Design and Analysis of Pelton Bucket for Variation in its Surface Roughness

Aditya Kumar Tripathi[1], Nishant Saxena[2]

[1]M.Tech Scholar, Department of Mechanical Engineering, Millennium Institute of Technology, Bhopal, M.P., India

[2]A.P. and Head, Department of Mechanical Engineering, Millennium Institute of Technology, Bhopal, M.P., India

Abstract: ***For power generation, in hilly areas, high head hydro power plants use Impulse turbine. All the available energy of water is converted to kinetic energy before water strikes the buckets. Buckets are designed such that water gets deflected by around 165°. And it may also not strike the back of successive bucket. In the present work, geometric modeling of Pelton bucket has been done. Meshing has been done in ICEM CFD. Multiphase flow analysis has been done and various parameters have been found out for variation in surface roughness of the bucket. From results it has been found that as the friction in the bucket increases, force experienced by the jet on the bucket decreases.***

Keywords: Impulse turbines, Buckets, Friction, Jet

1. Introduction

Pelton turbine have a series of buckets fitted to the rotating disk. Flowing water, after passing through the nozzle strikes the buckets of the turbine and makes disk and shaft to rotate. The velocity direction of the water changes while flowing through the Pelton turbines. This results in the development of torque and rotation of the turbine shaft. The design of the bucket affects the performance of the turbine. Water leaves at approximately 165° (which is close to 180°) but it is designed such that water when leaving must not strike the back of preceding bucket. Friction of the bucket surface leads to losses and Force experienced by the bucket on Pelton bucket decreases with increase in friction.

2. Literature Review

Marongiu et al. 2005 used the code to simulate the jet on Pelton Turbine bucket. Zhang 2007 studied the effect of friction on Pelton turbine bucket. Perrig et al. 2006 concluded that outer region contributed the most to the bucket power. Santolin et al., 2009 studied the influence of the shape of water jet on the turbine losses. Y X Xiao et al, 2013 concluded that bucket surface roughness influence the working process of each bucket. Vishal et al; 2016 simulated multi-phase flow in rotating six jet Pelton turbine. L K Gudukeya & C Mbohwa, 2017 concluded that roughness determines the friction which in turn affects the efficiency of a turbine.

3. Geometric Modeling and Meshing

3.1 Geometric Modeling

Geometry for existing Pelton bucket has been modeled. The flow domain consists of Bucket, Jet, Jet Back, side opening and flow domain. Flow domain contains both air and water. The side opening of the domain kept open to the atmosphere.

