“Development of Test Rig for
Study of Sediment Erosion in Guide Vanes of Francis Turbine”

Manufacturer’s Guide

Prepared by  | Ravi Koirala
Checked by   | Dr. Baoshan Zhu
             | Dr. Hari Prasad Neopane

State Laboratory of Hydrosience and Engineering, Tsinghua University, Beijing, China
Turbine Testing Lab, Kathmandu University, Dhulikhel, Nepal
Abstract

Sediment Erosion has been a crucial issue for sustainability of hydraulic turbine structures operating in sand laden water. The study of the phenomena and its effect on the flow has become a crucial issue for identifying resistant solution to the problem. Turbine Testing Lab, with an aim of becoming center of excellence for erosion test has been performing erosion analysis on turbine components. This approach is focused on the erosion study in the stationary component i.e. Guide Vanes.

The study is focused on the effect of guide vane erosion on flow around it. Hence, here guide vane are to be eroded first and then is to be studied for effect on flow. A model turbine parameter has been selected for the analysis. Three guide vane cascade arranged in the manner similar to the prototype turbine will be installed and tested at different laboratory conditions. This part of the work is for the development of the test rig and to manufacture the test rig for completion of this research work.
1. Introduction

For a part of the Masters of Science in Mechanical Engineering (By research) work at Turbine Testing Lab, a test rig needs to be developed for erosion test in guide vanes.

The test rig will have 3 guide vane cascade system with the facility to perform the test at different guide vane openings. The arrangements of the guide vanes and the dimension of the flow passage were determined from the series of the Computational Calculations. The rig should consist of:

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Particular</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Test setup</td>
<td>As per drawing</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Pressure Tank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Test Bench</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Guide Vanes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Operating Conditions

<table>
<thead>
<tr>
<th>Fluid Type</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>997 kg/m³</td>
</tr>
<tr>
<td>Head</td>
<td>42.8 m</td>
</tr>
<tr>
<td>Flow</td>
<td>0.0555 m³/sec</td>
</tr>
</tbody>
</table>

3. Work Description

The manufacturer has to perform following works:

i. High Precision manufacturing of the test setup
ii. Installation of the test setup at Turbine Testing Lab
iii. Materials required for manufacturing will be managed by the manufacturer himself

4. Installation Facilitation

Following facilities and materials required for installation will be provided:

a. Welding machine
b. Electrodes [Please specify the grades]
c. Hand grinder
d. Hand cutter
e. Pipe cutter
f. Pipes of required dimensions
g. Thread cutting facility is not available but we can arrange it from somewhere
h. Measuring instruments and gauges
5. Test Methodology

5.1 Test Variables

i. Sand Concentration
ii. Water Flow Rate
iii. Sand Diameter
iv. Guide Vane Angle

5.2 Study of Interest

i. Sediment Erosion in Guide Vanes of Francis Turbines

<table>
<thead>
<tr>
<th>Variable</th>
<th>Point 1</th>
<th>Point 2</th>
<th>Point 3</th>
<th>Point 4</th>
<th>Point 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>$C_{s1}$</td>
<td>$C_{s2}$</td>
<td>$C_{s3}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle diameter</td>
<td>$D_{p1}$</td>
<td>$D_{p2}$</td>
<td>$D_{p3}$</td>
<td>$D_{p4}$</td>
<td></td>
</tr>
<tr>
<td>Flow rate</td>
<td>$Q_1$</td>
<td>$Q_2$</td>
<td>$Q_3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guide Vane Angle</td>
<td>$\alpha_1$</td>
<td>$\alpha_2$</td>
<td>$\alpha_3$</td>
<td>$\alpha_4$</td>
<td>$\alpha_5$</td>
</tr>
</tbody>
</table>

Hence Total Set of Experiment will be around 180

And at least 182 guide vanes will be needed

180 Guide Vanes of Aluminum

2 Guide Vanes of Stainless steel

ii. Effect of Guide Vane erosion

Particle Diameter will be fixed $D_p = \text{Constant}$

<table>
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<tr>
<th>Variables</th>
<th>Point 1</th>
<th>Point 2</th>
<th>Point 3</th>
</tr>
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<tbody>
<tr>
<td>Concentration</td>
<td>$C_{s1}$</td>
<td>$C_{s2}$</td>
<td></td>
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<tr>
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<td>Guide Vane Angle</td>
<td>$\alpha_1$</td>
<td>$\alpha_2$</td>
<td>$\alpha_3$</td>
</tr>
</tbody>
</table>

