Nile Basin Capacity Building Network

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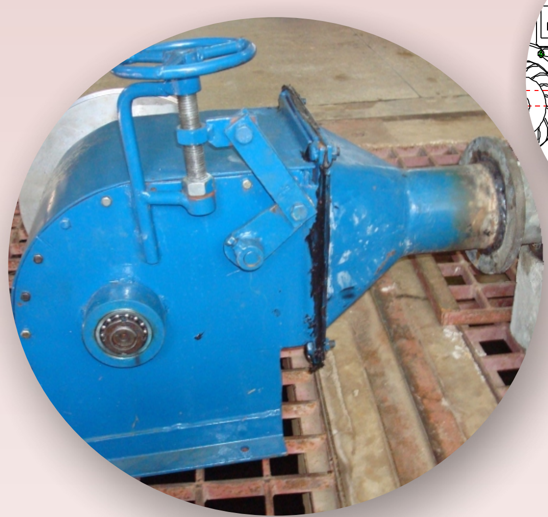

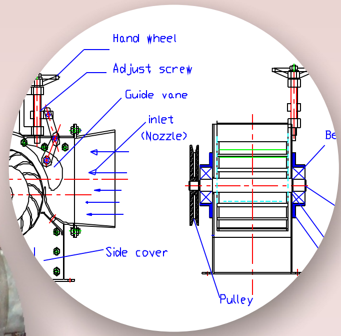

Design and Fabrication of Cross flow Turbine

NBCBN-RE

2010

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Project Title
Knowledge Networks for the Nile Basin
Using the innovative potential of Knowledge Networks and CoP's in strengthening human and institutional research capacity in the Nile region
Implementing Leading Institute
UNESCO-IHE Institute for Water Education, Delft, The Netherlands (UNESCO-IHE)
Partner Institutes
Ten Selected Universities and Ministries of Water Resources from Nile Basin Countries
Project Secretariat Office
Hydraulics Research Institute – Cairo - Egypt
Beneficiaries
Water Sector Professionals and Institutions in the Nile Basin Countries

Short Description

The idea of establishing a Knowledge Network in the Nile region emerged after encouraging experiences with the first Regional Training Centre on River Engineering in Cairo since 1996. In January 2002 more than 50 representatives from all ten Nile basin countries signed the Cairo Declaration at the end of a kick-off workshop was held in Cairo. This declaration in which the main principles of the network were laid down marked the official start of the Nile Basin Capacity Building Network in River Engineering (NBCBN-RE) as an open network of national and regional capacity building institutions and professional sector organizations.

NBCBN is represented in the Nile basin countries through its nine nodes existing in Egypt, Sudan, Ethiopia, Tanzania, Uganda, Kenya, Rwanda, Burundi and D. R. Congo. The network includes six research clusters working on different research themes namely: Hydropower, Environmental Aspects, GIS and Modelling, River Morphology, flood Management, and River structures.

The remarkable contribution and impact of the network on both local and regional levels in the basin countries created the opportunity for the network to continue its mission for a second phase. The second phase was launched in Cairo in 2007 under the initiative of; Knowledge Networks for the Nile Basin. New capacity building activities including knowledge sharing and dissemination tools specialised training courses and new collaborative research activities were initiated. The different new research modalities adopted by the network in its second phase include; (i) regional cluster research, (ii) integrated research, (iii) local action research and (iv) Multidisciplinary research.

By involving professionals, knowledge institutes and sector organisations from all Nile Basin countries, the network succeeded to create a solid passage from potential conflict to co-operation potential and confidence building between riparian states. More than 500 water professionals representing different disciplines of the water sector and coming from various governmental and private sector institutions selected to join NBCBN to enhance and build their capacities in order to be linked to the available career opportunities. In the last ten years the network succeeded to have both regional and international recognition, and to be the most successful and sustainable capacity building provider in the Nile Basin.

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FOREWORD

This report is one of the final outputs of the research activities under the second phase of the Nile Basin Capacity Building Network (NBCBN). The network was established with a main objective to build and strengthen the capacities of the Nile basin water professionals in the field of River Engineering. The first phase was officially launched in 2002. After this launch the network has become one of the most active groupings in generating and disseminating water related knowledge within the Nile region. At the moment it involves more than 500 water professionals who have teamed up in nine national networks (In-country network nodes) under the theme of "Knowledge Networks for the Nile Basin". The main platform for capacity building adopted by NBCBN is "Collaborative Research" on both regional and local levels. The main aim of collaborative research is to strengthen the individual research capabilities of water professionals through collaboration at cluster/group level on a well-defined specialized research theme within the field of River and Hydraulic Engineering.

This research project was developed under the "Local Action Research Modality" which has a main objective to contribute to the capacity building process at local level and enhance the collaboration among the researchers and institutions in the same country. This activity is the core activity of all NBCBN nodes and is contributing to the establishment of the in-country network.

This report is considered a joint achievement through collaboration and sincere commitment of all the research teams involved with participation of water professionals from all the Nile Basin countries, the Research Coordinators and the Scientific Advisors. Consequently the NBCBN Network Secretariat and Management Team would like to thank all members who contributed to the implementation of these research projects and the development of these valuable outputs.

Special thanks are due to UNESCO-IHE Project Team and NBCBN-Secretariat office staff for their contribution and effort done in the follow up and development of the different research projects activities.

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1 INTRODUCTION

1.1 General

1.1.1 Background

It has been found that over last few decades that there has been a growing realization in many developing countries like Tanzania that small hydropower schemes have a very important role to play in economic development of the rural population through electrification programs. Small hydropower schemes can provide power for industrial, agricultural and domestic uses through direct mechanical power or coupling of turbine generator.

Small scale hydro power potential sites are normally situated in remote isolated areas, with their development expected to serve as an engine towards economical and social development of the remote/local Tanzanian communities which are mostly supplied with power by isolated diesel stations. The majority of the Tanzanians have no access to electricity; only about 10% of the entire Tanzanian population has access to electricity services. The remaining gets locally available traditional energy (biomass) which accounts for 90% of energy consumption in the country. It is estimated that there exists about 300MW of small scale hydro power potential in total scattered around the country (Kassana, 2004)

Operation of diesel stations in the remote isolated systems depends on the expensive imported fuel which is a cost to the national economy. This fact opens a challenge to develop small hydro power to supply cheap and environmentally friendly electricity to the isolated communities.

The government underscores the advantages of investing in hydro electricity generation for those sites which have been evaluated and proved to be viable. Following the recent/on-going reforms of the power sector (trade liberalization, opening doors to private investors, privatization of public utilities, etc) it is anticipated that private firms will also increase their interest to invest in hydro-electricity generation.

1.1.2. Small hydro power in Tanzania

The small hydro power potential in Tanzania is attractive with hydro power potential of 3,800 MW of which only roughly 300 MW has been exploited, Tanzania is ripe for investment in its hydro power sector. More over with large isolated rural community unable to access the national grid, the government of Tanzania has placed rural electrification as a major component of its development programs to meet demand. Furthermore, Tanzania has liberalized its energy sector and allows inflow of foreign direct investment into hydro projects. Therefore, the government of Tanzania is keen of encouraging studies of hydro electric potential sites that appear to be attractive from the investment point of view (Mkumbo, 1997)

Although there are various energy technologies, the impact of these technologies on the access to affordable electricity can be evaluated using factors such as occurrence of the resources, capital cost, operating cost, efficiency, environmental impact and reliability. Despite the high capital cost and moderate environment impact, small hydropower schemes have almost negligible operating cost. Small hydropower is thus considered a reliable, low cost source of energy and is independent of the energy price volatility associated with plants using fossil fuels. Therefore, small hydro power is assertive sources of electricity in supplying rural areas with reliable and efficient energy. In addition, small hydro power projects can be installed to serve small community making its implementation more appropriate in the social political context of Tanzania. Therefore there is a scope for harnessing the micro hydro potential by identifying proper sites and design appropriate power generation system.

1.1.3 Problems in developing small hydro power sites in Tanzania

It has been found that despite the need of small hydropower schemes and availability of small hydro power potential sites in Tanzania; most of the sites are not yet developed due to a number of reasons. Various reasons have been mentioned by experts/practitioners in rural electrification in Tanzania (Sawe, 2005; Mwakasonda, 2007). The list is long but can thematically be aggregated into five major categories:1) Rural electrification policy, 2) financing of hydro power, 3) Characteristics of rural hydro power electricity market, 4) Institution set up, 5) Human resource development for small hydro power.

