

ENCIT-2018 SMOKE VISUALIZATION IN HYDROKINETIC TURBINES

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Abstract. *The present study analyzes different arrangements of hydrokinetic types of turbines. Considering the experiment of the number of blades of the rotor and analyzing it from the method of experimental visualization of flow using the technique of smoke wire. The tests were performed with the flow velocity of 5 m/s of the wind tunnel to the turbine rotor of 230 mm of diameter. With the smoke visualization method, it was possible to verify the behavior of the turbine before the flow and to approach qualitative properties of the phenomena inherent to the interaction of the components of the turbine with the flow. The characteristics of the flow were analyzed by two different turbine configurations: three-bladed turbine and four-bladed turbine. The characterization for the observed configurations shows the formation of blade-tip vortices and the influence of the generator hub on the fluid. The smoke wire technique used is also presented.*

Keywords: *hydrokinetic turbines, smoke wire, flow visualization and vortex.*

1. INTRODUCTION

The source of energy from a hydrokinetic turbine represents an alternative source capable of converting energy from a river source or a tidal source, taking advantage of the availability of energy from the water stream. The use of electric power is paramount to increase the quality of life of people. An important contribution is from the implantation of hydrokinetic turbines in riverside communities in its development and also allow rural producers to develop production in a sustainable way, in which they can contribute to increase renewable energy and also to technological development, thereby satisfying their energy needs, from rural activities to their own recreation. Thus, it is important to continue the study of technologies capable of efficiently meeting the demand for electricity.

The use of turbines of relatively small size can be used by riverain communities and as a source of exploitation of the kinetic energy obtained by the river current. The study of aerodynamic behavior of the turbine is necessary to establish improvements in the development of new concepts and new projects (Brasil Jr., 2016).

Yen et al., 2017 studied the effects of turbines arranged one behind the other and side to side, in order to verify the aerodynamic influence of the arrangements for different types of Reynolds number, such analysis was done using the method of visualization of the type of smoke wire, in which it was possible to observe track and vortex phenomena.

Another experimental study was the observation through visualization method for direct injection on the horizontal axis rotor carried by Haans et al., 2005, where it was possible to quantitatively studying the locations and measurements of the rotor blade tip vortices.

The present work shows the aerodynamic behavior of a turbine in scale of a horizontal axis type with three blades and four blades, with the method of visualization from the insertion of smoke in the fluid to the turbine mount.

The performance requirements of the turbines intensified the need to understand the characteristics of the flows, particularly turbulent structures on the near wake. It is possible to note blade-tip vortices in the turbine model under analysis.

2. MATERIALS AND METHODS

In order to study flow visualization, two flow visualization methods were used in order to qualify the method by means of the phenomena inherent in the passage of the fluid through the turbine. The smoke-wire method consists of a wire that is electrically heated and liquid-soaked while the other method is composed of a smoke machine and with a rod disposed of an electrical resistance in contact with an inner channel with smoke generating liquid. Results are presented for three-bladed rotor turbine and four-bladed turbine.

2.1 Wind tunnel

The wind tunnel used belongs to the Laboratory of Energy and Environment (LEA) of the University of Brasilia (UnB), it presents: general dimensions of 3 x 3 x 10,5 m; air velocity from 0 to 19.5 m / s; motor fan of 12,5 HP, power 220 VAC. For these experiments, a speed of 5 m/s was used and number Reynolds of $7,9 \times 10^4$.

2.2 Smoke method visualization method

The method of visualization by smoke wire uses a wire with a restricted diameter embedded with oil and connected to a source for heating and evaporation of the liquid capable of generating smoke. The system used here was based on the study done by Yarusevych (2009), where he studied the evolution of the outflow for turbulent and observations on the aspects of limitation of the boundary layer for aerodynamic profile from the acquisition of images of the visualization of the traced flow by smoke. The wire used was of 0.25 mm of diameter and as a smoke generating liquid was used ISO VG15. Figure 1 shows the schematic of the wind tunnel test section.