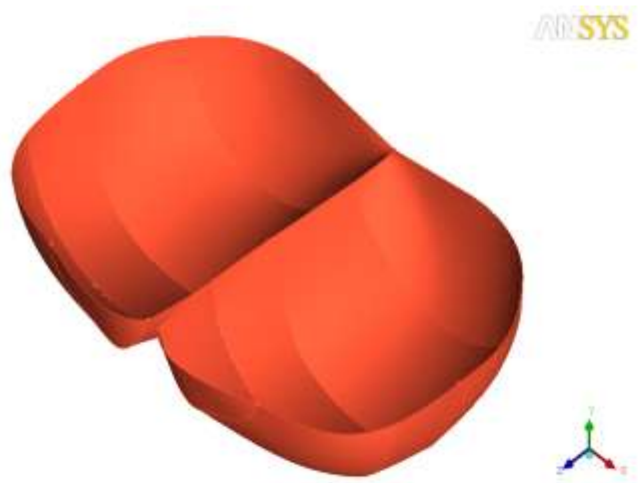

Figure 1: Isometric view of Pelton bucket

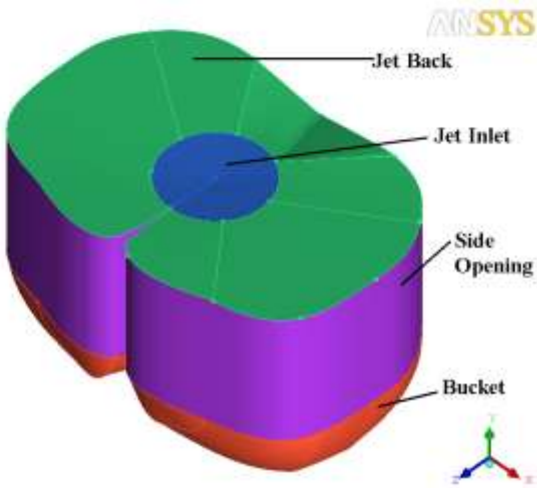

Figure 2: Complete Isometric View of Flow Domain

3.2 Meshing

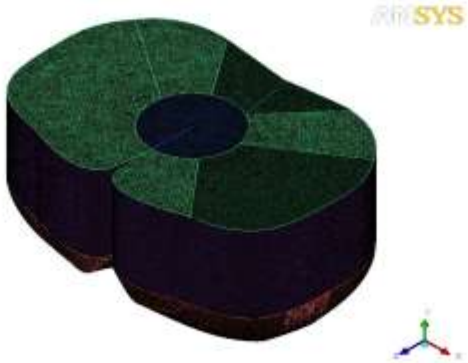

Figure 3: Mesh of Flow Domain

Table 1: No. of Mesh Elements

Part name	No. of Elements	Element Type
Jet	2587	Triangle
Jet Back	20848	Triangle
Side Opening	54567	Triangle
Bucket	57069	Triangle
Flow Domain	2043153	Tetrahedral

3.3 Boundary Conditions

- **Inlet Boundary Condition:** The mass flow rate and its direction which is normal direction to the inlet surface i.e., at inlet of jet is applied. Turbulence is set to medium intensity (upto 5%).
- **Outlet Boundary Condition:** Reference pressure at the side opening of the flow domain was set equal to 1 atmospheric.
- **Wall Conditions:** The bucket of the flow domains is assumed to be smooth, with roughness and no slip condition is assigned.

4. Results and Discussions

The roughness of the bucket has been varied to be smooth, roughness with value 1.6 micron, 3.2 micron, 6.3 micron, 25 micron and 50 micron. Inlet jet velocity is considered to have fixed velocity with value of 118 m/sec. The average values of velocity, pressure, total pressure at inlet and side opening were obtained using the function calculator in CFX Post. Using the function calculator, force experienced by the bucket is also found out.

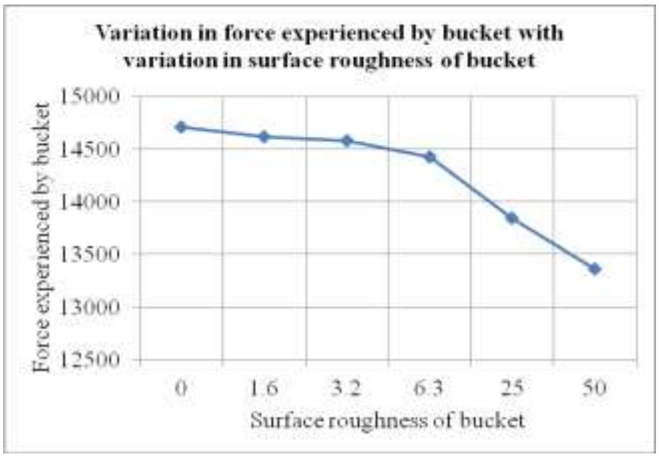

Figure 4: Variation in force experienced by bucket with variation in surface roughness of bucket

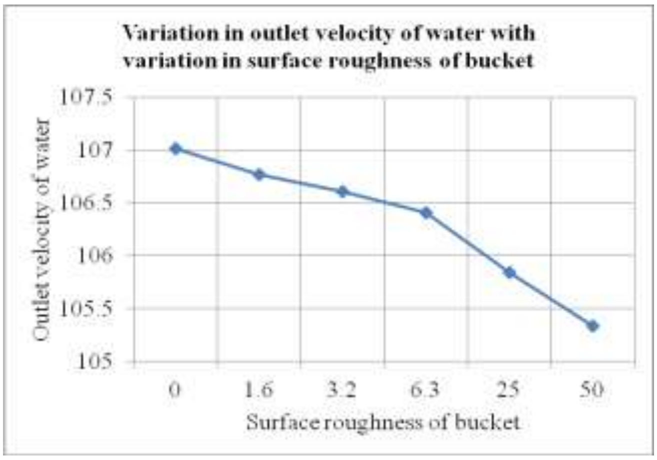

Figure 5: Variation in outlet velocity of water with variation in surface roughness of bucket

