Tohoku University’s Electric Car for Student Formula Japan

Agenda
1. Background
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3. Direction of Design
4. Chassis
5. Drivetrain
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1. Background

Student Formula Japan

A student design competition
Design, build and test a car on our own
Evaluation: Performance, marketing, planning, design, manufacturing, cost ...

- Organizer: SAE of Japan
- Sponsor: Toyota, Nissan, Honda ...
- The number of teams: 8 (EV class in 2013)
1. Background

Outline of Events

Events (Points)

- **Static**: Cost (100)
  - Presentation (75)
  - Design (150)

- **Dynamic**: Acceleration (75)
  - Skidpad (50)
  - Autocross (150)
  - Endurance (300)
  - Fuel Economy (100)

http://www.daido-news.jp/

http://blog.livedoor.jp/jsaeformula/
2. Objective

To win the total performance award at EV class of Student Formula Japan in 2013, we plan, design & build an EV car

http://www.jsae.or.jp/formula/jp/
Merits of EV

- The battery near the center of the car
  - Good weight balance & mass concentration

- The electric motor does not need big space
  - The driving position close to C.G.

Rival Car: The frame designed for CV
- Full advantage of electrification

http://www.sist.ac.jp/club/f-sae/

Designing a car tailored for the electric powertrain, excellent dynamic performance will be gained
3. Direction of Design

- Concept of TF13

Controllability

Human-Centricity
Unity of car & driver

Quick Handling

Easy Driving

Good performance in the autocross & endurance event will be expected
4. Chassis

**Human-Centricity**
- High stiffness
- Ergonomic driving position
- **Controllability**
- Short overhang & wheelbase
- **Quick handling**

**Easy Manufacturing**
- Steel pipe space frame
- **Cost, workability, repairability**
- Reduction of the number of welded point
- **Cost & accuracy**
5. Drivetrain

Human-Centricity
- Abolishment of multispeed gearbox
  ✓ Easy driving
- 50:50 front/rear weight balance
  ✓ Controllability
  - Mass concentration
  ✓ Quick handling

Easy Manufacturing
- Chain drive
  ✓ Cost, adjustability, robustness
6. Comparison with Competitor

**TF13**

- Frame: Steel
- Bodywork: GFRP
- Overall Length: 2,300 mm
- Wheelbase: 1,530 mm
- Front: 1,175 mm
- Rear: 1,175 mm
- Height: 1,050 mm
- Ground Clearance: 37.5 mm
- Wheel: 13 inch
- Weight: 240 kg
- Weight Dist.: 50:50
- Rated Power: 12 kW
- Max. Power: 30 kW
- Battery: Li-ion, 6 kWh, 96 V
- Suspension: Front: Pushrod
- Rear: Pushrod

**The Rival Car (2011)**

- Frame: Steel
- Bodywork: CFRP
- Overall Length: 2,815 mm
- Wheelbase: 1,600 mm
- Front: 1,150 mm
- Rear: 1,150 mm
- Height: 1,074 mm
- Ground Clearance: 36 mm
- Wheel: 13 inch
- Weight: 270 kg
- Weight Dist.: 30:70
- Rated Power: 15 kW
- Max. Power: 37 kW
- Battery: Li-ion, 380 V
- Suspension: Front: Pushrod
- Rear: Pullrod

http://www.kumikomi.net/
Our objective is to **win the total performance award** at EV class of Student Formula Japan in 2013.

To achieve it, we are designing a student formula car putting the first priority on **human-centricity**.

