The Manufacturing of Aluminum Bicycle Wheels

MEEG 453 Fall 2015

Self-Selected Homework #1
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SUMMARY

Bicycle wheels are a common product that many college students use or see every day. However, few people realize the complexities involved in manufacturing bike wheels, or the technical aspects that make them such an excellent structure for transportation. An overview of the manufacturing process is presented as well as a broad-view discussion of the technical aspects of a bike wheel.

Main Discussion

Most performance bike wheels that are used by the general public are made from aluminum tubing. Other options, including titanium and carbon fiber, are much more expensive and only used in the most competitive settings. Therefore, this discussion is based on the manufacturing of *aluminum* spoked bike wheels, assuming that spokes and a flange are used as raw materials.

The most common raw material consumed by the aluminum bike wheel manufacturing process is long lengths of aluminum tubing with a cross-section similar to that shown in Figure 1 (How It's Made). However, some manufacturers perform the aluminum extrusion themselves, beginning with solid aluminum rods (Production). These lengths are cut to smaller sizes such that four (4) to six (6) wheels can be made from each one. Each shortened tube is bent in a 3-point contact wheel bender such that the pointed end of the cross section is facing inwards. The four to six layers are stacked on top of each other to make a coil. This coil is then separated into individual wheel "blanks" by a single vertical cut along the axial direction of the coil (How It's Made). From here, each individual blank is joined on the cut ends by a combination of riveting and (typically) TIG welding (Production). Both the cutting and welding processes are automated for typical bike wheels. The welding process leaves a weld line that is removed by a CNC (computer numerical control) end-mill with special fixturing for the wheel.

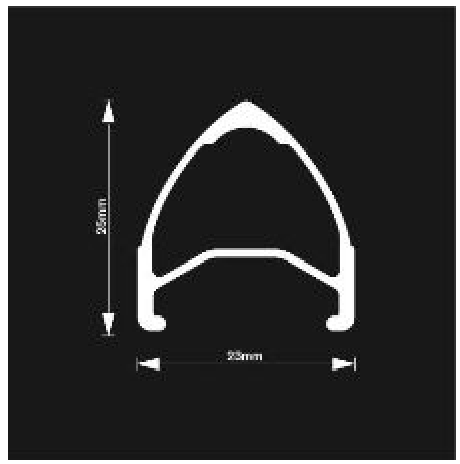

Figure 1. Typical aluminum tube cross section. *www.core77.com*

Now that the wheel blanks are fully prepared, materials finishing operations begin. The following operations are completed in *unit loads*, with up to 30 blanks loaded on a "cartridge" together. Depending on the initial aluminum alloy (7075 is a common choice for its stiffness and resilience), heat treating operations to reduce cold work from the bending process can occur (How It's Made).

Figure 2. Black anodization of a unit load of aluminum bike wheel blanks.

Afterwards, the blanks are cleansed with an acid bath before being anodized for corrosion resistance, but also for optical appearance, a non-mechanical property.

The next process steps are again processed in discrete parts, one at a time. For wheels that will use the traditional V-brake design, a surface on the outside of the blank is machined to create a flat that the brake will grip (Production). Then, a special CNC milling machine is used to create the spoke nipple holes through radial positions on the hub (How It's Made). These operations are typically performed via automated machines because of their repetitive nature.

Figure 3. The end of a spoke (in black) inserted into a spoke nipple, which is mounted inside the wheel hub.

Some operations must be performed manually, however, as no reliable controls system exists that can handle the complex sensory abilities of the human hand required for nipple placement and spoke tightening. (Note: Some manufacturers have adapted a pneumatic gun technology for delivering nipples to be placed, but even this operation is manually-assisted [Bicycle Wheel Production].) The drilled wheel hub is taken to a human operator, who uses a magnet to insert spoke nipples—the component that connects the end of the spoke to the wheel hub by threaded connection—into the hub and locating them around the perimeter of the wheel (How It's Made). A flange with spokes already attached is then attached to the hub by an operator by screwing the ends of each spoke into the corresponding nipple (see Fig. 3).

