Study of Silt Erosion Mechanism in Pelton Turbine Buckets

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ABSTRACT: An experiment was carried out in order to explore the mechanism of erosion of a small size Pelton turbine under actual flow conditions in the current study. Silt samples were taken from the head works of one of India's most silt-affected hydropower plants. The process of silt erosion on Pelton turbine buckets for different silt sizes was investigated using silt parameters (silt particle size and silt concentration). Hot areas were discovered in the initial half of the experiment when the silt content was high. The second phase of the experiment involved studying the erosion mechanism for tiny metal specimens that were fixed to the hot areas. According to the findings, silt size is a significant factor in erosion, and material removal from the surface is caused by plastic deformation and ploughing of the surface. Examination of different explanations for the decreased performance and efficiency of hydro turbines owing to silt erosions, as well as appropriate corrective techniques for such erosion offered by various scientists.

KEYWORDS: Erosion Mechanism, Hydraulic Turbine, Nozzles, Pelton Wheel, Silt Erosion.

1. INTRODUCTION

Silt erosion of hydro turbine components is a key hindrance to hydro power plant efficiency. During rainy seasons, a high concentration of unsettled silt particles passes through the turbines, causing erosion of turbine components. These issues are particularly prevalent in power plants that are run-of-river in nature[1]. The problem of silt erosion in turbines is exacerbated if the silt contains a high percentage of quartz, which is highly hard and can severely damage turbine components. In impulse turbines, the bucket, nozzle, and needle are the most susceptible elements, but in reaction turbines, guide vanes, face plates, runner blades, and seal rings are vulnerable. In the literature, certain erosion models based on experimental examination of erosive wear have been published [2]. The erosion rate is expressed in terms of the amount of material removed per unit mass of erodent affected [3].

The investigators implicitly imply that the degraded area's size and particle concentration are unimportant. In practise, monitoring turbine erosion is challenging, and there is no standard technique for measuring turbine component degradation. The specimens used in laboratory testing are tiny and have a consistent form or are flat plates. As a result, the effect of erosion can be measured in terms of weight loss, volume loss, surface roughness, or dimensional deformation [4]. The process of erosion over a Pelton turbine bucket is challenging to analyse using the techniques available in the literature since the diameters of turbines in actual hydro power plants are huge and the runner blades or buckets are not flat. The following is a broad discussion of erosion mechanisms. The material is removed by the cutting mechanism when particles impact the surface at a small impingement angle.

When abrasive grains contact a surface at a tiny impingement angle, they roll or slide, causing erosion by abrasion or cutting [5]. The substance is removed by scouring or scraping the particles' sharp edges, resulting in small track-length scars. A water reservoir is generally positioned at some height above the Pelton turbine when it is used to generate power. The water then travels via the penstock to specialised nozzles, which deliver pressured water to the turbine. The penstock is equipped with a surge tank that absorbs rapid changes in water pressure that might cause pressure anomalies. The Pelton turbine is an impulse turbine, as opposed to other types of turbines that are reaction turbines. This simply implies that rather than moving as a consequence of a reaction force, water causes the turbine to move by creating an impulse [6]. There were two primary sorts of cutting mechanisms proposed. While testing on a pin on disc wear test rig, the following mechanisms were discovered: a micro cutting mechanism and (ii) a wedge build up mechanism. Ploughing is a term for flake-like debris. Ploughing has been discovered to be a less efficient method of agriculture. Material removal in an effective manner. Underneath the surface of the water, Significant plastic deformation occurs on the abraded surface. When both wear mechanisms are involved, material loss is quicker. Fig. 1, Illustrates the pelton wheel turbine used to convert hydraulic energy in to kinetic energy.

