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

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Abstract

The four-river project is a government enterprise to prevent floods and secure water resources with 16 weirs including 41 small hydropower units. This study concerns the four-river hydraulic turbine efficiency test using the Acoustic Scintillation Flow Meter(ASFM) and index test.

Turbine efficiency test was performed at Sejong hydropower plant unit No. 2 on October 10 to 18, 2011. This test is to verify the hydraulic performance of Sejong hydraulic turbines with a turbine efficiency test. Sejong HPP is equipped with three horizontal Kaplan turbines (770kW*3) which rated net head is 2.51m.

Sejong HPP has a short intake and a low head, which is generally performed by current meters as absolute method. But in this case, 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. The results show that the efficiency by the ASFM is 89.8% and one by index test is 90.2% at rated output.

It seems like that the results are reliable and this is a good example of the efficiency measurement by the ASFM and index test. This study shows the procedures, analysis and results of two methods.

1. Introduction

In order to be accurate performance test of hydraulic turbine, K-water has exerted to secure the test technique and adopted the ASFM system for reliable efficiency test in the mid-2000s as part of this. The efficiency test using the ASFM was first applied to Yongdam hydraulic power plant(rated net head 41.7m, rated discharge 5.21㎥/s, output 1,800kW). Since then, Namgang and Hapchen hydraulic power plants were applied in turn.

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

This paper concerns the application of Sejong hydropower plant unit No.2, which was built as part of 4river project.

2. Measurements

The discharge was measured by the ASFM as absolute method because of convenient and economical aspects. Index test is conducted simultaneously to compare with the ASFM results and details on index test complied with the IEC code for hydraulic turbines(IEC60041, 1991). The measurements were done at four points, and the rest of the units(No.1 & 3) was not operated during the measurement

2.1 ASFM

The frame was designed to install the transducers(Rx & Tx). It was divided into 8 pieces made of steel, the transducer was mounted on each piece(see Fig 1). It was inserted into the slot, which were constructed in advance(not gate slot). The slot is away from approximately 6 meters downstream of the trash rack and located in uniform cross-sectional area(see Fig 2). The measuring section is 7.40m and the height is 5.60m.

Fig 1 - Frame for the transducers installation

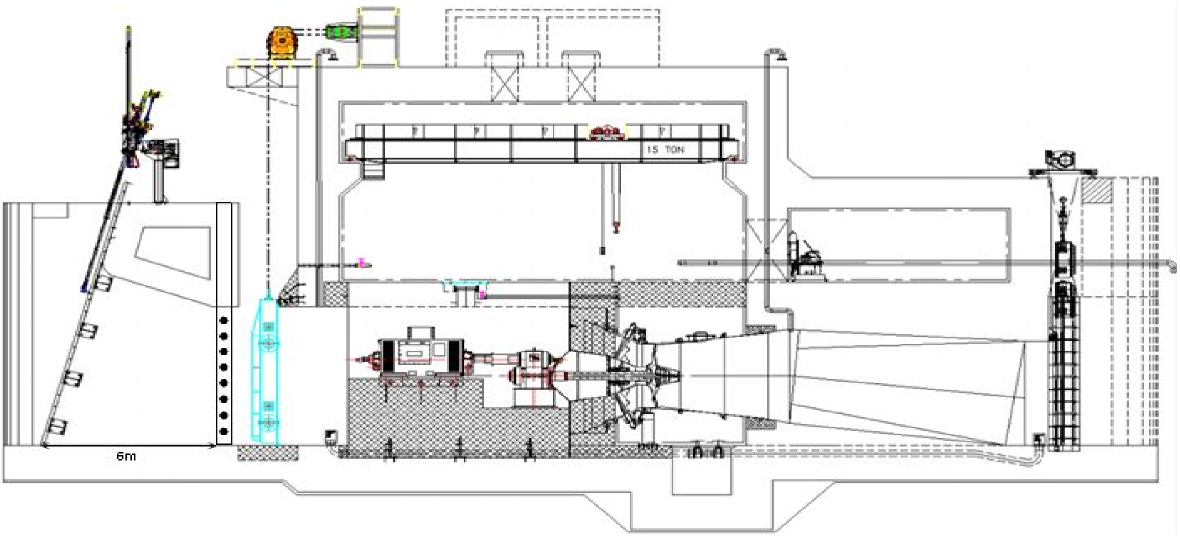


Fig 2 - Cross-section of Sejong HPP

The sampling time was approximately 660 seconds, in the meantime, other factors(output, G/V stroke, pressure, etc.) were measured by data acquisition system(DAQ).

