Design of a low-tech water turbine

Academic year:
2025-2026

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1 Introduction

The preliminary design phase is a crucial step in the development of a new product, as it lays the foundation for the subsequent detailed design and manufacturing processes. This phase involves defining the product's specifications, identifying potential design concepts, and evaluating their feasibility. We will have some constraints to respect, and some design parameters to choose.

1.1 Input Data

To start the design, we need to define the constrains of the system. Therefore, we have the following data imposed.

- Hauteur de chute $\Delta H = 1.0\,\mathrm{m}$
- Rayon extérieur $R_o = 0.1\,\mathrm{m}$
- vitesse du fluide $V_x = 2\,\mathrm{m/s}$
- rendement hydraulique théorique maximal $\eta = 0.93$

2 Blade design

The design of turbine blades is a critical aspect that directly influences the performance and efficiency of the turbine. We will here use the method proposed by ...(Abeykoon) for the blade design of a Kaplan turbine.

The first step is to estimate the extracted power of the turbine to start the design. Based on the input data, we can start by estimating the blockage factor with the following graph(from fig 15 of 2022 Abeykoon):

- $\sigma = 1.6$

Considering: (from fig 15 of 2022 Abeykoon)

$$R_i = 0.4 \times R_o = 0.04\,\mathrm{m} \tag{1}$$

We can calculate the volumetric flowrate Q:

$$Q = \pi(R_o^2 - R_i^2)V_x = 190.0\,\mathrm{m^3/h} \tag{2}$$

By taking the maximal theorical hydraulic efficiency for a Kaplan turbine, we can estimate the extracted power:

$$P_{extracted} = \eta P_{hydraulic} = \eta \rho g Q \Delta H \tag{3}$$

$$P_{extracted} = 481.5\,\mathrm{W} \tag{4}$$

First, we can calculate the rotationnal speed based on the following correlation: (Abeykoon)

$$N = \sigma \frac{(2gH)^{3/4}}{2\sqrt{\pi Q}} \tag{5}$$

Therefore, we have:

$$N = 1098.9\,\mathrm{rpm} \tag{6}$$

We can also obtain the mean speed of the blade:

$$U_m = 2\pi R_m \frac{N}{60} \tag{7}$$

with

$$R_m = \frac{(R_o - R_i)}{2} = 0.07 \text{ m} \tag{8}$$