Improvement in Cavity Fabrication Technology and Cost Reduction Methods

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MHI  Japan
1. SRF activities at MHI
2. Improvement in cavity fabrication method for cost reduction
   2-1 Fabrication of MHI-A cavity
   2-2 Fabrication of MHI-B cavity
   2-3 Other fabrication technology
3. Current status at MHI factory
4. Summary
1-1 SRF activities at MHI

‘86~ Tristan Cavity  36sets
1-1 SRF activities at MHI

’90~ L-band Cavity
1-1 SRF activities at MHI

'86~ Tristan Cavity
36 sets

'90~ L-band Cavity

'02~ Crab Cavity 2 sets

'02~ Crab Cavity 2 sets
1-1 SRF activities at MHI

‘06~ ERL Cavity 9 sets

Courtesy of KEK
1-1 SRF activities at MHI

- Tristan Cavity: 36 sets
- L-band Cavity: 9 sets
- Crab Cavity: 2 sets
- ERL Cavity: 9 sets
- STF Cavity: 22 sets

'05~ STF Cavity 22 sets
## 1-2 Activities for improvement of cavity performance

### In case of KEK STF cavities

<table>
<thead>
<tr>
<th>Phase</th>
<th>Cavity No.</th>
<th>Thickness of thinning</th>
<th>Shape of groove</th>
<th>Bead condition</th>
<th>Frequency of chemical polishing</th>
<th>Management of cleanness</th>
<th>High pressure gas safety law</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>#1-4</td>
<td>2.5 mm</td>
<td>Butt</td>
<td>Bumpy</td>
<td>Only after thinning</td>
<td>Air duster</td>
<td>—</td>
</tr>
<tr>
<td>1.5</td>
<td>#5-6 &amp; #7-9</td>
<td>2.0 mm</td>
<td>Smoother</td>
<td></td>
<td>Each step (just before EBW)</td>
<td>Clean area</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>#10-11</td>
<td>Step</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>2.0</td>
<td>#12-22</td>
<td>Step</td>
<td></td>
<td></td>
<td></td>
<td>Air top gun</td>
<td>Adapted</td>
</tr>
</tbody>
</table>
1-3 Recent result of vertical test for STF Cavity

Governing high pressure gas safety law in Japan

- **ILC Spec.**
  - \( E_{\text{acc}} = 31.5 \text{MV/m} \)
  - \( Q_0 = 1.0 \times 10^{10} \)

- **VT Spec.**
  - \( E_{\text{acc}} = 35 \text{MV/m} \)
  - \( Q_0 = 0.8 \times 10^{10} \)

**Graph Notes:**
- MHI-12 2nd VT
- MHI-13 1st VT
- MHI-14 3rd VT
- MHI-15 2nd VT
- MHI-16 1st VT
- MHI-17 1st VT
- ILC Spec.
- VT Spec.

**Courtesy of KEK**
1-3 Recent result of vertical test for STF Cavity

Governing high pressure gas safety law in Japan

ILC Spec.
\[ E_{acc} = 31.5 \text{MV/m} \]
\[ Q_0 = 1.0 \times 10^{10} \]

VT Spec.
\[ E_{acc} = 35 \text{MV/m} \]
\[ Q_0 = 0.8 \times 10^{10} \]

Achievement for ILC spec. (#18~22: under fabrication)

Courtesy of KEK
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2. Improvement in cavity fabrication method for cost reduction

General principles about cost reduction for mass-production:

1. Reducing number of parts
2. Automation or outsourcing
3. Batch process
4. Reducing process time
   ▪ Change of fabrication procedure
   ▪ Using special jig and machine
   ▪ Optimization of machine time and factory layout

Cavity have more than 50 parts
2. Improvement in cavity fabrication method for cost reduction

List of our proposed fabrication methods

Applied to Production cavities
- To simplify inner conductor of HOM coupler design
- Seamless beam-pipe (deep-drawing)

Applied to R&D cavities
- Using LBW instead of EBW for stiffener and flange
- Automatic finishing for inner surface of cell
- Seamless dumbbell

Under development
- Using brazing instead of EBW for stiffener and flange

Proposal
- Combination of pick-up port and flange
- Combination of base-plate and beam tube
2-1 Fabrication of MHI-A cavity

MHI-A was fabricated in order to establish new methods such as
- Deep drawing for HOM cup
- LBW for stiffener ring and flanges of beam tube

![Fabrication of MHI-A cavity](image-url)
2-1 Deep drawing for HOM coupler (MHI-A)

- Machining was used at the top of cup and the welding groove
- A nipple to tune a notch frequency was fixed by welding
- No finishing for Inner surface

We expect ▲30% cost reduction from prior method.

Nb disk φ130-3t

Forming

Machining

EBW for nipple, port and inner conductor
2-1 LBW for stiffener rings and flanges (MHI-A)

- Cooling time is shorter than EBW.
- Vacuum condition is not required.
  - argon gas atmosphere
  - oxygen content controlled
- LBW bead was equivalent to EBW bead

For dumbbell stiffener rings

For beam tube flanges
The MHI-A cavity achieved **29.5 MV/m** without problem at LBW points and HOM coupler.

- We found these new techniques can be available for future cavities.
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2-2 Seamless dumbbell 2 cell cavity (MHI-B)

Target:
Inspecting a performance of seamless dumbbell.

Under fabrication
This cavity is developed by JLab, KEK, and MHI.

