

Bicycle Frame Analysis and Design Improvement (1649 Words)

Materials and Manufacturing - Assignment 2 (ADDA4001)

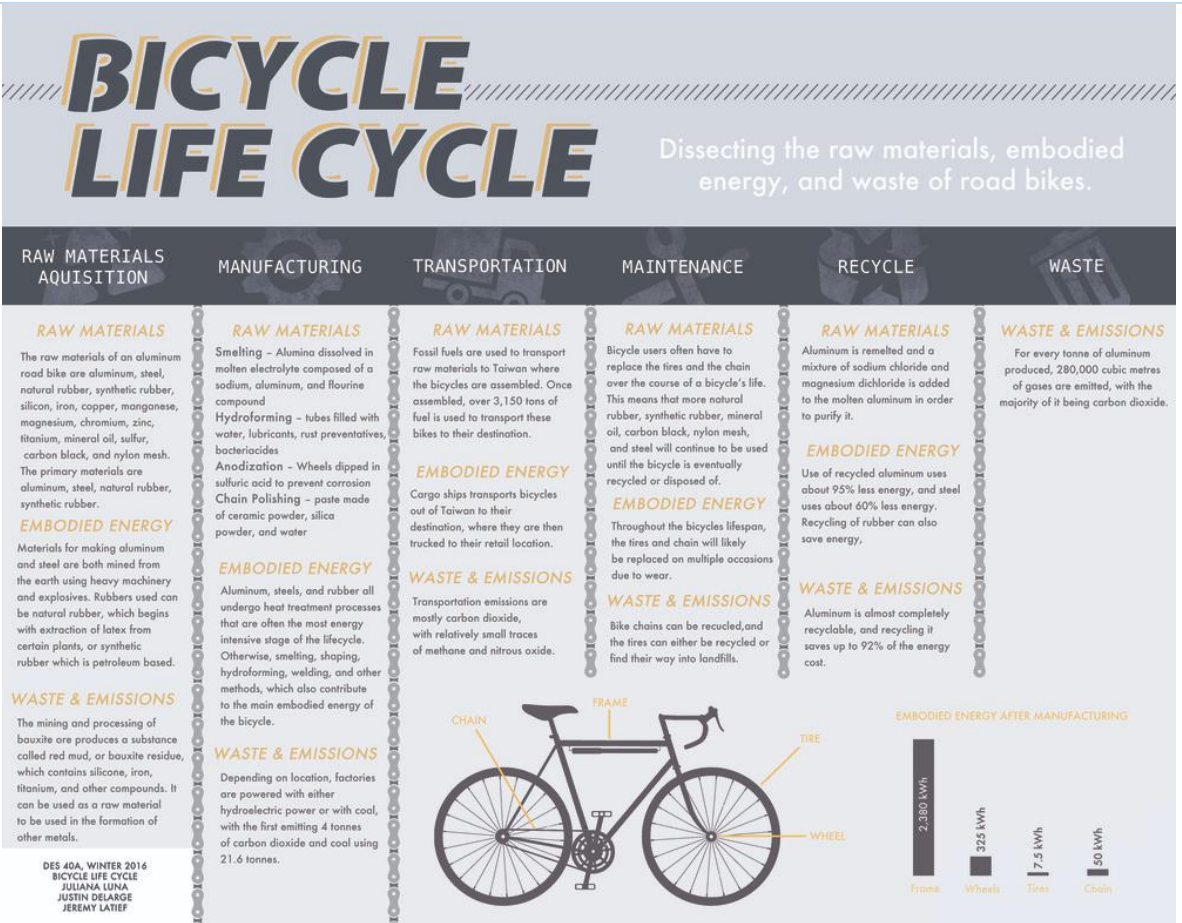
Keri Shaw (1703607)

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(Trust-inc, 2016)

