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Experimental Analysis of Liquid Ring Vacuum Pump Cavitation Reduction

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Abstract: Liquid Ring Vacuum Pump (LRVP) is a device that produces vacuum between a liquid ring and rotating disc. This paper deals with the reduction of unwanted noisy operation of LRVP due to cavitations. The main reasons for cavitations in LRVP are increase in circulating water ring temperature and pressure, which is also cause formation of vapour bubbles. The formation, growth and collapsing of these vapour bubbles is called cavitations. The flow characteristics of the pump vary widely based on the impeller design. Further, the main parameter of the impeller design is its blade outlet angle. So, here we reduce the blade angle to improve the performance of the pump.
Keywords: Impeller design, cavitations, blade angles, ANSYS FLUENT

I. INTRODUCTION

A liquid ring vacuum pump is different pump from other conventional pump. It can handle the fluid loads and has no metal-to-metal contact. Which also acts as heat absorber from condensation compression and friction generation the incoming gases are condense with liquid ring water and liberates heat to the water and the rotating ring applies a compression force on water eccentrically. It also filters the gas and removes contaminants by the circulating water. The design of impeller plays an important role to produce vacuum. In spite of critical design, and sizing and selection of blade angle gives the pressure and temperature develops in the pump.

A. Operating Liquid Feed (No Recovery)

The discharge fluid contains gases and they are separated further and allowed to drain. The operating liquid (generally water) with some required pressure and temperature. The efficiency of pumps is low because of increase in working liquid saturation pressure; other reasons are pumping of dust and non-condensable gases with water mixture. The recommended operating liquid pressure is 3-5 kg/cm^2. Therefore the increase in vapour pressure in operating liquid decreases the pump performance.

II. TOTAL RECOVERY SYSTEM

This pump provides for total recirculation of the operating liquid. The pump operates sludge and pulp also without affecting the pump performance. The seal water acts as piston to compress the gases and to produce the suction in the pump. A heat exchanger is added to remove the heat of compression and condensation from the operating liquid. It contains only one rotating part with simple design and maintenances. The rotary is connected to motor with a gear box. To overcome the excessive pressure drop in the system (heat exchanger, piping, valves, etc.), a circulating pump may be necessary.

III. WORKING

The impeller rotates to increase the velocity of the operating liquid, which is arranged concentrically in casing of a pump. Due to its rotation a centrifugal force creates liquid ring in pump. The suction creates between liquid ring and impeller to entrap the gas molecules. A separate port is arranged at impeller eye for suction of gas, then compression is occurs between eccentric rotations of the impeller and rotating liquid ring.

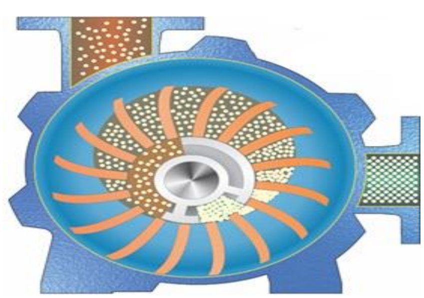

Fig: schematic of pump operation

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A. Cavitations in LRVP's

Cavitations occurs in circulating water by increase in vapour pressure .Generally in is process of increase of molecules kinetic energy and evaporates, and applies a pressure on the liquid surface. This pressure causes some more liquid molecules vaporise and form a bubble with moisture known as vapour bubble. As the temperature goes on increases, the formation and collapse of bubbles comes into picture. The phenomenon is called as cavitations, which further causes the application of high pressure force on the impeller to damage the blades. Water boils at high temperature at atmospheric pressure (212°F), while at a lower pressure vacuum will boil at a lower temperature, as the impeller rotates pressure increase gradually, and water will not boil until it reaches a higher temperature.. Therefore, in order to keep the pump free from cavitations, the temperature of the water must remain below the saturation point corresponding to the inlet pressure. The service liquid must be cold enough to avoid vaporization.