Feature
・No welding seam on iris and longitudinal line.
・Finishing for inner surface of dumbbell is auto buffing.
・Easy to inspect inner surface
・Easy to handle the forming die
2-2 Forming technique for seamless dumbbell

Present status

\[ \Phi 260-2.8t \ ; 2 \text{ sheets} \]

New process

\[ \Phi 500-3.0t \]

Material for
- Input port
- HOM coupler
- Stiffener ring

Seamless pipe by deep drawing

We expect \( \Delta 50\% \) cost reduction from prior method.
2-2 Details of seamless dumbbell

- Seamless pipe was produced by deep drawing (t = 2.87 - 3.05 mm)
- Inside shapes deviation from design was less than 0.5 mm
- It is possible to improve cell shape and deviation of thickness by changing die shape or forming condition.

![Diagram showing deviation of thickness and quality of inner surface]
2-2 Auto finishing for inner surface

- It takes much time for finishing by human hand.
- Finishing should be done automatically with a robotic finisher.
- We are developing auto buffing and carrying out basic test.

Auto buffing test; case of seamless dumbbell

Present status

Ra ≒ 80 before

We expect ▲ 80% cost reduction from prior method.

Ra ≒ 2 after

MHI-B cavity will be assembled in August and tested at JLab.
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2-3(1) 500MHz SRF cavity for NSRRC using deep drawing technology

508MHz 1cell Cavity (For KEKB R&B : Prior process)

Prior process
LBP

\[ \text{t3.0mm Niobium sheet} \]

\[ \text{Roll forming and EBW} \]
2-3(1) 500MHz SRF cavity for NSRRC using deep drawing technology

508MHz 1cell Cavity (For KEKB R&B: Prior process)
2-3(1) 500MHz SRF cavity for NSRRC using deep drawing technology

508MHz 1cell Cavity (For KEKB R&B : Prior process)

Prior process
SBP

---

Roll forming and EBW

Bulge forming

SBP

LBP

5mm Niobium sheet
2-3(1) 500MHz SRF cavity for NSRRC using deep drawing technology

508MHz 1cell Cavity (For KEKB R&B: Prior process)

New process
SBP

Deep drawing

Bulge forming

SBP

LBP

φ220mm

270mm

t3.0mm Niobium sheet
**2-3(2) Brazing Joint for flange and stiffener (for STF Cavity)**

**Under development**

We did the basic mechanical test result of brazing Nb and Ti joints and Nb and Nb joints

<table>
<thead>
<tr>
<th>Material</th>
<th>Brazing material</th>
<th>Surface treatment</th>
<th>Ave. Shearing strength (N/mm²)</th>
<th>Break point</th>
<th>Ave. Absorbing Energy $Kv_2$(J)</th>
<th>Leak test</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Nb/Ti</td>
<td>A</td>
<td>-</td>
<td>124</td>
<td>Nb</td>
<td>0.58</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>○</td>
<td>122</td>
<td>Nb</td>
<td>-</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>-</td>
<td>45</td>
<td>joint</td>
<td>0.55</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>○</td>
<td>40.7</td>
<td>joint</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>-</td>
<td>42.7</td>
<td>joint</td>
<td>0.6</td>
<td>○</td>
<td></td>
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<td></td>
<td></td>
<td>○</td>
<td>39.2</td>
<td>joint</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Nb/Nb</td>
<td>A</td>
<td>-</td>
<td>54.6</td>
<td>joint</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>-</td>
<td>120.6</td>
<td>Nb/joint</td>
<td>9.78</td>
<td>-</td>
<td>1sample:22J</td>
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<tr>
<td></td>
<td>C</td>
<td>-</td>
<td>121.6</td>
<td>Nb/joint</td>
<td>4.05</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>○</td>
<td>106.6</td>
<td>joint</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

A; Ti group

B, C; Ag group

- Need some test for brazing condition and cavity performance

Heat treatment after Brazing: 923K x 3H, 77K x 5 min.

Test temperature: room temperature
2-3(3) Change for material & coupling for flanges (for STF Cavity)

Proposal from MHI

Combination of monitor port and flange

- Can reduce one part
- Can reduce one welding seam
- Need some experiment to EP chemical
- Need some leakage test at 2K
2-3(4) Combination of end group parts
(for STF Cavity)

Proposal from MHI

Reduce for EBW seam by combination of base-plate and beam-tube

Present process

Beam tube
Base plate & Nb ring
End cell
2-3(4) Combination of end group parts  
(for STF Cavity)

Proposal from MHI

Reduce for EBW seam by combination of base-plate and beam-tube

Proposal process

Beam tube
Base plate
End cell
Proposal from MHI

Reduce for EBW seam by combination of base-plate and beam-tube

Assembly of End parts parts

Present shape

EBW two seam

Proposal shape

EBW one seam

Combination of end group parts
(for STF Cavity)
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3 Current status at MHI factory

Installed in April 2011

We will develop mass-production method by using new EBW and LBW machine

New EBW machine

Beam power : max 10 kW
Accelerating voltage : 80 kV

High power fiber laser welding machine

Generator : 25kW fiber laser system
Head : made by MHI
3 Current status at MHI factory

Max heat temperature : 1200 °C
Degree of vacuum : \(~10^{-4}\) Pa

We will develop mass-production method by using big furnace and clean room
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4. Summary

• We have supplied some 1.3GHz SRF cavities for STF and ERL projects at KEK for the last few years. The cavity performance are improving step by step.

• We have proposed some ideas for cost reduction and these method was established step by step. We need to estimate in detail the effect of cost reduction.

• According to MHI-A cavity, we were sure that using LBW joints instead of EBW joints for the parts of little influence to cavity performance was available.

• MHI-B cavity with seamless dumbbell is under fabrication. This cavity is going to be finished on August 2011. After inspection and surface treatment, RF test will be carried out at JLab on this autumn.
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and
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Thank you for your attention.