76mm circular hole and the drop weight load was applied to the center of the specimen and the diameter of the indenter was 12.6mm. Applied impact energy was 10J.

In this study, two kinds of experiments were done. First, effect of textile inserting sequence on impact properties was investigated. Secondly effect of melting state of PP fiber on impact properties was investigated by changing the melting temperature of PP fiber. In the case of first experiment, melting temperature of PP fiber was 174^{o}C.

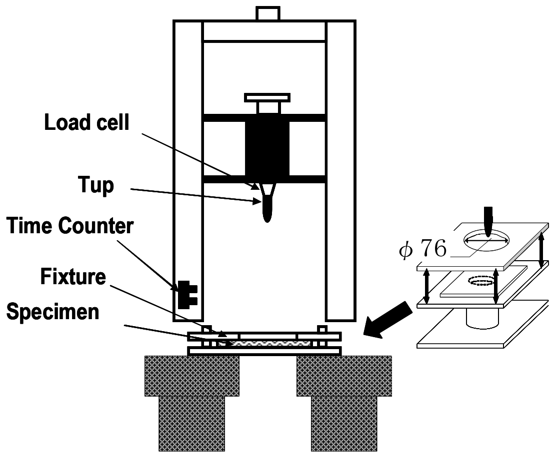

Fig.7 Test schematics for instrumented drop weight impact test

3 Results and Discussion

3.1 effect of textile inserting sequence

Figure 8 shows typical impact load-deflection curves of Foam, Knit face and PP face specimens. In Figure 8, all specimens showed a similar trend, that is to say, there were two peaks of load. First peak load occurred by incipient damage and second peak load occurred by ultimate damage of specimen. First peak load and second peak load were named initial peak load and maximum peak load. The incipient damage point corresponds to the first irreversible damage of the specimen such as interface failure or matrix cracking near the surface of the specimen.

In the case of Foam specimen, initial peak load showed at the displacement of 3.5mm and ultimate damage was at 7mm. After maximum peak load, the impact load dramatically dropped. In the Knit face, initial peak load showed at the displacement of 5.5mm and maximum peak load was at 11mm. In the PP face, initial peak load and maximum peak load showed at the displacement of 8mm and 15mm.

Initial peak and maximum peak load were summarized in Table 1. It is found that both initial peak load of Foam and Knit face were roughly equal. On the other hands, initial peak load of PP face was superior to that of other specimens. Maximum peak load was improved for the knitted fabric reinforced specimens as compared to the Foam and both maximum peak load of Knit face and PP face were almost same.

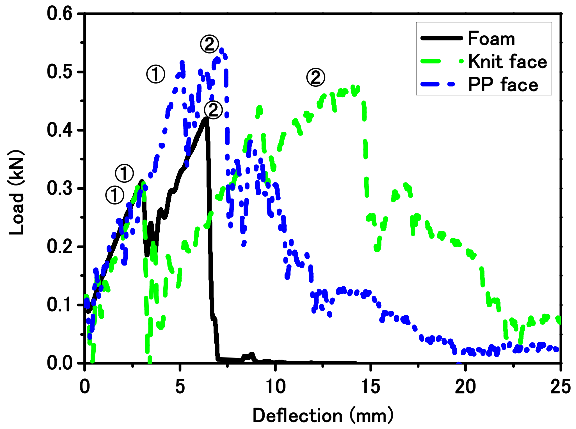

Fig.8 Load-Deflection curves

Table 1 Summary of drop weight impact test results

	Initial peak load (kN)	Maximum load (kN)
Foam	0.31	0.34
Knit face	0.31	0.49
PP face	0.52	0.55

Figure 9 shows schematic drawings of fracture aspect for each specimen. In the case of Form (Figure 9-(a)), some cracks occurred in back surface, which was solid part. Then cracks were progressed into core part, which was foamed part. Finally, the cracks passed completely through to the impact surface.

In the case of Knit face (Figure 9-(b)), similarly, some cracks occurred in the back surface and were progressed into core part. Because knitted fabric was inserted at impact face of Knit face specimen, crack propagation was restrained. As a result, maximum peak load and the deflection of Knit face were bigger than that of PP face.

In the case of PP face (Figure 9-(c)), any cracks did not occur in the back surface because of knitted fabric. Knitted fabric prevents crack initiation at the back surface, whereas solid surface was damaged at the impact face. Then cracks were progressed into the core part and finally cracks passed completely through to the back surface.

