Sn-added Ferritic Stainless Steel, NSSC FW series characteristics

7th June 2011
Nippon Steel & Sumikin Stainless Steel Corporation
Yuji Kaga
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➢ Company Profile of NSSC

➢ On NSSC’s Series Stainless Steel

➢ Introducing new products from NSSC
  Materials  Design of FW Series
Company Profile

- JV between Nippon Steel and Sumitomo metals.
- Started from Oct. 2003
- **Products**: Plates, Sheets & Strips, Bars & Wire rods
- **Capacity**: Crude Steel 1,100k tons
  - Plates 130K tons
  - Bars & Wirerods 130K tons
  - CR products 600K tons per year
- **Turn over**: 194 billion JPY (2.2 billion USD) in 2009 Fy
## NSSC Production Flow

<table>
<thead>
<tr>
<th></th>
<th>Melting</th>
<th>Hot phase</th>
<th>Products (HR/CR)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hikari</strong></td>
<td>EF-AOD 【Ni】</td>
<td>(Bars &amp; Wires)</td>
<td>ZM 【Ni】 270kt/y</td>
</tr>
<tr>
<td></td>
<td>550kt/y</td>
<td>140kt/y</td>
<td></td>
</tr>
<tr>
<td><strong>Kashima</strong></td>
<td></td>
<td></td>
<td>HR coils 90kt/y</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ZM 【Cr】 150kt/y</td>
</tr>
<tr>
<td><strong>Yawata</strong></td>
<td>LD-VOD 【Cr】</td>
<td>HR Mill 【Ni, Cr】</td>
<td>HR coils 160kt/y</td>
</tr>
<tr>
<td></td>
<td>550kt/y</td>
<td>(830kt/y)</td>
<td>TCM 【Cr】 160kt/y</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plates 130kt/y</td>
<td></td>
</tr>
</tbody>
</table>

### Capacity for finished products

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Location</th>
<th>ZM cold</th>
<th>TCM cold</th>
<th>Hot rolled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet &amp; Strip</td>
<td>ZM</td>
<td>420kt/y (Ni 270 /Cr 150)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TCM</td>
<td>160kt/y (Cr 160)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>250kt/y (Ni 90 /Cr 160)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bars &amp; Wires</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yawata</td>
<td>140kt/y (Ni 140)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kashima</td>
<td>130kt/y (Ni 130)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td>1,100kt/y (Ni 630 /Cr 470)</td>
</tr>
</tbody>
</table>

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NSSC Position in Japan
Production Share Based on Hot Rolled Strip (2007CY)

Cold Rolled Flat Products of JPN
*Ferritic + Austenitic*

1,659k TONNES
- NSSC: 21
- A: 34
- B: 19
- OTHERS: 26

944k TONNES
- NSSC: 23
- A: 33
- B: 2

2,230k TONNES
- NSSC: 30
- A: 25
- OTHERS: 25

NSSC is the top manufacturer of STS sheet in coil product, especially in Cr type, by proposing the optimum material with the best solutions.
On NSSC’s Series

Ferritic Stainless Steel
History of the development of Extra-low Interstitial ferritic steels at NSSC

1975
NSSC 430D (17Cr-Ti)
NSSC 190 (19Cr-2Mo-Nb-Ti)

1980
NSSC 180 (19Cr-0.4Cu-Nb)

1985
NSSC 436S (18Cr-1.2Mo-Ti)

1990
NSSC 220M (22Cr-1.6Mo-Nb-Ti)

2000
NSSC PDX (18Cr-Ti-ULC)

NSSC 160R (18Cr-0.4Cu-Nb-LC,N) ; Wire Rod
NSSC ECO Series; New, Mo-reduced steel grades (NSSC190ECO, NSSC480)
NSSC FW Series: New, alloy-saving steel grade made by adding small amounts of Sn.
Providing application technologies and solutions that are suited for different materials.
Positioning of relative performance attributes of major proprietary NSSC steel grades

