Abstract Book

International Symposium on

Current Research in Hydropower Technologies

CRHT – X

April, 2020

Welcome message by Prof. Dr. Bhola Thapa

Dear International Partners, Participants, Authors/Presenters, Media Persons and KU and TTL family,

I welcome you all in the 10th International Symposium in Current Research in Hydropower Technology 2020.

CRHT symposium has been moving ahead together with Turbine Testing Lab (TTL) of Kathmandu University (KU) and it has been witnessing the 20 Year journey of Turbine Testing Lab's accomplishments and contributions for hydropower development in Nepal.

KU was envisioned when political awareness of Nepalese citizens was increasing during the single-party Panchyat system. Since the pre-1990 era to now, it has passed through the different political and social journey. The university was conceptualized in a single political party and monarchy system, got approval from the first elected parliament of the multiparty democratic system of Nepal in 1991, and established as Kathmandu University with a lot of dreams and plans.

Turbine Testing Lab was also envisioned as a specialized lab for Research, Education, and Development of Hydro Turbine, as an opening for private investment even in Hydropower sector when liberalization in the economy was national policy. The planning and construction of TTL took place when the whole country was in Maoist insurgency. Even though that was a difficult period, there was a greater opportunity and expectation for overall social and economic development after political settlement.

After a downfall of the monarchy and settlement of the Maoist movement, even though youths were politically aware and they were educated, they could not be used for the economic development of the country. Rather most of the youths went for foreign employment in East Asia, the Middle East, and western countries. Around 4 million youth are in foreign employment besides India. Unfortunately, this human strength could not be utilized for national development and utilization of natural resources (hydro being one of the important resources) of the country.

Fortunately, higher education in the engineering profession was developing in Nepal in the same period, where KU emerged as a model institute for higher education in Nepal. The research was introduced and became an integral part of engineering education and facilities like TTL were established with support from the government, private sectors, and foreign donors.

It was not only to establish a specialized laboratory, but research was introduced through Graduate and PhD level education. KU has already produced high-quality graduates through TTL even though the journey of

TTL is not very old. It has significantly contributed to the research of hydro turbines especially sediment related problems. It has shown its presence in a specialized research area globally. TTL has developed research culture and produced a critical mass of quality graduates to address the global needs of highly trained manpower for which CRHT has been a showcase for its activities and achievements.

Nepal is in the difficult crossroad of the electricity industry. Until a few years back, we were in load shedding for almost 20 hours a day. But now, we are exporting electricity to India at a certain time of the year. In the coming years, we will be more in exporting position. Several new projects are under development. Once they start producing electricity and we will have surplus electricity, we will be indifferent management challenges. Electricity price is also lowered during the lockdown period, maybe the first time in history!

Nepal has already entered into a federal state with 3 tiers of government. The responsibility and authority of the utilization of natural resources (including hydro) will also lie in different levels of government depending upon the size of the project. Access to electricity to all in their area is the primary goal of all local governments.

Nepal government has done a study in 2018 entitled "Study and analysis of optimal distributed generation for access to grid electricity for all in five years with participation from the local-level government". Among several objectives of the study, two main objectives are: firstly, to study all the 753 municipalities and identify the optimum extension path of the Transmission and Distribution network to increase access to energy as well as integrate the proposed Distributed Generation plants and secondly, to find small-scale renewable sources of electricity generation in these municipalities that can be developed and operated in a sustainable manner with access to the grid. NEA Engineering and Consultancy Company did the study for National Planning Commission Nepal for the hydropower projects within the executive jurisdiction criteria of the local governments, ranging from 500 kW to 1000 kW. There are 277 local bodies where hydropower projects can be developed. They have identified 456 potential sites where projects of 500-1000 KW can be developed with the Viability Gap Funding (VGF) scheme. Total power potential in these 456 projects is expected 383.56 MW, which is much more than what we have developed through micro-hydro projects around the last 60 years.

The development of hydro projects under local government enhances the governance capabilities of local governments. In this context Norwegian experience of municipalities in energy management during the period 1907 - 1945 is a very interesting lesson to be learned. During the same period, Water Power Lab was established at NTNU. TTL was established just before municipal and village governments were included in a new constitution and established in Nepal. In Norway, the municipalities also developed local electricity utilities. Gradually most of the Norwegian homes got electricity supply. But, many municipalities bankrupted in the process. The capacity for the project and financial management should be established or improved in the case of the local government of Nepal to avoid the situation as in Norway.

We were optimistic about Hydropower development and associated research activities in association with local governments in Nepal. Before we entered to utilize, federal 3 tier government system for boosting the electricity sector, not only in Nepal, but the entire world is halted by COVID 19 pandemic. Now for some years, the priority sector for local governments may be public health compared to infrastructure projects.

Wuhan University, Korea Maritime and Ocean University in Busan, Norwegian University of Science and Technology in Trondheim, Indian Institute of Technology Roorkee, and KU are in close cooperation and collaboration for research and education in hydro turbine technology. We are also in the process of establishment of Hydropower Research Center for Himalayan Region (HRCHR) for wider collaboration. COVID 19 was originated from the place of one of our active partners. Even though all partners are affected by COVID 19 lockdown, our enthusiasm is intact and we are committed to a bright future for cooperation.

