ALPHA

CONCEPT

We set out to create a bicycle that would appeal to multiple sets of riders as well as push the boundaries of integrated systems. The result is Alpha, the first bicycle with a fully internal drivetrain including an electronically-controlled clutch allowing the rider to switch between fixed-gear and free-wheeling configurations. Alpha was designed, manufactured, and assembled at the University of Pennsylvania.

HANDLEBARS

The handlebars were designed for ergonomics as well as the internal routing of cables, wiring and mounting of a printed-circuit board and LCD screen. We made use of 3D printing to prototype sections and create the final handlebars. The resulting ABS assembly was laid up with preimpregnated carbon fiber for strength, while keeping the plastic core intact for routing and electronics purposes. The weight of the handlebars is 458 grams, lightweight for the bicycle industry.

ELECTRONICS

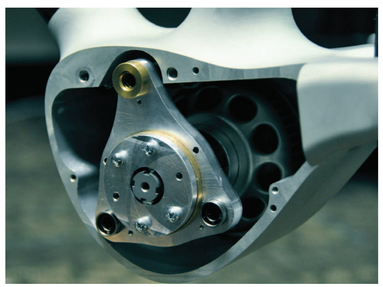
The front hub houses a drum brake and generates power for the onboard electronics. Rotation of the front wheel illuminates the integrated rear LEDs and charges a pair of capacitors, which in turn power a suite of sensors and an M1 microcontroller. This system includes a 6-DOF inertial-measurement unit, a clutch sensor, and two hall effect sensors, which provide cadence and wheel speed. An LCD screen shows useful real-time data to the rider. Additional data, which can be used to analyze bike dynamics post-ride, is stored on an SD card that is easily accessible from beneath the handlebars.

FRAME

The frame geometry, based on industry standards for urban cycling, ensures full integration of all mechanical and electrical components. It is constructed from carbon fiber tubes epoxied to aluminum lugs that were manufactured in-house using CAD, CAM, and CNC machining.

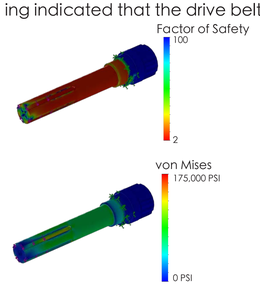
MANUFACTURING

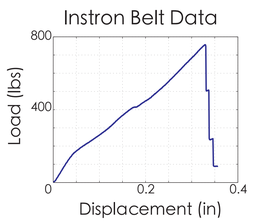
Rapid prototyping allowed the form, fit, and function of Alpha's many components to be examined and quickly refined. For final construction, all of Alpha's lugs were CNC machined from billet Aluminum, bead blasted, anodized, and sealed. Many of the transmission components were CNC milled, while the shaft was turned on a CNC lathe and post processed using a collet indexer on a mill.



ANALYSIS

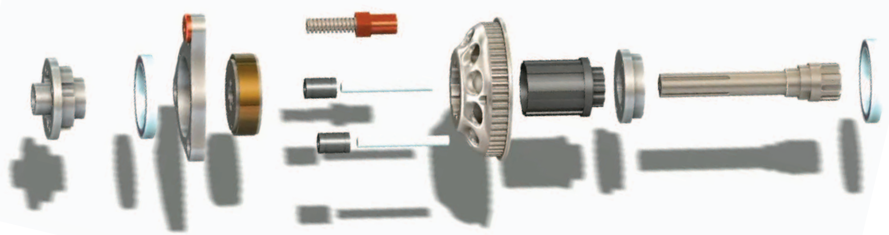
Analytical calculations and FEA of the shaft indicated the need for a material with an ultimate yield strength above 200 ksi. This informed our decision to purchase, machine, and harden this critical component from AMS-6514 maraging superalloy steel. Additional analysis of the drive belt and subsequent Instron testing indicated that the drive belt would not break under nominal loading.





TRANSMISSION

Alpha's bottom bracket houses the bike's SWIFT Drive Technology. The Switchable Integrated Free-Fixed Transmission uses an electromechanically actuated clutch to switch the bike's configuration between fixed-gear and free-wheeling modes. Metallurgical considerations played a major role in selecting materials for all of the transmission components. The strength and weight of Titanium 6Al4V made it the material of choice for the clutch plate, while AMS-6514 maraging steel was used for the central shaft due to its extreme hardenability (56 HRC). Bronze was used for its self-lubricating properties at the core of the clutch, while 6061-T6 Aluminum was used for lower-stress components. The geometrically complex belt pulleys were made from Stainless Steel using Direct Metal Laser Sintering, a process which allowed us to create otherwise un-machineable parts. Finally, the rear hub incorporates a compact three-speed planetary gear set actuated by a standard push-pull cable.



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