B. Elimination Method and Prevention

1) To improve the accuracy of selection, the vacuum pumps to run in a secure area. In the selection phase, select the vacuum pump suction pressure and temperature of the water volume should easily avoid a vacuum pump cavitations pressure range, which prevents the vacuum pump to run the vacuum degree in the area of critical or critical exhaust pressure, to minimize the generation of cavitations.
2) Selection of a liquid with a lower vapour pressure as the working fluid.

C. Parameters and inlet conditions

In this context we have considered the prototype impeller with following parameters and perform an air and fluent flow at low and at high temperature and pressure, estimated the kinetic energy and outlet pressure of the discharge fluid. The observation gives the conclusion as for high temperature and velocity

1) Modeling Of Impeller

a) LRVP Impeller in CreoParametric4.0.
b) The dimensions of the model are shown below.
c) Outer Diameter including blades: 1016 mm
d) Outer Diameter (Shaft): 508 mm
e) Inner Diameter: 254 mm
f) Blade Exit Angle: 40^{o}
g) Angle of deflection of blade at exit: 140^{0}

The cylindrical housing of the pump is designed in Creo Parametric 4.0 and the impeller model is assembled inside it eccentrically such that there is almost negligible distance between the wall of the pump and the impeller at the bottom most point. Necessary ports are designed at appropriate points for inlet and outlet of gases or other materials which would be drawn in by the vacuum inside the pump. The model initially contains water until half the level of the pump. (in Fig-A&B).

The software used for the analysis of the LRVP is ANSYS Fluent 18.0. ANSYS fluent is a general purpose Computational Fluid Dynamics (CFD) software suite that combines an advanced solver with powerful pre-processing and post processing capabilities. It includes the following features:

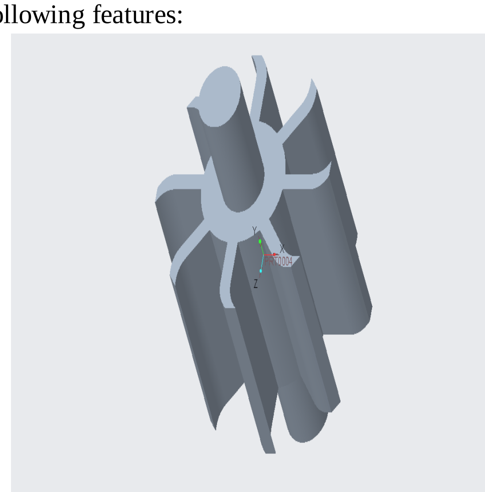

Fig-A: Impeller Model in Creo Parametric

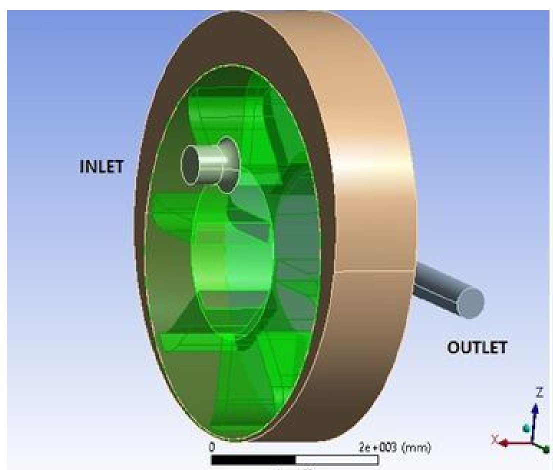

Fig-B: Model of LRVP showing impeller zone

D. Simulation By Deducing Rotor Blade out let Angle

1) *Meshing*: After importing go the analysis setting and select an ANSYS fluid flow and drag and leave on project schematic window as shown in figure
2) *Fluent Fluid Flow Process*: .In project schematics under the fluid flow fluent

a) *Step a:* under the fluent flow fluent In middle general properties will be modify and select the transient. Fig-B shows the inlet and out let ports with impeller
b) *Step b:* The temperature can be applied over the impeller if temperature is necessary.In viscous model goes to the model and selects the k-epsilon (2 equations.). In k- epsilon model,

