Flux cored Arc Welding- a productive process

Abby Joseph, voestalpine Böhler Welding India
Market overview and trends

Cored wire annual growth rate 6-8%

- **Shift from stick electrodes to cored wire and solid wire**
- **Higher deposition rate**, cored wire also applicable for **positional welding**
- **Ease to use**
- **MIG/MAG equipment** and gases getting cheaper

Source: figure 2013 from BM; growth rate from F&S
Market overview – Indian scenario

Highlights

1. Joining FCWs have a total market of 10,000MT/yr. and HF FCWs 2500MT/yr.

2. Industry segments- Pre-engineered buildings, Railways, Shipbuilding.

3. Structural steel joining is an early adopter of FCAW process, although SMAW still has a significant share.

4. FCAW has a good position in SS- mainly for cladding but also for high-thickness joining.

5. Oil & Gas segment has adopted FCAW utilizing the new features of low-H2, CTOD and NACE compliance.

6. LNG Tank construction use Ni-base FCWs for higher productivity in V-up welding
What is FCAW?

- Principle of FCAW process
- Slag systems
- Parameter settings

- Economical Aspects
- Welding techniques
- Wire production & QA/QC
Flux Cored Arc Welding (FCAW)

Operating principle of the process
Slag System

- With respect to the flux ingredients, the flux cored wire may be rutile based or basic based.

- Rutile gives good slag detachability whereas basic gives good mechanical properties.

- In rutile flux ingredients, the slag may be fast freezing or slow freezing.
Welding Techniques

Pushing

Neutral

Dragging
Production of folded cored wires
Production of seamless cored wires

1. Metal strip
2. Manufacturing tube from solid strip using HF welding
3. Annealing and calibrating to filling diameter
4. Manufacturing agglomerated flux and filling of the tube by vibration
5. Pre-drawing to annealing diameter and annealing of the filled tube
6. Drawing to final dimension and copper coating
Quality Assurance
Quality Assurance

Free for shipment

Stopped for further Investigation
Types of cored wires

Division by the filling

cored wires for gas shielded welding

- without slag
  - M metal cored wires

- slag formation
  - B basic filler
  - rutile filler
    - R slow freezing slag
    - P fast freezing slag

Self-Shielded

Joining
Hard facing
## Types of cored wires

**Division by production methods**

<table>
<thead>
<tr>
<th>Seamless Cored Wires</th>
<th>Folded Cored Wires</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image of Seamless Cored Wires" /></td>
<td><img src="image2.png" alt="Image of Folded Cored Wires" /></td>
</tr>
<tr>
<td><strong>Thicker tube (metallic coat)</strong></td>
<td><strong>Higher filling ratio</strong></td>
</tr>
<tr>
<td>→ optimal positioning of the wire for automatic welding</td>
<td>→ easier to optimize weldability</td>
</tr>
<tr>
<td><strong>100% copper coated</strong></td>
<td><strong>100% homogenous filling</strong></td>
</tr>
<tr>
<td>→ best current transition</td>
<td>→ uniform mechanical properties</td>
</tr>
<tr>
<td>→ and corrosion resistance</td>
<td></td>
</tr>
<tr>
<td><strong>low hydrogen content in closed tube</strong></td>
<td><strong>lower deformation in production</strong></td>
</tr>
<tr>
<td>→ no re-drying necessary</td>
<td>→ enables production of high alloyed and nickel base qualities</td>
</tr>
</tbody>
</table>

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Equipment, Arc Types and Welding Positions

Main Components of the Welding Machine

- Pressure Regulator
- Shielding Gas
- Spool Magazine
- Water Cooling
- Hose Package and Torch
- Wire Feeder
- Power Source
- Ground (Earth) Cable
Welder skill requirement
Comparatively lower

1. Semi-automatic process
2. CV against CC power source characteristics leads to nearly constant arc gap.
3. Much wider parameter window within the same dia. of wire lead to a lot of flexibility.
4. Advances in equipment/systems helps welder in self-correction while welding.
5. Modern equipment (programmable) helps welder in replicating the performance.
6. Less welder fatigue ensures consistent performance over long working hours

Skilled Welders + Advanced FCAW power source = Less repair and high productivity
High Deposition Efficiency

- Deposition efficiency = \( \frac{\text{Weight of Weld Metal}}{\text{Weight of Electrode Used}} \)

For FCAW: 85-90 %
For SMAW: 55-60%

Flux cored wires have a lower flux-to-metal ratio than coated electrodes, and thereby, a higher deposition efficiency.
Main properties of cored wires

Gives information about the efficiency of the process [%]

