CONTINUOUS PROGRESS!

Performance Friction Corporation launched its new carbon-carbon friction material at PRI, claiming that its continuous fibre technology could revolutionise the carbon brake market. Alan Lis reports

THE sample brake disc on display at the PFC booth caused consternation among the rival carbon-carbon brake manufacturers and distributors as it bucks the current trends in this technology.

PFC President Don Burgoon explains, "Our carbon disc is a little different. There are a variety of ways to make carbon discs. One way is to take a carbon tow, run it through a phenolic bath and chop it into $^{1}/_{2}$ - $^{3}/_{4}$ inch lengths to form what is called a pre-preg.

"The pre-preg material is put into a mould and subjected to heat and pressure to form a disc, which is then heated in a furnace to carbonise it. After that it is taken up to higher temperatures under the correct atmospheric conditions to densify it, making carbon-carbon.

"Another way is to take carbon felt, which is considered three-dimensional but the fibres are actually laid up two-dimensionally. A three-dimensional structure is formed by needling but there is a limit to how deep the needles can go into the felt. Once you have the 3D matrix laid up, you essentially follow the same carbonisation and densification processes.

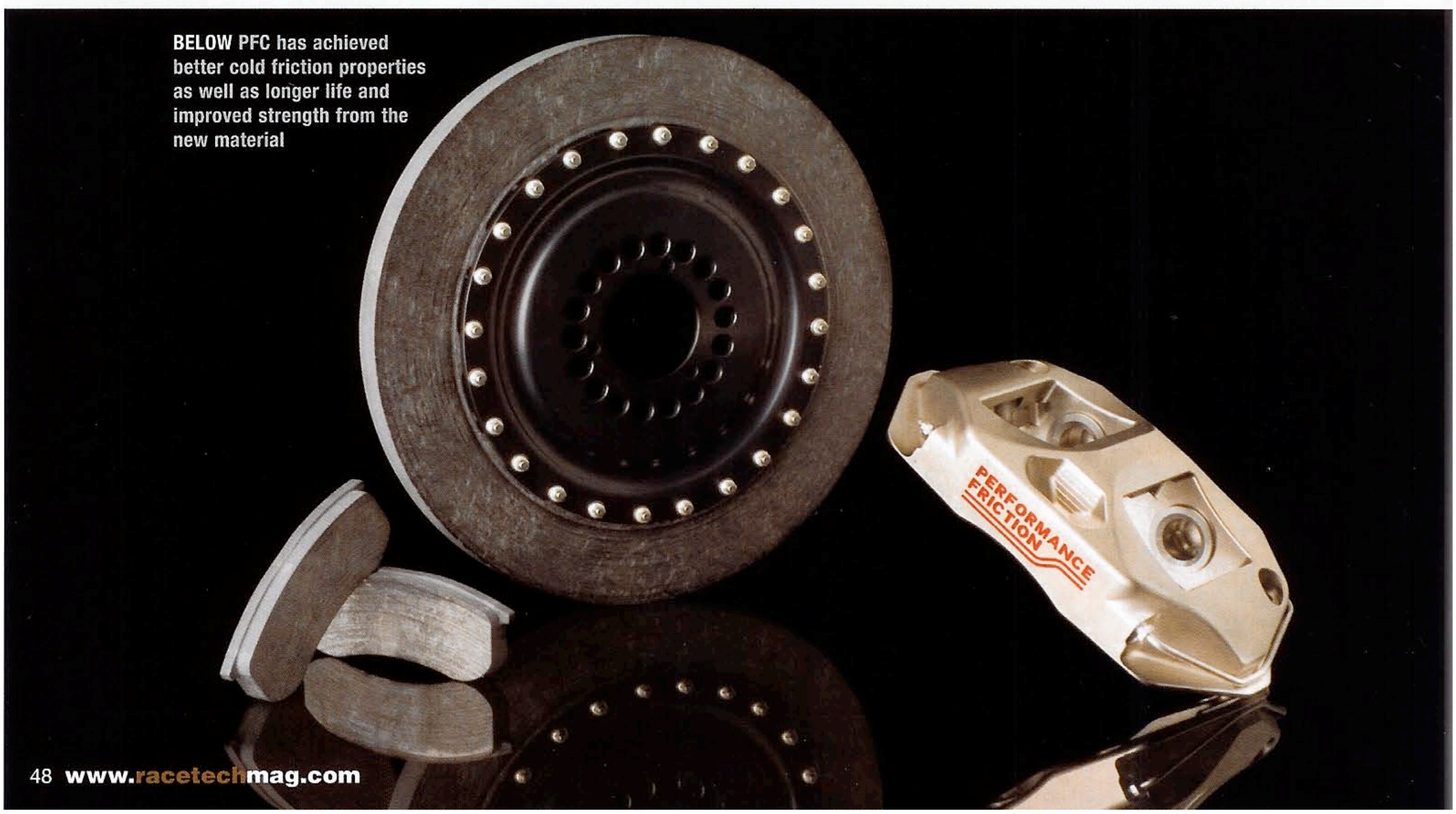
"A further method is to take woven carbon cloth, cut out doughnuts and lay them up to form the shape of a disc before following the carbonisation and densification processes.