1.1.3.1 Rural electrification policy

The government of the Tanzania has adopted a number of broad policy objectives relating to the development and governance of the energy sector. The government bears the responsibility of rural electrification in terms of creating an enabling environment for all stakeholders. The challenge to the Tanzanian policy makers is to forge a common understanding of public and private sector actors to fit together skillfully to form an intact mechanism for enabling rural electrification that will:

i. Formulate electrification plan that allows the rational use of available energy resources, including off grid schemes such as small hydro;
ii. Facilitate the transfer of expertise and capital for the implementation of projects;
iii. Promote initiatives that provide remote and rural electrification projects to be commercially viable, thus attractive to investors and banks.

Without appropriate policy and its implementation strategies, rural energy development follows an ad hoc path, as it is today, with little recourse to national energy plan

1.1.3.2 Characteristics of rural electricity market

The rural people in Tanzania are poverty prone that majority can not afford the initial connection costs and monthly bills, which are uniform throughout the country. Rural electrification projects are associated with long transmission and distribution distances because of sparse population as well low load centers. In addition a large proportion of electricity used in the rural areas is for household energy uses (lighting, heating, cooking) and social welfare services (education, health care, water supply) and limited income generating activities mainly service oriented business such as grain milling, preserving agricultural crops, irrigation, industrial production, entertainment and rarely ICT. For example, Kjellstrom et, al. (1992) reported a consumption pattern of 60 – 90 % of the energy consumed in three districts of Babati, Same and Sumbawanga to be residential and light commercials.

1.1.3.3 Institution set up for small hydro power development

Presence of well coordinated and comprehensive energy policy strategy with capacity for integrating stakeholder collaboration, as well as enhancing inter-linkages of arms of the government are vital for small hydropower development in rural areas (Wamkonya, 2001). This observation holds true for Tanzania because there are many potential actors in the rural electrification Tanzania such as the central government, power utility, IPPs, CBOs, NGOs, and development partners (World Bank UNIDO, SIDA, etc) but the current institutional arrangement is neither synergetic nor complementary for small hydropower development.

The current set up, the local government, i.e. the municipals, regional and districts government are left out of the mainstream of planning and development of strategies for implementation of energy projects. Because the local government and municipals are not incorporated in the SHP development process, rural electrification is not linked to the short term and long-term development programs at grass root levels. The absence of linkage between regional, district and village government levels in the rural electrification framework also hinders permeation of knowledge and skills for developing small hydropower actors in remote areas. The municipals and local governments are passively waiting for the TANESCO and central government electrify townships, commercials centers and villages.

1.1.3.4 Human resource development for small hydro power

Despite the long experience the country has in implementing small and mini hydropower schemes (about one century), one might wonder why this technology is not more widespread given that many Tanzanians have received good training in small hydro development, and participated in various refresher courses. Although the participation of the private sector in electricity service was formally accepted in Tanzania since 1992, its involvement is still very limited if not just beginning.

One of the explanations could be that the centralized administrative framework which tends to localize the knowledge, experience and skills in the ministries and the state power utility, this situation has left lower levels starved and un-networked. This argument is supported by the recent rural master plan study results which show that there are no qualified third party operators in rural areas to implement small hydropower projects except TANESCO which has offices in almost all districts in mainland Tanzania.

1.1.3.5 Financial Viability

So far, the most active financiers in remote and rural areas of Tanzania are the central government, international donors and religious societies. Experience elsewhere shows that no private-sector investor will invest in a project until it appears profitable and no private-sector banker will lend money to a project which has unacceptable risks. Rural electrification projects have the reputation of being both unprofitable and of high risk. Therefore these institutions have typically perceived the risks of investment in this sector as being too high, and the rates of return as being too low. Incumbent utility company, TANESCO, also view provision of electricity service and rural electrification in general as a burden, since it is not profitable.

Recently studied small hydropower potentials of Sunda Fall, Igamba Falls, Nzovwe and Pinyinyi, in the rural electrification master plan study of 2005 were found to be financially unviable even at the highest tariff scenario. This explains why so few small hydro projects have been built, as well as why the government in collaboration with donors and non profit organizations remain the main participants in rural electrification.

The main challenge however is how to make the projects financially viable to private investors as well as reduce the perceived risks so as to attract national commercial and development banks to finance small hydro projects for rural electrification.

1.2 Phase II Research

1.2.1 Objectives of the Study

The purpose of this research project is to develop a cross flow hydro turbine which can be fabricated locally using available expertise, materials and technology at a reasonable cost affordable by the rural community. The specific objectives of the research project are:

i. Designing a cross flow hydro turbine which can suit local manufacturing capability and water resource availability;

ii. Manufacturing of a cross flow turbine prototype;
iii. Documenting manufacturing technology and testing procedures of the designed turbine according to locally available resources; and
iv. Establishing economic viability for manufacturing the hydro turbine locally.

1.2.2 Justification of the Study

Development of small hydropower plants in Tanzania is facing a number of obstacles as stated above, not only because of the unfavorable conditions but also in adequate knowledge and technology to exploit the potential sites. So far there is no workable technology developed locally that has a scope of cost reduction and self reliance.

Preliminary survey carried out in the country shows that most of the hydropower mechanical equipments are imported from various countries in Europe and Asia (Kassana, 2006).The above equipments are expensive and lack support services in terms of spare parts and maintenance. Thus, the need for development of small hydro-turbines using locally available resources has been identified, in order to make a break-through in solving the scarcity of appropriate form of energy to rural communities.

The significances of this research project are and not limited to:

i. The technology will be beneficial to local manufacturing industries and will thus ensure availability of the turbines locally at low cost and will further, ensure the support services in terms of spare parts and maintenance. It will also stimulate productive activities through the provision of affordable and sustainable technology.
ii. The results of the research will ensure availability of a Prototype and documented procedures for designing, fabricating and testing of cross flow hydro turbine in Tanzania.
iii. The research establishes economic viability of fabrication of the turbine in Tanzania
iv. It provides information to various stakeholders and contributes knowledge to hydro power research.

1.2.3 Overview of Turbines for Small Hydropower Plants

There is no consensus definition of small hydro power plants (ESHA, 2004). For the sake of this research small hydro power plant is any scheme which has a capacity of generating electrical energy up to 10 MW. Small hydropower schemes combine the advantages of large hydro on the one hand and a decentralized power supply, on the other hand. They do not have many of the disadvantages, such as environmental issues, and high cost of investment in case of large hydro power plant. Moreover, the harnessing of small hydro-resources, being of a decentralized nature, lends itself to decentralized utilization, local implementation and management, making rural development possible basing on entrepreneurship and the use of natural, local resources. Small hydro power plants can be connected to electricity grid. Most of them are run-of-river type; they do not have any sizeable reservoir and produce electricity when water provided by the river flow is available, when river dries up generation ceases. Efficiency of small hydro units range from 60% to 90% while modern coal burning units are 43% to 60% efficient (Wazed and Ahmed, 2008)

2 RESEARCH METHODS AND MATERIALS

The main activities in this research entailed desktop study (literature search), Materials and technology survey, designing, manufacturing, and performance testing.

2.1.1 Literature review

In order to understand and obtain useful information in the research area, various literatures in hydropower, small hydropower development and past research findings such as NBCBC hydropower cluster in phase I and turbine designs of the existing mini hydro were reviewed. Accordingly methods, strategies and techniques for developing hydro turbine were thus established. They were tailored to suit the purpose of this study. The outcome of this stage gives useful information that forming basis for the follow up studies.

2.1.2 Materials and technology survey

As noted earlier, the purpose of this research is to come up with a turbine design that suit the local manufacturing capability in terms of materials, technology and human resource. It was therefore necessary to find out what type of technology and materials is available. Materials survey was thus carried out through visiting various hardware shops and suppliers in Dar es Salaam City, Tanzania to see what kind of materials are easily available in the market. Technology survey was also carried out by visiting various workshops to shop available technologies and expertise.

2.1. 3 Design

The design work was carried out using systematic design procedures from conceptual to detailed design based on market survey, available technology, material survey and the reviewed literatures. The design involved formulation of design requirements/specifications for cross flow turbine followed by conceptual design and detailed design of a cross flow turbine which also included preparation of detailed drawings, materials selection and cost estimates for manufacturing.

2.1.4 Fabrication of cross flow turbine model

Manufacturing carried out after completion of the design work. This stage also involved purchase of selected materials. All the manufacturing activities were carried out at Technology Development and Transfer Centre (TDTC) workshop based at University of Dar es Salaam except for the off-shelved parts such as bearings, bolts & nuts e.t.c. which were purchased from the market.

2.1.5 Testing

Preliminary performance tests were conducted in the Water Resources Engineering Department hydraulic laboratory. The tests aimed at determining its performance characteristics and identifying testing procedures and techniques. However, due to limited resources only some few parameters were tested and the results compared with calculated ones.

