Product Development and Validation of Electric Vehicles

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Seminar – Challenges of Future Vehicle Technology and Regulation
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01

Background

• Johary Chart
• Professional Experiences
• Electric Car: Opportunities and Challenges
Background | Johary Chart

SIGIT P. SANTOSA

EDUCATION:
- Enginieur, Ir – ITB (1991),
- Master of Science of Mechanical Engineering, MSME – MIT (1997),


Faculty Staff, Faculty of Mechanical and Aerospace Engineering, ITB, 2013- Now

Director – Intitute for Innovation and Entrepreneurship Development, LPIK ITB, 2018 - Now

Director – Center for Collaborative Research - National Center for Sustainable Transportation Technology – CCR NCSTT, 2017 - Now

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### Background | Professional Experiences

<table>
<thead>
<tr>
<th>Year</th>
<th>Experience</th>
<th>Car Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>Cadillac XLR</td>
<td>Senior Engineer</td>
</tr>
<tr>
<td>2004</td>
<td>Corvette C6</td>
<td>Senior Lead Eng.</td>
</tr>
<tr>
<td>2005</td>
<td>Corvette Z06</td>
<td>Senior Lead Eng.</td>
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<tr>
<td>2006</td>
<td>Cadillac DTS/ Buick Lucerne</td>
<td>PTL – Team Leader</td>
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<tr>
<td>2007</td>
<td>Chevy HHR</td>
<td>PTL – Team Leader</td>
</tr>
<tr>
<td>2007-2009</td>
<td>Senior PTL: Chevy Equinox GMC Terrain CREC – Canada GMM - Mexico</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>EGM: GMK – Korea Chevy Cruze Compact SUV Mini Car Small Car</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>EGM: Chevy Volt. Chevy Sonics Chevy Spark NG Compact SUV NG Compact</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>EGM: Cadillac ELR GMK – Korea GME – Germany PATAC – China NG EREV/Hybrid NG Mini</td>
<td></td>
</tr>
<tr>
<td>2013-Now</td>
<td>PI – Principal Investigator Product Dev. Electric Based Transportation NCSRR/SHERA</td>
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Background | Sustainable Transport

- **Sustainable transportation system:** a transport system that is accessible, safe, comfortable, environmentally friendly, and affordable.

- **Major issues of urban transport:**
  1. High-level Traffic congestion
  2. Dependence on fossil fuel / non-renewable energy
  3. Pollution

**Note:**
- Study in 2017: Economic impact for traffic congestion in Jakarta Rp. 31T/year (NCSTT – Green Drive, Sustainable Automotive Engineering)
- Jakarta is in the top 5 Air Quality & Pollution City Most Polluted Ranking, with AQI = 152 on July 22, 2019.
PROBLEM: Un-sustainable Transportation in Indonesia
- High traffic jam, pollution, dependence on fossil fuel
- Transportation system in Indonesia cannot support national economic development.
- Low Air Quality Index in Indonesian big cities

CHALLENGES: Electric Vehicle Revolution in 2025 and beyond
- Fuel Economy Regulation of 56.5 MPG (Mile Per Gallon) started in 2025
- The electric based transportation will be the solution wrt cost & regulation
- Global electric vehicle proliferation strategy in Indonesia will need to be addressed

OPPORTUNITIES: Indonesian Transport Expansion Plan in 2030
- Indonesian market for passenger vehicles will increase from 1.4 million to 4 million.
- New urban railways system of 3800 km will require 12,000 new passenger coaches will be needed (RIPNAS).
02 Solution

• Future Mobility
• Powertrain Technology Innovation
• Electric Vehicle Development Process
Solution | Sustainable Integrated Transportation

