排水管内発電装置の小型プロペラの設計 Numerical Study of Small Propeller in Wastewater Pipe

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Demand for renewable energy has steadily increased during recent years due to the shortage of fossil energy and concerns about global climate change. Generating renewable energy using a small propeller in a wastewater pipe is a promising idea to derive power from flowing water. We performed a numerical study to determine the maximum torque value from a propeller with 1.21 kg/s of mass flow rate and rotation frequency range from 0 to 3000 rpm. We also assessed the power efficiency and electrical power for this small propeller.

1 INTRODUCTION

Global warming has emerged a major issue during the last few years. Therefore, renewable energy is essential to address problems caused by global warming. Many methods of generating renewable energy have already been developed. In our study, we utilized non-potable water flowing in a wastewater pipe to generate electricity in our daily lives.

Flowing refuse in a wastewater pipe can be used to run a small propeller to generate electricity. This is similar in concept to a wind turbine, harnessing the hydrodynamic force rather than the aerodynamic lift or drag force. In this study, we computed the power generated by a small propeller to design an efficient mechanism of generating renewable energy.

2 METHODOLOGY

We used CFD to calculate the power coefficient a small propeller located inside a pipe (Figure 1).

Fig.1. Design of small propeller

The propeller used had a diameter of 60 mm and a height of 134 mm, while the pipe had a diameter of 80 mm and a length of 1500 mm. The angle of attack investigated was 25° with the rpm varying between 0 and 3000, and the mass flow rate was 1.21 kg/s.

Further, to collect numerical data, the above design was meshed via ICEMD CFD using an unstructured mesh. We performed numerical simulations under 3D transient conditions, K-ε turbulence model and $t_s = 2.1 \times 10^{-5}$ s.

3 ANALYSIS RESULTS

The calculated torque values at various rotation speeds are shown in Figure 2. It is apparent that the maximum torque occurred at 2000 rpm with a value of 0.01 N.m. The performance coefficient (C_p) is defined as the ratio of the power propeller to the power input. Hence,

$$C_p = \frac{T \cdot \omega}{\frac{1}{2} \rho v^3 A}$$

where T is torque (N.m), ω is rotational frequency, A

is the area swept through the rotor blades of the propeller spin (m^2), ρ is water density kg/m^3 and v is the velocity of water at the inlet (m/s).

Fig.2. Torque values at different propeller speeds

Further, the value of the power coefficient (C_p) for this numerical study is shown in Figure 3.

Fig.3. Power coefficient (C_p %) vs propeller speed

It is evident that the C_p at the maximum torque value is about 26.1%. C_p value also indicates the magnitude of energy changes.

4 CONCLUSION

We also calculated the electrical power electricity (wattage) the computed torque value and rpm. The maximum value of power was 2.09 W when the peak value of rpm is considered.