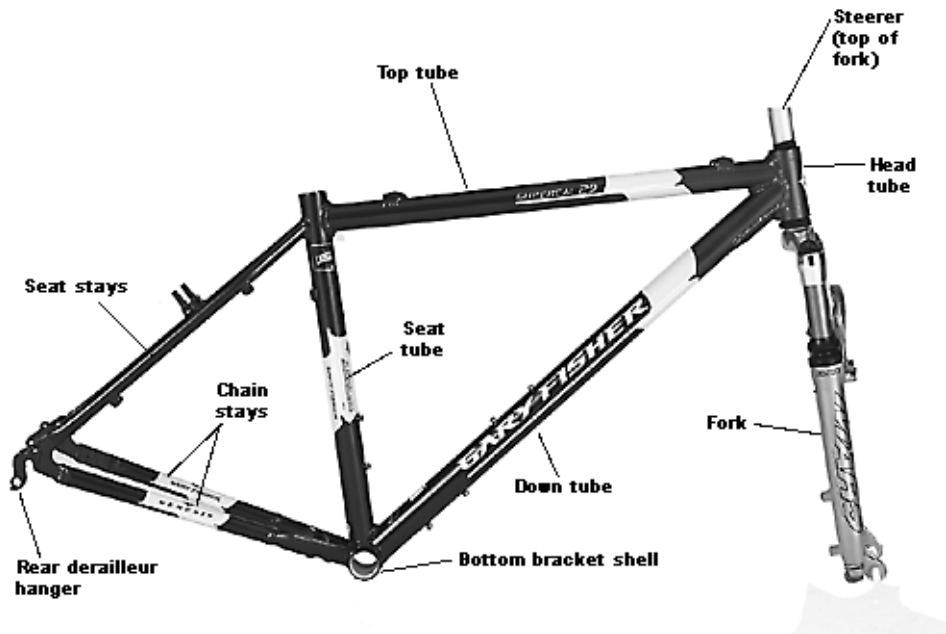
Research Area	Information Obtained																																								
Material Parameters	The given bicycle frame is made from grade 6061-T4/T6 Aluminium Alloy (Trust-inc, 2016). Below is a table of the material's cost, and physical/mechanical parameters (which are the two areas relevant for bicycle frames). Highlighted are the focal points of the material regarding bikes specifically. <table> <tr> <th colspan="2">Cost</th></tr> <tr> <td></td><td>1.69 (GBP per kg)</td></tr> <tr> <th>Physical Properties</th><th>Metric Measurement</th></tr> <tr> <td>Density</td><td>2.7g/cc</td></tr> <tr> <th>Mechanical Properties</th><th>Metric Measurement</th></tr> <tr> <td>Hardness (Vickers)</td><td>107</td></tr> <tr> <td>Ultimate Tensile Strength</td><td>310 MPa</td></tr> <tr> <td>Tensile Strength</td><td>290 MPa</td></tr> <tr> <td>Tensile Yield Strength</td><td>276 MPa</td></tr> <tr> <td>Elongation at Break</td><td>12%</td></tr> <tr> <td>Modulus of Elasticity</td><td>17%</td></tr> <tr> <td>Notched Tensile Strength</td><td>68.9 GPa</td></tr> <tr> <td>Ultimate Bearing Strength</td><td>607 MPa</td></tr> <tr> <td>Bearing Yield Strength</td><td>386 MPa</td></tr> <tr> <td>Poisson's Ratio</td><td>0.33</td></tr> <tr> <td>Fatigue Strength</td><td>96.5 MPa</td></tr> <tr> <td>Fracture Toughness</td><td>29 MPa-m^{1/2}</td></tr> <tr> <td>Machinability</td><td>50%</td></tr> <tr> <td>Shear Modulus</td><td>26 GPa</td></tr> <tr> <td>Shear Strength</td><td>207 MPa</td></tr> </table> (Dwyer, Shaw, Tombarelli, 2012; ASM.matweb, 2018)	Cost			1.69 (GBP per kg)	Physical Properties	Metric Measurement	Density	2.7g/cc	Mechanical Properties	Metric Measurement	Hardness (Vickers)	107	Ultimate Tensile Strength	310 MPa	Tensile Strength	290 MPa	Tensile Yield Strength	276 MPa	Elongation at Break	12%	Modulus of Elasticity	17%	Notched Tensile Strength	68.9 GPa	Ultimate Bearing Strength	607 MPa	Bearing Yield Strength	386 MPa	Poisson's Ratio	0.33	Fatigue Strength	96.5 MPa	Fracture Toughness	29 MPa-m ^{1/2}	Machinability	50%	Shear Modulus	26 GPa	Shear Strength	207 MPa
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(Bicycle Life Cycle, 2018)

