

Sediment in Nepalese hydropower projects

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Abstract

Nepal has huge potential for hydropower due to glaciers in the Himalayas, regular monsoon rain and local topography. Most of the hydropower plants in the Himalayan Rivers are affected by excessive sediment which decrease the capacity of reservoir and cause erosion of turbine components. The erosion of hydraulic machinery depends on operating environment, properties of eroding particles and substrates. The shape, size and mineral content of sediment vary at different locations of the same river system, depending on distance traversed by particles, gradient of the river and the geological formation of the river course and catchments area. Khimti hydropower project, Nepal represents typical high head power plant in the Himalayan River which is affected by river sediment. The laboratory erosion tests of turbine material revealed the dependence of erosion rate with respect to mineral content. Sediments in the hydro power projects are normally considered as burden, but there is a scope of industrial use of these sediments deposited in the reservoir or flushed from settling basins.

1. Introduction

Nepal is gifted by nature in terms of water resources because of the snow capped mountains, glaciers, regular monsoon rain with an average annual precipitation of 1503 mm and annual runoff of about 224 billion cubic meters through 6000 large and small rivers/rivulets. The topographical condition and runoff have made Nepal rich in hydropower with 83000 MW capacity. Despite of Nepal's enormous hydropower potential, only about 550 MW has been harnessed. An important challenge in developing hydropower projects, is the difficulty in operation and maintenance of the plants due large quantities of sediment with hard abrasive mineral/rock fragments in Himalayan Rivers. Excessive amounts of sediment in such rivers are due to presence of weak rocks and extreme relief and hence sediment management has become primary importance for the safety, reliability and life of infrastructures. Even with sediment trapping systems, complete removal of fine sediment from water is impossible and uneconomical; hence most of the turbine components in Himalayan Rivers are exposed to sand-laden water and subject to erosion, causing reduction in efficiency and life of the turbine.

The issues of sediment in the hydropower project with emphasis on turbine erosion and case study of 60 MW Khimti project are presented in this paper. The variation of hard mineral content in the sand samples from different rivers of Nepal and erosion rate estimated from laboratory measurement is reported. Even though sediment is generally considered as burden in the hydropower plants, some issues for its use for economic benefit are raised in this paper.

2. Sediment problem in Hydropower Plant

The sediment management is challenging discipline in civil engineering especially in the Himalayan region. The storage capacity of reservoirs decreases due to accumulation of sediment. Settling basins extracts clean water by settling particles, which are then drained back to the river by flushing system. The efficient settling and flushing of particles discharge excessive sediment into the river intermittently and on the other

hand, poor system causes erosion of turbine components. The erosion of turbine component depend on: (i) eroding particles - size, shape, hardness, (ii) substrates – chemistry, elastic properties, surface hardness, surface morphology, and (iii) operating conditions – velocity, impingement angle, and concentration and like that. Depending on the gradient of the river and distance traversed by the sand particles, the shape and size of sediment particles vary at different locations of the same river system, whereas mineral content is dependant on the geological formation of the river course and its catchments area.

The history of sediment data collection in Nepal goes back to 1963 in Karnali river basin in relation to hydropower development. Marsyangdi hydropower project started regular monitoring of sediment and its effects on turbines since 1989. Sedimentology has emerged as important task in most of the recent hydropower projects in Nepal. Even though Jhimruk, Khimti and some other power plants are monitoring sediment and its effect, still there is a lack of information for scientific analysis for estimation of its effects. Except Kulekhani, all others are Run-off-River (ROR) projects and all of them have effect of sand erosion. Francis turbines of Panauti, Trishuli and Sunkoshi are eroded frequently and mostly refurbished by welding and grinding. Both the Francis and Pelton turbines of Kulekhani reservoir are relatively less eroded compared to ROR projects because coarser particles settle down before reaching the intake. Even with the well designed sediment settling and flushing system, power plants like Marsyangdi, Khimti and Jhimruk are having severe erosion problem. The main strategy to combat erosion effect in Nepalese power plants is repairing the eroded turbines by welding and coating with erosion resistant hard materials.

