Summary of Support tube R&D

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Components at IR region
Supported by Tungsten tubes, CFRP tube
For high luminosity
Effects of; Ground motion, culture Noise
have to be eliminated.
- Analyses, Excitation tests

Study Items;
- Check consistency
  Analyses ↔ Excitation test
- Is necessary CFRP tube?
  - If yes, how much thickness?
- How much is relative amplitude?
  \(|P1-P2| < 2nm\) (Criteria)
Exciting Test

20t x 100w x 695L

2.5t x 100w x 200L

Measurement

1: 26Hz

2: 40Hz

3: 161Hz

FEM

1: 30Hz

2: 43Hz

3: 184Hz

1st ~ 3rd mode: Good agreement with FEM

Support structure should be modeled in FEM.
Stiffness: 1:512

2.5mm thick plate

20mm thick plate

By connecting very weak structure,
- Deviation can be absorbed.
- Correlation can be given.
- Relative amplitude can be estimated.
Calculation of relative amplitude

(Model-A)

\[ F_0 \cos(\omega t) = (m - a) \sin(\omega t) \]

QC-L: Tungsten (100mm)

\( \omega = 0 \rightarrow 1000 \text{Hz} \)

<table>
<thead>
<tr>
<th>7m</th>
<th>2m</th>
<th>3.85m</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC-L</td>
<td>CFRP</td>
<td>QC-R</td>
</tr>
</tbody>
</table>

(Model-B)

Data: Vertical @ KEK: ATF (17:00 Feb. 10, 2004)

Input Acc. = \(2 \times 10^{-7} \text{m/s}^2\)

Mass = 90tons/9.8 [m/s²]

Self weight

How much is relative amplitude?
Relative amplitude at 2\textsuperscript{nd} mode

(Model-A)

Less than 2nm. Small enough at 4m.

(Model-B)

Lager than 2nm at L*= 2m except for 10mm thick of CFRP.
Less than 2nm at L*= 4m.
Optimization of CFRP tube thickness

Right side: 70Hz

Left side: 75Hz

CFRP: Changed!

<table>
<thead>
<tr>
<th>CFRP(mm)</th>
<th>1st mode Freq(Hz)</th>
<th>2nd mode Freq(Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>73.6</td>
<td>85.2</td>
</tr>
<tr>
<td>10</td>
<td>72.9</td>
<td>80.1</td>
</tr>
<tr>
<td>5</td>
<td>75.5</td>
<td>78.4</td>
</tr>
<tr>
<td>3</td>
<td>72.0</td>
<td>76.5</td>
</tr>
<tr>
<td>1</td>
<td>71.5</td>
<td>75.7</td>
</tr>
</tbody>
</table>

Less than this thickness, correlation and opposite phase don't appear at 2nd mode.

1st mode(CFRP: 1mm)

2nd mode

At least, thickness of CFRP: >3mm
Conclusion

- Tungsten tube: 100mm thick, CFRP: 5mm thick
  - Correlation is given to both-sides tubes in oscillating behavior.

- In case of L* = 2m;
  - Support position: Both ends + 3.85m from I.P.
- In case of L* = 4m;
  - Support position: Both ends

- Active vibration isolation system is necessary.
  - Amplitude is magnified if support tube is mount on a support stand.
  - To eliminate culture noise.
  - CFRP tube is not efficient to reduce amplitude less than 2nm.

- It is necessary to design the stiff support base as possible
  - Natural frequency becomes high.
  - Amplitude decreases in proportion to frequency.
Tests (Hammering test)

FRF (Frequency Response Function)

\[
H_{ij}(f) = \frac{X_i(f)}{F_j(f)}
\]

X_i: Output Acc.
F_j: Input force

Input

Output

FFT

FRF Table
Estimation of Input Acc.