"Our process is different because we have a continuous fibre that is wound into the disc shape. It is wound both circumferentially, radially and in the z-direction, so that you have a true three-dimensional and continuous fibre.

"The important thing to understand is that a carbon fibre has very high thermal conductivity over its length; in the perpendicular direction of the fibre, thermal conductivity isn't nearly as high.

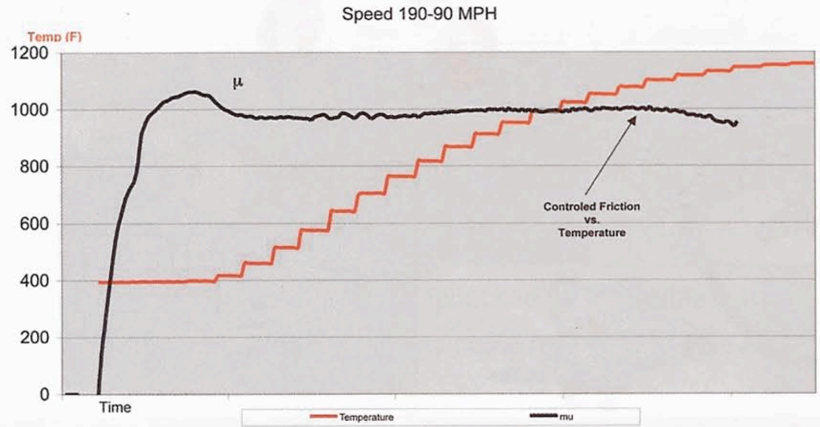
"When you make carbon-carbon what you are doing is forming carbon crystals or droplets on the fibres. These crystals interlace with those on the adjoining fibres but the thermal conductivity between the fibres via the crystals is not very high. Put simply, you have very high thermal conductivity in the direction of the fibre as it has been wound but limited thermal conductivity between adjoining fibres.

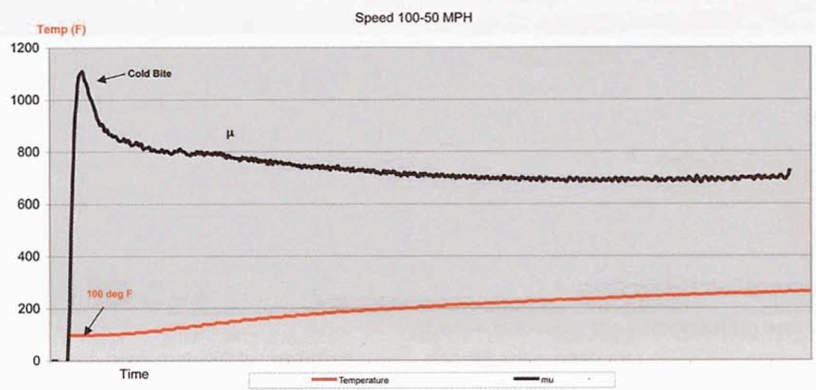
"To make a brake work well, you want maximum thermal conductivity and to effectively use the disc as a radiator so you can get the heat out of the system. If you cut the fibre, you lose the thermal conductivity as soon as the fibre ends. In ▶



BELOW PFC has achieved better cold friction properties as well as longer life and improved strength from the new material

BELOW The dyno data testifies to the material's constant friction. It is, says Burgoon, the best he has ever seen





terms of heat transfer, there is a huge benefit in using a continuously wound fibre to form the disc and there is also a huge benefit in terms of strength. The continuous fibre is extremely strong and gives the disc a far greater burst strength and higher structural integrity than discs made by other methods.

"Another benefit is that there are no contaminants that could affect the CVD (carbon vapour deposition) process. If you start with no impurities, you end up with a better disc.

"What we have been able to achieve with this continuous fibre production method is a stronger disc that has more consistent friction properties and has a flat torque curve.

"In fact, the torque curve is absolutely flat and the wear properties are incredibly good. The other thing that we've been able to achieve is better cold performance from temperatures starting as low as 100 degrees F. In other words, you could park the racecar for a while and still be ready to go for turn one on the first lap."

Using the continuous fibre production method results in the same production lead-time of around six months as other carbon-carbon production methods.

"Our base material before densification is different in its mechanical properties," says Burgoon, "but the carbonisation and densification processes are as in other carbon-carbon manufacturing methods with minor changes."

The continuous fibre method also results in a disc that does not have the traditional radially drilled ventilation holes on its outer circumference.

