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AM is going downhill - fast!

Downhill mountain biking is an adrenaline-fueled sport with a simple objective - to get from mountain top to valley bottom as quickly as possible. Competitors negotiate twisting, rock-strewn, tree-lined tracks that include drops, berms and enormous jumps. The demands on both rider and bike are extreme, and now additive manufacturing (AM) is playing a critical role in driving performance to new levels.

The Atherton family (Dan, Rachel and Gee) are World Championship-winning mountain bikers who are now developing their own downhill mountain bikes to race on the World Cup circuit. They will be taking full advantage of AM's flexibility to create bikes that are optimised to each rider to give them a competitive edge.

The Atherton siblings, Dan, Rachel and Gee

Behind the elite sport is a business: Atherton Bikes. The Athertons have teamed up with Piers Linney, former investor on BBC Dragons' Den (known as Shark Tank in the USA), renowned suspension designer Dave Weagle, along with Ed Haythornthwaite and other members of the former Robot Bike Company. Besides the competitive ambitions of the team riders, Atherton Bikes plans to make cutting-edge race developed technology available to downhill mountain bike and 'Enduro' competitors and enthusiasts, along with a range of less extreme machinery for trail riding, based around the same AM and carbon frame construction.

AM is central to achieving these aims. It is used to make the titanium 'lugs' which form the nodes of the bike frame, including the double-lap shear joints where the metal lugs and carbon tubes meet.

This agile construction method supports an almost infinite range of frame designs, whilst short manufacturing lead times give the Athertons the adaptability that they need to hone the bike to match their exacting racing requirements. Rapid prototyping of new models, mid-season design changes, or even bikes that are customised to suit particular downhill tracks, are all now possible.

Dan Brown, Dan Atherton and Piers Linney reviewing prototype builds for the new downhill mountain bike as they prepare for the 2019 UCI world cup series.

The Atherton Bikes design uses titanium nodes connected by carbon fibre tubes, combining the best of these two high-performance materials.

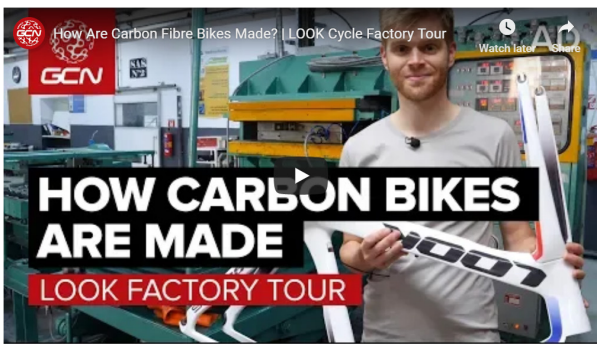
Atherton bike lugs on a build plate

In this *Vital MTB* interview, Gee Atherton introduces the new downhill bike, talks about the Atherton brand and his plans for the 2019 race season: https://youtu.be/8jhkMTJIZOU

So, AM will give the Athertons a competitive edge at the top of the sport, whilst also bringing new levels of performance to the committed enthusiast. Let's look a little deeper at why AM is set to break the mountain bike mould.

Carbon is good - but not always best

Conventional downhill bike frames are built from hundreds of pieces of resin-impregnated carbon fibre sheets, carefully bonded in multiple layers around a core and inside a mould. This labour-intensive process is suitable for producing frames in a limited range of sizes. The substantial investments in tooling and testing of these complex composite constructions limit the scope for tailoring the frame to suit the rider. A great explanation of the intricacies of carbon bike frame manufacturing can be found on YouTube here: https://youtu.be/4DKkueqcKmQ

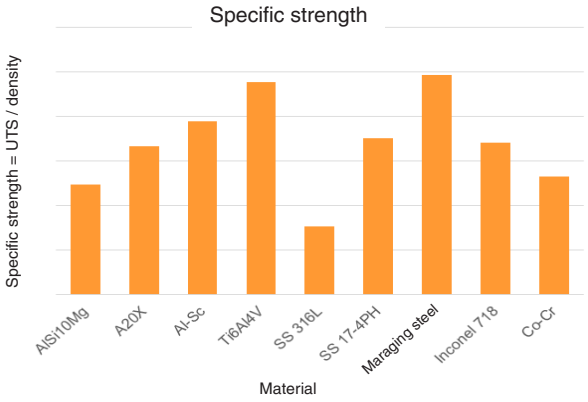


Carbon fibre can't be beaten for stiffness to weight ratio, but that doesn't necessarily make it the best material choice for an entire high-performance frame. The fibres are only strong in the direction in which they are aligned and so a series of layers must be overlaid with the fibres carefully orientated to provide strength for all the required load conditions.