Manufacturing Process

Within the rigid bike frame, there are eleven parts shown on the diagram below:



	(Bike-Manual, 2018) A. All tubular components are cut to the required lengths from different diameters of extruded stock Aluminium using an automated machine. B. The cut tubes are turned to the required external diameter on a CNC lathe, which also brings the exterior finish up. C. The component's ends are blanked, allowing the parts to interlock in the assembly, and a press and die deform the larger core components, for both structural and aesthetic purposes in a process called forming. D. Any holes/slots required for cable routes or fixings are CNC milled and/or punched out. E. The cable guides* are then brazed to the tope tube, seat tube and seat stays. F. Two stages of TIG welding occur concurrently, which are the connection of the rear dropout* to the chain and seat stays (two parts required per model), and the connection of the seat, top, head and down tube to the bottom bracket shell using a jig. G. The three new components are TIG welded to form a final frame. H. The frame is polished and buffed to a presentable finish using a rotary polisher/buffer, and then sent through a T4 Heat Treatment (if applicable). I. The cold frame is inspected and corrected using a jig and manual levers that corrects the misalignment. J. A slot is punched out of the seat tube and its internal diameter is partially bored out to allow for the seat post to be inserted and clamped. K. After that, the frame then enters a T6 Heat Treatment (if applicable), before being inspected for strength, stability and quality. This is required before any surface treatments or finishes such as a matt or gloss paint are applied. (Ideal Bike Corporation, 2016; Trust-inc, 2016, How it's Made Bicycle, 2009) *The cable guides are made through die casting (Trust-inc, 2016) *The rear dropout is forged (Slowswitch, 2013)
Design Considerations	An essential factor to consider in the design of a bicycle frame is the arrangement of the components to ensure that the structure is in equilibrium when not moving and under an applied force. This means having zero net force and zero net moments on the frame while in use. Essentially, the tensile and compressive forces must be the same to place the bike in a state of equilibrium. This is done through assessing which beams experience bending forces and what degree of force and bending moments are on the components under regular conditions of use.

	Because there are many more factors to the bicycles strength and functionality than simply the geometry of its frame it would be unwise to alter this arrangement when finding a substitute material. (Pinceton.edu, 2018)
Diagram	(Stack Exchange, 2018; Mountain Bike Anatomy, 2016)
Fasteners Connected to the Frame	Brake Bolt: A single 5mm bolt fitted below the down tube, and another on the rear brake bridge above the wheel. This fastener attaches the braking system to the fork and rear brake bridge. Top Cap: One adjusting bolt positioned at the top of the stem, holds the headset together and connects the fork and the frame. Clamp Band: A 5mm clamp bolt attaches the front derailleur onto to the seat tube. Hanger: Another 5mm bolt attaches the derailleur to its hanger below the right rear dropout. Bottle-Cage Mounts: Two to four 5mm bolts positioned on the front triangle holds a minimum of one bottle cage. Cable Guide Bolt: A 3 to 4mm hex bolt is sometimes located under the bottom bracket shell to act as guides for the front and rear derailleur cables and to secure them to the frame. (Bicycling, 2018)
Function	The bicycle frame is a component designed to support the human body and connect the functional areas of the bike in an arrangement that enables its intentional operation by the user. (Depts.Washington, 2018)
Life Span	In relation to actual use by cyclists, many riders are claiming a safe operation period of at least five, and up to ten years, and very few have stated failure under use. If it does occur then it is usually in the form of cracking at the welds near the seat post, as this undergoes the most direct stress. In relation to its performance against other materials, according to cyclists on the same forums, Titanium and Carbon Fibre provide a better strength to weight ratio and will last longer.

