Explosion bonded clad plates by means of vacuum technology

Unique in the world
Introduction

- Introduction of SMT
- What is explosive cladding?
- The explosive cladding process
- Applications
- Advantages explosive cladding
- Why explosive cladding in vacuum?
- Quality control
- Processing cladmaterial and conclusion
Introduction SMT

- Starting vacuum technology in 1985
- Worldwide active
- Production in 3 vacuum chambers
- Activity: explosive cladding
- Additional value such as technical recommendations and metallurgical support
Material Inspection

STEP 1: PLAIN MATERIAL INSPECTION

CLAD LAYER

BASE MATERIAL
Carbon steel grinding and preparing

STEP 2: GRINDING

CLAD LAYER

BASE MATERIAL
Set-up with stand-off space

**STEP 3: SET-UP**

CLAD LAYER

BASE MATERIAL
STEP 4: EXPLOSION IN VACUUM CHAMBER

EXPLOSIVE CLAD LAYER
JET
BASE MATERIAL

COLLISION POINT
METALURGICAL YIELD LINE
Flattening by rolling or pressing

STEP 5: FLATTENING & CUTTING
US and mechanical testing
The explosive cladding process

- Grinding of the surfaces
- Set-up
- Preparation of explosion process
- Explosion welding
The explosive cladding process during a snapshot
Mechanism of atomic bond

- Aluminium atoms
- Metal bond
- Electron clouds
- Nucleus
- Iron atoms
Explosive cladding

- Synonym for explosive welding
- Two or more dissimilar metals
- Cold pressure welding process
- Metals conventional often not weldable by thermal processes
Process configurations

- Possible process configurations:
  - Flat plates (square and rectangular)
  - Round discs (heads and tubesheets)
  - Pipes, long welding neck flanges
  - Pump shafts
Dimensions and capacity

- **Maximum sizes and capacity:**
  - Maximum Length: ± 14 meter
  - Maximum width: ± 4 meter
  - Maximum total area: 30 m²
  - Lifting capacity: 30 metric tons
  - Base material thickness: 10 - 500 mm
  - Clad material thickness: 1 - 25 mm
Properties metal joint

- Properties of the explosive metal joint
  - Homogeneous integral of two or more dissimilar metals
  - Joint bond stronger than the weakest material
  - Original metal properties are remaining
  - Good thermal and electrical conductivity
  - Oxide free
  - Atomic bond
  - No crevices
Applications

- Chemical and Petrochemical Industry
  - Base material
    - relatively cheap material with good mechanical properties
  - Clad layer
    - expensive thin layer, good corrosion resistant
- Applications
  - Tube sheets, reactors, heat exchangers, condensors, vessels, etc
Metal combinations

- Often used metal combinations:
  - Titanium / Carbon steel
  - Titanium / Stainless Steel
  - Aluminium Bronze / Carbon steel
  - Stainless Steel / Carbon steel
  - Nickel + Alloys / Carbon Steel
  - Hastelloy / Carbon Steel
  - Duplex - Super Duplex / C-steel
  - Aluminium / Carbon steel
Transition joints

- Marine applications
  - Triplate for shipbuilding and offshore
- Electrical applications
  - ETJ’s Electrical Transition Joints
Marine applications

- **Triplate® : Shipbuilding**
  - Aluminium/Steel transition joints
  - Base material: Carbon Steel
  - Interlayer: Aluminium 99,5
  - Super layer: AlMg4,5Mn

EXPLOSION BONDED TRANSITION JOINT BY VACUUM TECHNOLOGY

Queen Mary II
The processing of Triplate®

- Cutting into bars from tested clad plates
- Straightening and marking
- Enables to weld the aluminium superstructure to the steel hull
- Examples: mega yachts, cruise vessels, ferries, tenders, fishing vessels
Applications