Composite design is a relatively simple matter in the tubular areas between the bike nodes, but things get a lot more complicated where the tubes meet. This is where the peak stresses are often to be found, and the material must be strong in many directions to handle complex loads. Great care must be taken during the lay-up process to ensure that the fibre patches are correctly arranged and securely bonded to one another.

Titanium and carbon combination

By contrast, metals exhibit more uniform properties in each direction, so that strength analysis is more straightforward. This makes them well suited to managing the complex stresses found at the nodes of a bike frame. Titanium's high specific strength (i.e. the ratio of its strength to its density), as well as its toughness and corrosion resistance, make it the ideal choice for this application.

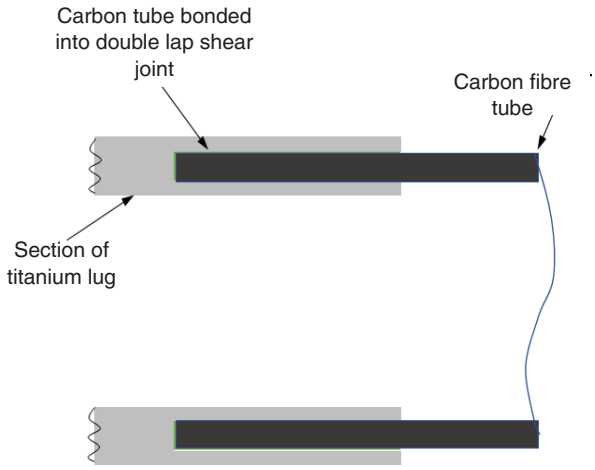


Titanium alloy Ti6Al4V, used to construct the nodes of the Atherton Bikes mountain bike frame, has one of the highest specific strengths of any AM material.

The Atherton Bikes mountain bike design combines titanium lugs with constant profile carbon tubes to create a frame that is both light and strong. The tubes meet the lugs in a double-lap shear joint, in which the carbon tube is inserted between an inner and outer skin of titanium with around 20 mm of overlap, creating a large area for bonding. Epoxy adhesive, similar to that used to bond wings on the Airbus A350, is used to fix the tubes into place, creating a joint that is stronger than the surrounding structures.

Example double-lap shear joints.

A key advantage of this construction technique is that it can be tailored to produce a wide range of frames. The inherent flexibility of AM means that subtle changes to the lugs are possible to accommodate different frame geometries. Frames can be customised to suit both the size of the rider and their riding style, by changing the angles at which the tubes meet and by cutting the carbon tubes to the required lengths. The lug designs can be quickly generated in CAD and then sent to the 3D printer, enabling custom frames to be built in the same way as standard versions, making mass customisation a viable business model.



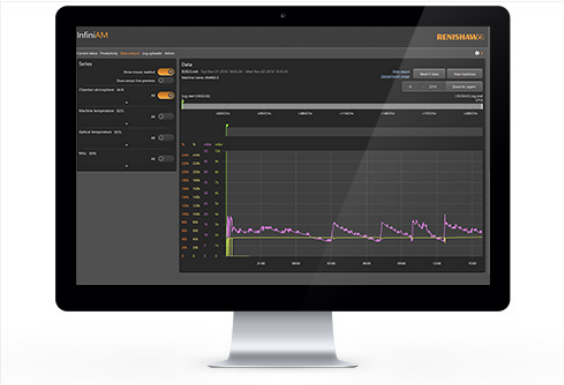
Efficient production - multi-laser build process

Renishaw is supporting initial production at its AM Solutions Centre in Stone, Staffordshire, whilst Atherton Bikes establishes its own production facility. As we gear up for volume manufacturing, production costs and quality are critical. Fortunately, the productivity and efficiency of AM processes are rising to meet this challenge, with the latest systems enabling faster builds and producing superior material properties.

One of the major trends in metal AM right now is the move towards machines with multiple lasers. RenAM 500Q industrial AM system features four lasers, each of which can address the whole build plate, enabling components to be produced at up to four times faster than conventional, single-laser machines. This boost to productivity means that a mountain bike lug set can now be produced in less than a day.

Quality is another key factor in optimising the bike performance and costs. Strong and robust material properties are critical to light-weight product design. We must ensure that the components are free from critical defects so that we unlock the full performance potential of the alloy. Consistency is key, as this allows us to optimise the design safety factor, so that we are not carrying any unnecessary extra weight due to excessively conservative material allowances.

In the case of the Atherton Bikes lugs, tensile test coupons are included with every build to demonstrate compliance with the material specification. Tensile data can then be collated and combined with the machine sensor signals, using Renishaw's InfiniAM software, and kept as a record of each build.



