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Analyzing hydro abrasive erosion in Kaplan turbine: A case study from India*

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Abstract: Sediment flow through hydro turbine causes erosion of hydraulic components resulting in drop of turbine efficiency, particularly in hydropower plants of the Himalayan region. The measurement of erosion and monitoring of sediment flow in turbine are major concerns in erosion study. Attempts have been made to study erosion mainly in Pelton and Francis turbines. In this study, a simple and effective method has been presented to measure erosion in a Kaplan turbine of a run-of-river scheme Chilla hydropower plant in foothills of Himalaya. Recent techniques were used to measure sediment parameters like concentration, size, shape and mineral content. A standard erosion model is applied to estimate the erosion in Kaplan turbine blade, runner chamber and draft tube cone. A calibration factor has been proposed to apply the erosion model for site specific conditions. It has been found that the outer trailing edges of the turbine blade and upper runner chamber are most erosion prone zones. Sediment analysis revealed that effective operation can reduce erosion in turbine components. The estimated erosion values from model are found to be consistent with measured values. Finally, suggestions for design improvements and effective operation of erosion affected hydropower plants are given.

Key words: turbine, sediment, erosion, measurement, IEC 62364, hydropower

Introduction

The sediment flow causes reduction in the active life of reservoirs, erosion of hydro-mechanical equipment and civil engineering structures. It is very difficult to remove all the silt before passing through hydro turbine especially in run-of-river hydropower plants. The silt in Himalayan region contains mainly quartz (65%-81%), an extremely hard mineral with hardness 7 on Mohs scale causing severe damage to hydraulic machinery[1-3]. This erosion of turbine parts abets cavitation, pressure pulsation, vibration, mechanical failures and associated frequent shut downs. The outcome of this is a gradual reduction of the output efficiency of the plant[3-6]. Increased global deployment of hydro, a renewable and sustainable energy, calls for the strong need for hydro-erosion related studies. The hydro-abrasive erosion due to sediment laden water is a complex process and depends on many factors such as sediment characteristics, flow characteristics and properties of substrate materials (hardness, surface morphology, properties of the coating)[7-9]. Although the parameters for hydro-abrasive erosion have been identified, to which extent these parameters contribute to the hydro-abrasive erosion is not fully understood[6,7,10].

One of the major difficulties in erosion study is the measurement of erosion[11,12]. In laboratory set-ups, the specimens are small in size and flat in shape, which allow relatively easy measurement of erosion by weight loss, volume loss, surface roughness or deformation dimension methods[8,11]. However, erosion measurements in prototype plants are difficult due to large-sized and non-flat components. The formation of erosion ripples makes the measurement of local thickness difficult. The thickness reduction is measured using general calipers during maintenance period of plants[11]. However, a major problem with this kind of erosion measurement is in locating the reference point for measurement. Moreover, higher accuracy of erosion data requires erosion measurement at more points on the profile. Recently, researchers have initiated and measured the erosion with optical 3-D scanners in prototype plants[4,5].

IEC 62364[13] outlines the information about the erosion study in hydro-turbines but does not provide the details of method of measurement for erosion though factors such as location, minimum number of erosion point measurements and number of turbine blades

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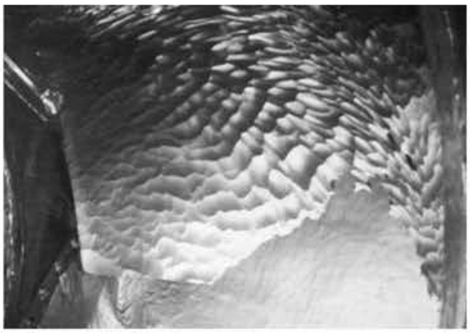
to be inspected for Francis, Pelton and Kaplan turbine have been provided. Few terms used in the IEC 62364[13], like the flow coefficient (K_f) and exponent of RS (p), are not prescribed for Kaplan turbine erosion. Several studies have produced estimates of erosion in prototype Francis[7,9,10] and Pelton turbines[3-5,14], but studies for Kaplan turbine are still insufficient. Monitoring suspended sediment properties like concentrations, size distributions, shape and mineral content along with erosion of turbine is still not common practice, which leads to inadequate information on erosion phenomenon[13].

In the present study, a run-of-river hydropower plant, located on Ganga river, India, is considered for erosion study. As per literature, the studies have focused mainly on the erosion of turbine blades rather than components of turbine i.e., runner chamber, draft tube etc. The objective of this case study is to present a simple approach to measure the erosion on the turbine blades, the runner chamber and the draft tube cone of a prototype Kaplan turbine unit. The content of this paper is composed of five parts. The first part deals with information of hydropower plant under study. The second part explains the methodology adopted for measuring erosion in different components of turbine unit, sediment properties measurement and process of estimation of erosion model parameters. The third part presents the results and explains the findings in context of literature. The fourth part explains the uncertainty involved in the study and the fifth concludes with steps to improve the erosion affected hydropower plants. The current study shall be useful for hydropower plant managers and researchers to measure erosion and develop a strategy for handling erosion issues effectively.

1. Study area

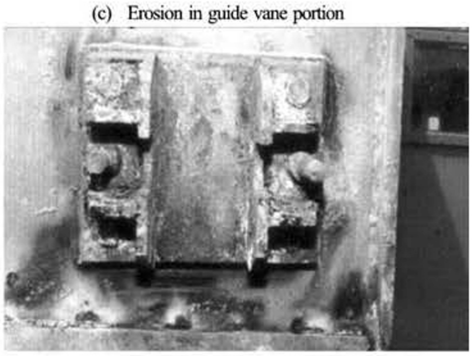
The Chilla hydropower project is a run-of-river scheme on river Ganga located upstream of the city of Haridwar in the foothills of Himalayas and was commissioned in the year 1980-1981. There are 4 Kaplan vertical shaft turbines of 36 MW capacities each with design head of 32.5 m at 187.5 rpm. A diversion barrage with head regulator is located at Pashulok, 5 km downstream of Rishikesh town, for diversion of water to a 14.3 km long, 565 m^3/s capacity lined power channel. Since commissioning of the power plant, the turbine components faced severe erosion[15]. The high erosive silt from river Ganga caused extensive damage to the underwater parts of hydro turbine units, cooler tubes, drainage pump impellers and valve seat. In initial years of the power plant, the blades were found to be extremely eroded and cracked in trailing side after few monsoon seasons[15]. The runner chamber also observed extensive erosion requiring heavy maintenance after every few years. Figure 1 shows the eroded components of Chilla hydropower plant from maintenance records during initial days. However, the erosion scenario improved significantly in recent years[16] due to the enhanced hydrological regulation in upper basins owing to commissioning of 239.5 m high over river bed earth rock fill Tehri dam in the year 2006. The hydropower plant is owned and operated by state utili-



(a) Eroded Chilla turbine blade in trailing side

(b) Concrete exposed in eroded runner chamber

(c) Erosion in guide vane portion



(d) Erosion in intake gate

Fig.1 Eroded components of Chilla hydropower plant