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Study of silt erosion mechanism in Pelton turbine buckets

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ABSTRACT

In the present study, an experiment was carried out to investigate the mechanism of erosion of a small scale Pelton turbine, under actual flow conditions. Samples of silt were collected from the head work of one of the most silt affected hydro power station in India. Silt parameters (silt particle size and silt concentration) were considered to investigate the mechanism of silt erosion on Pelton turbine buckets for different silt sizes. In the first part of the experimentation, hot spots (spots which are more prone to erosion) were identified under a high silt concentration. Second part of the experimentation was carried out to study the erosion mechanism for small specimens of metal which were fixed at the marked hot spots.

Based on the investigation, it has been found that silt size is a strong parameter to produce erosion and the material removal from the surface is due to plastic deformation and ploughing of surface.

1. Introduction

Silt erosion of hydro turbine components is a major problem for the efficient operation of hydropower plants. High content of unsettled silt particles pass through the turbines during rainy seasons resulting in erosion of turbine components. These problems are more prominent in power stations which are of run-of-river types. The problem of silt erosion in turbine is aggravated if the silt contains more percentage of quartz, which is extremely hard (hardness 7 in Moh's scale) and cause severe damage to the turbine components. Bucket, nozzle and needle are the most affected parts of impulse turbines while guide vanes, faceplates, runner blades and seal rings are vulnerable parts in reaction turbines. Some of the erosion models based on experimental investigation on erosive wear have been reported in the literature [1–14]. Various causes for the declined performance and efficiency of the hydro turbines due to silt erosions and suitable remedial measures for such erosion suggested by various investigators have been discussed by Padhy and Saini [15]. The erosion rate is given in terms of mass or volume of material removed per unit mass of impacted erodent. Investigators implicitly assume that the dimensions of the eroded area and the particle concentration are not important [16]. Monitoring of the turbine erosion is a difficult task in practice and there is no standard procedure to measure such erosion in turbine components. In laboratory tests, the specimens are small in size and they are of regular shape or flat plates. Therefore, it is easy to measure the effect of erosion in terms of weight loss, volume loss, surface roughness or dimensional deformation. Since the sizes of turbines in actual hydro power plants are large and the runner blades or buckets are not flat, it is therefore, difficult to study the mechanism of erosion over a Pelton turbine bucket by the procedures available in the literature [17,18].

The mechanism of erosion in general may be discussed as follows. When particles strike the surface at small impingement angle the material is removed by cutting mechanism. The abrasive grits roll or slide when they strike on the surface at small impingement angle and cause erosion by abrasion or cutting mechanism. The material is removed by scouring or scrapping by sharp edges of the particles forming short track-length scars. Two basic types of cutting mechanisms were suggested [1,2], while testing on pin on disc wear test rig as: (i) a cutting mechanism called micro cutting and (ii) a wedge build up mechanism with flake like debris called ploughing. Ploughing is found to be a less efficient mode of material removal. Beneath the surface of the abraded surface, considerable plastic deformation occurs [3,19]. The material loss is faster if the wear mechanism involves both cutting and surface fatigue. This mechanism of erosion is similar to erosion due to surface fatigue on rolling surfaces. When the

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particles strike the surface with large impact angle but at low speed, the surface cannot be plastically deformed. Instead the surface becomes weak due to fatigue action and cracks are initiated in surface after repeated hitting. The particles will be detached from the surface after several strikes.

The present investigation has been intended to study the mechanism of erosion damage on the Pelton turbine buckets. Based on the findings discussed under the present study, proper remedial measures can be considered for proper treatment of the bucket surface at manufacturing stage.

2. Expetimentation

An experimental setup was designed and implemented to carry out the required investigation. A small scale model Pelton turbine of 1 kW was selected to study the mechanism of erosion on different areas on the turbine bucket. Schematic arrangement of the test setup is shown in Fig. 1. Photograph of the test setup is shown in Fig. 2.