The Ambassador of Republic of Korea to Nepal H.E. Park Young-sik in an interview in the local magazine New Spotlight, in March 2019 shared important information for infrastructure development of Nepal including Hydropower. He said, "From 1966-1979, Korean nurses and minors went to Germany for employment. In the 1970s and 80s, about 2 million of Korean workers went to oil fields in the Middle East. Their money was not only used for individual expenses but also for Korea's national economic development". The situation in Nepal is now similar. Several million Nepalese are abroad for employment and the country is highly dependent on their remittance. Many of them will return home on their own or due to a forced scenario of foreign employment after the post COVID19 condition. Most of these people are from villages and rural areas of Nepal. They might not have technical skills as Gulf return Koreans may have. Foreign returned Nepalese workers at least have experience in working in the organized sector. Initially, they might be compelled to work in the agriculture sector, but we might take this opportunity to modernize Agriculture, and mechanization is the best tool for modernization. This could also be our fast track journey to industrialization. If small manufacturing industries can be developed in different parts of the country, those facilities can be utilized to even produce small hydro components including turbines. I know that the history of turbine industry development in Norway also has its root in the Agri-machinery company, Kavaerner.

We might need to give training like machining, welding, condition monitoring, Operation and Maintenance to the foreign returned youths and engage them in the industrial sector. These activities will, in the long run, create new opportunities for TTL. TTL will continue to excel to solve sediment induced problems in hydro-mechanical components. At the same time, it will open avenues of research in other hydraulic machineries and hydraulic components like pumps and valves. Similarly, we have also started education and research in other associated areas of flow measurement systems, efficiency measurement systems, condition monitoring, and automation, and so on. TTL is a firm believer interdisciplinary in education and research and hence always playing a facilitating role in engineering and design as multidisciplinary activities complementing each other. For our sustainability and survival of the electrical energy sector in the country, we need to work on the alternative use of electricity we produce and green energy; Hydro-to-Hydrogen is our special interest.

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Our 10th Journey of CRHT has been very different than others. We started as Current Research in Hydraulic Turbine symposium to share and record year-round activities of the researcher, but in these 10 years, it has been international in true scenes and expanded as Current Research in Hydropower Technology keeping the same acronym. We were forced for this virtual mode of the symposium this year due to COVID 19. I once again welcome all participants, contributors, and partners in the 10th International Symposium of Current Research in Hydropower Technology 2020. I thank you all for your kind support for our decade long journey. I believe the virtual mode of the symposium may be more effective and sustainable in the coming days. There could be broader participation and it may have wide dissemination. We are only keeping a social distance but all essence of CRHT is intact.

International Association of Hydraulic Research (IAHR)-Asia entrusted us for the Third International conference of IAHR Asia on Hydraulic Machinery and Systems. TTL is hosting this 3rd International Conference in 2021 in Nepal. This was announced during the 2nd Int Conf. of IAHR-Asia 2019 in Busan. I wish the situation in 2021 will be better and we will be able to welcome researchers, academicians, and professionals all around the world to participate in IAHR Asia 2021 in Kathmandu with great enthusiasm and joy.

Namaste and Stay Safe!

Dr. Bhola Thapa

Professor, Department of Mechanical Engineering, Kathmandu University

Chairperson, Organizing Committee, CRHT-X

28th April 2020, Kathmandu, Nepal

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Design of a reversible pump turbine

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Abstract. The design of reversible pump turbines for the purpose of retrofitting existing hydropower plants has been investigated. A preliminary design for further analysis with computational fluid dynamics has been made. As this is current work, the project has not yet been finished, and the author does not yet know if the resulting pump turbine has good efficiency or not.

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Analysis and improvement of a mathematical turbine model

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Abstract. A mathematical turbine model is necessary for dynamic and transient analysis of hydro power plants, also in the early stages of a project. Such models can be based on a first principles approach or on empirical data, many models are a combination. A first principles approach is practical when spec c laboratory data are unavailable, for example in the design phase of a new plant. These models can easily be simplified and linearized without losing physical correctness or generality, even though accuracy may vary when applied to a specific system.

The model studied in this work, was developed several years ago from the Euler turbine equation and the opening degree definition and has later been modified and linearized for simple implementation into simulation software. The model captures losses for varying rotational speed quite well but struggles to capture losses for varying ow rate. The hydraulic efficiency is over-predicted for ow far o the design point, because irreversible hydraulic loss phenomena such as 3D turbulence and dissipation are not inherently included in this 1D model. Empirical relations or Hill charts for exact t to a measured turbine can be included, however generality is then lost.

This paper analyzes and discusses the mathematical model compared to laboratory measurements, highlighting its performance in predicting the efficiency of best efficiency point (BEP). A mathematical improvement based on turbine data is presented and implemented for three specific Francis turbines. The possibility to generalize the procedure is also discussed.