2.2 Index test

Index test was performed to compare with the ASFM result. The IEC60041 code(section 15) states that an index test is a relative measure of flow and efficiency, not an absolute one. The results are on an arbitrary scale, but unless the flow data from the Winter-Kennedy taps has been calibrated by making measurements using another, absolute flow method, they can only be used to measure how the efficiency of the turbine changes, but not what its absolute value is.

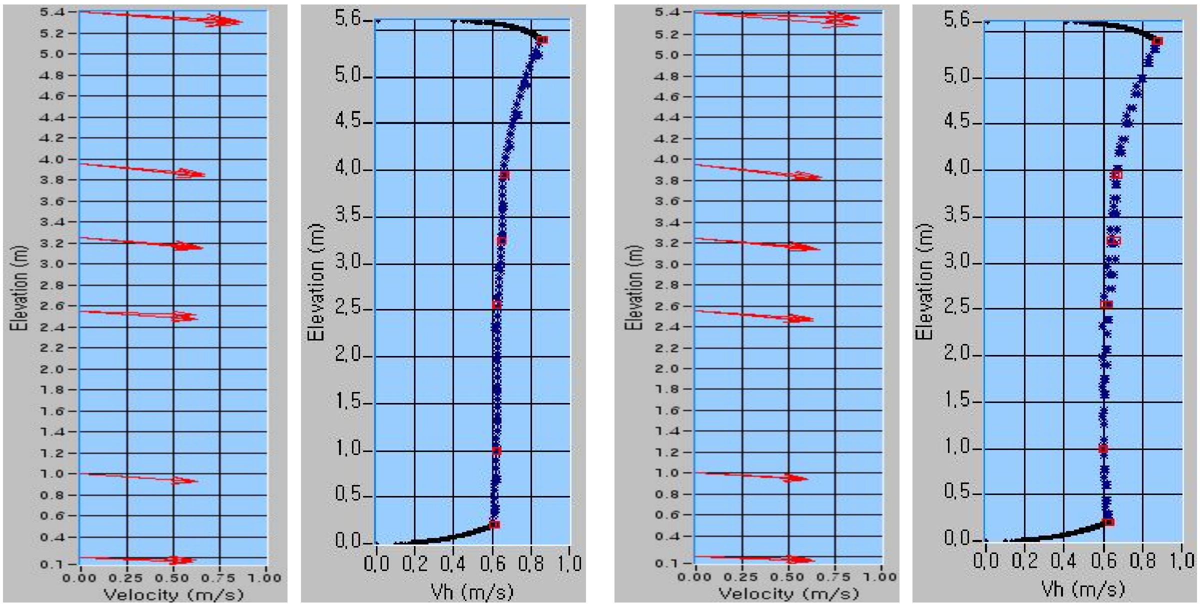
In this case, the relative value was calibrated by a method of the ASFM, and therefore the results can be considered as a part of the field acceptance test as well as an absolute value. The differential pressures were measured simultaneously with the discharge measurement using the ASFM, and the discharge was calculated by the coefficient values(k, n), which were derived from the discharge measurement results using the ASFM and the differential pressures.

3. Results and Discussions

3.1 ASFM

- Discharge

The discharge measurements were done at four points(Generator, 310~770kW). They were performed twice at the same point, and the velocity profiles are generally repetitive(see Fig 3).



620-1 620-2

Fig 3 - Velocity profiles in measuring cross-section at 620kW point

The discharge at the each point was computed using multiple file averaged(Qavg, Number of runs : 3) and the results show that the discharge is similar at the each point. They are listed in table 1

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)

Table 1 - ASFM discharge

- Efficiency

The results show that the highest efficiency is 91.8% at 620-1 point and the efficiency at rated output(Generator, 770kW) is 90.0~90.1%.(see table 2)

Test No.	ASFM															
	Measured data											Calculation data				
	Generator		Turbine												Hr [m]	2.51
	Gen output PG	Gen. eff. ηG	GVSS	RVSS	Turbine output Pm	Press. Sensor P1	Inlet head Hu	TWL Z2	Suction head Hs	Discharge Q	Dynamic press. Hv	Net head H	Turbine input Ph	Turbine eff. ηT	Qc	Pc
	kW	%	%	%	kW	mAq	mAq	EL.m	m	m³/s	mAq	m	kW	%	m³/s	kW
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	326.3	4.72	5.00	8.40	-2.40	15.7	-0.010	2.59	396.91	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	636.2	4.80	5.08	8.43	-2.43	27.1	-0.030	2.62	695.39	91.5	26.54	596.42
770-1	767.76	96.03	84.3	75.5	799.5	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	775.41

