Analysis and Optimization of Axial Flow Turbo Pump

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Abstract - *When a turbo axial pump works, it moves the liquid in forward and reverse direction to displace it from one place to another. This action is done mainly using the impeller and the bearing; initially it moves the liquid in forward direction and after sometime when it moves in the reverse direction, the liquid hammers. Water hammer is defined as a surge in pressure caused by a force applied to suddenly change or stop the direction of flow of water. Hammer occurs due to forward and reverses motion of the water simultaneously or due to sudden closure of the valve. A water hammer can also be called as hydraulic shock. Due to this even though the impeller pushes the liquid in reverse direction, some quantity of water moves in the forward direction. Due to this contrary action, (i.e) hammering, the impeller and the bearing is damaged and also the efficiency of the pump reduces. In order to reduce the hammering of liquid, a flow vane guider can be introduced. Since the turbo axial pump is not a pressure pump, the pressure and velocity of the pump can be modified to reduce the hammering. Introduction of the flow guider not only monitors the hammering but also the flow of liquid. In this paper we have compared the performance of the pump without a flow guider and a pump with a flow guider in terms of pressure and velocity. Introducing the flow guider* (12 vanes) *increases the efficiency of the pump and also the life span of the impeller and the bearing.*

1. INTRODUCTION

The project "Analysis and optimization of Axial Flow Turbo Pump" mainly focuses on the mechanical design and analysis of Pump Impeller and casing as it transmit the flow and its durability. During the visit to RK Tex Machines India Pvt Ltd we came to know about a problem of Low Pressure Flow Pump failure in their Axial Flow Pump Model. Due to this problem the bearing and the impeller life gets reduced and the flow becomes low. The main objective of our project is Flow analysis of Axial Flow Pump, radial thrust, axial thrust and essential Pump Impeller & Casing Model. The Analysis can be done on the basis of the Fluid flow Analysis using ANSYS software. In this project we are working with a view to get familiar with the technologies as well as application of theories into practical work done by industries.

1.1 MECHANICAL PUMP

A pump is defined as the device which moves fluids, gases or slurries by means of mechanical action.
Basically a pump can be classified into two types:

- Single stage pump:

  When only one impeller is revolving inside the casing it is known as single stage pump.

- Double/multi-stage pump:

  When two or more impellers revolve inside the casing then it is known as double/multi-stage pump.

It can be further classified into three types based on the mechanism of moving the fluid:

- Direct lift pumps.
- Gravity pumps.
- Displacement pumps.

The pumps operate using rotary mechanism and the used electrical energy is converted into mechanical work of moving the fluids from one place to another. The energy used by the pump can be by electricity, engines, wind power or by manual operation.

A mechanical pump has many applications, such in pumping water from wells, in pond filtering, aeration, aquarium filtering, in car industry for water cooling and fuel injection. In energy industry it is used for pumping oil and natural gas and for operating cooling towers.

1.2 RADIAL-FLOW PUMPS

A radial flow pump is also known as centrifugal pump. The fluid that enters along the axis/center is accelerated by the impeller and it exits at right angle to the shaft (i.e) radially. an example is the centrifugal fan, which is commonly used to implement a vacuum cleaner and centrifugal impeller is used in the positive section to carry the liquid from one place to another with increase in pressure.

1.3AXIAL-FLOW PUMPS

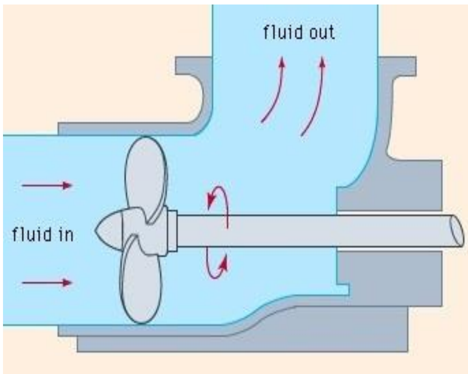

Fig-1: Axial Flow Pump

The axial flow pump is also known as the propeller pump. It is called a dynamic pump because to generate the pump pressure it utilizes both the fluid momentum and velocity. This velocity is produced by the impeller to apply the centrifugal force to pump the liquid. It has the highest flow rate and lowest discharge pressure compared to mixed flow and radial flow. In contrast to the radial pump, it directs the flow in a straight line parallel to the impeller shaft. The impeller is in the shape of a propeller, and is run by a motor either directly or through a drive shaft.

