ISSN (e): 2250 – 3005 || Volume, 07 || Issue, 02|| February – 2017 ||
International Journal of Computational Engineering Research (IJCER)

Modelling, Fabrication & Analysis of Pelton Turbine for Different Head and Materials

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ABSTRACT

India is a country with huge population and variety of geographical locations. It has many places where high altitude mountains are present and have potential to generate the electricity through Hydro power plants. For high head power projects Pelton turbine is the first choice for the alternators. As he Efficiency is better in the above turbine as the research and the previous study has shown. The material by which the turbine is constructed matters a lot in achieving speed as well as efficiency of the entire system

Here an attempt is to model construct the design the Pelton wheel turbine for such high altitude areas on Indian subcontinents especially in north and north east part of the country, some places in Madhya Pradesh may also discovers with such location to create micro hydel power plants. The present work is a combination of mathematical modeling, fabrication of the proposed work, its Drafting and analysis using Creo & ANSY Work bench 12.0 and ultimately forecasting of speed and efficiency using artificial neural network

Keywords: *Turbine, Pelton wheel, Turbine Analysis, Pelton wheel Design, Turbine modeling, Artificial Neural Network, Training, ANSYS*

I. INTRODUCTION

Water is the renewable source of energy and proximately 15% of world energy drives by hydropower plant. Pelton wheel turbine is the type of impulse turbine which is work under the atmospheric pressure and it work on high head which is lies in the range between 2000 meters. Pelton wheel turbine is an axial flow turbine. The water strikes on the bucket which is carried from the reservoir to penstock and lower end of penstock is connected with nozzle. Nozzle increase the velocity of jet and this high velocity jet strikes on bucket due to striking on bucket an impulse is act on bucket which is exert by jet by which the runner starts to rotate. The bucket is mounted on the edge of the runner around the circumference of runner and runner is mounted on the shaft. The turbine shaft is connected with the generator shaft. The generator shaft converts the mechanical work that is generated by turbine into the useful electric energy, so the water discharges into tailrace after striking on the bucket. So the process start from storing of water into the dam this potential energy of water converts into kinetic energy and the kinetic energy used for drive the wheel of turbine.

Advantages of hydro-electric power plants:

- No convention fuel is required to be burned that means hydro-electric power plants are pollution free.
- If flow is continuous, electric energy produced from hydro-electric power plants.
- Due to easy convertibility and availability it is reliable than wind and solar and other sources.
- The life of the plants is substantially long.
- The cost of hydro power plants are low as compared to other power plants here the cost are running, maintenance and operational.

Disadvantages of hydro-electric power plants:

- It is very expensive to build dam.
- Hydropower plant depends on proper site selection and locations.
- Siltation gets altered due to installation of reservoir.
- The impact of water in plant life, residents due to quality and quantity of water.

II. OBJECTIVE

The main purpose of this thesis work is to prepare a model under some standard and its parameter which is also depends on standard. The thesis includes the change in design parameter such as the change in discharge of water by which the velocity of jet change due to changing of this term directly affect on the force exerted by the jet on the bucket which is responsible for the movement or motion of bucket its means the changing in the speed of runner with respect to the change in the jet velocity. The speed of runner is change by two methods the first one is to change the discharge as well as the jet velocity and the second on is the modification in the runner. Here the modification is done by the changing of density of runner plate. The density is change by changing of material. Due to changing the plate material the speed of runner change and so the mass moment of inertia will effect on the system.

III. LITERATURE REVIEW

Bilal Abdullah Nasir describes the design of pelton wheel for obtaining maximum efficiency for all parameter. These parameters are turbine specific efficiency, number of bucket required, number of jets and the dimension of jet, nozzle dimension, turbine power, torque, runner speed, bucket dimension and during various conditions. In this paper to improve the maximum efficiency different steps of design included such as for preparing the site data included the head race and tail race of plant.

Raj Kumar Kapooria presented some modification by which the pelton wheel can be used for heavy discharge and at low head. Comparatively a heavy generator can be run under low head and heavy discharge due to this modification. The water potential as well as kinetic energy both is consumed by the runner wheel. In this turbine the bucket of pelton wheel is modified and the modification is adding extra bucket-cups it means it like as cattle pot where the water pouring is done at top opening and discharges at another opening.

Loice Gudukeya & Ignatio Madamhire presents the improvement of pelton wheel turbine on the power out of plant while keeping the cost of project in the acceptable range and also works on the parameters such as surface texture. Material used and process of fabrication by which improves the efficiency up to 20 to 25 percent for micro hydro power plants.

IV. METHODOLOGY

Methodology provides the successive information to achieve the objectives. The Methodologies in form of flow chart for analytical and simulation approaches also provides the overview of the way to achieve the objective. After the analysis and simulation a working model is fabricated as shown in figure

