24th COBEM - 2017

24th ABCM International Congress of Mechanical Engineering
December 3-8, 2017, Curitiba, PR, Brazil

COBEM-2017-2654
DEVELOPMENT OF AN EXPERIMENTAL BFT STAND

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Abstract. *This work has an objective study and the analysis of pump functioning as a turbine (BFT), being this an economically viable method, when compared to a conventional turbine. It will be worked in a theoretical and experimental way design and execution of the system, which will be composed of a water reservoir, a flow pump, to simulate the waterfall, the pump that will be used to act as a turbine, a meter flow and pipe fittings. The theorical development will be used on the Bernoulli equations and their derivations, also using the equations of the power of Turbines and hydraulic power. For the determination of the pump to be used in our stand, we will take as base the Viana selection method, which relates manometric height and flow rate. At the end, the results will be represented to verify the viability of the system. We will take as base the value of 161.8 KWh / month, which means the average residential consumption per consumer unit in Brazil.*

Keywords: *BFT, Power generation, Isolated Systems, Experimental stand.*

1. INTRODUCTION

In search of new methods for the production of electric power in the world, studies are carried for search means to generate renewable energy, with less cost, with little environmental impact, that is, clean energy, besides supplying the need of the consumers., with lower cost, with little environmental impact, that is, a clean energy, besides supplying the need of the consumers.

According to Silva (2010), the use of pumps running as a turbine has been the subject of research since 1950. This study began when accidentally German engineers discovered that the pumps had a considerable yield by reversing the flow direction. Since then the manufacturers had an interest in this type of application, but it would not be financially feasible to test all the pumps as turbines, so they tried to compare the behavior of ther BFT (Pump Function as Turbine) with that of a BFB (Pump Function as Pump).

The hydroelectric power plants have the principle of operation based on the kinetic energy of the water from the river flow, which will rotate the blades of the rotor, and a generator that will generate electricity. However, the maintenance and the cost of a turbine is high, besides the parts being produced to order and have difficult availability in Brazil (RAMOS,2012).

Countries such as the USA, Germany and France have implemented a new power generation method, which uses hydraulic flow pumps such as centrifugal, multi-stage, mixed, axial, to replace conventional turbines. The reason for this is the perfect functioning of the BFT in addition to its lower costs compared to turbines of the same power (VIANA, 2012a).

2. THEORICAL REFERENCE

With increasing demand for electric power in the world and seeking means of less polluting generation, BFT is a great choice to use because the pumps are manufactured in series, do not demand skilled labor, their parts are easily found, if compared to a turbine. There are also the disadvantages of using BFT, for example that it has a lower efficiency than a turbine, does not have a distributor for hydraulic control and does not allow load variations (EMILIO LOPES et.al., 2003, page 271).

Analyzing the pump that will be used as a turbine, when it reverses the flow of water in the pump, it is no longer a generator, that is, it will transform the mechanical energy produced by a motor to energy of speed of the fluid, to be a motive, where energy comes from the flow of water in the blades due to kinetic energy, where it will spin an axis to produce energy. Below we can see Fig. 1 that shows what happens in the pump and the BFT.

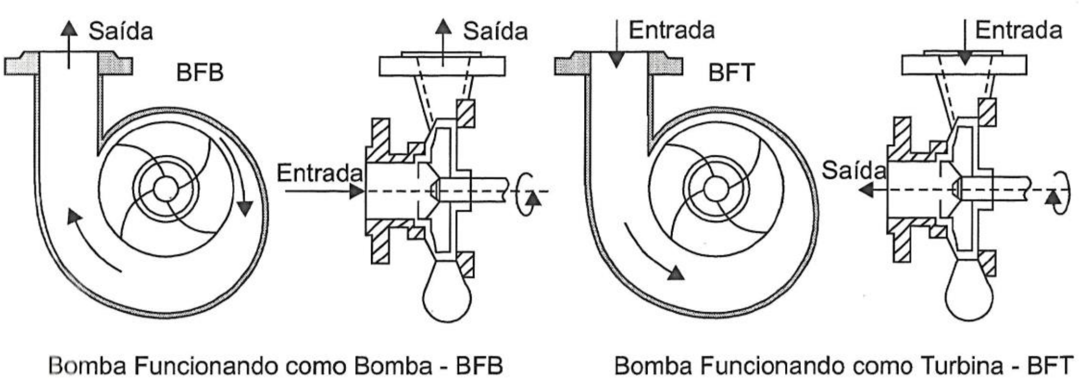

Figure 1. Centrifugal pumps functioning as a pump and as a turbine.