	(Bicycles, 2016; Bikeradar, 2012; Road.cc, 2014; Bikeforums, 2014)
Ergonomics	The ergonomics of the bicycle frame are to be the exact proportions for intended mechanical operation and human interaction, within a range of adjustability provided by the following: ▪ Stem Length ▪ Stem Clamp Depth ▪ Spacing Under the Stem ▪ Saddle ▪ Amount of Exposed Seat Post ▪ Seat Post Set Back ▪ Pedals ▪ Handlebars The adjusting of these combined with a specific riding position (shown below) enables the user to optimally and comfortably use the apparatus, especially when regarding racing.  (hewittcycles, 2018) Furthermore, I have determined that the ergonomics of a bicycle are mostly determined by the seat, handlebars etc., and the users riding position rather than the design of the frame. This is clearly shown through the following links that example documentation on the correct adjustments and riding positions of a bike. http://www.ergon-bike.com/en/fe-ergonomics.html http://www.hr.ubc.ca/ergonomics/files/Bike-Ergonomics-reduced-size.pdf

<http://www.hewittcycles.co.uk/frame-design-considerations>
[http://www.junik-hpv.de/assets/download/Bike Ergonomics for All People.pdf](http://www.junik-hpv.de/assets/download/Bike_Ergonomics_for_All_People.pdf)
<http://www.marreybikes.com/men-s-race-bikes-500-1499/7860-orbea-avant-h70-2018-road-bike.html>

Although I wanted to focus on designing the frame having a more revolutionary design in relation to its aesthetics, the key factor of this product is that it is intended for racing, because of this both its speed and ability to withstand impacts at these speeds are paramount and influenced by the products strength to weight ratio.

As a result, I will be looking into Bamboo as my material alternative for such bikes. It is said to be “the most useful raw material to be overlooked”, even better “bamboo may be the strongest stuff on the planet” (Newsweek Staff, 2008). It is an extremely versatile material boasting excellent tensile strength, impact resistance, brilliant strength to weight ratio, compression strength, just to mention a few (shown below). Its properties have the ability to crunch that of steel, thanks to the grain structure parallel in the axial direction, placing it in the anisotropic native materials of glass and, again, metal (Wikispaces Bamboo, 2008).

Properties of Bamboo

AN EXTRAORDINARY STRONG COMPOSITE



BAMBOO: a natural composite material longitudinally reinforced by strong fibers.

LIGHT: In wood the strongest fibres are packed in the centre of the trunk, however in bamboo the stems are full of cavities and the strongest fibres are distributed most densely in the outer surface region.

STIFF: As a consequence the most stable fibre structures in bamboo are most dense in regions of greatest longitudinal stress. Wood bends relatively easily but bamboo does not.

STRONG: Extremely strong wood fibres can resist up to 5kN/cm² and steel can resist at most 37kN/cm² whereas the outer fibres of slim bamboo tubes have tensile strengths of up to 40kN/cm²

Bamboo is therefore an ideal material for bike construction where stiffness and strength to weight ratios are important.

(Bamboo Properties, 2018)

Treated right i.e. coated in a statin polyurethane, smoked and heat treated, the material is extremely weather resistant. Meaning that it will not go soggy in the rain, split or crack, and other such things that happen with standard fibre-based materials (Cycling Weekly, 2010).

Craig Calfee initiated the application of Carbon fibre bikes since the 1990's, a huge step. He's now pushing bamboo, stating that it may be 'much' more superior to that of carbon fibre (Newsweek Staff, 2008). This is because it offers far better stiffness, relevant for power efficiency and compliance, which is thus required for dampening vibration within the frame.

