Flow Simulation With AcuSolve to Improve Railway Vehicles

SATÔ, Tetsuro
NIPPON SHARYO, Ltd.
TET-SATÔ@cm.n-sharyo.co.jp
Corporate Profile

Head office: Nagoya, JAPAN
Establishment: September 1896
Paid-in capital: 11,810 million yen
Sales: 94,842 million yen (896M Euro: FY 2010)
Employees: 1,969 (Apr. 2010)

Production capacity: 600 Commuter cars / year
Latest domestic trains

- Series 383 Tilting System for JR Central
- Series 313 for JR West
- Series 683 for Keio
- Type 220 DC for JR Kyushu
- Series 2000 Airport Express for Nagoya Railroad
- Series 187DC Tilting System for JR West
- Series 7000 for Nagoya City Subway
- Type 7000 for JR East
- Series 3300 for Nagoya Railroad
- Series 215 for JR East
- Series 8000 Tilting System for JR Shikoku
- "LINIMO" HSST-100 for Aichi Rapid Transit
- Type 8000 Articulated Train for Odakyu
- YURIKAMOME Series 7000 New Transit System
- Series 281DC Tilting System for JR Hokkaido
- Type 8000 Articulated Train for JR Shikoku
- Series 313 for Keisei
- Series 9000 for Keio
- Type 3000 for Keisei
- AE “Sky access” for Keisei
- Series 07 for Tokyo Metro
- Series 07 for Keisei
- Series 08 for Tokyo Metro
- Series 383 Tilting System for JR Central
- Series 07 for Tokyo Metro
- Type 3000 for Odakyu
- Series 3300 for Nagoya Railroad
- Type 3000 for Yokohama City Subway

Fig. 2
Trains in the world

Fig. 3
Shinkansen (bullet train)

- **1964** Series 0
  - 210 km/h
- **1982** Series 200
  - 220 km/h
- **1992** Series 300
  - 270 km/h
- **1997** Series E2
  - 275 km/h
- **2000** Type 923
- **1986** Series 100
  - 230 km/h
- **1997** Series 500
  - 300 km/h
- **1999** Series 700
  - 285 km/h
- **2004** Series 700T
- **2007** Series N700
  - 300 km/h

3,202 Shinkansen cars for revenue service

Fig. 4
CFD for railway vehicles

Safety
- Cross-wind load estimation
- Passing-trains aerodynamics

Amenity
- Vibration excitation
- Tunnel entry noise
- Aeroacoustics
- HVAC

Productivity
- FSW joining process

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1. Cross wind load estimation

Plan A

Plan B

Fig. 5 Time-average wind velocity
2. Trains passing by each other

Main interest: Intermediate car

Criteria: Unsteady load caused by the opposite train

Wind velocity at the ground level.

Fig. 6
3. Full transient passing-by

Main interest: Leading car design, ride comfort
Parameters: Leading car design, train velocities
Criteria: Aerodynamic forces acting on every car, Maximum/minimum of local pressure and wind velocity

Fig. 7
4. Mitigating aerodynamic excitation

Main interest: Ride comfort of the trailing car

Fig. 8 Unsteady flow over the trailing car
Breakdown of vortices

Fig. 9 Breakdown of trailing vortices
5. Train shape optimization to minimize the tunnel entry noise

Fig. 10 Tunnel entry pressure wave

time = 0.125
Tunnel entry flow simulation

Fig. 11  Moving boundary problem
Tunnel entry experiment

Fig. 12 Tunnel entry experiment
3D shape optimization using the “specific response”

Fig. 13 Tunnel entrance
Specific response of the tunnel

Fig. 14 Spatially non-uniform response function
3D shape optimization to minimize the tunnel entry noise

Fig. 15 Shape optimization
3D shape optimization to minimize the tunnel entry noise

Fig. 16  Shape optimization
6. Reduction of the noise from the door frame

Fig. 17 Door frame
Fig. 18  Aeroacoustics; flow model

320224 brick elements

2H = 1.26\delta_{eqn}

10H

4H

20H = 1.26\delta_{eqn}
Horizontal cross section

Pressure Deviation
\[ p' = p - \bar{p} \]

Instantaneous Helicity
\[ h = v \cdot \text{rot} \ v \]

Fig. 19  Aeroacoustics; flow field
Intensity of dipole noise source

Fig. 20 Pseudo-sound
Amenity

Acoustic analysis

Fig. 21  Aeroacoustics; Near sound field

0.827749
Shape improvement

Initial Design

Elliptic Quadrant

Fig. 22  Shape improvement
7. Heating, Ventilating and Air Conditioning system

Objective: Inlet and outlet design, suitable for both summer and winter.

Fig. 23 Unsteady cabin flow simulation

Forced convection, Free convection, Radiation, Unsteady flow with turbulence model, Heat transfer, Heat load, Solar radiation
HVAC system

Fig. 24 Cooling; Average flow field
HVAC system

Fig. 25 Heating; Average Flow Field
8. Friction Stir Welding

Objective: Optimization of the tool, welding parameters

Fig. 26 Self-Reacting Pin Tool
Butt welding

"Outflow" B.C.

"Inflow" B.C.

Fig. 27  F.E. mesh & boundary conditions
Fig. 28 Result; U=2500mm/min, 2000rpm

Max. T. = 572°C

Temperature

Productivity

Advancing side

Weld centerline

Retreating side

Temperature Contours:
- 50°C
- 100°C
- 150°C
- 200°C
- 250°C
- 300°C
- 400°C
Particle Tracing

Fig. 29 Result; U=2500mm/min, 2000rpm
Conclusions

Numerical simulation conducted by acuSolve is useful in getting the ideas for making decision.

It helps us improve our railway vehicles.
Thank you
Danke

http://www.n-sharyo.co.jp/

mail: TET-SATO@mn-sharyo.co.jp
References

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