<table>
<thead>
<tr>
<th>Consumable wire- ø: 1,2 mm</th>
<th>Weight wire [g/m]</th>
<th>Minus spatter, slag etc. [g/m]</th>
<th>Weight Weldmetal [g/m]</th>
<th>Average Process efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid wire</td>
<td>8,68</td>
<td>-0,19</td>
<td>8,49 (98%)</td>
<td>98 – 100 %</td>
</tr>
<tr>
<td>Metal cored</td>
<td>8,30</td>
<td>-0,22</td>
<td>8,08 (97%)</td>
<td>96 – 98 %</td>
</tr>
<tr>
<td>Basic</td>
<td>7,48</td>
<td>-0,43</td>
<td>7,05 (94%)</td>
<td>85 – 94 %</td>
</tr>
<tr>
<td>Rutile</td>
<td>7,22</td>
<td>-0,85</td>
<td>6,37 (88%)</td>
<td>83 – 92 %</td>
</tr>
</tbody>
</table>
Higher Operating Factor

%age of a welder's working day that is actually spent welding = \frac{Arc Time (Hours)}{Total Hours Worked}

**SMAW 15% to 40%**
- Because of Lesser ARC Time

**FCAW 40% to 50%**
- Because of Higher ARC Time

Operating factors ranging from 50% to values approaching 90% may be obtained depending on the degree of automation.

Operating factor depends upon,
- Machine set-up (electrode change, holder adjustment)
- Operator Skill
- Material Handling
Higher Current density

Current density \( J \, [A/mm^2] \) is the relation between the amperage \( I \, [A] \) and effective cross section \( A \, [mm^2] \) of the wire:

\[
J = \frac{I}{A} = \frac{I}{\frac{d^2 \cdot \pi}{4}} = \frac{I}{\frac{(d_a - d_i)^2 \cdot \pi}{4}} = \frac{A}{mm^2}
\]
Main properties of cored wires

Current density

**Solid wire, Ø 1,2 mm**
welding current I = 220 A
Shielding gas: M21 (18% CO2 + 82% Ar)

\[
J_1 = \frac{I}{d^2 \pi} = \frac{220 \text{ A}}{(1,2\text{mm})^2 \pi} = 194 \frac{\text{A}}{\text{mm}^2}
\]

**Rutile Flux Cored wire, Ø 1,2 mm**
welding current I = 220 A
Shielding gas: M21 (18% CO2 + 82% Ar)

\[
J_2 = \frac{I}{(d_a^2-d_i^2) \pi} = \frac{220 \text{ A}}{(1,2^2-0,75^2)\text{mm}^2 \pi} = 320 \frac{\text{A}}{\text{mm}^2}
\]

**Higher current density = Higher deposition rate**
Penetration compared to solid wire

- Flux cored wire have a wider arc
- Operate therefore with a very safe penetration
- The risk of lack of fusion is minimized
Cored wires welding parameters

More flexible welding parameter settings

- Steady low spatter welding in spray arc from approx. 150 A, 24V, 6.5 m/min. (solid wire Ø 1.2 mm from approx. 210 A, 28V, 7 m/min)
- Good welding behavior remains constant over wide range of currents and voltages

![Graph showing spatter formation and welding parameters]

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Comparison of deposition rates

Theoretical deposition rate
100% d.c. (kg/h)

Welding position: 1G PA

Amperage (A)

- Flux cored wire ø 0.9 mm
- Flux cored wire ø 1.2 mm
- Flux cored wire ø 1.6 mm
- Solid wire ø 1.0 mm
- Solid wire ø 1.2 mm
- Coated electrode

4 mm
5 mm
Comparison of weld length

**Flux-cored wire**
E316LT1-4(1)
EAS 4 PW-FD
Ø 1,2 mm
M 21

**Solid wire**
E316L-(Si)
EAS 4 M-IG (Si)
Ø 1,0 mm
M 12

**Covered electrode**
E316L-17
FOX EAS 4 M-A
Ø 3,2 mm

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**Flux cored wire**
- A = 180
- V = 27,5
- WS = 8,3 m/min
- L = 220 mm/min

**Solid wire pulsed**
- A = 100
- V = 20
- WS = 5,5 m/min
- L = 145 mm/min

**Covered electrode**
- A = 90
- V = 26
- L = 75 mm/min
Fabrication Codes & FCAW process

AWS D1.1
- FCAW process is deemed as qualified processes as per Section 3.0 – Prequalification of WPS.
- With respect to welder qualification, a 3G qualification qualifies for all other positions except Overhead position.

ASME SEC IX
- QW-255 covers the welding variables for procedure qualification for GMAW and FCAW.
- QW-355 covers the welding variables for welder qualification for GMAW and FCAW processes.