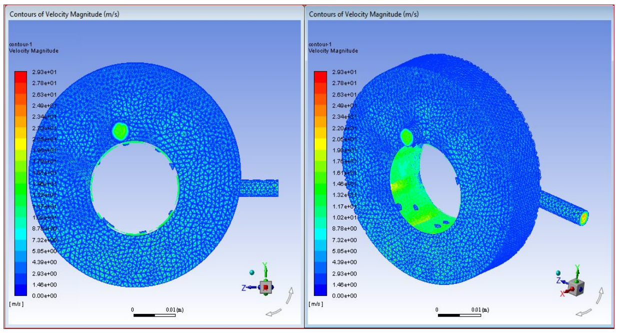

Fig –C: Contours – Velocity

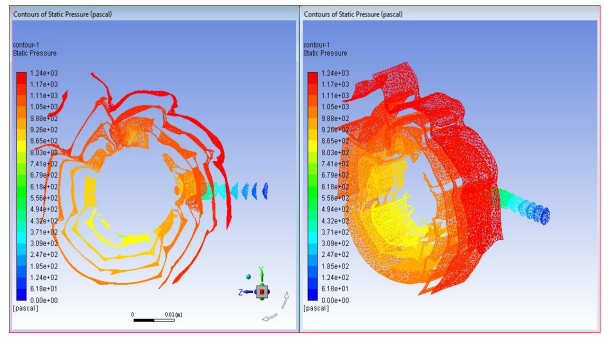

Fig-D: Contours- Pressure

a) *Step c:* Boundary Conditions. Now go to the boundary condition. In boundary condition select the inlet and specify the boundary conditions are velocity 15 m/s (900 m/min) and select temperature (thermal) – 22
b) *Step d:* In boundary condition select the inlet and specify the boundary conditions are velocity 15 m/s (900 m/min) and select temperature (thermal) – 22 c

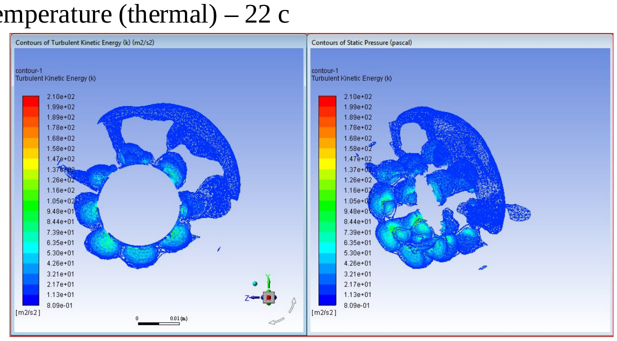

Fig –E: Contours - turbulent kinetic energy

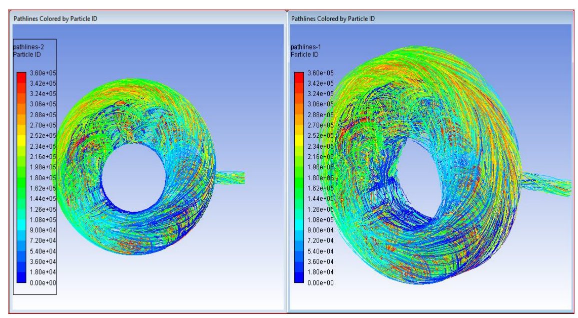

Fig-F: Path line

The simulation and analysis started at(Fig-C) by taking the inlet speed of impeller 1000 rpm with low velocity pressure and temperature by selecting the required boundary conditions. The outlet flow is at atmospheric pressure at high velocity .since by comparing the Fig-C&D, it is clear that the pressure and temperature are increase with inlet conditions. In the practical vacuum pump in the casing consider the inlet conditions .Therefore by reducing the blade out let angle we can reduce the dynamic force acting on the liquid ring in vacuum pumps which increase the pressure and kinetic energy of the gas.

