American Journal of Electrical and Computer Engineering
2017; 1(2): 81-89
http://www.sciencepublishinggroup.com/j/ajece
doi: 10.11648/j.ajece.20170102.14

Research/TechnicalNote

Computer Aided Analysis of Pelton Turbine Runner

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To cite this article:
Fapetu Oluseyi Feyisetan, Raimi Oluwole Abiodun, Adesina Fisayo, Akinola Adebisi Olayinka, Akintunde Mutalubi Aremu. Computer Aided Analysis of Pelton Turbine Runner. *American Journal of Electrical and Computer Engineering*. Vol. 1, No. 2, 2017, pp. 81-89.
doi: 10.11648/j.ajece.20170102.14

Received: April 12, 2017; **Accepted**: April 22, 2017; **Published**: June 8, 2017

Abstract: The research paper develops and implements computer aided software for the analysis of pelton turbine runner. The software design incorporates the use of Php programming language and MysQL for the data management system. Important constants and equation formulas were loaded into the database attached to the designed program. The software is design to eliminate the manual process of analysingpelton turbine runner so as to reduce stress, delay and established an excellent output. The software is capable of displaying the mass flow rate, velocity, area, diameter of jet, peripheral velocity, pitch circle diameter, specific speed & number of nozzle and the bucket development. The software shows a reasonable agreement between the results which indicates that it is free from mistakes and performs efficient faster operations which are reliable in analysingpelton turbine runner. The program is fully interactive, user-friendly and run on any operating system windows.

Keywords: Pelton Turbine Runner, Computer Aided Analysis, Php Programming Language, MysQL, Data Management System

1. Introduction

There has been necessity for an automated application to be incorporated for any calculations that involves a pelton turbine runner analysis so as to ease the tedious stress of analysing manually. Pelton turbine is one such power source which develops electricity by converting kinetic energy of water into mechanical energy [1]. In a layout of pelton wheel or pelton turbine, the water strikes the bucket along the tangent of the runner which comprises mainly of nozzle and flow regulating arrangement (spear), runner and buckets, casing and breaking jet [2]. Also, the important efficiencies of the runner comprises of hydraulic efficiency, mechanical efficiency, volumetric efficiency and overall efficiency [2]. The pelton turbine has been given increasing interest by the research community within multiple fields. This is due to the increasing demand for energy on a global basis in addition to the growing focus on meeting the increasing demand by utilizing renewable energy resources [3].

A lot of research study had been done on pelton turbine buckets based on design and analysis using various CAD modelling software to optimize the different materials for the design by performing coupled field analysis [2-8]. Every material has its own particular properties, one of these being the permissible anxiety. The breaking points for the application must be ascertained deliberately for every material [6].

Analysing bucket geometry of a pelton turbine wheel, [9] considered the pressure exerted on different points of the bucket using SOLIDWORKS 2015 for the bucket modelling and analysis and MATLAB to calculate the maximum efficiency of all the design parameters. The bucket was analysed for the static case and results of Von Mises stress, static displacement and factor safety were obtained. In a similar study, [10] focused on the fatigue analysis of the Pelton turbine bucket by numerical approach that showed the results of life cycles, damage, Von Mises stress, and mean biaxiality ratio to estimate the better design and operating performance of the Pelton turbine bucket with minimum corrosion and failures.

In the modelling design of Pelton wheel turbine for high altitude areas, [11] presented a work on the combination of mathematical modelling, fabrication of the proposed work with drafting and analysis using Creo& ANSY Work bench 12.0. The design ultimately forecast speed and efficiency using artificial neural network. The aim of this paper is to design a computer aided application which can easily and conveniently analyse parameters related to pelton turbine runner using Php programming language and MysQL for the data management system.

2. System Analysis and Design

In order to achieve the goal and objective of this paper, the methodology of this research comprises of method of data collection and the technical perspective.

2.1. Method of Data Collection

Thorough investigations were carried out on the internet based on various study on pelton turbine runner and also extended to computer aided users. From the investigations, answers to various questions were gotten and which are:

1) What is the primary purpose of computer aided analysis of pelton turbine runner?

To get the pelton turbine analysis for a material runner and to ensure that they are analyzed without traces of error.

2) Is pelton turbine runner computer aided analysis compulsory?

