The 24th Conference of the Mechanical Engineering Network of Thailand

October 20 – 22, 2010, Ubon Ratchathani

Performance Characteristics of Micro Hydro Generation with Spiral Turbine

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Abstract

Recently micro scale generation systems are attempted to recover wasted water energy. In e-san area, plenty of solar energy is available by solar panel generation because of so many fine days. However, in rainy season, solar energy cannot use effectively. So recovering their rain water energy with some way, it's able to use clean energy for generation in a whole year.

This study supposes to use rain water in a paddy field or widely flat field which has head of about 1m and enough volume. For this condition spiral turbine was selected to micro generation. It has features that even if water includes rubbish like leaves, it will move well. However it's characteristics is not clarified sufficiently. The purpose of this study is to clarify the characteristics of micro hydro generation system, obtain design data and experience technical problem. Test system is consisted mainly by water tank set in bottom, recirculation water pump, spiral turbine with a length of 1700mm, speed up gear and generator.

In this paper, power and efficiency of the spiral turbine, output of the generator and efficiency of generation system are described. And further study is suggested to get higher efficiency.

***Keywords**:* Renewable energy, micro generation, spiral turbine, water energy

1. Introduction

Water energy is considered as one of the main renewable energy. Lower than 100kW power generation is called micro generation [1] and it's seemed to contribute climate change through unutilized energy usage. Currently small scale power generations with spiral turbine are attempted to recover wasted water energy [2-4]. The feature of this type of the generation system is able to use in low head and low flow rate of water. However tested generation systems are a few and their performance is not clarified yet.

In e-san area, plenty of solar energy is available because of so many fine days. However in rainy season, it cannot use effectively. So recovering rain water energy by generation system with spiral turbine, it can compensate less solar energy in rainy season. This study supposes to utilize rain water in paddy land or widely flat field. Used water condition for design is lower than 1m head, small flow rate and big volume pooled in flat field.

The purpose of this study is to clarify the characteristics of micro hydro generation system, obtain design data and experience technical problem. The system is consisted mainly by water tank, recirculation pump, spiral turbine with 1700mm length and generator. Test was performed by varying flow rate, rotation speed and load.

In this paper, performances of the spiral turbine, the generator and the generation system are described. Further improvement for higher efficiency is also mentioned.

2. Micro Hydro Generation System

Outline of the generation system is shown in Fig.1. Water tank with a volume of 750L is set in the bottom of the apparatus. Water is pumped up from the water tank to the supply pipe by engine-powered water pump, and flows into the inlet pipe. Water from the inlet pipe moves the spiral turbine passing through it. After that it flows down to the water tank and continues circulation. Water flow rate is controlled by the engine throttle and a valve equipped between the pump and the supply pipe. When measures flow rate, the supply pipe is turned to the scaled tank horizontally.

Water head was fixed at 0.85m (H). The spiral turbine was tilted in 30deg against horizontal direction, and connected to the generator by speed up gear. Load was varied about 10 steps by combination of resistances.