2.2 Design Principles

In carrying out the design work systematic design principles were followed from conceptual to detailed design. The design process involved a rather fast method of adopting and improving on proven operating turbines. The operating turbine was studied and later compared with the available literatures on hydro turbines. However, in designing hydro turbine both mechanical and hydraulic designs should be taken into consideration in order to enable the turbine to be able to sustain both mechanical and hydraulic forces exerted in the turbine during its normal operation without failure. In addition, other consideration such as materials and manufacturability were taken into account.

2.2 Capacity of Workshop in Tanzania

Technology Development and Transfer Centre (TDTC) at UDSM has a multipurpose workshop with 20 technical staff of different cadres. CoET, a campus College of UDSM, outreach programmes are also coordinated by TDTC. The outreach programmes' staff include three (3) Incubator Managers, three (3) Incubator Field Assistants and six (6) security guards for SME Clubs. The objective of the Centre is to develop and disseminate technologies to the general public.

The following TDTC workshop facilities, among many others, are used for teaching and learning, research and technology development, consultancy and services to industry:

i. Four machine workshops equipped with metal working machines including a CNC lathe and a computer controlled flame cutting machine;

ii. Two laboratories for water quality analysis and one chemical laboratory equipped with chemical and biological analysis facilities including a Gas-Chromatograph/Mass spectrometer (GCMS), and Bio-reactors;
iii. Electrical, electronics, telecommunications, computer systems and high-voltage laboratories;
iv. Soil mechanics, hydraulics and water resources, and structures and building materials testing laboratories;
v. Structures and Materials technology laboratory with facilities for ultrasonic crack detection, hardness and testing of strength of reinforced concrete metals and other building materials, heat treatment, and micro-structure and chemical composition analysis.
vi. Energy laboratories with facilities for various tests in research, consultancy and services. Equipment available in these laboratories include: engine test rig, bomb calorimeter, hot-wire anemometer, compressor test rig, air-condition and refrigeration test rig, pump test rig, cooling tower, concentric tube heat exchanger and Pelton turbine test rig.
vii. Chemical laboratory with modern equipment for experiments, process developments, standard chemical analysis and quality control for different products and raw materials at laboratory scale. Equipment available include: High Performance Liquid Chromatography (HPLC), Atomic Absorption Spectrometer (AAS), Gas-Chromatography (GC) and other analytical equipment.
viii. Highway and Transportation and Surveying laboratories
ix. Five (5) computer laboratories and other facilities; 3 at the Main Campus and 2 at Kijitonyama Campus.

Apart from TDTC workshop several local workshops are available in Tanzania possessing relevant capabilities such as welding, machining, forging, foundry and computer Aided Design (CAD). Engineers, technicians and artisans who design and manufacture various machines and equipments are also available. These can be trained on how to design and manufacture turbines. Cross flow turbine can be manufactured in a non-specialized metal workshop as the machine tools required are standard: turning lathe with a centre height greater than 200 mm, Drilling machine with a capacity up to 25 mm and boring attachment, milling machine or sharper, acetylene cutting torch, plate shear (optional), arc welding equipment, a number of jigs and fixtures made for the purpose, general hand tools, and bend saw and power hacksaw. All these are within the local capacity. Manufacturing can be carried out by a team of 3 or 4 people, consisting of a trained mechanic, a skilled worker trained on the job, and semi-skilled helpers. The major challenge is testing facilities for in-house tests.

3 DESCRIPTION OF CROSS FLOW TURBINE

3.1 Hydraulic Parameters and Operation Principles

The main characteristic of the Cross-Flow turbine is the water jet of rectangular cross-section which passes twice through the rotor blades -arranged at the periphery of the cylindrical rotor - perpendicular to the rotor shaft. The water flows through the blades first from the periphery towards the centre and then, after crossing the open space inside the runner, from the inside outwards. Energy conversion takes place twice; first upon impingement of water on the blades upon entry, and then when water strikes the blades upon exit from the runner. The use of two working stages provides no particular advantage except that it is a very effective and simple means of discharging the water from the runner.

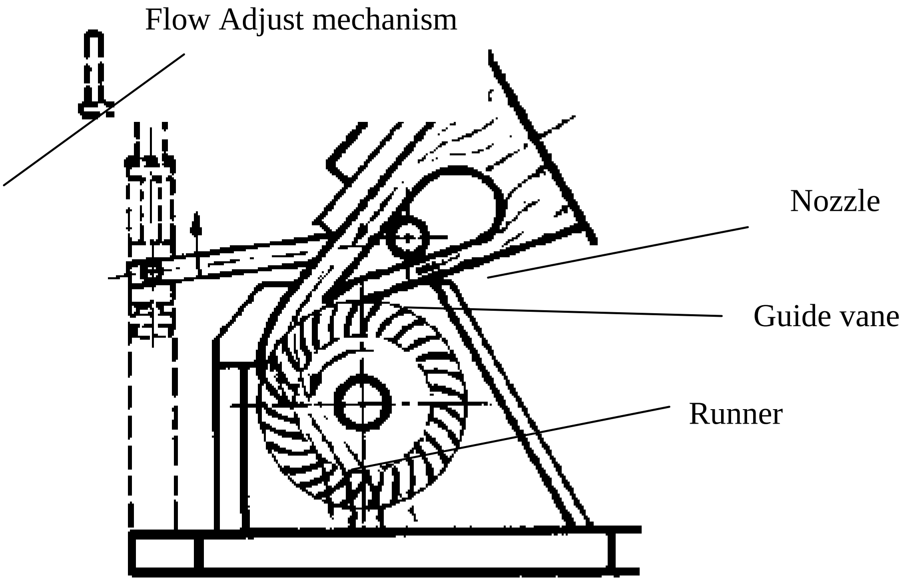

Figure 3.1: Schematic diagram of Cross flow Turbine (adopted from Wakati, 2010)

The cross flow turbine is normally classified as an impulse turbine. This is not strictly correct and is probably based on the fact that the original design was a true constant-pressure turbine. A sufficiently large gap was left between the nozzle and the runner, so that the jet entered the runner without any static pressure (free jet creation). Modern designs are usually built with a nozzle that covers a bigger arc of the runner periphery. With this measure, unit flow is increased, permitting to keep turbine size smaller. These designs work as impulse turbines only with small gate opening, when the reduced flow does not completely fill the passages between blades and the pressure inside the runner therefore is atmospheric. With increased flow completely filling the passages between the blades, there is a slight positive pressure; the turbine now works as a reaction machine.

Cross-Flow turbines may be applied over a head range from less than 2 m to more than 100 m (Ossberger has supplied turbines for heads up to 250 m). A large variety of flow rates may be accommodated with a constant diameter runner, by varying the inlet and runner width. This makes it possible to reduce the need for tooling, jigs and fixtures in manufacture considerably. Ratios of rotor width/diameter is normally from 0.2 to 4.5 have been made. For wide rotors, supporting discs (intermediate discs) welded to the shaft at equal intervals prevent the blades from bending.

The effective head driving the Cross-Flow turbine runner can be increased by inducing a partial vacuum inside the casing. This is done by fitting a draft tube below the runner which remains full of tail water at all time. Any decrease in the level creates a greater vacuum which is limited by an air-bleed valve in the casing. Careful design of the valves and casing is necessary to avoid conditions where water might back up and submerge the runner. This principle is in fact applicable to other impulse type of turbines but is not used in practice on any other than the cross flow; It has additional advantage of reducing the spray around the bearing by rending suck air into the machine

3.2 Sizing of Main Elements

The Cross-flow turbine has been specifically designed for manufacturing facilities available in many workshops in Tanzania, and on one side is partly welded and bolted. Due to the poor infrastructures such as roads to most installation sites, special consideration can be given to such that individual parts of the turbine can be bolted together and kept in position by taper pins. Thus, a turbine carried to the site in individual parts, can readily be assembled. This is also an advantage, if it should become necessary after some years of operation to repair or replace one of the parts.

