Power Reclamation of Utilizing Micro-Hydro Turbines in Wastewater Treatment Plants' Aeration Basins

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VISION

Wastewater is treated by various physical, chemical, and biological processes in Wastewater Treatment Plants (WWTPs). Energy is consumed throughout the plants, but the aeration process dominates other processes in terms of energy consumption. Aeration process is done by introducing compressed air to the wastewater. Air can remove the dissolved gases and oxidized the dissolved organic chemicals and metals.

A part of this energy can be restored by installing micro-propellers above the air diffusers to extract the kinetic energy from the high-velocity location in the water column and convert it into useful power. Maximizing the reclaimed power without negatively affecting the treatment processes is the main objective of this study. Therefore, the height of the micro-propeller above the diffuser, water static head in the aeration tank, and the Dissolved Oxygen (DO) levels should be investigated.

APPROACH

Design, Build and Control → **Testing and Data Analyses** → **Optimization**

- Design and build the experimental setup and its components to be placed in an aeration tank.
- Electric circuits design.
- Control the outputs (Power, torque, RPM, and Dissolved oxygen DO)

- Multiple variables are considered to determine the location of the propeller. (CFM, Height, Water static head)
- Perform Multiple experiments to investigate the DO levels in the aeration tank with and without the proposed system

- Optimize the results to maximize the power reclamation and enhance the oxygen transfer.
- Introduce new variables that affect the power and the oxygen transfer.
- Perform error analysis

METHODOLOGIES

Experiment Preparation:

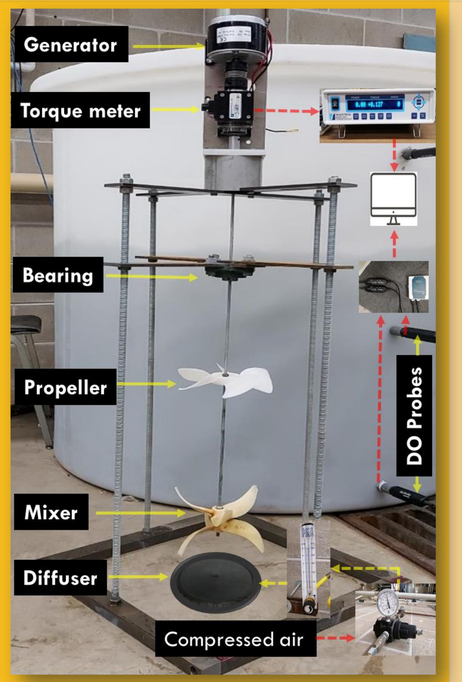
- Setting up the required water static head and the propeller height and placing the setup in its location inside the aeration tank.
- Non-hazardous additives are introduced to the water to simulate the water quality in a real WWTP aeration tank.

Operation:

- Compressed air is introduced through the air diffuser, air flowrate is controlled by a flowmeter.
- The propeller rotates as the air travels upward in the aeration tank.
- The rotation of the propeller drives the shaft. A part of this rotational motion is utilized to overcome the inertial forces of the mixer and force it to rotate.
- The rest drives the shaft connected to the generator to generate electricity.

Measurements:

- The torque and the rotational speed (RPM) are measured by the torque sensor connected to the rotational shaft.
- The Oxygen concentration in the water is measured by the DO probes connected to the tank.



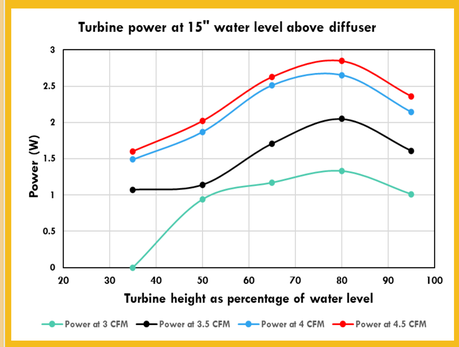
TERMINOLOGY

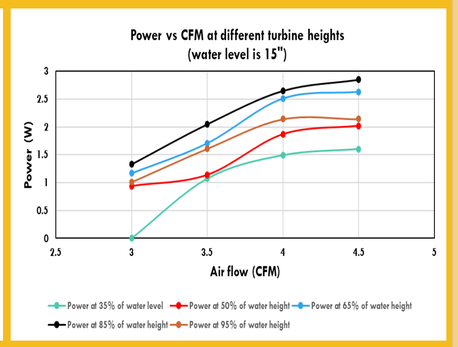
- **Propeller height:** Vertical distance from the tip of the diffuser to the center of the propeller.
- **Water Head:** Height of water in the tank.
- **CFM:** Air flow unit, Cubic feet per minute.

RESULTS

Different propeller heights, water heads, and air flows are investigated without the addition of the mixer, The results can be summarized as:

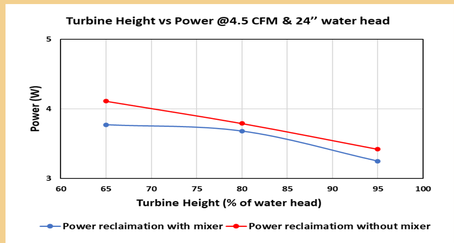
- The optimum location of the propeller ranges between 65% to 80% of the water head for all water heads and CFMs.
- An increase in the generated power is noticed as the water head increases for all water heads and CFMs.
- More power can be generated as the air flow increases. The airflow is taken to emulate the operating conditions of a real WWTP.





- The presence of the propeller inside the aeration tank harms the DO concentration, the addition of the mixer can improve the DO with a little sacrifice of the power production. Standard Oxygen Transfer Efficiency is used to measure the effect of the proposed setup.

CFM	Standard Oxygen Transfer Efficiency %			
	Water Head (inches)	Tank	Tank + Turbine	Tank + Turbine + Mixer
4.5	24"	6.15 %	5.95 %	6.12 %
	30"	7.68 %	7.41 %	7.76 %
3	24"	4.92 %	4.56 %	4.65 %
	30"	5.31 %	5.23 %	5.61 %



CONCLUSIONS

- The highest velocity is obtained in the upper half of the water column (65% - 80%), while the lowest velocities were obtained just above the air diffuser and at the water surface.
- It's recommended to install the micro-propeller at the locations of the highest velocity to harness the high momentum at this region and therefore maximizing the power reclamation.
- The reclaimed power is directly proportional to the diffuser air flow and the water column.
- The addition of the mixer at the bottom of the shaft reduces the reclaimed power due to the loss of momentum resulted from the blending action of the mixer.

BIBLIOGRAPHY

- Hasan A., Salem A.R., Abdelhadi A., Qandil M., Alkhalidi A., and Amano R., The power reclamation of utilizing micro-hydro turbines in the aeration basins of wastewater treatment plants, Journal of Energy Resources Technology 143(8), 2020

- Energy data management manual for the wastewater treatment sector report, US department of energy, 2017.

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