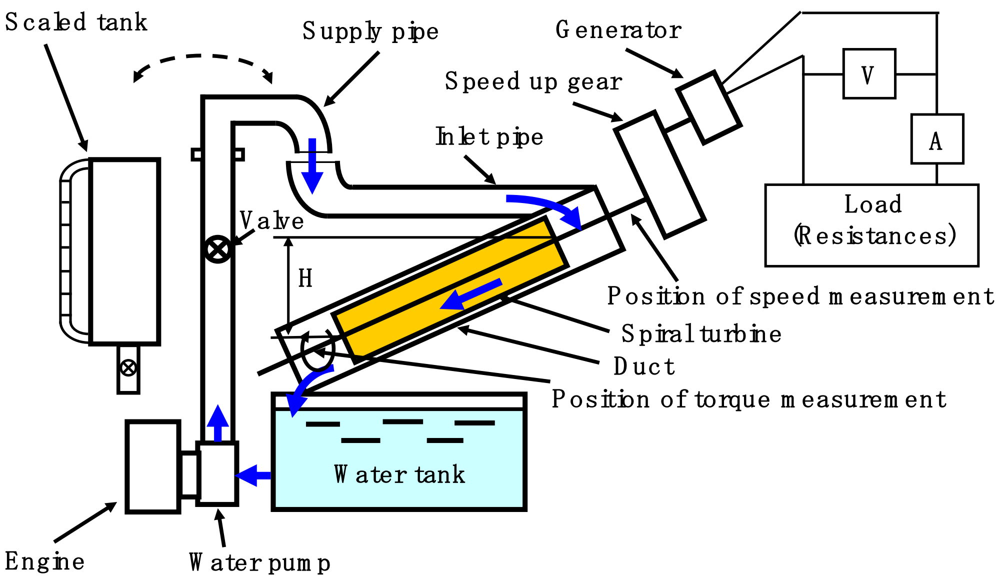

Fig.1 Outline of generation system

2.1 Spiral turbine

Dimensions of the turbine and duct were decided tentatively that half of the duct was filled by water at water flow rate of 10L/s. Fig.2 shows the configuration of the spiral turbine. Single spiral vane is spot-welded continuously to the shaft of 60mm diameter. The spiral vane has 1700mm length, 80mm height, 15 stages with 110mm interval in 1700mm length. Both side of the shaft are supported by ball bearings. Lower half of the duct is semicircle with 250mm diameter. Clearance of the turbine and duct is 15mm.

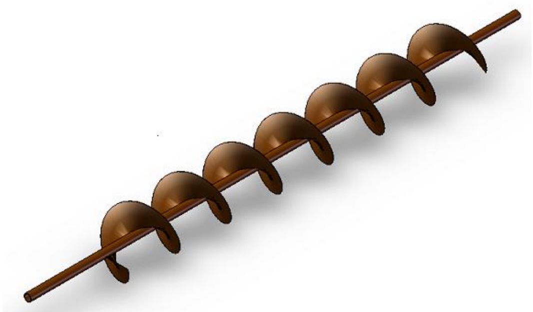

Fig.2 Configuration of spiral turbine

2.2 Speed up gear

Speed up gear was assembled using a wheel hub of a bicycle. Gears were linked by chain for a bicycle or a motorcycle. Three gear ratios were used for generators. The ratios were 7.5 with a bicycle chain, 15(7.5×2) with a bicycle and motorcycle chains, 2.33 with a motorcycle chain.

2.3 Generator

Two types of generator were used for test. Type 1 is a DC generator for appliance. Specification is shown in Table 1.

Another generator (Type 2) is handmade three phase generator. It was altered DC with an all wave rectifier. Specification of type 2 is in Table 2. Outside view of both generators is shown in Fig.3.

Table1 Specification of the generator (Type 1)

Voltage	DC140V
Max. output	28W
Speed	1500~ rpm
Pole	8P

Table2 Specification of the generator (Type 2)

Voltage	DC70V
Max. output	160W
Speed	200~1000 rpm
Phase	3
Rectifier	All wave (6diodes)

Type 1 DC28W　　　　Type 2 DC160W

Fig.3 Outside view of tested generators

3. Test Procedure

Test was initiated by starting the water pump with maximum power. After 10minuites warming up of the apparatus, the supply pipe was turned to the scaled tank and measured time which the tank volume of 100L was filled by water. Flow rate was calculated by the water volume of 100L divided by the measured time, and estimated with the average value of 3 measurements.

Tests of the spiral turbine and generator were conducted under flow rate conditions of the maximum, medium and small. First of all, characteristic of the spiral turbine was measured independently. It was disconnected to speed up gear and generator. Torque and rotation speed were measured. Power was calculated by Eq. (1).

$$P = \frac{2\pi T n}{60} \quad (1)$$

P: Power [W]

T: Torque [Nm]

n: Speed [rpm]

Torque measurement was according to the method expressed in section 3.1. Speed measurement was by means of an optical equipment. Measuring positions of them are shown in Fig.1.

Characteristics of the turbine and generator system were examined with varying load condition.

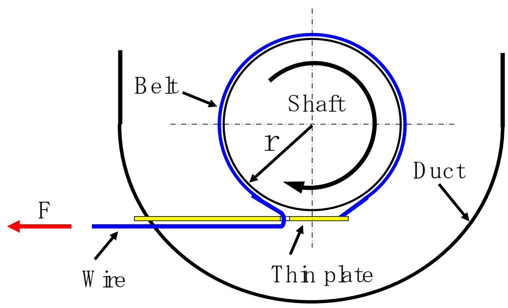

Fig.4 Torque measurement method

3.1. Measurement of turbine torque

Owing to commercialized small torque meter was unavailable, handmade device shown in Fig.4 was used for measuring torque. Main parts are a thin plate spot-welded with the duct, a steel belt and a wire. Each part is linked flexibly by hole and pin around the shaft. When measuring torque, wire is pulled and force (F) is read by spring scale. Torque is calculated by Eq. (2).

$$T = 9.8 \times \mathrm{F} \times \mathrm{r} \quad (2)$$

T : Torque [Nm]

9.8 : Factor [N/kg]

F : Force [kg]

r : Radius [m]

4. Result

Input water power is calculated by Eq.3. Input energy can estimate by multiplying the power by required time.

$$P_{in} = 9.8 \times \rho \times \mathrm{Q} \times \mathrm{H} \quad (3)$$

P_{in}: Water power [W]

9.8: Factor [N/kg]

ρ: Water density [kg/L]

Q: Water flow rate [L/s]

H: Head [m]

4.1 Characteristic of spiral turbine

At the maximum of input water power, characteristic of spiral turbine only was examined. Water flow rate was 9.6L/s. The turbine was disconnected with speed up gear and generator.

