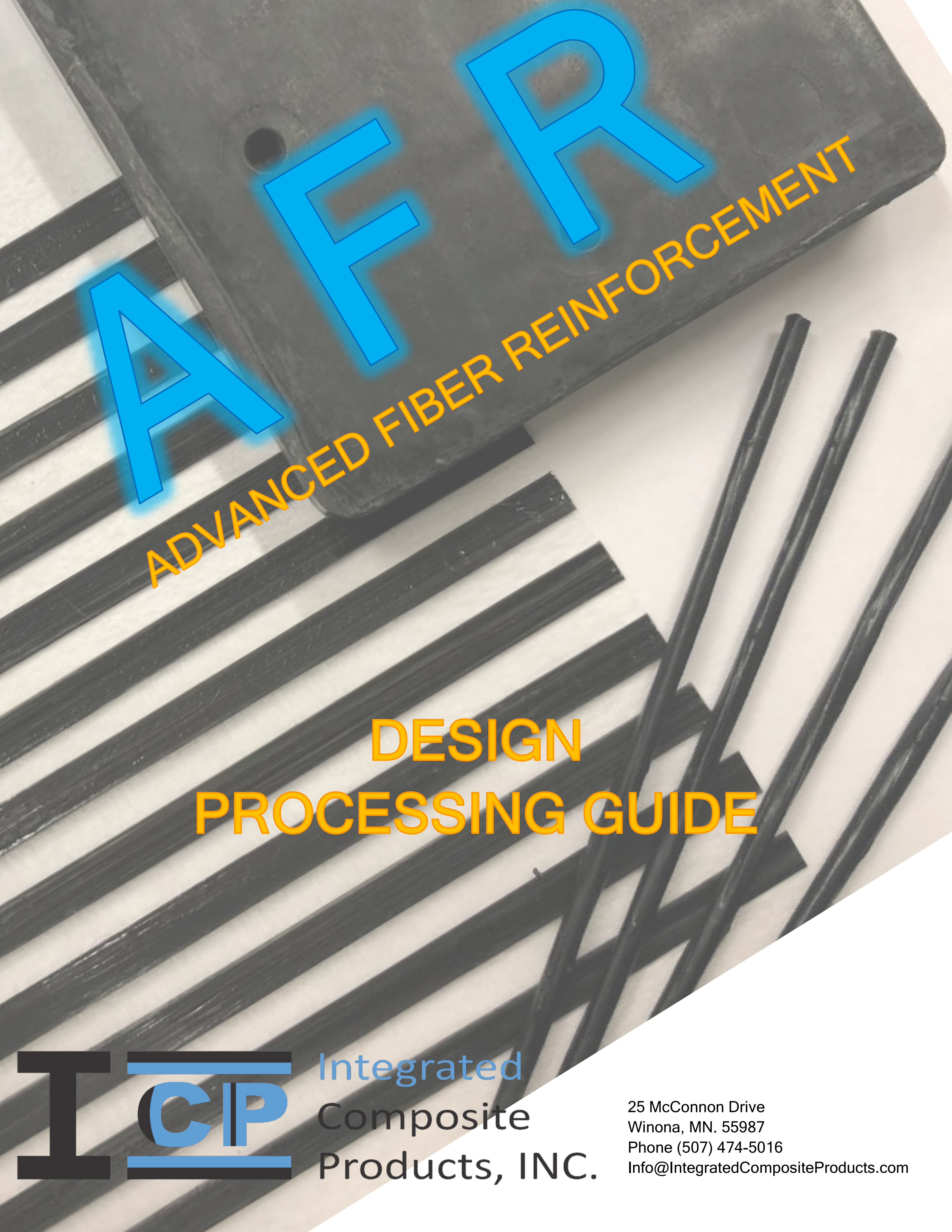

AFR

ADVANCED FIBER REINFORCEMENT

DESIGN
PROCESSING GUIDE

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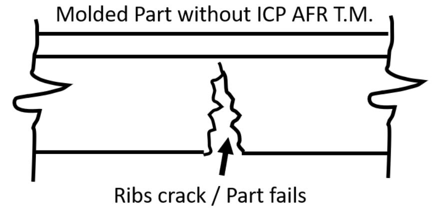
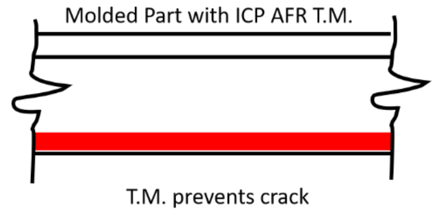
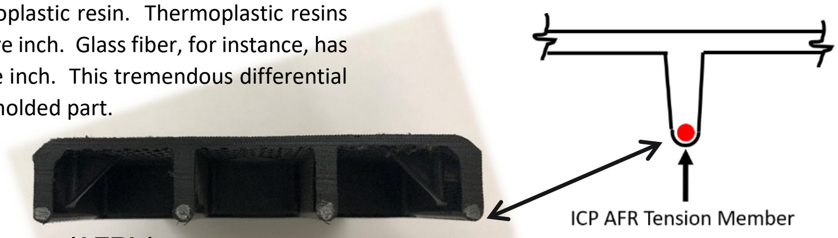
What are Advanced Fiber Reinforcements (AFR's)?

Reinforcing fibers (glass, carbon, graphite, ceramic etc.) are stronger than the thermoplastic resin they are embedded or encapsulated in. Typical reinforcements in a molding compound are chopped reinforcements of 1 to 12 mm in length. Diameters vary between 12 and 20 microns. Stress on a molded part made with these reinforcing fibers is transferred from fiber filament to fiber filament through the base thermoplastic resin. The strength of a molded part is therefore determined by the bonding of the thermoplastic resin to the reinforcing fiber and the strength of the thermoplastic resin.

ICP's Advanced Fiber Reinforcement's (AFR's) are **continuous length reinforcing fibers** (glass, carbon, graphite, ceramic etc.) embedded / encapsulated / wet out with thermoplastic resin. In most cases, the ICP AFR is used in such a way as to place the AFR member in tension. Since the reinforcing fibers are continuous length the stress is transferred along the entire length of the AFR without going through the lower strength thermoplastic resin. Thermoplastic resins have tensile strengths of 5,000 to 15,000 pounds per square inch. Glass fiber, for instance, has a tensile strength of as high as 300,000 pounds per square inch. This tremendous differential in tensile strengths can be very helpful when designing a molded part.







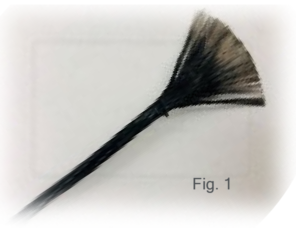
Proper Placement of Advanced Fiber Reinforcements (AFR's)