Yes of course, for you to analyse accurately, you must have a valid computer application that is free from analysing errors.

3) What are the processes involved for the pelton turbine runner aided application?

The processes are:

a. Input your power, head, wheel speed and temperature in watts, metres and ^{0}C units respectively;
b. It calculates:
   i. The mass flow rate (Q) in m^3s^{-1};
   ii. Velocity (V) in ms^{-1};
   iii. Area (A) in m;
   iv. Diameter of Jet (d_j) in m;
   v. Peripheral Velocity (V_P) in ms^{-1};
   vi. Pitch Circle Diameter (D_{PC}) in m;
   vii. Jet Ratio;
c. It specify the specific speed and the number of nozzle based on the analysis done as in (b);
d. It calculates the bucket width, bucket length, bucket depth and bucket cut-out in metres units;
e. It specifies the bucket range based on the analysis as in (vii).

2.2. The Technical Perspective

The technical perspective of this study has to do with the development, deployment, testing and maintenance of a computer-aided analysis for pelton turbine runner which is all software engineering processes. Under this aspect, an application or portal to automate and handle the process of analysis of pelton turbine runner is developed and deployed. The application will make use of a database in which it will reside all entries of a pelton turbine runner analysis.

2.3. Analysis and Evaluating the Manual Process

The analysis involves all the processes that are carried out as regarding ordinance of pelton turbine runner. Before obtaining the result of a particular analysis, the applicant has to first of all, present the necessary input which will be accessed. Therefore, for a quality engineer or design engineer to analyse an appropriate pelton turbine runner, they must have to make sure that the entire document on the pelton turbine runner parameters is authentic.

After evaluating the manual process we can conclude that the system is ineffective, tedious, monotonous of its operation, inaccurate, inconsistent, incapacitated, unreliable, unproductive, substandard and redundant. Having considered all these, it becomes obvious that a computer-aided analysis of pelton turbine runner is highly needed in the design industry.

2.4. Efforts Aimed at Solving the Problems Facing the Existing System

Having itemized the problem facing the manual process, there is need for an alternative system. This alternative system is a computer aided system that will obviate the problem experienced in the current system. The need for this new system cannot be over emphasized as it is aimed at achieving productivity, effectiveness &efficiency by reducing work intensity, less tedious, speed optimization & reduced use of paper, ease of update and maintenance of operation, accuracy of computation, consistency of data and reports, productivity achieved through the optimization of speed & enhanced connectivity to other stakeholders and enhancement of service delivery through prompt accurate & concise retrieval of information.

2.5. System Model of the Proposed System

Since the system to be implemented is already predefined, it is assumed that based on the problems actualized in the manual process, the new system is technically, operationally and economically feasible.

2.6. Program Flowchart Design

The structure of the flow chart in Figure 1 below describes the directional path in which users link from page to page. The flow chart has the Home page as the root page which is the first page encountered on opening the portal. The home page which serves as the input windows links the various parameters to each other.

