Scenario 2 : Manufacturing and Design : Bicycle Frame

Group 7

Fergus Stewart	14032492
Frederick Panks	14010407
Gaurang Sanganee	14028423
Gawrisan Chandrakumar	14035140
George Lundy	14017121
Karamveer Kapoor	14008558
Karan Pinto	13055036

Design Requirements

Brief:

- To design the frame for a high-end commuting bicycle that can be used in major cities like London with similar road infrastructure.

Objectives:

- Minimization of mass
- Minimization of cost
- Effective use of sustainable or eco-friendly materials.
- An aesthetically pleasing design

Functional and Geometric Constraints:

- **Safe:** No failure under loads generated from the weight of an average rider and typical road conditions (e.g. potholes)
- **Durable:** No failure from fatigue loading or environmental corrosion for a minimum of 10 years of daily use.
- **Comfortable:** Stiffness $\geq$ a steel frame of the same height.

Agenda:

- Assessed the material and structural characteristics of a front fork.
- Executed **material selection** and **design sustainability analysis** for the components of the frame using **CES Edupack**.
- Created a **CAD model** of our bicycle frame using **Catia**.
- Demonstrated the structural integrity and performance of the frame under static loading conditions using **Finite Element Analysis** on **Catia**.

Description of Frame Design and Features

Downtube and Chainstays: Larger load region → Oval cross-sectional shape.
- Stiffer in the vertical plane.
- Not for all components because round is more balanced, force evenly distributed.

Head tube: Vertical angle of 16° with top of stem higher than top of rear tube.
- Improved steering ideal for the urban terrain & reduces risk of accidents.

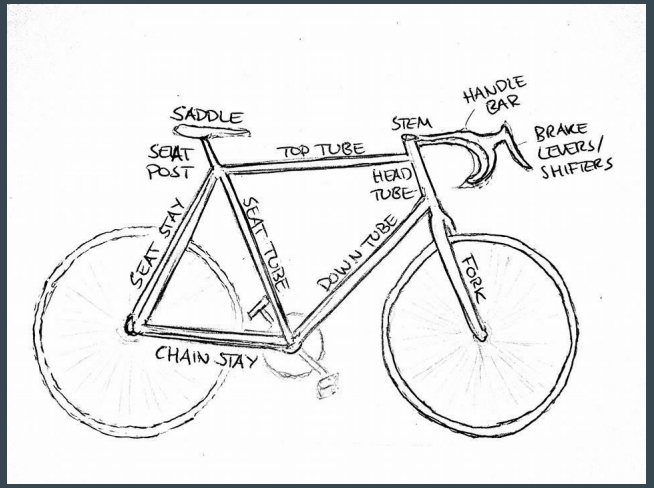
Top tube: 7° with horizontal.

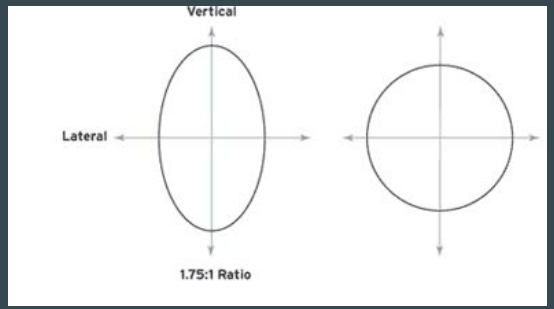
Bottom Bracket Drop (BBD):
- Low centre of gravity → Greater control and enhanced safety.
- Tradeoff with maneuverability around corners (Pedal height).

Wheelbase: length of 1m directly proportional to shock absorption.

Seat tube: Steep angle of 106° reflects a commuter bikes upright seating and non- racer features.

Longer chainstays help deliver a better quality ride. When you climb, the bike has more traction.