The most important part of the setup was the Pelton turbine runner. A Pelton turbine runner having a pitch circle diameter of 245 mm and nozzle diameter 10 mm, mounted with 16 buckets was used for the experiments. Buckets made up of brass were chosen as specimens to get measurable amount of erosion in a short duration.

A steel tank 600 mm long, 510 mm wide and 780 mm deep was used to store the required amount of water and to mix silt with water. Different sizes of sieves having a 20 cm diameter, spun brass frame and best quality wire meshes of 355 μm, 215 μm, 180 μm and 90 μm sieve openings were used for grading the silt sizes. The required size range of silt was mixed with water in the tank to prepare silt water mixture as per the requirement of the experiment. The same silt water mixture was circulated through turbine under required operating conditions. A stirrer connected with a 0.5 hp motor was provided in the middle of the tank. It was operated continuously during experiments so as to provide uniform mixture of silt and water. In order to create required hydro potential head to be applied to the turbine under desired conditions a centrifugal pump was used. The centrifugal pump delivered silt water mixture to the turbine. The silt water mixture before striking the turbine bucket passed through a nozzle. The nozzle was fixed at the end of the penstock to convert the hydro potential head to velocity head. A digital pressure transducer was used to measure pressure head at the inlet of the turbine. A constant pressure head was maintained by a control valve connected at the outlet of the centrifugal pump. Water from the turbine outlet was allowed to flow back to the water tank. A generator was directly coupled to the runner shaft to apply the electrical load.

Fig. 2. Photograph of experimental setup.

The experimental setup is already discussed in detail under the previous study carried out by the authors [20,21].

3. Range of parameter

In the present study, erosion of Pelton turbine buckets due to silt was investigated. Sand sample was collected from the river Bhagirathi (India) near the head works of Maneri Bhali Hydro Electric

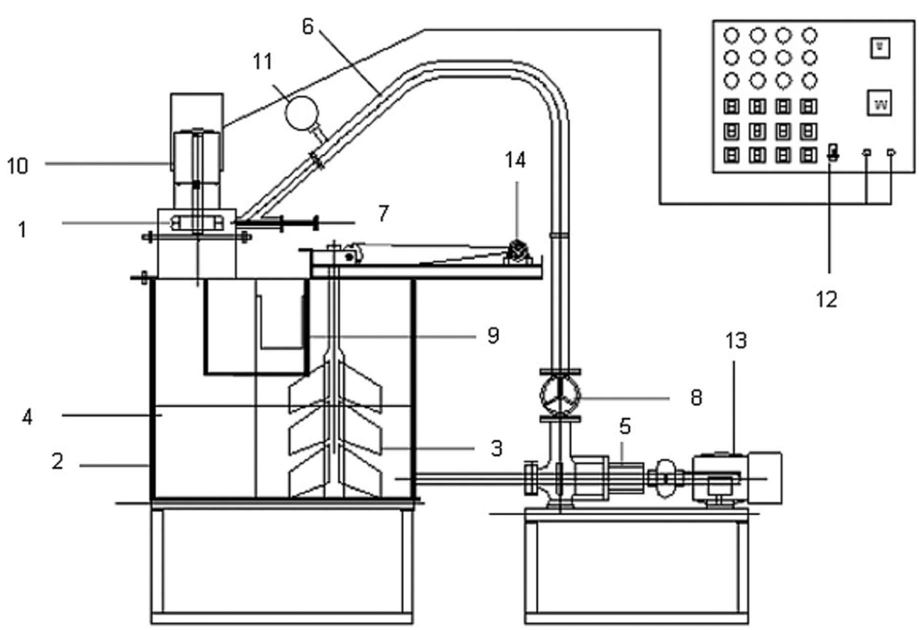

Fig. 1. Schematic of experimental setup. Description: 1: Pelton turbine runner, 2: Water tank, 3: Stirrer, 4: Cooling jacket, 5: Service pump, 6: Penstock pipe, 7: Spear valve, 8: Control valve, 9: Channel with weir, 10: Generator set, 11: Pressure transducer, 12: Control panel with ballast load, 13: Driving motor, and 14: Motor for driving stirrer.