Renewable Energy: Electric, fuel cell, geothermal, HTGR Power Plant

Integrated Transportation System/Intermodal Solution: Electric Based Transport

Technology Development: Electric Based Propulsion, Advanced Materials

Infrastructure Development Roadmap: charging station

Transport Authority: Master Plan supported by all stakeholders

Government Policy: Emission/polluion, Safety – Type approval/Certification

Implementation/ Monitoring/ Enforcement
Solution | Future Mobility

- Electric vehicle / Range Extender Technology
- Autonomous Vehicles
- Artificial intelligent / Deep Learning
- Next generation electric propulsion

Key enabler:

*Safe & Fast to market* vehicle development – Short Vehicle Development Phase
Future/Next Generation Powertrain Technology:

- Electric/hybrid: Industrial Revolution 2020 – 2030
  - Parallel system: Both engine and motor are used to power the drive
  - Serial system: Engine is only used to recharge the battery – Extended range electric vehicle (EREV) – Chevy Volt
  - Conventional gasoline engine will cost on the average of $300 / month for local commute
  - Electric vehicle will cost $0.85 x 30 = $ 25.5 / Month

- Hydrogen Fuel Cell: Next Industrial Revolution 2030-2050
  - In-car power drive is generated by fuel cell reaction of \( \text{H}_2 + \text{O}_2 \), resulted in \( \text{H}_2\text{O} \) – environmentally friendly exhaust product
  - However, Carbon dioxide is generated when the \( \text{H}_2 \) is produced outside of the car from fossil fuels
Vehicle Development Process - VDP

- Technological Opportunities & Challenges
- RESS (Reserved Energi Storage System)
- Electric Vehicle Development Process
- Validation
Electric bus for shuttle transportation

e-Trike: Electric vehicle for delivery

RESS - Reserved Energy Storage System (Li-Ion NCA Battery, Solid State Battery)

Battery integrity/safety system

Infrastructure development, static/dynamic induction charging system
VDP | Key Technology Development

- RESS: Reserved Energy Storage System – Battery System
- Electric Propulsion
- Vehicle Platform
- Control and Instrumentation
- Accessories and Electrification System
RESS/Battery is the most critical system required to resolve vehicle electrification technology application: Energy capacity and Safety/Integrity.
VDP | Opportunity on RESS Battery Development

**Micro-scale**
- Physics/Materials
  - Microstructures
  - Molecular Dyna.
  - Dislocation Dyna.
- Techniques
  - SEM
  - EBSD
  - TEM
  - X-ray Diffraction
  - Micro CT scan

**Meso-scale**
- Continuum Mechanics
  - Elasticity
  - Plasticity
  - Fracture
- Objects: components
  - Anode
  - Cathode
  - Separator
  - Coating

**Macro-scale**
- Structural Mechanics
  - Deflection/Stiffness
  - Crashworthiness
  - Finite Element Methods
  - Design & optimization

**Macro system**

- Bottom up
- Top down
- Collaboration ITB-MIT Under USAID/SHERA Program
VDP | Opportunity – Efficient Technology on Motor Drive

Internal Combustion Engine = 200 parts

Electric Motor (Tesla) = 17 parts

- Patent US7741750 - Induction motor with improved torque density
- Patent WO2007145726A3 - System and method for an efficient rotor for an electric motor
- Patent EP2237392A3 - AC motor winding pattern
Safe and affordable RESS – Battery System: Thermal event issues and high cost/kwh ($200-$400/kwh)

- 32 km/h side pole impact crash test by NHTSA in 2011
- Vehicle caught fire 2 weeks after the crash test
- RESS thermal issues: Dendritic crystalization of coolant creating voltage short

Source: NHTSA Report # DOT HS 811 573
VDP | Challenges on RESS – Battery Thermal Event

PHEV #1: Thermal event (2014)

EV #2: during normal road travel (2015)

EV #3: after struck object on the road (2018)
• Ground impact protection for battery safety
• Axial deformation limit of battery < 3 mm
**High Voltage Electrical Integrity Requirement: US FMVSS305 & Consumer Metrics**

