RF Cavities Manufacturing Techniques I
CAS 2010 June 16, Ebeltoft Denmark
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The main aims of this presentation are:

- To unveil and list the under jacent basic and quite simple concepts ruling the NC RF Cavities construction techniques.

- To show and describe now a days Standard Technologies mastered by Industry for manufacturing NC RF Cavities.

- To illustrate the talk with several typical examples based on SDMS experience.
Who is SDMS Technologies? A few numbers:

- 1 High Technology French SME Company
  - For highly demanding customers… when Technology matters!

- 2 Plants locations:
  - St Romans: 130 p. (30 engineers and managers) 20 M€/year
  - Manosque: 90 p. (20 engineers and managers) 10 M€/year

- 3 Fields of Activities:
  - Energy, Research, Defence&Space

- 4 Technologies Poles:
  - Nuclear, Vacuum, Cryogenics, Mecatronics
NC RF Cavities made by Industry (Ideal Case)

1 - Design

2 – Materials

3 – Forming Techniques

4 – Cleaning Techniques

5 – Joining Techniques

6 – ND Control Techniques, RF and Vacuum Conditioning

7 – New ESRF Cu Cavity: Comparison between 2 Manufacturing Routes
BASIC DESIGN (made by the Customer)

- General Design (needs of the Research Center... dreams of the Physicist !)

- Global shapes, mandatory dimensions, RF parameters...

- Conditions in use, thermo mechanical requirements, vacuum...
ENGINEERING DESIGN (made by the Industry)

- Precise Design (imperatives of Industry… from dreams to reality)

- Detailed Design: Mechanics, Cooling systems, Interfaces…

- Manufacturing Design: Processes choices, Toolings, Fabrication route…
### « IDEAL » MATERIALS FOR NC RF CAVITIES

#### Important « Physical » Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Electrical Conductivity</th>
<th>Thermal Conductivity</th>
<th>Mechanical Stiffness</th>
<th>Secondary Emission Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFHC COPPER</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>$5.8 \times 10^9 , \text{Ω.m}^{-1}$</td>
<td>$400 , \text{W/m/K}$</td>
<td>$1.2 \times 10^{10} , \text{daN/m}^2$</td>
<td></td>
</tr>
<tr>
<td>COPPER ON STEEL</td>
<td>Good</td>
<td>Poor</td>
<td>Very Good</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>$5.0 \times 10^9 , \text{Ω.m}^{-1}$</td>
<td>$20 , \text{W/m/K}$</td>
<td>$2.1 \times 10^{10} , \text{daN/m}^2$</td>
<td></td>
</tr>
<tr>
<td>PURE ALUMINUM</td>
<td>Good</td>
<td>Good</td>
<td>Bad</td>
<td>Bad</td>
</tr>
<tr>
<td></td>
<td>$3.7 \times 10^9 , \text{Ω.m}^{-1}$</td>
<td>$220 , \text{W/m/K}$</td>
<td>$0.7 \times 10^{10} , \text{daN/m}^2$</td>
<td></td>
</tr>
</tbody>
</table>
**» IDEAL » MATERIALS FOR NC RF CAVITIES**

