Sustainable Stainless Steel for Wagons

Ramesh R. Gopal
Executive Director

National Workshop on Stainless Steel Coach & Wagon Manufacture
Jadavpur University
8 - 9 September 2011, Kolkata
Iron and Steel are the most commonly used fabrication material for Railway wagons
Reasons . . .

• Abundantly available
• Low initial cost
• Easy to fabricate, cast and forge
• Good strength
• Easy to enhance properties by adding alloying elements and heat treatment
• Recyclable & eco-friendly
BUT, they are

- Prone to general & other forms of corrosion.
- Corrosion protection, repair, maintenance and replacement processes are costly and time consuming.
Are there any options? Yes!

Aluminum for instance has different sets of limitations of fabricability, cost, strength, availability, recyclability and impact on environment.
VARIATIONS OF IRON & STEEL LIKE STAINLESS STEELS, PROVIDE A Viable OPTION.
Which Stainless Steel?

• Stainless steels are part of the steel family containing a minimum of 10.5% chromium.
• They are much more corrosion resistant than most structural and engineering steels.
• There are more than 100 grades of standard stainless steels, and many proprietary grades.
• For wagon application, we will be talking about only one utility grade stainless steel 1.4003, which has numerous local names in different countries.
EFFECT OF CHROMIUM CONTENT ON CORROSION RATE

% CHROMIUM
0 2 4 6 8 10 12 14 16

CORROSION RATE
mmpy
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025

% CHROMIUM
UTILITY STAINLESS STEEL GRADE
1.4003

- 3CR12 South Africa
- HYFAB 3/12 United Kingdom
- 1.4003 Germany
- F 12 N France
- YUS 410W Japan
- S41003 USA
- 409M India
- IRSM 44/97 Indian Railways
- CK 201 Indian Railways
Utility Grade 1.4003

- Far more corrosion resistant than standard engineering steels, yet less expensive than high alloy stainless grades.
- Good resistance to Corrosion & Abrasive wear
- High strength (Yield Strength > 320 Mpa)
- Good weldability, easy to fabricate
- Can be welded using all known processes.
- Eminently suited where corrosive attack is accompanied by abrasive wear
### Chemical Composition Utility Ferritic SS

<table>
<thead>
<tr>
<th>Element</th>
<th>X2CrNi12(1.4003) EN 10088 - 2 ASTM S40977</th>
<th>DIN 5512 Part 3 X2Cr11</th>
<th>IR CK – 201 X2CrNi12 (409M) 2002</th>
<th>IRS M 44/97</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>%</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>0.03 max</td>
<td>0.03 max</td>
<td>0.03 max</td>
<td>0.03 max</td>
</tr>
<tr>
<td></td>
<td>1.50 max</td>
<td>0.5 – 1.5</td>
<td>0.5 – 1.5</td>
<td>0.8 - 1.5</td>
</tr>
<tr>
<td></td>
<td>0.04 max</td>
<td>0.04 max</td>
<td>0.04 max</td>
<td>0.03 max</td>
</tr>
<tr>
<td></td>
<td>0.015 max</td>
<td>0.015 max</td>
<td>0.03 max</td>
<td>0.03 max</td>
</tr>
<tr>
<td></td>
<td>1.0 max</td>
<td>1.0 max</td>
<td>0.03 max</td>
<td>0.03 max</td>
</tr>
<tr>
<td></td>
<td>10.5 – 12.5</td>
<td>10.5 – 12.5</td>
<td>10.5 – 12.5</td>
<td>1.0 max</td>
</tr>
<tr>
<td></td>
<td>0.3 – 1.0</td>
<td>0.3 – 1.0</td>
<td>0.3 – 1.0</td>
<td>10.8 – 12.5</td>
</tr>
<tr>
<td></td>
<td>0.03 max</td>
<td>0.03 max</td>
<td>0.03 max</td>
<td>1.5 max</td>
</tr>
<tr>
<td></td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.03 max</td>
<td><strong>Nil</strong></td>
<td><strong>Nil</strong></td>
<td>0.75 max</td>
</tr>
<tr>
<td>Phosphorous</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphur</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titanium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Mechanical Properties Utility Ferritic SS