NSSC is a registered trademark of Nippon Steel & Sumikin Stainless Steel Corporation
Introducing new products from NSSC

Materials Design of FW Series
Sn Added, Extra-low interstitial Ferritic Stainless Steel
— The FW Series
~ Resource-saving and highly corrosion resistant NSSC® FW1 and FW2 ~
Basic Technology Underlying the NSSC FW Series

~ Effects of adding Sn ~

Effects of Sn on corrosion resistance

Appearance after 168 hr immersion test

| 14 Cr (for comparison) | 14Cr-0.1Sn (NSSC FW1) |

Immersion 168 hrs in a 0.5% NaCl water solution at 80°C
30mm x 30mm, with #600 polish finish

Schematic of Sn's form of existence based on results of surface analyses

Passivity film
\((\text{Fe,Cr})_2\text{O}_3 + (\text{Sn-O,Sn})\)

Metal substrate
\((\text{Cr-Sn-Low C,N})\)

Cr incrassation

2~5 nm
Advantages and steel grade characteristics of NSSC FW1

NSSC® FW1 (Forward 1) 14Cr-0.1Sn-LC, N

[Advantages]

1. While FW1 is a 14% Cr steel, it delivers corrosion and rust resistance that is equal to or better than 17% Cr (NSSC 430D and TP439) steels. A small amount of Sn is added to strengthen the passivity film.

2. FW1 offers among the best formability of our high-purity ferritic steels, and excellent post-forming surface properties (anti-ridging).

3. Thorough alloy-saving efforts have been made (Ni and Mo-free, reduced Cr content, and appropriate content of trace elements) to minimize the effects of fluctuating raw material prices.

[Chemical composition]

<table>
<thead>
<tr>
<th>Mass%</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Sn</th>
<th>Nb+Ti</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade values</td>
<td>≤ 0.010</td>
<td>≤ 0.50</td>
<td>≤ 0.50</td>
<td>≤ 0.040</td>
<td>≤ 0.030</td>
<td>13.75</td>
<td>~ 15.00</td>
<td>~ 0.25</td>
<td>≥ 10(C+N)</td>
</tr>
<tr>
<td>Representative example</td>
<td>0.004</td>
<td>0.12</td>
<td>0.10</td>
<td>0.024</td>
<td>0.001</td>
<td>14.4</td>
<td>0.11</td>
<td>0.20</td>
<td>0.010</td>
</tr>
</tbody>
</table>

[ Mechanical characteristics ]

<table>
<thead>
<tr>
<th></th>
<th>Yield strength 0.2% offset (N/mm)</th>
<th>Tensile strength (N/mm)</th>
<th>Elongation (%)</th>
<th>Hardness (HV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade values</td>
<td>≥ 175</td>
<td>≥ 360</td>
<td>≥ 28</td>
<td>≤ 180</td>
</tr>
<tr>
<td>Representative example</td>
<td>260</td>
<td>420</td>
<td>35</td>
<td>130</td>
</tr>
</tbody>
</table>

(Surface finish: 2B, thick plate; 0.6mm, JIS13B, L direction)
Steel grade characteristics of NSSC FW1

~ Corrosion resistance ~

- Pitting resistance potential

Potential at which pitting occurs (V vs. AgCl)

- Tp.430 (17Cr)
- SUS430LX (17Cr-Ti-LC)
- NSSCFW1 (14Cr-0.1Sn-LC)

Appearance after salt spray test

- Tp.430 (17Cr)
- SUS430LX (17Cr-Ti-LC)
- NSSCFW1 (14Cr-0.1Sn-LC)

Continuously sprayed for 168 hrs with a 5% NaCl water solution at 35°C, Complies with JISZ2371. 50mm x 100mm, with #600 polish finish.

