Study of Sediment Erosion in Hydraulic Turbine Using Rotating Disc Apparatus

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Abstract

There are huge potential for hydropower development in Himalayan region in general and Nepal is particular. However, there are also technical challenges for hydropower development due to sediment erosion problem. Erosion not only reduces efficiency and life of hydropower turbines but also causes problems in operation and maintenance. A large number of factors can influence the process of sediment erosion damage in hydro turbine components. The erosion intensity depends on the sediment types and their characteristics (shape, size, quantities etc.), hydraulic design and operating conditions of turbine (flow rate, head, rotational speed, velocity, acceleration, turbulence, impingement angle etc.), and material used for the turbine components. In this paper, laboratory studies of particle size effect on erosion prediction in a Rotating Disk Apparatus (RDA), is briefly discussed. It is found that the intensity of erosion (weight loss) has directly proportional relation with sediment size and also erosion is directly proportional with run time when all other variables are kept constant.

**Keywords:** Sediment erosion, Sediment characteristics, Rotating Disk Apparatus (RDA), Erosion rate

1. Introduction

Nepal, a Himalayan country with total estimated hydropower potential of about 83,000 MW has total installed capacity of about 680 MW, of which about 84% is produced from Run-of-River (RoR) hydropower plants. Therefore, RoR hydropower plants are the main sources of electricity in the country. And hydraulic turbine is the heart of hydro power to generate electricity. This hydraulic runner faces various problems of erosive wear which results in decrease of efficiency of plant. Erosion in hydraulic turbine is mainly due to sediment erosion and cavitation erosion.

Hydraulic turbine components operating in sediment-laden water are subject to abrasive and erosive wear (Brekke, 2002, Thapa, 2004, Neopane, 2009). This wear not only reduces the efficiency and the life of the turbine but also causes problems in operation and maintenance, which ultimately lead to economic losses (Ole, 2009, Neopane, 2010). The high sediment concentration combined with a high percentage of quartz content in water causes severe damage to hydraulic turbine components for example spear valve needle, Pelton bucket, stay vanes, guide vanes, runner vanes, facing plates.

Sediment erosion depends on large number of factors that influence the process of sediment erosion damage in hydro turbine components. The erosion intensity depends on the sediment types and their characteristics (shape, size, concentration, hardness, etc.), hydraulic design and operating conditions of turbine (flow rate, head, rotational speed, velocity, acceleration, turbulence, impingement angle etc.), and material used for the turbine components. All these factors are needed to be considered for predicting the erosion (Neopane, 2010).

The main purpose of this paper is to discuss the erosion caused by the sediment size and to establish the relationship between the sediment size and erosion. A previously made Rotating Disk Apparatus (RDA) was reviewed and modified to generate the effect of sediment erosion in laboratory set-up. The relationship between characteristics of sediment (size) and rate of erosion (weight loss) is established.

2. Rotating Disc Apparatus (RDA): Experimental Setup

A Rotating Disc Apparatus (RDA) is an experimental test rig which can address erosion and cavitation of material due to sand laden water flow at high speed. The main purpose of such type of test rig is to achieve high relative velocity of test specimen with respect to water. Test specimen is mounted in to a disc or arm which is rotated with the help of high speed motor. For cavitation erosion analysis specimen disc is fitted with inducer rods and for sediment erosion analysis a specimen disc without inducer is used. The housing is filled with water and sand, which is kept almost stationary by using a set of baffles to restrict the water to attain velocity from the contact of rotating disc. Continuous circulating of water is arranged for cooling of housing. After operation for certain time, the erosion pattern can be seen on the specimen disc and also the weight loss due to erosion can
be measured. The RDA test rig is shown below with its different views.

Figure 1: Architecture of RDA

3. Methods

3.1 Sediment Collection and Sieving

For the real life behavior of sediment erosion, the sample of sediment was collected from Bagmati River with feasible Sundarijal Hydropower and Roshi Khola with feasible Panauti Hydropower. The sample was collected from reservoir (settling basin) where some portion of sediment settles down. The collected sediment was sieved to three size range of sediments as: 1000 µm, 600 µm and 250 µm.