<table>
<thead>
<tr>
<th>Property</th>
<th>X2CrNi12(1.4003) EN 10088-2 ASTM S40977</th>
<th>DIN 5512 Part 3 X2Cr11</th>
<th>IR CK – 201 X2CrNi12 (409M) 2002</th>
<th>IRS M44/97</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield Strength (MPa)</td>
<td>280/320</td>
<td>320</td>
<td>320</td>
<td>350 - 450</td>
</tr>
<tr>
<td>Tensile Strength (MPa)</td>
<td>450 - 650</td>
<td>450 - 600</td>
<td>450 – 650</td>
<td>500</td>
</tr>
<tr>
<td>Percentage Elongation</td>
<td>20</td>
<td>18 - 20</td>
<td>20</td>
<td>25</td>
</tr>
</tbody>
</table>
Why Utility Grade Stainless?

• Stainless steels account only for 2-3% of total steel production worldwide.

• Hence, carbon steels find use even in applications where expensive steps have to be taken to prevent corrosive damage, such as extra thickness as corrosion allowance or surface coatings.

• These add to the actual cost to the user.

• A lean stainless steel is a better option.
ADVANTAGES OF SS

• General corrosion and abrasion resistance is vastly superior to carbon / corten steel.

• Can be easily fabricated and indigenously available without supply constraints.

• Initial cost is higher per tonne, but over the life of the wagon (say 25/45 years) they are economical for the user.
ADVANTAGES OF SS

The most important benefit is that stainless steel is a sustainable material.

- (a) Over 60% of the raw material used for making stainless steel is scrap.
- (b) Stainless steel products highly durable, easily serviceable for several decades.
- (c) After a long service life, there is very little loss of material due to corrosion.
- (d) Almost 100% is available for recycling.
- (e) Stainless steel is Recycled not DOWN cycled.
HOW IS IT POSSIBLE THAT AN EXPENSIVE MATERIAL CAN BE CHEAPER IN THE LONG RUN?
Comparison of life cycle costs
Schematic comparison

Installation costs
Material costs

Unexpected costs
- Additional operating costs
- Replacement costs
- Lost production costs
- Maintenance costs
- Installation costs
- Material costs

Stainless Steel
Carbon / Corten steel
# Life Cycle Maintenance of COR-TEN v Utility Stainless Steel

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>6</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>30</th>
<th>36</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Years in service</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Carbon steel (COR-TEN)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Replace</td>
</tr>
<tr>
<td>Ends</td>
<td>Paint</td>
<td>Paint</td>
<td>Paint</td>
<td>Replace</td>
<td>Paint</td>
<td>Paint</td>
<td>Paint</td>
<td>Scrap</td>
</tr>
<tr>
<td>Bellies</td>
<td>Paint</td>
<td>Paint</td>
<td>Replace</td>
<td>Paint</td>
<td>Paint</td>
<td>Replace</td>
<td>Paint</td>
<td>Scrap</td>
</tr>
<tr>
<td>Days out of service</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td><strong>Utility stainless steel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years in service</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>6</td>
<td>12</td>
<td>18</td>
<td>24</td>
<td>30</td>
<td>36</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Inspection</td>
<td>Inspection</td>
<td>Inspection</td>
<td>Inspection</td>
<td>Inspection</td>
<td>Inspection</td>
<td>Inspection</td>
<td>Inspection</td>
</tr>
<tr>
<td>Days out of service</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
CONTAINER

Grade 1.4003/410, painted (frame and door panels)
COAL WAGON

Grade 1.4003/410 (panels), Columbus, S. Africa. In service for over 20 years.
COAL WAGON

Grade 1.4003/410 (panels), Columbus, S. Africa. In service for over 15 years.
COAL WAGONS

Grade 1.4003 (interior of previous), SASSDA, S. Africa
COAL WAGON

Grade 1.4003/410, painted, Europe
COAL WAGON

Grade 409/410, painted, TISCO, PRC
COAL WAGON

Grade 1.4003, SASSDA, S. Africa
409M wagon under fabrication (IRSM 44/97)
Stainless Steel wagon painted (IRSM 44/97)
Stainless Steel wagons ready for service (IRSM 44/97)
Properties Desirable for Wagon Application