AFR's are designed to be used as "Selective Reinforcements" in a thermoplastic molded part. Stress and strain are not constant in every location within a molded article. Certain areas are under more stress than other areas. A homogeneous molded part will be heavier and more-costly because more expensive material is used throughout the part even in areas where it is not needed. A study of failure modes will determine locations likely to fail and these locations can then be reinforced with ICP's AFR's to greatly improve the molded part's performance. Performance gains of 200 to 400 percent are common without adding significant weight to the part. The design engineer then has the latitude to decide: 1) "Should the molded part be improved by this much?", or 2) "Should the molded part be redesigned to lower overall weight and cost?". ICP will need to know the length of your required "Selective Reinforcement" and will supply the correct length ready to be used in your molded article.

Rib design for ICP AFR Tension Members (T.M.)

ICP's Tension Members (TMs) can and will improve the strength of all rib designs; however, some rib designs show better improvement than others. The number of fiber filaments within a TM will also have a significant bearing on the amount of improvement of performance within a given rib design. ICP has completed significant test data performance on many different rib designs (i.e. length and width of a rib) and can provide this complete rib design and performance report upon request. ICP will need to know your process, required lengths and number of filaments in order to provide the currect TMs for your application. Below images show an example of a TM with glass filaments (Fig. 1) and a rib design coupled with ICP AFR TM (Fig. 2).

AFR Tension Member (T.M.) Sizes:
T.M. 4,000 – 0.070 Inch Diameter
T.M. 8,000 – 0.100 Inch Diameter
T.M. 12,000 – 0.121 Inch Diameter
T.M. 16,000 – 0.140 Inch Diameter
Cut and Delivered to length.



