

FIBER GEOMETRY EFFECTS ON PHYSICAL PROPERTIES OF CHOPPED FIBER COMPOSITES

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ABSTRACT

The Radlite™ Technology describes a process by which Chopped Fiber Glass and Powdered Thermoplastic Resin are blended and formed into a Fiber Glass Reinforced Thermoplastic Laminate. Ingredients are dispersed in a pulping medium and the pulp stock is deposited onto a driven conveyor via a headbox. The white water is removed by vacuum and the resultant web is treated with a binder, dried, and consolidated. As in other Thermoplastic Composites, Fiber Glass Aspect Ratio has a notable effect on physical properties performance. Strength, Modulus, Impact, and Flow of Chopped Fiber Composites will be examined.

KEYWORDS

Performance Trends, Fiber Geometry, Unconsolidated Web, Basis Weight

INTRODUCTION

Fiber Glass Reinforced Thermoplastic Composites are being used in a large variety of applications. The Injection Molding Process offers uniform glass distribution and ease of fill (1), while Thermo-stampable Continuous Fiber Reinforced Thermoplastic Composites offer superior impact strength and dimensional stability (2). Chopped Fiber Reinforced Thermoplastic Sheet Composites (3,4,5) bridge the performance gap between Chopped Fiber Injection Moldable and Continuous Fiber composites. Chopped Fiber Reinforced Thermoplastic Sheet Composites are materials consisting of individual glass filaments randomly dispersed throughout a resin matrix. Chopped Fiber Reinforced Thermoplastic Sheet Composites are flow moldable and retain uniform glass distribution. Chopped Fiber Reinforced Polypropylene Laminates or CF-Azdel™, marketed by Azdel Inc., are produced via a proprietary wet-laid process called Radlite™. Similar to papermaking, the process offers the flexibility and precision needed to vary composite formulations while maintaining uniformity and quality. As in all wet-laid applications, the use of handsheets as a product development tool for Chopped Fiber Composites is essential. For purposes of this investigation, handsheets were used as a source of experimental data. Fiber Geometry (Length and Diameter) was varied while the resin matrix, glass content, and molded part thickness were held constant. The response of Tensile Strength, Flexural Strength, Flexural Modulus, Impact Strength, and Composite Flow to Fiber Geometry was examined.

PROCEDURE

The handsheet equipment used to form Chopped Fiber Composite Sheets is similar to most traditional units. It consists of a mixing chamber and a combination formation and dewatering chamber. All parameters including mixing speed, mixing time, and dewatering vacuum were selected to best simulate production line

operation. Nine different fiber geometries were used with diameters ranging from 10 to 23 microns and lengths ranging from 0.25 to 1 inch. All fiber glass reinforcements used were of an E-glass composition, produced from a continuous melt furnace and treated with the same sizing chemistry. Polypropylene powder was the resin matrix. The wet chopped fiber glass and powdered thermoplastic resin were blended in white water until intimately dispersed, the resultant mixture was transferred to the formation chamber and immediately dewatered. The wet web was treated with a binder and the residual moisture was removed by convection type drying. The final unconsolidated handsheets had a basis weight of 0.82 pounds per square foot and a glass content of 30% by weight. Consolidation to maximum specific gravity of 1.13 was carried out at 420°F and 25 psi for 3.5 minutes and the resultant laminates were compression molded into flat panels (450°F preheat temperature at 3500 psi for 1 minute). Sample preparation and testing were conducted in accordance with ASTM procedures. The lettering nomenclature used to reference fiber diameter will be used interchangeably with numerical values throughout this paper; i.e., G=10 microns, M=16 microns, and T=23 microns.

The flowability of Chopped Fiber Composites compounded with 1/2-in. G-fiber and 1/2-in. M-fiber was also measured. The value generated by dividing Initial Laminate Thickness by Final Part Thickness is referred to as Absolute Flow and is a measure of composite flow. Prior to molding, the thickness of each laminate was recorded. Seven laminates for each composite formulation were tested. The laminates were preheated at 460°F for 6 minutes then transferred to the press and compression molded at 3100 psi for 15 seconds. The final part thickness was measured and the Absolute Flow calculated.