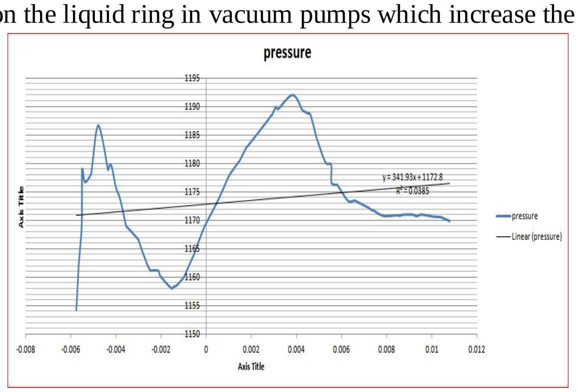

Fig-G: pressure in inlet pipe

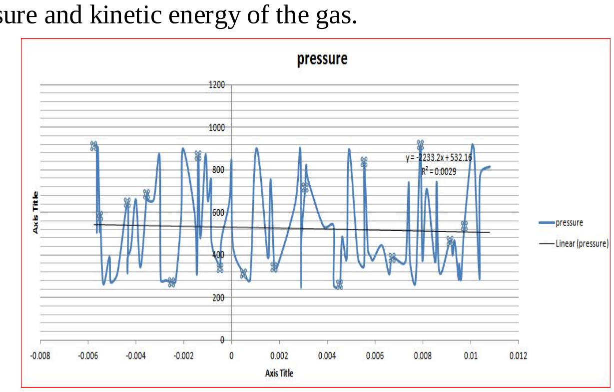

Fig-H: pressure in out let pipe

In the Fig-E the turbulence of kinetic energy at outlet of the pump is simulated with same velocity of impeller, it is low at inlet compared to outlet. The graphs represent (Fig-G&H) the pressure variations inside the pump and at out let the turbulence in pressure is maximum at atmospheric condition due to high velocity. Hence we conclude that the cool inlet service water at low pressure with low impeller blade out let angle the efficiency of the pump increase by reducing the cavitations effect.

E. Drawn From Results

1) As the pressure is maintained within a range of values at a section, the temperature rise inside the pump is prevented.
2) As the temperature rise inside the pump is prevented, the operating temperature is always below the saturation point corresponding to the vapour pressure.
3) This ensures that vaporization does not take place inside the pump. Hence there is a very less scope of formation of vapour bubbles inside the pump.
4) As the vapour bubble formation is very less, the cavitations problem is reduced significantly inside the pump.
5) The model used in this project has a blade angle of 40o which is lesser than the existing LRVP's in the industry.

	in			out			
osition	pressure	velocity	kinetic energy	pressure	velocity	kinetic energy	pressure
-0.00578	1154.27	0	17.3021	911.579	15.4596	14.8355	1160.04
-0.00567	1162.58	5.06019	24.2111	911.588	19.112	15.3468	1160
-0.00566	1163.04	5.57211	24.5174	506.061	21.0758	7.40743	1166.11
-0.00562	1164.87	7.59711	25.7291	906.22	19.6968	15.6907	1164
-0.00554	1169.84	12.1038	30.8247	509.564	21.1016	7.46063	1167.41
-0.00553	1179.1	13.441	39.6293	508.497	21.093	7.43743	1168.55
-0.00553	1170.24	12.4647	31.2327	582.943	21.6357	9.07701	1173.31
-0.00551	1178.8	13.4324	39.8014	589.102	21.633	9.29776	1179.58
-0.0054	1176.76	13.3744	40.9617	266.085	20.3656	3.98073	1168.38
-0.00513	1178.16	13.5814	43.9118	391.296	20.5893	5.35453	1168.21

IV. CONCLUTION

A Liquid ring vacuum pump is used for the purpose of creating vacuum. In LRVP all parts of the pump are very important for performance of the vacuum pump. But most critical part of pump is impeller and impeller is heart of pump and its function needed very properly to get higher performance. So we have performed CFD analysis which is very friendly software to finding fault and for improve design of vacuum pump. Hence the impeller of the LRVP is modified by reducing its blade exit angle. From the results, we can observe the changes obtained after the modifications. As the cavitations problem is reduced, the wear and tear of the impeller blades is reduced. Also the efficiency of the pump increases due to reduced losses of cavitations. This increase in efficiency of the LRVP is highly desired in industries

