# Comparative Analysis of Orifice Area and Differential Pressure Along a Penstock of Hydro Turbine

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***Abstract- The study, comparative analysis of orifice area and differential pressure along a penstock of hydro turbine was successfully investigated using data gotten from simulink simulation of System block models from simscap- hydraulics. 5 variable orifice areas, 0.1$m^2$, 0.04$m^2$, 0.15$m^2$, 1.5$m^2$ and 0.0002$m^2$ and their corresponding differential pressures were analyzed and graphs plotted, using Excel and MATLAB. At orifice area of 0.1$m^2$, differential pressure was found to be 150bar. As orifice area was reduced to 0.0002$m^2$, differential pressure increased to 30,000,000bar. These results suggested that narrowing or decreasing hydraulic orifice area, will increase differential pressure along the penstock of a hydro turbine and vice-versa. In addition, MATLAB was used to evaluate the variance and standard deviation between the orifice area and differential pressure data. The variance was found to be 2.1493e-07 while standard deviation was found to be 4.6361e-04. The researchers made the following recommendations: Influences of hydraulic orifice area and differential pressure have to be controlled if hydro turbine must operate at full power, this research can also be done in future using different hydraulic design orifice models and other advanced software for generalization.***

***Indexed Terms- Excel, MATLAB, penstock, differential pressure, orifice area, simscap-hydraulics, block models, hydro turbine.***

## I. INTRODUCTION

Nkwor et al, (2023) stated that any restriction in the conduit or channel will cause a reduction in the flow rate of the entire line but the flow will be constant throughout the line. Resistive pressure drop occurs due to resistance to flow offered by orifices due to change in cross-sectional area of flow. Inertia pressure drop occurs when frictional forces caused by resistance to flow, act on a fluid as it flows through a conduit or channel.

Frank et al, (1990) as cited in Nkwor et al, (2023) opined that fluid dynamics suggested that orifice geometry (area) is a determinant of discharge properties and therefore, should influence empirical constants governing orifice formulas.

According to Rajput (2011), hydro turbine is a device established for renewable energy resource for electricity generation. It converts the energy of moving water into mechanical energy. Penstock is a long pipe that conveys the water flowing from the reservoir to the power generating unit. It is made up of elbow joints, valves and nozzles.

Undoubtedly, as hydraulic orifice area changes, differential pressure along the penstock of a hydro turbine also changes as well. Hence, researchers aimed at studying comparative analysis of orifice area and differential pressure along a penstock of hydro turbine.

## II. MATERIALS AND METHODS

The results or the data required for the comparative analysis of orifice area and differential pressure along a penstock of hydro turbine were gotten using simulink simulation in MATLAB. According to the study done by Nkwor et al, (2023), simulink in the MATLAB command window contains simscap-hydraulics block models that were used to represent the entire elements of hydraulic orifice flow model. Block ports were connected as shown in Fig 1.0 below.

## III. RESULTS AND PRESENTATIONS

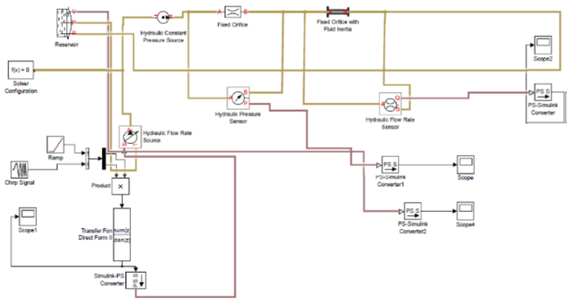

Fig 1.0 System Hydraulic Orifice Model (Source: Nkwor et al, 2023)

Table 1.0: Orifice Properties (Source: Nkwor et al, 2023)

| S/N | Name | Value | Unit |
|---|---|---|---|
| | FIXED ORIFICE | | |
| 1 | Area | 1e-1, 4e-2, 1.5e-1, 15e-1& 0.2e-3 | $m^2$ |
| 2 | Coefficient of discharge | 0.2 | |
| 3 | Critical Reynolds's Number | 12 | |
| 4 | Orifice hydraulic diameter | 0.0113 | m |
| 5 | Minimum pressure for turbulent flow | 1 | Pa |
| 6 | Flow rate | 0.2 | $m^3/s$ |
| 7 | Initial differential pressure | 1.5 | bar |
| | | | |
| | FIXED ORIFICE WITH FLUID INERTIA | | |
| 1 | Area | 1e-1, 4e-2, 1.5e-1, 15e-1& 0.2e-3 | $m^2$ |
| 2 | Orifice length | 0.01 | m |
| 3 | Coefficient of discharge | 0.2 | |
| 4 | Critical Reynolds's Number | 10 | |
| 5 | Flow rate | 0.2 | $m^3/s$ |
| | RESERVIOR | | |
| 1 | Pressurization level | 2 | bar |
| 2 | Initial fluid volume | 0.08 | $m^3$ |
| 3 | Return line diameter | 0.02 | m |