The corrosion resistance of NSSC FW1 (14Cr-0.1Sn-LC) is superior to SUS430XL (17Cr-Ti-LC)
NSSC FW1 steel grade characteristics

Formability and moldability

Limit drawing value (cylinder drawing test)

<table>
<thead>
<tr>
<th>Material</th>
<th>Limit Draw Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSSCFW1 (14Cr-0.1Sn-LC)</td>
<td>2.30</td>
</tr>
<tr>
<td>SUS430LX (17Cr-Ti-LC)</td>
<td>2.25</td>
</tr>
<tr>
<td>Tp430 (17Cr)</td>
<td>2.10</td>
</tr>
</tbody>
</table>

Flangeability (Erichsen test)

<table>
<thead>
<tr>
<th>Material</th>
<th>Erichsen Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSSCFW1 (14Cr-0.1Sn-LC)</td>
<td>~14mm</td>
</tr>
<tr>
<td>SUS430LX (17Cr-Ti-LC)</td>
<td>~14mm</td>
</tr>
<tr>
<td>Tp430 (17Cr)</td>
<td>~14mm</td>
</tr>
</tbody>
</table>

NSSCFW1 (14 Cr - 0.1 Sn-LC) offers better formability than SUS430LX (17 Cr-Ti-LC), with less surface roughness after it is formed.
Advantages of NSSC FW1

Reduce rare metal content by 23%
Sn Added, Extra-low interstitial Ferritic Stainless Steel — The FW Series

~ Resource-saving and highly corrosion resistant NSSC® FW2 ~

Nippon Steel & Sumikin Stainless Steel Corporation
Advantages and steel grade characteristics of NSSC FW2

NSSC® FW2 (Forward 2) 16Cr-0.3Sn-LC, N

[Advantages]

1. While FW1 is a 16% Cr steel, it delivers corrosion and rust resistance that is equal to that of SUS304 (18C-8Ni) under regular conditions.
2. FW2 offers among the best formability of ferritic steels. By selecting the appropriate forming conditions (drawability), FW2 offers mold formability equal to that of SUS304.
3. Thorough alloy-saving efforts have been made (Ni, Mo, and Cu-free, reduced Cr content) to minimize the effects of fluctuating raw material prices.

[Chemical composition]

<table>
<thead>
<tr>
<th>Grade values</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Sn</th>
<th>Nb+Ti</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 0.010</td>
<td>≤ 0.50</td>
<td>≤ 0.50</td>
<td>≤ 0.040</td>
<td>≤ 0.030</td>
<td>15.75</td>
<td>~ 17.00</td>
<td>0.3</td>
<td>≥ 10(C+N)</td>
<td>≤ 0.015</td>
</tr>
<tr>
<td>Representative examples</td>
<td>0.005</td>
<td>0.07</td>
<td>0.06</td>
<td>0.02</td>
<td>0.001</td>
<td>16.4</td>
<td>0.31</td>
<td>0.22</td>
<td>0.01</td>
</tr>
</tbody>
</table>

[Mechanical characteristics]

<table>
<thead>
<tr>
<th>Grade values</th>
<th>0.2% bearing force (N/mm)</th>
<th>Tensile strength (N/mm)</th>
<th>Elongation (%)</th>
<th>Hardness (HV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 205</td>
<td>≥ 390</td>
<td>≥ 25</td>
<td>≤ 200</td>
<td></td>
</tr>
<tr>
<td>Representative examples</td>
<td>279</td>
<td>463</td>
<td>32</td>
<td>144</td>
</tr>
</tbody>
</table>

(Surface finish: 2B, thick plate; 0.6mm, JIS13B, L direction)
Steel grade characteristics of NSSC FW2
~ Corrosion resistance 1~

Improved salt spray corrosion test (salt water environment)

Test sample shape: 50 x 100 with top end bent at 90º angle. Surface: Finished at #600
Solution: 24 hrs in 0.5% NaCl + 2% H₂O₂ at 35ºC. Other conditions comply with JISZ2371

Rust resistance in salt water environments was greatly improved over SUS430 and is equal to that of SUS304.
Various formability characteristics of NSSC FW1 and FW2

By selecting the appropriate forming conditions, NSSC FW1 and FW2 can be mold formed in the same way as SUS304.