1.4 MIXED-FLOW PUMPS

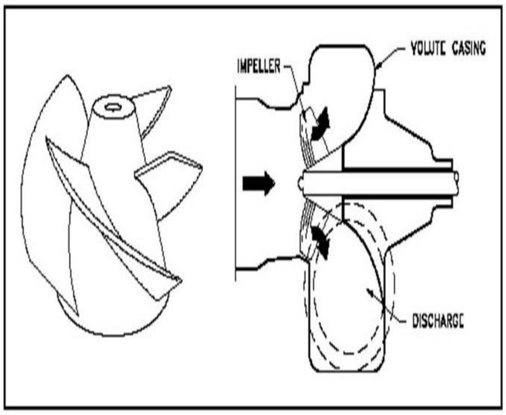

Fig-2: Mixed Flow Pump

A Mixed-flow pumps function as a compromise between radial and axial-flow pumps. Radial flow pumps operates in a horizontal plane with respect to the direction of flow of liquid, whereas a axial flow pump operates in a vertical plane with respect to the direction of flow of liquid. The mixed flow pump works in a diagonal plane in relation to the flow of the liquid. Centrifugal force is used to move the liquid and when in need of acceleration, the liquid is pushed from the axial direction of the impeller which results in high flow rate.

1.5 THURSTS IN PUMP

While operating a centrifugal pump, the kinetic energy of the flowing liquid is converted into pressure energy. This high pressure liquid gets trapped between the impeller and the casing. This trapped liquid exerts pressure on the outlet path and the protecting shield of the impeller, resulting in radial and axial thrust. The radial thrust is generated in lateral direction due to the difference in the pressure generation in the volute. The axial thrust is generated in longitudinal direction due to different areas of impeller exposed to trapped liquid.

1.6 RADIAL THRUST

The unequal velocity of the liquid through the casing results in non-uniform distribution of the pressure on the circumference of the impeller, this is known as radial thrust. The radial force depends on the total head. Width and diameter of the impeller.

1.7 METHODS OF BALANCING RADIAL THRUST

1.7.1 DIFFUSER PUMP

In diffuser pump method, the diffuser is located between the impeller and the casing. By placing the diffuser between the impeller and the casing, when the liquid flows out of the impeller it is directed to diffuser which in turn directs to the casing. By this the pressure between the impeller and the casing is reduced, thus reducing the radial thrust.

1.7.2 DOUBLE VOLUTE CASING

In this the volute is divided into two partitions and the two joins into a common discharge. Due to the partition radial force exerted on the shaft is very small and does not require heavy shaft, the design of pump is also economical.

1.7.3 AXIAL THRUST

Axial thrust is the sum of unbalanced impeller force acting in the axial direction. Axial thrust is maximum at the starting and shutting down of the pump, this is because the liquid flows at the high speed during the start of the pump which puts a pressure on the bearings. Due to the high pressure the bearings is damaged and the bearing life is reduced.

1.8 METHODS OF BALANCING AXIAL THRUST

1.8.1 DOUBLE SUCTION IMPELLER

In double suction impeller an equal and opposite axial thrust acts on suction sides, thus balancing each other.

1.8.2 BACK VANES

In this radial ribs are used in the outer covering of the impeller to reduce the pressure between the impeller and the casing. It acts as the auxiliary impeller that restricts the entry of the liquid between the impeller and the casing.

2. DESIGN AND ANALYSIS

In the absence of a flow guider inside the casing, water gets hammered. The hammering is because of the turbo operating on both forward and reverse direction. Due to the hammering, the main shaft, impeller leaf and the bearings get damaged, which is an undesirable effect. Thus we can analyze the flow rate in axial pump model and the effect of bearing and impeller.

The hammering of water is due to the absence of flow vane guider. Initially the impeller moves the liquid in the forward direction and after sometime it has to move the liquid in the reverse direction, but due to the absence of a proper guider vane the liquid continues to move forward while the impeller tries to moves the liquid in reverse, this effect results in hammering of liquid. A flow vane guider can be introduced between two impellers and the casing.

By adding a flow vane guider we can increase the shaft, bearing and the impeller life. The flow vane guider is inserted at an angle- 30 degree. When the flow guider is placed at this angle the pressure and velocity on the impeller and the bearings can be reduced .The design can be done using SOLIDWORKS, and the fluid flow can be analyzed using SOLIDWORKS software.

