Analysis on the Cavitation Behaviour of a Semi-Closed Impeller operated Centrifugal Pump with varying Axial Clearance

F. Paul Gregory¹*, D. Agusta¹, R. Ganesh Kumar¹, U. Punithasri¹, M. Vignesh¹

¹School of Energy, Department of Mechanical Engineering, PSG College of Technology, Coimbatore, India.

*Corresponding author E-Mail ID: paulgregoryresearches@zoho.com, Mobile: +91-9629431403

ABSTRACT

Machines that cater the everyday needs of mankind tend to be of inevitable and the researches that focus on improvements on such unique machinery are never ending. One among such machines is a pump that is ineludible for household, industrial, and automobile applications. Centrifugal pump is one such category. The type of impeller being used in centrifugal pump and also the contour of the casing adapted plays a hefty role in its performance. In an attempt to modify the contour of the casing and combine it with a semi-closed impeller, this research work has progressed in design and experimental analysis. A semi-closed impeller type centrifugal pump was designed with a tailor-made annular casing and the axial clearance of the pump was made the key parameter in the experimental analysis. This research work is hence an experimental analysis that would possibly conclude an optimum axial clearance that would maximize the performance of the centrifugal pump. Performance plots were recorded for three axial clearance cases and a comparison has been conferred from the cases.

Keywords- Annular Casing; Axial Clearance.

1. INTRODUCTION

Conventional centrifugal pumps are ranked based on the efficiency of the pump. Cavitation, Hydraulic losses, vibrations are some among the key parameters that affect the performance of the pump. Cavitation behaviour of the pump causes wearing of rotating parts and reduces the efficiency of the pump. Axial clearance, the clearance in assembly, between the tip of the impeller and the casing, is selected as the key parameter in this research work. Several researches have pondered upon this parameter and have recorded consummate results with this parameter. Wood et al [1] has researched on the cavitating and non-cavitating behaviour of centrifugal pumps with varying axial clearance. Engeda and Rautenberg [2] knocked-off that correlating between axial clearance and the performance was unpredictable as there was non-uniform. Ishida and Senoo [3] researched on the axial clearance effect on the pressure drop in centrifugal blowers. The researches varied the axial clearance and have recorded the pressure distribution throughout. Howard and Kimmer [4] measured velocity components in impeller passages of rotating machinery. And this too, to a certain extent! Researchers are still striving hard to correlate the effects of axial clearance directly on the performance of pumps. An attempt was made by Hesselgreaves [5] to predict the effect of such clearances on axial flow and mixed flow turbo machineries. A breach in these findings makes way for the current research on axial clearance to progress forward, taking a step towards optimizing the axial clearance effects.

In this research work a semi-closed impeller was designed and fabricated and was fitted to a tailor-made annular casing, constituting a custom made centrifugal pump. The detailed specification of the pump is as shown in Table 01.
Table 1 Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Head</td>
<td>25 m</td>
</tr>
<tr>
<td>Pump Discharge</td>
<td>600 Liters per minute</td>
</tr>
<tr>
<td>Electric Motor Speed</td>
<td>1440 rpm</td>
</tr>
<tr>
<td>Power output required from motor</td>
<td>3.3 HP</td>
</tr>
</tbody>
</table>

**Impeller Specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impeller Type</td>
<td>Semi-closed Type (Only Back Shroud)</td>
</tr>
<tr>
<td>Shaft diameter of impeller</td>
<td>25 mm</td>
</tr>
<tr>
<td>Hub diameter of impeller</td>
<td>35mm</td>
</tr>
<tr>
<td>Number of blades of impeller</td>
<td>06</td>
</tr>
<tr>
<td>Blade design methodology</td>
<td>Single Arc Method</td>
</tr>
<tr>
<td>Blade Inlet angle</td>
<td>24.5°</td>
</tr>
<tr>
<td>Blade Outlet angle</td>
<td>27°</td>
</tr>
<tr>
<td>Peripheral velocity at inlet</td>
<td>6.4 m/s</td>
</tr>
<tr>
<td>Peripheral velocity at outlet</td>
<td>20 m/s</td>
</tr>
</tbody>
</table>

An experimental test rig was constructed and provisions were made to vary the axial clearance between the impeller and the casing. Annular casing was employed for the case instead of conventional vortex based casing. The casing was fabricated and assembled as three compartments. Front compartment was made completely transparent facilitating for stroboscopic studies. The fabricated impeller and casing is shown in Fig.1 and Fig.2 respectively.