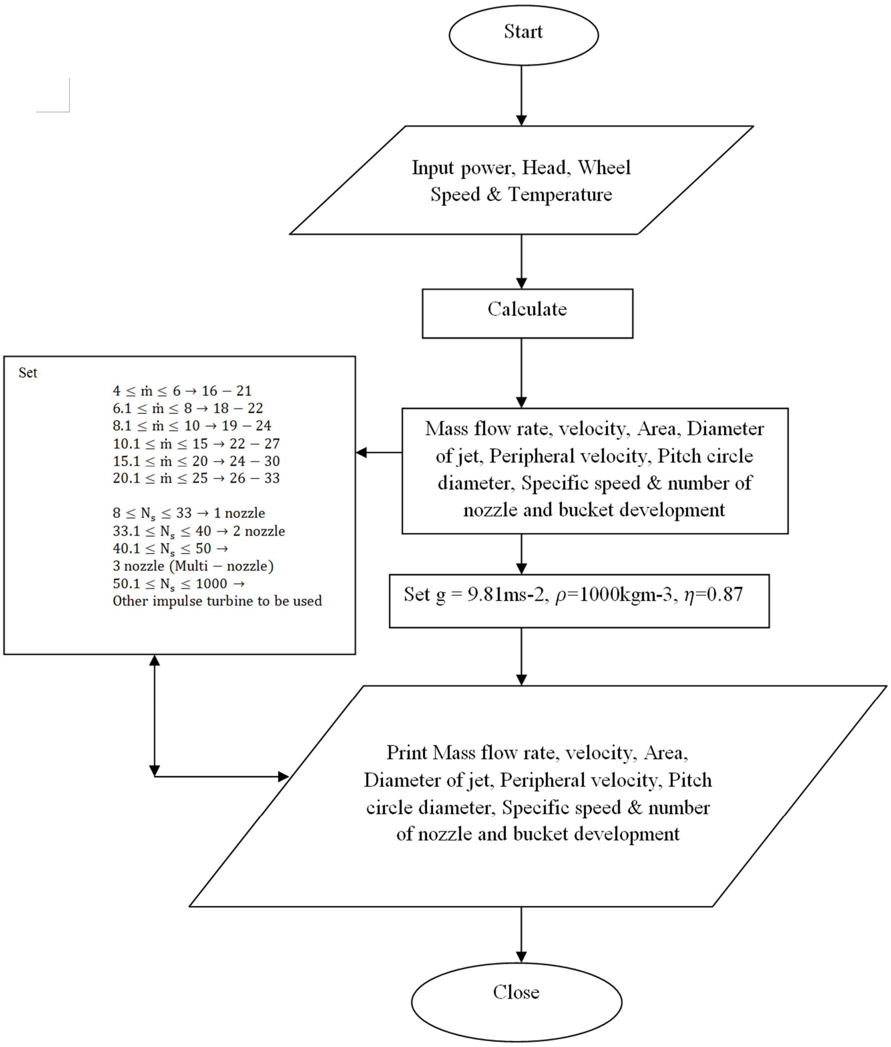

Figure 1. *Flow chart of the computer aided analysis of pelton turbine runner.*

3. System Implementation, Testing and Integration

3.1. Choice of Development Tools

The development tools are the necessary requirement tools used during the design to enable us achieve the system design. The listed packages were used because of their features, accessibility and also because it is more effective:

1) XAMPP control panel;
2) My SQL database application;
3) PHP scripting Language; and
4) HTML language

Xampp Control Panel

XAMPP control panel integrates with Adobe Browser Lab, one of the new XAMPP online services, which provides a fast and accurate solution for cross-browser compatibility testing. With BrowserLab you can preview web pages and local content using multiple viewing and comparison tools. XAMPP lets you build everything from basic data-driven websites to powerful online stores. XAMPP includes updated and simplified starter layouts.

Dynamically-Related Files

The Dynamically-Related Files feature lets you discover all of the external files and scripts necessary to assemble PHP-based Content Management System (CMS) pages, and displays their filenames in the Related Files toolbar. By default XAMPP supports file discovery for the Wordpress, Drupal, and Joomla! CMS frameworks.Live view navigation activates links in live view, allowing you to interact with server-side applications and dynamic data. The feature also allows you to enter a URL to inspect pages served from a live web server and edit pages you have browsed to if they exist in one of your locally defined sites.

A XAMPP site provides a way to organize and manage all of your web documents, upload your site to a web server, track and maintain your links, and manage and share files. A XAMPP site consists of as many as three parts, or folders, depending on your development environment and the type of website you are developing:

a. Local root folder

Stores the files you are working on. XAMPP refers to this folder as your “local site”. This folder is typically on your local computer, but it can also be on a network server.

b. Remote folder

Stores your files for testing, production and collaboration; XAMPP refers to this folder as your “remote site” in the Files panel. Typically, your remote folder is on the computer where your web server is running. The remote folder holds the files that users access on the Internet. Together, the local and remote folders enable you to transfer files between your local hard disk and web server, making it easy to manage files in your XAMPP sites. You work on files in the local folder, and then publish them to the remote folder when you want other people to view them.

