INTRODUCTION OF CORN BY-PRODUCTS TO COMPOSITES FOR USE WITH IN-LINE COMPOUNDING

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Abstract

Composite Products, Inc. has been developing their Advantage and Advantage Plus In-Line Compounding Processes to use alternative reinforcements and filler materials for automotive and non-automotive applications. While fiberglass remains the favorite when it comes to reinforcing thermoplastic composites, natural reinforcements are beginning to gain renewed interest. Corn by-products when added to polypropylene can offer several advantages. Corn by-products offer low cost, weight savings, environmental friendliness, and relatively good material properties.

Natural Reinforced Composites Using In-Line Compounding

Although natural fiber composites have hung around automotive manufacturing since the 1940s, most of the practical automotive applications of natural fiber composites have taken place in the last decade or two and are numerous. The primary investigations of natural reinforcements for in-line compounding applications have been taking place since the late 1990s. Past reinforcements investigated have included: kenaf fiber, flax shive, sisal, jute, balsa core, wood flour and hemp. Previous investigations of these reinforcements have shown them to be good reinforcing agents as well as fillers to thermoplastic resin systems such as polypropylenes, polyethylenes, and polyesters. They have shown to work in conjunction with, or in place of, typical reinforcements such as fiberglass. The two primary limitations of natural reinforcements have been their hydrophilic nature requiring drying and their temperature sensitivity restricting their use to low melt temperature polymers.

Introducing Corn By-Products To Polypropylene Using In-Line Compounding

Through the use of in-line compounding, Composite Products Inc. recently used its Advantage Process to compound various corn by-products with polypropylene. Three variations of corn hull products were selected for evaluation. The selected materials, supplied by Grain Processing Corporation, offer a healthy infrastructure to ensure supply, are cost competitive with other natural fibers, and have a density similar to other natural fibers.

The three variations included in the study were corn hull, corn hull flour, and corn bran. Additionally, a hybrid of corn hull and fiberglass (13mm length) was trialed. The corn hull used where thin rectangular particles with length dimensions mostly between 0.5mm and 5mm. Corn Hull Flour and Corn Hull Bran where also thin rectangular particles with length dimensions mostly less than 0.5mm (a powder-like substance). With moisture weight content from the manufacturer below 0.5%, drying of the corn products was unnecessary. The corn products were in-line compounded and molded with a polypropylene homopolymer. Table I includes a summary of physical and mechanical properties of the four sets of composite test samples.

Table I: Comparison of physical and mechanical properties of corn by-products with the virgin resin.

	Base Resin PP-Homo	40%wt Corn Hull	40%wt Corn Hull Flour	40%wt Corn Bran	30%wt Corn Hull 10%wt Glass
Specific Gravity	0.900	1.028	1.043	0.976	1.028
Impact Strength, Notched Izod (J/m)	25	80	80	85	95
Tensile Strength - Ultimate (MPa)	34	25	22	29	35
Tensile Elongation at Break (%)	20	2	2	2	2
Tensile Modulus (MPa)	1,400	2,530	2,848	2,627	3,896
Flexural Strength - Yield (MPa)	41	43	36	47	60
Flexural Modulus (MPa)	1,448	2,062	2,117	2,186	2,868

When combined with the base resin, the corn products, by themselves, were able to enhance the impact strength and the stiffness (moduli) of the materials. Any loss to strength properties were quickly recovered when combined with a minor amount of fiberglass. As evident by the low elongation at break, brittle failure modes were observed on all samples made with the corn products.

Comparison of Corn with Other In-Line Compounded Natural Fibers

The corn by-products share a number of common advantages with other natural reinforcements.

- They help meet material cost-down pressures. Price is significantly lower when compared with fiberglass and the base resin.
- They help meet part weight savings goals. Low densities translate into part weight savings.
- They save time and energy. Low processing temperatures translate to short cycle times and low energy usages.
- They are a renewable and environmentally friendly resource.

The corn by-products also share a number of common disadvantages with other natural reinforcements.