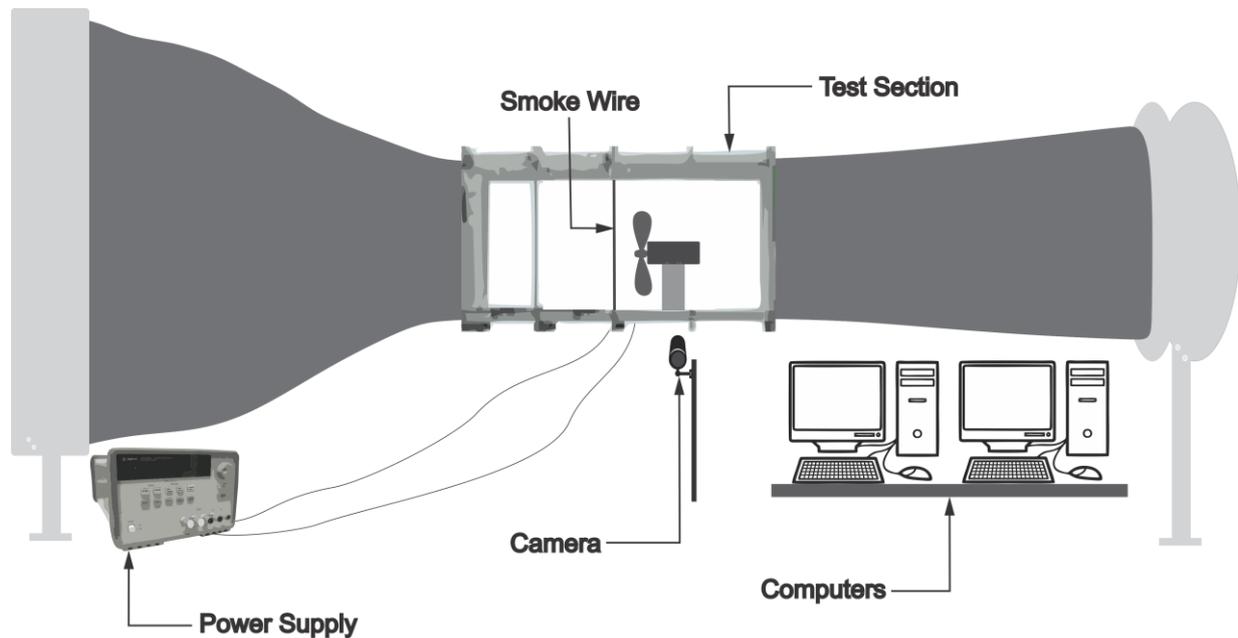


Figure 1 – Wind tunnel with method smoke wire

2.3 Direct injection with smoke generator

The direct injection visualization method uses a machine with constant flow of smoke generated by polyethylene glycol liquid type, the system uses a rod that contains an electric resistance in conjunction with a passageway of the smoke generating liquid and with an air compressor coupled to the machine, the smoke exits through a nozzle of diameter of 0,30 mm when reach the temperature of evaporation. The rod was positioned upstream of the turbine to run fluid flowing into the turbine (figure 2).