MySQL Database Server

MySQL is a popular choice of database for use in web applications, and is a central component of the widely used LAMP open source web application software stack—LAMP is an acronym for "Linux, Apache, MySQL, Perl/PHP/Python".The MySQL Database powers the most demanding Web, E-commerce and Online Transaction Processing (OLTP) applications. It is a fully integrated transaction-safe, ACID compliant database with full commit, rollback, crash recovery and row level locking capabilities. MySQL delivers the ease of use, scalability, and performance that has made MySQL the world's most popular open source database. MySQL is the database construct that enables PHP and Apache to work together to access and display data in a readable format to a browser. It is a Structured Query Language serverdesigned for heavy loads and processing of complex queries. As a relational database system, MySQL allows many different tables to be joined together for maximum efficiency and speed. Some of the more popular features of MySQL are as follows:

a. Multiple CPUs usable through kernel threads;
b. Multi-platform operation;
c. Numerous column types cover virtually every type of data;
d. Group functions for mathematical calculations and sorting;
e. Commands that allow information about the databases to be easily and succinctly shown to the administrator;
f. Function names that do not affect table or column names;
g. A password and user verification system for added security;
h. Up to 32 indexes per table permitted; this feature has been successfully implemented at levels of 60,000 tables and 5,000,000,000 rows (version 4.1.2, currently in development, will allow 64 indexes); and
i. International error reporting usable in many different countries

MySQL is the perfect choice for providing data via the Internet because of its ability to handle heavy loads and its advanced security measures.

PHP

PHP is a server-side scripting language that allows your Web site to be truly dynamic. PHP stands for PHP: Hypertext Preprocessor Its flexibility and relatively small learning curve (especially for programmers who have a background in C, Java, or Perl) make it one of the most popular scripting languages around. PHP’s popularity continues to increase as businesses, and individuals everywhere embrace it as an alternative to Microsoft’s ASP language and realize that PHP’s benefits most certainly outweigh the costs.

HTML Language

Hypertext Markup Language (HTML), the standard text-formatting language for documents on the interconnected computing network known as the World Wide Web. HTML documents are text files that contain two parts: content that is meant to be rendered on a computer screen; and markup or tags, encoded information that directs the text format on the screen and is generally hidden from the user. Some tags in an HTML document determine the way certain text, such as titles, will be formatted. Other tags cue the computer to respond to the user's actions on the keyboard or mouse. For instance, the user might click on an icon (a picture that represents a specific command), and that action might call another piece of software to display a graphic, play a recording, or run a short movie. Another important tag is a link, which may contain the Uniform Resource Locator (URL) of another document. HTML also includes markups for forms that let the user fill out information and electronically send, or e-mail, the data to the document author, and initiate sophisticated searches of information on the Internet, or order goods and services.

3.2. Software Requirements

1) A windows XP or higher version operating system;
2) SQL Server;
3) Internet explorer;
4) XAMPP control panel; and
5) PHP scripting language

3.3. Hardware Requirements

The software designed needed the following hardware for an effective operation of the newly designed system.

1) Pentium IV system;
2) At least 256MB of RAM;
3) Enhanced keyboard;
4) 20GB hard disk space;
5) SVGA monitor; and
6) Mouse.

3.4. System Implementation

System implementation is a collection of inter-dependent physical devices together with their programming which provides the functionality and performance for which the system was designed. It covers all the activities necessary to set the system that has been analysed and designed to be fully functional to the users.

3.5. Authentication and Authorization

The software is incorporated making most of the pages secured or protected which demands only approved users gaining access to such pages. The secured pages comprises of bearing catalogue guide information. The software utilized the PHP membership to validate and store user credentials which help manage user information.

3.6. System Test

This software has been tested with data and it is functioning well. This was done through the use of properly selected input data; ensure reliability and accuracy of output. The test data consists of data as suggested by the authors.All these varying data used in testing the system's performance, gives the assurance that the new system will achieve its purpose and objectives.

3.7. Integration

The general deployment process consists of several interacted activities with possible transitions between them. The integration would be performed using visual web developer under the visual studios 2008 package. This entails a web server where users can access the site using an internet explorer of their choice.

The application is ready to be used. Simply click on the web address box and type http://localhost/design/peltonturbinerunner/ and the user interface of the application displays. The list of display designed modules includes:

1) Power (watts);
2) Head (metres);
3) Wheel Speed (rpm);
4) Temperature (°C).

This modules has been dynamically designed in such a way that each of the module's content can be manipulated, edited without even going to the database area. How can these modules be used?

4. How to Use the Computer-Aided Analysis of Pelton Turbine Runner

The module panel interface provides access to the control features of your application. The module panel interface of the computer aided system is shown on Figure 2.

