"Know It? Apply It!" Kit - The Pelton Wheel

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1 Abstract

We present to you the "KIAI"-Kit designed with an aim of bridging the gap between the theoretical knowledge provided in the class rooms and the practical knowledge required to handle real-life problems. The kit will act as a TLM (Teaching and Learning Material) by the students for the students. The very first edition of the kit presents a model of the Pelton turbine.

The idea of the kit originated from a very serious issue faced by the students, specifically in India. An article from a renowed newspaper India Today describes the finding of an employability test by Aspiring Minds on 1,50,000 engineering students who graduated in 2013 and the results actually need immediate attention. According to the article, "As many as 97 per cent of graduating engineers want jobs either in software engineering or

core engineering. However, only 3 per cent have suitable skills to be employed in software or product market, and only 7 per cent can handle core engineering tasks." Isn't that really shocking? This is not the only evidence of the lack of skills graduates, specifically in India, possess. The internet can provide a lot of such examples. All us are aware of the problem, but some actually try to find a reason behind this scenario and a few work towards solving it. We want to be in the last group and so we are here with our idea of "KIAI"-Kit.

2 Description

KIAI stands for "Know It? Apply It!". In class-rooms students are usually loaded with a lot of information. But "Knowing" is not the same as "Understanding". As Resnick (1989) aptly noted, "learning occurs not by recording information but by interpreting it", we want students to apply the knowledge they learn in the classrooms and emerge as "real-life problem solvers".

The first edition of our kit brings with it a model of the Pelton turbine and an experimental setup to calculate it's efficiency. We've tried to use day-to-day materials as much as we can so that each and every student across the country can easily make the whole setup on their own and get hands on experience at their home.

3 Experimental Setup

The main part of the turbine is the Wheel (shown in Figure 1) and it's made using some plastic boards which serves the purpose of the circular disc of runner. Some plastic bottles are cut into halves and mounted over the periphery of the plate which can serve the purpose of the buckets. A rod is connected to the runner in the axial direction and it is connected to the shaft of the dynamo with the help of a belt-pulley system (shown in Figure 2).

The working fluid of the turbine is water as it is easily available. It is supplied using a pipe with a nozzle at the outlet. When a jet of water is made to strike the vanes of the runner, the runner starts rotating. Thus the kinetic energy of the water gets converted into the mechanical energy of the runner. As a result the shaft connected to it starts rotating and this motion is transmitted to the shaft of the dynamo with the help of a belt and pulley system. The dynamo converts the mechanical energy to electrical energy. The manifestation of this electrical energy is the glowing of the small LED connected to it.

4 Methods

4.1 Calculation of power input to turbine

At the inlet to the turbine or outlet to the nozzle the energy possessed by water is kinetic energy, thus the water power (P_i

Figure 1: Runner with vanes made of Plastic bottles

Figure 2: The pulley and the belt system connected to the shaft of dynamo

Figure 3: The front view of the final model

Figure 4: The side view of the model

in Watts) can be easily calculated from the rate of change of KE of the water per unit time using the relation:

$$P_i = \frac{1}{2}\dot{m}v^2 \tag{1}$$

where $\dot{m}$ is the mass flow rate (in kg/s) of the water through the pipe and v is the velocity (in m/s) of water striking the runner.

The mass flow rate can be easily obtained from the relation

$$\dot{m} = \rho Q \tag{2}$$

Where ρ is the density (in kg/m3) of water and Q is it's volume flow rate (in m3/s).
The velocity of the water striking the runner blades is the velocity of the water ejected from the nozzle outlet which can be calculated using the relation

$$V = \frac{Q}{a} \tag{3}$$

where Q is the volume flow rate of water through the pipe and a is the cross-sectional area (in m2) of the nozzle outlet.
Thus,

$$P_i = \frac{1}{2}\rho Q \times \frac{Q^2}{a^2} = \frac{1}{2}\rho\frac{Q^3}{a^2} \tag{4}$$

Since the working fluid is water and considering it was an incompressible fluid, $\rho = 10^3$ kg/m3.

To measure the cross-section of the nozzle outlet, the following steps are followed:

1. The circumference (c in cm) of the outlet is first measured using a string
2. The pipe width (w in mm) is measured using a scale

Therefore,
Outer radius of the nozzle comes as $Ro = \frac{c}{2\pi}$ (in cm)
Inner radius $Ri = Ro - \frac{w}{10}$ (in cm)
Area of flow of water $a = \pi R_i^2 \times 10^{-4}$ (in m2)

As per our experimental setup:

1. $c = 4.4$ cm
2. $w = 2.5$ mm

Therefore, $a = 6.362 \times 10^{-5}\ m^2$

The volume flow rate is measured using a measuring beaker. The water is made to flow into the beaker up to a level of 800 mL and the time (t in sec) is noted. Thus the volume flow rate becomes $Q = \frac{800 \times 10^{-6}}{t}$ (in m3/s)

Thus the final expression for power input (in Watts) becomes

$$P_i = \frac{1}{2} \times 10^3 \times \frac{(800 \times 10^{-6})^3}{t^3} \times \frac{1}{(6.362 \times 10^{-5})^2} = \frac{63.249}{t^3} Watts \tag{5}$$

The value of t is calculated just before the experiment and it came up as $t = 5.7$ secs.
Thus $P_i = \frac{63.249}{5.7^3} = 0.34153\ W$

4.2 Calculation of power input to turbine

As the jet of water is made to strike the runner vanes, the LED starts glowing confirming the generation of electric power. The current and voltage readings of the Multimeter are noted. The value of the power output (P_o in Watts) is measured using the relation:

$$P_o = iV \tag{6}$$

where i is the current reading (in Amperes) and V is the voltage reading (in Volts)
With the above flow rate, the current and voltage readings come up as

$$i = 16.75\ mA$$

$$V = 0.65\ V$$

Therefore,

$$P_o = 0.01089\ W$$

4.3 Calculation of efficiency of the turbine

Thus the overall efficiency of the handmade motor can be calculated using the relation

$$\eta_o = \frac{P_o}{P_i} = \frac{0.01089}{.34153} = 0.03188 = 3.19\% \tag{7}$$

5 Discussion

This experimental setup provides a virtual environment where the students can vary different flow conditions, say, differing the volume flow rate and get different values of efficiencies for the turbine model. Using all those data, one can easily plot a "Discharge vs. Efficiency" and "Discharge vs. Power" graphs and analyse the Operating characteristic curves for the Pelton turbine.

The KIAI Kit aims at developing more complex situations where other parameters could be varied just like the flow rate and the performance and behaviour of the turbine can be analysed under those working conditions.

References

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