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This erosion mechanism is comparable to surface fatigue erosion on rolling surfaces. The surface cannot be plastically deformed when particles strike it with a significant impact angle but low speed. Instead, after repeated striking, the surface becomes weak due to fatigue action, and fractures appear. After many hits, the particles will be separated from the surface [7]. The goal of this inquiry was to learn more about the mechanism of erosion damage on Pelton turbine buckets. Correct remedial actions for proper treatment of the bucket surface at the manufacturing stage might be considered based on the findings mentioned in this study. The Pelton turbine runner was the most essential element of the arrangement. The trials were conducted using a Pelton turbine runner with a pitch circle diameter of 250 mm and a nozzle diameter of 12 mm, fitted with 18 buckets. Brass buckets were chosen as examples in order to obtain a detectable quantity of erosion in a short period of time. To hold the needed amount of water and mix silt with water, a steel tank 600 mm long, 510 mm wide, and 780 mm deep was utilized. For grading the silt sizes, several sizes of sieves with a 20 cm diameter, spun brass frame, and highest quality wire meshes of 355 mm, 215 mm, 180 mm, and 90 mm sieve apertures were utilized. In the tank, the necessary size range of silt was combined with water to create a silt water combination that met the experiment's requirements [8]. Under the proper operating conditions, the same silt water mixture was cycled through the turbine. In the center of the tank, a stirrer with a 0.5 h p motor was installed. During the trials, it was kept running continuously to provide a consistent combination of silt and water. A centrifugal pump was utilized to produce the needed hydro potential head to be applied to the turbine under the correct circumstances.

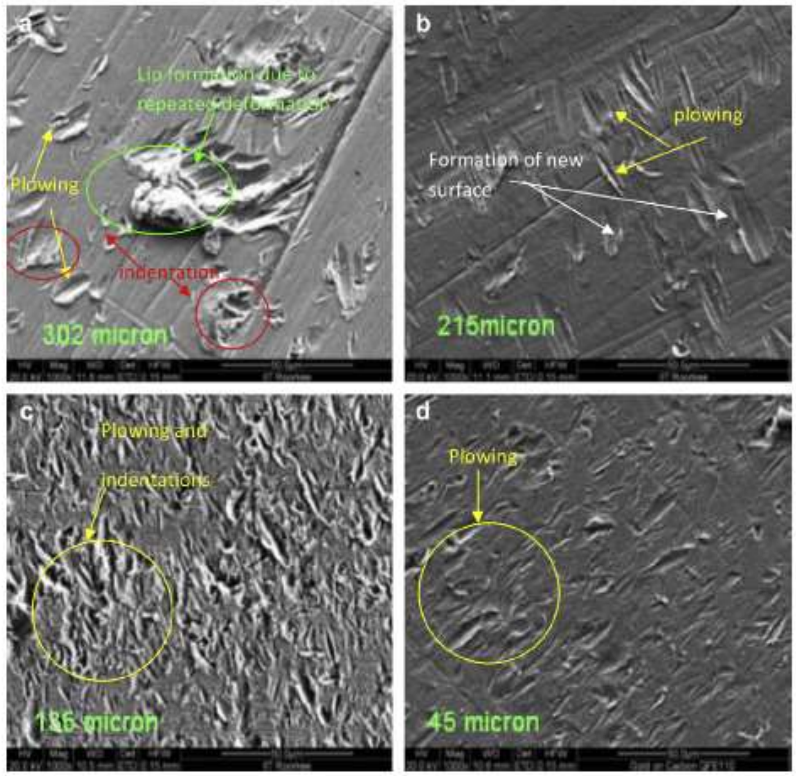

Fig. 2: Illustrates the erosion over plate of the Pelton wheel turbine at micro level [9]**.**

Fig. 2, Illustrates the erosion over plate of the pelton wheel turbine at micro level the silt water combination was supplied to the turbine by a centrifugal pump. Before hitting, the silt water combination was pushed via a nozzle by the turbine bucket. To convert the hydro potential head to a velocity head, the nozzle was attached to the end of the penstock. The pressure head at the turbine's intake was measured using a digital pressure transducer. A control valve attached to the centrifugal pump's output maintained a constant pressure head. Water was permitted to flow back to the water tank from the turbine output. To apply the electrical load, a generator was directly connected to the runner shaft. The severely eroded portions hot spots on the Pelton turbine bucket were discovered in order to examine the mechanism of erosion in different sections of the turbine bucket. To avoid hot spots in a shorter duration of turbine operation, a coating of readily worn out material was applied to the bucket surface. A thin coating of nickel was applied to the surface. The silt and water combination was made with a 5% weight concentration of silt. The fine form of silt molecules will cause erosion in the region of the pointer, but not enough in the buckets. When contrasted to needles, coarse particles will substantially damage the buckets. The silt pieces' intermediate size will erode the needle as well as the buckets. In terms of increasing the applied magnitude, the multi-scale replica is a brave step**.** Fig. 3, Illustrates the particle separation at high speed of jet coming on plate**.**