The pump working as a pump, the water in the low speed in the suction channel and will come out with a high kinetic energy and pressure. In the pump working as a turbine, in the suction channel, the water in a high pressure and speed, and in the settling, leaves with a low speed, remembering that to install a BFT, it is necessary to have a kinetic energy or a geometric difference.

3. MATERIALS AND METHODS

There are many methods for selecting a BFT, and to know which one to use, we must analyze the variables such as flow, specific velocity and others.

The methodology of this paper will be based on the Bernoulli equations and their AS derivations, which correlates the pressure gradient with the fluid elevation velocity using the Turbine Power Calculation (FOX, 2014).

The Bernoulli equation, where ρ is the density of water expressed in kg / m³, g is the gravity in m / s², v is the velocity in m / s and z is the difference in gauge height in meters.

$$\frac{P}{\rho g}+\frac{v^2}{2g}+z=0$$

To calculate the hydraulic power available for the turbine, the use EQ. (2), where ρ is the density of water expressed in kg / m³, g is the gravity in m / s², Q is the flow in m³ / s, H_m is the head in meters.

$$P_h=\rho gQH_m$$

Will be used EQ. (3) power of hydraulic lifting systems, for basement in the calculation of the estimated flow for the bench, where Pot is the power expressed in cv, "γ" is the specific gravity of the liquid in kg / m³, Q is the flow in m³ / h, "η" is the yield and "H" - "man" is the manometric height in meters.

$$Pot=\frac{\gamma QH_{man}}{3600*75}$$

To calculate the manometer height, which is the amount of energy the pump transfers to the water, it follows the EQ. (4), where H_t is the geometric height expressed in meters; an h_t is the total head loss in meters.

$$H_m=H_g+H_t$$

For calculate the total head loss, which is the sum of the suction and pressure head loss, use h_s, which is the suction head loss in meters plus, the h_r which is the head loss in the repression in meters .

$$h_t=h_s+h_r$$

3.1 Method Viana

For the determination of the pump to be used in the bench, the Viana selection method (1987) is used as the basis. This method determines the height and flow of commercial pumps to function in their inverted flow and uses values obtained experimentally by the author himself.

The method consists of a determined turbine design flow-BFT (Q_t) and fallen height of the liquid - BFT (H_t), the specific rotation (N_{qa}) is calculated, initially using the rotation (N_t) of 3600 rpm. If the specific rotation does not fall within the 40 to 200 range, the specific rotation (N_{qa}) is recalculated using N_t of 1800 rpm and the gravity in m / s² (g). The rotations 3600 rpm and 1800 rpm are adopted for economic reasons, because the higher the rotation, the cost of the generator set is lower (Viana, 2012b).

$$N_{qa} = \frac{10^3 N_t \sqrt{Q_t}}{H_t g}$$

Defined the Nqa, we obtain the coefficients of flow (K_q) and height (K_a) by means of the graph of Fig. 2.