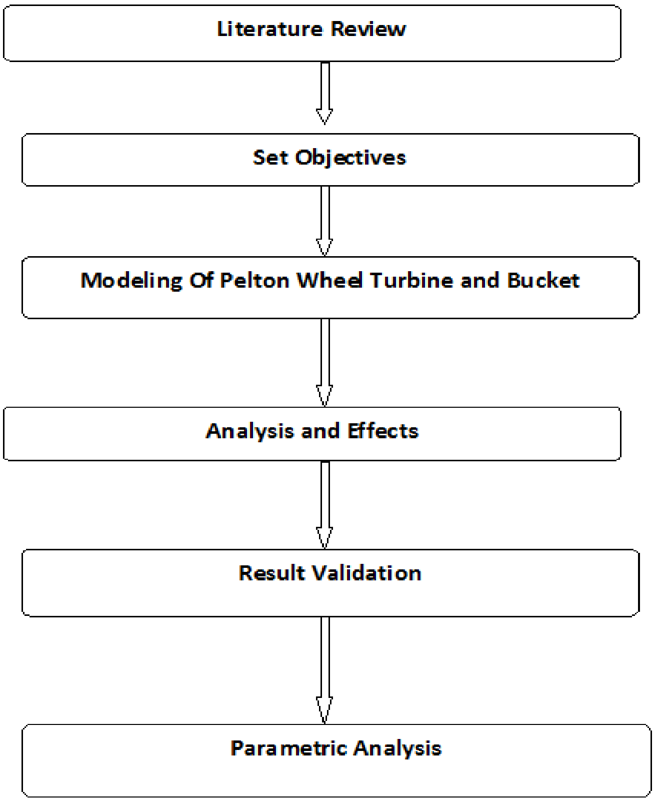

Figure 1 Methodology

V. SIMULATION PROCEDURE

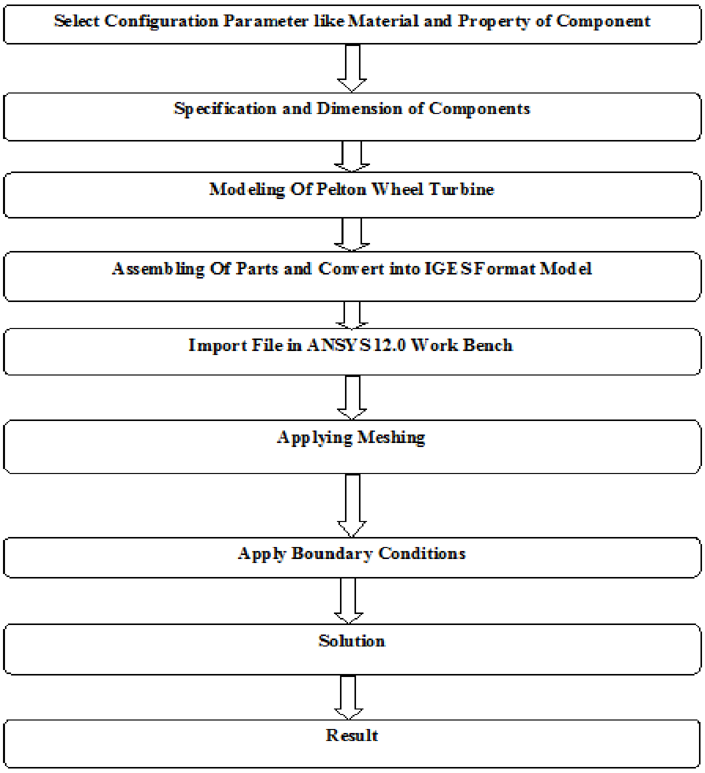

Figure 2 Simulation

VI. MODELING

As we know the pelton wheel turbine is run at very high kinetic energy which is produced by the available head which is also high approximately 1000m but for such condition available head is not possible in the testing on working model. Due to this condition the available head is responsible for getting high velocity so to elongate this by an electric motor pump is used. This high velocity jet is strikes on the bucket and the bucket is mounted on the runner of pelton turbine which exerts a force and due this force bucket starts move and due to motion of bucket the wheel also rotates.

Modeling of runner

For construction of model for pelton wheel turbines first choose the runner size and its thickness so from calculation let us assume the diameter of shaft is 300mm or 0.3m. This chapter shows the material and the construction of model. Here material of runner change for the neglecting the effect of mass moment of inertia, the different types of material and properties are described below

Material 1(wood): wood is the first material that I used it is lightest material as compare to cast iron and other metal such as aluminum and mild steel. The wood is used in runner of diameter of 0.3m and the thickness of plate is 0.029m.

Figure 3 Runner (wooden)

Table 1 Specification of Runner used in pelton wheel turbine

S No	Material	Weight Of Runner (Kg)	Overall weight of Runner
1	Wood	0.800	13.8 Kg
2	Cast Iron (hollow)	10.100	23.1 Kg
3	Cast Iron (solid)	13.400	26.4 Kg
4	Bakelite	4.600	17.6 Kg

Material 2 (Cast Iron solid): The next material that I choose is cast iron solid the thickness of plate is of 0.029 m. This weight of runner is 13.400 Kg.

Figure 4 Runner (Cast Iron solid)

Material 3 (Cast Iron Hollow): The next material that I choose is cast iron hollow here hollow means the thickness of plate change means in the place of 0.029 m plate I replace it by two plate which has a thickness of 0.010m and gap is filled by washer. This weight of runner is change by modification of runner plate thickness the weight of solid cast iron runner is 13.400 and the weight of hollow cast iron is 10.100 kg.

Figure 5 Runner (Cast Iron Hollow)

Material 4 (Bakelite): The Bakelite is also used for its properties. In wind turbine the blades of wind turbine is made up of FRC (fiber reinforced concrete) material. So I used it in the place of runner for enhancing the speed of runner as well as the blade of runner which is mounted on the runner.

Figure 6 Runner (Bakelite)

VII. METHOD OF CONSTRUCTION

- To make experimental setup a water reservoir is used for the storage of water which is a tank of 0.365x1.100x0.900 m with capacity of 360 liter capacity.
- For convert potential energy of water store in tank into kinetic energy a submersible pump is used of 0.5 hp and 2880RPM.
- A PVC pipe is used in place of penstock to carry water from pump to nozzle of inside diameter of 0.026m or 26mm.
- The runner of pelton wheel is mounted on the flange and shaft which is supported by the bearing
- The bucket is mounted on the circumference of runner with nut and bolt assembly.
- Now the nozzle is adjust on the angle of 180^0 to the bucket splitting angle.
- Now the jet is strikes on the bucket which exerts a force by which runner starts rotating.
- The speed of runner is calculated by device known as Tachometer.

Plan of Experimental Setup

Figure 7 Plan of experimental setup

The theoretical calculation for Modeling

The theoretical calculations are done by the formulas of design and obtained results from the experiment as given in the table below:

VIII. CAD MODELING AND ANALYSIS

General Procedure to Create Parts and Assembly of Pelton Wheel Turbine

The sequence of procedures employed to generate the parts of turbine are as follows:-

1. Set up the geometric parameters for bucket.
   - Volume of bucket
   - Bucket axial width
   - Bucket radial length
   - Bucket depth
2. Create the basic geometry such as the bucket axial width and radial width
3. Create two ellipse of that size and merge it using extrude command extrude it to create the modeling of bucket.

Table 2 Geometry of bucket

Volume of bucket	170	mm^3
Bucket axial width	100	mm
Bucket radial length	90	mm
Bucket depth	36	mm
No. of bucket	20	

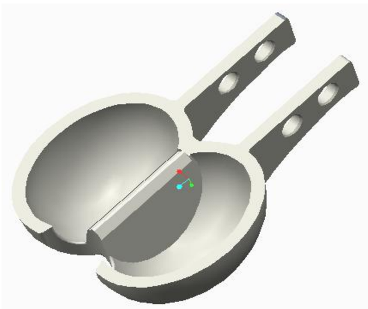

Figure 8 Solid model of Bucket for pelton wheel turbine using Creo software

4. Set up the geometric parameter for flange.
- Outside Diameter of Flange
- Thickness of Flange
- Length of Hub
5. Create the basic geometry using sketch command and revolve it around the central line axis.

Figure 9 Solid model of Flange for pelton wheel turbine using Creo software

6. Setup the geometric parameter for runner plate
- Diameter of runner
- Diameter of pitch circle of bolt
7. Create the plate using diameter of runner and make hole of 10mm for bolt using pitch circle diameter of hole.
8. Finally using pattern command for hole.

