2009/2010 SHELL ECO MARATHON
CHASSIS AND BODY

Design Team 16

Peter Inglis  Scott Flindall  Jason Belliveau
Agenda

- Background
  - Goals
  - Requirements
- Design Considerations
- Chassis
- Shell
- Steering/Wheels/Brakes
- Budget
- Next Steps
- Question Period
Background

Competition

- The principle of the Shell Eco-marathon is simple: to design and build a vehicle that uses the least amount of fuel to travel the farthest distance.” - Shell

Goals

- Improvements from 2008-2009 Car
- A 15% reduction in weight from the 2008/2009 Supermileage car.
- Reduce rolling resistance as well as air drag from the 2008/2009 Supermileage car.
- Design a chassis and body which will help the Super-Mileage team place 1st in the 2010 Shell Eco-Marathon in Houston, Texas.
Design Requirements

- **Chassis**
  - *Structural Integrity, Visibility, Vehicle access*

- **Body**
  - Max height < 100 cm & < 1.25 times track width
  - Width < 130 cm
  - Length < 350 cm
  - *Ventilation*

- **Steering assembly**
  - Track width > 50 cm
  - Wheelbase > 100 cm

- **Total weight of vehicle < 140 kg (w/o driver)**
Initial Considerations

- Observations
  - 2008/2009 Car
    - Large
    - Heavy
    - 42.5 lb Body
    - 46.6 lb Chassis
    - Poor visibility

- Chassis
  - Entirely supporting
  - Lightweight
  - Small
  - Good driver position
  - Safety

- Body
  - Non load bearing body
  - Wheels inside or out
  - Construction requirements
  - Cost

- Steering / Wheels / Brakes
  - Simple, precise
  - Good brakes from 2008/2009
  - High performance bearings from 2008/2009
  - Custom machined hubs / spindles
Chassis Constraints

- Requirements
  - Fit engine & drive train – (8” x 8” x 10”) envelope
  - Contain driver – Reasonable driving position
  - Safely support
    - a driver (120lbs),
    - all components (Motor/drive train 50 lbs) and body
  - Support installation of a safety harness
Design Process – Chassis

Material & Budget

- Considerations
  - Non Structural Body
    = Space Frame
  - Strong, Lightweight materials.
  - Chassis
    - Carbon Fiber vs. Aluminum
Carbon Fiber Tubing vs. Aluminum Tubing

**Strength**

- **6061-T6 Aluminum Tube**
- **Braided Carbon Fiber Tube**

**Weight**

- **6061-T6 Aluminum Tube**
- **Braided Carbon Fiber Tube**

Super mileage Chassis and Body – Design Team 16

12/4/2009
Chassis Material Selection

Material Selection

- Carbon Fiber
  - Very Expensive
  - Very High Strength to Weight

- Aluminum
  - Inexpensive
  - Workable
  - Predictable

- Best material for this application

Cost

- 6061-T6 Aluminum Tube
- Braided Carbon Fiber Tube

$/ft
Stress Analysis of Chassis

Initial calculations

- Approximated 2D frame
- Modeled as beams under bending and axial loading
- Analytically solved
  - Maximum moment location and magnitude
- Approximate required tubing
Aluminum Tubing Selection Process

In tube stress

<table>
<thead>
<tr>
<th>Weight (lbs/ft)</th>
<th>1.5&quot; 1/16&quot; wall</th>
<th>1.25&quot; 1/8&quot; wall</th>
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<th>1&quot; 1/8&quot; wall</th>
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<th>3/4&quot; 1/16&quot; wall</th>
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<td>0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
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Weight

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<td>0.3</td>
<td>0.5</td>
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</table>
FEM Analysis

- 2D mesh
  - Triangular elements.

- Worst case scenario loading condition
  - Proper constraints

- Adjust mesh size
  - Observed convergence

Stress VS Mesh Size Convergence

Super mileage Chassis and Body – Design Team 16

12/4/2009
Chassis Analysis

- Results display a safety factor above 3.0
- Tool to observe high stress locations, stress concentrations.
Chassis Design

Safety

- Roll Bar
  - Shell regulations

- Safety Harness
  - 5 point safety harness
    - Last year's harness will be mounted in similar fashion
    - Also provides a lightweight seat for the driver
Final Chassis Design

Chassis

- 1 ¼” .065 wall Aluminum Tube
- 1 ¼” 0.125 wall square tube
- 1/16” sheet aluminum
- ~15 ½ lbs
DESIGN PROCESS

