R&D Q&A

6061, 2014, 7005, 7075, EA70

What's with all the numbers? What do they mean? Which alloy is best? Easton often gets asked these and many other similar questions. This special report will attempt to answer these as well as other questions.

To understand which alloy is right for which purpose you need only understand a few basic principals. Pure aluminum is too soft and weak to offer any benefit as a frame or bicycle component. It is necessary to combine additional elements with the base alloy to create the high tech, strong, robust alloys we enjoy today.

An alloy's number indicates which elements are added to the base aluminum. 1000 series is pure aluminum and as such offers very low strength and hardness. The alloys most cyclists are familiar with are 2000, 6000 and 7000 series. Bicycle components are made primarily from 6000 and 7000. It is important to note that a higher number does not necessarily mean that an alloy is superior.

The first digit in the series number designates the primary element that is used in the recipe to create the final alloy. In 6000 series alloys, magnesium is added while in 7000 series there are high amounts of zinc. Most 6000 and some 7000 series alloys are weldable.

Terms of Endurance

Up front, let's define some of the generally used terms associated with the physical properties of materials.

Ultimate strength – This is the amount of stress needed to push the material over its breaking point. This is represented by a number in thousand of pounds per square inch (ksi) e.g. 35 ksi.

> ***"It is important to note that a higher number does not necessarily mean that an alloy is superior."***

Yield strength – This is the amount of force needed to permanently deform or bend the material. It is also expressed in ksi. Even though the ultimate strength may be higher, yield strength is the more critical factor when developing tubing and components.

Modulus of elasticity (stiffness) – This is also expressed as a number in ksi. The important thing to remember is that typically all aluminum alloys have the same stiffness.

Density – This is represented as a number that expresses weight by volume. If you have a one-inch square block made from steel and a one-inch square block made from aluminum, the aluminum will weigh less because of its lower density. All aluminum alloys have essentially the same density.

Elongation – This is expressed as a percentage. Think of taffy. As you pull it apart, the center portion gets longer before it breaks. Elongation is the percentage of stretch before failure.

There are additional material properties, but these are the properties of most interest when choosing an alloy.

While the strengths vary widely by alloy, some properties do not change from one alloy to the next. For instance, 6000 and 7000 series alloys have the same stiffness and density.

So which alloy is best? At first glance, it would seem that the best bet would be to choose an alloy by its yield strength. After all, once a bar or tube is bent it must be replaced. Before we jump on the strength bandwagon however, we also need to consider elongation and toughness—a measure of an alloy's ductility. Glass, for instance might be quite strong, but would not make a good material for bikes because of its lack of ductility. Bicycle frames and components need tough ductile materials to survive the rigors of use.

Also consider this; steel has five times the yield strength of

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MATERIALS/ALUMINUM

most aluminum alloys. Steel is also three times as stiff. So why aren't all components built out of steel? And aren't aluminum frames much stiffer than steel?

The point is you can't just look at the material properties and know what works best. There is much more to the story.

The major role of design

So far, we have been talking about raw material properties. We have yet to consider the impact of design. This includes the geometry (diameter, shape, wall thickness) and other physical aspects of the final component. The reason engineers are so interested in a material's properties is because, through design, they can take advantage of the material's inherent performance characteristics.

We can affect the strength and stiffness of a tube by controlling the diameter alone. Larger diameters increase stiffness and the amount of load a tube will sustain. We can improve fatigue life by controlling variations in wall thickness. At Easton we control this with our proprietary TaperWall™ process.

While aluminum may have lower yield strength than steel, with proper design, aluminum is the superior material because of its higher strength-to-weight ratio. If the engineer understands each alloy's properties, the component or frame can be designed to maximize strength and durability, and minimize the chance of failure.

In the quest for optimal performance, we can see the importance of both material properties and proper design. Many manufacturers are content to select a material, design a component and leave the manufacturing up to someone else.

How important is the manufacturing process?

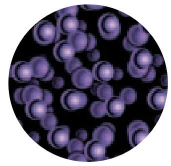
How important is your choice of a contractor in constructing a house? Even with the best plans and materials, poor building techniques can produce a brand new fixer-upper. The manufacturing process is critical.

To turn raw materials into a finished product, the alloy must be manipulated. Let's explore a few of the terms and issues related to the manufacturing process.