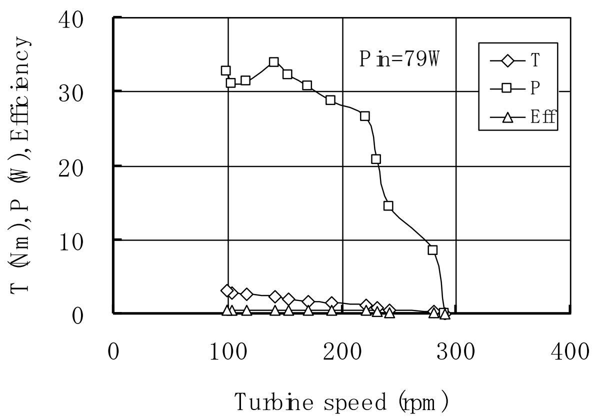

Fig.5 Characteristic of spiral turbine

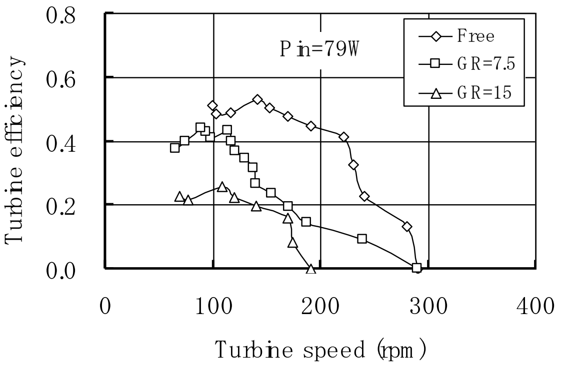

Fig.6 Characteristic of spiral turbine with speed up gear and generator

The result is shown in Fig.5. High efficiency of around 0.5 was obtained at the range of speed 100-200rpm. Maximum power of the turbine was about 34W.

4.2 Characteristic of generation system

In the no load condition of the generation system, characteristic of spiral turbine with speed up gear and generator was examined.

4.2.1 Effect of combination of speed up gear

Characteristic of spiral turbine with generation system was measured and compared with the turbine only. The characteristic is shown in Fig.6. The difference of the efficiency at the case of the free and the case of with gear is equivalent to mechanical loss of speed up gear connected with generator. Combination of speed up gears with different gear ratio (GR) and the generator is indicated in Table 3.

Two stages gear was clearly higher loss than single stage. A bicycle chain was moved more smoothly than a motorcycle chain. High efficiency of the spiral turbine was obtained the range of 70-150 rpm speed in these cases. In designing, the generator speed should be optimized in this range of the turbine speed. Tendency in the efficiency of the free and GR15 are different to GR 7.5. This was caused by the different belts used for measuring torque. In the former case, laminated with 3 steels belt was used. The latter was a single steel belt. Laminated belt was stronger and better contact to the shaft than the single. It was found that laminated belt was able to use the wide range of speed. To confirm the torque measurement method, it is necessary to check with the reference equipment.

Table 3 Combination of speed up gear

Gear ratio	1 stage	2 stage	Generator
7.5	7.5, bicycle chain		DC 28W
15	7.5, bicycle chain	2, motorcycle chain	DC 28W
2.33	2.33, bicycle chain		DC 160W

4.2.2 Effect of input water power

On the generation system with gear ration of 7.5 and type 1 generator, characteristic of spiral turbine including mechanical loss of the gear and generator was examined.

When it was changed Input water power at the maximum, medium and small of 79, 64 and 52W, the water flow rate were 9.6, 7.7 and 6.2 L/s respectively. Turbine torque, turbine power and turbine efficiency are shown in Fig.7-9.