STEERING / BRAKES / WHEELS
Steering Design

Considerations

- Rack and Pinion
  - Pros
    - Small space required
  - Cons
    - Relatively expensive and heavy

- 4-Link Style
  - Pros
    - Lightweight, simple, inexpensive
  - Cons
    - Steering operation not intuitive

- Ackerman Style Setup
  - Pros
    - Improves rolling efficiency when turning
  - Cons
    - Requires more precision to work correctly
    - More expensive parts
Design Choice

- **4 Link Style**
  - Adjustable
  - Relatively simple to construct
  - Lightweight

- Total weight: approx. 1.5 lb
- Total cost: approx. $50
Final Design

Rolling Components

- Shell Eco-marathon radials 44-406
  - 150 grams each
  - Low coefficient of rolling resistance
    - 0.0024 (Tested by PAC car)
- Lightweight wheels to be built by Nauss Bike shop
- Custom (last years) front hubs and axles, high performance bearings
- High performance rear hub
- Disk brakes
  - Last years set-up
  - Good quality
  - Integrated into spindles
Rolling Chassis
DESIGN PROCESS

SHELL
Design Process

Shell Design

- Closed wheel design
  - Steering not exposed
  - More compact front end
- Smooth, streamlined body
- Simplicity of construction
  - Time requirements
  - 3 person team
    - Chassis Construction
    - Body Construction
    - Steering / Wheels / Brakes components
Shell Design

Shape

- Shell conforms to chassis dimensions
- Polycarbonate windshields
  - Will be placed during driver fitting/testing
- Collaboration with Team 15 to integrate an air intake and exhaust outlet.
- Get access to CFD software
  - Testing/refinement
Shell Material Selection

Carbon Fiber vs. Kevlar vs. Fiberglass

- **Determining factors:**
  - Strength requirement
  - Weight
    - Very similar cloth weight
    - Resin requirements differ, fiberglass requires less
  - Cost
    - Carbon Fiber - $39/yard
    - Kevlar - $30-40/yard
    - Fiberglass – $8-12/yard
Shell Material

Fiberglass Composite

- Divinycell H 60 3/8“ Rigid Foam
  - 4lbs/ft^3
  - Workable
  - Scored grid, flexible.
- Fiberglass Boat cloth
  - 6oz /yd^2
- MAS Epoxy Kit
  - ~ 10lbs / ¾ Gallon
- No mold required!

Images courtesy of:
www.jamestowndistributors.com
www.masepoxies.com
Final Body Design

Body

- 6oz Fiberglass cloth
- Epoxy and Hardener
- 3/8 “ Polystyrene Foam core
- ~20 lbs

- Estimated total weight
  - Approx. 58 Lbs (conservative)
  - Approx 35% weight reduction
  - More compact, better driving position
Final Design

Budget

- Overall Low costs
- Bang for buck material
- Local purchases
  - Marine Fiberglass Supply
  - Metals-R-Us
  - Nauss Bike Shop
- Local machining
- Reusing components

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost (CAD)</th>
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<tr>
<td><strong>Body</strong></td>
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<td>Components</td>
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<td>Supports</td>
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<td>Raw Material</td>
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<td>Polycarbonate windshield</td>
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<td>Body construction Materials - PPE, Plywood Etc</td>
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<td>Raw Material</td>
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<tr>
<td>1 1/4&quot; Aluminum Tubing 1/16 wall 6061</td>
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<td><strong>Wheels</strong></td>
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<tr>
<td><strong>Grand Total</strong></td>
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NEXT STEPS

WINTER BREAK & DESIGN PROJECT II
Next Steps

- **Body Refinement**
  - CFD over the break
    - Working to access CFD software
  - Construction Planning

- **Collaboration with team 15**
  - Drive train Fitting, Air intake, Exhaust, Rear hub, Component Mounting, throttle controls
Next Steps - Construction

Schedule
Competition

- Testing Feb 9 – Mar 1
- Car leaving March 1
- Competition
  - Houston, Texas
  - March 26 - 28
Area of potential revision

Steering setup

- May need to revise steering geometry
- Rack and pinion located
  - Inexpensive
  - Lightweight
- Throttle and Brake controls

Ackermann Angle Comparison

<table>
<thead>
<tr>
<th>Turning Radius (ft)</th>
<th>Wheel Angle Difference (Deg)</th>
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<tbody>
<tr>
<td>0</td>
<td>1.58</td>
</tr>
<tr>
<td>20</td>
<td>0.64</td>
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2008/2009 Car
2009/2010 Car
http://www.rouesartisanales.com/