Wear 362-363 (2016) 53–60

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

# Sediment erosion in guide vanes of Francis turbine: A case study of Kaligandaki Hydropower Plant, Nepal

Ravi Koirala [a,b,*], Bhola Thapa [a], Hari Prasad Neopane [a], Baoshan Zhu [b], Balendra Chhetry [a]

[a] Turbine Testing Lab, Kathmandu University, Dhulikhel, Nepal
[b] State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing, China

ARTICLE INFO

*Article history:*
Received 5 January 2016
Received in revised form
12 May 2016
Accepted 13 May 2016
Available online 20 May 2016

*Keywords:*
KG-A hydropower
Guide vane
Sediment erosion
Computational analysis

ABSTRACT

Sediment erosion is a crucial issue that affects the reliability of hydraulic turbines operating in sediment laden water. Guide vanes are the prime components for allocating water to produce the useful work, and shape changes due to wear affect the water flow properties. Profile changes can induce wakes, create boundary layer friction, and generate cross flows and leakage flows, all of which eventually deteriorate the performance of turbine. Erosive wear is dependent on the properties of the sand, turbine materials, particle velocity and impact angle. Since these factors vary with the site and the duration of the operation, there is no consistency in erosive wear behavior.

This case study discusses sediment erosion in guide vanes in the largest operational hydropower plant in Nepal (Kaligandaki-A (KGA) Hydropower). Observations were combined with computational analysis. Sediment properties and mineral content, the turbine material, the erosion patterns, erosion protection methods, and numerical estimates of erosion have all been addressed. High quartz content, increasing inefficiency of the flushing system, higher sediment load, high impingement velocity, and operation at low guide vane angles were all found to be major contributors to erosive wear in this system.



## 1. Introduction

Hydropower utilizes the energy of naturally moving water to produce sustainable and renewable electrical energy, fulfilling current energy demand. Production cost consistency, low operation and maintenance cost, environmental acceptability, economical viability and constant control makes it to be the reliable and perpetual energy source. Current facility fulfills 16.2% of global energy demand and it is estimated to increase by 3.1% every year for next 25 years [1]. Thus the newly developing hydropower should consider existing problems for enhanced harnessing.

Unexplored resources in Asia and South America are in higher percentage where the great Himalayas and the Andes Valley lie. The water flowing through these regions contain erosive mineral; Quartz, in the sediment which upon contact with the exposed turbine components affects life and performance of turbine [2,3].

Earlier the political, social, economical chaos including insurgency and terrorism, hydropower in Chile, Cambodia, Peru of South America and Nepal, India, Pakistan, Afghanistan of Asia were not developed [4]. With the realization of the use of renewable energy and after the stability in harmony, these countries have felt its need for prosperity. Although lots of hydropower systems are in developmental and operational phases with severe problem of sediment deposition and erosion, effective solutions are still lacking. The scenarios of each of the plant operating in these regions are of its own kind with distinct facility, features and problems. This paper deals with the sediment erosion in the biggest operational run off river type hydropower project of Nepal, KG-A Hydropower Project. The sediment samples, turbine materials and existing problems and the reason have been studied.

## 2. Study case: Kaligandaki – A Hydropower Plant

KG-A hydropower plant is the largest operational hydropower plant in Nepal with the capacity of 144 MW. It is a runoff river project generating 700 to 842 GWh of electricity per annum. The project was commissioned in the year 2002, with hydraulic steel works by Noell Stahl of Germany; electrical works by Mitsui/Toshiba/Alstom Joint Venture; mechanical works by Mitsui /Toshiba Joint Venture and 132 KV transmission lines and substations by TATA/Marubeni Joint Venture.

The main project site is located in Syangja district encompassing Palpa, Parbat, Gulmi, Kaski and Rupandehi districts. The

* Corresponding author.
*E-mail address:* ravikoirala@ku.edu.np (R. Koirala).

http://dx.doi.org/10.1016/j.wear.2016.05.013
0043-1648/

**Nomenclature**

| | |
|---|---|
| $\underline{Q}$ | Reduced flow |
| KG-A | Kaligandaki – A |
| $\underline{\omega}^*$ | Reduced speed at best efficiency point |
| LE | Leading edge |
| $\Omega$ | Speed number |
| TE | Trailing edge |
| $\alpha_o$ | Guide vane full opening angle |
| 3-GV | 2 Guide vane |

diversion dam is about 500 m downstream from the confluence of Kaligandaki River and Adhi Khola and in between Mirmi and Harmichaur villages of Syangja and Gulmi districts respectively. The main component of project comprises of a concrete gravity diversion dam of about 100 meters in length and 43 m of height, open surface desander, tunnel of about 6 km length and 7.4 m diameter and a surface powerhouse. The power generated from the project is transmitted to 132 kVA line in Pokhara and Butwal substations through 66 km and 40 km long transmission lines, which are connected to Integrated Nepal Power System (INPS). Fig. 1.