Table 2.0: Shows Values of Differential Pressure at Various Orifice Areas

| S/N | Orifice Area $(m^2)$ | Differential Pressure(bar) |
|---|---|---|
| 1 | 0.1 | 150 |
| 2 | 0.04 | 1000 |
| 3 | 0.15 | 70 |
| 4 | 1.5 | 0.8 |
| 5 | 0.0002 | 30000000 |

(Source: Nkwor et al, 2023)

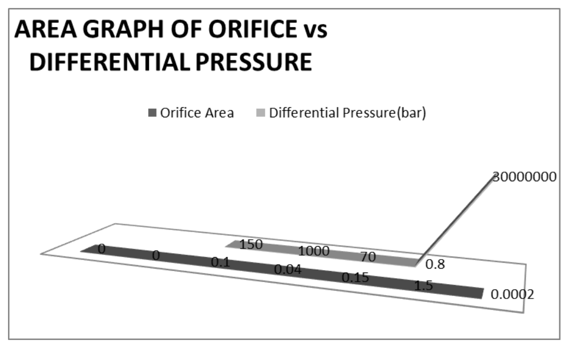


Fig 2.0 Area Graph of Orifice Area and Differential Pressure.

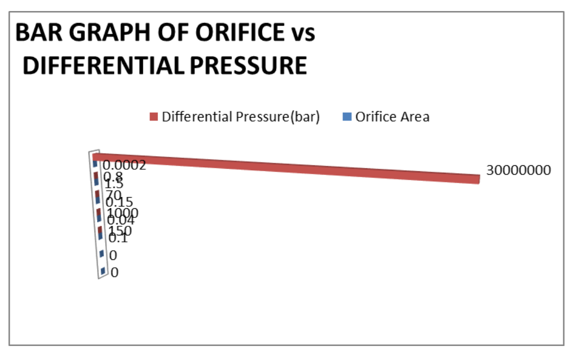


Fig 3.0 Bar Graph of Orifice Area and Differential Pressure.

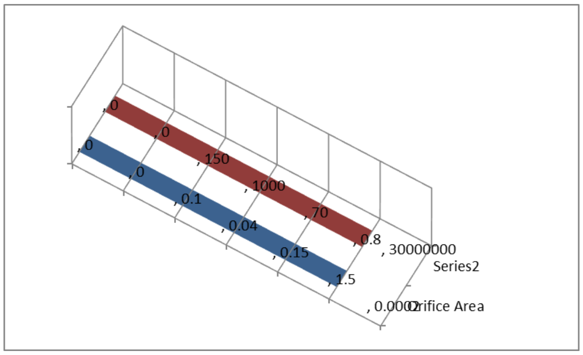


Fig 4.0 Area Graph of Orifice Area and Differential Pressure.

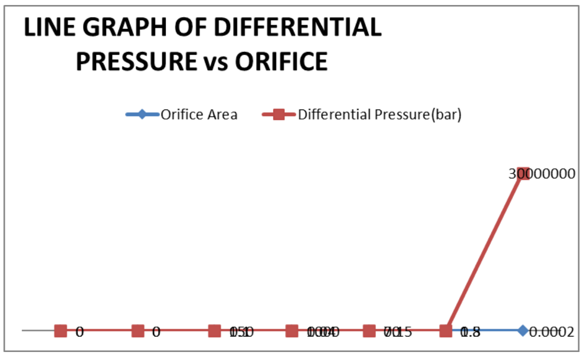


Fig 5.0 Line Graph of Orifice Area and Differential Pressure.

