Passenger Coach Design: Ease of Maintenance & Examination and Design Tools

By
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Integral Coach Factory, India
Flow of Presentation

- Design Criteria
- Aspects influencing maintenance
- Current Important Projects in Indian Railways highlighting Ease of Maintenance
- Important Design Tools
- Futuristic Design Technologies
Design Criteria
Design Criteria

- Buffing Load of 101.6t at each buffer
- Vertical Load of 2.165 t/metre run
Coach Cross Section

- Carline
- Partition
- Body Pillar
- Trough Floor
- Solebar
- Window
FE Analysis
Height  –  1771 mm
Overall width  –  619 mm
Knee space  –  270 mm
Width over abdomen – 302 mm
Body Weight – 74 kg
Ease of Maintenance

- Selection of Material
- Design Improvements
- Painting System
Selection of Material

- One of the important aspect considered while selecting material for Coach Construction is Corrosion Resistance
What is Corrosion?

“Corrosion is oxidation of steel in the presence of moisture”

or

“Conversion of any metal into hydrated metal oxides is also termed as corrosion”
Types of Corrosion Noticed in Coaches

- **Poultice corrosion**

  Surface accumulations (poultices) that retains moisture promotes corrosion known as poultice corrosion.

- **Pitting corrosion**

  It is a non-uniform corrosion that results from inhomogeneities in metal due to inclusion & distorted zones which set up differences of potential at localised spots to cause deep isolated holes or pits.
Types of Corrosion Noticed in Coaches

- **Galvanic corrosion**
  
  When dissimilar metals are held in contact in the presence of moisture galvanic corrosion occurs.

- **Crevice corrosion**
  
  Unprotected crevices as mating surfaces can collect and retain moisture that may form a pathway for corrosive electric current leading to Crevice corrosion.
Types of Corrosion Noticed in Coaches

- Filliform corrosion

  Filliform corrosion occurs on painted surfaces where a defect or scratch in the coating occurs allows access.

- Intergranular and stress corrosion cracking

  Stress corrosion cracking occurs due to unlikely combination of alloys and products
Selection of Material – Stainless Steel

Stainless steel can resist corrosion in coastal, saline and other chloride bearing environment.
Selection of Material – Stainless Steel

- Stainless steels - alloys of iron containing minimum of 10.5% chromium

- Chromium forms a passive film of Chromium Oxide, which prevents corrosion

- Nickel, Manganese, Nitrogen help in forming austenitic structure in Stainless Steel or impart special properties
Selection of Material – Stainless Steel

- Stainless Steel absorbs 2.5 times more energy than carbon steel
- Less Fatal accidents
- High strength at high temperature. Retains half the room temperature strength at $500^0$ C
- No painting required
- Not prone to fire
# Properties of Stainless Steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>UTS Min</th>
<th>0.2% Proof Stress Min</th>
<th>%Elongation Min 50mmGL</th>
<th>Hardness Max RB</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS 301</td>
<td>515</td>
<td>205</td>
<td>40</td>
<td>95</td>
</tr>
<tr>
<td>SS 304</td>
<td>515</td>
<td>205</td>
<td>40</td>
<td>92</td>
</tr>
<tr>
<td>SS 304L</td>
<td>485</td>
<td>170</td>
<td>40</td>
<td>92</td>
</tr>
<tr>
<td>SS 310S</td>
<td>515</td>
<td>205</td>
<td>40</td>
<td>95</td>
</tr>
<tr>
<td>SS 316</td>
<td>515</td>
<td>205</td>
<td>40</td>
<td>95</td>
</tr>
<tr>
<td>SS 316L</td>
<td>485</td>
<td>170</td>
<td>40</td>
<td>95</td>
</tr>
<tr>
<td>SS 321</td>
<td>515</td>
<td>205</td>
<td>40</td>
<td>95</td>
</tr>
<tr>
<td>SS 409</td>
<td>380</td>
<td>170</td>
<td>20</td>
<td>88</td>
</tr>
<tr>
<td>+SS 409M</td>
<td>450</td>
<td>275</td>
<td>20</td>
<td>90</td>
</tr>
<tr>
<td>SS 410S</td>
<td>415</td>
<td>205</td>
<td>22</td>
<td>89</td>
</tr>
<tr>
<td>SS 420</td>
<td>690 (max)</td>
<td>205</td>
<td>15</td>
<td>96</td>
</tr>
<tr>
<td>SS 430</td>
<td>450</td>
<td>205</td>
<td>22</td>
<td>89</td>
</tr>
<tr>
<td>Country</td>
<td>Model</td>
<td>Tons</td>
<td>No. of coaches</td>
<td>Length (m)</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------</td>
<td>-------</td>
<td>---------------</td>
<td>------------</td>
</tr>
<tr>
<td>Japan</td>
<td>Series 200</td>
<td>714.4</td>
<td>12</td>
<td>300</td>
</tr>
<tr>
<td>Japan</td>
<td>Series 700</td>
<td>634.2</td>
<td>16</td>
<td>400</td>
</tr>
<tr>
<td>UK</td>
<td>Class 390 (P)</td>
<td>459.7</td>
<td>9</td>
<td>215.1</td>
</tr>
<tr>
<td>Germany</td>
<td>ICE-3`</td>
<td>409</td>
<td>8</td>
<td>200</td>
</tr>
<tr>
<td>France</td>
<td>TGV PBKA</td>
<td>385</td>
<td>10</td>
<td>200</td>
</tr>
<tr>
<td>India</td>
<td>AC 2-Sleeper-ICF</td>
<td></td>
<td></td>
<td>21.8</td>
</tr>
<tr>
<td>India</td>
<td>LHB Design</td>
<td></td>
<td></td>
<td>23.5</td>
</tr>
</tbody>
</table>