Table 2 - Efficiency test results(ASFM)

If the deviation of net head is within ±3% under testing condition, i.e. when the following term is satisfied,

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

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

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

At this time, turbine efficiency is not changed, and the turbine efficiency curve converted into this way is shown in Fig 4. The criteria of turbine efficiency curve, the highest efficiency is 91.6% and the efficiency at rated output is 89.8%.

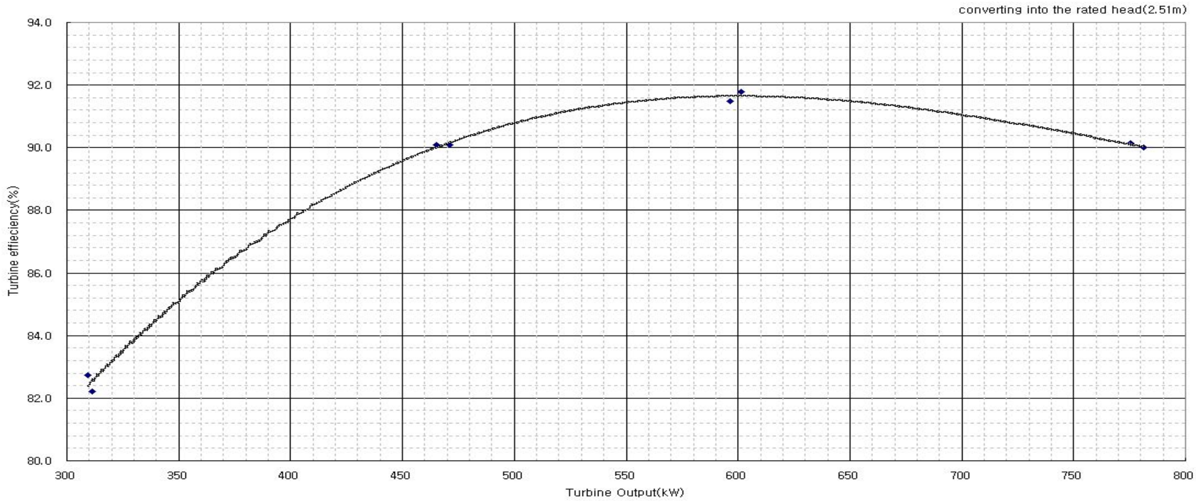


Fig 4 - Turbine efficiency curve(ASFM)

3.2 Index test

- Discharge

The coefficient values(k:40.369, n:0.4852) were derived from the discharge measurement results using the ASFM and the differential pressures. The discharge was calculated by this values, and the results are listed in table 3.

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)

Table 3 - Index test discharge

- Efficiency

The results show that the highest efficiency is 91.6% at 620-1 point and the efficiency at rated output(Generator, 770kW) is 90.4~90.8%.(see table 4)

Test No.	Index							
	Measured data			Calculation data				
	Diff. pressure	Discharge	Dynamic press.	Net head	Turbine input	Turbine eff.	Hr [m]	2.51
	Δh	Qi	Hv	H	Ph	ηT	Qc	Pc
	mAq	m³/s	mAq	m	kW	%	m³/s	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	90.4	35.16	781.01
770-2	0.75	35.1	-0.05	2.56	879.63	90.8	34.76	775.07

Table 4 - Efficiency test results(Index test)

Fig 5 shows the turbine efficiency curve. The criteria of turbine efficiency curve, the highest efficiency is 91.7% and the efficiency at rated output is 90.2%.