RESULTS

A summary of mechanical properties is given in Table 1. Graphs illustrating individual performance trends versus Fiber Diameter and Fiber Length are given in Figures 1-8. The coefficient of variance (standard deviation divided by the mean) for all physical properties reported ranged from 1-4%. The results indicate that both Tensile Strength and Flexural Strength increase as Fiber Diameter decreases. These trends are in agreement with a well observed phenomena in Injection Molding that as fiber diameter decreases or surface area increases physical properties increase. Both Tensile and Flexural Strengths are independent of Fiber Length due to the fact that the fiber aspect ratio is substantially higher than the critical aspect ratio required for providing reinforcement. Since no trends are detectable, it appears that Flexural Modulus is independent of both Fiber Diameter and Length. Impact Strength increases as Fiber Diameter decreases, but the performance levels off when comparing 16 and 10 micron fibers. Classically, Impact Strength increases as Fiber Length is increased. When comparing the performance of 1/4-in. to 1/2-in. fibers, Impact Strength increases 10-20% independent of Fiber Diameter; while it actually decreases slightly when comparing the performance of 1/2-in. to 1-in. fibers. This slight drop off in Impact performance is probably attributable to the lack of dispersion and some fiber entanglement of 1-in. fibers when forming handsheets, resulting in slightly lower resin wet-out.

Table 1: Measured Physical Properties of Chopped Fiber Reinforced Polypropylene Composites.

Glass Loading=30%

Fiber Geometry Diameter/Length (microns)	(in.)	Tensile Strength (psi)	Flexural Strength (psi)	Flexural Modulus (psi)	Dynatup Impact (ft-lb)
10	0.25	11,900	18,500	690,600	17.3
10	0.5	13,300	19,200	680,100	21.2
10	1.0	13,600	19,500	750,800	19.7
16	0.25	11,600	16,600	630,100	19.0
16	0.5	13,800	18,700	680,300	21.6
16	1.0	11,600	18,200	678,600	18.9
23	0.25	8,100	15,500	757,300	14.6
23	0.5	9,700	16,300	704,700	18.7
23	1.0	8,000	16,800	665,500	17.1

As described in the previous section, composite flow of Chopped Fiber Sheet Composites containing 1/2-in. G-fiber and 1/2-in. M-fiber was evaluated. Absolute Flow values of 1.6 and 1.7 were calculated for the G-fiber and M-fiber based composites, respectively. This result indicates that decreased surface area provides improved flow. In fact, when the two composites were ground to a 20 mesh particle size and measured for composite melt flow index (MFI) in accordance with ASTM procedures, values of 10 grams/minute and 18 grams/minute were recorded for the G-fiber and M-fiber based composites, respectively. Both moldability and MFI results indicate that decreased fiber diameter afford higher melt viscosity composites.

SUMMARY

The purpose of this investigation was to observe the effect of Fiber Geometry on the physical properties of Chopped Fiber Reinforced Thermoplastic Sheet Composites. Fiber Geometry was varied while all other process and composite parameters were held constant. ASTM procedures were used exclusively when preparing and testing samples. The effect of Fiber Diameter on composite flow was determined by comparing Absolute Flow values. The results show that Tensile Strength and Flexural Strength increase as Fiber Diameter decreases, and that these strength properties are independent of Fiber Length. Flexural Modulus is independent of both Fiber Length and Diameter. Impact Strength is dependent on both Fiber Length and Diameter. Impact performance improves as fiber diameter decreases and as fiber length increases. The slight drop off in Impact performance between 1/2-in. and 1-in. fibers is attributed to the lack of dispersion and some fiber entanglement of the 1-in. fibers when forming handsheets, resulting in slightly lower resin wet-out. Finally, composite flow improves as Fiber Diameter is decreased.

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PROCEDURES CITED

ASTM Procedures D638-89, D790-86, D1709-85 and D1238-88.

The Dynatup Impact values reported were recorded on a Dynatup Fall Dart Impact Tester, sold by Dynatup General Research Corporation.