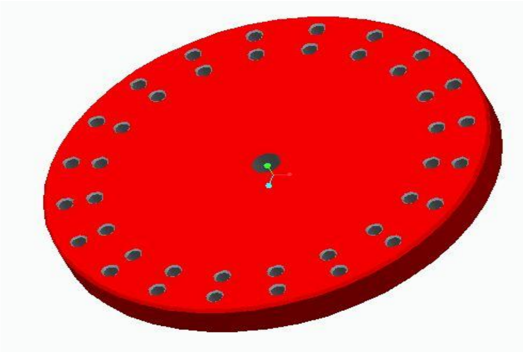

Figure 10 Solid model of runner for pelton wheel turbine using Creo software

9. Assembly all parts to make assembly of it.

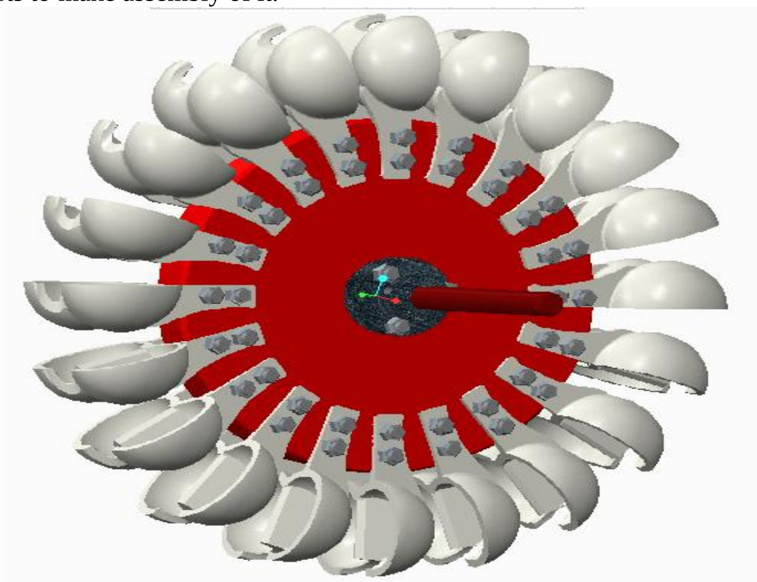

Figure 11 assembly of pelton wheel turbine using Creo software

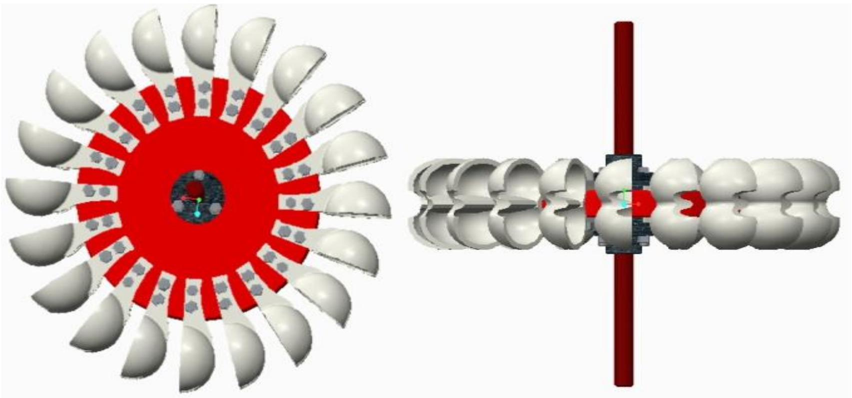

Figure 12 schematic view of pelton wheel turbine set up using Creo software

FEA using ANSYS Workbench 12.0
All numerical simulation and analysis are carried out using FEM software 12.0 and the simulation and analysis list are as follows:-

- Engineering data
- Geometry
- Model/mesh
- Setup
- Solution
- results

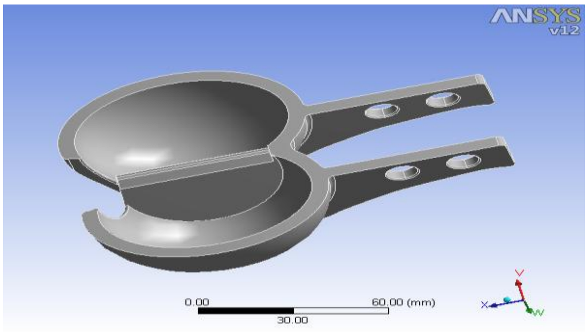

Figure 13 Bucket ANSYS model

Table 3 Statistics of bucket

Statistics	Quantity
Bodies	1
Active Bodies	1
Nodes	18758
Elements	10151

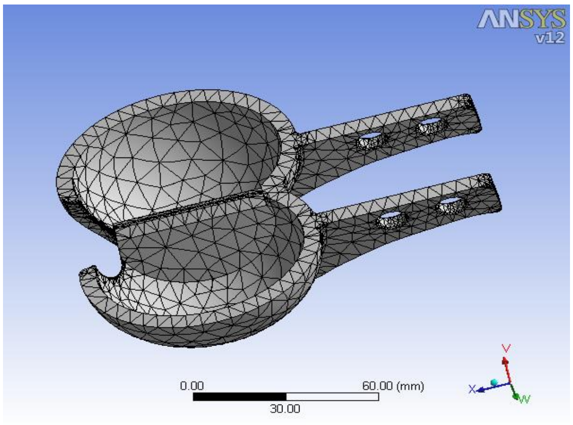

Figure 14 Meshing of bucket

Table 4 Properties of Aluminum Alloy

S No	Properties	Values
1	Density	2700 kg/m^3
2	Compressive Yield Strength (MPa)	280
3	Tensile Ultimate Strength (MPa)	310
4	Young's Modulus (MPa)	71000
5	Poisson's Ratio	0.33

Table 5 Model Static Structural Loads

Type	Force
X Component	0. N (ramped)
Y Component	5. N (ramped)
Z Component	0. N (ramped)

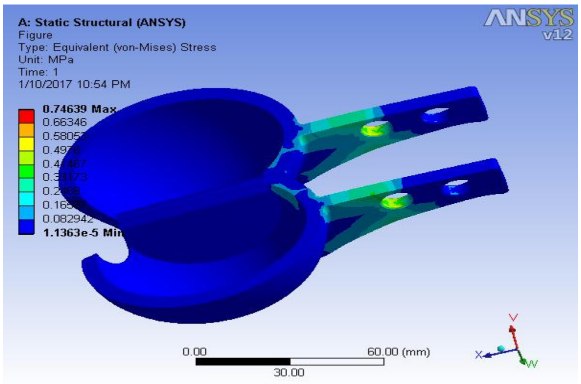

Figure 15 Equivalent stress of bucket

IX. MODEL STATIC STRUCTURAL SOLUTION RESULTS

Table 6 Deformation and stress analysis

Type	Equivalent (von-Mises) Stress	Total Deformation
Minimum	1.1363e-005 MPa	0. mm
Maximum	0.74639 MPa	1.192e-003 mm

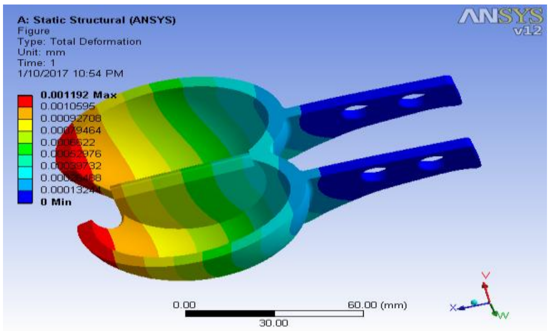

Figure 16 Total deformation of bucket

Analysis of Full model:-

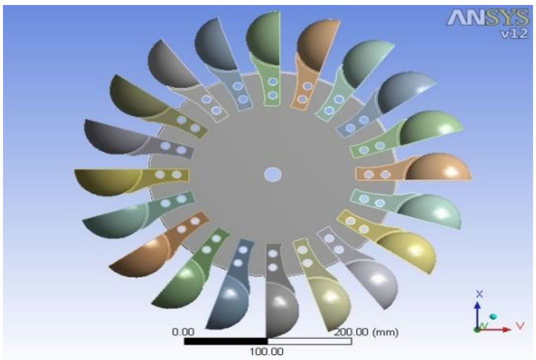

Figure 17 Full assembly ANSYS model of pelton runner

Table 7 Statistics of assemble parts

Statistics	Quantity
Bodies	110
Active Bodies	21
Nodes	195780
Elements	101911

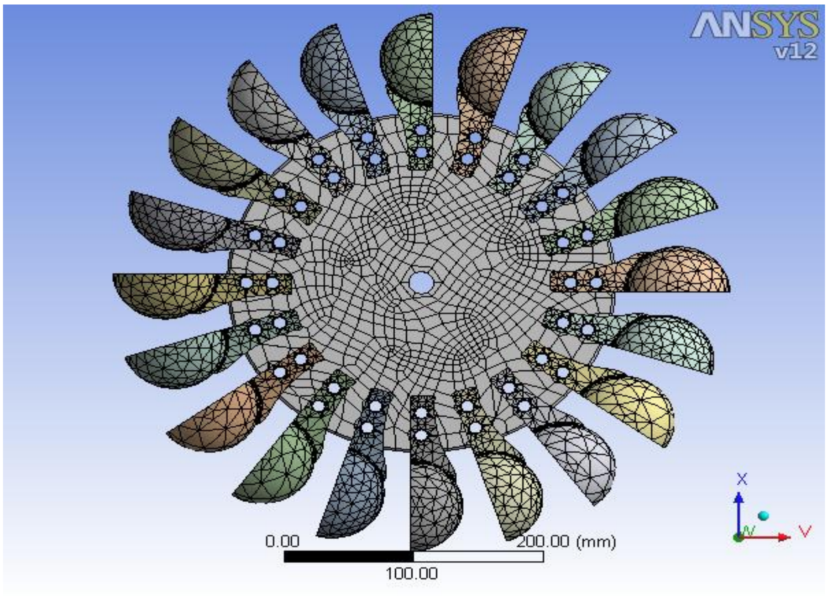

Figure 18 Meshing of pelton runner

Table 8 Properties of Runner

S .no	Properties	values
1	Density	7200 Kg/m^3
3	Tensile Ultimate Strength (MPa)	240
4	Young's Modulus (MPa)	10000
5	Poisson's Ratio	0.28