ASME SEC VIII
- UHT-82 clause describes the welding requirements per process
- For FCAW, the consumable should conform to SFA 5.29 and SFA 5.36
Fabrication Codes & FCAW process

API RP 582: Welding Guidelines for the Chemical, Oil and Gas Industries
- As per its section 5.1 FCAW is an acceptable welding process
- FCAW-G (Gas shielded) may be used for either groove or fillet welds for pressure boundary or structural welding
- For use of FCAW consumables in pressure containing equipment, diffusible hydrogen limit should be met as specified in Table 5-1 (H4 or H8)

API 1104: Welding of Pipelines and Related Facilities
- As per Section 12 – FCAW Automatic Welding is an acceptable process
- For each process details of essential variable is given in its sub section 12.5
Fabrication Codes & FCAW process

M-601: NORSOK Standard for Welding and Inspection of Piping

- Section 4.4 gives details of essential variables and details with respect to FCAW process variable are also discussed e.g. any increase in filler wire diameter

ASME B31.1, B31.3 and B31.8

- These have no reference for any process and it is the client that gives acceptance to fabricators those comply with design requirements
- Clients, which accept FCAW process for welding of piping spools in Oil & Gas sector are GE, Flour Canada, Thermax, ISGEC, NTPC, L&T, Alstom
### Project Details

<table>
<thead>
<tr>
<th><strong>Customer</strong></th>
<th>Bronswerk Heat Transfer BV Nijkerk – the Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fabrication shop</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Component description</strong></td>
<td>High pressure gas coolers</td>
</tr>
<tr>
<td><strong>Base materials</strong></td>
<td>Duplex &amp; AISI 321 stainless steels</td>
</tr>
<tr>
<td><strong>Filler metal type</strong></td>
<td>Full package of solid wires, fluxcored wires and wire-flux combinations for stainless steel</td>
</tr>
<tr>
<td><strong>Quantity</strong></td>
<td></td>
</tr>
<tr>
<td>BÖHLER SAS2-FD FCAW</td>
<td></td>
</tr>
<tr>
<td>BÖHLER CN 22/9N-FD FCAW</td>
<td></td>
</tr>
<tr>
<td><strong>Engineering company</strong></td>
<td>Vetco Aibel AS, Norway</td>
</tr>
<tr>
<td><strong>Owner</strong></td>
<td>Petrobras, Brasil</td>
</tr>
<tr>
<td><strong>Project name</strong></td>
<td>FPSO P53 floating production unit – compression modules</td>
</tr>
</tbody>
</table>

**Success story:** active support to WPQS, excellent consumables, in time delivery
Product Applications
Bronswerk Heat Transfer, Netherlands

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Product Applications
Worm Shaft

Base metal:
- AISI 316Ti/1.4571

Filler metal:
- EAS4M-FD (E316LT0-4(1))

Customer/Country:
- M/S Andritz AG/Austria
Product Applications

Water injection system for a fire fighting equipment

Base metal:
- UNS S 31803/1.4462 15-25mm

Filler metal:
- CN22/9PW-FD (E2209T1-4(1))
- CN22/9N-FD (E2209T0-4(1))

Customer/Country:
- M/S Frank Mohn/Norway
Product Applications

Largest pulp digestor worldwide welded with CN 22/9 PW-FD

- BOHLER CN 22/9 PW- FD
- Diameter: 0.045 (1.2 mm)
- Wall thickness: 2.17” (55mm)
- Horizontal/vertical position 2G
- Vertical position 3G
- acc. to ASTM A 923 B
Product Applications
4000m³ LNG storage tank

Welded with EAS2 PW-FD from M/S Izotechnik/ Poland in Norway
Product Applications
Bohler Ti 80 T-FD

Application for Chord and Rack welding

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Product Applications
Alform 700-MC

Welding in Lang Fang, China
Base material: X100
Pipe diameter: Ø1016 x 16,5 mm
Joint preperation: Narrow gap
Shielding gas Argon + 18% CO2

Root pass welded with Böhler NiMo1-IG Ø 1,0 mm (ER90S-G)

Joint preparation. Narrow gap
Product Applications
Self shielded flux cored wire for pipeline application

China – X52 Ø 20"x 10 mm, 30 km

BÖHLER Pipeshield 71 T8-FD
Application X52 Ø 20.8” x 10 mm
Length: 30Km
Product Applications
Saipem Karimun – Jangrik & Kaombo project

- Estimated steel weight:
  18,000 tons for Jangrik
  27,000 tons for Kaombo

- Material Requirement: EN E275, E355, E420 & E460

- Consumable requirement:
  Welding Process: FCAW
  Chemistry: 1%Ni wire,
  Shield Gas: 100% CO2,
  Tensile Strength: 480 – 620 Mpa
  Yield Strength: 420 Mpa min
  Impacts: 40J avg @ -46C in stress relieved condition
  Stress relief: 620C x 3 hours.

- Bohler Ti60T-FD(Co2) meet all the requirements given above.
Product Applications

Hardfacing

Surfacing of continuous casting rolls

SK 742N-SK
SK 410 NiMo-SA
Product Applications

Hardfacing

SK 255-O
SK 256-O
SK A43-O

Excavator bucket

Cement roller press

Grinding chamber wall lining

Transport screw

Rotor of hammer crusher

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Backup
Market overview – Indian scenario

India Welding Consumables Market, 2013 – 2020 (Kilo Tons) (INR Mn)

(Source: www.transparencymarketresearch.com)