Tension Member showing fiber filaments

Fig. 1

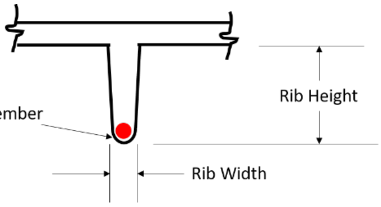


Fig. 2

ICP conducted a molding study of various rib designs (i.e. different rib heights and widths) utilizing Tension Members reinforced with 4,000, 8,000 and 12,000 glass fiber filaments and placed at the end of each rib. The molded test bars were nine inches in length overall and then tested in flex to give the ultimate flex strength improvement with each Tension Member. The test fixture span was 7.25 inches and cross head speed was 0.375 inches per minute and test bars were supported both under the rib and second major surface of the test bar. Test data in total pounds to failure and inches of deflection is given below (average of 5 test samples) :

ICP Tension Member Data: Pounds of Force to Failure

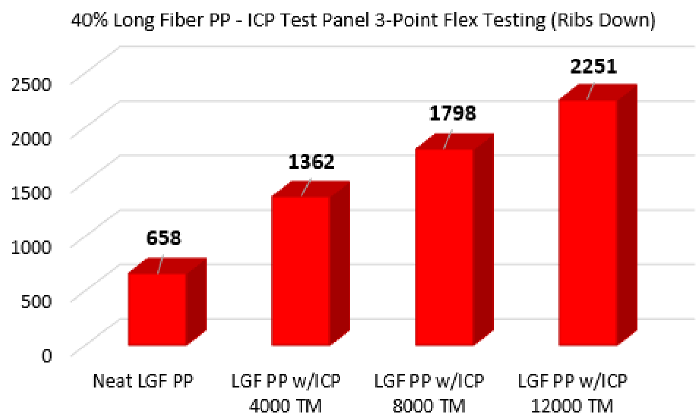
Rib Height (inch)	1.0	0.5	1.0	0.25	0.5	0.75	1.25	1.5	1.14	0.326	1.14
Rib Width (inch)	0.106	0.25	0.125	0.125	0.125	0.125	0.125	0.125	0.371	0.315	0.25
Neat	201	231	285	90	116	145	221	389	1,300	168	877
4,000 f	362	304	510	136	261	339	524	702	1,384	199	1,124
8,000 f	471	367	600	131	293	371	578	843	1,560	233	1,119
12,000 f	598	413	789	80	214	397	799	1,188	1,591	223	1,196

ICP Tension Member Data: Inches of Deflection - Comparative

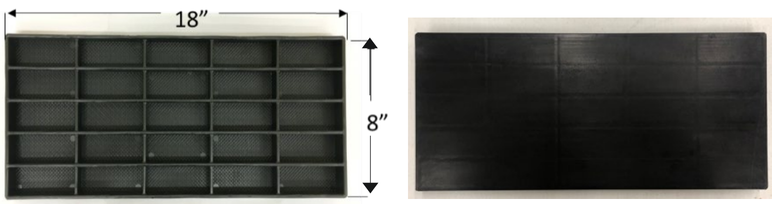
Deflection (Inch)											
At _____ Pounds	200	200	200	75	100	100	200	300	1,300	100	700
Neat	0.147	0.233	0.104	0.289	0.217	0.074	0.080	0.087	0.230	0.170	0.190
4,000 f	0.124	0.187	0.085	0.242	0.114	0.060	0.063	0.074	0.213	0.179	0.164
8,000 f	0.093	0.168	0.084	0.215	0.100	0.050	0.058	0.084	0.206	0.160	0.143
12,000 f	0.108	0.154	0.073	0.240	0.095	0.044	0.056	0.082	0.187	0.150	0.132

In addition, ICP also compression molded 8” wide x 18” long x 1” tall ribbed panels using Tension Members and test data is below:

Tension Member Test Panel Data



ICP Test Panel 8” x 18” x 1”



ICP AFR Structural Members (SM)

ICP’s Structural Members (SMs) improve the impact, flex strength, long-term creep, and modulus in the “second major” surface of a molded article. These SMs are produced by a pultrusion system that adds a binding “non-woven scrim” component designed to hold the reinforcing filaments together for proper placement and still allowing the molding compound the ability to flow through the scrim and encapsulate the filaments on the underside within the molded part. The patented placement of these SMs on the second major surface allows for the show surface to be resin rich and meeting surface quality requirements (Fig. 3). Proper design of the mold with texture on the second major surface is required to achieve proper molding compound flow through and encapsulation of the SM. A texture depth of at least .015” -.020” is required on the second major surface to allow for proper encapsulation (Fig. 4). Supplying the proper SMs, ICP will require your needed width and length dimensions for application needs.