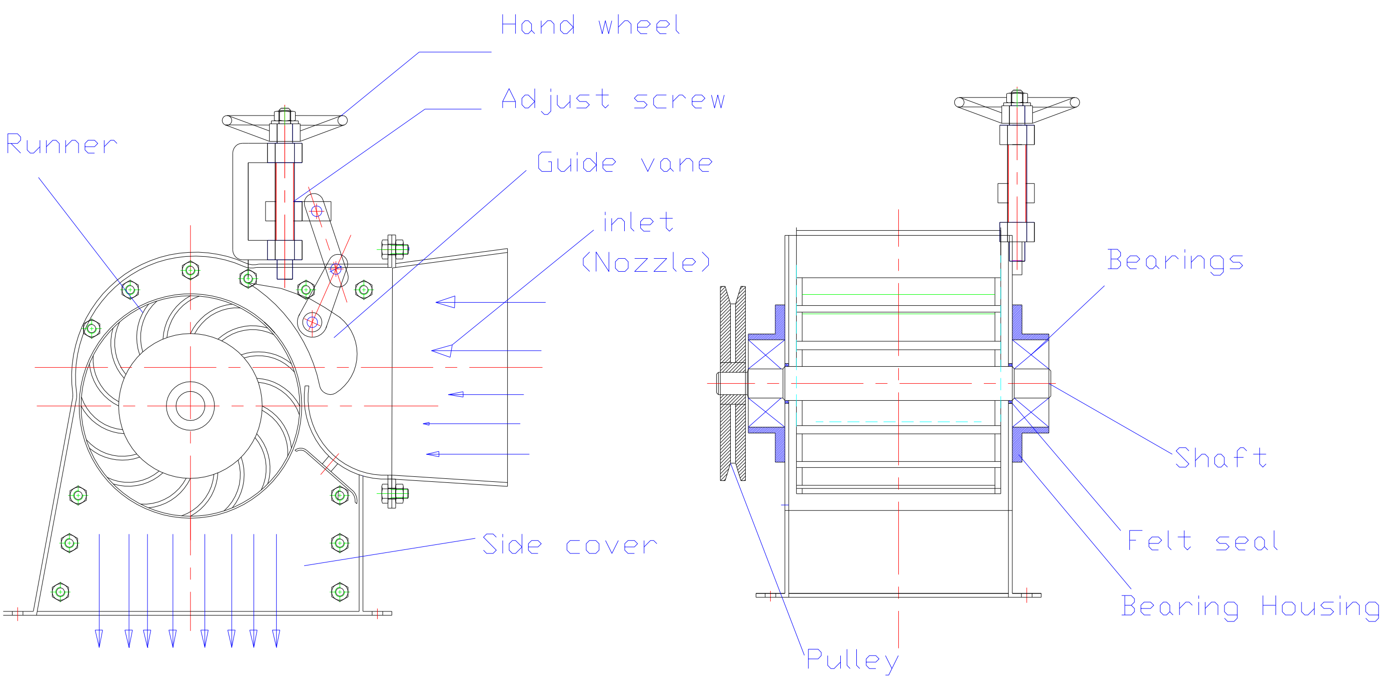

Figure 3.2 Detail of the locally designed cross flow hydro turbine

Table 3.2: Summary of the cross flow turbine dimensions

S/N	Parameter	Specification	S/N	Parameter	Specification
01	Runner diameter	230 mm	**08**	Entry angle	16 degree
02	Runner width (bo)	200 mm	**09**	Area of the jet	0.00824m^2
03	Jet thickness	41.23 mm	**10**	Blade radius	37mm
04	No. of blade	18	**11**	Shaft speed	354 rpm
05	Jet velocity	9.7 m/s	**12**	Nozzle width	180 mm
06	Nozzle arc	73	**13**	Power (calculated)	2.5 kw
07	Overall Dimensions	523x343x520	**14**	Bearing	SKF 62206C

Source: Wakati (2010)

The cross flow has a welded housing made from quality steel, rigid enough to withstand high operational stress and to enable a smooth operation. The design and the hydraulic layout result in minimized vibrations and noise level. Special care was taken in the layout of the main bearings for the runner and the guide vane. The casing is designed in such a way that different options for the bearing system are available to cope with the specific site requirements, like flywheel or belt drive. A sealing system (contact free or conventional type) is integrated in the side flanges. The guide vane unit can easily be taken out through a side flange for inspection, cleaning or replacement. To obtain the guaranteed efficiency, the cylindrical runner is fabricated with high precision.

The inlet consists of two curved metal plates one side is welded to side plate and another is bolted to the second side plate to form a rectangular inlet section and nozzle. The rotor/runner consists of 18 blade segments that are cut from standard diameter four inch pipe of 5 mm wall thickness, which fit into slots of two side discs of 230 mm diameter, where they are welded in. The central shaft is also welded to the rotor discs and final machining of the rotor outside diameter, including the blade tips as well as the shaft diameter, is done after completed welding. The shaft extends from both sides of the rotor and is usually symmetric. Depending on the application of the turbine, either both shaft ends can be provided with pulleys to drive two machines via belt-drive, or, if a generator is connected on one side, the other end may be used for operating a speed governor. Bearings used are of the self-aligning spherical double-roller type, which makes accurate machining of the bearing supports unnecessary.

Flow is controlled by a guide vane .Its shaft is parallel to the rotor shaft; it fits neatly inside the nozzle to keep leaks at the sides in the closed condition within limits. It guide water to the runner and controls the amount of water interring the runner. The device is operated by a screw and nut which is connected to a hand wheel. It can also be coupled to automatic operation, to the hydraulic cylinder of a speed governor.

In addition, rubber gaskets are required to seal up the turbine housing. In all cases, an adaptor can be provided at the turbine inlet that connects the penstock with the turbine. This part is of square shape at one end, to fit to the square inlet, and of circular cross section at the other end to fit to the penstock pipe used. Depending on the setting above tail water in an installation, a draft tube must be provided.

3.3 Manufacturing

All the manufacturing process carried out at TDTC workshop with the exception of the standard parts such as bearings, bolts & nuts e.t.c. which were purchased. Manufacturing can be carried out by a team of three or four people, consisting of a trained mechanic, a skilled worker trained on the job, and semi-skilled helpers. The cross flow turbine have been developed which suit local manufacturing capacity. Machine tools required were standard, such as:

x. Turning lathe with a centre height> 200 mm
xi. Drilling machine with a capacity up to 0 25 mm and boring attachment
xii. Milling machine or shaper
xiii. Acetylene cutting torch, plate shear (optional)
xiv. Arc welding equipment
xv. A number of jigs and fixtures made for the purpose
xvi. General hand tools

Manufacturing was carried out by a team of three/ people, consisting of a trained mechanic, a skilled worker trained on the job, and semi-skilled helpers.

3.4 Casing and Finishes

The turbine housing is entirely made of mild steel plates, robust which is tougher than grey cast iron and is good in impact and frost resistance and rigid enough to withstand high Operational stress and to enable a smooth operation (Figure 3.4). The design and the hydraulic layout result in minimized vibrations and noise level. Special care was taken in the layout of the main bearings for the runner and the guide vane. The casing is designed in such a way that different options for the bearing system are available to cope with the specific site requirements, like flywheel or belt drive. A sealing system is included in the side covers. The guide vane unit can easily be taken out through a side cover for inspection, cleaning or replacement. To obtain the guaranteed efficiency, the cylindrical runner is fabricated with high precision.

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Figure 3.4 Turbine casing and finishes

4 PERFORMANCE CHARACTERISTICS

4.1 Instrumenttaion and calibrations

It was necessary to carry out preliminary tests for the model in order to identify performance characteristics of the turbine (Figure 4.1). However, due to limited resources only a few tests were carried out and few parameters were tested in the hydraulic laboratory at the college of engineering and technology.

Figure 4. 1 Cross flow turbine testing (Wakati (2010)

4.2 Tests

Two tests were conducted. In the first test 1000 litres water tank was used to supply water in the turbine, the tank was elevated to a height of 2.2 meter and supported by a metal frame. Centrifugal pump used to supply water in the tank from the underground water wells through a 2 inches pipe as shown in the Figure 4.1 above. Water supplied in the turbine from the tank via a 4 inches pipe and controlled by a gate valve. To start, the pump is first switched on to fill the tank and water is released from the tank to drive the turbine when the tank is full by opening the gate valve in the tank discharge pipe. The water is then discharged (by gravity) back to the wells after driving the turbine.

The tests started by switching on the pump in order to drive the turbine, the gate valve between the turbine and pump used to control water flow from the pump to the turbine. The turbine speed measured at a different gate opening and different position of a guide vane using hand tachometer.

The second arrangement was such that the turbine connected directly to the pump, which means it utilizes direct pump flow and head. Two different pumps of different specifications were used in two different tests. The first pump specifications shows that the maximum flow rate is 35 cubic meters per hour and maximum head is 10 m, the second pump flow rate is 120 cubic meter/hour and head is 16 m. The pump flow controlled by gate valve fixed just after the pump.