Paper ID: CRHTX-2

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Average-Value Modelling of Machine-Converter Systems for Variable Speed Hydropower

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Abstract. The development in frequency converter technology has enabled the use of converter-fed synchronous machines for variable speed operation of hydropower plants. This is beneficial due to improvements in hydraulic efficiency and increased flexibility for the power grid. Because system studies involving such machine-converter based system can be quite computational expensive, there is a need for more simplified models. Average -value models are effective tool for simplifying machine-converter systems and may execute simulations magnitudes faster than detailed models. This paper will present the work done in the preliminary work for the author's master thesis. The focus of this work was to implement an average -value model for a machine-rectifier system and to assess the accuracy of the developed model. In the successive master thesis, this work will be expanded to a variable speed hydropower plant, consisting of a full-rated converter-fed synchronous machine.

Keywords: Variable Speed Hydropower, System Studies, Computer Modelling, Average-Value Modelling.

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Design of a contra-rotating booster pump

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Abstract. In Norway there are many existing hydropower plants located on sites suitable for pumped storage. By exchanging the turbine with a reversible pump turbine, the retro fitting of the plant can become an economically viable investment. However, the problem of cavitation in the reversible pump turbine must be solved. In the case of Roskrepp hydropower plant installing an axial booster pump has been proposed as a solution. To reduce the swirl of the ow after the booster pump, a contra-rotating design would be beneficial. Alternatives that can provide a solution for lifting the booster pump up from the ow when the reversible pump turbine is in turbine mode is also being investigated. For this, utilizing the same concept as the rim-driven thruster can be an option. This paper discuss the strengths and weaknesses of these concepts with the intent of using the information for design of the booster pump.

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Design optimization of Francis turbine draft tube

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Abstract. This paper is based on ongoing master thesis work at NTNU with the topic: Design optimization of Francis turbine draft tube. The work is part of on-going research activities in the Waterpower Laboratory, Department of Energy and Process Engineering, NTNU and is done with collaborate research under H2020-HydroFlex-WP3 project. The focus is optimization of draft tube under variable-speed operating condition. Newly optimized runner design will be used to improve existing draft tube design. The object of the project is design and optimization of a high head Francis turbine draft tube for variable-speed turbine operation. The focus area is steady state operating conditions of the turbine. Ansys CFX is used for CFD calculations. Optimization results are not jet provided. The paper focus on motivation for doing design optimization, theoretical description of draft tube performance and description of the optimization method.

Keywords: Variable Speed Hydropower, Optimization, Draft tube, Francis turbines, HydroFlex

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Test of a Francis turbine with variable speed operation

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Abstract. The paper present the plan of procedure a model test of a Francis turbine runner designed for variable-speed operation (VSO). The new turbine is designed for having it operated more flexible and thus meet the increasing demand for o -design load at the European grid system. The purpose of the model test is to compare the results and verify numerical simulation related to the turbine. The model test will take place at the Waterpower Laboratory at NTNU, Trondheim, and the standard for model acceptance tests, *Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests*, will carefully be followed. Measurements included in the test are hydraulic efficiency, pressure pulsations, axial load and runaway speed. Raw data from the logging will be post-processed and results presented in Hill-chart and different contour plots related to the Hill-chart. Finally, the results will be compared with numerical simulations, and the design will be discussed based on this.

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Vortex generator's effect on trailing edge wake and fluid structure interaction

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Abstract. A study on effects vortex generators (VGs) have on the mitigation of vortex induced vibrations (VIVs) of hydrofoils is done at the Waterpower laboratory of the Norwegian University of Science and Technology as a part of a master's thesis. The VGs are placed close to the trailing edge of a blunt hydrofoil. A preliminary study was done on the VGs in order to find devices which would induce the strongest vortices and at the same time have the smallest drag. Vibration frequencies of the hydrofoil are measured using a strain gauge situated close to the trailing edge. This paper presents the final result of the preliminary study on the VGs and some initial results of the experiments performed on these devices.

Paper ID: CRHTX-11

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Pressure pulsations at Iveland Power Plant

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Abstract. Iveland 2 is a power plant located in the south part of Norway that was commissioned in 2016. Since the start up they have been struggling with loud noise and vibrations when the turbine is running at part load. In order to investigate what causes these vibrations, the pressure pulsations will be measured and analysed. To measure the pressure pulsation, two pressure sensors will be placed at the draft tube, and one at the inlet. In addition there will be done test with reduced air ow to the draft tube, to see if that affect the pressure pulsations. The measurement showed that the pressure pulsation were dominated by the Vortex rope. The reduced air ow at the air intake had little effect on the on amplitude. A spectral analysis of an audio recording showed that the frequency of the noise may lie in the range of 60-70 Hz.

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Signature Investigation of Typical Faults on Francis Turbines

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Abstract. The increased amount of intermittent renewable energy sources entering the electrical grid, together with a high price competition on electricity, requires new strategies for the operation of hydropower plants. Due to its reliability and regulating capacity, hydropower can provide stability to the grid and flexibility in the energy production. Consequently, the turbines are forced to operate at off-design conditions, which affects the dynamic stability of the turbine and can cause undesired hydraulic phenomena, that increase the risk of degradation and damages. At the same time, the extended use of digital systems in the hydropower industry has increased the focus on implementation of intelligent models and algorithms for fault detection and condition prediction. A real-time monitoring system enables an improved understanding of degradation of critical components. This may contribute to detect faults at an early stage and reducing potential downtime.