Model Static Structural Loads

Table 9 Model Static Structural Solution Results

Type	Equivalent (von-Mises) Stress	Total Deformation
Minimum	7.6942e-005 MPa	0. mm
Maximum	1.7893 MPa	3.2376e-003 mm

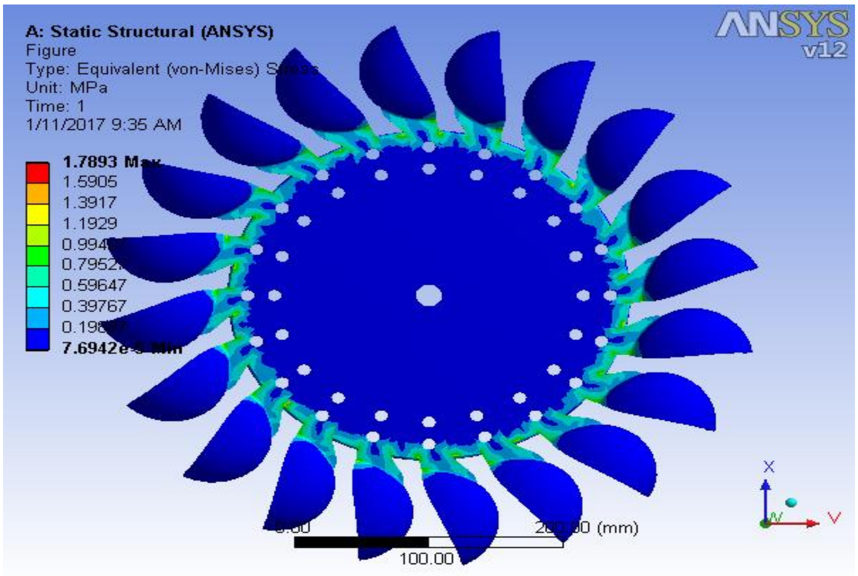

Figure 19 Equivalent stress of pelton runner

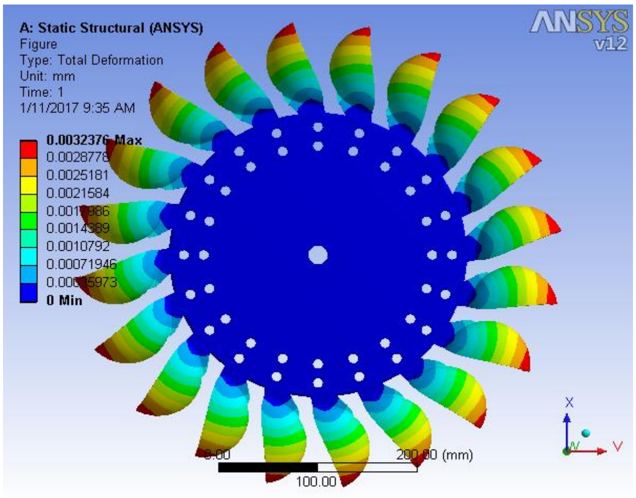

Figure 20 Total deformation of pelton runner

X. PROPOSED WORK

There are different results were found at different power input for the different runner materials of pelton wheel turbine. The velocity of jet, discharge and power output were found and this experiment was performed on Wooden , Cast iron (hollow), Cast iron (solid) and Bakelite material of runner.

These reading are given below in the table:

First setup is on the cast iron (Solid) material runner which is a solid plate of 29mm thickness.

Table 10 Result on changing on speed of runner due to velocity variation on cast iron (solid) runner

S No	Discharge (m^3/s)	Velocity (m/s)	Power input (Watt)	RPM	u	Power output	Efficiency □
1	0.001246	2.32	3.35	117.8	1.84	1.172	64
2	0.001655	2.96	7.25	156.5	2.45	1.654	56
3	0.001721	3.17	8.64	172.1	2.71	1.552	49

Result: We can see from the result that as the discharge increases the runner speed also increased. The maximum runner speed was noticed as 172.1 RPM at 0.001721 m^3/s discharge and 3.17 m/s jet velocity.

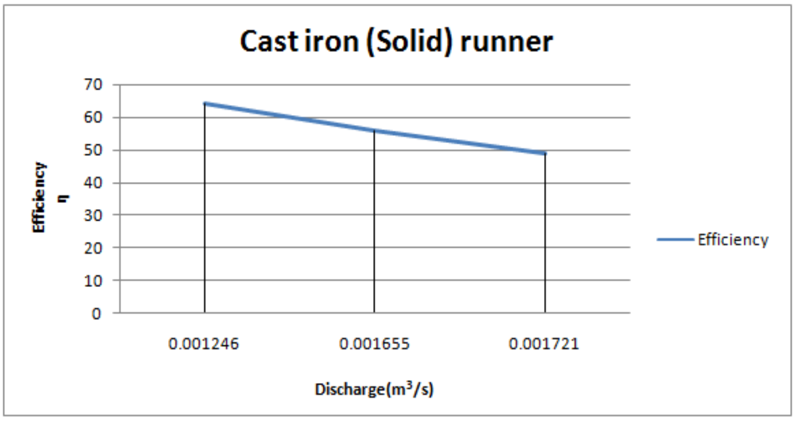

Figure 21 Graph of Efficiency against Discharge graph for the cast iron (Solid) runner

Experiment-2

Second setup is on the cast iron material runner which is also a solid plate but of 10mm thickness and we are taken two plates of 10mm and 9mm gap is filled by the washer for reducing the weight of runner.

Table 11 Result on changing on speed of runner due to velocity variation on cast iron (Hollow) runner

S No	Discharge (m^3/s)	Velocity (m/s)	Power input (Watt)	RPM	u	Power output	Efficiency □
1	0.001246	2.32	3.35	122.5	1.92	0.977	56
2	0.001655	2.96	7.25	159.5	2.5	1.492	51
3	0.001721	3.17	8.64	179.4	2.81	1.214	39

Result: the second experiment was done on the same setup used in first experiment, but in this experiment 10mm thick cast iron (solid) plat were used. These two plates were connected with washer and the gap between the plates was maintained at 9mm in order to make the hollow plate arrangement. The result from this experiment is as shown in the table above.