4.3 Results and Analysis

It was observed that, when the water is released at the beginning when the tank is full, the turbine speed measured by using hand tachometer is 205 rpm. When the amount of water in the tank get reduced, the speed of the turbine is reduced to 110rpm.This is due to the fact that the water flow rate reduce due to amount of water in the tank. This means that the amount of water supplied is small compared to that discharged. This arrangement was then changed and the second arrangement made by connecting the turbine to the pump directly utilizing the direct pump flow. The results of which are shown in Table 4.1.

Table 4. 1: Performance Characteristics - Test results (Wakati (2010)

Fully Guide Vane Open		**Minimum Gate open**	
Gate valve adjustment	**Shaft speed (rpm)**	**Vane adjustment**	**Shaft speed (rpm)**
01	130	01	100
02	130	02	110
03	128	03	100
04	128	04	105
05	120	05	100
06	120	06	98
07	119	07	99
08	118	08	99
09	118	09	99
10	108		
11	100		
12 (Minimum flow)	100		

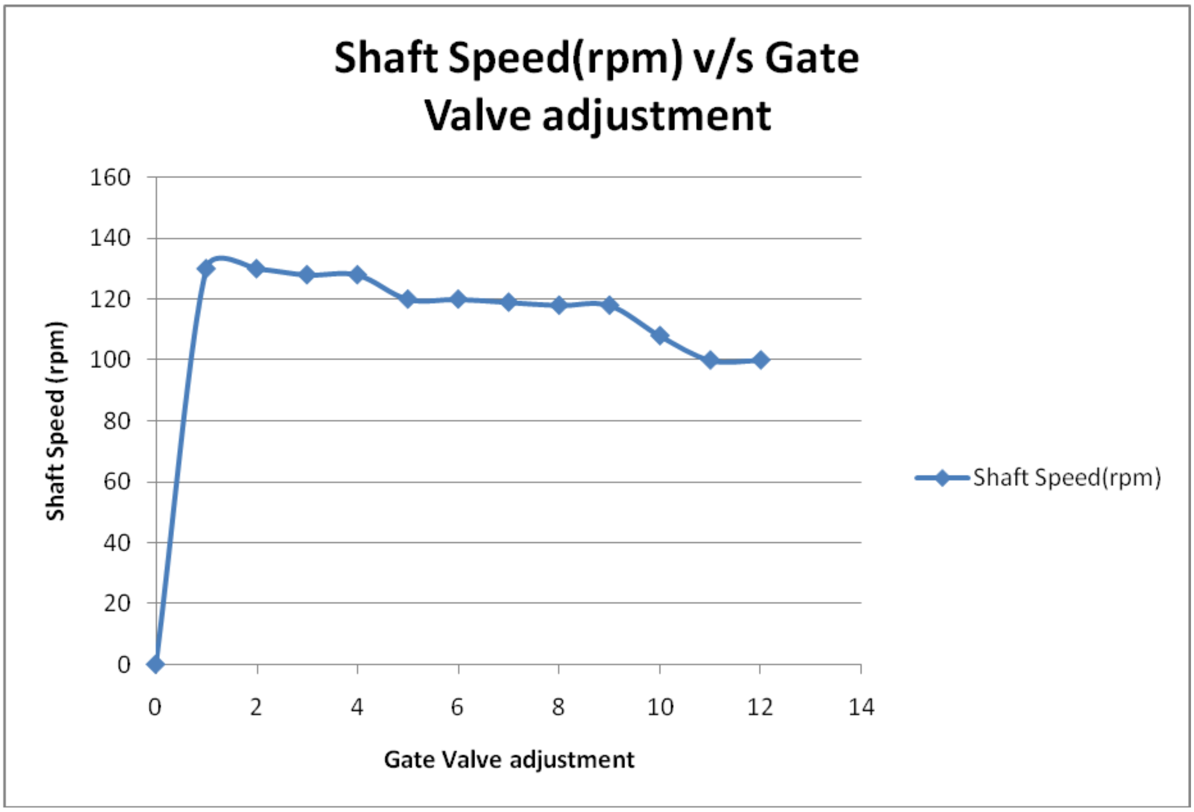

Figure 4.2 Shaft speed versus valve adjustment (Wakati (2010)

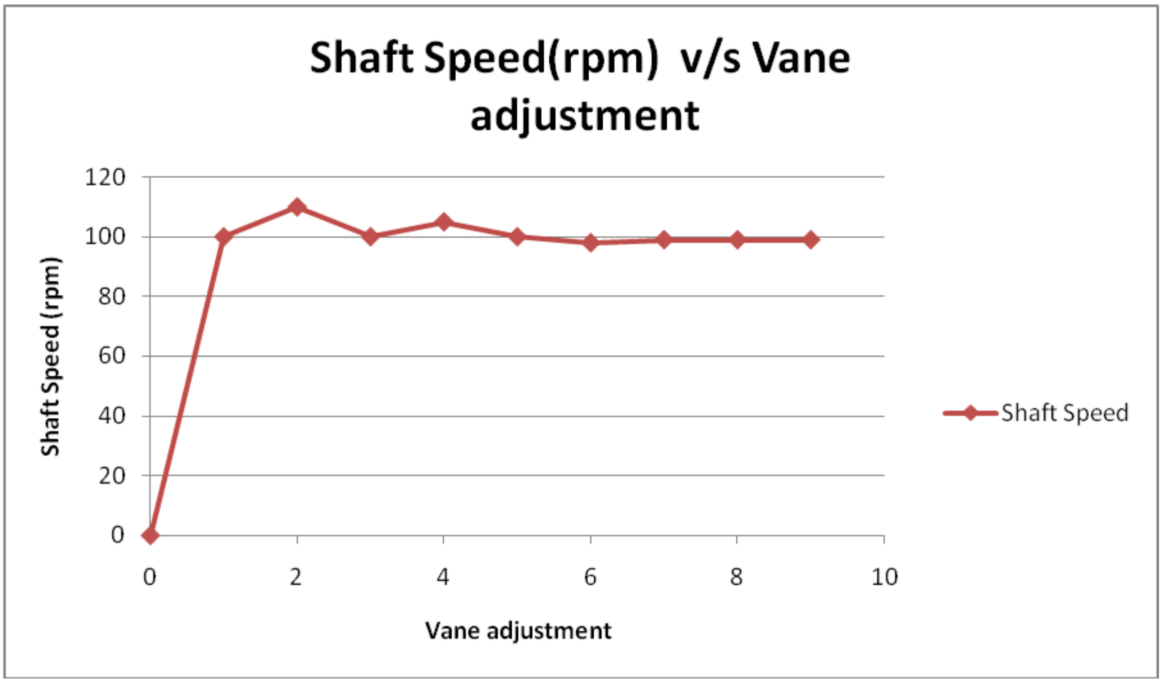

Figure 4. 3 Shaft speed versus vane adjustment (Wakati (2010)

5 CONCLUSIONS

5.1 Findings of Theme IB of Phase II Study

This research concentrated in the development of cross flow hydro turbine which can be locally produced at low cost. The research gives clear procedures on design and fabrication of a cross flow hydro turbine after organizing the information from different sources (literatures and experienced persons). Therefore these provide simplified procedures on design and manufacturing steps. The literatures survey has been done in order to ensure the designer go for appropriate design and feasible for local manufacturing.

The cross flow hydro turbine is successfully designed and a physical prototype model has been fabricated at the College of Engineering and Technology in TDTC workshop. Preliminary tests carried out in Hydraulic laboratory aimed at observing performance characteristics of the turbine. The tests show that the cross flow turbine works well in a wider range of water flow. The performances graphs indicate that the turbine speed depend on water flow rate. The higher the flow the higher is the speed, hence the power and vice versa.

Therefore, the results from the preliminary tests carried out in the laboratory are promising. This is therefore a step forward in solving the scarcity of suitable technology and form of energy to rural communities. From the design, it can be concluded that, the project is technologically feasible and economically viable. Therefore commitment of R&D Institutions and manufacturing industries is important in carrying out projects of this nature for the betterment of the nation and strengthening local capability and reputation. From the results, design and manufacturing of prototypes can now be carried out locally even by small workshops in the country.

5.2 Limitations

Due to limited resources some tests could not be carried out in the laboratory. Further tests will have to be carried out in the field. Field tests will thus give more realistic values for the turbine specifications.

6 RECOMMENDATIONS AND PLANS FOR FUTURE ACTIVITIES

6.1 Recommendations

Due to limited resources some tests could not be carried out in the laboratory. Further tests will have to be carried out in the field. Field tests will thus give more realistic values for the turbine specifications. The authors are therefore recommending for further tests and parametric studies in the cross flow turbine and improvement in various parameters for better performance of the locally manufactured cross flow turbine. There is also a need for disseminating the technology to various stakeholders and creating awareness of the technology to the stakeholders, government, policy and decision makers and identify local companies which can manufacture the turbine at reasonable cost.