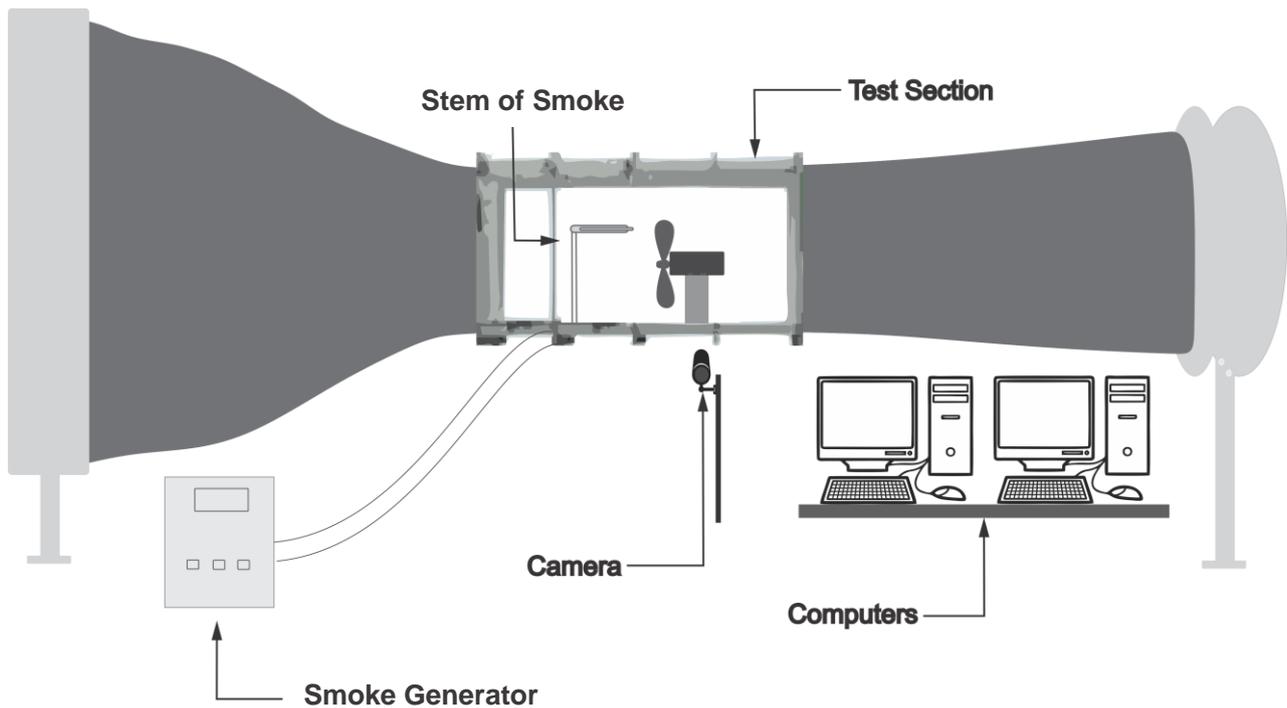


Figure 2 – Wind tunnel with method smoke generator

2.4 System for acquisition of images and components for the generation of smoke

The system composed of several elements requires several repetitive tests to fit the experimental configuration in order to obtain more satisfactory results. The camera model used was a flir Blackfly S BFS-U3-13Y3M1. The acquisition system has a laser plane generated to contrast with the smoke and also with the software being able to acquire and modify properties in real time.

The components referring to the smoke generation for the smoke-wire method are basically composed of a 0.25-mm diameter smoke-wire, a smoke-generating liquid, and a power supply for electric wire heating. As for the smoke generator fluid were tested several fluids such as olive oil, soybean oil, brake oil, baby oil, polyethylene glycol and glycerin, but the oil that presented better availability characteristics of smoke and density was ISO lubricant oil VG15 (singer). The conductive wire for the production of smoke is the basis for the smoke-wire method, it was necessary several tests to determine the diameter and the type of wire capable of generating sufficient smoke for characterization. The metal wire that presented the best characteristics of smoke production was the aluminum-nickel alloy.

The direct injection method used in this work is composed of some components, such as: smoke generating machine that has a compressor coupled, and in the output has a smoke rod composed of an electric resistance capable of heating the smoke generating liquid to a temperature above 280 °C, a needle with a diameter of 0.30 mm was installed at the outlet of the smoke rod to filter the smoke in order to reduce the turbulence.

3. RESULTS

3.1 Turbine with three blades with method smoke wire

Three-bladed turbine tests were performed at a tunnel speed of 5m/s. Several flow visualization configurations (luminosity, camera, etc.) were tested to achieve qualitative results. Figure 3 shows a rotor-scale turbine of 230 mm; it is possible to note the presence of three blade tip vortices, indicating a complete rotor cycle.

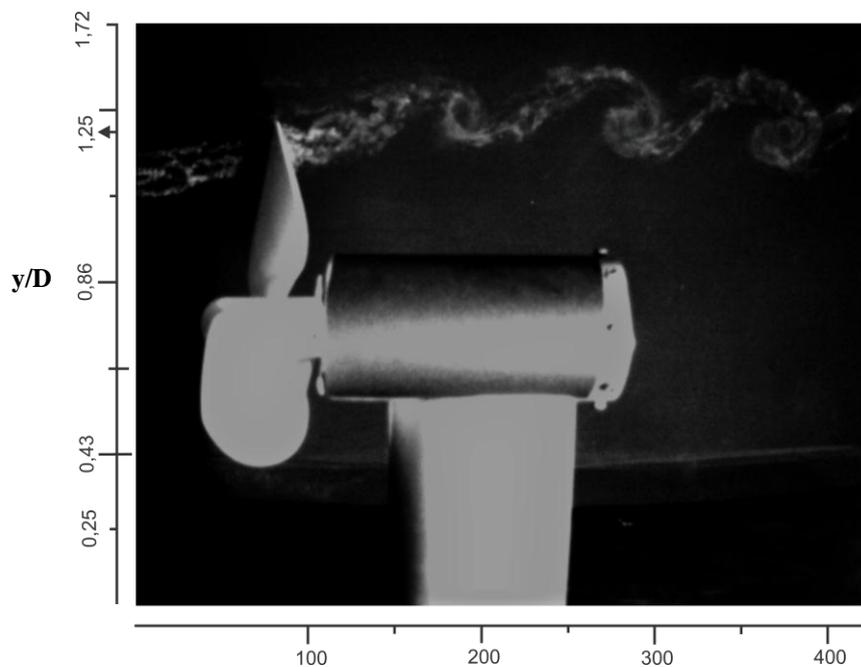


Figure 3.1 – Tree-bladed turbine

3.2 Turbine with four blades with method smoke wire

Tests conducted with the turbine four blades with the wireless smoke method as observed in figure 3.2 showed blade tip vortices according coherent structures associated turbulence, immediately downstream is remarkable the presence of four vortexes, which is four paddle passes (complete cycle). It is noted that such experimental configuration depends on the smoke generated by the wire leading upstream of the turbine.