- 30% weight savings/ meter through the use of Stainless Steel in Indian Railways
# Life Comparison

<table>
<thead>
<tr>
<th>Material</th>
<th>Life</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel (1955- 1976)</td>
<td>5-6 years</td>
<td>High Maintenance</td>
</tr>
<tr>
<td>Corton Steel (1976- onwards)</td>
<td>20 years</td>
<td>Major corrosion Repairs every 7-8 years</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>&gt;40 years</td>
<td>Negligible Maintenance</td>
</tr>
</tbody>
</table>
Cutting of Stainless Steels

Stainless Steels Are Easily Cut Using a Range of Common Processes

Mechanical
- sawing
- shearing
- abrasive wheel cutting
- water-jet cutting

Thermal
- plasma cutting
- laser cutting

Oxy-acetylene is not satisfactory
Formability

Austenitic Stainless Steels Have Excellent Formability

- They are among the most formable of all the engineering materials.
- They have high work hardening rates.
- This means the strength increases as they are formed.
- It also means they have greater springback than carbon steels, and allowance must be made for this.
Welding of Stainless Steel

Stainless Steels are Easily Welded Using a Range of Common Processes

“If you can’t weld austenitic stainless steel, you can’t weld.”

Fronius
Tack Welding

Place tacks in a proper sequence to minimise distortion.

Use about half the spacing between stainless steel tacks as is used for carbon steel welding.
Post Fabrication Cleaning

Stainless Steel Structures Generally Require Some Form of Post-Fabrication Cleaning Treatment

Main objectives are:

• Remove heat tint.

• Make sure there is no surface contamination, such as smeared or embedded iron.

• Ensure there is a strong, continuous, protective chromium-rich oxide layer all over the surface.
Cross Section of Stainless Steel Weld

- heat tint welding scale
- low-Cr layer just under the heat tint low corrosion resistance

stainless steel plate

stainless steel weld

stainless steel plate
Removing Heat Tint

- **grinding** (abrasive discs or flapper wheels)
  - Do not smear (e.g. wire brushes) or overheat the surface.
  - (e.g. worn abrasives or excessive pressure)

- **blasting** (e.g. glass beads)
  - Local or large area cleaning
  - Do not use carbon steel shot or blast media contaminated with iron.