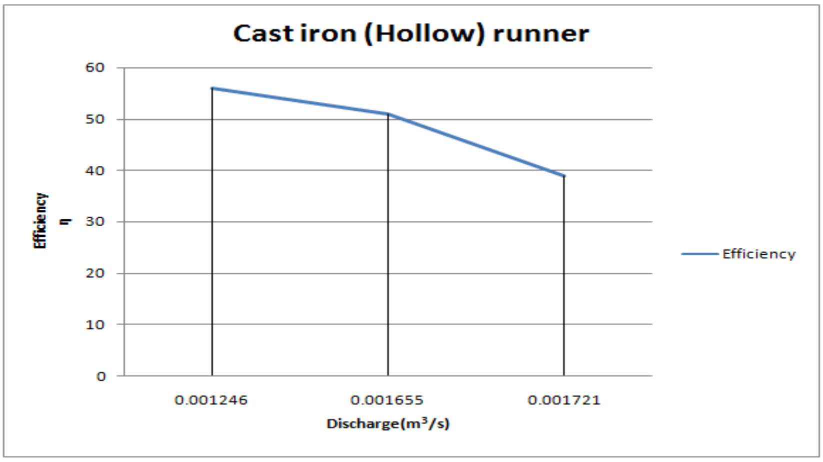

Figure 22 Graph of Efficiency against Discharge graph for the cast iron (Hollow) runner.

Experiment-3
Third setup is on the wooden material runner which is a solid plate of 29mm thickness

Table 12 Result on changing on speed of runner due to velocity variation on wooden runner

S No	Discharge (m^3/s)	Velocity (m/s)	Power input	RPM	u	Power output	Efficiency
1	0.001246	2.32	3.35	137.5	2.15	0.415	27
2	0.001655	2.96	7.25	184.5	2.8	0.519	20
3	0.001721	3.17	8.64	195.9	3.07	0.337	12

Result: The third experiment was done on the same setup used in first experiment, but in this experiment 29mm thick wooden plat were used. The result from this experiment is as shown in the table above. The maximum runner speed was observed as 195.9 RPM at 0.001721 m^3/s and Velocity m/s.

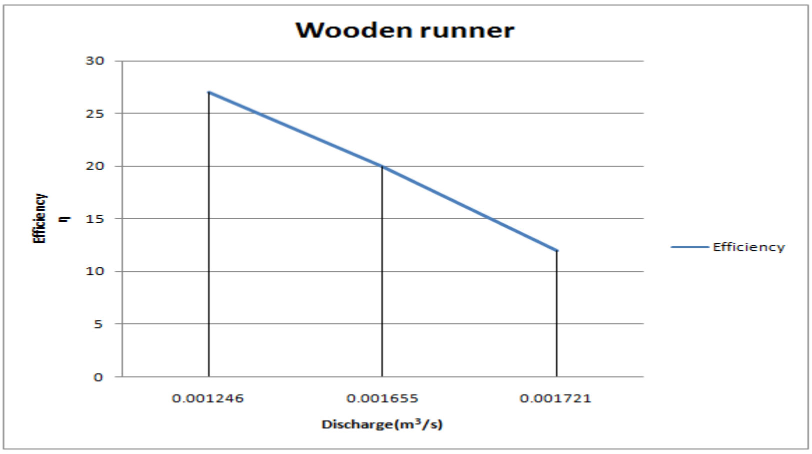

Figure 23 Graph of Efficiency against Discharge for wooden runner.

Experiment-4
Fourth setup is on the wooden material runner which is a solid plate of 29mm thickness

Table 13 Result on changing on speed of runner due to velocity variation on Bakelite runner

S No	Discharge (m^3/s)	Velocity (m/s)	Power input	RPM	u	Power output	Efficiency
1	0.001246	2.32	3.35	142.5	2.23	0.220	15
2	0.001655	2.96	7.25	189.5	2.9	0.195	8
3	0.001721	3.17	8.64	199.8	3.13	0.135	5

Result: The fourth experiment was done on the same setup used in first experiment, but in this experiment 29mm thick Bakelite plat were used. The result from this experiment is as shown in the table above. The maximum runner speed was observed as 199.8 RPM at 0.001721 m^3/s and Velocity m/s.

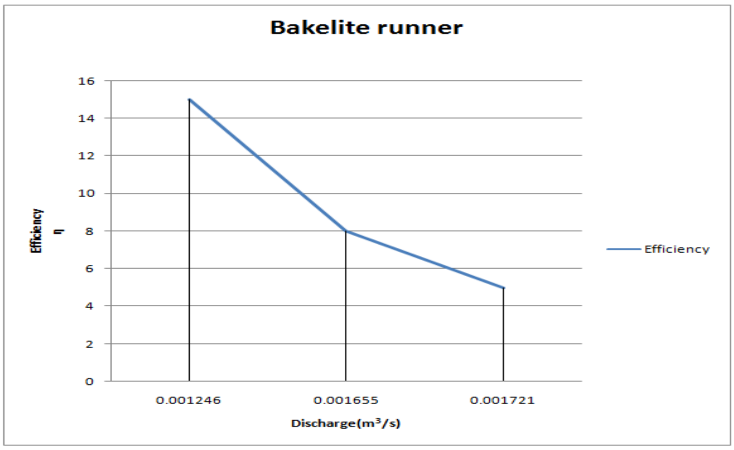

Figure 24 Graph of Efficiency against Discharge for Bakelite runner.

Comparative Analysis and Discussion

Comparison between the performances of the different runner of different materials

The performance comparisons for different runners of different materials shown in table 5.The results from the experiment show that at same discharge and velocity the runner speed changes and also the efficiency of turbines varies. The maximum efficiency was observed as 64% in case of solid cast iron runner while lowest in the case of Bakelite runner. On the other hand the maximum RMP was measured as 142.5 in case of Bakelite while 117.8 in case of solid cast iron runner.

Table 14 Comparison between performances of the runners of different materials at 0.00125 m^3/s and 2.32m/s.

S No.	Material	Power input (Watt)	RPM	u	Power output	Efficiency □
1	Cast iron (solid)	3.35	117.8	1.84	1.172	64
2	Cast iron (hollow)	3.35	122.5	1.92	0.977	56
3	Wooden	3.35	137.5	2.15	0.415	27
4	Bakelite	3.35	142.5	2.23	0.22	15

The performance comparisons for different runners of different materials shown in table 5.The results from the experiment show that at same discharge and velocity the runner speed changes and also the efficiency of turbines varies. The maximum efficiency was observed as 56 % in case of solid cast iron runner while lowest in the case of Bakelite runner. On the other hand the maximum RPM was measured as 189.5 in case of Bakelite while 156.5 in case of solid cast iron runner.

Table 15 Comparison between performances of the runners of different materials at 0.00166 m^3/s and 2.96m/s.

S No	Material	Power input (Watt)	RPM	$u=u_1=u_2$	Power output	Efficiency (□)
1	Cast iron (solid)	7.25	156.5	2.45	1.654	56
2	Cast iron (hollow)	7.25	159.5	2.5	1.492	51
3	Wooden	7.25	184.5	2.8	0.519	20
4	Bakelite	7.25	189.5	2.9	0.195	8

The performance comparisons for different runners of different materials shown in table 5.5.The results from the experiment show that at same discharge and velocity the runner speed changes and also the efficiency of turbines varies. The maximum efficiency was observed as 56 % in case of solid cast iron runner while lowest in the case of Bakelite runner. On the other hand the maximum RPM was measured as 199.8 in case of Bakelite while 172.1 in case of solid cast iron runner.

Table 16 Comparison between performances of the runners of different materials at 0.00172 m^3/s and 3.17 m/s.