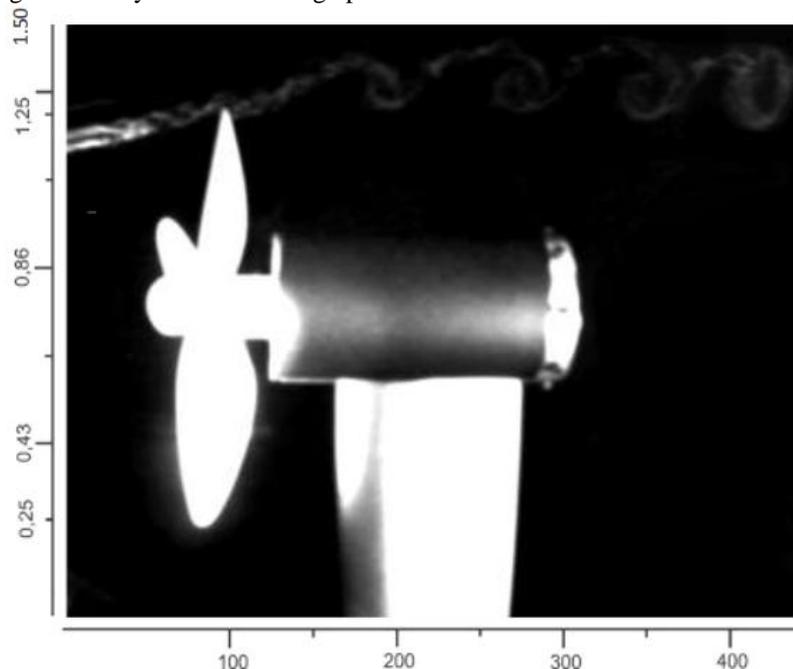


Figure 3.2 – Four-bladed turbine

3.3 Turbine with three blades with method direct injection

Figure xx shows the formed vortices (seven structures), indicating two complete cycles of the turbine rotor. It was noticed that the structures are well defined and characterizing vortexes of blade tip. The tests performed for this configuration were the same for the smoke-wire method, or the same camera, same as the unlimited system, Reynolds number in the test section, flow velocity.