As it is the first time for us to entry the events, we also think much of **manufacturability**.
### 8. Outline of Events

<table>
<thead>
<tr>
<th>Static Events</th>
<th>Cost</th>
<th>The validity/competitiveness of cost calculation are examined. (100P)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design</td>
<td>Appropriateness, the reformation, the processability, and the repair, etc. of the design are examined. (150P)</td>
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<tr>
<td></td>
<td>Presentation</td>
<td>The presentation technology for the manufacturing sales is examined. (75P)</td>
</tr>
<tr>
<td>Dynamic Events</td>
<td>Acceleration</td>
<td>The acceleration performance from 0 to 75m. (75P)</td>
</tr>
<tr>
<td></td>
<td>Skid-pad</td>
<td>The vehicle’s cornering performance is evaluated in steady state turns over a figure-of-eight course. (50P)</td>
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<tr>
<td></td>
<td>Autocross</td>
<td>Vehicles are driven over an approximately 800 m course comprised of a combination of straights, turns, and slaloms. (150P)</td>
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<tr>
<td></td>
<td>Endurance</td>
<td>Vehicles are driven over an approximately 20 km course comprised of a combination of straights, turns, and slaloms. (300P)</td>
</tr>
<tr>
<td></td>
<td>Fuel economy</td>
<td>Fuel economy is evaluated in terms of the amount of fuel consumed in the endurance. (100P)</td>
</tr>
</tbody>
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9. Work Environment

- Funding
  $ 53,000 (from club budget, Univ. and Co.)
  x Enough money
- Design
  2D CAD: Jw_cad, 3D CAD: SolidWorks2010
- Manufacturing
  Tools, welder (manual, semiautomatic), etc.
  x The surface plate
  -> Made a small surface plate by steel scrap

We need to use these extremely limited resources much effectively
Roadmap

Important performance in future race: Energy Efficiency
- EV as race car attracts attention

Problem: Mass of Battery
- Improvement of energy efficiency is needed

Objective: Reduction of mass of battery by improving energy efficiency
Target: 0.1kWh/km (Champion in 2012: 0.13kWh/km)

Approach: Lightening & Control

2013: Vehicle development, data acquisition, problem finding
2014: Approach finding, computation & experiment
2015: Test run, use in actual competition
2013: Vehicle development, Data acquisition, Problem finding

Development: Controllability, Quick handling, Manufacturability

①Frame
- Less welded points (Max. error without jig: 5 mm)
- Small inertia moment, Good weight balance (50:50)
- High stiffness (Toe variation on 1 G turn: 0.001°)

Available GFRP cowl

②Suspension
- Simple structure & geometry easy to make & adjust

③Drivetrain
- Robust & adjustable chain drive
- Easy drive by lightweight single speed gearbox
- High-energy density lithium-ion battery

Research: Running data acquisition such as suspension, brake, steering, motor & battery setting, current & voltage value, acceleration, angle of pedal & handle, research of broken point, seeking of approach for slip sensing
TF14

2014 : Seeking of approach, Computation, Experiment

Development : Minor change (Partial improvement of TF13)
  ① Frame  ...Lightening by wet carbon cowl -> - 5 kg
  ② Suspension...Lightening by optimization of parts
  ③ Drivetrain  ...Lightening by improvement of motor & reducer (Aluminum & carbon hybrid gearbox) -> - 4 kg
  improvement of energy efficiency by motor control

Research : Running data acquisition, research of broken point,
  dry carbon panel (Forming, adhesion to steel pipe),
  computation of flow field around drag reduction frame & cowl
2015 : Test run, Use in actual competition
Development : Full model change (Radical reform applying research in 2014)
①Frame ...Lightening by semi-monocoque -> - 3 kg
  Lightening by 10 inch magnesium wheel -> - 5 kg
  Improvement of energy efficiency by drag reduction
②Suspension...Lightening by 10 inch magnesium wheel -> - 5 kg
③Drivetrain ...Lightening by hand-made controller
  Improvement of electric energy storage system
  (Capacitor or flywheel)
Research : Running data acquisition, research of broken point,
  development of application to support eco driving,
  seeking of approach for more improvement of energy efficiency
  (4 wheels, power, brake, suspension, steering cooperative control),
  making energy by solar panel on paddock