S No	Material	Power input (Watt)	RPM	$u=u_1=u_2$	Power output	Efficiency (□)
1	Cast iron (solid)	8.64	172.1	2.71	1.552	49
2	Cast iron (hollow)	8.64	179.4	2.81	1.214	39
3	Wooden	8.64	195.9	3.07	0.337	12
4	Bakelite	8.64	199.8	3.13	0.135	5

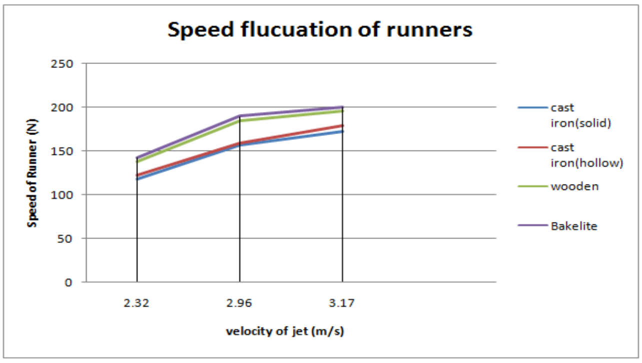

Figure 25 Graph of speed of runner against velocity of jet**.**

XI. FORECASTING OF TURBINE OUTPUT AND EFFICIENCY USING ARTIFICIAL NEURAL NETWORK (ANN)

Artificial neural network is a powerful algorithm for the detection of real life problems and output. Here supervised learning technique is used for the detection of turbine output and efficiency of the system.

For the input, training and testing the input parameters are; discharge diameter, speed and blade velocity while output or target is turbine output and efficiency. Figure 5.6 shows the training window of ANN using Mat lab:

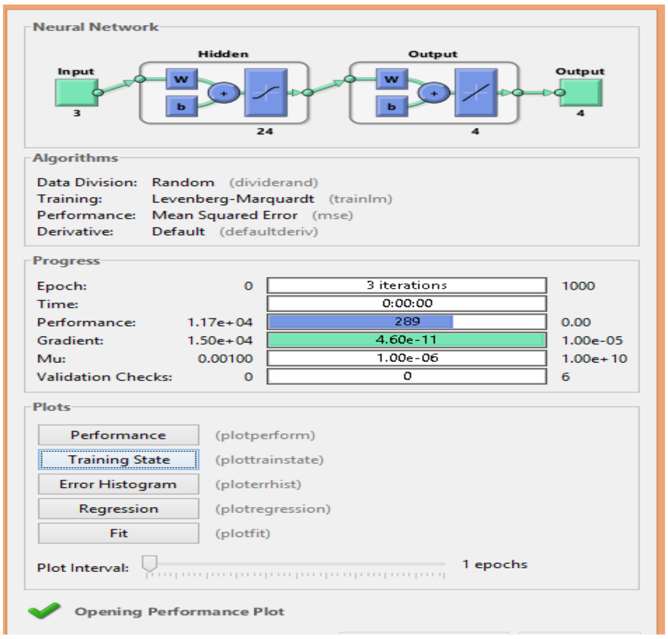

Figure 26 ANN Training Window

Figure 27 shows the validation and best performance of ANN:

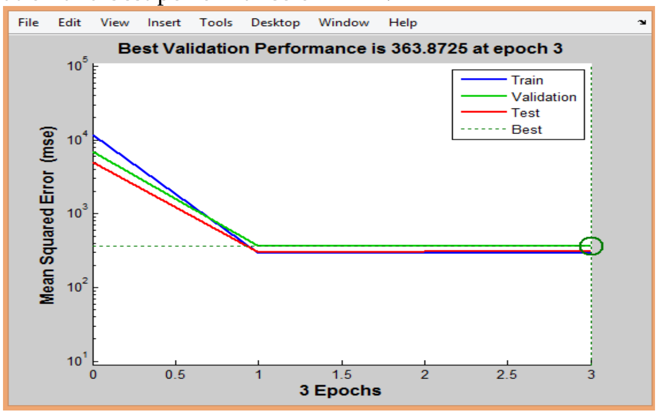

Figure 27 Validation of ANN

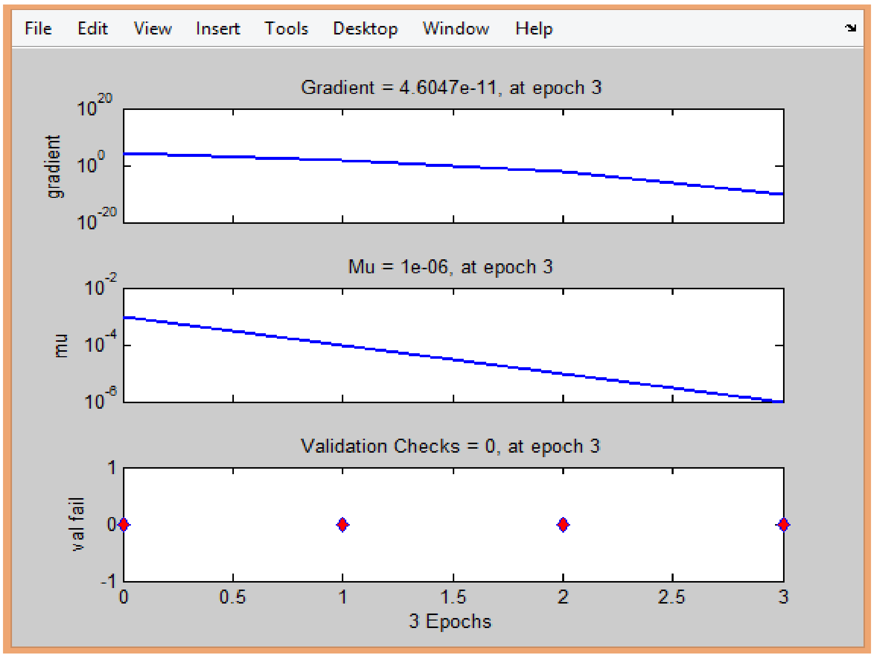

Figure 28 Training State ANN

Figure 29 shows the regression curve with overall curves:

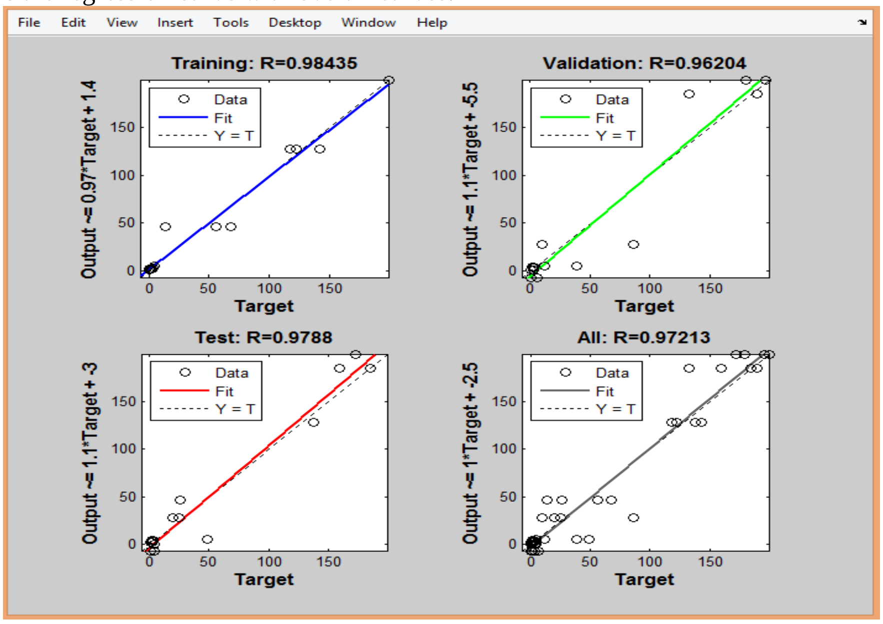

Figure 29 Regression Curve ANN

Table 17 shows the result of ANN forecasting of Speed and error.