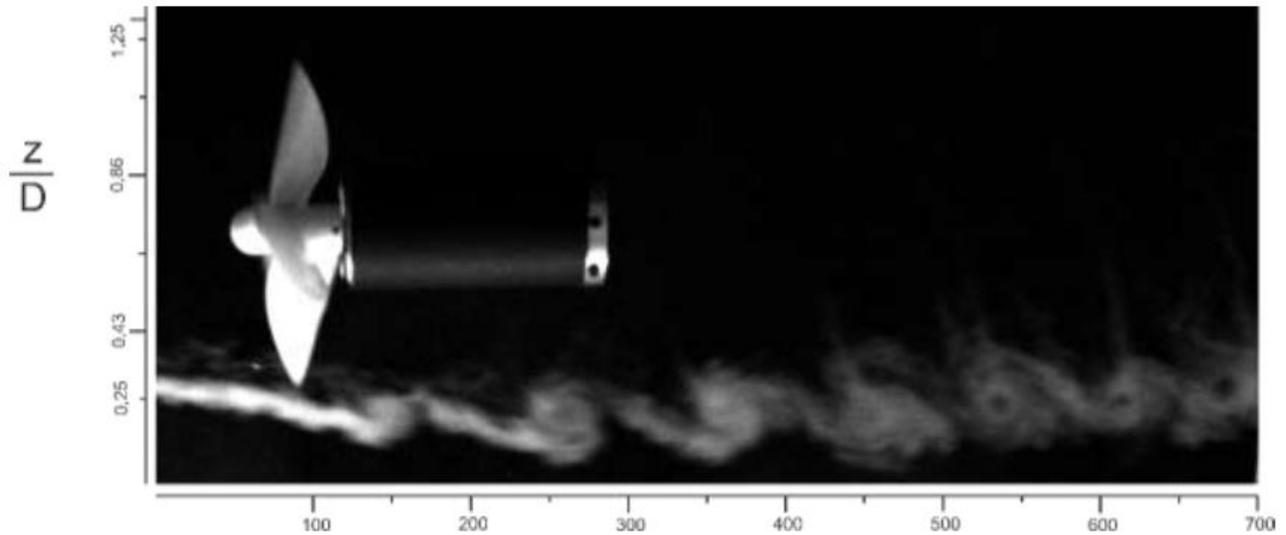


Figure 3.3 – three-bladed turbine

3.4 Turbine with four blades with method direct injection

Figure 6.16 shows the tip vortices at the bottom of the image, it is possible to quantify the presence of eight vortices, indicates eight paddles. The difference in the visual appearance of the photo is remarkable compared to the result of the smoke-wire method, since the continuous availability of smoke and a continuation of the continuous supply of the smoke generator implies a better visibility of the traced flow.

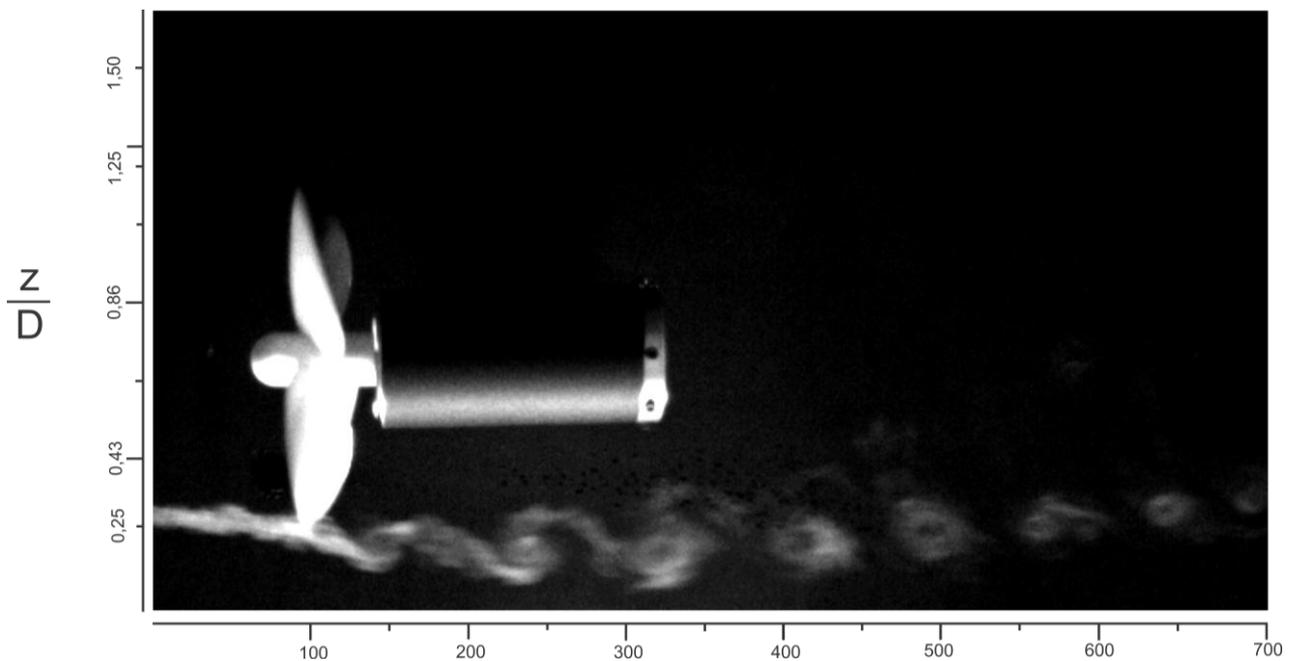


Figure 3.4 – Four-bladed turbine

4 CONCLUSIONS

Experimental visualization tests of horizontal axis turbines have been performed in a wind tunnel, with starting results of the power variable and the turbine. The results were observed from two methods of visualization of smoke (smoke wire and direct smoke injection method).

The work was carried out with a turbine in scale of the hydrokinetic type with rotor diameter of 230 mm. Numerous tests were performed using video visualization models in order to find the resource models capable of characterizing the files at the same time.

The vertical wire smoke method presented more satisfactory results when compared to the direct injection method with camera on the side, while the direct injection method with smoke generator with superior camera denoted flow visualization more defined than smoke horizontally, such comparisons and differences are related to the density and dispersion of the smoke, camera distance and other factors related to turbulence.

5 REFERENCES

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