This paper will present the work done in the preliminary work for the author's master thesis. The focus has been to characterize the normal behaviour of a Francis turbine through amplitude and frequency analysis and suggest how to identify selected fault modes. Measurements of pressure pulsations have been conducted on the Francis rig at the Waterpower Laboratory at NTNU.

Keywords: Hydropower, Francis turbine, fault detection, pressure pulsations, sensors

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How to Avoid Total Dissolved Gas Supersaturation in Water from Hydropower Plants by Utilizing Ultrasound

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Abstract. In Norway, more than 10 hydropower plants are known to have caused biologically relevant levels of total dissolved gas supersaturation in the rivers downstream power plants. This phenomenon is causing fish kills due to gas bubble disease and have large impacts on the biodiversity. The gas supersaturation is often caused by undersized or blocked brook intakes creating turbulent flows and resulting in large amounts of air dragged into the tunnel. One possible solution to this problem is utilizing ultrasound for degassing water prior to releasing it back into the river system. Acoustic cavitation is known to have a positive effect on the degassing mechanism, and this paper is investigating whether ultrasound can be applied to create acoustic cavitation and avoid biologically relevant levels of total dissolved gas supersaturation from hydropower plants. The objective is to develop background knowledge for constructing an experimental setup in the Waterpower Laboratory at NTNU to investigate whether gas supersaturation can be decreased from power plants by application of ultrasound. Experiments exploring the behaviour of the degassing process at different ultrasonic frequencies and powers conclude that the most effective degassing occur at high power and a frequency of 24 kHz.

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Technical investigation of Nepalese electricity market – An econometric modelling approach

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Abstract. The article inspects the options of renewable energy technologies within the background of long-lasting power shortages that Nepal has been facing. The article examines the energy-related policies of Nepal and provisions to promote renewable energy technologies in Nepal and its regulatory framework. It analyses the pertinent energy policies related to energy generation and distribution. The research has focused on the context of the renewable energy sector of Nepal and its effects on future of renewable energy. The research has found a positive role in renewable energy policies for adoption of renewable energy technologies and poses a positive impact on electricity generation. The article has also examined the trend of electricity generation, peak demand and the resulted import to meet the gap. The almost linear electricity generation of NEA (Nepal Electricity Authority) (including generation of Individual Power Producers (IPPs)) against the steep gradient of peak power demand has ultimately increased the power purchase from India pushing towards unsustainability. It shows that energy policies are not up to the optimal. The research has further analyzed the impact of per capita GDP on electricity per capita by econometric modelling. The econometric model analysis has found, higher the GDP per capita would increase the consumption of electricity per capita. The paper discusses issues and barriers for promotion of rural electrification and suggested economical, technical and geographical to be the three most pertinent barriers in developing countries.

Keywords: Energy Policy, Electricity per capita, GDP per capita, Econometric modelling.

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Numerical simulation of cavitation on a Reversible Pump Turbine

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Abstract. The modern power grid instabilities are increasing, arising from renewable power sources. There are a lot of different ways of stabilising the power grid, but pumped storage hydropower plants are considered to be one of the best ways of storing energy in a large scale. In these plants, it is common to have one turbine in addition to a pump. This requires two different waterways in addition to a turbine and a pump which is expensive to build. An alternative is to use a single reversible pump turbine (RPT) that can act as both a turbine and a pump.

In this paper, steady state simulation of cavitation a reversible pump turbines impeller has been successfully performed and validated using experimental data. The break in efficiency was found to happen at about the same cavitation number for both the simulations and experiments. However, the efficiency in the simulations is higher than the experimental data. This was as expected due to simplifications in the geometry in comparison with the full geometry. Further work needs to be done in order to check if the efficiency will correlate better if the full geometry including guide vanes, stay vanes, spiral casing and draft tube. Additional operating points should also be simulated in the future.

Keywords: Reversible pump turbine, cavitation, pump mode, CFD, hydropower

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Development of a Model of Pelton Runner for Laboratory Testing

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Abstract. Pelton turbines are less sensitive to head variation and are commonly used from medium to high head sites. The most common and conventional technique used for manufacturing Pelton Turbine is Casting, for which a metal pattern with the correct shrinkage allowance is required. The casted turbine to be within the tolerance with the hydraulic design is often a challenging and costly process. Different techniques used for the development of model Pelton runner for testing in laboratory conditions have shown different scenarios of cost-time-accuracy trade-off. The rapid prototyping unlike casting does not require surface finishing using dies, hammers and presses. The tolerances and accuracy of the prototype depends upon the printer's resolution usually measured in Dots per inch (DPI) or micrometres (μm) and its use is both time and cost efficient. The paper discusses the standard practices followed for laboratory testing of model Pelton turbines with the use of rapid prototyping manufacturing technique. Experiences of a case of design and model testing of a Pelton runner developed by rapid prototyping techniques using Acrylonitrile Butadiene Styrene (ABS) material will be presented.