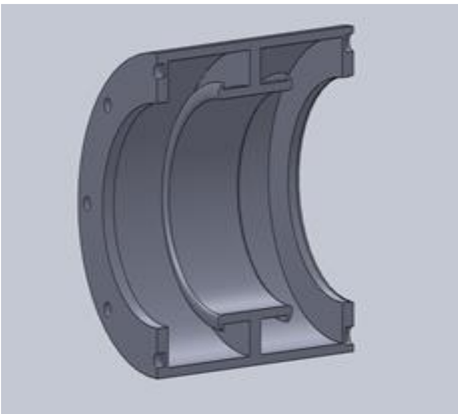

Fig-3: Pump without flow guider

Without a flow guider the liquid will hammer when the impeller tries to move the liquid moving in the forward direction to move in the reverse direction, which will affect the impeller and the bearing life. The liquid also will not be effectively moved from one end to another.

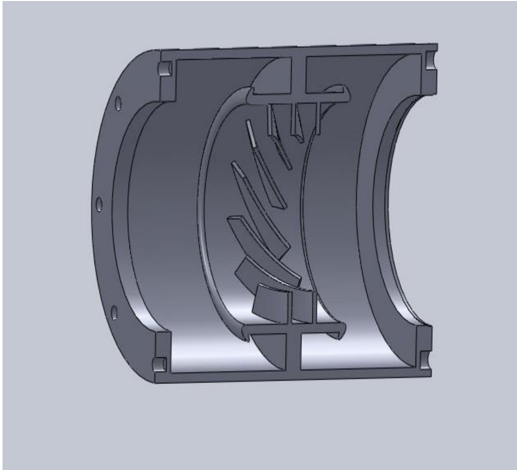

Fig-4: Pump with flow guider

When the pump is fitted with a flow guider the hammering of liquid does not take place. (i.e) the liquid will flow in the forward and reverse direction without any hammering and the impeller and bearing life span will also be increased.

3. SIMULATION RESULTS

The analysis of the pressure and the velocity in the pump with the flow guider and without flow guider is done in SOLIDWORKS simulation software. For the proper flow and to reduce the damage to the impeller the pressure and velocity of the water should be stabilized or minimized. Failing which, will result in hammering to the pump.

3.1 COMPARISON OF PRESSURE IN THE PUMP WITH AND WITHOUT VANE (FLOW GUIDER)

From the results we can see that the pressure in the pump with flow guider is less and stabilized compared to the pressure in the pump without flow guider.

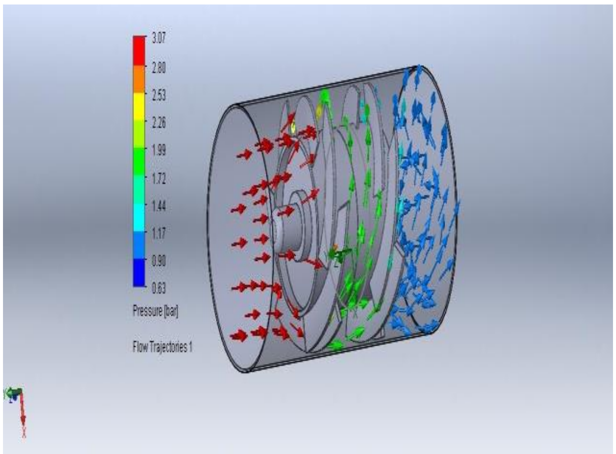

Fig-5: Pressure in pump without flow guider.

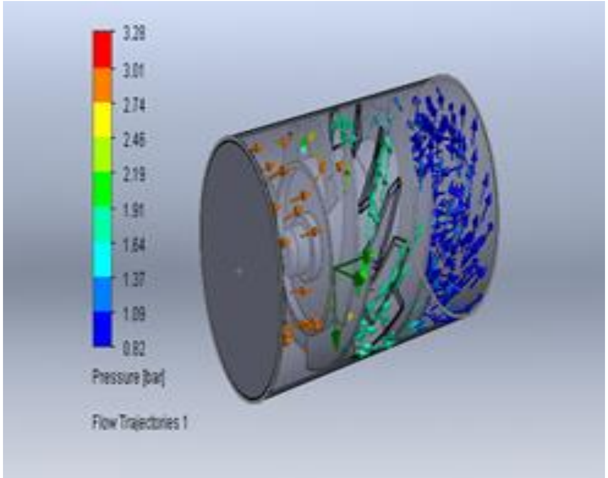

Fig-6: Pressure in pump with flow guider.