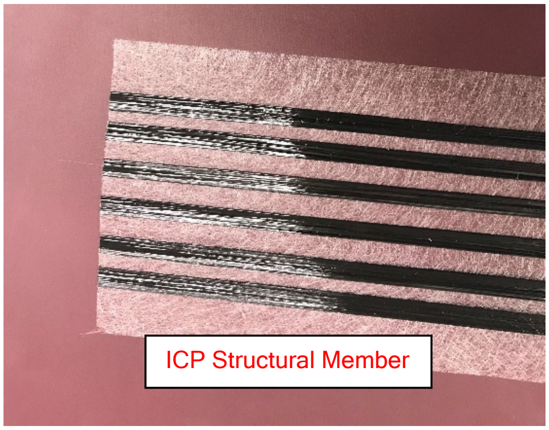
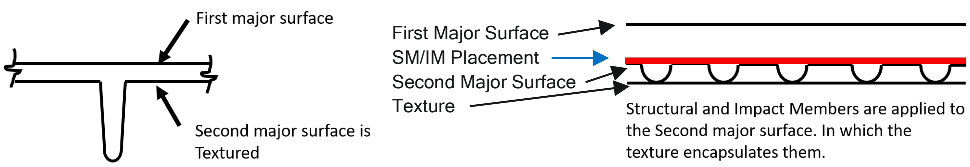
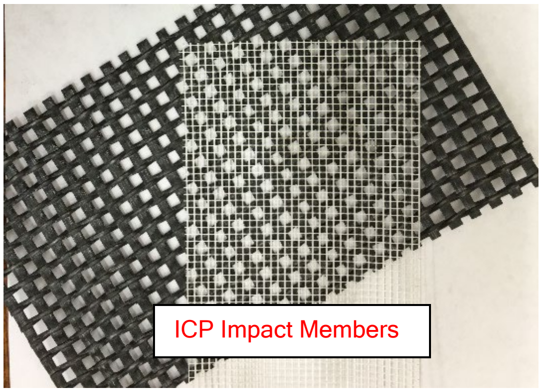
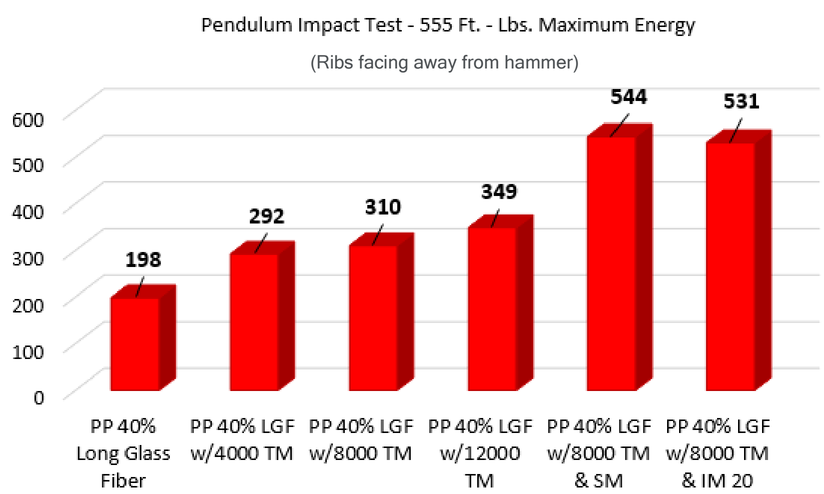