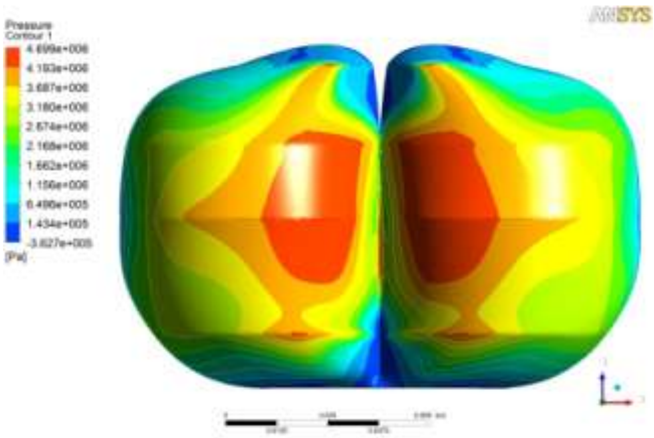

Figure 6: Pressure contour for smooth bucket

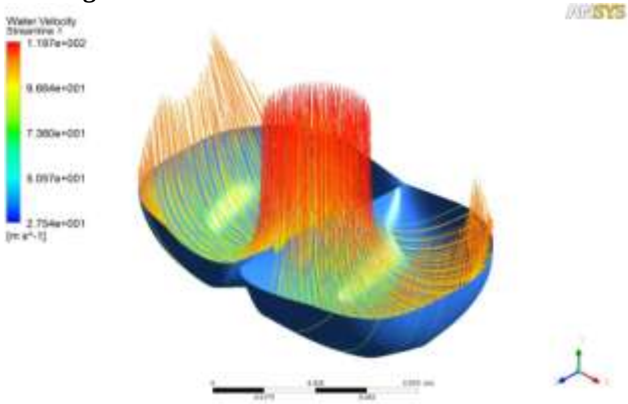

Figure 7: Streamlines pattern for smooth bucket

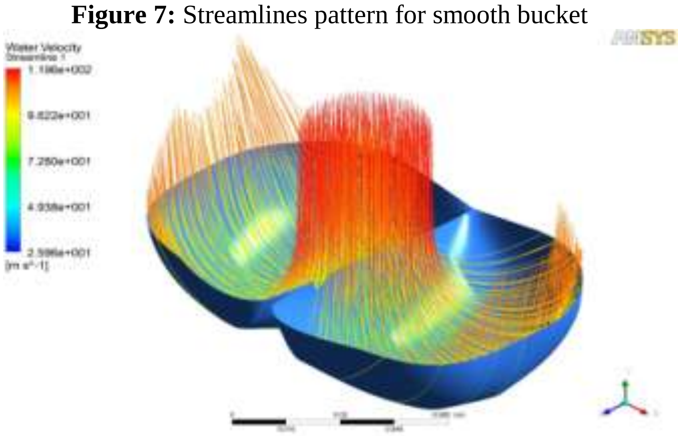

Figure 8: Streamlines pattern for bucket with surface roughness= 1.6 micron

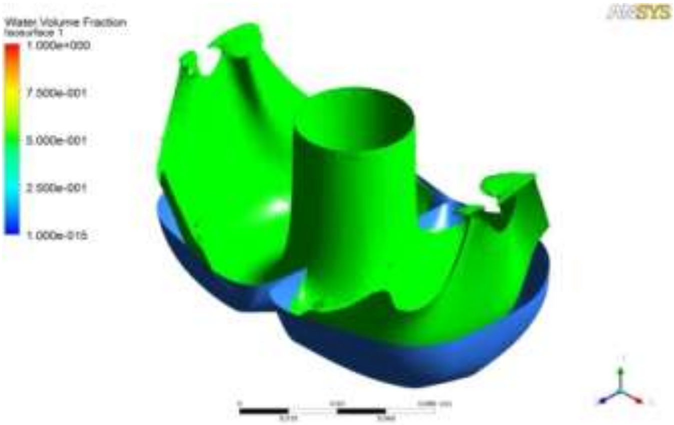

Figure 9: Water iso-surface= 0.5 for bucket with surface roughness= 1.6 micron

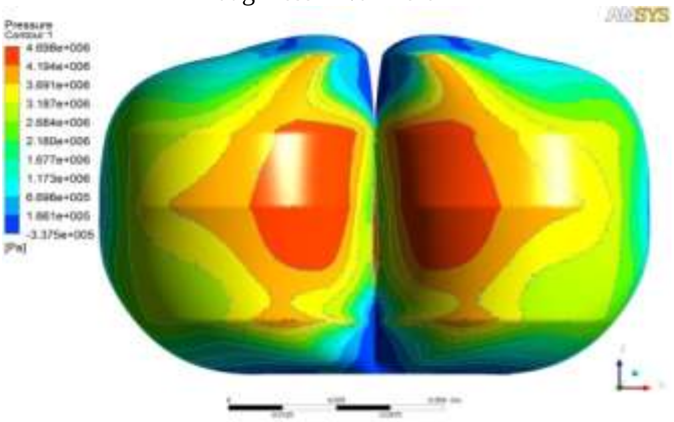

Figure 10: Pressure contour for bucket with surface roughness= 6.3 micron

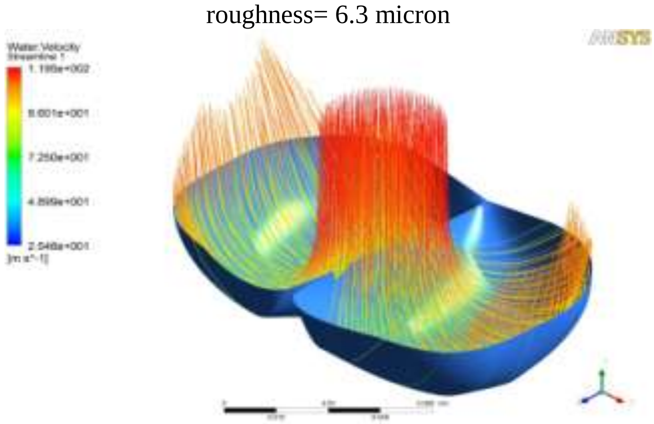

Figure 11: Streamlines pattern for bucket with surface roughness= 25 micron

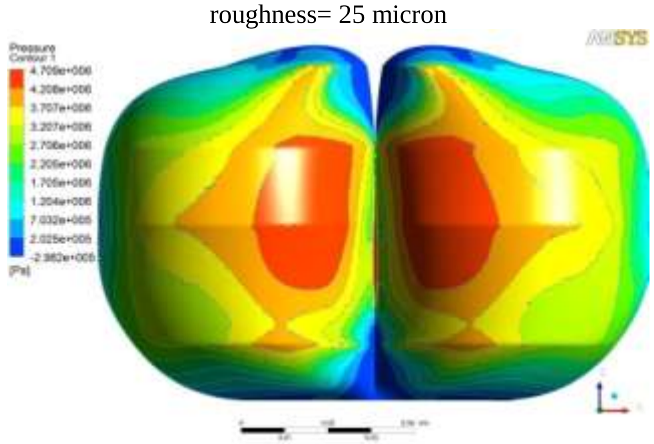

Figure 12: Pressure contour for bucket with surface roughness= 50 micron

5. Conclusion

From all the above pressure contours it is observed that highest pressure is observed in the deepest zone of the buckets. As the roughness of the buckets increases, the difference between maximum value and minimum value of pressure decreases. Maximum pressure difference is observed for smooth bucket

Highest total pressure is also observed in the deepest zone of the buckets. As the roughness of the buckets increases, the difference between maximum value and minimum value of total pressure decreases also. Maximum total pressure value is nearly same for all the cases. But value of minimum total pressure increases as roughness increases.

From water velocity streamlines, it is seen that water jet uniformly strikes the bucket and gets divided into two parts at splitter. Least water velocity is observed at the deepest zone of the buckets which confirms momentum transfer. Water smoothly leaves the bucket at the outlet angle of the buckets.

From water volume fraction iso-surfaces, it is seen that not much variation is seen for variation in surface roughness of the bucket.

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