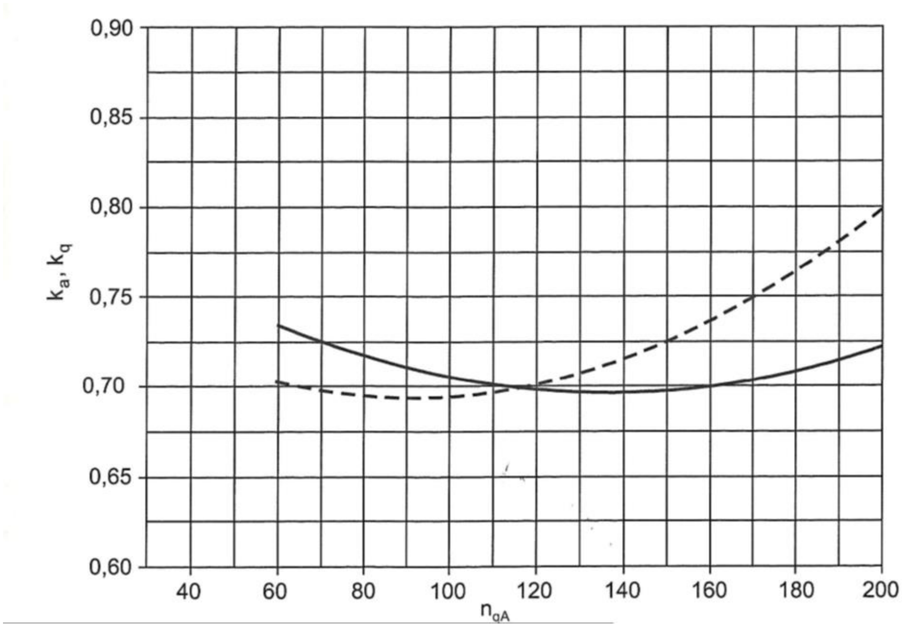

Figure 2. Flow and height coefficients.

Have the values of K_q and Ka, the height (H_b) and pump flow (Q_b) are calculated.

$$Q_b = K_q Q_t$$

$$H_b = K_q Q_t$$

With the values of Q_b, H_b and manufacturer pump catalog, select the appropriate pump that will operate in reverse as a turbine.

3.2 Height and flow correction

According to Viana (2012), will be corrected the height and flow find for the nominal rotation of the pump, since the pumps operate with rotations below 1800 and 3600 rpm and due to the slip factor. The slip factor happens when we turn on the electric motor which is generated a magnetic field, where this field has a certain speed and when placing the axis inside the field, it will rotate with a different speed, so it occurs the phenomenon of slipping, due to this reason we must recalculate. Below we have the equation to make the correction of height and flow, where Q_{bc} is the corrected flow expressed in m³ / s, N_{nb} is the nominal pump speed in rpm and H_{bc} is the height already corrected in meters.

$$Q_{bc} = \frac{N_{nb}}{N_t} Q_b$$

$$H_{bc} = (\frac{N_{nb}}{N_t})^2 H_b$$

The efficiency of the BFT is considered the same as that of the pump at the selected point (manufacturer's catalog). Finally, to prevent the pump from cavitation, the maximum suction height of the BFT is calculated using the EQ. (11), where H_s is the geometric suction height expressed in meters, H_b is the height referring to the barometric pressure or the atmospheric pressure at the downstream level in meters, A is the place altitude in meters and σ is the Thoma coefficient.

$$H_s = H_b - (\sigma H) = 10 - 0{,}00122A - (\sigma H_t)$$

Cavitation occurs due to absolute pressure lowering until it reaches the vapor pressure of the liquid, forming vapor bubbles that are carried by the liquid stream until its collapse usually in the blades of the rotor, causing small holes in the surface that collide (MACINTYRE, 1997a).

Another analysis of the occurrence of cavitation is to verify the NPSH, which is the absolute minimum pressure in meters of water column, above the vapor pressure of the product in order to avoid the formation of vapor bubbles (MACINTYRE, 1997b). To assist in the calculation of NPSH, one can use the Thoma Factor (of Cavitation), which can be calculated by the EQ. (12) and represents a non-dimensional characteristic value for cavitation, relating the specific rotation with some constants (VILLAR, 2010).

In Viana's work (2012), the Thoma coefficient for BFT was considered to be of a Francis turbine.

$$\sigma = 0{,}025(1 + 10^{-4} N_{qa}{}^2)$$

The viability of the system is verified through experimental results, based on the total cost of the project and the average energy cost, taking into account the value of 161.8 kWh / month, which represents the average residential consumption by consumer unit in Brazil (EPE, 2016). Figure 3 shows how the experimental stand was planned.