REFERENCES

1. J. C. Watkins, P. C. Gaa, and R. G. Swisher, "Effect of Glass Fiber Diameter on The Mechanical Properties of Crystalline and Amorphous Thermoplastic Composites" SPE Antec, 1988.
2. R. L. Stadterman and T. Willis, "Thermoplastic Composites-Products and Applications" TAPPI Nonwovens Symposium, 1988.
3. J. M. Dick, P. Gerault, and R. M. Burkhart, "Structural Composites for Compression Molding" TAPPI Nonwovens Conference, Pg 253-258, 1989.
4. L. D. Yat and M. W. Edens, "A Unique Process for The Preparation of Random Fiber Reinforced Composites" TAPPI Nonwovens Symposium, 1988.
5. C. F. Diehl, W. J. McAdams, and K. M. Shaw, "Random Fiber Composites-Fiber Reinforced Thermoplastic Sheet Products" The Society of Plastic Industry, Inc., Session 5-E, Pg 1-7, 1987.

Figure 1. Diameter vs. Tensile Strength

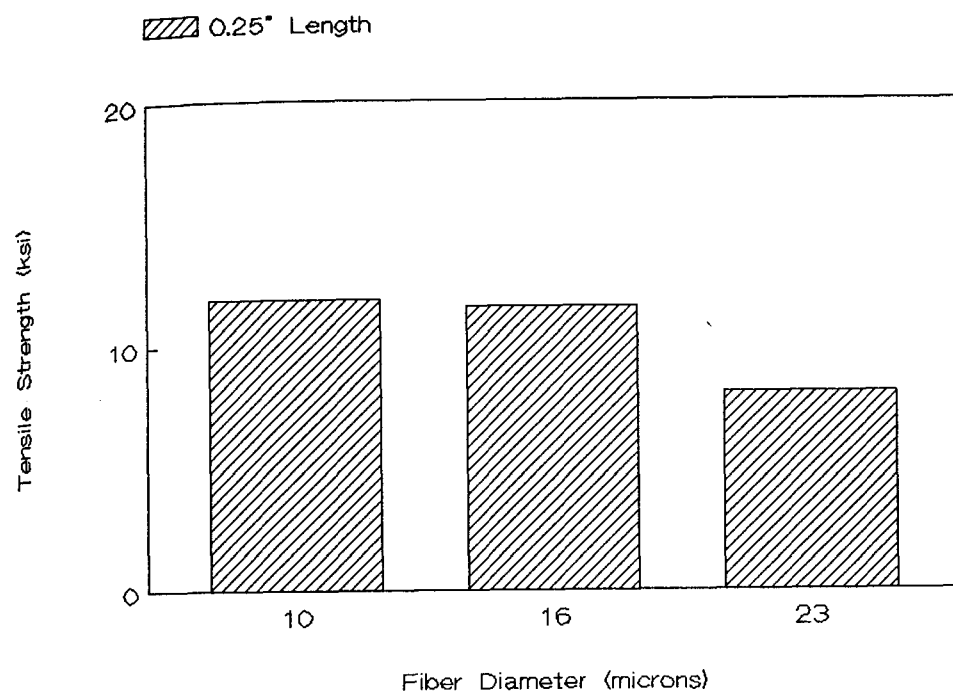


Figure 2. Length vs. Tensile Strength

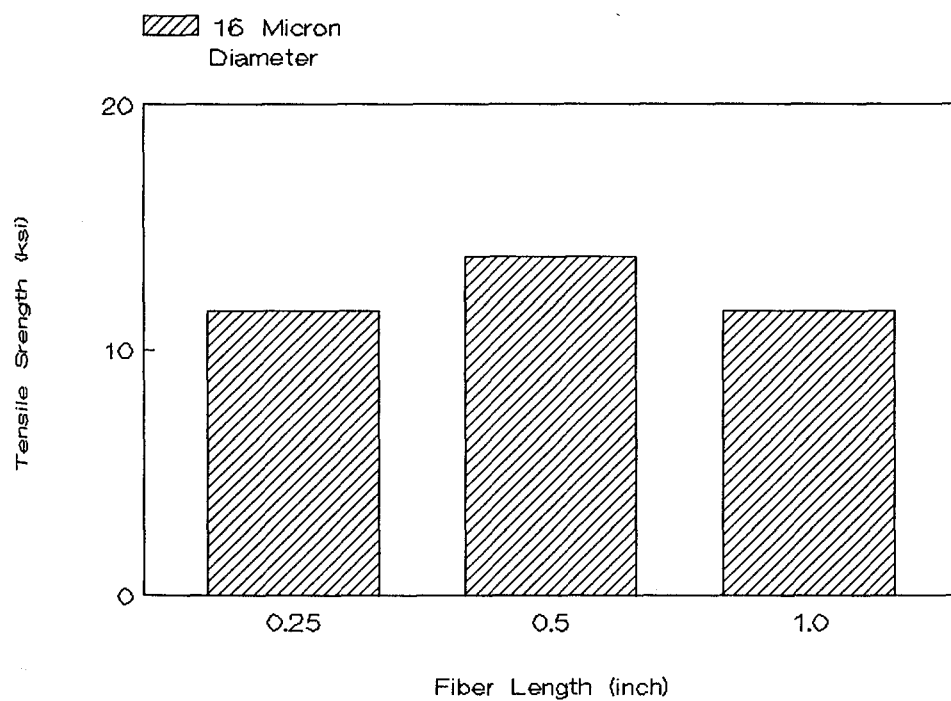


Figure 3. Diameter vs. Flex Strength

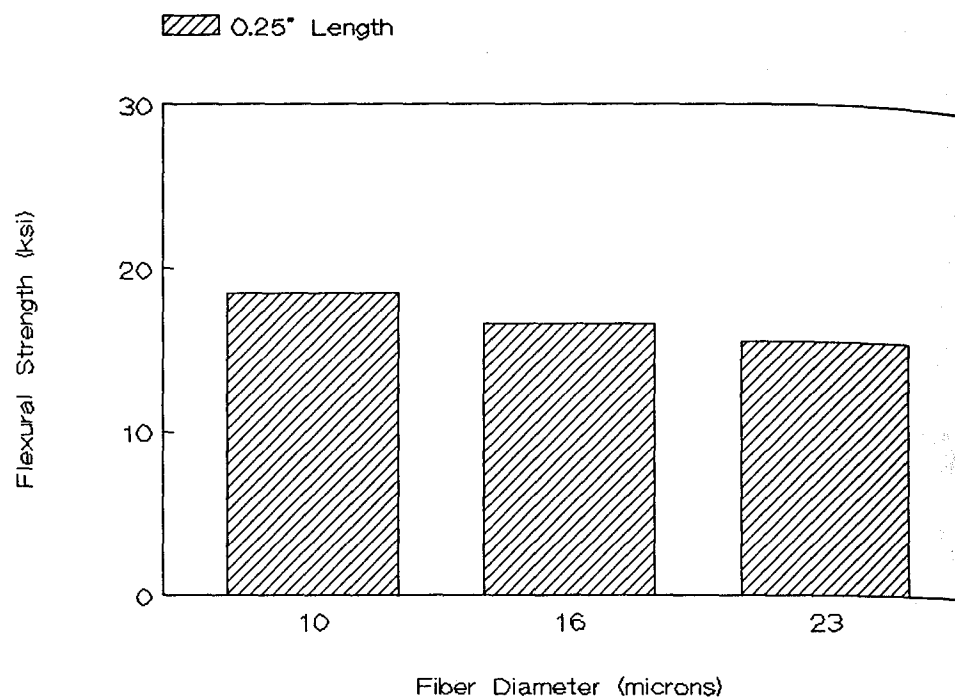