3. Case study of Khimti I Hydropower Plant

Khimti I Hydropower Plant (KHP) represents a typical power plant in Himalayan Rivers with high river gradient and heavy monsoon flow with high sediment concentration of hard abrasive particles. Nearly 50% of its catchments area is in the Middle Mountain region, which is formed as a result of local tectonic movements, river down cutting and sedimentation. In Khimti River, average concentration of suspended sediment was recorded in between 13 to 1244 ppm (parts per million) in 1994-95 monsoon. The maximum recorded concentration was 8536 ppm, but 20000 ppm is used as design value for design of sediment settling and flushing capacity. Two parallel sediment settling basins are designed to exclude 85% of particles with fall diameter of 0.13 mm and 95% of particles with fall diameter of 0.20 mm (Bishwakarma, 2003). Minimum discharge of 500 liters per second is released in dry season to maintain downstream water requirements. With the gross head of 684 m, KHP has 60 MW installed capacity and approximately 350 GWh annual energy (5X12 MW Pelton units with rated flow 2.15 m³/s). The power plant has been in commercial operation since July 2000 and the effect of sediment has already appeared in runners and needles and spare runners are already changed in all units.

The damage in the turbine components were inspected in July 2003. After 1 year of operation (about 6000 hours), significant amount of erosion had appeared in turbine bucket and needles. Even though the settling basin with Sediment Sluicing Serpent System (S4) is performing satisfactorily, huge sediment load with fine particles pass through turbines causing severe erosion. The damage of needle and bucket of Pelton turbine due to erosion are shown in figure 1(a, b). The erosion of needle and nozzle destroys the jet and reduces the performance of the turbines. The reduction of bucket thickness is critical due to strength and hence the reliability of the component. The sharp edge of the splitter has blunted and the width became approximately 4 mm. With this 1% loss of relative efficiency can be expected in these runners, which is significant loss of revenue for this power plant. In addition, the maintenance cost also increases. HPL has tried to minimize the effect of erosion by spraying hard ceramic coatings in the bucket and needle surface at the cost of around US\$ 25000 per runner, but initial inspection of the coating have not shown promising performance.

Large quantity of sediment settled in the settling basin are flushed to the Khimti River at downstream of the head works, where discharge is low. The unnatural disposal of this sediment at high concentration causes environmental imbalance in the river. At present this sediment is a burden for KHP, but if it can be managed properly, it can be converted into wealth.

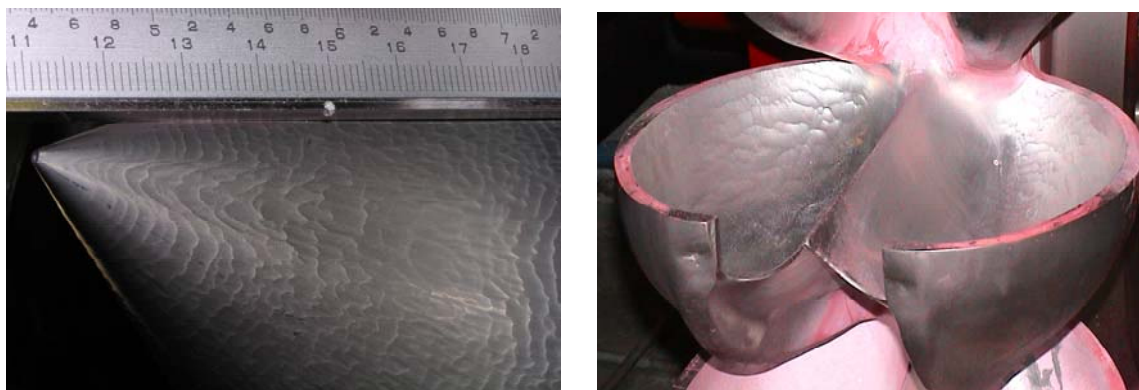


Figure 1: Eroded Pelton turbine component of KHP1 (a) needle (b) bucket

4. Erosion test

The effect of river sand on turbine blade material is investigated on high velocity test rig at Kathmandu University (KU). The description of test rig can be found in Thapa and Dahlhaug (2003). Sediment samples are collected from Nepalese rivers of different river basins, which include sections of same rivers along their length, tributaries, waterway of the existing power plant and proposed power plant locations and so on. All the sediment samples are studied under the binocular microscope to identify quartz content and their shape. The erosion tests are carried out on turbine material 16Cr5Ni stainless steel.