"We have ventilation holes in our iron discs," says Burgoon. "It does not necessarily follow that we should have them in our carbon-carbon discs. That is not the way that carbon-carbon works. In my opinion, a major reason for the ventilation holes in carbon-carbon discs is that people try to use carbon and carbon composite components in the same way as metallic components and that's not always appropriate.

"Take, for example, a thin wall tubular bicycle frame. In metal that is a proven structure; in carbonfibre, it would not be as good because the geometry of the carbon structure would not be optimised. We have applied that principle to the manufacture of our brake discs.

"You have to build the disc according to the properties of the material that you are working with. The reason that we don't drill ventilation holes in our discs is the continuously wound fibre. We don't want to interrupt the fibre because it damages the thermal properties of the disc."

With its new material PFC is targeting any market that allows the use of carbon-carbon brakes, including Formula One. "We have done some testing with teams in various series," says Burgoon. "The carbon-carbon disc that we displayed on our stand at the PRI Show had not only been track tested but had also been on a dynamometer for a race distance. A lot of people thought it was a new disc. No one has raced the carbon-carbon disc yet but we have some customers lined-up who will race it in 2006."

Manufacturing of discs is done in conjunction with PFC's unnamed technical partner at an undisclosed location. At the time of writing, PFC declined to answer questions on the manufacturing process, such as the method of winding. "We have to be careful what we say about it," says Darrick Dong, PFC's Director of Motorsport, "The other companies that manufacturer and distribute carbon-carbon friction material are very keen on keeping the details of their technology close to their chests. As far as we understand it, we are the first company to introduce this technology to motorsport." ▶

"As we understand it, we are the first company to introduce this technology to motorsport"

RIGHT The continuously wound fibre surface seen in detail

The method for mounting the carbon-carbon discs on the disc bells is similar to that used by PFC for its iron discs. "The reason we use that mounting is that it puts your attachment mechanisms in double shear and takes the moment out of the disc flange," says Burgoon. "It's more direct in the way it takes out torque, which removes a lot of the twisting and is far less stressful on the component."

Burgoon adds that, given the heat rejection and heat management properties of the PFC solid carbon-carbon disc, a customer will be able to use a narrower disc compared to a conventional carbon-carbon disc.

"It's possible to use a thinner disc simply because you don't need the extra width to make room for the ventilation holes," he says.

So how does the weight of the new material compare with rival materials? "I can't speak for the other manufacturers, but our density is around 1.78," says Burgoon. Dong adds, "Density is obviously the key to all carbon, so the true density of the material is something that we don't want to go into too deeply."

The lack of conventional ventilation holes in the disc suggests that more thermal load will be imposed on other parts of the brake system. So will the use of a dedicated caliper be required?

"With carbon-carbon the majority of the heat is rejected through the face of the disc and radiation which the ventilation holes won't help if you have instantaneous heat transfer," Burgoon explains. "Obviously the user will need to address the heat and the radiation that carbon-carbon will generate. He will need to address the whole system depending on the car and what it is used to running. If he is switching from iron discs to carbon-carbon, he would obviously need to look at the cooling and ducting required for the thermal issues that he was going to face."

"The ducting used with our discs will be more in-line with what Formula One teams are doing in using drum-type ducts to provide face cooling as opposed to centre vent cooling," adds Dong. "What we would recommend is disc face cooling and pad cooling and what cooling the upright needs to keep the bearings happy.

"With larger diameter discs, from 350-380mm, bearing temperatures may not be much of an issue. In smaller disc applications, say 288 mm, bearing temperatures will be a huge consideration."

The same manufacturing method used for disc production is also employed for the compatible carbon-carbon brake pads and, according to Dong, this has resulted in a further performance gain.

"The material has shown itself to have very little temperature sensitivity in the testing that we have done so far," he says. "The drivers have told us that the material has higher bite than the current sprint-based specs that they have been accustomed to from other manufacturers. Our wear testing indicates that the pads have easily the same wear rate and driveability as rival endurance spec materials.

"The biggest single advantage that the drivers have reported is that because the torque curve was so flat, modulation was greatly improved. There wasn't a friction rise with temperature with the material.

"They think that the biggest advantage is going to be on re-starts because they won't have to worry about getting the discs, pads and other parts of the system up to temperature as they try to get into turn one ahead of the other guy."

With regard to caliper design, Burgoon says that, depending on what a series regulations allow, PFC will use multi-pad calipers with the carbon-carbon material.

Dong adds, "There will also be provision made for quick pad changes if required. We can't tell what the wear rate is going to be compared to other products on the market but, based on the information that we have, we think there will be a significant lap time advantage."

So how do the friction characteristics of PFC's new material compare to other carbon-carbon materials? "The friction that we have seen on the dyno with our carbon-carbon material is the most consistent that we have ever seen, even down to 100 degrees F." says Burgoon.

"It's also the highest friction that we have seen for any material we have ever tested and it lasts longer than anything we have ever tested. Keep in mind that we have had three dynamometers running 24/7 for the last 15 years..." ■