- Temperature sensitivity limits the resin systems to those that melt below 200°C.
- Hydrophilic in nature, so they are sensitive to atmospheric moisture interactions. This translates to potential drying equipment and potential negative effects on mechanical properties.
- Odor emission. Like it’s natural fiber counterparts, the corn tends to retain odors through processing.

Table II compares the same mechanical and physical properties of corn products from Table I with other natural fibers produced using in-line compounding.

Table II: Comparison of physical and mechanical properties of corn by-products with other natural fibers in polypropylene homopolymer.

	40%wt Corn Hull	40% wt Corn Hull Flour	40% wt Corn Bran	30%wt Corn Hull 10%wt Glass	40%wt Kenaf Fiber	40%wt Flax Shive	30%wt Flax Shive 10%wt Glass
Specific Gravity	1.028	1.043	0.976	1.028	1.000	1.000	1.045
Impact Strength, Notched Izod (J/m)	80	80	85	95	185	89	113
Tensile Strength - Ultimate (MPa)	25	22	29	35	33	36	46
Tensile Modulus (MPa)	2,530	2,848	2,627	3,896	4612	3520	4807
Flexural Strength - Yield (MPa)	43	36	47	60	59	62	78
Flexural Modulus (MPa)	2,062	2,117	2,186	2,868	3834	3213	3412

The corn by-products tended to have lower mechanical properties when compared to Kenaf Fiber and Flax Shive. The Flax and Kenaf are more fiberous in nature with the ability to have aspect ratios higher than the corn hulls. This translates into higher load bearing properties. Given the particle size and powder-like nature of the corn samples tested in this sample, it seems appropriate to also compare the corn with other composite fillers like talc, calcium carbonate, and mica.

Comparison of Corn with Other Composite Fillers

Limited physical and mechanical data is available for the specific grade of polypropylene used in this study with in-line compounding of 40% by weight of talc, calcium carbonate, and mica. Nonetheless, there is enough data from similar processes and materials to make general comparisons with the corn by-products. Table III once again takes the physical and mechanical properties of the 3 corn products and compares them to literature compiled by the on-line materials property database MatWeb.

Table III: Comparison of physical and mechanical properties of corn by-products with other natural fibers in polypropylene.

	40%wt Corn Hull	40% wt Corn Hull Flour	40% wt Corn Bran	40%wt Mica Filler	40%wt Talc Filler	40%wt Calcium Carbonate (CaCO3)
Specific Gravity	1.028	1.043	0.976	1.21-1.24	1.20-1.26	1.22-1.25
Impact Strength, Notched Izod (J/m)	80	80	85	30-140	20-NB	30-110
Tensile Strength - Ultimate (MPa)	25	22	29	14-40	20-34	19-28
Tensile Modulus (MPa)	2,530	2,848	2,627	3,800-6,900	2,400-5,200	2,500-3,100
Flexural Strength - Yield (MPa)	43	36	47	28-53	29-62	32-48
Flexural Modulus (MPa)	2,062	2,117	2,186	2,207-6,000	1,900-4,100	1,586-2,800

The corn by-products fair well in this mechanical property comparison. The obvious unique advantage shared by corn and most natural fibers are the low densities. A low density is a primary component needed when discussing weight savings through the use of a filler.

Summary and Next Steps with Corn By-Products

It is a never ending search for formulating products, both automotive and non-automotive, with the perfect balance of low cost, high strength, low weight, and environmentally friendliness. In-line compounding has shown continued promise of finding this optimum set of materials through the use of some unique natural fiber reinforcements. Whether used as a reinforcement used in conjunction with fiberglass, or as a low-cost filler, corn by-products show excellent potential in the use of molded thermoplastic composite structures. Future work on corn by-products should include studying the effects of corn hulls with various resin systems, interactions with higher loadings of fiberglass and other reinforcements, studying interactions with atmospheric moisture, and studying it's interactions with color concentrates and other performance enhancing additives.

References

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