- **pickling** (mixed nitric-hydrofluoric acids)
  - Immersion, spray or paste

- **electropolishing** (electrocleaning)
  - Site or shop treatment
Pickling

- Chemical treatment to corrode the surface of stainless steel in a controlled fashion to remove both the heat tint and the underlying low-chromium layer.
- covered by: ASTM A 380
Electro-polishing

- removes heat tint
- removes surface contamination
- smooths the surface
Electro-polishing

Hand-held Electropolishing Tool

- Electrolyte held in a nylon sponge
- Copper cathode
- Stainless steel (anode)
- Insulated handle
- DC current

See Nickel Institute publication 10068
*Specifying Stainless Steel Surface Treatment*

- Red: Heat tint
- Blue: Chromium depleted zone
Iron Contamination

Corrosion of Iron Embedded in a Stainless Steel Weld by Using a Carbon Steel Wire Brush
Selection of Material – Stainless Steel

- Advantages of Stainless Steel
  - Corrosion resistance
  - Strength
  - Better aesthetic look
  - Low on maintenance
# Stainless Steel – Areas of Usage

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trough floor</td>
<td>AISI - 301</td>
</tr>
<tr>
<td>Luggage rack</td>
<td>AISI - 202</td>
</tr>
<tr>
<td>SS sink with drain board</td>
<td>AISI - 304</td>
</tr>
<tr>
<td>Sole bar in pantry</td>
<td>AISI – 409M</td>
</tr>
<tr>
<td>Sidewall upto window level in pantry</td>
<td>AISI- 409M</td>
</tr>
<tr>
<td>Body pillars in pantry</td>
<td>AISI-409M</td>
</tr>
<tr>
<td>Door corner sheet in pantry</td>
<td>AISI-301</td>
</tr>
<tr>
<td>SS Pantry equipments</td>
<td>ICF/ MD/SPEC-124</td>
</tr>
<tr>
<td>SS Paneling in entire pantry area</td>
<td>AISI-304</td>
</tr>
<tr>
<td>Floor side moulding</td>
<td>AISI-301</td>
</tr>
<tr>
<td>Modular toilet-SS</td>
<td>AISI-304</td>
</tr>
<tr>
<td>Lavatory latch with indicator</td>
<td>AISI-304</td>
</tr>
<tr>
<td>SS handle</td>
<td>AISI-304</td>
</tr>
<tr>
<td>SS pipes and double ferrule fittings</td>
<td>ASTM-A269, TP GR-304, ASTM-A276 TP-316</td>
</tr>
</tbody>
</table>
## Stainless Steel – Areas of Usage

<table>
<thead>
<tr>
<th>Item</th>
<th>Material Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand rail</td>
<td>IS-6913-73 Gr.B for tube and AISI-304 for Base plate</td>
</tr>
<tr>
<td>Hand holds</td>
<td>AISI-304</td>
</tr>
<tr>
<td>Sunk in type shelf</td>
<td>AISI-304 2B finish</td>
</tr>
<tr>
<td>Soap dish</td>
<td>IS-6911-92 X04 Cr19 Ni9</td>
</tr>
<tr>
<td>Wash basin</td>
<td>AISI-304 Bright finish</td>
</tr>
<tr>
<td>Toilet paper holder – sunk in type</td>
<td>AISI-304 2B finish</td>
</tr>
<tr>
<td>Lavatory inlay</td>
<td>AISI-304</td>
</tr>
<tr>
<td>SS towel rail</td>
<td>IS-6913-73 Gr.B for tube and AISI-304 for Base plate</td>
</tr>
<tr>
<td>Alarm handle</td>
<td>AISI-304</td>
</tr>
<tr>
<td>Sunk in type alarm housing</td>
<td>AISI-304</td>
</tr>
<tr>
<td>Back rest lock</td>
<td>AISI-304</td>
</tr>
</tbody>
</table>
Stainless Steel Toilet Pan
Stainless Steel Wash Basin
Stainless Steel Paneling in IAC Toilets
Stainless Steel Paper Holder in Toilet
Stainless Steel Bottle Holder
Stainless Steel Fan
Stainless Steel Seat Frames
Stainless Steel doorway partition
Stainless Steel Pipes And Double Ferrule Fittings for Air Brake System

- Advantages
  - Leak proof
  - Torque free
  - Maintenance free seals at all tube connections
  - Self aligning
  - Works on thin wall tubes (No threads)
  - Resists vibration
  - Easy to install
  - Re-usable upto 25 times reassembling
Stainless Steel Pipes and Double Ferrule Fittings
Stainless Steel Pipes and Double Ferrule Fittings
Stainless Steel Double Ferule Fittings
Selection of Material - Composites