Table 17 Error analysis in Speed using ANN

S No	Speed *(N)* (RPM)	Speed using ANN	Error (In %)
1	137.5	134.5	2.181818
2	122.5	119.5	2.44898
3	117.8	115.5	1.952462
4	142.5	139.5	2.105263
5	184.5	180.5	2.168022
6	159.5	158.5	0.626959
7	132.5	129.5	2.264151
8	189.5	185.5	2.110818
9	195.9	192.2	1.888719
10	179.4	174.9861	2.460352
11	172.1	169.9861	1.228281
12	199.8	196.9861	1.408345

Figure 30 shows the comparative chart of turbine speed of actual and ANN forecasted:

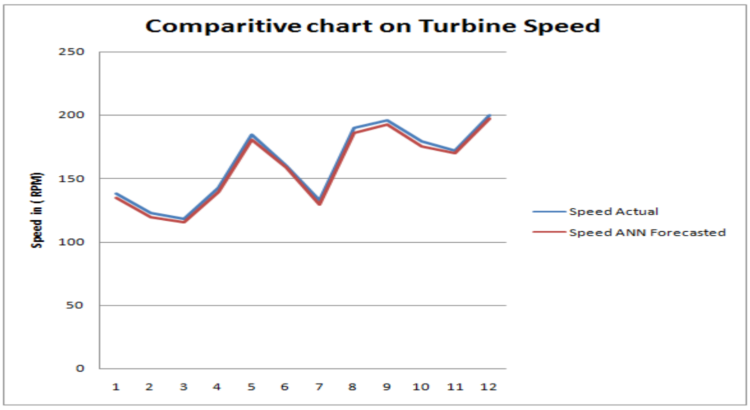

Figure 30 Comparative Chart for Turbine Speed

Table 18 shows the result of ANN forecasting of Blade velocity and error.

Table 18 Error analysis in Blade velocity using ANN

S NO	**Blade velocity (u)**	**Blade velocity using ANN**	**Error (In %)**
1	2.15	2.11	1.860465
2	1.92	1.87	2.604167
3	1.84	1.8	2.173913
4	2.23	2.2	1.345291
5	2.8	2.76	1.428571
6	2.5	2.46	1.6
7	2.0	1.96	2
8	2.9	2.85	1.724138
9	3.07	3.01	1.954397
10	2.81	2.78	1.067616
11	2.71	2.68	1.107011
12	3.13	3.09	1.277955

Figure 31 shows the comparative chart of turbine Blade velocity of actual and ANN forecasted:

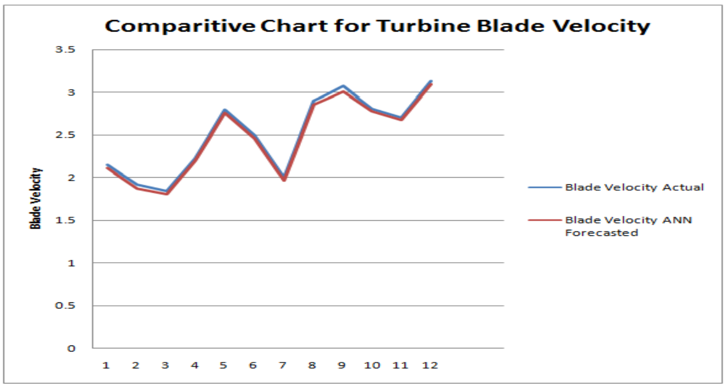

Figure 31 Comparative Charts for Turbine Blade Velocity.

Table 19 shows the result of ANN forecasting of Blade velocity and error.

Table 19 Error analysis in Turbine power output using ANN

S NO	**Power output (P_{to})**	**Power output using ANN**	**Error (In %)**
1	0.87	0.85	2.298851
2	1.88	1.83	2.659574
3	2.16	2.11	2.314815
4	0.49	0.45	8.163265
5	1.45	1.409	2.827586
6	3.74	3.7	1.069519
7	6.246	6.12	2.017291
8	0.566	0.556	1.766784
9	1.03	1.03	0
10	3.42	3.35	2.046784
11	4.21	4.15	1.425178
12	0.423	0.414	2.12766

Figure 32 shows the comparative chart of turbine power output of actual and ANN forecasted:

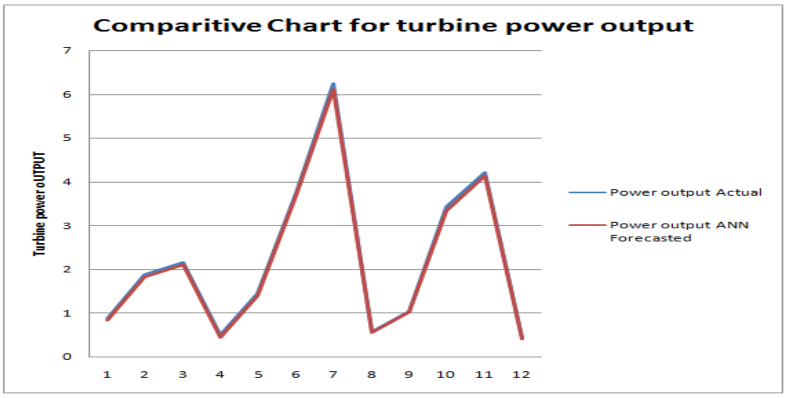

Figure 32 Comparative Chart for Turbine Power Output.

Table 20 shows the result of ANN forecasting of Efficiency and error.

Table 20 Error analysis in Efficiency using ANN

S NO	**Efficiency(□)**	**Efficiency using ANN**	**Error (In %)**
1	26	25.3	2.692308
2	56	54.5	2.678571
3	68	67.2	1.176471
4	14	13.6	2.857143
5	20	19.46	2.7
6	25	24.36	2.56
7	86	84.65	1.569767
8	10	9.856	1.44
9	12	11.763	1.975
10	39	38.55	1.153846
11	49	47.98	2.081633
12	5	4.859	2.82

Figure 33 shows the comparative chart of turbine Efficiency of actual and ANN forecasted.