Important « Engineering » Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Availability</th>
<th>Machinability</th>
<th>Weldability</th>
<th>Vacuum</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFHC COPPER</td>
<td>Expensive</td>
<td>Good</td>
<td>Good</td>
<td>Good 1.5 $10^{-11}$ mbar.l/s/cm²</td>
</tr>
<tr>
<td></td>
<td>40 €/Kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COPPER ON STEEL</td>
<td>Cheap</td>
<td>Good</td>
<td>Very Good</td>
<td>Bad 1.5 $10^{-10}$ mbar.l/s/cm²</td>
</tr>
<tr>
<td></td>
<td>4 €/Kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PURE ALUMINUM</td>
<td>Rather cheap</td>
<td>Good</td>
<td>Bad</td>
<td>Good 1.5 $10^{-11}$ mbar.l/s/cm²</td>
</tr>
<tr>
<td></td>
<td>10 €/Kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technique</td>
<td>Cost</td>
<td>Toolings</td>
<td>Accuracy</td>
<td>Surface Quality</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------</td>
<td>----------</td>
<td>--------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>MACHINING / ED STRIKING</td>
<td>Cheap</td>
<td>None</td>
<td>High (+/- 2 µm)</td>
<td>Very Good (&lt;0.1 µm)</td>
</tr>
<tr>
<td>ROLLING / FOLDING</td>
<td>Cheap</td>
<td>Few</td>
<td>Good (+/- 0.5 mm)</td>
<td>Good (&lt;2 µm)</td>
</tr>
<tr>
<td>FORGING / MATRICING</td>
<td>Expensive</td>
<td>Heavy</td>
<td>Rough (+/- 10 mm)</td>
<td>Damaged Crust</td>
</tr>
<tr>
<td>SPINNING / FLUOTURNING</td>
<td>Cheap</td>
<td>Shapes</td>
<td>Good (+/- 0.2 mm)</td>
<td>Good (&lt;4 µm)</td>
</tr>
<tr>
<td>DEEP DRAWING / PRESSING</td>
<td>Cheap</td>
<td>Dies</td>
<td>Good (+/- 0.2 mm)</td>
<td>Good (&lt;4 µm)</td>
</tr>
<tr>
<td>HYDROFORMING</td>
<td>Expensive</td>
<td>Multi Dies</td>
<td>Good (+/- 0.2 mm)</td>
<td>Orange Peel</td>
</tr>
<tr>
<td>ELECTROFORMING</td>
<td>Expensive</td>
<td>Lost Mould</td>
<td>Good (+/- 0.2 mm)</td>
<td>Etching Pits</td>
</tr>
<tr>
<td>EXPLOSING</td>
<td>Cheap</td>
<td>Shapes</td>
<td>Good (+/- 0.2 mm)</td>
<td>Damaged Crust</td>
</tr>
</tbody>
</table>

A combination of several techniques can be used for one given cavity, according to the concerned part.
ROLLING
FOLDING
FORGING
MATRICING
DEEP DRAWING
PRESSING
SPINNING
FLUOTURNING
HYDROFORMING

Procédé de mise en forme par HYDROFORMAGE

Etape 1: Mise en place

Etape 2: Injection d'eau

Etape 3: Mise sous pression

Etape 4: Compression

La pièce à former est formée par deux mâchoires, et formée aux extrémités.

L'eau sous pression est injectée dans la pièce à former.

La pièce se déforme sous l'action de la pression interne.

La pièce est compressée de l'extérieur pour sa mise en forme finale.

Procédé valable pour mono et multi-couches
ELECTROFORMING
ELECTROPLATING
CLEANING TECHNOLOGIES FOR NC RF CAVITIES

DEGREASING
Hot Solvent Vapours + Alkaline Detergent + US

ETCHING
Acid Desoxydation + Etching (A or B) + Passivation

CHEMICAL POLISHING
Acid + Alcool + Hydrogene Peroxyde Mixture

ELECTROPOLISHING
Acid + Alcool + Current Density

PURE WATER RINSING

ETHANOL DRYING
JOINING TECHNOLOGIES FOR NC RF CAVITIES

VACUUM BRAZING

DIFFUSION BONDING

SOLDERING

TIG/MIG WELDING

ELECTRON BEAM WELDING
VACUUM BRAZING
DIFFUSION BONDING
SOLDERING
TIG/MIG WELDING
ELECTRON BEAM WELDING
ND TESTING TECHNOLOGIES FOR NC RF CAVITIES

3D CONTROLS
HELIUM LEAK TESTS
RF TESTS AND ADJUSTMENTS
VACUUM CONDITIONNING
PSI 56 MHz pure Al Cavity
Al TIG, MIG, and EB Welded

PSI 65 MHz pure Cu Cavity
Cu TIG and EB Welded
SS/Cu Brazed and Soldered
GANIL 9 to 15 MHz Cu and SS CAVITIES
Cu EB Welded and Brazed
SS TIG Welded
Cu Plated on SS
THE NEW ESRF Cu CAVITY: RF Design by the Lab

A NICE COMPARISON OF 2 MANUFACTURING ROUTES
A FAIR COMPETITION BETWEEN 2 SKILLED SUPPLIERS

EB Welded Concept (SDMS)

Vacuum Brazed Concept (RI)
Thanks to SDMS Industrial partners for photos credit:

BONITEMPO (Spinning), COURBIS (Deep Drawing), CORIMA (Electroforming), BRILLAT (Rolling), OMG (Machining), HYDROPRESS (Hydroforming), CARLIER (Forging), EXPLOFORM (Explosing)

THANK YOU FOR YOUR KIND ATTENTION…! 