In the BFB, which was used a SOMAR Peripheral Motor Pump, model SHIP-35 0,5 CV, we put the suction channel in the bottom of the reservoir and the repression, which is the pipe after the BFT, will be in the upper part of the reservoir and not immersed so that the water column pressure and the turbulence does not hinder the flow of the water and its passage through the BFT. In order to act as a BFT, a Schneider BC-98 Centrifugal Pump 0.5 CV 60 127 was used. This bench will have the following accessories: 2 that 90º elbows, a flow meter, a pressure gauge, 1 drawer valve and a reservoir.

The main function of the pump running as a pump is to simulate a water fall because, for better performance, the BFT being a driving machine, it needs a high pressure at the inlet and a high flow rate.

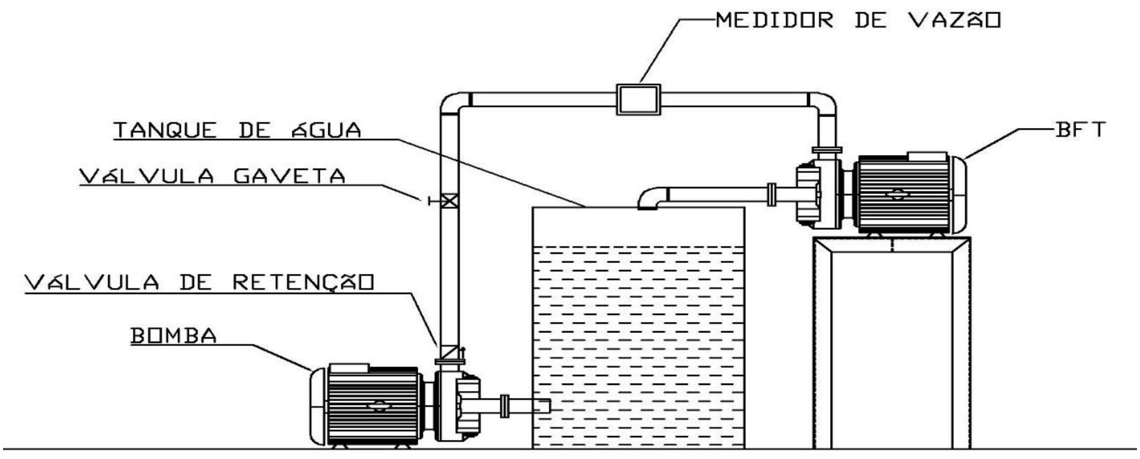

Figure 3. Schematic of the BFT experimental stand.

Using the methodology of the article to calculate the estimated flow rate for the prototype, the following resolution is determined:

Initially, will accomplished the calculated total loss of the system was using the EQ. (5), where the pressure drop in suction is equal to zero. Therefore, h_t is equal to h_r.

$$H_t = \frac{L_{eq} * contante\,de\ perda\,de\,carda\,em\,encanamentos}{100}$$

Note: The pressure drop constant in pipes is obtained in Fig. 4 and its value is divided by 100, as the values in the table take into account 100 meters of pipe, and L_{eq} is obtained in Fig.5.

3/4"		1"		1 ¼"	
VELOC.	PERDA	VELOC.	PERDA	VELOC.	PERDA
0,366	1,90				
0,549	4,10	0,342	1,26		
0,735	7,00	0,454	2,14	0,262	0,57
0,918	10,50	0,567	3,25	0,326	0,84
1,836	38,00	1,134	11,7	0,653	3,05
2,751	80,00	1,708	25,0	0,976	6,50
3,669	136,00	2,269	42,0	1,308	11,10
		2,837	64,0	1,635	16,60
		3,400	89,0	1,961	23,50
		3,971	119,0	2,290	31,20
		4,538	152,0	2,617	40,00
				2,943	50,00
				3,269	60,00
				4,578	113,00

Figure 4: Loss of load on PVC pipes.