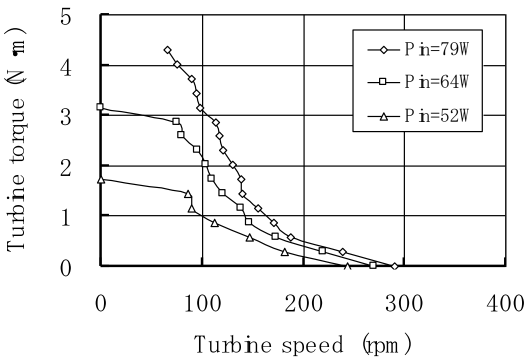

Fig.7 Turbine torque

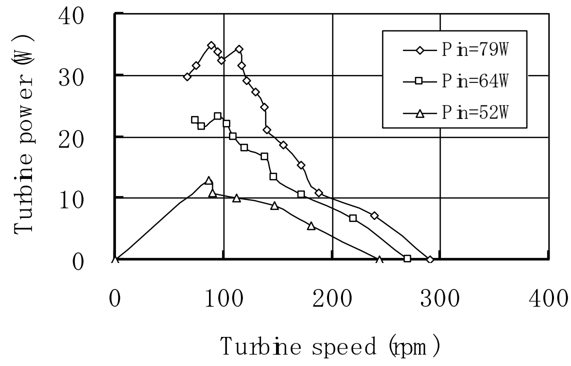

Fig.8 Turbine power

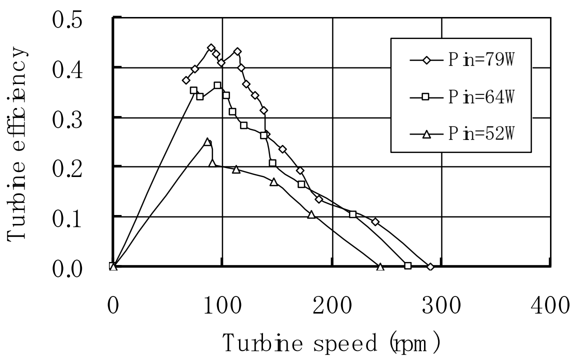

Fig.9 Turbine efficiency

The maximum of turbine power and efficiency are about 35W, 0.45 respectively. It is clarified that turbine speed of 70-150rpm is the optimum design speed in each water power conditions.

4.3 Performance of generation system

Output power was examined by changing the load. In the testing of the type 1 and 2 generators, loads were varied 150 to 22Ω and 62 to 11Ω respectively.

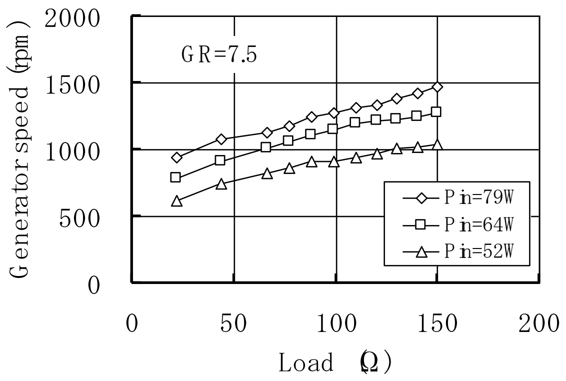

Fig.10 Generator speed (Type 1, GR=7.5)

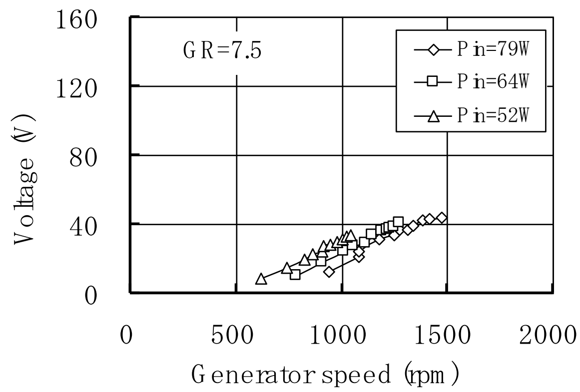

Fig.11 Voltage (Type 1, GR=7.5)

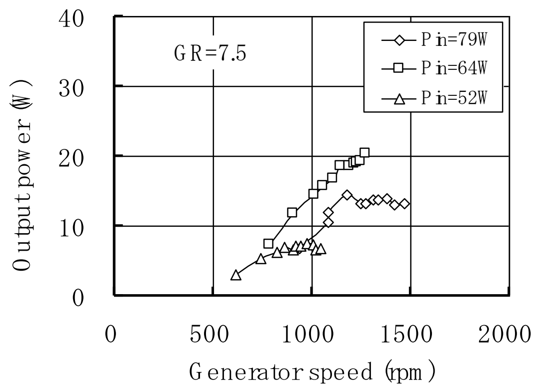

Fig.12 Output power (Type 1, GR=7.5)

Fig.10 shows generator speed of the type 1. In this test, turbine speeds were 80 to 200rpm. Voltage and output power are shown in Fig.11, 12. From Fig.11, voltage was increased in depending on the increase of generator speed when decreased the load.