![Fabricated Impeller](image1)

![Fabrication of Casing](image2)

**Fig 1 Fabricated Impeller**

**Fig 2 Fabrication of Casing**

2. **EXPERIMENTAL STUDY**

The constructed test rig was operated for three ranges of axial clearances. Axial clearances were 1.5mm, 3mm and 4.5 mm for the three cases. The experimental study was mainly of two categories.

1. Performance Study on the pump
2. Stroboscopic Analysis on the cavitating behavior

Major instrumentation for the experimental analysis include (01) Suction and Delivery pressure measurements, (02) Water Level Indicator to measure water level in the discharge tank, (03) Timer to calculate the mass flow rate of water.
3. EXPERIMENTAL RESULTS

The performance plots for the pump for three axial clearance values are shown in Figure 04-06.

![Performance of Pump at 1.5mm Clearance](image)
A stroboscopic analysis was also conducted to study the cavitation behaviour of the pump. Stroboscopic analysis records the cavitation formed in between the impeller blades. Stroboscope, through its relative visualization technique makes way for the observer to visualize the cavitation as if the pump is at stationary state. The rotating impeller is visualized to be non-rotating and only the cavitation is visualized to be in motion. The formation of vacuum bubbles indicates cavitation. This experiment was conducted in a darker environment such that even very small variations in cavitation can be visualized. Figures 07- 09 shows the cavitation behaviour at various stages of the experimental analysis at 1.5 mm, 3mm, 4.5 mm axial clearance respectively.
High Cavitation
(At Very Low and Very high heads)

Low Cavitation
(At Intermediate head)

No Cavitation
(At High Heads)

Fig 7 Cavitation Behaviour of Pump at 1.5mm Clearance

High Cavitation
(At Very Low and Very high heads)

Low Cavitation
(At Intermediate head)

No Cavitation
(At High Heads)

Fig 8 Cavitation Behaviour of Pump at 3 mm Clearance

High Cavitation
(At Very Low and Very high heads)

Low Cavitation
(At Intermediate head)

No Cavitation
(At High Heads)

Fig 9 Cavitation Behaviour of Pump at 4.5mm Clearance
4. CONCLUSION

Outlandish trends have been reported in the experimental analysis.

1. Insomuch as efficiency is concerned, the pump hits its maximum efficiency of 36% when operated at 4.5 mm clearance and at 294 Lpm operation. Maximum trend of efficiency was observed at 4.5mm and then at 3mm further down at 1.5mm. Hence the observation can be deciphered that as the clearance gets own, so is the efficiency of the pump. The head values find a linear variation and are never found to be a game-changer.

2. Consider power, it is an exigent parameter to be considered on. From the performance tenor, Input Power is found to be preeminent when operated at 1.5mm clearance. When operated at 4.5mm the trends are found to be of bush-league. The output power delivered is also found to favor 4.5mm case.

3. Regarding the cavitation behaviour, the trend observed is uniform. Cavitation is found to be nethermost at very low heads and thereafter increases to a peak and then at very high heads it drops down. The intensity of cavitation is at its aiguilles at lower discharges.

4. The mode of formation of cavitating streams is cumulative. Streams of bubbles arises in-between individual impeller vanes and then cumulate. At 1.5mm clearance, the cavitating behavior of the pump is more intense.

Hence, from all the cases, it is evident that the 4.5mm case is suitable for better performance of the pump. The authors highly recommend that higher the clearance better will be the performance.

ACKNOWLEDGEMENT

The authors thank the Almighty for His blessings. The authors would also like to acknowledge their parents for their efforts to make our minds cherished with love and peace. The authors would also like to extend their thanks to Info Institute of Engineering, Coimbatore for their laboratory support to pursue the research work. The authors would also like to thank Mr. Balamurugan of Department of Mechanical Engineering, SVS College of Engineering, Coimbatore for his moral support during the research work.

REFERENCES


