INVESTIGATING CARBON BICYCLE ACCIDENTS

Was It a Defect or Something Else?

By James Mason

In July 2018, Eric Barton from *Outside Magazine* reported on a rash of unexpected failures of carbon fiber reinforced bicycle frames, which resulted in severe injuries to the riders. If a rider is traveling at 20 mph and the front fork breaks into the spoke and suddenly locks the front wheel, then the rider can be launched 15 feet or more ahead of the bike, likely resulting in significant injuries. Barton reported that all carbon fiber components are susceptible, including handlebars, forks, seat posts, and frames.

The failures have caused some to question the durability of carbon fiber composites in general. However, the possible existence of a defect should always be investigated. Barton implied that by attempting to lower production costs, manufacturers may be producing more defects.

One of the foremost questions to ask when investigating a bicycle accident involving a carbon component or frame failure is whether the accident caused the failure or whether the failure caused the accident. In order to answer that question, an investigator needs to consider several types of defects that might exist in the composite materials used in the bicycle's components or frame. But before defects are discussed, let's get more detail about how carbon composite bicycles are made.

BUILDING BLOCKS

A composite material is defined as a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. Steel-reinforced

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concrete, for example, is a composite where the combination of the two materials increases the final product's strength. Fiberglass' polyester and glass fibers is another example.

Carbon fibers are often added to an epoxy to make carbon fiber materials. The material to which the fiber is added is called a "matrix." A carbon fiber material can be comprised of any number of matrix materials with carbon fibers added. Carbon fiber composites have increased in popularity in the bicycle industry over the last two decades due to their low weight, high stiffness, and high strength. A quality carbon bike frame can weigh about 1.5 pounds, while a good steel frame typically weighs about three pounds.

Generally, the carbon fiber used comes in rolls of thin sheets of uncured epoxy resin that is pre-impregnated with long, continuous fibers (prepreg). How much resin is present, and what type it is, depends on the grade and end use of the carbon fiber prepreg. These are then added together in layers to form the preliminary part. To give the manufactured component good properties in multiple directions, the angle of the fibers is alternated or varied in each layer. This process is called the "layup" step, and the angle of the fibers in each layer is often listed as the "layup orientation." See figure one for more detail.

A variety of techniques can be used to make the entire bicycle frame, but typically after layup the assembly is placed under pressure to ensure the layers are pressed tightly together, then baked to cure the epoxy that joins the layers and hardens up the entire frame. During this process, it is relatively common for wrinkles and voids to appear where air remains trapped between layers. These are called "delaminations," and they can result in a weaker frame.

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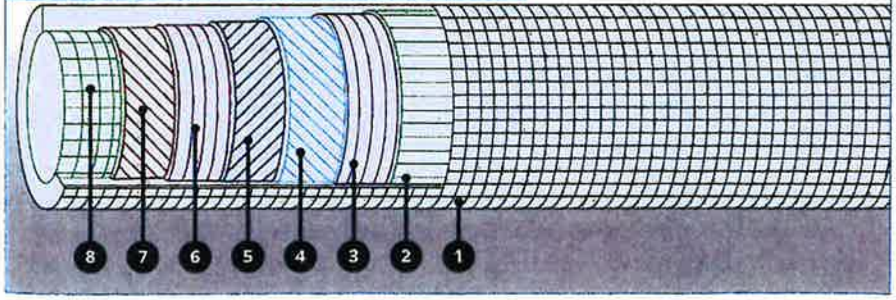
ALL DEFECTS ARE NOT THE SAME

There are many types of defects that can occur and must be considered when investigating bicycle accidents. First, there can be delaminations due to manufacturing errors, as previously mentioned. Delaminations are particularly nefarious because they can lie dormant for miles of riding, growing slowly but undetected until they reach a critical size and cause a failure. In some cases, they grow to near-critical size and, when the rider hits a particularly large bump in the roadway, a failure results. In this case, the rider might blame the bump, not realizing that a defect was the actual cause.

There can also be voids in the material. Voids between the layers are more or less delaminations. Voids within the matrix, however, are different. These can act like perforations in paper, allowing the material to be torn apart along the voids more easily than expected. And the fibers themselves can be weak or broken, causing them to act like voids by providing perforations for easy tearing of the material. But they can be worse than voids in the matrix, because their added reinforcement is also lost.

Finally, there can be inclusions in the composite—materials that shouldn't be there. Such inclusions can cause stresses to be elevated.

FIGURE ONE: EXAMPLE OF A TUBE LAYUP.



INVESTIGATING CARBON COMPOSITE ACCIDENTS

The investigation of defects in carbon fiber composites can be challenging. The complex structure of the material can make the investigation tedious and lengthy. Often the fracture area is frayed, with lots of created surfaces to examine. If both sides of the fracture are recovered, one side is examined in depth, using optical microscopy and possibly scanning electron microscopy, excising each of the fracture surfaces as needed. The methods of fractography—the study of fracture surfaces—are applied to trace the failure back to its origin. Once origin is identified, the material is examined for any defects, such as delaminations, voids, inclusions, or another type of defect.

If no defect is found, then the investigation turns to the stress on the component. In such cases, it might be necessary to perform computer modeling to calculate and visualize the forces applied and the resulting stress created in the component, due to the complexity of the geometry and of the composite materials. The stress calculations are then compared to the expected strength of the defect-free material. If the calculated stress is higher than the strength, then the failure is explained and was likely due to excessive loading or improper design. If it is not, then mechanical testing of the material might be needed to determine its actual strength. In the end, determination of the cause of the fracture will point to the responsible party and will indicate proper actions to take to prevent it in the future. ■