Future Developments in Stainless Steels Containing Niobium

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Sheffield, UK
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The City of Sheffield...is understood by all as the undisputed origin for the foundation of the knowledge that ended up in the development of...steels containing niobium. Tadeu Carneiro, CEO of CBMM, 2014

In this bright future you can’t forget your past - Bob Marley

Harry Brearley
Produced first commercial scale cast of stainless steel in Sheffield August 1913

Stainless Steels
Niobium
Outokumpu
Sheffield

Brown-Firth
Firth Vickers
British Steel Corporation
British Steel Stainless
Avesta Sheffield
Outokumpu
Outokumpu operates around the world
Outokumpu Stainless Steel Production

- Austenitic (CrNi) 58%
- Austenitic (CrNiMo) 17%
- Ferritic 19%
- Duplex 3%
- Other 3%
Balanced customer base across industries

- Consumer goods & Medical: 17%
- Chemical, petrochemical and energy: 17%
- Metal processing & Tubes: 27%
- Heavy industries: 8%
- Automotive: 9%
- Architecture, Building & Construction: 10%
- Other: 12%
Austenitic 304 is all around us
Stainless Steel in Commercial Kitchens
Requirements of Stainless Steels in professional catering equipment

- **Surface Finish and Appearance**
  - Uniform, consistent & smart appearance
  - Low surface roughness & no crevices at joints

- **Corrosion resistant**
  - No rust spots during use
  - Resistant to foodstuffs eg acidic foods such as vinegar & salt (eg soup)
  - Resistant to cleaning fluids & disinfectants, many of which contain strong chlorine based bleaches

- **Two grades predominate today in UK**
  - 304, 1.4301; ~18Cr, 8Ni austenitic stainless steel
  - 430, 1.4016; ~17Cr ferritic stainless steel
Greater corrosion risks with 430 grade
Roping in 430 grade ferritic stainless steels

- Surface roughening that occurs during cold working (e.g., deep drawing) operations
- Strong directional furrows become visible only after forming
- Caused by: Texture development in the sub-structure - non-equiaxed & unfavourable orientation of grains
- Poor surface appearance
- Time consuming & high cost to remove by polishing
Roping Index indicates polishing need

- Outokumpu has developed a Roping Index (RI) that is based on advanced surface profile measurements
- A sophisticated technique for roping intensity evaluation
- The Roping Index is used for process development, benchmarking, customer support and quality control purposes
Weldability of standard ferritic stainless steels

Sensitization

- formation of chromium carbides; loss of corrosion resistance in 430/1.4016

Embrittlement

- martensite formation in standard 430/1.4016
- development of very large grains {“Elephant Grains”} in the Heat Affected Zone.
CORE 1.4622  Ferritic Stainless Steel

• Basic Concept:  A new ferritic stainless steel that can be a low cost alternative to 304L/1.4307 in “everyday” applications.
  
  o Pitting corrosion resistance equal or slightly better than grade 304
  
  o Good weldability of cold rolled wide sheet
  
  o Ability to produce excellent surface finish, including deep drawn components

<table>
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<th></th>
<th>C</th>
<th>Cr</th>
<th>Ni</th>
<th>Ti</th>
<th>Nb</th>
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<td>0.025</td>
<td>18</td>
<td>8</td>
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<tr>
<td>CORE 1.4622</td>
<td>0.020</td>
<td>21</td>
<td></td>
<td>0.1 – 0.7</td>
<td>0.1 – 0.7</td>
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</table>
Niobium & Titanium Stabilisation

- Acting jointly together to produce (Ti, Nb) (C, N) particles
- Help produce favourable crystallographic texture during hot rolling of slabs
  - in combination with controlled casting & hot rolling process parameters
- Produce roping-free surfaces after forming
- Easily polished
- Prevent Sensitisation
  - Retain good corrosion resistance after welding
- Control (Reduce) level of grain growth in weld HAZ
  - Adequate ductility

Cube shaped particle of (Ti, Nb) (C, N) with small particles of NbC attached
Cube side is 3µm (Nooning et al, 2001)
Roping Index below 1 – Virtually roping free

Lower RI ensures less polishing is needed after deep-drawing
Corrosion Resistance

Salt spray testing can be used to compare performance of different grades.