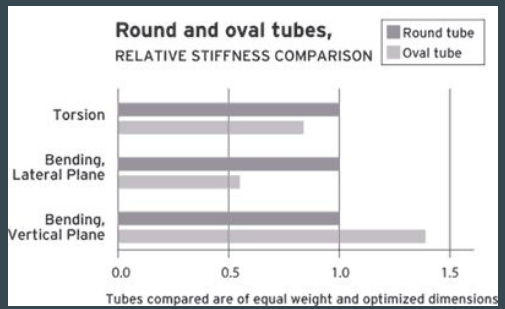
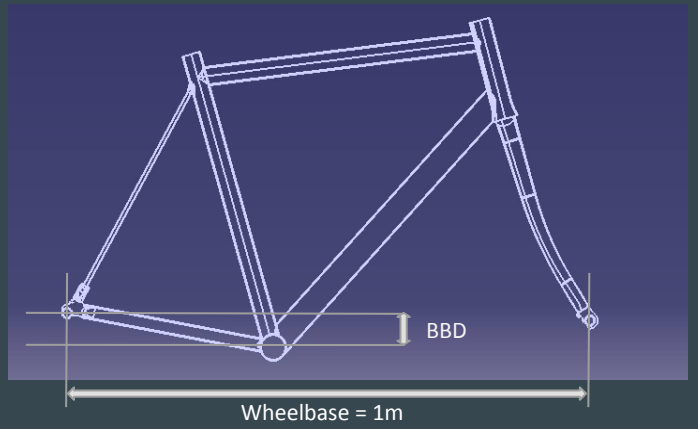


Diagram comparing the stiffness of the two tubes



Material Selection

Objective equation: m = ALρ

Constraint equation: $F^*/A \leq \sigma_f$

Performance Function: $m \geq (F^*)(L)(\rho/\sigma_f)$

Translator - Material Indices

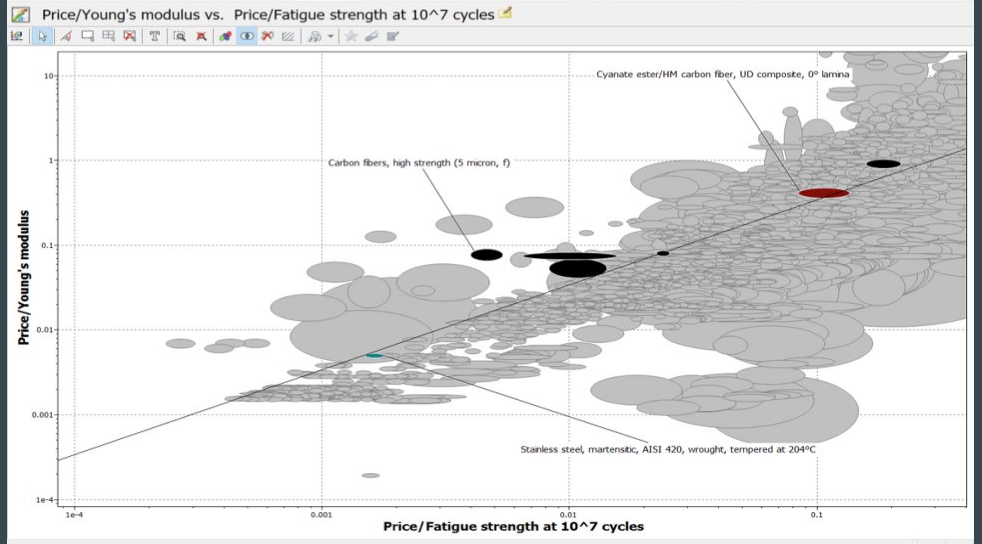
Simple Properties: E - Young's Modulus , σ_f - Fatigue Strength, ρ - Density