With the comparison in graph of pressure in pump with and without flow guider we can see that the pressure is stabilized in the pump with flow guider.

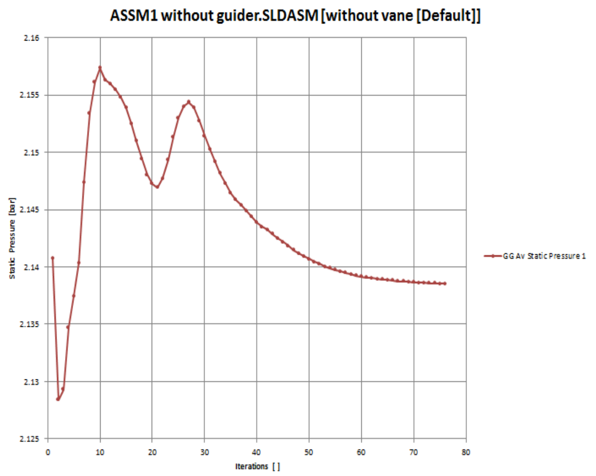

Fig-7: Pressure in pump without flow guider.

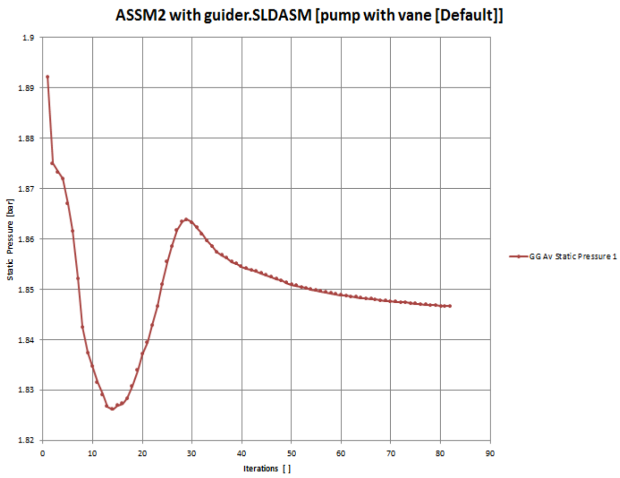

Fig-8: Pressure in pump with flow guider (12 vane).

3.2 COMPARISON OF VELOCITY IN THE PUMP WITH AND WITHOUT VANE (FLOW GUIDER)

In a pump if the velocity increases it will also contribute to the hammering effect in the pump. In order for the stabilized flow, the velocity should be maintained at a constant speed. The velocity is stabilized or reduced in a pump with a flow guider/vane. Below we will see the comparison of velocity in a pump with a flow guider and without a flow guider.

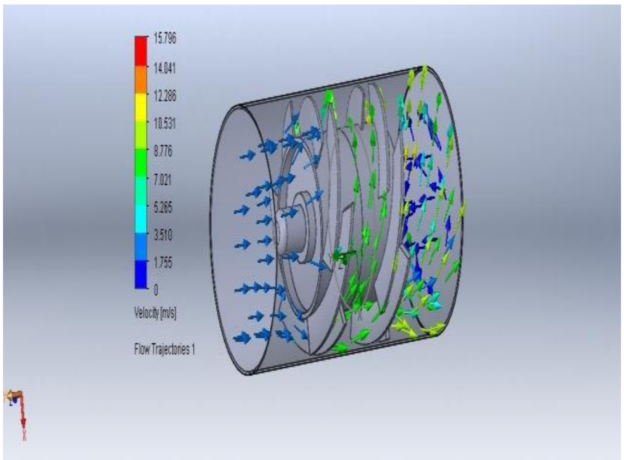

Fig-9: velocity in pump without flow guider.

