Rotodynamic pump operating as a motor machine

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Abstract. Rotodynamic pump is a commercial machine and very used in the factories so the use of centrifugal pumps or rotodynamic pump operating as turbines or motor machine offers a technically and economically viable alternative to traditional turbines, the selection and implementation of a pump that functions as a turbine is a subject that is still under development. In this investigation the process of selection and implementation of the centrifugal pump is performed where centrifugal pump works in reverse mode, as a turbine, and mechanical adaptations are made for proper operation. The hydraulic system consists mainly of a forced pipe and a tank at a height of 13.3 m. In the built equipment a maximum efficiency of 58% was obtained at 890 rpm and an electric power of 45 W with a consistent load of a 120 V and 70 W bulb. The results obtained in this case study are comparable with the results of conventional turbines.

1. Introduction
The scientific community tends to investigate two fundamental issues: The design of technologically efficient articles and the use of low environmental impact fuels [1].

Studies have been carried out in relation to the performance of a centrifugal pump operating as a turbine. S. Barbarelli, M. Amelio and G. Florio [2], They established a methodology to select a centrifugal pump to work as turbine in a micro plant for a certain site, the results obtained are comparable with those obtained by other authors.

Si Huang [3], introduces an innovative method to predict the flow rate and head in the (BEP) best efficient point for pump and turbine mode, according to the principles of coupling between the rotor and the volute, the proposed method was verified with results and turbine mode.

F. Pugliese [4], investigated two centrifugal pumps, operating as a turbine, a single stage horizontal pump and a vertical multistage pump, the results showed that the model of Derakhshan and Nourbakhsh is reliable also outside the range investigated these results also extend to the multistage vertical centrifugal pump [5,6]. The use of pumps as turbines (PAT) significantly reduces maintenance costs, initial costs and there is a high availability of spare parts [7].

There are some disadvantages when installing a PAT, the performance curves of a pump are normally provided by the manufacturer, but the similar curves of the same machine operating as a turbine are not usually available [8-13].

This research work has a great impact on the technological development of Colombia because it encourages the use of hydraulic microgeneration that is of great importance in areas not interconnected to the electricity grid. This paper aims to select, with statistical method [2], a suitable PAT for hydrological conditions and whose geometric height Hg is known, additional experimental performance tests are carried out. In the case of the study, a laboratory bench is implemented with a water tank...
elevated to 13.3 m with a forced pipe of 2 inches in diameter that feeds the PAT and whose objective is to expose the methodology developed.

2. Methodology

2.1. Selection procedure

The selection of a centrifugal pump that is installed to work as a turbine at a known location usually begins with the calculation of the specific velocity required for the site (nst), defined by Equation (1).

\[ n_{st} = N * \sqrt{Q_{site} * H_{site}^{-3}} \tag{1} \]

\( H_{site} = 0.75 \) Hg, \( Q_{site} \): It is obtained from Table 1 with the loss, the percentage of loss and the diameter of the forced pipe whose procedure is detailed in the case study. \( N \) (rpm). Equation (2) defines the specific speed of the pump operating as a turbine.

\[ n_{sp} = 0.9867 \ n_{st} + 5.2818 \tag{2} \]

The correlations of the \( C_H \), \( C_Q \) conversion factors were obtained with measurements of a sample of pumps at the University of Calabria [7] according to Equation (3) and Equation (4).

\[ C_H = -0.00003n_{sp}^3 + 0.0044n_{sp}^2 - 0.20882n_{sp} + 4.64293 \tag{3} \]

\[ C_Q = 0.00029n_{sp}^2 - 0.02771n_{sp} + 2.01648 \tag{4} \]

With the values of \( Q_p \) and \( H_p \) as input data in the manufacturer’s performance graphs, we can select the pump to be used as a turbine. Figure 1 shows the overall procedure for selecting the PAT.

![Figure 1. Selection of the PAT.](image-url)
2.2. Experimental tests of the pump operating as a turbine

Figure 2 shows the assembly used to evaluate the performance of the PAT. The characteristics of the pump and generator used in the assembly are presented in Table 1.

The PAT was tested for flow rate vs rpm, hydraulic power vs rpm, voltage vs rpm and electric power vs rpm with load and without load. The charge consists of a set of bulbs connected in parallel. As shown in Figure 2.

Table 1. Characteristics of pump and generator.

| Machine   | Characteristic                                      |
|-----------|-----------------------------------------------------|
| Pump      | KSB 32-125.1 diameter of impeller: 134 mm           |
| Generator | Motor of direct current of permanent magnet Serie 42A Model 4037 of 1/3 HP, 2.3 A to 130 V, 2500 RPM. |

3. Results and case study

In Figure 2 the elevated tank is observed to level difference 13.3 m. \( H_{\text{site}} \approx 10 \text{ m} \), \( Q_{\text{site}} \approx 75 \text{ gpm} = 0.0047 \text{ m}^3/\text{h} = 16.9 \text{ m}^3/\text{h} \).

In Table 2, the parameters of the procedure in Figure 1 are reported.

Table 2. Calculation of the pump parameters.

| \( Q_{\text{site}} \) (m\(^3\)/h) | \( H_{\text{site}} \) (m) | rpm | ns | Cq | Cn | Qp (m\(^3\)/h) | Hp (m) |
|---------------------------------|-----------------|-----|----|----|----|----------------|--------|
| 16.9                            | 10.0            | 1750| 21.2| 1.4| 1.6| 11.3           | 6.1    |

The flow parameters \( Q_p \) and head \( H_p \), obtained in Table 2, are used to select the centrifugal pump that will operate as a turbine. By entering the manufacturer’s performance curves, the appropriate pump can be selected for the required application.

In Figure 3, the valve position vs. flow performance test is illustrated, a higher flow rate is observed when the system is unloaded or empty.

In Figure 4, it is observed that in the no-load system a higher rpm is obtained, for the same opening of the valve, than when the system is loaded.

As seen in Figure 5, the higher the rpm or the greater the opening of the valve, the greater the voltage generated. Therefore, when the system is running under vacuum, the highest voltages of 130 volts are obtained with the system without load. In Table 2, the behavior of the main performance variables of the PAT can be observed, observing a maximum efficiency of 76% to 950 rpm. The efficiency is defined according to Equation (5).
\[ \eta = \text{Potencia eléctrica} \times (\text{Potencia hidráulica})^{-1} \]  \hspace{1cm} (5)

**Figure 3.** Characteristic curves PAT Ksb 32-125.1.  \hspace{1cm} **Figure 4.** Characteristic curves PAT Ksb 32-125.1.

**Figure 5.** Characteristic curves PAT Ksb 32-125.1.

4. Conclusions
In the present paper, a PAT was selected for a hydroponic site using a statistical method [7] that allows to calculate conversion factors C_Q and C_H, in such a way that the capacity and head of the pump suitable for the site can be found.

For the case study, which consists of a tank raised to 13.3 m, a 2-inch forced pipe was selected centrifugal pump KSB 32-125.1, whose performance curves are known and presented, which provides a maximum output power of 90 w with an efficiency of 76%, values that are adequate when compared with conventional turbines.

The method used in the selection of the PAT is one of several methods that have the objective of helping the designer to select the PAT quickly for a specific application and that is also in the process of improvement.
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