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An Experimental Investigation of PAT in Direct and Reverse Mode at Turbine Testing Lab

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Abstract. PAT is typically employed as the electromechanical component, especially in the rural communities of developing countries in order to reduce the initial cost of a power plant. In the context of Nepal, there have been few researches about its feasibility but have given promising outcomes regarding its implementation. As a part of this continuation, this paper deals with the experimentation performed on end suction, KDS-520+ centrifugal pump of 3.5 kW on direct as well as reverse mode to study its performances. The main purpose of this study was to test the characteristic performance of the pump in turbine as well as pump mode to compare the variation in their efficiency in laboratory environment so as to shed light upon the importance of PAT in micro and mini hydropower and to study the prospect of replacing traditional water mills with PAT. The test rig for the operation of pump in turbine mode was developed as a part of the research and characteristic curves have been plotted on different flow rates. The efficiency of the centrifugal pump was found similar to the rated efficiency, 60.85% at the best efficiency point at the head of 17m and discharge of 17lps. In addition, performance of the same pump in turbine mode showed a maximum efficiency of 40.15% at flow of 11.5lps and head 10m which concluded that the centrifugal pump can operate in turbine mode without any modifications.

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Performance analysis of Gravitational water vortex power plant using scale-down model

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Abstract. Gravitational water vortex power generation plant is ultra-low head micro hydro concept which requires mere 0.7-2m of height. GWVPP is based on the principle of power generation with rotation of turbine with the help of vortex generated due to basin structure when water can pass tangentially. This technology is in a primitive phase of development in various part of world. So, developers across the world are interested on how it performs in real site as only few real installations have been made far. This paper attempts to analyze the performance of different scale down model of GWVPP. First, the performance is compared among various experimental studies and pilot installations done so far in Nepal. After that the analysis of different computational studies is performed. To accesses the validation of the result obtained from the past researches, 1:20 scale down model of a plant which is to be installed in Johannesburg South Africa is developed and whose computational and experimental result is compared and predicted the model performance.

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Uncertainty evaluation of efficiency measurement in laboratory conditions

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Abstract. Uncertainty is a parameter associated with the result of a measurement, which characterizes the dispersion of the values that could reasonably be attributed to the measurand. All measurements are subject to uncertainty and a measurement result is complete only when it is accompanied by a statement of the associated uncertainty, such as standard deviation or error band. The identification of uncertainty of individual sensors and standardization in calibration process is under progress in Turbine Testing Lab at Kathmandu University. The lab aims to establish a Francis turbine test rig and procedures meeting the standards set by IEC. This needs a major investment on calibration systems and development of procedures to estimate the uncertainty in measurement much precisely then it is done now.
This study aims to identify the source of uncertainties and its quantification for efficiency measurement systems at laboratory conditions. The study is done on the 14 kW Francis turbine project at Turbine Testing Lab, Kathmandu University. The experimental setup consisted of a torque transducer, an electromagnetic flow meter and two pressure sensors attached to mechanical shaft, inlet of spiral casing and inlet and outlet respectively.
Based on the review of literature review on different papers published on the topic uncertainties, the data was analysed using the statistics. The type A and type B uncertainties were evaluated separately then combined to get combined uncertainty of each components. The uncertainty in efficiency was then calculated using the rules of uncertainty calculation.
In this paper, the standard methods developed to evaluate the uncertainties in sensor-based measurement system is presented and discussed. The same methods are used in investigation of the uncertainty to the extent it was possible and feasible in the lab. The value of efficiency and uncertainty in efficiency at 1300 rpm is calculated to be 66.7% and 0.30222% respectively. The results indicate uncertainty level very close to meet IEC standards.

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Francis Turbine: Manufacturing in the context of Nepal

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Abstract. Developing a sustainable way of designing and manufacturing hydro turbines is a major goal of every turbine industry. Due to the wide range of application and higher efficiency rate, Francis turbine stays apart from all other turbines and is most preferred around the globe. Continuous research and development of Francis turbine are carried out by a huge number of researchers and a group of engineers. Talking about the turbine development in the underdeveloped country like Nepal, the country has also taken some major steps for designing and manufacturing Francis turbine within the country. EnergizeNepal Project has also encouraged human resources to carry out the research for the development of renewable energy in Nepal. Every development gives birth to the new challenges that need to be overcome. The paper presents the inventions, discuss and review the possible way to design and manufacture the Francis turbine for small hydropower projects within Nepal. The study focuses on the design, manufacturing and analysis of Francis turbine. Different conventional and modern way of manufacturing turbines are studied.

Keywords: Francis Turbine, Sediment Erosion, Manufacturing

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Design and Optimization of Butterfly Valve Disc Using Numerical Simulation

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Abstract. This paper describes the numerical method to optimize the butterfly valve used in hydropower projects for flow and pressure regulation, safety, maintenance and shut-off purposes. The main objective is to optimize butterfly valve disc based on stress criteria, head loss and weight, where the parameters taken to optimize the model are disc thickness, stiffener height and stiffener thickness. Main inlet valve under study is of size DN 2800, placed at a gross head of 169m and flow rate of 63.5 m3/s. Initially, sizing of the valve disc is based on preliminary calculations and experience. Three levels of designs for each parameter are set. This resulted in twenty-seven cases for analysis. However, Taguchi Orthogonal Array is applied, which reduced to nine different cases for optimization. ANSYS Spaceclaim is used to prepare the 3D model and determine the weight of the geometry. Head loss and flow distribution in fully open condition between the upstream and downstream, each of which is ten times the nominal valve diameter is calculated using ANSYS Fluent. Then, the structural and deformation of the valve disc at fully closed position is achieved using the ANSYS Structural. Finally, the optimized model is selected based on structural stress, deformation and minimum head loss.