- Why Composites are preferred
  - Design flexibility
  - Rapid construction
  - High stiffness and strength
  - Weight savings
  - Low maintenance
  - Passenger Safety
## Composites – Comparison of Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Phenolic GRP</th>
<th>Polyester GRP</th>
<th>Mild Steel Painted</th>
<th>Aluminum Painted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/ml)</td>
<td>1.4 to 1.5</td>
<td>1.4-1.5</td>
<td>1.6-2.3</td>
<td>7.8</td>
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<tr>
<td></td>
<td></td>
<td>1.6-2.3</td>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td>TS (MPa)</td>
<td>100-140</td>
<td>100-140</td>
<td>30-75</td>
<td>410-480</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30-75</td>
<td></td>
<td>80-430</td>
</tr>
<tr>
<td>Coeff. Thermal expansion (°C x10^{-6})</td>
<td>10-15</td>
<td>25-35</td>
<td>18-25</td>
<td>11-14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22-24</td>
</tr>
<tr>
<td>Coeff. Thermal Conductivity (W/m/k)</td>
<td>0.20-0.24</td>
<td>0.20-0.23</td>
<td>0.20-0.30</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>140-190</td>
</tr>
</tbody>
</table>
Selection of Material - Composites

- Advantage of Composites
  - Corrosion resistant
  - Longer life
  - Light in weight
  - Good aesthetics
Composites – Areas of Usage

- Toilet Module
- Berth
- Bath room fittings – Mirror frame, Toilet cabinet etc.
- Wall panels
- Driver control panel
- Seat cum backrest
- Sliding door
- Dust bin
- Partitions
- Compartment doors
- Roof panels
- Main entrance door
- AC duct and so on
Composite Toilet Inlay Indian Style
Folding snack tables on chair cars
COMPOSITE CENTRE SNACK TABLE
Panel For Coach Interior

- Developed to replace laminated plastic sheets fixed by means of mouldings & Screws. FRP panels are manufactured by RTM process.

- Provides better aesthetic look.

- Fixed by means of dual lock system eliminating the use of screws and moulding.
Selection of material - Polycarbonate

- Polycarbonate seat - Recyclable thermoplastic material for MRVC coach
Selection of material - Polycarbonate

- Double sealed window unit - Polycarbonate sheet (outside) & Toughened glass inside in lieu of window glass for all AC coaches
## Upgraded materials

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Description</th>
<th>Old Specification</th>
<th>Upgraded specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vinyl coated upholstery fabric</td>
<td>RDSO/Spec/C-9503</td>
<td>RDSO/2006/CG-16</td>
</tr>
<tr>
<td>2</td>
<td>L.P.Sheet</td>
<td>RDSO/Spec/C-9602</td>
<td>RDSO CK-514</td>
</tr>
<tr>
<td>3</td>
<td>PU Foam</td>
<td>RDSO/Spec/C-8914</td>
<td>RDSO/2007/CG-04</td>
</tr>
<tr>
<td>4</td>
<td>PVC Flooring</td>
<td>RDSO/Spec/CK- 604</td>
<td>RDSO/2006/CG -12</td>
</tr>
<tr>
<td>5</td>
<td>Densified thermal bonded polyester block for seats and berths</td>
<td>RDSO CK-309</td>
<td>RDSO CK-607</td>
</tr>
<tr>
<td>6</td>
<td>High capacity Hytrel Upper and lower washers used in the primary suspension for Mainline coaches</td>
<td>RDSO/ IRS/ R-64</td>
<td>RDSO/CK- 409</td>
</tr>
<tr>
<td>7</td>
<td>Phenolic Bushes for Brake Gear of Mainline coaches</td>
<td>RDSO/CK -307</td>
<td>RDSO/CK-510</td>
</tr>
</tbody>
</table>
Design Improvements

- Introduction of Cold Rolled Formed (CRF) items
  - Reduced weld joints thus less maintenance
- Modular Design
- Standardization of Back pieces & stiffeners
CRF items

- Trough floor
- Sole bar
- Cantrail
- Waist rail
- Light rail
- U-stiffener
- Standardized integrated trough floor for SCN, SDC & GS coaches
CRF INTEGRATED TROUGH FLOOR

No. of joints reduced from 6 to 2
CRF SOLE BAR

- No. of joints reduced per coach from 10 to 2
CRF CANTRAIL

- No. of joints reduced per coach from 10 to 4
Modular Design

- Interchangeability
- Maintenance friendly
Painting System

- Poly Urethane Painting System
- Expected lifetime - four years
  (two years for conventional alkide painting)
Painting System