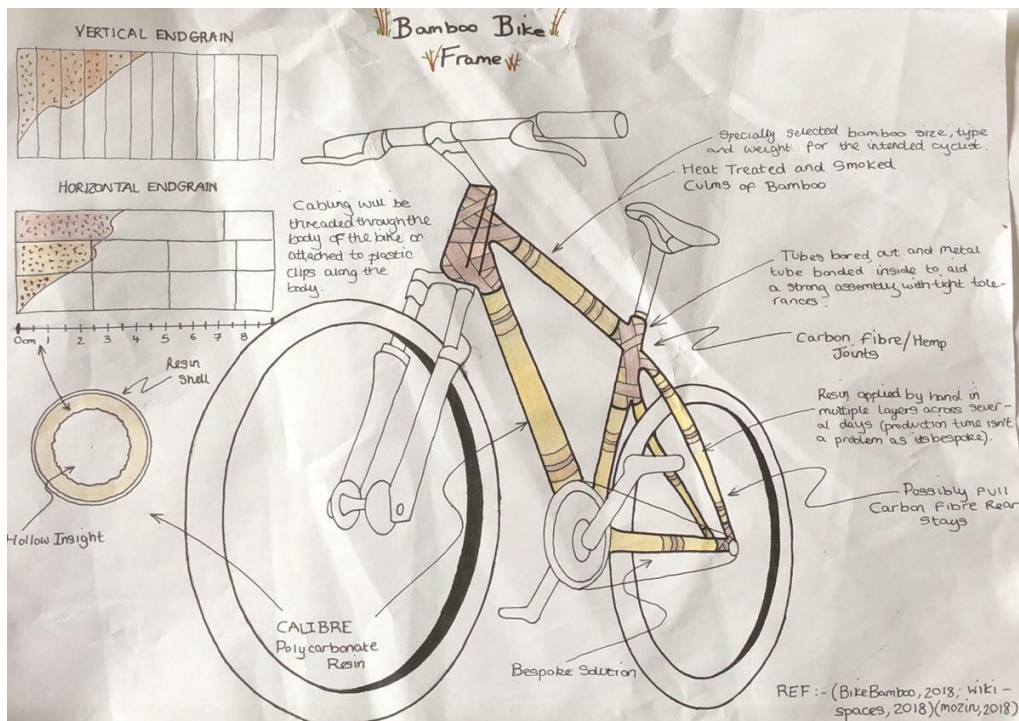
That all said, right now it is a costly option. In fact, Craig Calfee has recently built one of his own costing around £3,500, which puts it in excess of £1000 compared to standard bamboo frames (Cycling Weekly, 2010).