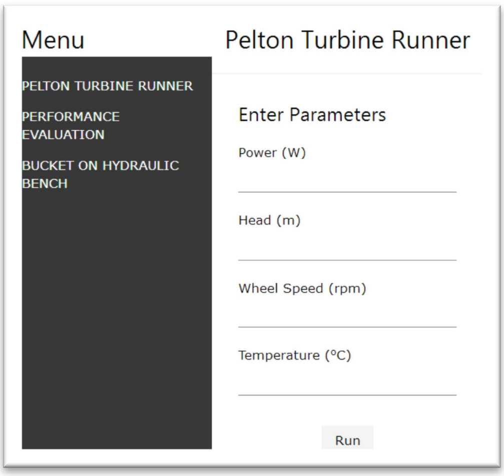

Figure 2. *Module panel Interface.*

Suggested data by the authors were used to run the developed software so that its result can be compared with that obtained manually as follows.

Example: Given Power, P = 3000watts, Head = 28m, Wheel Speed = 1000rpm and Temperature = 21.6°C. Take the following constant values: $g=9.81ms^{-2}$; $\rho = 1000kgm^{-3}$ at 0°C-25°C; $\eta = 0.87$. Calculate the following:

i. Mass Flow Rate (Q);
ii. Velocity (V);
iii. Diameter of Jet (d_j);
iv. Peripheral Velocity (V_p);
v. Pitch Circle Diameter (D_{pc});
vi. Jet Ratio;
vii. Specific Speed and specify the number of nozzle;
viii. Bucket width, bucket length, bucket depth and bucket cut-off; and
ix. Number of bucket range.

Solution: After performing this task manually, the results are shown as follows:

i. Mass Flow Rate (Q):

$$Q = \frac{P}{\rho g H \eta} \quad (1)$$

$$Q = \frac{3000}{1000 \times 9.81 \times 28 \times 0.87} \cong 0.01255ms^{-3}$$

ii. Velocity (V):

$$0.98 \times \sqrt{2 \times g \times H} \quad (2)$$

$$0.98 \times \sqrt{2 \times 9.81 \times 28} \cong 22.9697ms^{-1}$$

iii. Diameter of jet (dj):

$$d_j = \left(\frac{4 \times A}{\pi}\right)^{1/2} \quad (3)$$

Where $\text{Area}, A = \frac{Q}{V}$

$$A = \frac{0.01255}{22.9697} m^2 \cong 0.000546m^2$$

$$d_j = \left(\frac{4 \times A}{\pi}\right)^{1/2} = \left(\frac{4 \times 0.000546}{\pi}\right)^{1/2} \cong 0.02637m$$

iv. Peripheral Velocity (Up):

$$0.46 \times \sqrt{2 \times g \times H} \quad (4)$$

$$0.46 \times \sqrt{2 \times 9.81 \times 28} \cong 10.566ms^{-1}$$

v. Pitch Circle Diameter (DPC):

$$D_{pc} = \frac{U_p \times 60}{\pi \times N} \quad (5)$$

$$D_{pc} = \frac{10.566 \times 60}{\pi \times 1000} \cong 0.201770m$$

vi. Jet Ratio $(\dot{m})$

$$\dot{m} = \frac{D_{pc}}{d_j} \quad (6)$$

$$\dot{m} = \frac{0.201770}{0.02637} \cong 7.7$$

vii. Specific Speed and specify the number of nozzle:

$$\text{Specific Speed, } N_s = \frac{N\sqrt{P}}{H^{1.25}} \quad (7)$$

$$N_s = \frac{1000\sqrt{3000}}{28^{1.25}} \cong 850$$

Conditions for the specifying the number of nozzle:

$$8 \le N_s \le 33 \rightarrow 1 \text{ nozzle}$$

$$33.1 \le N_s \le 40 \rightarrow 2 \text{ nozzle}$$

$$40.1 \le N_s \le 50 \rightarrow 3 \text{ nozzle (Multi} - \text{nozzle)}$$

$$50.1 \le N_s \le 1000 \rightarrow \text{Other impulse turbine to be used}$$

Therefore, the number of nozzle suggested other impulse turbine to be used since the specific speed value is between 50.1 and 1000.