- High performance Anti-corrosion Epoxy coating (two packs) as per RDSO spec. No. M&C/PCN/123-06
High performance Anti-corrosion Epoxy coating
High performance Anti-corrosion Epoxy coating
Improvements in Bogie for Less Maintenance attention
Air Springs in Secondary Suspension

- Expected seven years of maintenance free service
Metacone Spring in primary (on trial)

- A conical rubber spring with external hydraulic damper from TRELLEBORG-UK
- Elimination of Dash pot arrangement reduces maintenance
Hytrel Washers

- Hytrel washers in place of conventional rubber washers in primary suspension
- Inert to oil hence longer life
Axle box housing

- Axle box housing design improved to avoid wing cracks
Anchor Link

- Fixing arrangement of Anchor link of bolted design in lieu of screwed design for maintenance free service
Silent Block for Anchor Link

- Conventional silent block changed to injection moulded design for better life
Forged eye piece

- Forged Eye piece for anchor link in line with Fiat bogie design has been developed
Fabricated Brake Head

- Brake Head design modified to avoid rubbing with wheel and allow full wear of brake block
Bushes

- Phenolic bushes are introduced in Bogie in place of Nylon bushes for better life
Current Important Projects
MRVC coaches for Western & Central Railway (AC-DC Dual Voltage System) with features for better maintenance
Features of MRVC coaches

- Aerodynamic Front End
- PU Paint Scheme
- Cushion seats with Stainless Steel frame for First Class
- Polycarbonate seat with Stainless Steel frame for Second Class
- Stainless Steel Grab poles and Grab Rails (3 Each)
- Forced Ventilation System
- Public Address & Information Systems
Features of MRVC coaches

- Flooring – Aluminium Chequered Sheet (2mm)
- Aesthetic FRP Panels
- Stainless Steel Semi-Bulk and Bulk-Head Partition
- Central Ducting with Twin Tube lights
- Lift-up type Wider Windows with top half Polycarbonate Louvers
- Stainless Steel Brake Piping with Double ferrule Fittings
- Stainless Steel Reservoirs for brake system
Aerodynamic Front End
Cushioned seats for First Class
Polycarbonate Seats for Second Class
FRP Paneling
Stainless steel Hand Holds
Powder coated Inner frame for Window
Aluminum Sliding Doors
Stainless steel Full Bulk Head
Stainless steel Semi Bulk Head
Stainless steel Grab Poles at Doorway
Exterior PU painting
Exterior Stickers
Air Handling Unit
Public Information System
Air Spring Suspension
Coaches for Cape Gauge
INTERIOR VIEW OF SECOND CLASS DAY COACH
TOILET WITH SS COMMODE, PANELLING & FITTINGS
WASHBASIN ARRANGEMENT IN SDC
Important Design Tools
Shifting from 2D to 3D

- Better Product Visualization
- Superior Parametric Design
- Quicker FE Analysis
- Least revisions
- Physical Prototype Elimination
- Instantaneous Bill of Materials generation
- Achieving Zero Defect Design
Important Designs developed using 3D modeling software

- SPART Medical Van (Shell Design)
- MRVC Nose Cone
- Seats for MRVC coaches
- Traction Motor duct for Motor coaches
- Stainless Steel luggage rack for Garib Rath
- Roof water tank for Non AC Coaches
- Under slung water tank for AC coaches
- Lavatory inlay
SPART Medical Van – Shell Installation
SPART Medical Van – Isometric View
SPART Medical Van – Body Shell
SPART Medical Van – Sidewall
SPART Medical Van – Sidewall
SPART Medical Van – Endwall Inside view
SPART Medical Van – Roof
SPART Medical Van – Roof
SPART Medical Van – Underframe
Seats for MRVC coaches
Seats for MRVC coaches

THREE SEATER DOUBLE FOR MRVC COACHES
Traction Motor duct for Motor coaches
Stainless Steel luggage rack for Garib Rath
Roof water tank for Non AC Coaches
Under slung water tank for AC coaches
Lavatory inlay
MRVC Nose Cone

Developed using CATIA Software
MRVC Nose Cone
MRVC Nose Cone
MRVC Nose Cone
High Capacity Bogie for DPC (180 KN) developed using CATIA
High Capacity Bogie for DPC
Futuristic Design Technologies

- MRVC Coach – A Walk through
- SCN 84 berth - study
Take a Break

- Madhubani paintings displayed in few coaches
Thanks