Keywords: Butterfly valve, ANSYS Fluent, ANSYS Structural, Taguchi Orthogonal Array, Disc Thickness, Stiffener

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Design and construction practices of hydropower tunnel in the Nepal Himalaya

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Abstract. Due to steep terrain and fast flowing rivers in the Himalayan region of Nepal, medium to mega size hydropower projects are constructing day-by –day. Tunnel is one of the best and short routes for water conveyance system for power production. Hundreds of kilometres of tunnels have been constructed and new tunnels are planned in this region. The availability of high head for hydropower generation, the tunnel cross sections are relatively small, up to 6 m diameter in size, and there is high rock cover above the tunnel alignment. This paper focuses on the design and construction practices of hydropower tunnel passes through weak rock mass with high rock cover of the Himalayan region of Nepal. Most of the hydropower tunnels undergo excessive deformation and support failure during the tunnel construction, which delayed the project as well as increases the cost of project. The paper first discusses the available construction practices for tunnel and underground structures. In the second part, the current practice employed during construction in the Himalayas is discussed along with the shortcomings of the methods and how it is addressed in the region.

Keywords: Hydropower tunnel construction, design methods, deformation, support failure, field investigation

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Tunnel Support Design in Fault Zone in Hydropower Project in the Himalaya: A case study

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Abstract. Tunneling through faulted rock mass is associated with long lasting displacements, stability problems, overburden squeezing, high deformations and dynamic stress conditions. With the dominance of faults in Nepal Himalaya, determination of behavior of the rock mass and tunnel, physical parameters for tunnel support is very challenging and demanding. Tunnel support and rock mass stability in tunnel are always dominated by fault. In this paper a hydropower tunnel in the vicinity of the fault has been used as a case study for the application of tunnel support using the Geological Strength Index (GSI) have been done. Rock mass is characterized, behavior of the unsupported rock mass is evaluated, and support is designed. The system behavior of the rock mass and the tunnel support are analyzed for the various combinations of geomechanical ground conditions. In order to simulate fault numerical modelling in commercially available software RS2 is used. The displacement, stress, yielded elements and plastic region are studied for the influence of the fault and its stress conditions of the designed tunnel supports. And the results of the design and the analysis are presented in details.

Keywords: Fault, Geological Strength Index(GSI), Tunnel Support, Joint element, Numerical Modelling in RS2.

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Numerical investigation of flow field and performance of the Francis turbine of Bhilangana-III hydropower plant

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Abstract. Computational fluid dynamics is an alternate tool to predict the performance as well as to investigate the flow field of a hydraulic turbine at different operating conditions. The objective of this paper is to analyze the flow field numerically and to predict the performance of Francis turbine of Bhilangana–III power plant. A numerical model of the prototype Francis turbine is undertaken to perform the simulation under the actual working condition of hydropower. The steady-state simulation has been performed at different operating conditions such as high load, part load, and best efficiency point using two turbulence model k- ω shear stress transport (SST) and standard k-ε with zero clearance gap and with a gap due to erosion. Based on computational results, an attempt has been made to compare the performance of the turbine under erosive wear conditions. The computational results are very close to the expected performance characteristics curve of the prototype turbine under no-gap condition. A difference of 0.24% and 1.71% in efficiency is observed between the numerical and manufacturer's data at the best efficiency point (BEP) and full load conditions, respectively. The simulation has also been performed with a clearance gap of 1.85 mm to study the effect of the gap, due to erosion, on the efficiency. The leakage flow through the 1.85 mm clearance gap has resulted in a decrease in the efficiency of the turbine. The efficiency drops around 5.73 % at BEP condition and 5.83% at full load condition. These computational results may be useful for further study of the turbine of Bhilangana –III power plant.

Keywords: CFD, Francis turbine, performance, efficiency, clearance gap, leakage flow

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Effect of welding pattern during repair and maintenance of Francis runner on sediment erosion: An experimental investigation using RDA

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Abstract. In Nepal, sediment erosion is major cause of turbine failure. Every year many runners erode and fail resulting in loss of efficiency as well as increase in the repair cost. Therefore, welding repair is chosen due to low cost to build up the eroded surface but a specific welding pattern on the eroded Francis runner has not been used. Experimental analysis of the welding patterns on the Francis blades through laboratory tests were carried out. Four different welding patterns on four different specimens were developed and experiment was carried out in the Rotating Disc Apparatus (RDA) at Turbine Testing Lab (TTL), Kathmandu University. The turbine blades used were of Dhamile Khola (14 KW). Since the experiment was an accelerated test, so the concentration of the sediments was increased. The erosion pattern on forged blades were compared with the CFD results and found to be similar. After an operation time of 1050 minutes, the extent of wear was found significantly less in the test specimen with right inclined welding pattern when the comparison was made based on the material loss. This paper deals with the various welding patterns on the Francis runner blades with the aim to provide a specific welding pattern with relatively less erosion rate.