<table>
<thead>
<tr>
<th></th>
<th>Drawability</th>
<th>Bulge expandability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average r value</td>
<td>LDR</td>
</tr>
<tr>
<td>NSSC FW1</td>
<td>1.7</td>
<td>2.3</td>
</tr>
<tr>
<td>NSSC FW2</td>
<td>1.7</td>
<td>2.3</td>
</tr>
<tr>
<td>SUS430</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>SUS304</td>
<td>1.1</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Steel grade characteristics of NSSC FW1
~ Formability and moldability ~

Results from comparative simulations of moldability under the same conditions

**NSSC 180 ; h=24mm**

**NSSC FW1 ; h=32mm**

**SUS304 ; h=52mm**

---

Blank: 240 x 240mm
Punch: 100 x 100mm,
Corners: r 20mm, rp 10mm
Die: 103 x 103mm, rd 5mm
Friction coefficient: 0.10, Plate thickness: 0.8mm
Fold pressure: 20 tons
Steel grade characteristics of NSSC FW1
~ Formability and moldability ~

Results from simulations of moldability under appropriate conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Image 1</th>
<th>Image 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smaller fold pressure</td>
<td>NSSC 180; $H=52\text{mm}$</td>
<td>NSSC FW1; $h=60\text{mm}$</td>
</tr>
<tr>
<td>Friction coefficient: 0.06</td>
<td>NSSC 180; $H=52\text{mm}$</td>
<td>NSSC FW1; $h=60\text{mm}$</td>
</tr>
</tbody>
</table>
Steel grade characteristics of NSSC FW2

~ Formability and moldability ~

Multi-drawing characteristics ~ Appearance after multi drawing ~

NSSC FW2 leads to forming by multi-drawing without developing any cracks.

Season cracking occurs with SUS304.

Plate thickness: 0.6mm (cold-finished once)  Blank diameter: 80mm  Lubricant: J.W. #122
Punch diameters (mm): 1st stage 40 → 2nd stage 35 → 3rd stage φ 30 → 4th stage φ 25

NSSC FW2 (16Cr-0.3Sn)  SUS304 (18Cr-8Ni)
Advantages of NSSC FW2 -Resource-saving-
Small amounts of added Sn improves corrosion resistance, and thereby
Rare metal (Cr, Ni) use can be reduced by 40%.
Examples of NSSC FW1 applications

IH (induction-heating) rice cookers

Lithium-ion battery cases (Deep drawing applications)

Large rectangular vats

Washing machine drums

Rice washing bowls

Candidate applications for NSSC FW1

Building materials and architectural members

Hinges
Examples of NSSC FW2 applications

Kitchen sinks  Cooking trays  Expanded metal (mesh)

Yukihiro pan

All existing applications where SUS304 (18 Cr-8 Ni) is used are candidate applications for FW2.
Range of manufacturability of cold-finished products from NSSC FW1 and FW2

<table>
<thead>
<tr>
<th>Shape</th>
<th>Thickness (mm)</th>
<th>Width (mm)</th>
<th>Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutlength sheets</td>
<td>0.3 ~ 3.0</td>
<td>300 ~ 1,250</td>
<td>No longer than 8,000</td>
</tr>
<tr>
<td>Coils</td>
<td>0.3 ~ 3.0</td>
<td>200 ~ 1,250</td>
<td></td>
</tr>
</tbody>
</table>

* Available in high-gloss 2B finish.
* A variety of finishes, including BA, are also available.
* Please inquire for dimensions and specifications not shown here.
Thank you very much for your kind attention.

http://www.ns-sc.co.jp
http://www.ns-sc.co.jp/fw

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