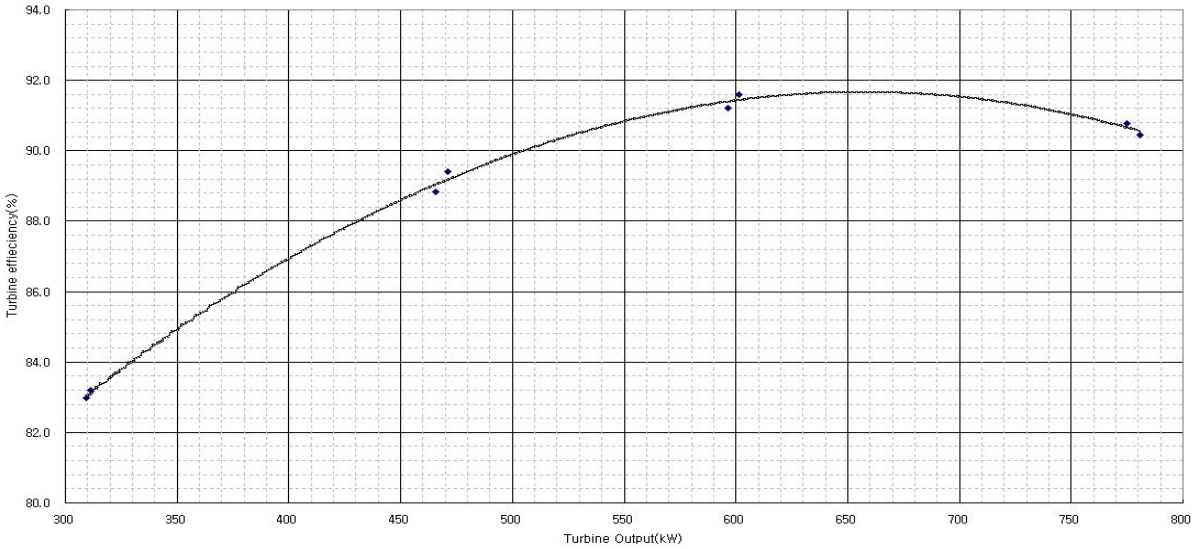


Fig 5 - Turbine efficiency curve(Index test)

3.3 Comparison

Simultaneous measurements taken with the ASFM and index test in Sejong HPP unit NO.2 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 460-1 point, and the overall agreement between the two method was within 1%. Also in the same manner, the turbine efficiency curves have similar characteristics(see Fig 6).

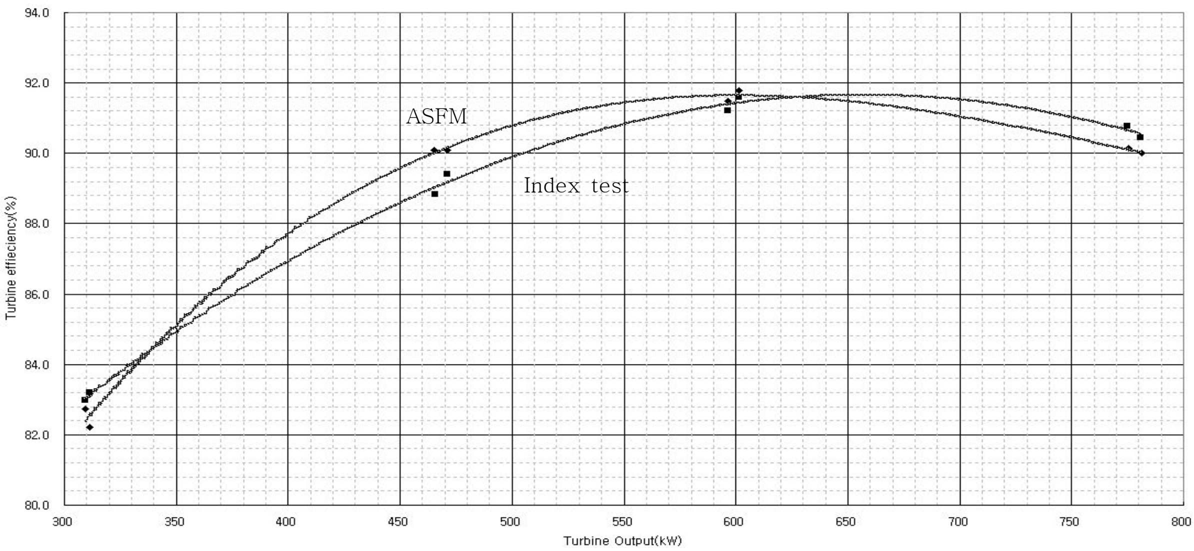


Fig 6 - Comparison of turbine efficiency curve(ASFM vs index test)

4. Conclusions

It seems like that the results are reliable and this is a good example of the efficiency measurement by the ASFM and index test. And the significance is that the ASFM is applicable for performance verification of the 4river hydraulic power plants that have short intakes and low-head turbines.

In spite of good results, work remains to be done to resolve the transducer's signal detection. In this case, two pairs of 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.

5. References

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