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- 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 16weirs including 41 hydropower units.



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 4river 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



Bird's eye view of Sejong HPP

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

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.



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



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Results

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- Discharge

- > The discharge measurements were done at 4 points.
- They were performed twice at the same points, and the velocity profiles are generally repetitive.



Results

- Discharge

- The discharge at the each point was computed using multiple file average .
- The results show that the discharge is similar at each point.

| 310-1 | 310-2 | 460-1 | 460-2 | 620-1 | 620-2 | 770-1 | 770-2 |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 15.5(cms) | 15.7(cms) | 21.2(cms) | 21.4(cms) | 27.2(cms) | 27.1(cms) | 35.6(cms) | 35.4(cms) |

ASFM discharge

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Results

- Efficiency

• This results show that the highest efficiency is 91.8% at 620kW and the efficiency at rated output is about 90.0%.

| | ASFM | | | | | | | | | | | | | | | |
|-------|---------------|-------|------|---------|---------|--------|-------|-------|---------|-----------|---------|------------------|---------|---------|-------|--------|
| Test | Measured data | | | | | | | | | | | Calculation data | | | | |
| | Gene | rator | | Turbine | | | | | | | | | | | U. | |
| No. | Gen | Gen. | GVSS | RVSS | Turbine | Press. | Inlet | TWL | Suction | Discharge | Dynamic | Net | Turbine | Turbine | [m] | 2.51 |
| | output | eff. | | | output | Sensor | head | | head | | press. | head | input | eff. | 0.0 | Bo |
| | PG | n,G | | | Pm | P1 | Hu | Z2 | Hs | Q | Hv | н | Ph | ąT | w.C | re |
| | ΧW | 2 | 茨 | 2 | k₩ | mAq | nAq | EL.m. | n | m² /s | mAq | n | XW | 22 | nº /s | XW |
| 310-1 | 310.53 | 95.17 | 53.3 | 29.7 | 326.3 | 4.73 | 5.01 | 8.40 | -2.40 | 15.5 | -0.010 | 2.60 | 394.40 | 82.7 | 15.23 | 309.45 |
| 310-2 | 310.53 | 95.17 | 53.4 | 29.5 | 325.3 | 4.72 | 5.00 | 8.40 | -2.40 | 15.7 | -0.010 | 2.59 | 395.91 | 82.2 | 15.42 | 311.28 |
| 460-1 | 457.98 | 95.99 | 66.8 | 46.6 | 477.1 | 4.74 | 5.02 | 8.45 | -2.45 | 21.2 | -0.018 | 2.55 | 529.64 | 90.1 | 21.04 | 465.44 |
| 460-2 | 457.84 | 95.99 | 66.7 | 46.7 | 477.0 | 4.72 | 5.00 | 8.45 | -2.45 | 21.4 | -0.018 | 2.53 | 529.39 | 90.1 | 21.28 | 470.89 |
| 620-1 | 613.52 | 96.21 | 75.6 | 59.1 | 637.7 | 4.81 | 5.09 | 8.45 | -2.45 | 27.2 | -0.030 | 2.61 | 694.73 | 91.8 | 26.67 | 601.30 |
| 620-2 | 612.11 | 96.21 | 76.0 | 59.2 | 635.2 | 4.80 | 5.08 | 8.43 | -2.43 | 27.1 | -0.030 | 2.62 | 695.39 | 91.5 | 26.54 | 596.42 |
| 770-1 | 787.76 | 95.03 | 84.3 | 75.5 | 798.5 | 4.84 | 5.12 | 8.52 | -2.52 | 35.6 | -0.051 | 2.55 | 888.18 | 90.0 | 35.34 | 781.24 |
| 770-2 | 766.84 | 96.03 | 84.1 | 75.1 | 798.5 | 4.87 | 5.15 | 8.54 | -2.54 | 35.4 | -0.050 | 2.56 | 885.90 | 90.1 | 35.03 | 275.41 |

Efficiency test results(ASFM)

Results

- Efficiency

• If the deviation of net head is within $\pm 3\%$ under testing condition,

$$\left|\frac{H-H_r}{H_r}\right| = 0.03$$
 (H : net head, Hr : rated head)

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

 $P_c = P_m (\frac{H_r}{H})^{\frac{3}{2}}$ (Pc : converted turbine output, Pm : measured turbine output)

At this time, turbine efficiency is not changed.

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Results

- Efficiency

The criteria of turbine efficiency curve, the highest efficiency is
 91.6% and the efficiency at rated output is 89.8%



Turbine efficiency curve(ASFM)

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.

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.

| 310-1 | 310-2 | 460-1 | 460-2 | 620-1 | 620-2 | 770-1 | 770-2 |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 15.5(cms) | 15.5(cms) | 21.5(cms) | 21.5(cms) | 27.3(cms) | 27.2(cms) | 35.4(cms) | 35.1(cms) |

Index test discharge

Results

- Efficiency

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

| | Index | | | | | | | | | | | |
|-------------|----------|---------------|---------|------------------|---------|---------|-------------------|--------|--|--|--|--|
| | | Measured data | | Calculation data | | | | | | | | |
| Test No. | Diff. | Discharge | Dynamic | Net | Turbine | Turbine | Hr [m] | 2.51 | | | | |
| | pressure | | press. | head | input | eff. | 0.0 | Pa | | | | |
| | ۸h | Qi | Hv | н | Ph | ąT | QC: | re | | | | |
| | mAq | m² /8 | mAq | m | k₩ | 2 | m ¹ /8 | KW | | | | |
| 310-1 | 0.14 | 15.5 | -0.01 | 2.60 | 393.22 | 83.0 | 15.18 | 309.44 | | | | |
| 310-2 | 0.14 | 15.5 | -0.01 | 2.59 | 392.25 | 83.2 | 15.23 | 311.24 | | | | |
| 460-1 | 0.27 | 21.5 | -0.02 | 2.55 | 537.10 | 88.8 | 21.34 | 465.58 | | | | |
| 460-2 | 0.27 | 21.5 | -0.02 | 2.53 | 533.54 | 89.4 | 21.45 | 470.98 | | | | |
| 620-1 | 0.45 | 27.3 | -0.03 | 2.61 | 696.23 | 91.6 | 26.73 | 601.35 | | | | |
| 620-2 | 0.44 | 27.2 | -0.03 | 2.62 | 697.41 | 91.2 | 26.62 | 596.48 | | | | |
| 770-1 | 0.76 | 35.4 | -0.05 | 2,55 | 883.89 | 80.4 | 35,16 | 781.01 | | | | |
| 770-2 | 0.75 | 35.1 | -0.05 | 2.58 | 879.63 | 90.8 | 34.78 | 275.07 | | | | |

Efficiency 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 difference in the details.
- The values at each point are very similar, the biggest difference is
 1.3% at 460kW, and the overall agreement between, the two method
 was within 1%

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2. Test results_Comparison

Results

Comparison of turbine efficiency curve(ASFM vs Index test)

2. Test results_ Conclusions

Conclusions

- The results are reliable and this is 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.

2. Test results_ Conclusions

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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