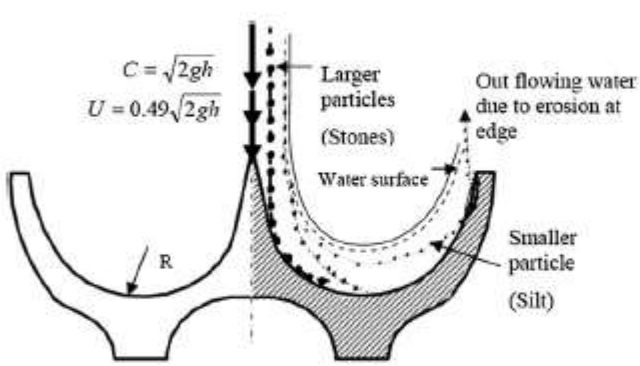

Fig. 3: Illustrates the particle separation at high speed of jet coming on plate [10]**.**

An important attribute for the drawing of optimal turbines in the environment of the siltladen hydraulic situation of growing value is the ability to predict a degradation of hydraulic mechanism components. The research revealed that undertaking was simply the first step toward improvement. That was a significant amount of work on this subject. A parametric analysis of the circle that shifts the thickness of the band has been completed, and it should be able to enhance the loop. Pelton wheel exhaustion assessment should be possible. It is also possible to predict the life cycle of a Pelton wheel by guiding the experiment. Because of the pail and jet link, destruction happens in the first and second zones.

2. DISCUSSION

The third and fourth zones of cavitation begin as a result of the bucket's uneven border, which influences flow bifurcation and the formation of vortices. The zone five form of cavitation is caused by monsoon erosion. The sixth and seventh types of cavitation zones are caused by an incorrect bucket release angle. Because of the pail and jet link, destruction happens in the first and second zones. The third and fourth zones of cavitation begin as a result of the bucket's uneven border, which influences flow bifurcation and the formation of vortices. The zone five form of cavitation is caused by monsoon erosion. The sixth and seventh types of cavitation zones are caused by an incorrect bucket release angle. To assess the necessary impacts of the characteristics on the bucket surface, a continuous improvement tracking system is required. This study can provide information regarding the effect of erosion on Pelton to turbine manufacturers, engineers, and plant executives. Based on the features of the water flow bifurcation in the bucket, the influence of erosion on several components of the Pelton pail was discovered. The metal turbine components have been subjected to plastic deformation. The development of cracks for material removal is due only to coatings. The main source of erosion in the middle is the impact of sat particles on the plane, which results in the creation of bowls. This survey will be beneficial to material specialists and power plant officers. The two components of the Pelton turbine, needle tips and nozzles, are exposed to the increased kinetic energy of the water. Nickel and chromium levels should be in the range of 13 to 16 percent and 4 to 5 percent, respectively. To prevent severe silt erosion, a ceramic coating is placed to the needle tip and nozzle circular. The commercial usage of ceramic as a coating material for Pelton components is a research goal. To investigate the effect of erosion, experiments were carried out on a prototype Pelton turbine model with a size of one to eight. Plastic distortion has been experienced by metal turbine components. Coatings induce cracks to develop, which allow material to be removed. The hit of solid particles on the plane, which creates bowls, is the primary cause of erosion in the center area. The Pelton turbine's needle tips and nozzles are exposed to the water's increased kinetic energy. Nickel and chromium levels should be between 13 and 16 percent and 4 and 5 percent, respectively. To prevent significant silt erosion, a ceramic coating is placed to the needle tip and nozzle circular.