- For high voltage DC systems, there shall be no sustained shorts or arcs between the high voltage DC positive and high voltage DC return.
- For high voltage AC systems, the system shall maintain 500 ohms/volt isolation between individual AC phase circuits and vehicle chassis.
- For high voltage AC systems, there shall be no sustained shorts or arcs between the individual AC phase circuits.
- No visible trace of electrolyte from energy storage devices shall spill into the passenger compartment.
Impact test conditions, as applicable for US/EU:

**North America**
- Frontal Barrier Impact at 35 mph (NCAP)
- Frontal 40% Overlap Deformable Barrier Impact at 64 kph (IIHS ODB)
- Dynamic Side Impact with a Deformable Moving Barrier at 38.5 mph (Side NCAP)
- Dynamic Side Impact with a Deformable Moving Barrier at 50 kph (IIHS)
- FMVSS 214 (Oblique Pole, 5th & 50th%ile Occupants)
- Rear 70% Overlap Deformable Moving Barrier Impact at 87.6 kph
- Protection against ground impact

**Europe**
- Frontal 40% Overlap Deformable Barrier Impact at 65 kph (EuroNCAP)
- Dynamic Side Impact with a Deformable Moving Barrier at 50 kph (EuroNCAP)
- Dynamic Side Pole Impact at 29 kph (EuroNCAP)
- Rear Moving Barrier Impact at 54 kph
- Protection against ground impact
The automatic voltage disconnect function provides an eventual means of isolating the battery pack from external circuitry or components without user intervention, based on some input triggering event:

- Vehicle Crash Sensor
- Detected Loss Of Battery Isolation (Ground Fault)
- Hazardous Voltage Interlock Loop (HVIL)
- Overcurrent
Crash Impact Strategy

Low Speed Events

- High Voltage System
  - Package cable and components outside of the potential damage zone as much as possible
  - If the cable and/or components were expected to be in the damage zone, then package protect the HV system to activate the automatic disconnect function

High Speed Events

- High Voltage System
  - Provide friendly surface around cable and components
  - Design additional cover/shields to protect components if necessary

High Voltage System
- Activate the automatic disconnect function
RESS Located in the Passenger Compartment

RESS (Reserved Energy Storage System)

- Package RESS to prevent direct loading of the modules.
- Reduce the amount of crush by strengthening the structure around ESS.
- Build fuse in RESS to provide short circuit protection.

High Voltage Cable

- Activate the automatic disconnect function for all high speed crash events
- Package the cable pass through toward center of the floor pan or provide additional protection to the cable at pass through.
- Route the cable toward center of the vehicle, inboard of underbody rails.
- Use plastic conduit to secure cable to body and to provide additional protection to the cable.
VDP | EV Validation Program

| US NCAP/208 | MVSS208, Unbelted | US/Canada Bumper Part 581 | EUNCAP & EU Phase 1,2 Pedestrian | EuroNCAP Frontal 64 kph |
| US NCAP/208 | MVSS208, Unbelted | US/Canada Bumper Part 581 | EUNCAP & EU Phase 1,2 Pedestrian | EuroNCAP Frontal 64 kph |

| Side NCAP 62 kph | IMHS Side Impact 50 kph | FMVSS214 Side Pole 32 kph | Side Barrier to Vehicle 80 kph | MVSS301+20% 88 kph | FMVSS216 Roof Crush | 54 kph RMB | Danner/Thatcham Damageability |

**Total Global Load Cases**: ~ 120

**Global Legally-Required Load Cases**: ~ 100

**Global Voluntary Load Cases (Safety Rating)**: ~ 20
Summary | Conclusion

• The electric vehicle is part of the industrial revolution for future mobility
• High opportunity for new industry development as the EV technology acquisition is in the same level playing field for all countries
• Need national priority for EV development to solve the burden of diseases due to pollution
• Comprehensive EV validation is required to ensure public safety
TERIMA KASIH