Keywords: Sediment erosion; Efficiency; Francis runner; Weld repair; Welding pattern; Erosion rate

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Application of reverse engineering method to model eroded Francis runner

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Abstract. Damage of runner and other components of turbine by sediment erosion and cavitation erosion is an inevitable problem associated with hydropower established in a region with mountainous topology. The paper attempts to investigate the suitability and sustainability of the reverse engineering method for the design of the eroded Francis runner. This manufacturing technology is in a progressive phase of development in various parts of the world, so research scholars have been constantly working on the concept to increase the speed and efficiency of the method. The case investigation was conducted on Puwa-Khola 1HPP eroded Francis runner. The paper investigates on reverse engineering design methodology of eroded runner and discusses scope and limitation in utilization of method at Hydropower sector. Also, the paper suggests suitable 3D scanning techniques, reverse engineering tools and optimization methods for obtaining mathematically sound models without any hydraulic profile deviation between actual and reversed engineered model.

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Investigation of Mechanical Properties of Brass Francis Turbine Manufactured by Local Investment Casting Technique in Nepal

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Abstract. Most of the hydro turbines in Nepalese power plants are imported from the foreign industries. Findings from the studies have shown that up to 60% of the 13,000 MW capacity hydropower projects under survey stage in Nepal would need Francis type of turbine with unit size below 5 MW. In order to meet the demand of turbines, Nepal has imported turbines worth US$ 5,616,072. The imported turbines from the foreign industries could not addresses local problems of Nepalese hydropower. In Nepal, due to the sediment laden condition of rivers alternative design and manufacturing techniques of turbines are necessary. In order to provide the new manufacturing techniques of Francis turbine in Nepal local casting process can be a solution because metal casting is hereditary professions in Nepal since ancient periods till now. Large sized bronze casted bells that are placed in Nepalese temples were manufactured in the ancient time without a proper theoretical study on them. This paper discusses about the materials testing of investment casted and sand casted brass materials of 14 kW Francis runner of Turbine Testing Lab (TTL) for exploring the possibilities of manufacturing Francis turbine. Tensile, compressive and charpy impacts test were performed on the basis of ASTM standards and also microscopic study were conducted at Kathmandu university laboratory. These testing results can be helpful for further studies on alternate turbine manufacturing processes as well.

Keywords: Francis Turbine, Hydropower, Brass, Investment Casting, Material Testing

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Experimental and CFD study of influence of sediment size on efficiency of hydrocyclone for use as filtration device

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Abstract. Hydrocyclones are separation devices used in several industrial applications for separation of particles even smaller than 5 μm. However, this paper presents the feasibility of using hydrocyclone as a sediment separation system in hydropower plants, as well as in the development of a non-recirculating type of an erosion test rig. The design of experimental set up is a part of the erosion test rig that consists of discrete sediment feed and separation system to conduct erosion related researches. Experimental as well as numerical investigation of effect of sediment particles sizes on overall separation efficiency of hydrocyclone geometry is conducted. Hydrocyclone's overall efficiency is depicted by measuring the particle separation and its variation with sediment particle's size. The results indicated that under appropriate flow conditions, particles below 200 μm that are responsible for turbine wear can be separated and prevented from entering into the system. Also, it can be concluded that this system can be used to develop non-recirculating type of erosion test rig.

Keywords: Hydrocyclone, Separation, Sediment sizes, Erosion, Efficiency

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A review on casting technology with the prospects on its application for hydro turbines

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Abstract. Casting is one of the oldest manufacturing processes that has been in use since 3400 BC. Over the years, casting technology has evolved tremendously and is one of the most integral parts of ancient history as well as modern society. The world produced a total of 109.8 million tons of casting in the year 2017, which is a clear indicator of the massive capacity of this industry. Most of it in the current scenario is being used by the automotive industries. Despite being the biggest and the richest industry in the field of energy, hydropower has never been a major market for the casting industry. This might be because the hydropower components are mostly manufactured using other techniques such as machining and rolling. Nevertheless, studies have proven that casting can be used for the manufacturing of several components of the hydropower, especially hydro turbines. Casting technology comes with its own sets of advantages and limitations. This study presents an overview of the status of the casting technology and challenges, the proper optimization in casting that needs to be considered and the latest technological advancements in this area. This paper aims to develop a theoretical foundation for show-casing the beneficiary, challenges and possibility of manufacturing hydro turbines through casting technology.

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Numerical investigation on the effects of leakage flow from Guide vane-clearance gaps in low specific speed Francis turbines

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Abstract. Clearance gap in guide vanes of Francis turbine induces the leakage vortex. This vortex flow interacts with the main flow and leads to the instability in the fluid flow pattern and eventually deteriorates the performance of the turbine. In this study, the detailed numerical examination of the unsteady flow due to leakage vortex and influence of this in the performance of turbine is carried out using time dependent numerical analysis. The numerical simulation is carried out using SST turbulence model with numerical validation. The development of leakage vortex is studied within the clearance gap region. Time dependent numerical simulation is carried out to investigate the growth and vortex propagation considering five revolutions of the runner. Results shows that the leakage vortex travelling form the guide vane clearance gaps influence the performance of the runner. On analysing the leakage vortex path, it is seen that the vortex travels from the pressure side of runner blade to the suction side of adjacent blade opposite to the runner rotation. Furthermore, this leakage vortex is carried down to the draft tube where the vortex rope seems to grow up to 50% geometric progression of draft tube cone and gradually decreases before reaching the elbow. Upon investigation of resulting torque and head during runner rotation, the periodic variation of torque and head can be seen, however with different phase. This is inferred to be the influence of leakage vortex that travels along with the main flow.