To investigate the effect of erosion, experiments were carried out on a prototype Pelton turbine model with a size of one to eight. Six different types of composite materials were tested in a similar manner in order to choose the best one for future testing. The finest coatings material is a hard ceramic tungsten mono carbide and a softer CoCr metal binder. The high velocity oxygen fuel technique covers WC-CoCr. To reduce silt erosion, a Cr_2O_3 coating is applied using a plasma sprayed technique. As an erodent, silt particles with diameters ranging from 90 to 180 mm are employed. Scratches caused by silt particles may be observed in abundance on the specimen. The length of cut in this example, however, has been reduced from the length of cut attained in previous situations. Silt particles appear to be entrenched in the specimen surface and raise a lip along the silt particle flow route. Smaller particles create micro indentations with shorter lengths and become lodged in the surface, losing their kinetic energy, as shown in the micro graph. The approaching jet may cause the imbedded silt particles to spill out of the substrate's surface.

When compared to the specimen put at the Pelton turbine bucket's intake, the scratches caused by erosion have shown more on the specimen surface. The material from the specimen surface seems to be pushed sideways along the silt particle's transit route. This depicts the material removal ploughing mechanism. On the specimen's surface, minor scars and indentation marks may also be seen. Most erodent particles appear to travel near to the splitter and lose kinetic energy at the intake, resulting in a reduced impact force on the output surface. As a result, material removal at the outlet surface is reduced. In the case of erodent in the range of silt particles, the target surface is sheared, and scar lines left by the sharp edges of the erodent are visible on the surface. Ploughing and the creation of a new surface appear to be the modes of erosion. For silt particles in the size range, a micrograph of the specimen put at the outflow of the Pelton turbine bucket was taken. The outflow of the surface is extensively eroded, as can be seen in the image. Ploughing and indentation by the erodent appear to be the primary method of erosion.

It's possible that the smaller scars are owing to the tiny particles' lower kinetic energy. For the same concentration levels examined, the number of particles is higher for smaller size particles. However, when compared to the specimen put in the bucket's inlet, the same size erodent induced less erosion at the inlet than at the outlet. The erosion process is discovered to be distinct from all of the previous examples of erosion at the intake and outflow of the Pelton turbine bucket. The erodent particles appear to have impacted the target surface at a normal impact angle in this example, resulting in craters. The surface looks to be pushed deep into the surface at these points. Pit holes may be visible in certain sections, and the material from these regions appears to have been lost as wear debris. It appears that erosion occurred at a faster pace along the bucket's depth than at the entrance and outflow. Scars of varying lengths appeared thickly throughout the surface as well. Based on the findings, it can be assumed that larger particles flow at faster velocities and strike at higher impact angles along the bucket's depth, perhaps causing pits and craters on the surface. The shearing effect of the silt particles' surface induced erosion when the particles flowed close to the splitter. Smaller particles, on the other hand, have a lower relative velocity in relation to the water jet and flow with it, generating abrasive erosion. Plastic distortion and indentation have degraded the tip of the splitter. On the splitter tip, overlapping craters were discovered, and erosion was caused by both plastic deformation and ploughing at the surface along the bucket's depth. The Pelton turbine has a straightforward design. A rotor is a revolving shaft with a big circular disc placed on it. Cup-shaped blades known as buckets are equally placed around the circumference of this circular disc. The buckets are usually positioned in pairs around the rim. The nozzles are then placed around the wheel and serve to introduce water into the turbine. Water jets emanate from these nozzles, tangential to the turbine's rotor. As a result of the impact of the water jets on the buckets, the turbine spins.

3. CONCLUSION

Based on observations, it is expected that coarser particles flowing at a faster pace than the water jet formed pits and craters along the bucket's depth at a greater impact angle. The erosion is caused by coarser particles flying at a faster speed in the area of the splitter. This might be owing to the shearing effect of the silt particles' surfaces. Smaller particles float along the water jet, creating abrasive erosion along the bucket's depth and outflow. Due to their reduced kinetic energy, these particles appear to be lodged in the surface at the bucket's intake and are blown away by the oncoming stream. The splitter tip has been found to have been degraded by plastic deformation and indentation, with overlapping craters. However, erosion along the bucket's depth was shown to have occurred due to both plastic deformation and ploughing.

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