Total 12 sets of experiment is necessary for this work

With repetition, twice total number of guide vanes required will be 26
24 guide vanes of aluminum and 2 guide vane of Stainless steel

Test Counts

| $C_{s1}, Q_1, \alpha_1$ | $C_{s1}, Q_1, \alpha_2$ | $C_{s1}, Q_1, \alpha_3$ | $C_{s1}, Q_2, \alpha_1$ | $C_{s1}, Q_2, \alpha_2$ | $C_{s1}, Q_2, \alpha_3$ | $C_{s2}, Q_1, \alpha_1$ | $C_{s2}, Q_1, \alpha_2$ | $C_{s2}, Q_1, \alpha_3$ | $C_{s2}, Q_2, \alpha_1$ | $C_{s2}, Q_2, \alpha_2$ | $C_{s2}, Q_2, \alpha_3$ |
6. Cascade Development

Velocity Matching at Runner Inlet Diameter

Position in Guide Vane

Velocity

\( \text{Cu} \quad \text{Cm} \quad \text{Cua} \quad \text{Cma} \quad \text{Cu-turbine} \quad \text{Cm-turbine} \)
7. **Mechanical Design of Cascade**

Fluid Structural Analysis was performed with the computational result to identify the maximum stress in the material used in this geometry. Iterative design method was followed by periodically changing the thickness and arrangements.
8. **Drawing**
- All dimensions in Drawing are in MM.
- Components Diffuser 1, Diffuser 2, Diffuser 3 and Draft Tube has thickness of 2 mm and Cascade has thickness of 5 mm.
- Detail about support has not been provided in the drawing and will be installed as per the need.
  - Materials required for the support during installation will be provided at KU.
- The layout of the piping and other component’s drawing will be provided at the time of installation.
- AutoCAD drawing will be provided to estimate the missing dimensions.
Turbine Testing Lab
Kathmandu University
Sediment Erosion in Guide Vanes of Francis Turbines

Scale:
1:6

NOTE:
1. All Dimensions are in mm.
NOTE:
1. All Dimensions are in mm.
FLANGE 1

NOTE:
1. All Dimensions are in mm.

Front view
Scale: 1:2

Right view
Scale: 1:2

Bottom view
Scale: 1:2

Front view
Scale: 1:1

NOTE:
1. All Dimensions are in mm.
Girdle

NOTE:
1. All Dimensions are in mm.
Thicknness of the Lining = 1.829 mm i.e. 15 Gauge

NOTE:
1. All Dimensions are in mm.
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NOTE:
1. All Dimensions are in mm.
2 TOP COVER SEGMENTS ARE TO BE MANUFACTURED

NOTE:
1. All Dimensions are in mm.
This Part is the most essential part of the setup, hence I would suggest you to please trace the drawing so that high precision can be achieved.

NOTE:
1. All Dimensions are in mm.
**NOTE:**
1. All Dimensions are in mm.

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**Front view**
Scale: 1:1

**Section view A-A**
Scale: 2:1

**Section view B-B**
Scale: 2:1

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2 SUCH PLATES FOR UPPER AND LOWER COVERS OF THE CASCADE
3 GUIDE VANE LOWER CAPS ARE REQUIRED
IN THE GROVED HOLE, IT IS EXPECTED TO HAVE A PLAIN BEARING FOR EASE OF LOWER CONTROL.

3 GUIDE VANE TOP BUSHING ARE REQUIRED
GROOVES HAS BEEN MADE TO INSTALL DOUBLE ORING. YOU CAN ALTER THE DRAWINGS OF THIS CAP TO ADJUST THE GROOVE AND THE REQUIRED ORING.

NOTE:
1. All Dimensions are in mm.
2. 18 Samples of Guide Vane, Material is Aluminum.
1. All Dimensions are in mm.

A COPY OF THIS FLANGE WILL BE USED WITH CASCADE OUTLET TO MESH WITH THIS

A COPY OF IT WILL BE FITTED WITH CASCADE OUTLET

NOTE:

Front view
Scale: 1:1

Bottom view
Scale: 1:1

NOTE:
1. All Dimensions are in mm.