6.2 Planning activities

6.2.1 Further tests will have to be carried out in the field. Field tests will thus give more realistic values for the turbine specifications.

6.2.2 Disseminating the technology to various stakeholders and creating awareness of the technology to the stakeholders, government, policy and decision makers and identify local companies which can manufacture the turbine at reasonable cost.

6.3 Topic for Future Research

6.3.1 Parametric studies in the cross flow turbine and improvement in various parameters for better performance of the locally cross flow turbine.

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APPENDICES

Appendix 1 – Cross Flow Turbine: Parts and Dimensions

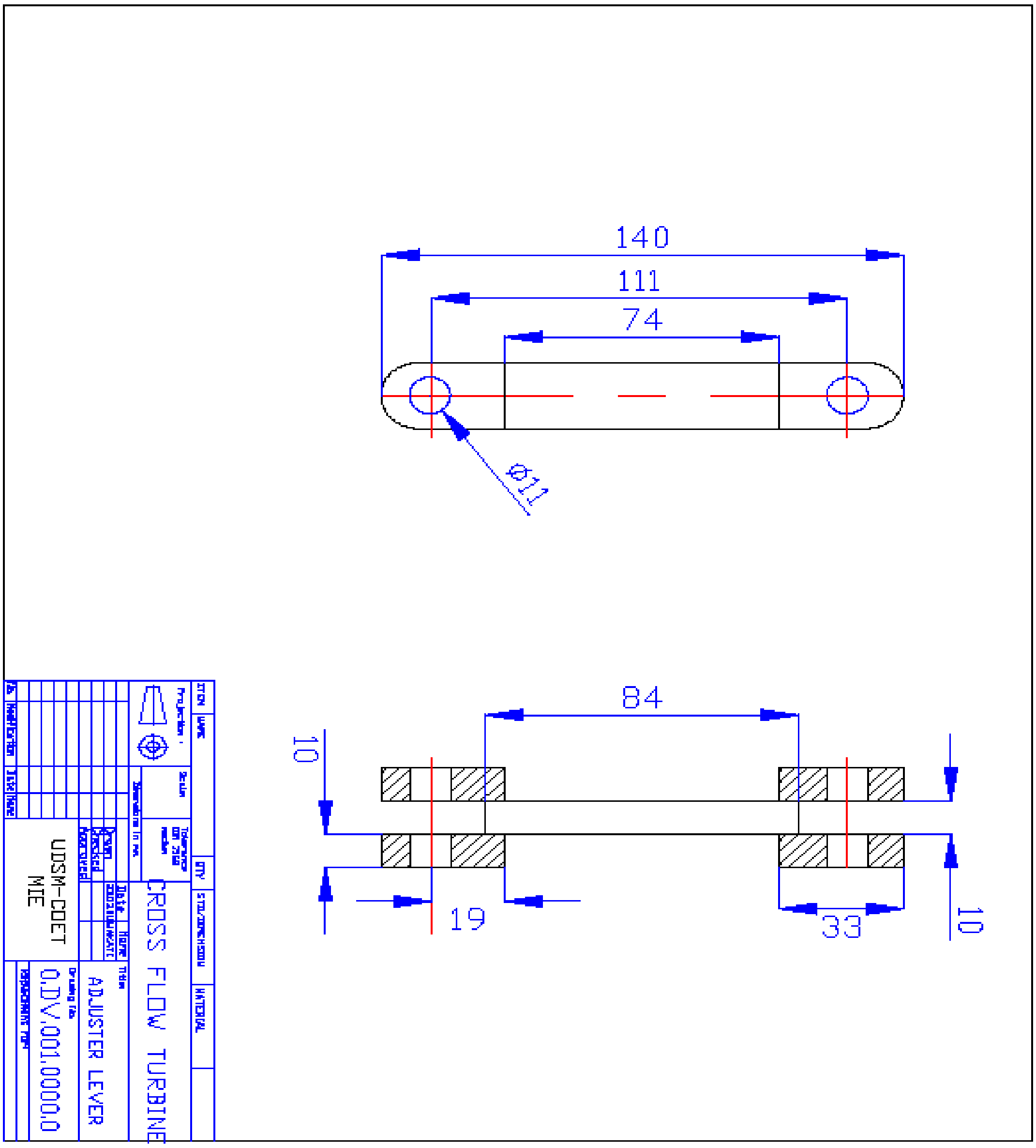

Figure A-1: Adjuster lever, Source: Wakati (2010)

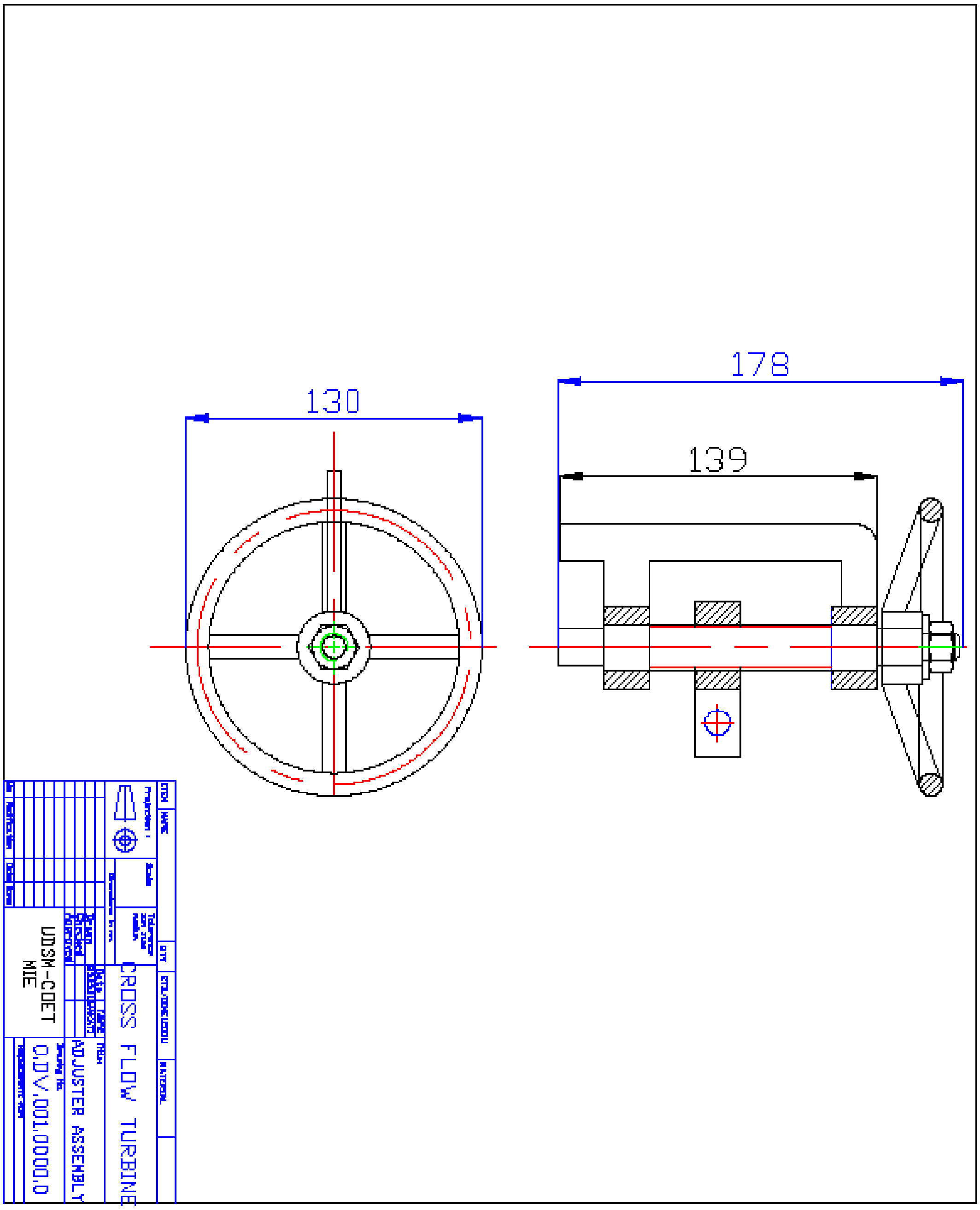

Figure A-2: Adjuster sub assembly, Source: Wakati (2010)