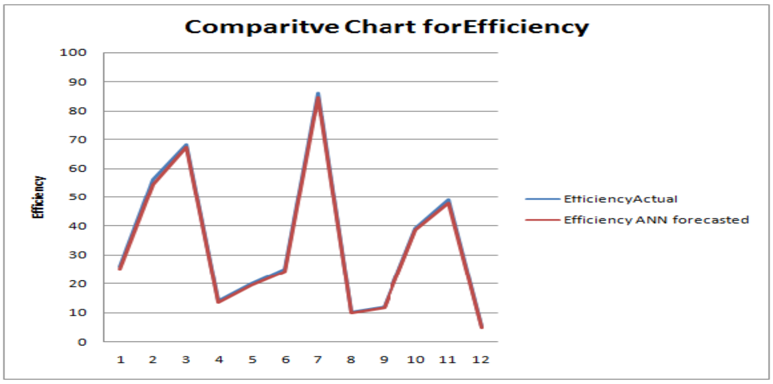

Figure 33 Comparative Chart for Turbine Efficiency

XII. CONCLUSION

This thesis work includes studies on the speed of different material runner which is operates on different discharge and effect on the efficiency of plant. The solid model of pelton wheel turbine has been developed in Creo software and all analysis was performed in ANSYS 12.0 software. This chapter covers the conclusion of the thesis work. The present work was based on to check the performance of pelton wheel turbine by using different runner material. In this experimental study wooden, solid cast iron, hollow cast iron and Bakelite runner were used. To perform experimental study design of physical model of pelton wheel turbine was done. To compare the performance of different runners materials discharge, velocity, relative velocity, power input, power output and efficiency was measured at different velocities. This work was carried at varying velocities for same material of runner shaft and also this procedure was done for all materials of runners. It was observed in first experiment that at 2.32 m/s and 0.00125m^3/s for the solid cast iron runner the RPM was 117.8 while 122.5, 137.5 and 142.5 for hollow cast iron, wooden and Bakelite respectively. From experiment first it was observed that at the same speed Bakelite runner gives maximum RPM (142.5) on the other hand solid cast iron runner gives minimum RPM (117.8). Same procedure was carried out for experiment second and third at different velocities for different materials of runner. After analyzing these results from all three experiments it can be said that the Bakelite runner gives maximum RPM as compare to wooden, solid cast iron and hollow cast iron runners. Also these results shows that the solid cast iron runner gives minimum RPM as compare to wooden, hollow cast and Bakelite runners. These experiments were done at low head so we can conclude that Bakelite runner is very beneficial as compare to other three materials we used at low head. We know that pelton wheel turbine works under high head and if Bakelite rubber will be used for this turbine ultimate results may be obtained in terns it will increase the performance of turbine. The artificial Neural Network is also used here to predict the actual speed and efficiency of the turbine through modern techniques and accuracy.

In next phase the system may be model and optimize using different evolutionary algorithms and may get the optimum results

REFERENCES

[1]. Bilal Abdullah Nasir. "Design of High Efficiency Pelton Turbine for Micro Hydro Power Plant" IJET, Volume 4, Issue 1, January-February (2013), pp. 171-183.

[2]. Nikhil Jacob George, SebinSabu, Kevin Raju Joseph, AshwinChandy Alex. "Static Analysis on Pelton Wheel Bucket" IJERT, Vol. 3 Issue 3, March - 2014

[3]. Bryan R. Cobb, Kendra V. Sharp "Impulse (Turgo and Pelton) turbine performance characteristics and their impact on pico-hydro installations" ELSEVIER, 7 August 2012

[4]. Chukwuneke J. L, Achebe C. H., Nwosu M. C., Sinebe J. E. "Analysis and Simulation on Effect of Head and Bucket Splitter Angle on the Power Output of a Pelton Turbine" EAAS, Volume 5, No. 03, Aug. 2014.

[5]. I.U. Atthanayake"Analytical Study On Flow Through a Pelton Turbine Bucket Using Boundary Layer Theory" IJET-IJENS, Volume 9, No. 9.

[6]. LoiceGudukeya,IgnatioMadanhire. "Efficiency Improvement Of Pelton Wheel And crossflow Turbines In Micro-Hydro Power Plants: Case Study" IJECS, Volume 2 Issue 2 Feb 2013 Page No. 416-432

[7]. Raj Kumar Kapooria "An efficiency assessment analysis of a modified gravitational Pelton-wheel turbine" Journal of Energy in Southern Africa, Volume 20 No 4, November 2009.

[8]. SaurabhSangal, ArpitGarg, Dinesh Kumar. "Review of Optimal Selection of Turbines for Hydroelectric Projects" IJETAE, Volume 3, Issue 3, March 2013.

[9]. Dr. Vishnu Prasad. "Numerical simulation for flow characteristics of axial flow hydraulic turbine runner" Energy Procedia 14 (2012) 2060 – 2065.

[10]. Bilal Abdullah Nasir. "Design of High Efficiency Cross-Flow Turbine for Hydro-Power Plant" IJEAT, Volume 2, Issue 3, February 2013.

[11]. UgyenDorji, Reza Ghomashchi. "Hydro turbine failure mechanisms" ELSEVIER, Engineering Failure Analysis, Volume 44 (2014) 136–147.

[12]. P Drtina, M Sallaberger. "Hydraulic turbines—basic principles and state-of-theart computational fluid dynamics applications" ProcInstnMechEngrsVol 213 Part C.

[13]. E Hernández. "Design and construction of an impulse turbine" Journal of Physics: Conference Series 466 (2013) 012036.

[14]. E. Parkinson, C. Neury, H. Garcin, G. Vullioud, Th. Weiss. "Unsteady analysis of Pelton runner with flow and mechanical simulations"Hydro 2005, October 31 to November 3, Villach, Austria, Hydropower & Dams, Issue Three, 2006 (Magazine).

[15]. AlexandrePerrig, François Avellan, Jean-Louis Kueny, Mohamed Farhat. "Flow in a Pelton Turbine Bucket Numerical and Experimental Investigations" Volume 128, March 2006.

[16]. A.A.Lahimer, M.A.Alghoul, K.Sopian, Nowshad Amin, NilofarAsim, M.I.Fadhel. "Research and development aspects of Pico-hydro power" ELSEVEIR, Renewable and Sustainable Energy Reviews 16 (2012) 5861–5878.

[17]. Edvard Ho¨ fler1, Janez Gale2, Anton Bergant."Hydraulic Design and Analysis of theSaxo-Type Vertical Axial Turbine"Transactions of the Canadian Society for Mechanical Engineering, Volume 35, No. 1, 2011.

[18]. V.G.Vijaya. "Analysis of Rigid Flange Couplings" IJIREST, Vol. 2, Issue 12, December 2013.

[19]. Chandra SekharKatta, KamanaSrinivasaRao. "Design and Analysis of Flange Coupling", IJPES, Volume 4, Issue 4, AUG 2016.

[20]. Sourabh Mehto, Rahul Agarwal, Manish Shah, "A Comparative Study Based on PI and Fuzzy Control of Inverter fed Induction Motor Drive", International Journal of Research (IJR) Vol-2, Issue-2 February 2015 ISSN 2348-6848, pp.75-79.

[21]. Juhi Nagpal, Rahul Agarwal & Manish Shah, "A Comparative Study on Different Speed Control Methods of D.C. Drives for Electric Vehicle", International Journal of Research (IJR) e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 07, July 2015, pp. 1-6.

[22]. Khushboo Hardia, Neha Maithil & Manish Shah, " Particle Swarm Optimization Applied To Economic Load Dispatch Problem", International Journal of Research (IJR) e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 09, September 2015, pp. 834-843.

[23]. Jyoti verma, Manish Shah, "Simulation and Analysis of H-bridge Cascade Multi level Inverter Fed Induction Motor Drive for Industrial Applications", International Journal of Innovative Research In Electrical, Electronics, Instrumentation And Control Engineering Vol. 4, Issue 3, March 2016, pp. 17-19.

[24]. Manish Shah, Rahul Agrawal, "A Review On Classical And Modern Techniques with Decision Making Tools For Load Forecasting", International Journal of Emerging Trends in Engineering and Development Issue 3, Vol.6 (November 2013), pp. 174-184.

[25]. Ritu Bhateja, Manish Shah, "A Proposed Method for Smooth Speed Control of Indirect Vector Control Inverter-Fed Induction Motor Drive using Boost Converter Topology", International Journal of Emerging Trends in Engineering and Development Issue 6, Vol. 5 (September 2016), pp. 1-10.

[26]. Sudeep Mohaney, Sourabh Mehto, Manish Shah, "Modeling and Optimization of Elevator Group Control System for High Rise Commercial Building", IEEE International Conference on Computer, Communication and Control (IC4-2015).

[27]. Sudeep Mohaney, Manish Shah, "Emerging Trends in Vertical Elevating System", International Journal of Engineering and Management Research Vol.-5, Issue-1, February-2015, pp. 51-56.

[28]. Khushboo Nagar, Manish Shah, "A Review on Different ANN Based Fault Detection Techniques for HVDC Systems", International Journal of Innovative Research in Engineering & Management Vol.-3, Issue-6, November-2016, pp. 477-481.