Two Pioneering Hydrail Projects in Japan and technical issues for the hydrails

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1. Back Ground
2. Hydrail project by JR EAST
3. Hydrail project by Railway Technical Research Institute
4. Hybridalization technologies to boost up the hydrails
5. Concusions
1. Background

Technical issues for the Energy supply

- **Electrified railway vehicle**
  - Silent and recuperative
  - High cost for the electrification
  - [http://www.jreast.co.jp/train/local/kiha58.html](http://www.jreast.co.jp/train/local/kiha58.html)

- **Diesel powered vehicle**
  - Autonomous
  - Non-reuperative, noisy
Price and lifelong target for railway traction application

- Engine cost: 1PS/10000JPY ⇒ 3-5 mil JPY / Engine
- Final stage: 1 kW / 10000 JPY (same as diesel engines)
- Heavy maintenance: Every 4-6 years (Ave. 40000 hours)
- Life time target: Minimum 40000 hours (A heavy maintenance period)

Fuel cell can enjoy the both benefits.

- Electric railways without the catenary
  - Low cost, less maintenance
  - Visual prolusion free
- Energy efficient non electrified train
- Recuperate the kinetic energy
- Silent and high ride comfort
Two projects in Japan
Fuel cell and battery hybrid experimental projects

-East Japan Railway company (JR East)
- 2006 – 2009
  - Experimental car basis
  - 150kW PEMFC and battery

-Railway technical Research Institute (RTRI)
- 2006
  - Experimental car basis
  - 120kW PEMFC and battery

Reference
(1) JR East press release;
  "http://www.jreast.co.jp/e/press/20060401/index.html"
(2) R. Furuta, J. Kawasaki, K. Kondo,
  "Hybrid Traction Technologies with Energy Storage Devices
  for Non-Electrified Railway Lines”,
  IEEJ Transactions on Electrical and Electronic Engineering,
Aim of the development

View point: Railway operator

- Reduce the environmental impact (Higher efficiency)
- Catenary less electrified railway system.

Purpose of the development

- Prepare technically when fuel cell technologies mature.
- Reveal the technical problems to apply fuel cells to railway vehicle traction.

Specifications

Number of vehicle: 1 car/train
Dimension: 20m × 2.8m × 4.2m
Max. speed: 100km/h

System configuration
**Efficiency**

- Fuel (hydrogen gas)
- Fuel cell Stack
- DC/DC Converter
- Traction Motor
- Gears
- VVVF Inverter
- Secondary battery
- Regenerative energy
- Storage loss
- Conversion loss
- Generative loss
- Mechanical loss
- Motor loss
- Conventional loss
- Tank (\(\text{\*6}\)) to wheel

*1 Nominal value of Ballard HY-80
*2 Nominal value of fuel cell hybrid experimental car
*3 Efficiency of parallel cardan driving devices: 97.5%
*4 Quoted from the JHFC report (LHV-base loss)
*5 We suppose that the battery is charged with only regenerative energy.

**Running test**

- Successfully running on a commercial line (experimental train schedule)
- Tests on Nagano area
- Max. speed 100km/h
3. Hydrail project by RTRI

Reference

Aim of the development
To contribute technically to solve these problems
To encourage the railway operators to apply FCs.

- Safety issues
  - Anti-hydrogen leakage structure
  - Anti-firing mechanism
  - Anti-explosive construction
  - Regulations

- Power electronics
  - Circuit configuration
  - Control technology

- Hydrogen supply
  - On board accumulation
  - On board reformer
  - Hydrogen infrastructure

- Fuel cell and BOP
  - Durability/Cost
  - Efficiency
  - Load following performance

- Regenerative power absorbing
  - Energy accumulation measures
  - Control technology

- Innovative hydrogen application

- Other innovative

Fig.3. Technical issues for fuel cell trains.
Possible application objects

Candidates of application of PEMFC Power Supply

<table>
<thead>
<tr>
<th>Items</th>
<th>Benefits</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auxiliary Power Unit</td>
<td>Noise Reduction at running. Lower Emission.</td>
<td>Up to 100kW almost constant power</td>
</tr>
<tr>
<td>DMUs for Commuter</td>
<td>Noise Reduction at running.</td>
<td>Up to 500kW variable power</td>
</tr>
<tr>
<td></td>
<td>Lower Emission.</td>
<td>Large scale power storage for regenerative brake</td>
</tr>
<tr>
<td>DMUs for Express</td>
<td>Lower Emission. Energy saving.</td>
<td>800kW or more variable power</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Large scale power storage</td>
</tr>
</tbody>
</table>

Test plan and results

R&D test plan

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Study on FC Chara.</td>
<td>Study on the Propulsion System for 150 kW FC.</td>
<td>Drive test with hybrid system with energy storage system</td>
</tr>
<tr>
<td>Study on the Traction System for 30 kW Class FC.</td>
<td>Drive Test on an test track and rolling stock test facility in RTRI.</td>
<td></td>
</tr>
<tr>
<td>Completed</td>
<td>Completed</td>
<td>On going</td>
</tr>
</tbody>
</table>

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Full scale passenger vehicle with 150kW fuelcell

18.75 kW * 6 stacks

35MPa Pressurized Hydrogen cylinder

150 kW PEMFC power module on board

Running Test on the RTRI test track (w/o batteries, up to 40 km/h, phase 2)

Running Test on the RTRI test facility (Up to 100 km/h)
Specifications of the experimental train (phase3)

Number of vehicle: 2 car/train
Dimension: Length of a vehicle 20m
Max. speed : 100km/h

System configuration

Fuel: 35MPa compressed hydrogen

4. Hybridization technologies to boost up the hydrails
**Benefit of Hydrail**

- Energy storage on board can cover the drawbacks of the electric traction system.
- Hydrail may enhance the electric traction system with the energy storage perfect autonomous system.

**Hybridalization with the energy storage devices**

- Effective to reduce the FC cost for the first commercial stage
- Higher power during long period is assisted by the batteries or EDLCs
Traction circuit for the hybridization

EDLCs or Li-ion batteries

Designing method of the hybridization

Energy is determined for the powering the vehicle. Power is determined for the regenerative brake.
Feasibility study to cut the FC power by the energy storage.

Ttractive Power (MAX) 211 kW
FC Power 120kW => 90kW for FC power is saved.

5. Conclusions
- East Japan Rail Co., the world largest railway operator, has successfully carried out the experimental running of their own Fuelcell train.

- Railway Tech. Research Inst., a subsidy research arm of Japan railways, is studying the technical aspect of the fuel cell train with their two cars test train.

- Hybridalization is key technologies to boost up the fuel cell in the application market.

Thank you for your kind attention