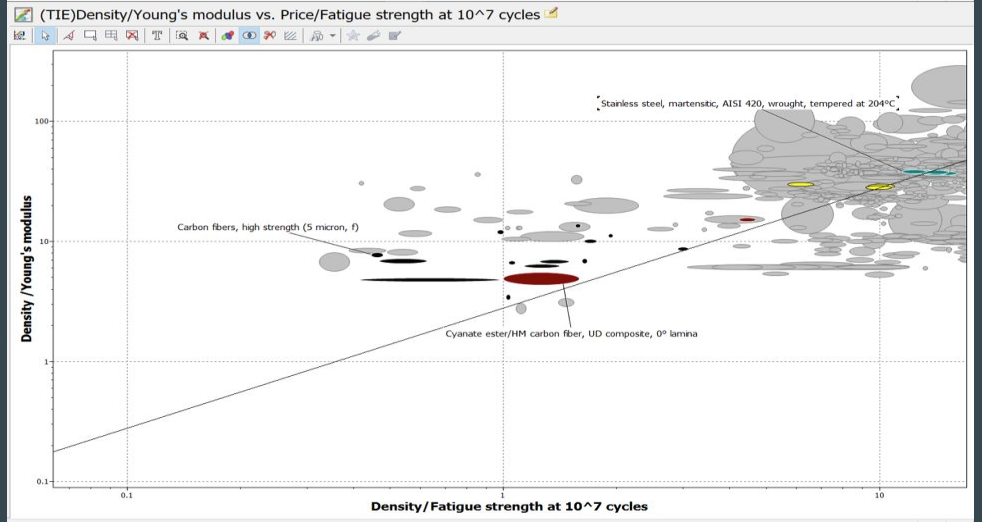
Mass MPI	$M=E/\rho$	$M= \sigma/\rho$
Cost MPI	$M=E/C_m\rho$	$M= \sigma/C_m\rho$

Materials Selector (CES database)

Shortlisted Materials

1) Cyanate ester/HM carbon fiber, UD composite, 0° lamina
2) Carbon fibers, high strength (5 micron, f)
3) Stainless steel, martensitic, AISI 420, wrought, tempered at 204°

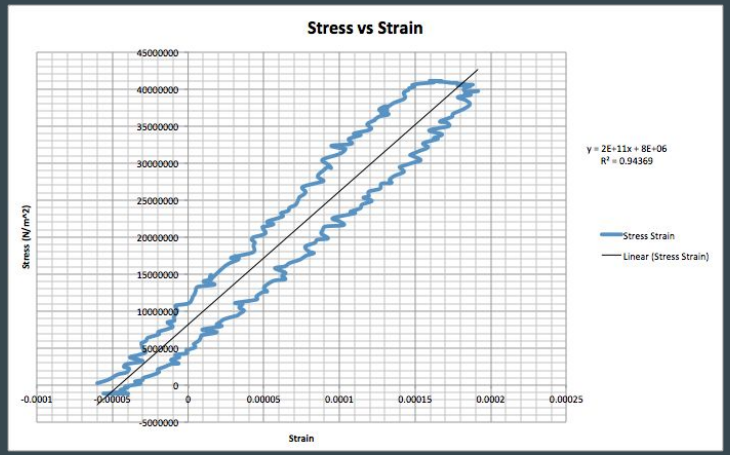




Material Selection

Materials	Price Rank	Mass Rank	CO_2 Removal
Stainless steel	1	3	3 (-39 kg)
Carbon fibers	2	2	2 (-150 kg)
Cyanate ester	3	1	1 (-160 kg)

Evaluation of Design Performance



Comparison between CATIA analysis and experimental data: 11.32% Error

- Clip gauge position
- Catia displacement is not strictly vertical

Method: Average value of compression from data within 50mm strain gauge was compared with multiple readings of displacement from section of simulation.

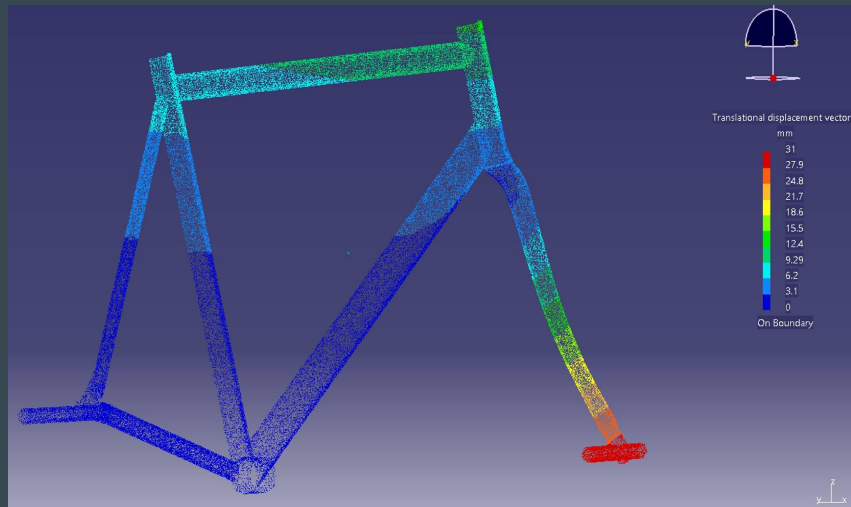
Graph obtained from the lab experiment:

