A case study on the 4river turbine efficiency test using the ASFM and index test -

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I. Outline
### 1. Outline

**What is the 4river project?**

- A government enterprise to prevent floods and secure water resources with 16 weirs including 41 hydropower units.

<table>
<thead>
<tr>
<th>River</th>
<th>Number of Weirs</th>
<th>Number of Units</th>
<th>Total Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Han gang(river)</td>
<td>3</td>
<td>9</td>
<td>12,945</td>
</tr>
<tr>
<td>Geum gang(river)</td>
<td>3</td>
<td>9</td>
<td>7,950</td>
</tr>
<tr>
<td>Nakdong gang(river)</td>
<td>8</td>
<td>19</td>
<td>27,841</td>
</tr>
<tr>
<td>Youngsan gang(river)</td>
<td>2</td>
<td>4</td>
<td>2,020</td>
</tr>
</tbody>
</table>
1. Outline

Measurement history of the ASFM in K-water

- K-water has exerted to secure the test technique and adopted the ASFM system for reliable efficiency test in the mid-2000s as a part of this.

- The efficiency test using the ASFM was first applied to Yongdam hydraulic power plants. Since then, Namgang and Hapcheon hydraulic power plants were applied in turn.

- The test result showed that the ASFM is reliable as the efficiency test method, especially Hapcheon’s result showed the ASFM is applicable for performance verification of the 4 river power plants that have short intakes and low-head turbines.
1. Outline

Application site

Sejong hydropower plant No.2
- Turbine type: Horizontal Kaplan
- Capacity: 2,310kW (770*3)
- Net head: 2.51m
- Discharge: 37.8cms
1. Outline

Methods

- The discharge was measured by the ASFM as absolute method because of convenient and economical aspects.
- And also index test was conducted simultaneously to compare with the ASFM results.
II. Test results
2. Test results _ASFM

Measurement

- The frame was designed to install the transducers.
- The frame was divided into 8 pieces made of steel, the transducer was mounted on each piece.
2. Test results - ASFM

Measurement

- The slot is away from approximately 6m downstream of the trash rack and located in uniform cross-sectional area.
- The measuring section is 7.40m and the height is 5.60m
2. Test results - ASFM

Results

- Discharge

- The discharge measurements were done at 4 points.

- They were performed twice at the same points, and the velocity profiles are generally repetitive.

![Velocity profiles in measuring cross-section at 620kW point](image-url)
2. Test results—ASFM

- Discharge

- The discharge at each point was computed using multiple file average.

- The results show that the discharge is similar at each point.

<table>
<thead>
<tr>
<th>310-1</th>
<th>310-2</th>
<th>460-1</th>
<th>460-2</th>
<th>620-1</th>
<th>620-2</th>
<th>770-1</th>
<th>770-2</th>
</tr>
</thead>
</table>

ASFM discharge
2. Test results - ASFM

Results

- Efficiency

This result shows that the highest efficiency is 91.8% at 620kW and the efficiency at rated output is about 90.0%.
2. Test results - ASFM

Results

- Efficiency

- If the deviation of net head is within ±3% under testing condition,

\[
\left| \frac{H - H_r}{H_r} \right| = 0.03 \quad (H : \text{net head, } H_r : \text{rated head})
\]

the turbine output (Pm) can be converted into the rated head as follows (JEC4002, 1992)

\[
P_c = P_m \left( \frac{H_r}{H} \right)^{\frac{3}{2}} \quad (P_c : \text{converted turbine output, } P_m : \text{measured turbine output})
\]

- At this time, turbine efficiency is not changed.
2. Test results - ASFM

Results

- Efficiency

The criteria of turbine efficiency curve, the highest efficiency is 91.6% and the efficiency at rated output is 89.8%
2. Test results - index test

Measurement

- The relative value was calibrated by a method of the ASFM, and therefore the results can be considered as a part of the field acceptance test as well as absolute value.

- The differential pressures were measured simultaneously with the discharge measurement using the ASFM.
2. Test results - Index test

Results - Discharge

The coefficient values were derived from the discharge measurement result using the ASFM and the differential pressures.

The discharge was calculated by this values.

<table>
<thead>
<tr>
<th></th>
<th>310-1</th>
<th>310-2</th>
<th>460-1</th>
<th>460-2</th>
<th>620-1</th>
<th>620-2</th>
<th>770-1</th>
<th>770-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>cms</td>
<td>15.5</td>
<td>15.5</td>
<td>21.5</td>
<td>21.5</td>
<td>27.3</td>
<td>27.2</td>
<td>35.4</td>
<td>35.1</td>
</tr>
</tbody>
</table>
2. Test results - Index test

Results

Efficiency

- The highest efficiency is 91.6% at 620-1 point and the efficiency at rated output is about 90%.

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Measured data</th>
<th>Calculation data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diff.</td>
<td>Discharge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>press.</td>
</tr>
<tr>
<td>Ah</td>
<td>mAq</td>
<td>m³/s</td>
</tr>
<tr>
<td>310-1</td>
<td>0.14</td>
<td>15.5</td>
</tr>
<tr>
<td>310-2</td>
<td>0.14</td>
<td>15.5</td>
</tr>
<tr>
<td>460-1</td>
<td>0.27</td>
<td>21.5</td>
</tr>
<tr>
<td>460-2</td>
<td>0.27</td>
<td>21.5</td>
</tr>
<tr>
<td>620-1</td>
<td>0.45</td>
<td>27.3</td>
</tr>
<tr>
<td>620-2</td>
<td>0.44</td>
<td>27.2</td>
</tr>
<tr>
<td>770-1</td>
<td>0.76</td>
<td>35.4</td>
</tr>
<tr>
<td>770-2</td>
<td>0.75</td>
<td>35.1</td>
</tr>
</tbody>
</table>
2. Test results - Index test

Results
- Efficiency

The criteria of turbine efficiency curve, the highest efficiency is 91.7% and the efficiency at rated output is 90.2%
2. Test results - Comparison

Results

- Simultaneous measurements taken with the ASFM and index test have allowed comparison of the efficiency measured by two methods.

- The comparison of efficiency test results shows good general agreement between the two methods, although there are differences in the details.

- The values at each point are very similar, the biggest difference is 1.3% at 460 kW, and the overall agreement between the two methods was within 1%. 
2. Test results  
Comparison

Results

Comparison of turbine efficiency curve (ASFM vs Index test)
2. Test results – Conclusions

- The results are reliable and this is a good example of the efficiency measurement by the ASFM and index test.

- And the thing is that the ASFM is applicable for performance verification of the 4river hydraulic power plants that have short intakes and low-head turbines.
Conclusions

In spite of good results, work remains to be done to resolve the transducer’s signal detection.

In this case, two pair transducers were not operated during the measurement.

The causes were not verified, and it is necessary to analyze the causes and to supplement the faults.

If this gets solved, the results will be more reliable.
Thank you for your attention

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