Keywords: Clearance gap, Francis Turbine, Leakage Vortex, Unsteady flow

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Method of erosion prediction hill diagram to investigate the performance of Francis turbine operated in sediment laden water

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Abstract. Sediment erosion problem in hydropower plants located under Himalayan regions of Nepal is inevitable. Reliance to the performance curves from model test data in terms of hydraulic efficiency cannot predict the actual performance in context of sediment laden hydropower projects in Nepal. This paper presents novel technique to predict the erosion affecting regions in various operating points in terms of sediment erosion hill diagram. A 2-D representation of erosion rate in several operational points is presented in this paper. This representation is compared with the efficiency characteristics of the same turbine that will be useful for considering the compromise between efficiency and erosion wear for erosion affected hydropower projects. A reference hydropower projects severely affected with sediment erosion is chosen for this study. Using suitable numerical modelling technique, performance of the turbine is calculated in terms of efficiency. Similarly, area averaged erosion rate in the walls of the numerical model was computed at various operating condition. It gives the idea that the turbine can be operated in variable speed operation that in one hand improves the efficiency and minimizes the erosion effects as well.

Keywords: Francis Turbine, Efficiency, Sediment Erosion, Hill Diagram

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Opportunity for Research and Manufacturing of Pump in Nepal

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Abstract. Pumps are the mechanical device used to increase the pressure energy of fluids. Generally, they are used to transport fluids from lower level to higher level or from one place to another. Pumps are very widely used technology in different types of industries where fluids are involved. Applications like water distribution system, sewage management, irrigation, hydropower and various other application areas cannot function without the use of pumps. In context of Nepal, pumps are being used in different industrial as well as household applications. Almost all the pumps being used in Nepal are imported from either India or China. As of today, Nepalese industries have not been able to comprehend the prospect of manufacturing pumps in Nepal. Although Nepal has a long history of using pumps in industrial scale, no research have been done in this area. In this study, history of pumps used in Nepal is discussed. The existing application areas of pumps in country with various types, sizes and capacity are described. Similarly problems associated with existing pumps are highlighted. The maintenances market of pumps and its reliability are discussed. The data for existing market of pumps is presented. Finally design and manufacturing of pump in context of establishment of TTL and expertise in Francis turbine are discussed as a future prospect for Nepalese academy and industry.

Keywords: Pump, Maintenance, Francis Turbine

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Design of Francis turbine for micro hydropower applications

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Abstract. This study presents a Francis turbine designed for micro hydro application, using Bovet approach of design and other general techniques, with some variations which make the manufacturing procedure relatively simpler. It also depicts the status of micro hydro in Nepal. Simplifications has been administered on runner, vane cascade and spiral casing. The study has been carried out under single ow condition, which is generally the case in micro hydropower, which divert a small portion of water from the main source, generally rivers or springs. The design procedure used for the design of each hydraulic components have been described in brief. The numerical study performed on the turbine have also been presented. Effects of simplifications administered on each component has been analysed. The small variation in efficiency due to simplifications administered has been justified for use in micro hydropower projects in view of the drop in efficiency caused due inaccuracies during manufacturing of turbine.

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Green Hydrogen Energy as a Future Multi-disciplinary Research at Kathmandu University

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Abstract. Over 100 million tons of hydrogen are produced every year for a range of industrial purposes. The vast majority of this industrial hydrogen is produced from coal gasification or steam methane reforming, both of which need a lot of energy and generate significant carbon dioxide emissions. A much smaller proportion of hydrogen is produced from the electrolysis of water, which can be a far more sustainable and clean method if the electricity is produced from renewable sources. The cost of hydrogen supply from renewables has come down and continues to fall. While the urgency of greenhouse gas emission mitigation has increased, many countries have begun to take action to decarbonize their economies. Nepal is expected to have 3000 MW electricity surplus by Year 2030. It is a time to explore alternative use of electricity to make hydropower projects financially feasible. Fuel cells can emerge as alternative to fossil fuels. Hence it is also a high time to investigate the Hydropower-to-Hydrogen (H2H) technology and transfer the relevant knowledge in the region. The development of hydropower systems to produce green hydrogen energy for commercial applications can change the future of hydropower development in the Himalayan region by becoming exporter of green fuel worldwide.

Kathmandu University (KU) has been leading to initiate and institutionalize the new academic programs and research avenues to address the future need for this country. KU has played a role model to introduce and establish innovative and unique programs in engineering education in Nepal since it was established in 1994. Since the establishment period, KU carried the vision to establish itself as a research-based university. KU has carried the objective to design its academic programs, courses, and curricula to directly contribute to the research problem the industry or society has been facing. The intuitional realization that Green Hydrogen Energy is the future academic and research need of this country will be the far-slightness of KU.

Keywords: Fossil Fuels, Climate Change, Hydropower, Hydrogen Energy, Research Centre

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