5. Results and discussion

The average erosion rate from laboratory test with sand sizes 425-300, 300-212 and <212 μm are presented in figure 2 along with corresponding quartz content in sand. The rivers in the Koshi basin have more than 60% quartz contents in average. Several of the samples in this basin are from rivers originating in the high Himalayas. Compared to east, quantity of quartz in western part are varying, but certainly less than that of east. Some of these rivers originate in Middle Mountains and hence local geology may have great influence in the quartz contents. The quartz content in Jhimruk is highest but corresponding erosion rate is small. Bagmati basin, which is in the middle of the country have quartz content in between eastern and western basins. The result shows some trend along length of the country, for instance the erosion rate is almost equal for all the samples in their respective basins in east and west. Eastern basins have higher erosion rate compared to western basin, which can be justified by higher quartz content. The fluctuation of erosion rate in the middle region could be because of origin of rivers in the Middle Mountains with most unstable landscape; hence the properties could be highly localized with fresh sharp edges. Once the particles traverse a certain distance, it will be rounded off and lose its eroding capacity, which can be seen in the result of Bagmati River close to origin and at Gaur. This study hinted that besides quartz content in sediment, the shape of particles could also have significant influence in erosion rate. The analysis of particle shape by image processing technique is under progress at KU. The relation between shape of the particles with geographical locations, mineral content and erosion rate and so on can be used for ranking the erosivity of different existing and forthcoming power plants.

There are many sources of sand in the earth, but whatever is the source, they are rich in quartz grains, which are formed by weathering of rocks such as granite. The silica is physically stable and it makes sand valuable for several applications such as construction, foundry, production of glass and abrasive materials and so on. Though there are enormous sources, it could be a costly commodity due to recovering, processing and transporting cost. Environmental impact has great price because of unplanned extraction of sand from river channels and flood plains. Mostly sand are used for construction purpose in Nepal, which are basically supplied by river channels. The degradation of river system at Kathmandu valley and other part of the country is basically because of extraction of sand. The estimated industrial consumption of sand in Nepal is about 150 tones of foundry sand and 20 tones for sand blasting, which is basically imported.

Sediment in the river is considered as hurdle for the development of hydropower plants in Nepal. On the other hand, its economic value is never thought of. The mineral analysis of sand samples indicates possibility of its use for industrial purpose. With in the range of 1 km from the Sunkoshi power plant, sand is extracted from the Sunkoshi river bed and supplied to Kathmandu valley. If such extraction can be coordinated with the settling basins at power plant, the burden can be used as a by-product.

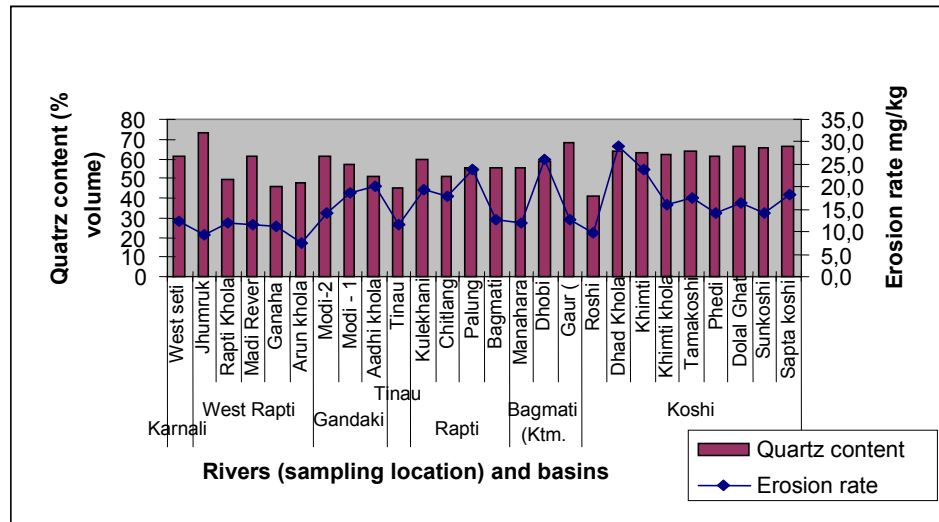


Figure 2: Quartz content from mineral analysis and erosion rate from laboratory test from corresponding sand samples

6. Conclusion and recommendation

Sediment is a problem for the development of hydropower plants in the Himalayan region and in Nepal. Sediment management is important for longer life of reservoir and turbine components. The buckets and needles of Khimti Power Plant are eroded by particles less than 0.2 mm due to high quartz contents. Higher amount of quartz content gives higher erosion rate and the percentage of quartz, shape of the particles also has influence in erosion rate. The analysis of sand in term of mineral content and their shape shows possibility of using minerals present in the sediments from power plant as a by-product, which could have economic importance. Environment activist should create awareness for impact of disposing unnatural concentration of sediment in river and possible benefit from better management of sediment in power plants.

Acknowledgement

The authors sincerely acknowledge Mr KB Bisht and Ishar M Desar of Himel Power Limited, Nepal for their help for inspection visit at KHP. First author duly acknowledge Prof. Hermod Brekke and Ole G Dahlhaug for their guidance and support for this study. The assistance of colleagues BB Chhetri and other staff of KU for the experiment and analysis are highly acknowledged.

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