DIÂMETRO						
mm	pol.					
13	1/2	0,3	1,6	4,9	0,4	1,1
19	3/4	0,4-	2,4	6,7	0,5	1,6
25	1	0,5	3,2	8,2	0,7	2,1
32	1 ¼	0,7	4,0	11,3	0,9	2,7
38	1 ½	0,9	4,8	13,4	1,0	3,2
50	2	1,1	6,4	17,4	1,5	4,2
63	2 ½	1,3	8,1	21,0	1,9	5,2
75	3	1,6	9,7	26,0	2,2	6,3
100	4	2,1	12,9	34,0	3,2	8,4
125	5	2,7	16,1	43,0	4,0	10,4
150	6	3,4	19,3	51,0	5,0	12,5
200	8	4,3	25,0	67,0	6,0	16,0

Figure 5: Length equivalent to localized PVC losses.

$$L_{eq} = comprimento\ da\ tubulação + comprimento\ equivalente\ das\ válvulas + comprimento\ equivalente\ dos\ cotovelos$$

Note: Equivalent flow meter and pressure gauge lengths were considered zero.

4. RESULTS AND DISCUSSIONS

In the equation of the total load loss with the EQ (13), a value of 3.9m was obtained. After knowing the total load loss in the system, the manometric height was calculated according to the EQ. (4), resulting in a value of 4.5m.

After finding the manometric height, the flow calculation was done by the EQ. (3). Based on the average energy consumption in a residence, 161.8 KWh / month, as mentioned above, and transforming it to KWh / h, we obtain a value of 0.2247 and later for cv, there is the value of 0.305. The calculated flow rate with these values was 13.5 m^3 / h (0.00375m^3 / s).

These results infer that the theoretical flow rate of this system would be 13.5 m^3 / h. However, this value is obtained without taking into account the loss of load of the BFT itself, so this actual flow will be lower than the one found.

4.1 The BFT Experimental Bench

At de conclusion of assembly the stand, the pump used to operate as a turbine was readjusted, since the half-open rotor of the pump did not meet the system parameters. Using an enclosed rotor pump the system performed normally as expected, thus the bench was completed and is shown in Fig. 6, where 1 is the pump running as a pump, 2 is a vertical check valve, 3 is a drawer valve , 4 is a flow and volume meter, 5 BFT and 6 is the reservoir

Figure 6: BFT countertop.

In the calibration of the rotation with the use of a Lutron Mark DT-2236 Photo / Contact Tachometer Rotation Range Photo 5 at 100,000 RPM and Contact 0.5 to 19,999 RPM, the maximum rotation of 1180 rpm was recorded, as shown in Fig 9, while the flow meter recorded an average flow rate of 34.07 L / min (0,566 L/s).

For the model proposed by the work, it will only be possible to take advantage of the energy if the rotation is greater than or equal to 1800 rpm, and the experimental model reached 1180 rpm, so it will be necessary to use a power transmission system with pulleys, since It is necessary to raise the rotation levels in order to achieve voltage values higher than 110V - voltage used in the commercial electricity distribution network.

Having reached the rotation level of 1800 rpm, which would be sufficient to generate power in an alternator-type synchronous generator, for example the 3.5 kVA single-phase TOYAMA TA3.5CS2 Alternator with 3.5 KW output generating voltages 110 / 220V and maximum currents of 31.8 / 15.9A.

Figure 7: Tachometer measuring 1180 RPM.

5. CONCLUSION

With the development of the work it was possible to evaluate the disadvantage of the use of semi-open rotors in BFTs, because this system avoids the retention of the volume of water that would displace turbine blades for the generation of energy. Closed rotors, however, make it possible to restrict the volume of water, so that the energy is easily transformed, because the restriction of the rotor increases the kinetic energy.

The rotation found in the experimental system was not adequate for residential power generation, since the voltage values were below the 110V used by the commercial network. However, it would be feasible to use a power transmission system by pulleys, where rotation would occur, causing the residential voltage values to be reached.

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