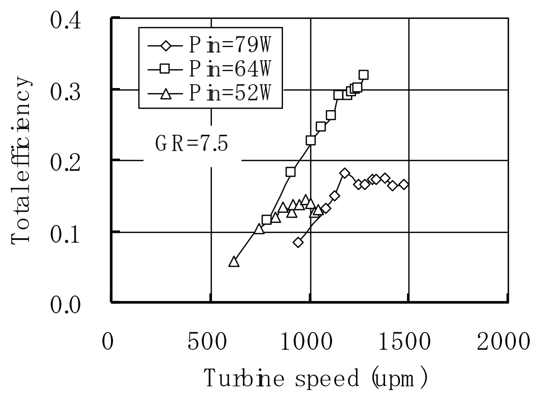

Fig.13 Total efficiency (Type 1, GR=7.5)

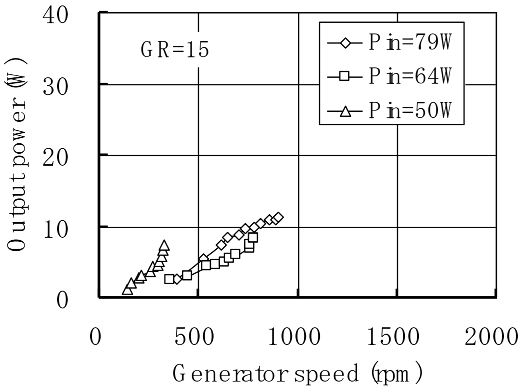

Fig.14 Output power (Type 1, GR=15)

Maximum voltage at P_{in}=79W was 44V. Open voltage (Open circuit) was 108V. From Fig.12, output power was larger in the case of Pin=64W than in 79W. The reason is that the turbine was operated in 105 to 170rpm speed at P_{in}=64W and in 125 to 196rpm speed at P_{in}=79W. In other word, the turbine was operated in higher efficiency range of turbine speed at P_{in}=64W than that at P_{in}=79W.

Fig.13 shows total efficiency which is derived form output power divided by input water power. Maximum total efficiency was 0.32 at Pin=64W, output power of 20W, turbine speed of 170rpm and generator speed of 1275rpm.

Fig.14 shows the output power of type 1 generator with gear ratio of GR=15. Output power was about 10W.

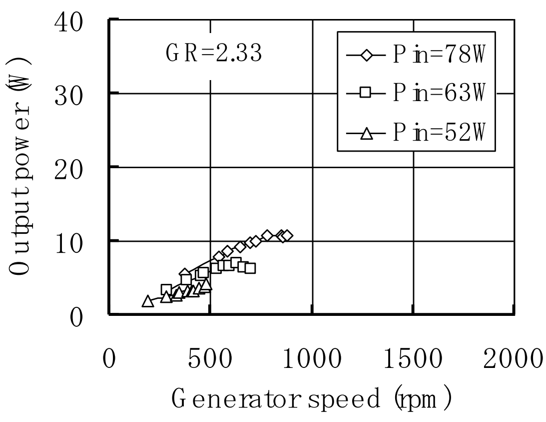

Fig.15 Output power (Type 2, GR=2.33)

Turbine speed was in the range of 20 to 60rpm. Then generator speed was 140 to 900rpm.

Matching of the operating speed range of the turbine and generator is important to get high efficiency of the generation system.

Fig.15 shows the output power of type 2 generator. Peak of output power was indicated in P_{in}=78 and 63W. The operation range of turbine and generator speed was matched obviously. However the rated power of type 2 generator was rather large for this spiral turbine. This generator uses 6 diodes for rectifying three phases AC. The loss of rectifier about 1W is also included. Single phase is preferable.

5. Summary

A micro hydro generation system with spiral turbine was designed, handmade, assembled and evaluated. From the results, the followings were found.

1. Optimum speed of the spiral turbine exists in the range of 70 to 150rpm.
2. Maximum turbine power and efficiency of about 35W and 0.45 were obtained respectively.
3. Maximum output power of 20W was obtained on Type 1 generator with GR=7.5 at Pin=64W. Maximum total efficiency was 0.32 at the same condition.
4. The matching of the operating speed of the turbine and generator is important when generation system is designed.
5. Handmade torque measurement method was available in this study.

6. Further study

Performance improvement is pointed in the spiral turbine and duct especially. In order to get improvement, followed items should be tried.

1. Decrease the clearance of the turbine and duct.
2. Search the shape of the turbine vane to catch well water.
3. Optimize the angle of the vane to the shaft.

7. References

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