Figure 4. Length vs. Flex Strength

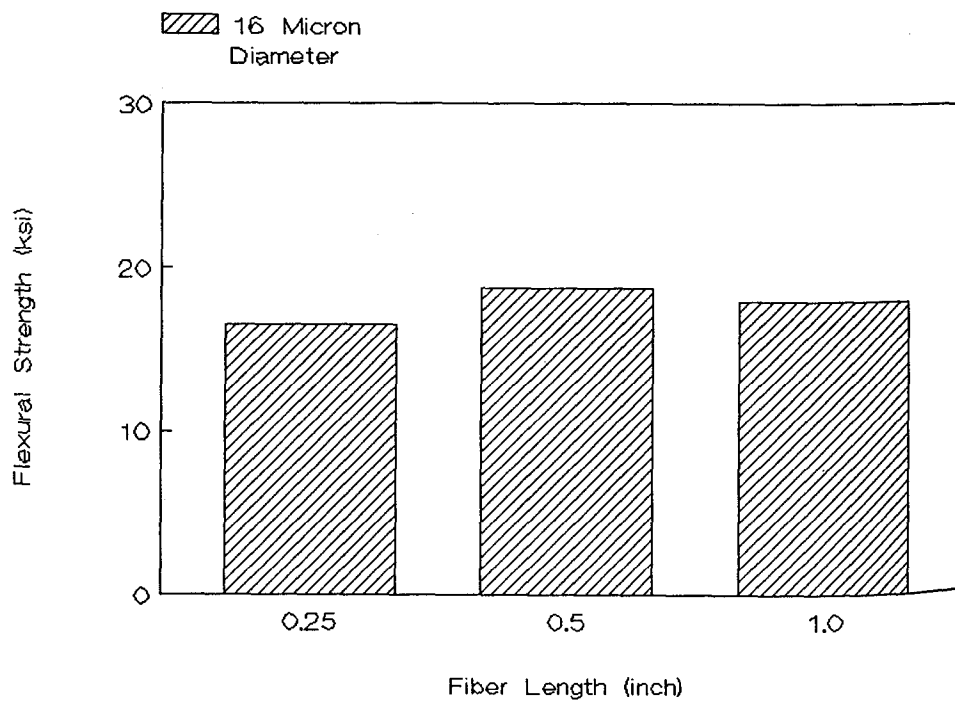


Figure 5. Diameter vs. Flex Modulus

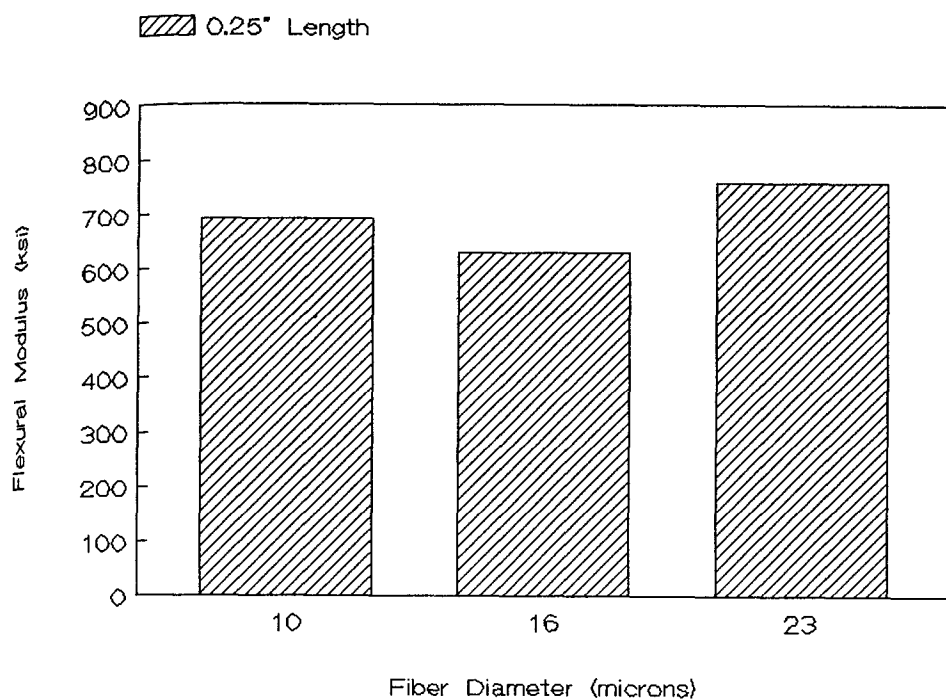


Figure 6. Length vs. Flex Modulus

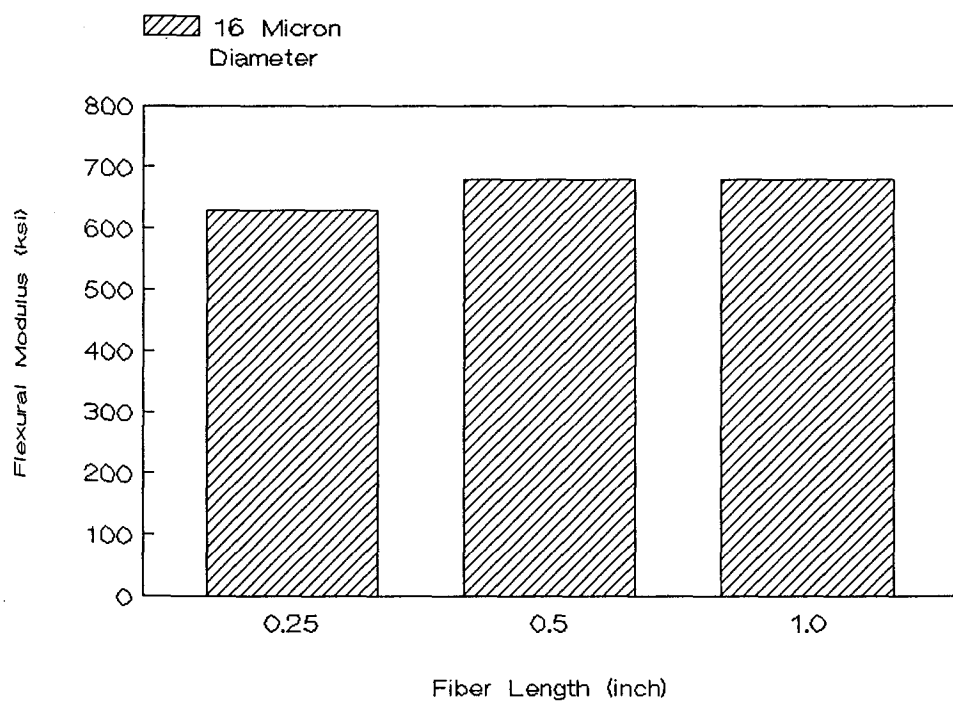


Figure 7. Diameter vs. Dynatup Impact

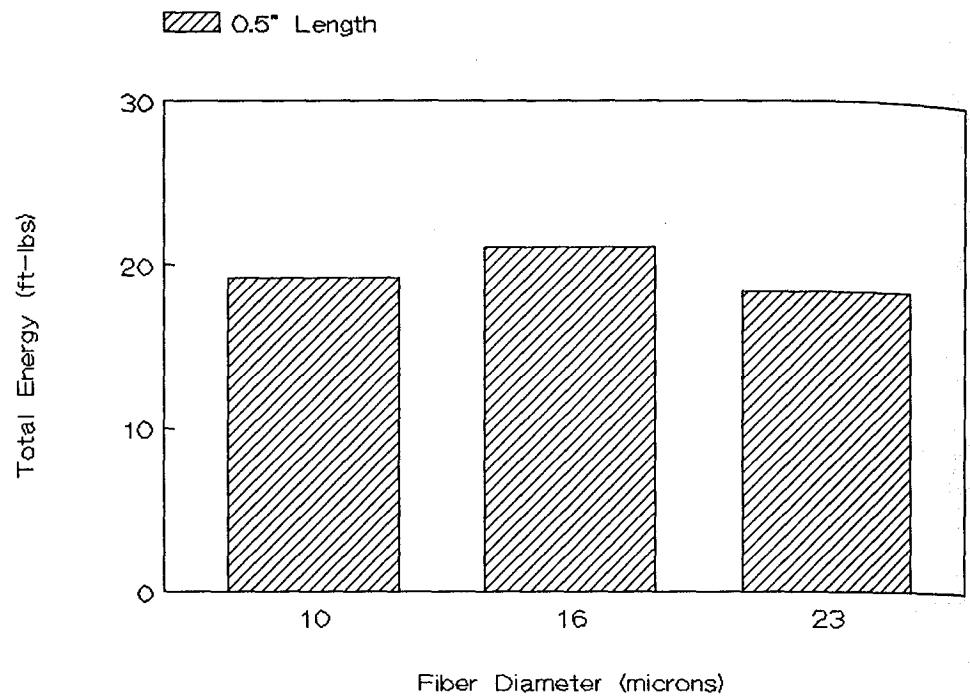


Figure 8. Length vs. Dynatup Impact