Figure 4. A bike technician manually *trues* a bike wheel by tensioning its spokes. *www.bikeradar.com*

The finishing processes are the most important in differentiating high- and low-quality wheels. The most important of these is called *truing*, which measures the concentricity of the flange within the hub, and measures the roundness of the hub itself. Although some manufacturers have developed automation technology for the complicated processes of tensioning each spoke and re-measuring (Bicycle Wheel Production), the process is traditionally done manually or with semi-automated equipment (Gale). The tensioning and truing process can take a skilled operator up to 15 minutes to complete for a single wheel (Tech). Further tensioning adjustments are often made via automated machine, and add even more time to the manufacturing time of a single wheel (How It's Made).

Once the wheels are trued, painting and other packaging operations are performed specific to each manufacturer to communicate its qualities to customers purchasing wheels at a bike shop.

Technical Discussion

Because bike wheels are generally sold as a part of a complete bicycle, little economic information is publicly available about the wheel industry in particular. Therefore, a few technical aspects of the bike wheel are discussed below, as they relate to its manufacturing.

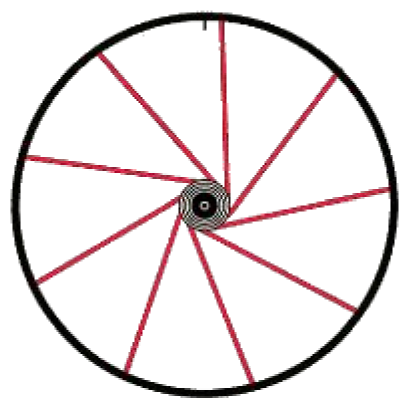

Figure 5. Exaggerated diagram showing tangential positioning of bicycle wheel spokes. *www.midlifefitnesscrisis.com*

First, it should be noted that the tangential-spoke pattern is now universal in bike tires. This is because spokes loaded tangentially to the flange/axle are able to translate the driven rotation of the pedals into forward motion, whereas radial spokes would simply bend under this type of loading (Doherty). The second unique technical aspect is the pre-stressed nature of the bike wheel. Tensioning the spokes provides compression in the structure before it is even installed on the bike. This is similar to the concept of rebar in concrete structures, which provides pre-compression that makes building structures stronger. The bike wheel is pre-compressed for the same reason: to provided added stiffness and strength during loading which wants to deform the wheel. Last, an important technical detail of the bike wheel is its incredible strength-to-weight and stiffness-to-weight ratio. In fact, a typical bike wheel will deform only 0.1 mm under an 85-lbf load (Swanson). In other words, a rider won't ever feel deflection due to his bike tire, even though it is only a fraction of the weight of the whole bike. It is because of this lightweight and stiff design that bike manufacturers have no need to "reinvent the wheel."

Engineering Relevance

Beginning Engineer

The significance of this topic for a beginning engineer is to recognize the number and complexity of manufacturing steps in a seemingly simple product. Even a bike wheel has sub-components and sub-assemblies, and important materials handling operations.

Experienced Engineer

The significance of this topic for an experienced engineer is to appreciate the value of manual processes in a manufacturing world that is being automated at a high rate. Even in the modern industry of bike wheels, manual labor operations still very much have a place and are important.

What Did I Learn?

By exploring various production videos, technical information from bike wheel manufacturers, and browsing bike enthusiast online forums, the current author learned several things: (a) materials handling during production can use a mix of continuous, discrete, and unit load operations, (b) even a simple product can involve many complex automated (CNC) steps and complex manual operations, and (c) even a simple product can involve mechanical engg. fundamentals (materials science, solid mechanics) and chemical engg. fundamentals (coatings).

Originally, I had assumed that the wheels were created by slicing sections of a large extruded aluminum cross-section. Then, I learned that linear sections of tube were bent/rolled into the desired shape. I realized that this process implied more joining and finishing operations were required, but understood that linear cross-sections of aluminum are more cost-effective to produce than much larger tubes. Because I am an every-day bike *user*, it is interesting for me to understand the details that went into designing the wheels on my bike.

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