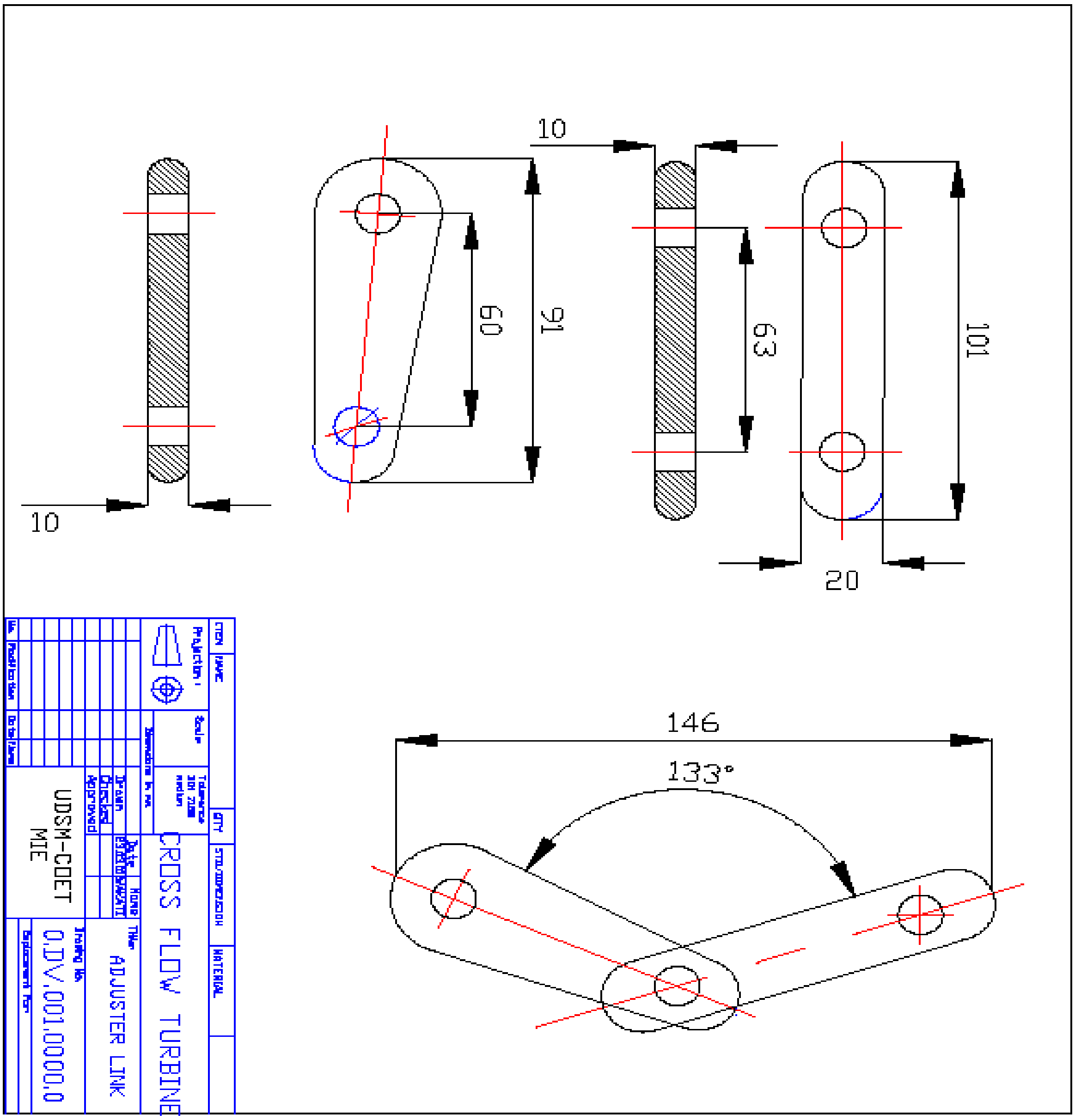

Figure A.3: Adjuster link, Source: Wakati (2010)

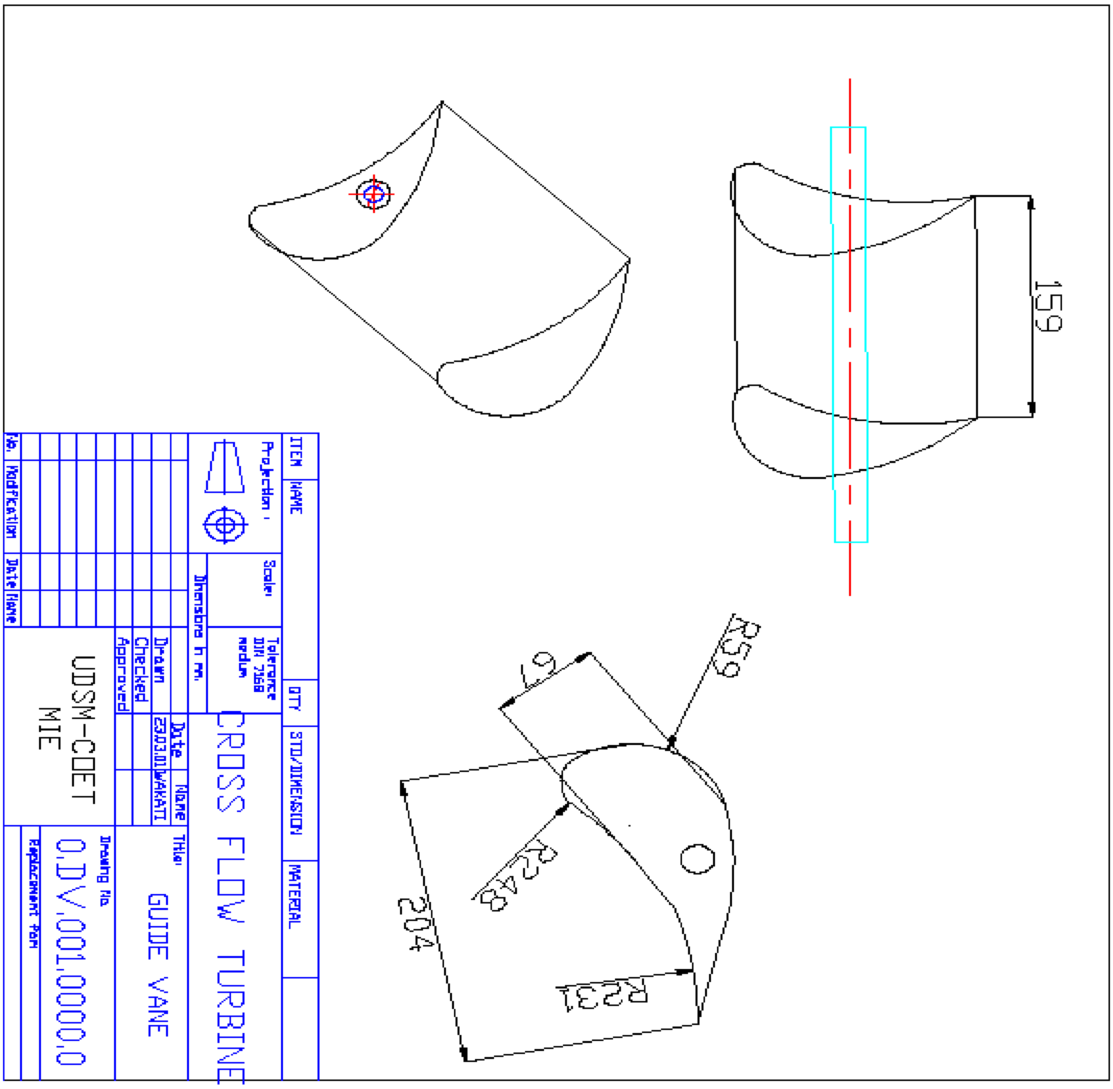

Figure A-4 : Guide vane, Source: Wakati (2010)