- Inside cladding of pipes / LWN
  - Thickness clad layer: 3-4 mm
  - Wall thickness pipe piece: minimum 40 mm
  - Internal diameter: 25 - 1200 mm
  - Length: max. 1 meter
Advantages Explosive Cladding

- Metal combinations possible which are conventional impossible to weld i.e.: Ti/Steel, Cu/Al, Al/Steel etc.
- Saves costs: thin layer of expensive material cladded on a thicker layer of cheap material
- Original metal properties remains
- Joint bond stronger than the weakest material
Advantages explosive cladding

- Low electrical resistance of anode/cathode blocks
- Required clad layer thickness in one step realized
- Smooth surface after cladding
- Save expensive material
- Intermediate quality control not necessary
Why explosive cladding in vacuum?

- Different explosive cladding methods:
  - Open air cladding
  - Vacuum cladding
Why explosive cladding in vacuum?

- Vacuum cladding
  - Cladding in a vacuum chamber
  - Under pressure: 50 mBar
  - Noise level: 70 dB(A)
- Environmental friendly
- No air in the stand-off space during welding
- No turbulence in the interface
- Optimal process control such as:
  - Detonation velocity, vacuum condition, temperature, moisture, stand-off space, etc.
Three different interfaces

- Smooth wave interface
- Undulating wave interface
- Turbulent wave interface (open air)
- Perfect wavy interface due to vacuum cladding
- Oxides caused by washing of waves (open air)
Side bend and hammer bend test

Side Bend Test 90°

Top: Atmospheric cladded
Bottom: Vacuum cladded Triplate
Micro shear cracks caused by high waves

- Special when the clad metal is less ductile
- Neglect risk by using vacuum technology

Source: R. Hardwick
Atmospheric versus vacuum

<table>
<thead>
<tr>
<th>Open air cladding</th>
<th>Vacuum cladding</th>
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<tbody>
<tr>
<td>Oxides with porosity</td>
<td>100% dense</td>
</tr>
<tr>
<td>Oxides initiate fractures</td>
<td>Does not apply</td>
</tr>
<tr>
<td>Holes initiate corrosion</td>
<td>Does not apply</td>
</tr>
<tr>
<td>Stress relief treatment due to cold working</td>
<td>Not necessary since cold working is limited</td>
</tr>
<tr>
<td>Variable weather conditions</td>
<td>Does not apply since it is inside</td>
</tr>
<tr>
<td>Harder to machine (sawing and bending)</td>
<td>Easy sawing and forming thanks to high ductility</td>
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Technical support

- SMT is supporting their customers in order to achieve an optimal operation condition.
- An important issue is the welding procedure and recommendations.
- And of course the do’s and the dont’s.
- Moreover we are grinding the contact surfaces to reduce the resistance after welding to the anode and steel bracket.
The vacuum chamber

Entrance of the vacuum chamber

Cladding set-up just before the explosion welding process
The vacuum chamber

- Advanced vacuum pumps
Quality control

- Procedures according to ISO 9001 (since 1992)
- Testing of the explosive cladded material:
  - Ultrasonic Testing
  - Destructive testing:
    - Tensile test
    - Bend tests
    - Shear test
    - Impact tests
    - Fatigue test
Quality control

- Independent inspection authorities such as Lloyd’s, TUV, GL, DNV, ABS, Bureau Veritas
- Certificates according to EN 10204 3.1 or 3.2
Processing the explosive clad material

- Processing of the explosive clad material:
  - Welding
  - Machining
  - Plasmacutting, lasercutting, waterjet cutting
  - Bending pressing to vessel heads
  - Rolling to cylinders for shells
  - Heat treatment
Conclusions

- High tech material
- No bad influence on the environment
- Saves costs
- Research for new applications: new metal-combinations
- Increasing of possibilities
- Sizes of the clad plates and production capacity
Thank you very much for your attention

LasGroep Oost

We're very proud to serve you!

SHOCKWAVE METALWORKING TECHNOLOGIES BV