viii. Bucket width, bucket length, bucket depth and bucket cut-off:

$$\text{Bucket Width, } B_W = 3.5 \times d_j \cong 0.092295\text{m}$$

$$\text{Bucket length, } B_L = 3.5 \times d_j \cong 0.092295\text{m}$$

$$\text{Bucket Depth, } B_D = 1.2 \times d_j \cong 0.031644\text{m}$$

$$\text{Bucket Cut, } B_C = 1.1 \times d_j \cong 0.029007\text{m}$$

ix. Number of bucket range:

Number of bucket for the system condition:

$$4 \le \dot{m} \le 6 \rightarrow 16 - 21$$

$$6.1 \le \dot{m} \le 8 \rightarrow 18 - 22$$

$$8.1 \le \dot{m} \le 10 \rightarrow 19 - 24$$

$$10.1 \le \dot{m} \le 15 \rightarrow 22 - 27$$

$$15.1 \le \dot{m} \le 20 \rightarrow 24 - 30$$

$$20.1 \le \dot{m} \le 25 \rightarrow 26 - 33$$

Therefore, since the value of the jet ratio ($\dot{m}$) is 7.7, it falls between 6.1 and 8; we select bucket range of 18-22.

Typical computer display of this analysis is as shown in Figure 3 and Figure 4 respectively.

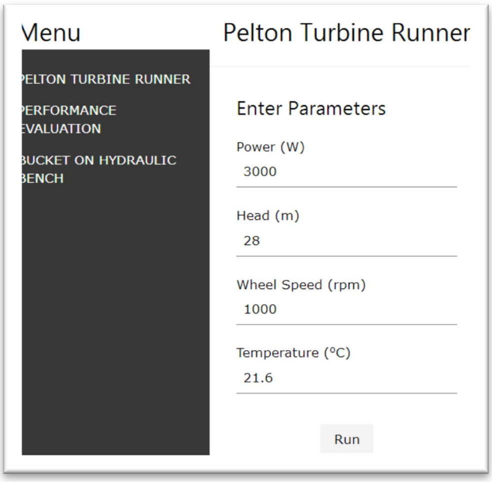

Figure 3. *Computer aided analysis ofpelton turbine runner input window.*

The input window of the computer aided analysis of the pelton turbine runner after the suggested data has been inputted by the user into the interface.

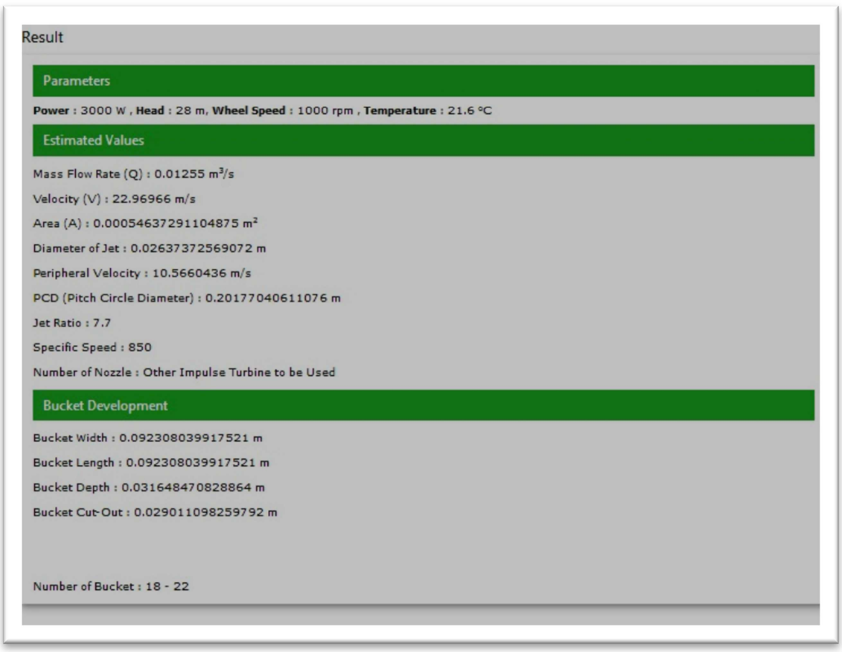

Figure 4. *Computer aided analysis of pelton turbine runner output window.*

The output window of the computer aided analysis of the pelton turbine runner of the displayed results.

