In-Line Compounding of Long Fiber Thermoplastics for Injection Molding

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SUMMARY: A new process has been developed for in-line compounding and injection molding in a single operation. Selected short to long fiber reinforced thermoplastic mixtures are created and fed directly into the injection-molding barrel while still hot. Compositions containing glass fibers of 3 to 12mm in length have been molded successfully on a 230 ton injection press. The new processing system is adaptable to existing injection molding machines. This novel technology permits molded parts to be produced with longer fiber lengths than heretofore possible, thereby improving finished product performance. In-line compounding also permits molded articles to be produced at cost levels competitive with those incurred when molding parts from conventional long and short fiber reinforced thermoplastic compounded pellets.

Key Words: Long fiber, injection molding, in-line compounding, Pushtrusion™, viscous entrainment, hot fiber chopping

Introduction

Investigation and development of the new process began in 1999 in the laboratories of Woodshed Technologies, Inc., which had been founded for the purpose of developing and commercializing in-line compounding of long fiber thermoplastics for injection molding. The new process utilizes the same formulation ingredients typically found in pultruded "long fiber" injection molded pellets [1]. The long fiber composites industry understands that impregnation/wet-out of the glass fiber filaments must take place prior to extensive mixing in order to preserve fiber length [2, 3, 5]. It is also known that initial contact of the resin and glass fiber must be done gently and is best accomplished by coating the glass fiber with resin melt [4]. The process gently coats continuous length glass fiber with resin in controlled percentages, chops the glass fiber into consistent, specified lengths between 6 mm to 25 mm while imbedded in molten resin, and feeds the hot mixture directly into the screw and barrel of an injection molding press. Since the material is hot when fed into the injection press barrel, longer fiber lengths can be processed and maintained. The in-line compounding process is available for licensing. Equipment is available as an add-on to the molder's existing injection press. This paper describes the features and advantages of in-line compounding for long fiber thermoplastic injection molding.

The In-Line Compounding-Injection Molding Process

The in-line molding process is represented by the schematic drawing in Figure 1. Thermoplastic resin pellets are fed into the hopper of the resin "shooter." The shooter is a typical injection barrel capable of melting resin, homogeneously mixing and injecting the melt into the process at high rates and pressures. Continuous length glass fibers are pulled from the supply creel and into the process die by the high-pressure flow of molten resin. The viscous entrainment die is designed to meter glass fiber and molten resin, keeping the glass fiber percentage within close tolerances. The glass fiber strand and molten resin mixture is pushed from the viscous entrainment die at 122 m to 183 m per minute. The process starts and stops instantaneously, as dictated by the material feeding requirements of the injection press barrel. An inline chopper cuts the glass fiber imbedded in the molten thermoplastic resin as it exits the viscous entrainment die. The chopper's cutting chamber is heated to maintain the cut mixture in the molten state and this cut mixture is directed through a nozzle positioned directly above the injection press screw. Glass fiber cut lengths of 6 mm through over 25 mm are possible. The process is capable of controlling glass fiber percentages within a narrow range. A total variation of less than 1% by weight is typical.

A single input signal from the injection press controls is required for the system to operate. When the injection press screw is turning, the system is delivering molten material. The system stops delivering material when the injection press screw stops turning.

Four significant process advantages occur when chopped glass fiber and molten resin are fed into the injection press barrel. 1) Conventional pultruded pellets in lengths of 25 mm or longer are difficult to feed. The mixture from the new process system is flexible, allowing very long fiber lengths to be processed without experiencing feeding problems. Cut lengths of 50 mm or greater would be possible if the injection press were large enough to handle them. 2) The resin has already been melted allowing for gentle mixing and maximizing retained fiber length of any given chop length. 3) The screw and barrel wear associated with pellets composed of partially melted resin and glass fiber is eliminated. 4) The resin has undergone a single melt history, minimizing degradation and improving physical properties. Table 1 summarizes the properties found in a typical part made of 40% long glass fiber reinforced polypropylene.