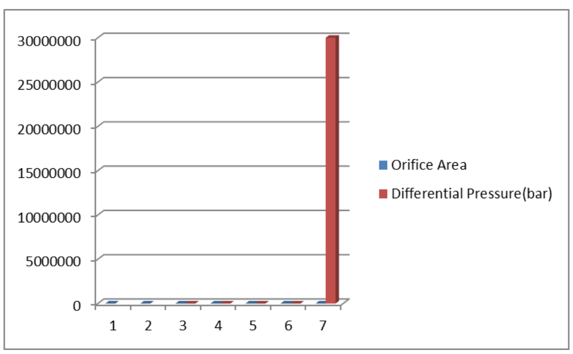


Fig 6.0 Bar Graph of Orifice Area and Differential Pressure.

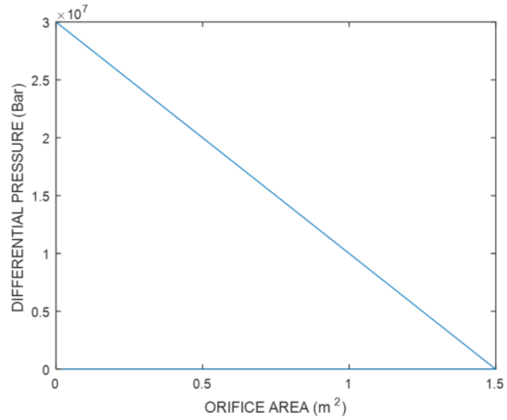


Fig 7.0 Graph of Differential Pressure and Orifice Area

MATLAB CODES FOR THE GRAPH OF Fig 7.0
function createfigure1(X1, Y1)
%CREATEFIGURE1(X1, Y1)
% X1: vector of x data
% Y1: vector of y data

% MATLAB on 16-May-2023 14:26:17

% Create figure
figure1 = figure;

% Create axes
axes1 = axes ('Parent', figure1);
box(axes1,'on');
hold(axes1,'on');

% Create plot
plot (X1, Y1);

% Create xlabel
xlabel({'ORIFICE AREA (m^2)'});

% Create ylabel
ylabel({'DIFFERENTIAL PRESSURE (Bar)'});

MATLAB EVALUATION OF VARIANCE AND STANDARD DEVIATION BETWEEN ORIFICE AREA AND DIFFERENTIAL PRESSURE

>> A = [0.10, 0.04, 0.15, 1.50, 0.0002];
>> B = [150, 1000, 70, 0.8, 30000000];
>> var(A, B)
ans =

```
  2.1493e-07
>> std (A, B)
ans =
  4.6361e-04
```

## IV. DISCUSSION

Comparative analysis of orifice area and differential pressure along a penstock of hydro turbine were investigated using simulink simulation method and was discussed here. According to Fig 1.0 and Table 1.0, block models gotten from simscap- hydraulics were used to represent all the elements of orifice flow hydraulic model. The study adopted 5 variable orifice areas, $0.1m^2$, $0.04m^2$, $0.15m^2$, $1.5m^2$ and $0.0002m^2$.

According to Table 2.0 and Fig 2.0 to Fig 7.0, at orifice area of $0.1m^2$ , differential pressure was found to be 150bar. Furthermore, orifice area was reduced to $0.0002m^2$ , differential pressure increased to 30,000,000bar. These results indicated that narrowing or decreasing hydraulic orifice area, will increase differential pressure along the penstock of a hydro turbine and vice-versa. In addition, orifice coefficient of discharge influences differential pressure along the penstock of a hydro turbine.

MATLAB was used to evaluate the variance and standard deviation between orifice area and differential pressure data. The variance was found to be 2.1493e-07 while standard deviation was found to be 4.6361e-04.

## CONCLUSION

From the findings of the study, we can conclude that narrowing or decreasing hydraulic orifice area, will increase differential pressure along the penstock of a hydro turbine and vice-versa. In addition, increasing orifice coefficient of discharge, will decrease differential pressure and increase discharge through the orifice. These results are in line with Frank et al. (1990) as cited in Nkwor et al (2023), which stated that orifice geometry (area) is a determinant of discharge properties and therefore, should influence empirical constants governing orifice formulas.

## RECOMMENDATIONS

The following recommendations are suggested based on the study:

1) Influences of hydraulic orifice area and differential pressure have to be controlled if hydro turbine must operate at full power.
2) This research can also be done in future using different hydraulic design orifice models and other advanced software for generalization.

## REFERENCES

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