V. ACKNOWLEDGMENT

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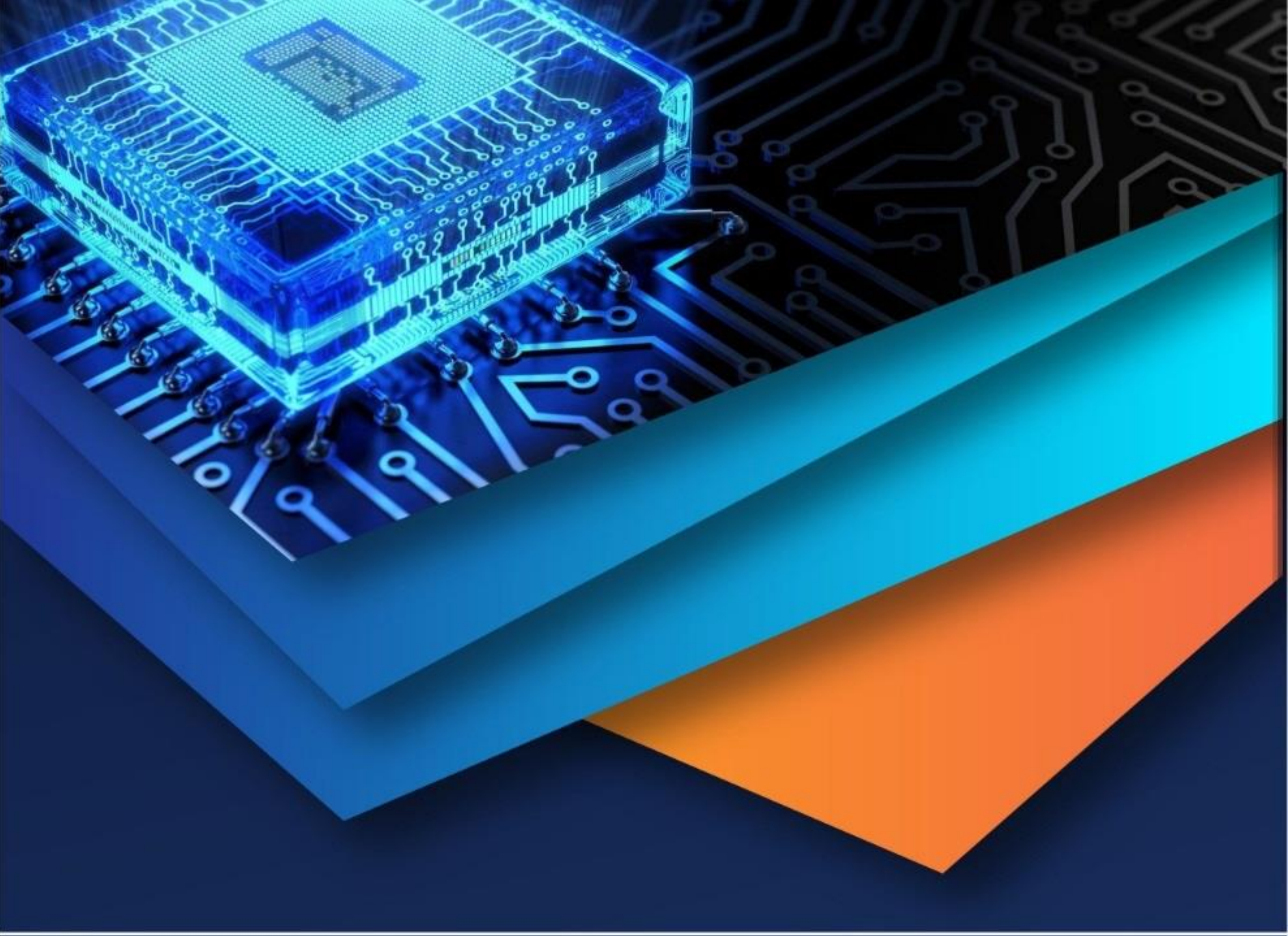

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