Figure 2 shows the new system mounted on a 230 ton injection press. The system is compact and efficient, in comparison with other in-line compounding systems, which involve weight feeders (with attendant material losses), compounding extruders, and accumulators, all mounted on an injection press. Figure 3 is a close up of the fiber / resin mixing chamber, viscous entrainment die and hot fiber chopper. The new in-line compounding injection molding process is initially targeted to mold composite parts from 0.25 kg to about 1.35 kg in size on presses with clamping capacities of 200 to 500 tons. Future larger systems employing the same principles are under development.

Economics

In-line compounding of long fiber thermoplastics for injection molding provides a compelling cost advantage. The same raw materials used to produce pultruded long fiber thermoplastic pellets are used in the new system. The economic advantage of in- line compounding and direct feed of the press is derived from the efficiency of the process and the elimination of a "middle man" processing step, thereby resulting in as much as a 50% reduction in raw material costs vs. purchased pellets.

References

1. R. C. Hawley, U.S. Patent 6,186,769 (2001), *Resin and Fiber Compounding Apparatus for Molding Operations*
2. R. C. Hawley, U.S. Patent 5,165,941 (1992), *Extruder Apparatus and Process for Compounding Thermoplastic Resin and Fibers*
3. R. C. Hawley, U.S. Patent 5,185,117 (1993), *Process for Compounding Thermoplastic Resin and Fibers.*
4. R. C. Hawley, U.S. Patent 4,312,917 (1979), *Fiber Reinforced Compound Composite Structure and Method of Manufacturing Same*
5. R. F. Jones, *Guide to Short Fiber Reinforced Plastics,* Hanser Publishers, Munich 1998

Table 1 Product Properties

Physical Properties	**Direct molded LFTP**
Fiber Length	**12 mm**
% Glass Fiber	**40**
Polymer	**Polypropylene**
Tensile Strength, MPa	**125**
Tensile Modulus, MPa	**10,350**
Flexural Strength, MPa	**167**
Flexural Modulus, MPa	**7,800**
Notched Izod, J/m	**382**

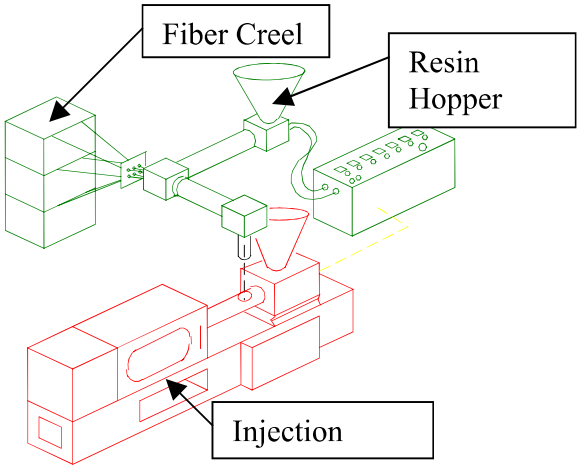

Figure 1
In-Line Molding System Schematic

Figure 2
In-Line Compounding System

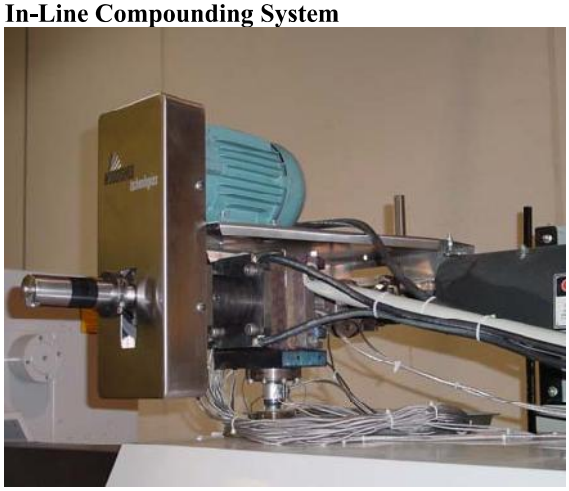

Figure 3
Fiber chopper