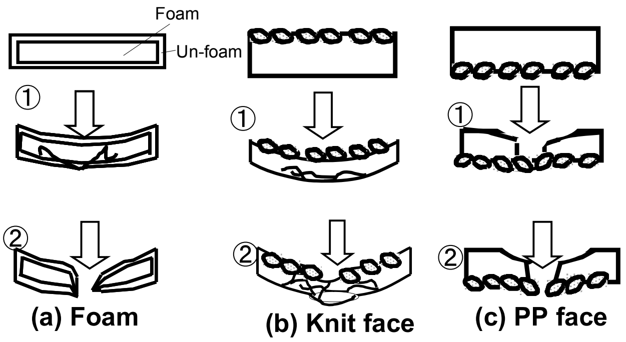

Fig.9 Schematics of fracture aspects

Impact properties of Foam, PP face and Knit face are shown in Table 2. Figure 10 shows the definition of total energy, energy to initial peak load and progressive energy. Total energy means all energy which was absorbed during drop weight test, energy to initial peak load means energy before initial peak and progressive energy means energy after initial peak. The total energy, energy to initial peak load and progressive energy of Knit face and PP face were higher than those of Foam. In the case of energy to initial peak load, PP face became bigger than that of Knit face. Conversely, in the case of total energy, that of Knit face became bigger than that of PP face.

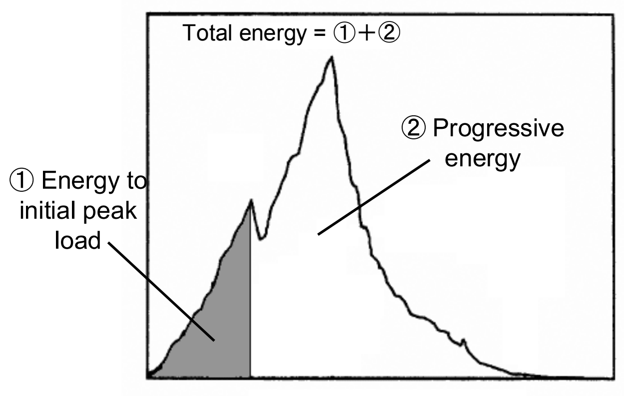

Fig.10 schematic of total energy, energy to initial peak load and progressive energy

3.2 effect of melting temperature on impact properties

Figure 11 shows load-deflection curves of PP face specimens with different melting temperature of PP fiber. There were two peaks both in Tm167°C and Tm174°C. Initial peak load of Tm174°C was higher than that of Tm167°C, whereas maximum peak load of Tm167°C and Tm174°C were the same.

The decrease in load at the initial peak of Tm174°C was bigger than Tm167°C. On the other hand, the decrease in load at the maximum peak of Tm167°C was bigger than Tm174°C. The reason why decrease in load at the initial peak of Tm167°C was smaller was attributed to the fact that fiber melting condition of Tm174°C and Tm167°C was different. Tm167°C had good interfacial adhesion between fiber and matrix since filaments of Tm167°C melted in the matrix more than that of Tm174°C. For the reason of big decrease in load at the maximum peak of Tm167°C, filaments dissolved too much into matrix to keep fiber shape because of lower melting temperature. Therefore most of filaments cannot play the role as reinforcements.

Table 2 Summary of drop weight impact energy results

	Total energy (J)	Energy to Initial peak load (J)	Progressive energy (J)
Foam	1.50	0.46	1.04
Knit face	6.22	0.55	5.67
PP face	4.48	1.38	3.10

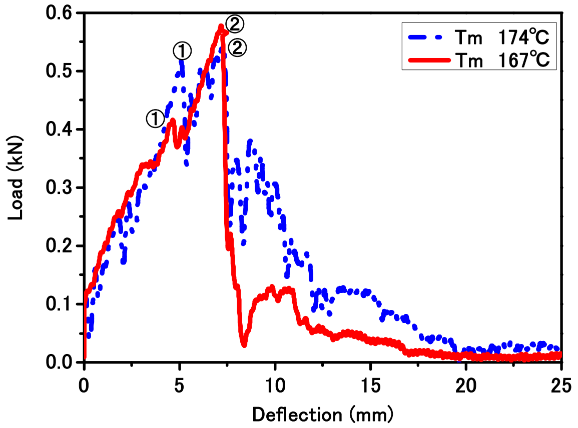

Fig.11 Load-Deflection curves

Conclusion

A knitted fabric was selected as reinforcement, and mechanical properties of PP/PP foamed composites by using injection molding were investigated. It was found that textile inserted Foam had higher impact property than Foam only. Moreover initial peak load and maximum peak load of PP face specimens, which had knitted fabric placed on back side, were higher than that of Knit face specimens, which had knitted fabric placed on impact side. In the case of Foam and Knit face, initial fracture occurred in back surface of specimens and in the case of PP face, initial fracture occurred in impact surface. When fiber of a low melting temperature was used, the decrease in load at the initial peak was smaller than that with fiber of a high melting temperature and whereas both maximum load was almost same.

Reference

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