Utility grade ferritic stainless steel 1.4003 has the following characteristics of value in wagon applications:

1. CORROSION RESISTANCE
2. ABRASION RESISTANCE
3. IMPROVED SLIDEABILITY OF MATERIAL
4. NO ‘UNDER THE PAINT’ CORROSION
Corrosion Resistance
In medium to severe marine environment

MS 5 yrs
1.4003 10 yrs
SS 304 20 yrs
Abrasion Resistance

(Abrasive – Corundum + 15-20% water)
Abrasion + Corrosion
When Corrosion & Abrasion work together, in wet or damp conditions, both un-alloyed engineering steels and abrasion resistant grades fare very poorly; The main reason is their being easily prone to corrosion.
The damp conditions produce loosely adherent oxides of iron and abrasion removes the corrosion products, thus quickly exposing fresh steel surface for further corrosion. This accelerates the corrosion of steel.
NOT the case with corrosion resistant 1.4003
Abrasion + Corrosion

Graph showing accumulated volume loss over time for different materials and abrasion frequencies. The graph compares the performance of Mild Steel (A) and Stainless Steel (B) under high and low corrosion resistance conditions.

- **A**: Mild Steel
- **B**: Stainless Steel
- **A1, A2**: Increasing Corrosion Resistance
- **B1, B2**: Different Abrasion Frequencies:
  - 1 = High
  - 2 = Low
Slidability

- When Abrasion and corrosion work in tandem, the corroded surface of steel is rough and gouged in many areas and thus create hurdles to the flow of material over them.
- The relatively smooth surface of 1.4003, because of its corrosion resistance and high wear resistance, provides easy passage to materials flowing over them. THIS IS THE REASON FOR ITS HIGH SLIDABILITY QUOTIENT. This property is very useful in preventing ‘hanging’ which is very common in carbon steel wagons.
SS IN INDIAN RAILWAYS

- 1965 – Toilet pan, wash basin in SS 304
- 1984-85 – Trough floor in SS 301
- 1990 – Toilet inlays in SS 304
- 1990 – LHB Coach in SS in DIN 5512 – 1.4003
- 1995 – Internal furnishings in SS 304
- 1997 – IRS M 44/97 specs for wagons
- 1998 – Box N wagon in SS - 44/77
- 2000 – CK-201 specs of SS for coaches
- 2000 – 44/97 used for structural in ICF designed coaches.
History of Ferritic SS for Wagons/Coach

• 1980’s – developed in South Africa and UK as 3 CR12 grade utility SS for coal/ore transportation. (low carbon, 11% Cr and Titanium)
• 1990’s – Modified 3 CR12 for better toughness (low carbon, 11% Cr, 0.3 minimum Ni, Ti removed)
• DIN 5512 of German Spec for railway SS specify this grade for freight wagons and passenger coach as 1.4003
• LHB specifies DIN 5512 (1.4003) for new coach design in India. LHB approves Indian manufacturer.
• 1997 – IR specifies 44/97 (containing Ti max for trial wagons)
• 2000 – ASTM spec UNS – 40977 for Utility Ferritic SS (low carbon, 11% Cr, minimum Ni, no Ti)
• 2001 – IR specifies in CK – 201 utility Ferritic matching 1.4003
• 2005 – Internationally EN 1.4003 and UNS – 40977 specifications followed for utility grade Ferritic SS (Low carbon, 11% Cr, 0.3 min Ni and NO Ti)
Painting of 1.4003

Type 1.4003 provides good corrosion resistance, excellent abrasion resistance, hence does not need coating or painting systems to be applied for performance reasons. For aesthetic reasons it may be desirable in some applications to apply paint, especially as type 1.4003 will tend to discolor in corrosive conditions. Type 1.4003 has exceptional under-paint corrosion resistance and will continue to resist corrosion even where the paint coat has been damaged. Normal preparation is required such as ensuring a clean surface free of grease and other contamination. A primer coat is recommended for cold rolled material due to its smoother surface, but hot rolled 1D finish material may be suitably painted in a single coat.—Krupp Thyssen
Under the Paint Corrosion

Corrosive attack visible on steel surface after removal of acrylic paint coating (200 cycles of high humidity exposure)

Unalloyed Engineering Steel – 1.4003 – No corrosion under paint
Severe corrosion under paint under paint (Unaffected)
Painting of utility grade SS wagons

In moderate marine environments, 1.4003 gives an improvement of 250 times the life of unpainted mild steel under the same conditions.