The plant has 3 units of vertical Francis turbines operating at a net head and flow of 115 m and 47 m$^3$/s respectively. This study is limited to the sediment erosion in guide vanes exploring the possible causes of erosion around it.

## 3. Sediment at Kaligandaki A project

Like all other major rivers in Nepal, Kaligandaki also originates from the great Himalayas. Himalayas are the newly formed land form in active stage [5]. The irregular geographical terrain and presence of soft sedimentary rocks are the major reasons behind high sediment content. Every year about 6349 million tons of sediment are deposited in the ocean from Asian continent and major portion comes from the Himalayan rivers [6]. This sediment, during its travel also passes through the hydraulic turbine of Run of River projects resulting into hydro abrasive/sediment erosion on exposed turbine components. The effect of impact of sediment deteriorates life and performance of turbines. The major factors associated with erosion are sediment properties (shape, size, concentration and mineral composition), turbine properties (physical, chemical and design), impact velocity and angle [7]. This part explores the erodent prospect related to the erosion i.e. study of sediment sample.

### 3.1. Sediment sample analysis

Sediment samples from the desilting basin and tailrace were collected for the analysis and to identify the possible sediments passing through the turbines. These samples were analyzed at Sediment Laboratory, Kathmandu University. The analysis related to PSD and Mineral compositions were considered during the study.

#### 3.1.1. Particle size distribution

The sieve analysis of the composition was performed following the methodology explained by Koirala et. al. [8]. The manual sieving on 60.62 kg of sediment sample was performed and particles size distribution was observed. Fig. 2 shows the particle size distribution of the sediment samples from KG-A Hydropower Project.

92% of the particles at the desilting basin and 99% at downstream are finer than 1000 μm whereas 0.5% and 2.3% particles are finer than 75 μm in the consecutive locations. At desilting basin, particles ranging from 300 to 600 μm are in larger concentration whereas at downstream, particles ranging from 125–200 μm are in higher concentration. The concentration may have varied due to the desilting basin or break down because of the impact inside the turbines.

#### 3.1.2. Mineral composition analysis

The mineral composition analysis for the project was performed using the particle count method with a Radial Trinocular

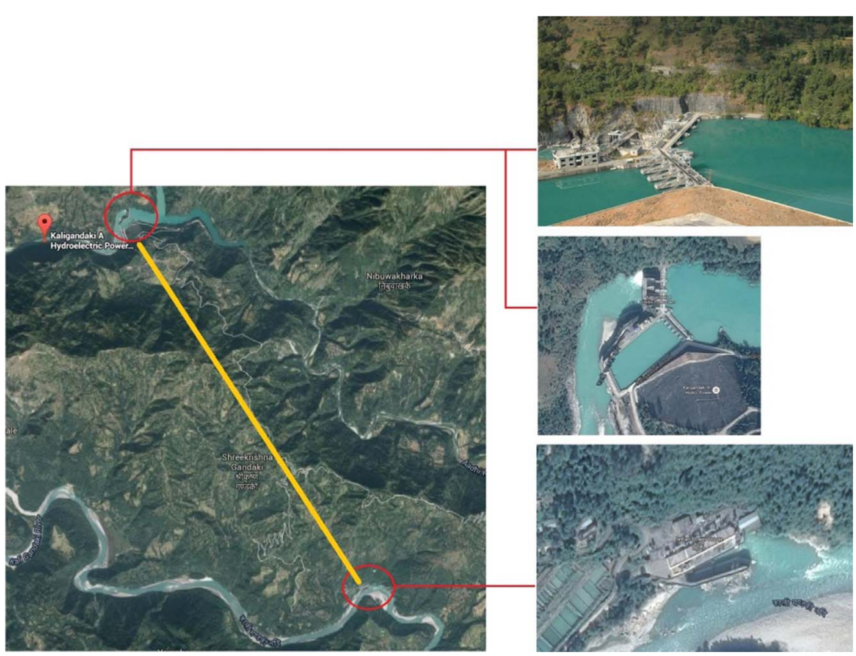


**Fig. 1.** Location of Kaligandaki - A Hydropower Plant.