- Yield Stress is at strain = 0.00015
- Plastic deformation was achieved
- Young's Modulus (Slope of stress-strain curve)= 2E+11

Mechanical Failure due to:

- Plastic collapse
- Fatigue

→ Increasing thickness and tube radius which are directly proportional to the cyclic bending moment of the tube



Evaluation of Design Sustainability

Life Cycle Assessment

How?
Relevant inventory inputs and outputs

What?
An assessment of the environmental aspects and potential impacts associated with a product

Why?
To guide the design initially and assess the product in post production stages.

Maximise resource productivity:

- Transport
- Energy
- Feedstock

Minimise:

- Emissions (CO_2, NOx,SOx)
- Liquid and solid wastes
- End of life and manufacturing costs
- Use less hazardous, more eco-friendly materials

Drivers:

- **Depleting resources**
- **Promoting environmental awareness**
- **Current and future legislation**
- **Customer, supply chain and competitor pressure**

Evaluation of Design Sustainability

Aim:

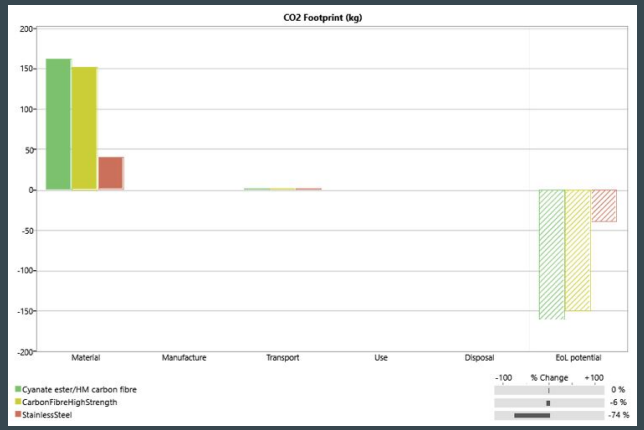
- **Minimize embodied energy or CO_2 footprint per unit of function.**

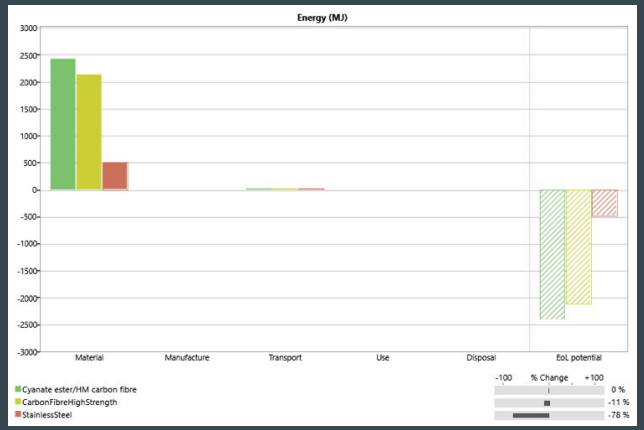
Conflicts:

- **Trade off between lowest direct eco-impact, lightest and cheapness.**

Our material choice : Carbon Fibres,high strength (5 micron,f)
Why and Features:

- Dominates all but low end bike market
- Can last a lifetime
- Fatigue strength > Aluminium > Steel
- Extremely durable due to composite nature
- Frame is made from a composite of carbon fibre and resin (akin reinforced concrete)
- Interplay between carbon and resin (minimise voids, resin cross link)
- High strength to weight ratio
- Susceptible to impact loads but impact resistance has improved over time
- Great mix between light weight,crash resistant, construction flexibility and longevity





Justification for meeting Design Requirements

Objectives:

- Minimization of mass
- Minimization of cost
- Effective use of sustainable or eco-friendly materials
- An aesthetically pleasing design

Functional and Geometric Constraints:

- Safe
- Durable
- Comfortable

References

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