Data: Vertical @ATF(17:00 Feb. 10, 2004)

Input Acc. = \(2 \times 10^{-7} \text{m/s}^2\)

Mass = 90 tons / 9.8 [m/s²]

Self weight
In case of 100mm-5mm(CFRP)-100mm

(1st mode) (2nd mode)

Relative amplitude

Same phase
Opposite phase

Relative amplitude

Frequency(Hz)

Amplitude(nm)
Other calculations ($L^* = 2m$)

<table>
<thead>
<tr>
<th></th>
<th>3-Point fixed(Both end+3.85m)</th>
<th>2-Point fixed(Both end)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CFRP</td>
<td>Tungsten</td>
</tr>
<tr>
<td>δf</td>
<td>Mode</td>
<td>3mm</td>
</tr>
<tr>
<td>0Hz</td>
<td>1st</td>
<td>Freq.(Hz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diff.(nm)</td>
</tr>
<tr>
<td></td>
<td>2nd</td>
<td>Freq.(Hz)</td>
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<td></td>
<td></td>
<td>Diff.(nm)</td>
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<tr>
<td>1Hz</td>
<td>1st</td>
<td>Freq.(Hz)</td>
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<tr>
<td></td>
<td></td>
<td>Diff.(nm)</td>
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<tr>
<td></td>
<td>2nd</td>
<td>Freq.(Hz)</td>
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<tr>
<td>3Hz</td>
<td>1st</td>
<td>Freq.(Hz)</td>
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<tr>
<td>5Hz</td>
<td>1st</td>
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<tr>
<td>Canti</td>
<td>1st</td>
<td>Freq.(Hz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amp(p-p)</td>
</tr>
</tbody>
</table>

Diff: Relative amplitude between QC-R and QC-L ($ΔZ=4m$).
MAC (Modal Assurance Criteria)

\[ MAC_{rr'} = \left( \frac{\left\langle \psi_r^{\text{test}}, \psi_{r'}^{\text{FE}} \right\rangle}{\left\langle \psi_r^{\text{test}}, \psi_r^{\text{test}} \right\rangle} \cdot \frac{\left\langle \psi_{r'}^{\text{FE}}, \psi_{r'}^{\text{FE}} \right\rangle}{\left\langle \psi_{r'}^{\text{FE}}, \psi_{r'}^{\text{FE}} \right\rangle} \right)^{1/2} \]

MAC = 1: Mode shape pairs is exactly match
MAC = 0: pairs that are completely independent

Damping ratio

\[ \zeta = \frac{f_1 - f_2}{2 \times f_n} \]

Comparison with FEM

<table>
<thead>
<tr>
<th>Mode</th>
<th>Freq.</th>
<th>Damping(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30.4Hz</td>
<td>1.68</td>
</tr>
<tr>
<td>2</td>
<td>188Hz</td>
<td>0.422</td>
</tr>
<tr>
<td>3</td>
<td>419Hz</td>
<td>0.303</td>
</tr>
<tr>
<td>4</td>
<td>584Hz</td>
<td>0.113</td>
</tr>
<tr>
<td>5</td>
<td>992Hz</td>
<td>8.02E-2</td>
</tr>
</tbody>
</table>
Results

(Model-A)

- Natural frequency: 76Hz
- Relative amp. : 0.2nm max. < 2nm (L* = 2m), small enough (L* = 4m)
- This is ideal configuration.
- In case of no CFRP tube (Cantilever): Amplitude = 0.2nm < 2nm
  CFRP tube is not necessary because of less than 2nm.
  However, it is difficult to amount them on a very stiff base stand.
  So realistic natural frequencies must be lower than this value.

(Model-B)

- Natural frequency: 17Hz,
- Relative amp. : 2~3nm (L* = 2m), 1.2nm (L* = 4m)
- In case of no CFRP tube (Cantilever): Amplitude = 4nm

Efficient of CFRP tube:
- Relative amplitude can not decrease drastically. But it is about half amplitude of cantilever type.
- Deviation of natural frequency between two tubes can be absorbed.