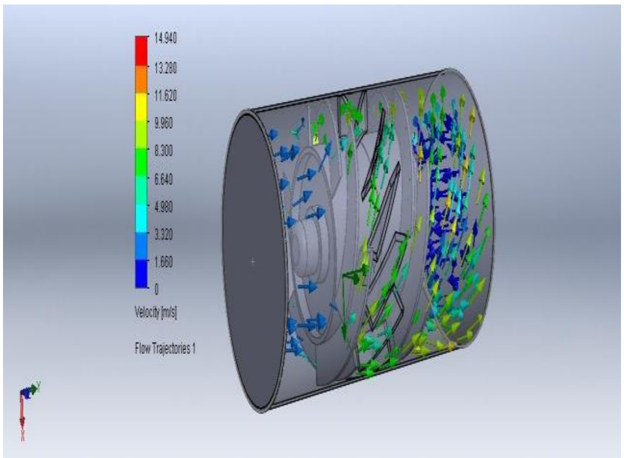

Fig-10: velocity in pump with flow guider (12 vane).

Comparison graph of the velocity in the pump with and without flow guider/vane.

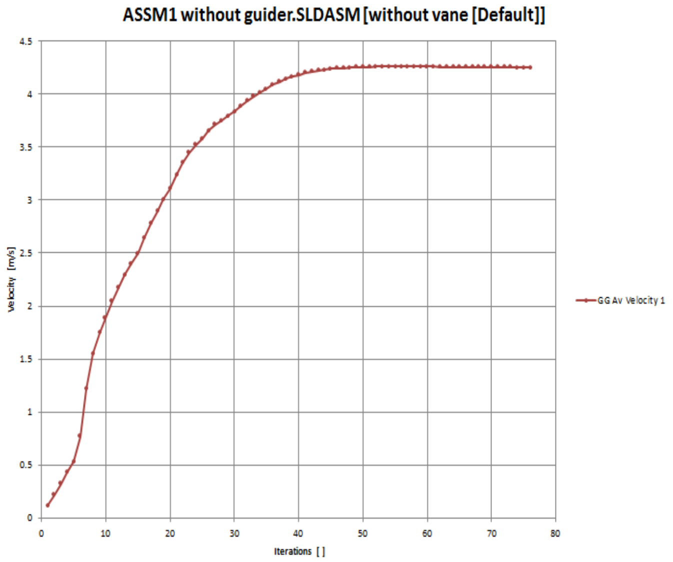

Fig-11: velocity in pump without flow guider.

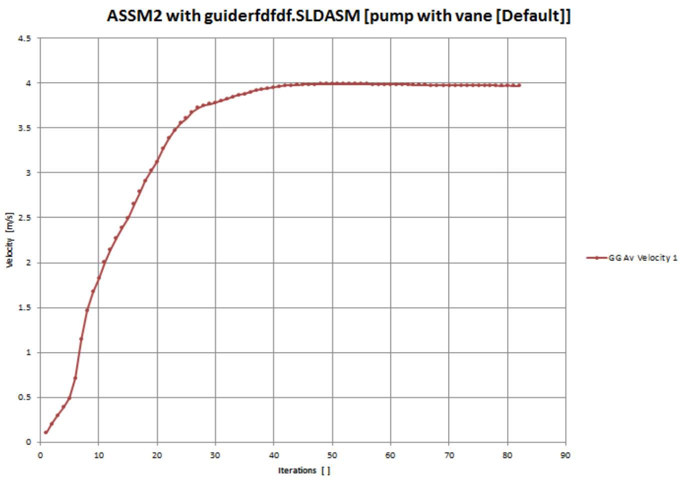

Fig-12: velocity in pump with flow guider (12 vanes).

1.4RESULT AND CONCLUSION

In the absence of a flow guider (12 vane) inside the casing, water gets hammered. The hammering is because of the turbo operating on both forward and reverse direction. Due to the hammering, the main shaft, impeller leaf and the bearings get damaged, which is an undesirable effect. Thus we have analyzed the flow rate in axial pump model and the effect of bearing and impeller.

The hammering of water is due to the absence of flow vane guider (12 vanes). Initially the impeller moves the liquid in the forward direction and after sometime it has to move the liquid in the reverse direction, but due to the absence of a proper guider vane the liquid continues to move forward while the impeller tries to moves the liquid in reverse, this effect results in hammering of liquid. A flow vane guider can be introduced between two impellers and the casing. By adding a flow vane guider (12 vanes) we can increase the shaft, bearing and the impeller life. The flow vane guider is inserted at an angle- 30 degree. When the flow guider (12 vanes) is placed at this angle the pressure and velocity on the impeller and the bearings can be reduced .The design is done using SOLIDWORKS, and the fluid flow can be analyzed using SOLIDWORKS software.

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