3.2 Experimental Analysis

After all sized sediments and specimen disc was ready, initial weight of specimen was noted. Then the disc was run in RDA with 1 kilogram of specific sized sediment for an hour and the final weight was also noted. This procedure was followed for 7 hours. After that same sized sediment from another source was used in next specimen disc. This procedure was followed for all considered three sizes of sediment for Sundarijal and Panauti Hydropower.

Specifications used in our experiment are:

- Material used: Mild Steel
- Sediment source: Sundarijal and Panauti Hydropower
- RDA Motor: 2880 rpm (7.5 kW)
- Diameter of RDA (D): 292 mm
- Length of RDA (L): 60 mm
- Volume of RDA: \( \frac{\pi}{2} \times D^2 \times L \) = 4017971.34 mm³ = 4.018 x 10⁻³ m³
- Amount of Sediment: 1 Kg
- Concentration of Sediment: 1 Kg per 4.018 x 10⁻³ m³ water = 248.88 Kg/m³
- Weighing Machine: CAMRY (model: BCS)

Weighing Capacity: 50 g to 15 Kg
Error of Weighing Machine: ±5 g
Run Time: 1 hr

4. Results and Discussion

The experimental results were plotted and compared the results of erosion of specimen material depending on size of sediments. Also different patterns of sediment erosion were observed.

4.1 Graphical Representation

From figure 2, it is observed that weight loss of specimen increases as the size of sediment increases. The larger the sediment the more weight loss was found. When individual size range was considered, wt. loss was found increasing as time progress. Similar results were found for sediment from Roshi Khola.

Figure 2: Wt. Loss Vs Run Time for Sundarijal

Figure 3: Wt. Loss Vs Run Time for Panauti
Above graph shows the comparison of weight loss for sediment size range between 600 µm to 1000 µm from two different sources. Even if the size were same it was found that the weight loss were different. Similarly the results for sediment size range between 250 µm to 600 µm and below 250 µm also had different weight loss as shown below.

Figure 5: Wt. Loss Vs Run Time (250 µm < Sed. ≤ 600 µm)

Large number of factors can influence the process of sediment erosion damage in hydro turbine components. The erosion intensity depends on the sediment types and their characteristics (shape, size, quantities etc.), hydraulic design and operating conditions of turbine (flow rate, head, rotational speed, velocity, acceleration, turbulence, impingement angle etc.), and material used for the turbine components. All these factors are needed to be considered for predicting the erosion (Neopane, 2010). In above experiment except shape all other variables described above are kept constant. So the variation in weight loss for same size range may be due to variation in shape of the sediment. And it also may be due to different mineral content (quartz) of sediment for two different sources.

Figure 6: Wt. Loss Vs Run Time (250 µm ≤ Sediment)

In our analysis we had only considered size of sediment keeping all other variables constant except shape. We are neither able to ensure constant shape nor able to consider it in our analysis. Due to this we found sudden change in nature of curve in same size range of sediment operating in constant condition except characteristic of shape and mineral content (quartz content) unknown. Thus we conclude this variation may be due to shape factor. So for any sediment erosion analysis all characteristics and factors affecting erosion must be consider including shape, size, and mineral content.

So during any sediment erosion analysis size, shape, mineral analysis data and all other required variables included above must be consider to get precise and accurate result.

4.2 Erosion Pattern

Due to continuous action of sediment and water mixture on specimen disc, the surface material is eroded forming a pattern of erosion as shown below.

Figure 7: Pattern after 1 hour
5. Conclusion and Recommendation

Hydraulic turbine working on sediment laden water gets eroded rapidly. From this project work, erosion (weight loss) was found directly proportional with sediment size and also erosion was found directly proportional with run time when all other variables were kept constant. For same sediment size and same operating condition except shape and mineral content unknown, erosion was found different. So erosion also depends on sediment shape and mineral content. Thus in any erosion analysis all the factors affecting erosion must be considered.

Erosion patterns were found almost similar for all size of sediment and the observed patterns were always smooth surface. Also the turbine material should be free from any manufacture defect as the erosion rate was found severe at these spot compared to defect free surface. Thus smoothness and erosion pattern was found depended on manufacture condition of the turbine material. So turbine material should be free from manufacture defect.

References