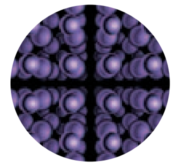
"Larger diameters increase stiffness and the amount of load a tube will sustain."

Cold working – forming processes which are performed at ambient temperature. For example, reducing the diameter of the tube through drawing, bending and crimping.

Grain Refinement – A byproduct of cold working and thermal processes. As tube diameter and wall thickness are reduced, the grain size of the alloy is reduced. Smaller grains promote longer fatigue life and increased toughness.



Initial grain pattern



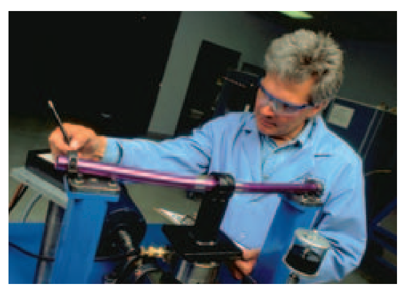
Grain pattern refined by Easton's TaperWall process

Thermal processes – Solution heat treatment is when the alloy is heated near its melting point for a period of time and then rapidly cooled (quenched). After a solution heat treatment the alloy must be placed in an oven and heated at a low temperature for an extended period of time. These processes are used to bring the alloy to full strength (T6).

The amount of cold-work processing translates directly to the strength and longevity of the final product.

Bringing it All Together

Easton's approach is to control all three aspects of manufacturing: the material, the design and the manufacturing process. Easton has metallurgists, chemists and engineers on staff as well as an in-house sports lab to thoroughly test and evaluate products.



Continual testing of Easton products as well as those of competitors is a way of life at Easton. The sports lab has designed a myriad of tests specific to each component.

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Easton's Material Advantage

Easton has been processing aluminum for sporting goods since the 1940s. Easton's experience, technology and knowledge allow in-house metallurgists and chemists choices that go beyond buying off-the-shelf.

Easton formulates the chemistry for unique alloys which must be cast into ingots in very large quantities. These ingots are then processed into seamless start stock. EA70 is just one of Easton's proprietary alloys (and no, this is not just a marketing ploy or an attempt to make up a name for some commercially off-the-shelf alloy available to everyone). Why don't others use EA70? They can't.

EA70 is quite unusual, even though it is a very high-strength alloy, elongation and toughness do not suffer. EA70 is an ideal alloy for handlebars, as well as suspension forks (stanchion and steering tubes), motorcycle bars, and seat posts. Higher strength is a benefit as the average stress that is applied through riding and hitting bumps is far below the materials yield strength. This gives components made with EA70 superior fatigue life. In addition, its ability to absorb higher impact loads allows bicycle components to withstand incredible amounts of abuse without bending. Here's how EA70 compares with some other alloys:

The large diameter and thickness of Easton's start stock allows for ample cold-working while reducing the tubes to final size.

Alloy	Yield	Elongation	Density
6061	40 ksi	12%	.1
2014	60 ksi	10%	.1
7075	73 ksi	11%	.1
EA70	78 ksi	12%	.1

"Easton can place material only where needed to maximize strength and performance while minimizing weight."

More Design Options

Because of their proprietary TaperWall process, Easton's design engineers can count on precise control over tube wall thicknesses and transitions in the manufacturing process. They can place material only where needed to maximize strength and performance while minimizing weight. Truly innovative products can be designed with this high level of control over materials and processes. Further, Easton has its own in-house sports laboratory that continually measures and evaluates the performance of new designs.

Process of Elimination

Easton's typical start-stock size is more than 3" in diameter—with a very thick wall. Easton then cold works this start stock by repeatedly drawing it into smaller diameter tubes. Grain alignment and strength are enhanced with each draw. During the final draws the tube walls are precisely shaped using Easton's proprietary TaperWall process. The final product faithfully reflects the initial design. Lightweight performance is acheived by eliminating unneeded material.

Drawing Conclusions

The material accounts for just a part of component performance and reliability. Manufacturing processes are equally important. The processing actually works to enhance the raw materials. More cold work equals better performance.

Ultimately the design of the tube should dictate the process needed. By placing metal in the right location the bar or tube can be optimized for fatigue and impact strength.

It is easy to make something lightweight. Just carve out enough material. However, it is difficult to make something light and strong that performs well at the same time. For this you need the combination of all aspects: superior material, superior processes and superior design.

Easton is one of the few manufactures that can deliver on performance by controlling all three aspects.

In the next installment: Composites.