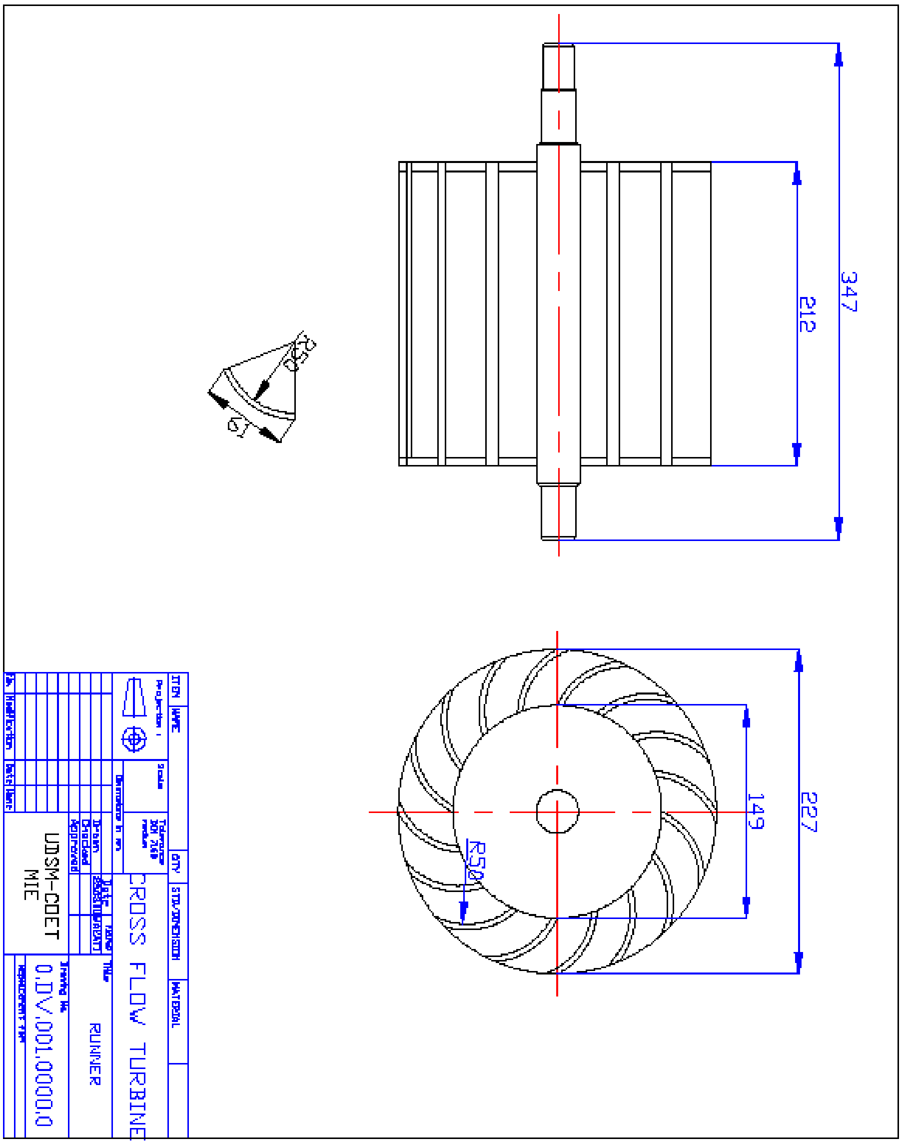

Figure A-5: Crossflow turbine Runner Source: Wakati (2010)

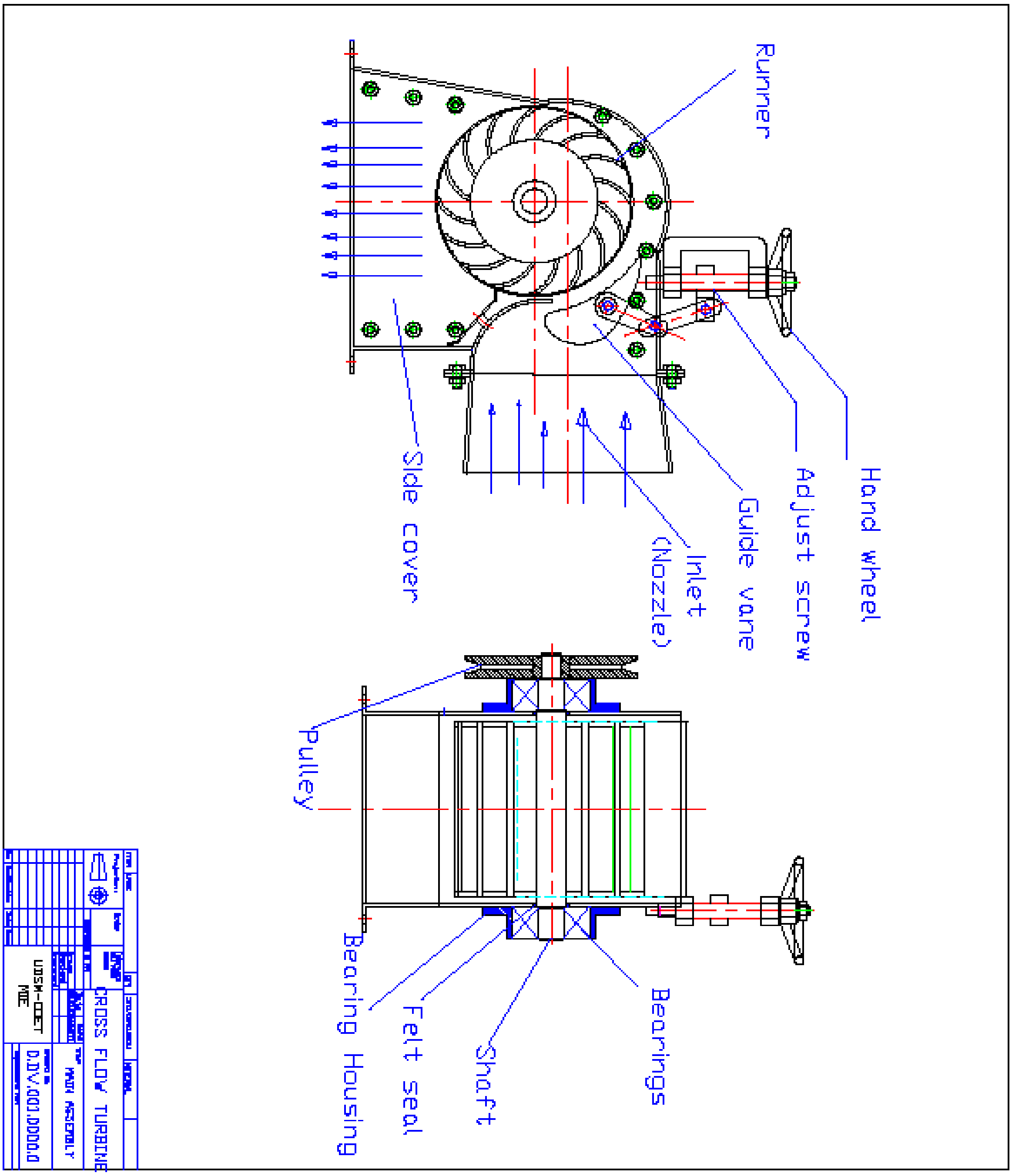

Figure A-6: Details of the locally designed cross flow hydro turbine. Source: Wakati (2010)

Table A-1: Summary of the cross flow turbine dimensions. Source: Wakati (2010)

S/N	Parameter	Specification	S/N	Parameter	Specification
01	Runner diameter	230 mm	08	Entry angle	16 degree
02	Runner width (bo)	200 mm	09	Area of the jet	$0.00824m^2$
03	Jet thickness	41.23 mm	10	Blade radius	37mm
04	No. of blade	18	11	Shaft speed	354 rpm
05	Jet velocity	9.7 m/s	12	Nozzle width	180 mm
06	Nozzle arc	73	13	Power (calculated)	2.5 kw
07	Overall Dimensions	523x343x520	14	Bearing	SKF 22206C

2010

Design and Fabrication of Cross flow Turbine

It has been found that over last few decades that there has been a growing realization in many developing countries like Tanzania that small hydropower schemes have a very important role to play in economic development of the rural population through electrification programs. Small hydropower schemes can provide power for industrial, agricultural and domestic uses through direct mechanical power or coupling of turbine generator.

This research concentrated on the development of cross flow hydro turbine which can be locally produced at low cost. The research gives clear procedures on design and fabrication of a cross flow hydro turbine after organizing the information from different sources (literatures and experienced persons). Therefore these provided simplified procedures on design and manufacturing steps. The literatures survey has been done in order to ensure the designer go for appropriate design and feasible for local manufacturing. The cross flow hydro turbine is successfully designed and a physical prototype model has been fabricated at the College of Engineering and Technology in TDTC workshop. Preliminary tests carried out in Hydraulic laboratory aimed at observing performance characteristics of the turbine. The tests show that the cross flow turbine works well in a wider range of water flow. The performances graphs indicate that the turbine speed depend on water flow rate. The higher the flow the higher is the speed, hence the power and vice versa. Therefore, the results from the preliminary tests carried out in the laboratory are promising. This is therefore a step forward in solving the scarcity of suitable technology and form of energy to rural communities. From the design, it can be concluded that, the project is technologically feasible and economically viable. Therefore commitment of R&D Institutions and manufacturing industries is important in carrying out projects of this nature for the betterment of the nation and strengthening local capability and reputation. From the results, design and manufacturing of prototypes can now be carried out locally even by small workshops in the country.

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