Fig. 3





Structural/Impact Member Data



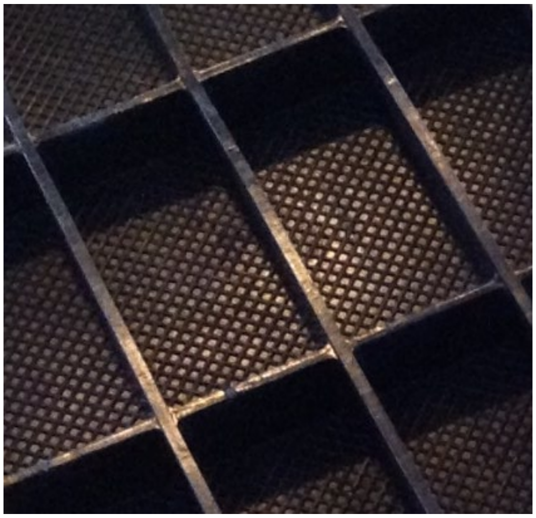


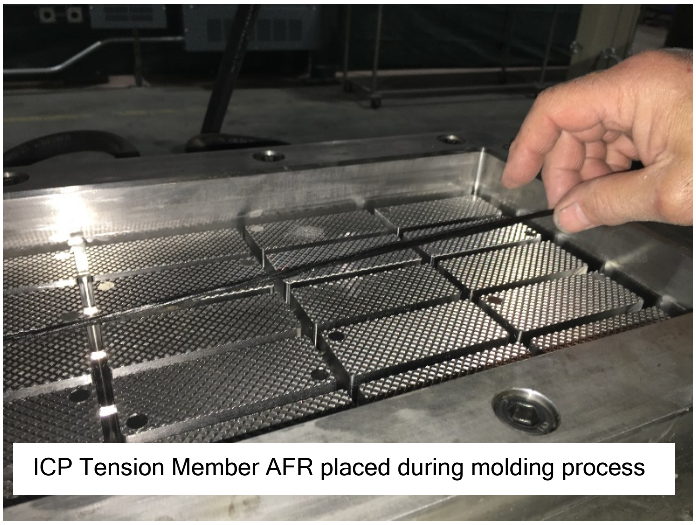
Fig. 4 Texture showing in a molded part

Molding/Processing Methods Recommended Using ICP AFRs

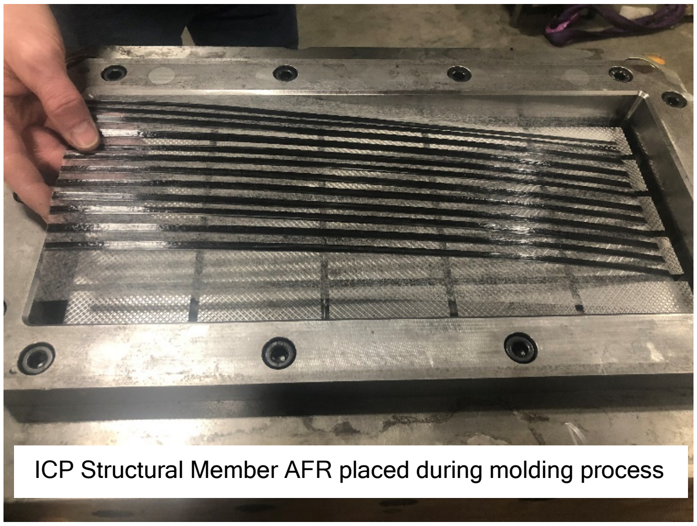
Compression Molding: Most of the work that ICP has done to date has been using compression molding of thermoplastic composite materials. The benefit of using compression molding is that the mold opens and closes in a horizontal fashion, thus allowing for gravity to keep the AFRs in place during the molding/shaping of the molded article. The molded articles produced to date with ICP's AFRs have been larger structural parts, which compression molding is a common method of producing such parts.

Injection Molding: ICP has done limited molding using AFRs with the injection molding process. The main issue is that the mold in injection molding normally operates in a vertical fashion (unless vertical injection molding is used), thus making it more difficult to "hold" the AFRs in the mold during processing. When inserting ICP's Tension Members (TMs) in the bottom of the rib(s), a small amount of force is required to press them to the very bottom of the rib. Installing TMs can be done either manually, or with robotics having proper end-of-arm tooling to properly install these in the bottom of the rib. When Structural Members and/or Impact Members are used in injection molding, the mold should be equipped with a vacuum system on the "second major surface" (usually the "B" side) to hold the AFRs in place – this is a process similar to insert molding of paper, or in-mold labeling production.

Other Processing Methods: Processing methods such as Structural Foam Injection Molding, Injection/Compression Molding, Thermoforming and others may also benefit from the use of ICP's AFRs; however, these other processes have been investigated on a limited basis at this time.

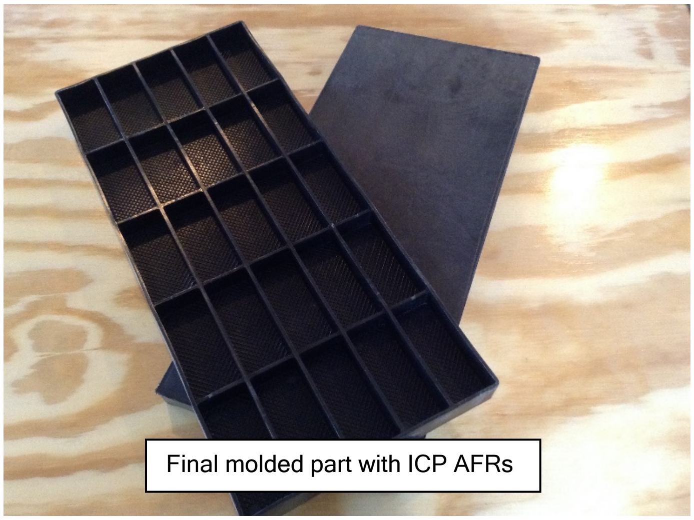


ICP Tension Member AFR placed during molding process



ICP Structural Member AFR placed during molding process

Placing the LGF compound in the mold after AFRs in place



Final molded part with ICP AFRs