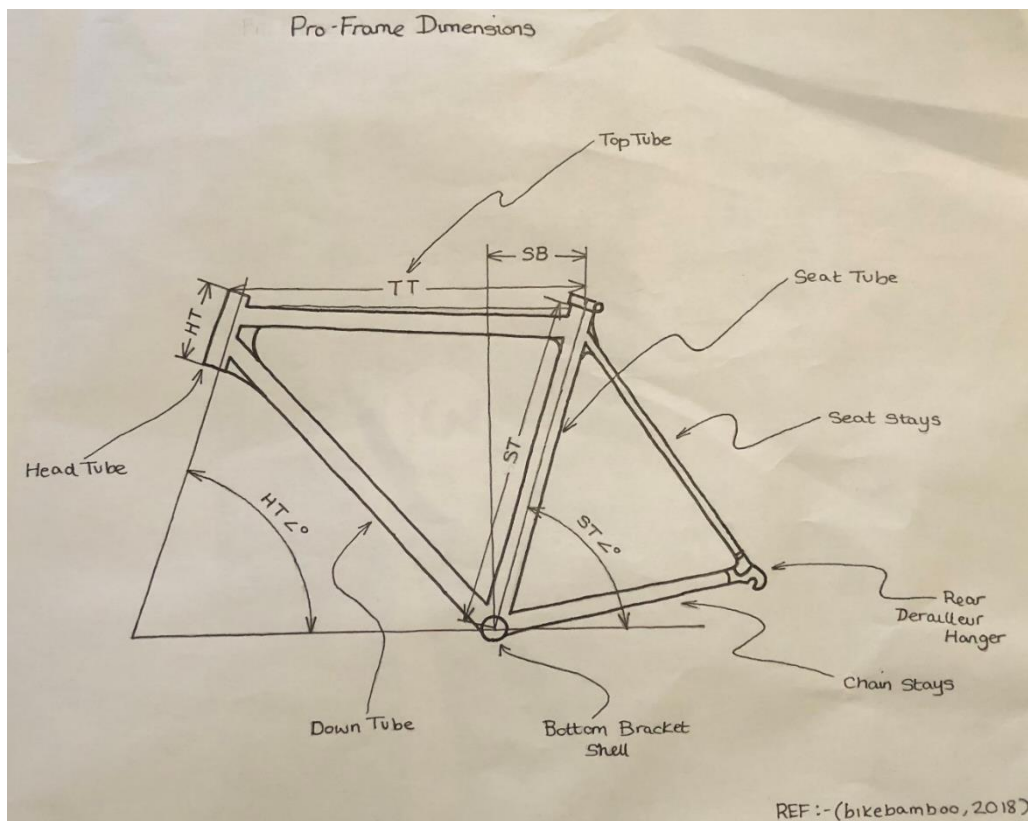
A major problem is up keep, so keeping it at peak functionality can be very labor intensive, coupled with the vast variations in tube types, finding the perfect one requires expertise (Jeff Greenwald, Craig Clafee, 2016). This is why a more composite based frame should be implemented to pull even more benefits and push drawbacks.

In my opinion, resin supported fibers is a good direction with frame material developments (Jeff Greenwald, Craig Clafee, 2016). Taking the strengths of bamboo previously stated, whilst combining them with **CALIBRE Polycarbonate**, as this could potentially improve the impact resistance and strength heavily whilst keeping crystal clear clarity showing off all bamboo's unique aesthetics (Trinseo, 2017).

Subsequently, things to take into consideration are the curing times, it needs to be fast enough to match current product turnarounds, and slow enough to be worked into the bamboo effectively. The suggestion dresses the compliance of a racing bike. What's better, it addresses social, economic and environmental issues, helping support growers of bamboo in Uganda, China etc., construction in Ghana and Zambia, as well as offering a sustainable quick growing solution. (Jeff Greenwald, Craig Clafee, 2016).

A graphical, physical and dimensional format of the final bamboo proposition for a pro-frame are provided below:





(Shaw, 2018)

Pro Frame Geometries

Size*	top tube length TT	seat tube angle ST	set back SB	chainstay length	stand over height	b.b. drop	head tube angle HT	head tube length HT	wheel base
46**	50	75	11.9	39	71.5	4	72	9.1	93.4
48	51.5	74.5	12.7	41.5	74.0	7	72	9.1	97.0
50	52.5	74.5	13.4	41.5	76.2	7	72.5	10.0	97.1
52	53	74	14.3	41.5	77.4	7	73	11.3	97.2
54	54.8	73.5	15.3	41.5	79	7	73	12.8	98.0
56	56	73	16.4	41.5	81.3	7	73.5	15.0	98.8
58	57	73	17.0	41.5	82.3	7	74	16.0	99.4
60	58.3	72.5	18.0	41.5	84.4	7	74	18.0	100.0
62	60	72.25	19.0	41.5	85.8	7	74	20.0	101.0
64	61	72	19.8	41.5	87.3	7	74	22.0	102.0
66	63.3	71.5	20.8	41.5	88.0	7	74	24.0	104.3

*Frame size is measured from center of bottom bracket to bottom of binder. Measure standover height (ground to top of top tube) and add 1 to 2cm to be sure of proper fit.

**46 cm frames use 650 c wheels

(bikebamboo, 2018)

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