In aggressive environment, it will tend to form a light surface rust coloured patina. This discoloration is superficial and does not affect the structural performance of the steel.

If needed, wagons could be given one coat of primer. IN SOME COUNTRIES (SOUTH AFRICA & AUSTRALIA) THEY DO NOT PAINT THEIR WAGONS OF 1.4003.
Suggestions

• Modify IRSM – 44 in line with CK 201 to meet International standards. This will help improve weldability, especially in thicker (>8mm) sections.

• Use 308 L consumables, and 309L for thicker sections

• Can avoid painting for wagons (if required one primer coat)
## Growth of Rolling Stock Demand

<table>
<thead>
<tr>
<th>Rolling Stock Type</th>
<th>Extra rolling stock required under Vision 2020</th>
<th>Average Annual Demand of Rolling Stock</th>
<th>Present estimated Manufacturing Capacity</th>
<th>% Demand excess over capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Locomotives 3-phase</td>
<td>2595</td>
<td>259</td>
<td>230</td>
<td>13%</td>
</tr>
<tr>
<td>Electric Locomotives Conventional</td>
<td>1686</td>
<td>168</td>
<td>40</td>
<td>320%</td>
</tr>
<tr>
<td>3-Phase AC EMU</td>
<td>600</td>
<td>60</td>
<td>30</td>
<td>100%</td>
</tr>
<tr>
<td>Diesel Locos</td>
<td>5334</td>
<td>533</td>
<td>260</td>
<td>105%</td>
</tr>
<tr>
<td>Coaches</td>
<td>50880</td>
<td>5088</td>
<td>3000</td>
<td>70%</td>
</tr>
<tr>
<td>Wagons</td>
<td>289136</td>
<td>28913</td>
<td>14000</td>
<td>107%</td>
</tr>
</tbody>
</table>
1. Population of wagon till date: 2,25,000 (approx)

2. SS wagons till date: 22,300 - 25,000 (approx)
# Wagon Production & IRSM-44 Consumption

<table>
<thead>
<tr>
<th></th>
<th>2008-09</th>
<th></th>
<th>2009-10</th>
<th></th>
<th>2010-11</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>TOTAL SS (MT)</td>
<td>No.</td>
<td>TOTAL SS (MT)</td>
<td>No.</td>
<td>TOTAL SS (MT)</td>
</tr>
<tr>
<td>WAGON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOXNHL</td>
<td>2000</td>
<td>21600</td>
<td>4992</td>
<td>53913</td>
<td>5000</td>
<td>54,000</td>
</tr>
<tr>
<td>BCNHL</td>
<td>115</td>
<td>977.5</td>
<td>3068</td>
<td>26078</td>
<td>4800</td>
<td>40,800</td>
</tr>
<tr>
<td>BOXN-R</td>
<td>500</td>
<td>1800</td>
<td>800</td>
<td>2880</td>
<td>1000</td>
<td>3600</td>
</tr>
<tr>
<td>BOBRN</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>700</td>
<td>1120</td>
</tr>
<tr>
<td>BRN 22.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2615</td>
<td>24377.5</td>
<td>8860</td>
<td>82,871</td>
<td>10,800</td>
<td>99,520</td>
</tr>
</tbody>
</table>
Annual No. of SS Wagons purchased by Railways

- 2008-09: 2000
- 2009-10: 8000
- 2010-11: 12000
Annual usage of SS for wagons by Railways

- 2008-09: 20000 MT
- 2009-10: 40000 MT
- 2010-11: 60000 MT

Total SS (MT)
Future Prospects for Stainless Steels in Rail Wagons

- Covered Wagons
- Oil tankers
For further details contact:

INDIAN STAINLESS STEEL DEVELOPMENT ASSOCIATION (ISSDA)
L-22/4, Ground Floor, DLF Phase-II, Gurgaon - 122 002
Tel. 91 124 4375501, 02, 03 Fax : 91 124 4375509
Email : nissda@gmail.com
Website : www.stainlessindia.org