This are the functions of the modules designed for this computer aided system. There are indeed other functions which are not explained here but are best shown practically.

5. Conclusion

The experience acquired from this computer aided analysis cannot be over-emphasized. It has really bridged the gap between classroom paper work and practical work involved in software development in the manufacturing industry. The computer aided analysis software of the Pelton turbine runner can conveniently calculate the mass flow rate, velocity, diameter of jet, peripheral velocity, pitch circle diameter, jet ratio, specific speed and also specify the nozzle of the turbine runner. It can also determine the bucket width, bucket length, bucket depth and bucket cut-off of the runner and also specify the bucket range. The application designed software is efficient, consistent and can perform an operation faster compared to the manual process which in turn will be of great importance to manufacturers who are interested in hydropower design system. Furthermore, this design portal is still open for further studies and modifications to increase its efficiency.

Appendix

```
<!DOCTYPE html>
<html>
<head>

<title>Home</title>

</head>
<body>

<nav class="w3-sidenav w3-black-clear w3-collapse w3-hide-small w3-animate-left w3-padding-0" id="mysidenav"
style="width: 20%;">

<h2 class="w3-animate-top w3-white w3-padding-0 w3-margin-0">
<c class="w3-padding-4 w3-padding-medium">Menu</c>

<a href="javascript:void()" onclick="closenav()" style="height: 45px;" class="w3-hide-large w3-padding w3-margin-0
w3-large w3-right w3-closenav w3-black w3-text-white">&times;</a>
</h2>

<ul class="w3-padding-0">


<a href="peltonturbinerunner" class="w3-padding-medium w3-text-white">PELTON TURBINE RUNNER</a>


</ul>
</nav>



<div class="w3-main" style="margin-left: 20%;">

<header>



<ul class="w3-navbar w3-hide-large w3-light-grey w3-hide-medium w3-padding" >


<li><a href="peltonturbinerunner" class="w3-green w3-padding-medium">PELTON TURBINE RUNNER</a></li>
```

```
    </ul>


    <h2><span class="w3-opennav w3-xlarge w3-hide-small w3-hide-large" onclick="opennav()">&#9776;</span><c
class="w3-padding-left">Pelton Turbine Runner</c></h2>
    <hr>

    </header>


    <div class="w3-row">

    <div class="w3-col s12 m4 l4">
    <div class="w3-container">

    <h3 class="w3-container">Enter Parameters</h3>

    <form id="peltonform" class="w3-form" method="post"
action="app/CliqsStudio/StreamController/streampeltonturbinerunnerindex.php">

    <label>Power (W)</label><input class="w3-input" type="number" name="power" min="0" id="power" autofocus><br>
    <label>Head (m)</label><input class="w3-input" type="number" name="head" min="0" id="head"><br>
    <label>Wheel Speed (rpm)</label><input class="w3-input" type="number" name="wheelspeed" min="0"
id="wheelspeed" ><br>
    <label>Temperature (<sup>o</sup>C)</label><input class="w3-input" type="number" max="60" min="0"
name="temperature" id="temperature" >

    <br><p class="w3-center"><button id="sbpelton" class="w3-btn w3-light-grey" type="submit">Run</button></p>

    </form>
    </div>
    </div>

    <div class="w3-col s12 m8 l8">
    <h3 class="w3-container">Result</h3>
    <div class="w3-container">

    <div class="w3-container w3-card-4">
    <p id="result_space">No Result Yet...</p>
    </div>

    </div>
    </div>

    </div>
    </div>
    </body>


    <style type="text/css">
    @import "app/CliqsStudio/view/presentation_core/css/w3.css";
    @import "app/CliqsStudio/view/presentation_core/css/style1.css";
    </style>

    <script type="text/javascript">
```

```
functionclosenav(){
var x = document.getElementById('mysidenav');
x.style.display = 'none';
}

functionopennav(){
var x = document.getElementById('mysidenav');
x.style.display = 'block';
}

</script>
<script type="text/javascript" src="app/CliqsStudio/view/presentation_core/js/jquery-1.9.0.min.js"></script>
<script type="text/javascript" src="app/CliqsStudio/view/presentation_core/js/process1.js"></script>

</html>
```

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