1.4016 / 430

1.4307 / 304L

1.4622

14 day Neutral Salt Spray test ISO 9227 (5% NaCl at 35 °C)
Surface Finish: Outokumpu Phoenix Brushed surfaces
Corrosion Resistance

Cyclic salt spray test, 100 hours

1.4509/441  
(18% Cr)

1.4301/304  
(18%Cr, 8%Ni)

1.4622  
(21% Cr)

5% NaCl  5 min spraying, 55 min drying at 35°C, humidity 70%
Corrosion Resistance

Relative values of pitting corrosion potential in 0.02M NaCl as a function of PREN.
Weldability

- Pitting corrosion resistance of autogenous TIG weld similar to parent metal

Intergranular corrosion test EN ISO 3651-2 (Strauss-test) for autogenous weld: **passed.**

- Stabilization prevents precipitation of Cr carbides

![Graph showing relative pitting corrosion potential in 0.02M NaCl](image)
What is the advantage of 1.4622?

- Save money

- Stainless Steel sold on a two-part price:

\[
\text{Total Price} = \text{Base price} + \text{Alloy Surcharge (Alloy Adjustment Factor)}
\]

- Average European **Base Price**: 304L 2mm thick cold rolled sheet: **€1070 per tonne**
  
  (Beginning of July 2015, Source: Steel First)
Alloy Surcharges

Outokumpu Alloy Adjustment Factor
Jan 2014 to July 2015  304/1.4301 and 1.4622

AAF, Euros per tonne

Month


Core 304/4301
Alloy Surcharges

Outokumpu Alloy Adjustment Factor
Jan 2014 to July 2015  304/1.4301 and 1.4622

AAF, Euros per tonne

Month

Core 4622
Core 304/4301
Alloy Surcharges

Outokumpu Alloy Adjustment Factor
Jan 2014 to July 2015   304/1.4301 and 1.4622

Source: www.outokumpu.com
What are the advantages of CORE 1.4622?

- **Save money**
- Increase likelihood of selection of stainless steels over plastics & coated mild steels
- Reduce threat from “stainless look-alike” materials

- **Improved environment and more sustainable option**
- Reduced use of the Earth’s nickel resources, compared to 304 grades
- Encouragement of use of stainless steel promotes sustainability of resources:
  - Long life stainless steel lasts longer than less durable alternatives
  - Stainless Steel is itself 100% recyclable at end-of-life
  - “New” stainless steel from Outokumpu contains 80% recycled material
Primary Raw Material for Stainless Steel
Recycled Scrap
Adages in stainless steel

Adage - definition

“a traditional opinion that is accepted by many as true or partially true”

1. The general public view:

“Stainless Steel is one type of material and it is completely rust-proof in all circumstances”

2. The catering trade buyer’s view:

“Stainless Steel occurs in two forms.

There is a non-magnetic stainless steel (the best type that is completely rust-proof), and there is a magnetic type that is cheaper, not as good, and might go slightly rusty over time”
Applications

- Many possibilities for stabilised ferritic stainless steels in catering equipment
- Flat panel fabrications
- Deep drawn & polished cookware
Applications

“Light/medium weight” welded fabrications & structures

Mine rescue chamber (under construction)

Stainless steel for fire resistance; no paint coating required

Courtesy: HEAT-IT
Applications for 1.4622

Mine rescue chamber installed and ready for use

Courtesy: HEAT-IT
Summary

- Niobium-Titanium stabilised Ferritic Stainless Steel **CORE 1.4622** can be a good alternative to standard 304L in many everyday applications.

- The metallurgy & processing operations are proven and understood.

- There are significant cost advantages over 304L.

- This helps increased use of stainless steels in general, which leads to a more sustainable and environmental friendly world.
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