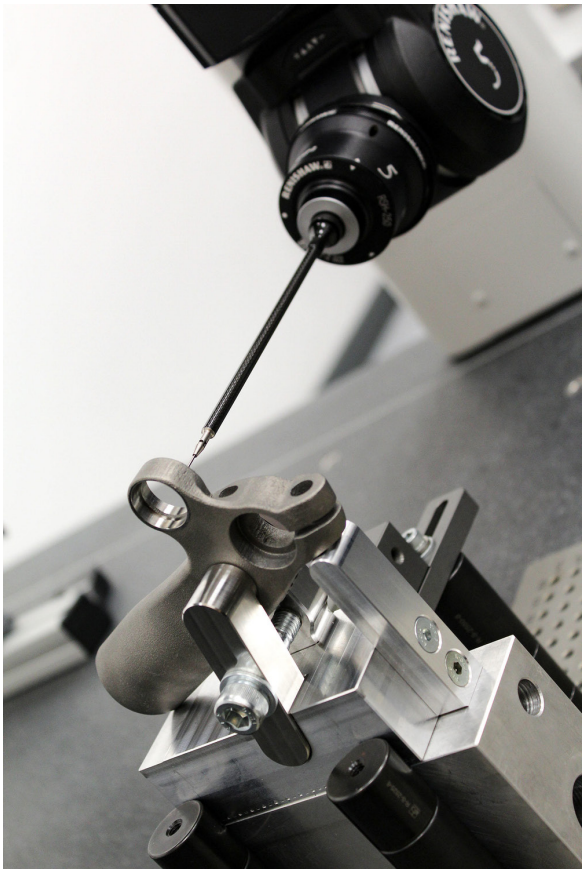
Post-processing

Several of the lugs require finish machining to produce the precision bores required to interface to the rest of the bike mechanism. The lugs have complex forms and may vary in shape to accommodate different frame sizes. Machining fixtures must be adaptable and provide effective clamping during cutting.

Quality assurance

The final step of the lug production process is to verify the precision of the finish-machined components. This is performed on a coordinate measuring machine equipped with a Renishaw REVO ® 5-axis measurement system. With five axes of simultaneous motion and patented tip-sensing technology, REVO is able to inspect the machined and 'as built' features of the lugs to ensure that they meet the specification.

REVO is a multi-sensor inspection system, including contact scanning and surface finish measurement capability, enabling a comprehensive assessment of part quality in a single inspection set-up.



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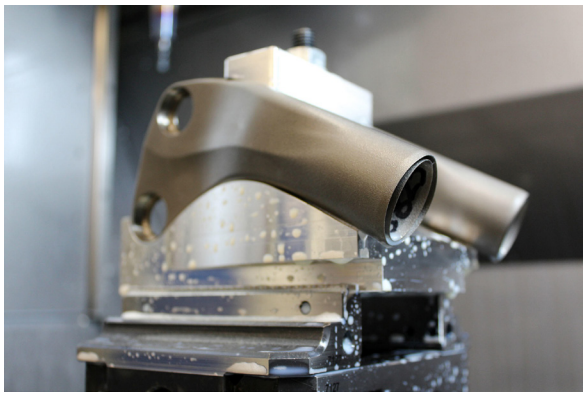

Machining of the 'yoke' - a key component of the rear suspension. Cutting of the precision bearing holes is performed on a 5-axis machining centre, using probing to establish datums and control tool wear to meet the required tolerances.

Summary

AM has the power to disrupt markets by enabling innovative product designs and new agile business models. Atherton Bikes is taking advantage of these capabilities to break free of the rigid, labour-intensive conventional bike manufacturing mould.

AM gives Atherton Bikes the flexibility to hone their race bike designs, and to make custom bikes accessible to enthusiasts at an accessible price point. Look out for the Athertons making an impact on the world cup circuit and in the business world during 2019.

Next steps

Look out for more articles in the coming months as we explore the design, engineering and manufacturing challenges of making a volume production AM mountain bike.

Visit www.renishaw.com/amguide for more education resources and to access downloadable versions of feature articles by Renishaw authors.

About the author

Marc Saunders, Director of AM Applications

Marc Saunders has over 25 years' experience in high tech manufacturing. In previous positions at Renishaw, he played a key role in developing the company award-winning RAMTIC automated machining platform, and has also delivered turnkey metrology solutions to customers in the aerospace sector.

Marc manages Renishaw's global network of Additive Manufacturing Solutions Centres, enabling customers who are considering deploying AM as a production process to gain hands-on experience with the technology before committing to a new facility.

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