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CFD ANALYSIS OF WATER RING VACUUM PUMP OF 904 SERIES FOR DIFFERENT OPERATING PARAMETERS.

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Abstract — *With increasing demand of vacuum pump also require high performance of pump demanded by market. Vacuum pumps to give their function properly but many vacuum pumps not give work properly as per requirement just because of poor design of vacuum pump. So design of pump being changed to improve function, but it is costly and time consuming using experimental work. So CFD analysis use for this purpose.*

The main objective of this project is to improve vacuum level of water ring vacuum pump. In Fine tech engineering , during testing process of water ring vacuum pump see that in WRVP the vacuum level is very low as per requirement and therefore efficiency is low.

To improve the efficiency of SV-20water ring vacuum pump, Computational Fluid Dynamics analysis is one of the advanced tools used in the pump industry. A detailed CFD analysis is used to predict the flow pattern inside the impeller which is an active pump component. From the results of CFD analysis, vacuum level of the impeller is justified and validated with experiment result here with very low deviation in result of 2.24%. Now modified impellers are modeled using CAD modeling software. Here we changed thickness of blade, inlet and outlet angle of impeller based on empirical relation and literature. Here 11 modified impellers are modeled. These models are analyzed individually using CFD analysis to find the performance of the modified impeller WRVP. By using CFD analysis impellers with the improved value of vacuum level 485.88 mm of hg vacuum get and by means improved efficiency achieve.

Keywords*-Vacuum pump, design modification of vacuum pump, cfd analysis of WRVP, water ring vacuum pump, efficiency improvement of WRVP.*

I. INTRODUCTION

A vacuum pump is a device for creating, improving and/or maintaining a vacuum. Mechanical vacuum pumps work by the process of positive gas displacement, that is, during operation the pump periodically creates increasing and decreasing volumes to remove gases from the system, and exhaust them to the atmosphere. The major component of the liquid ring pump is a multi-bladed rotating assembly positioned eccentrically in a cylindrical casing. (See Figure) This assembly is driven by an external source, normally an electric motor.

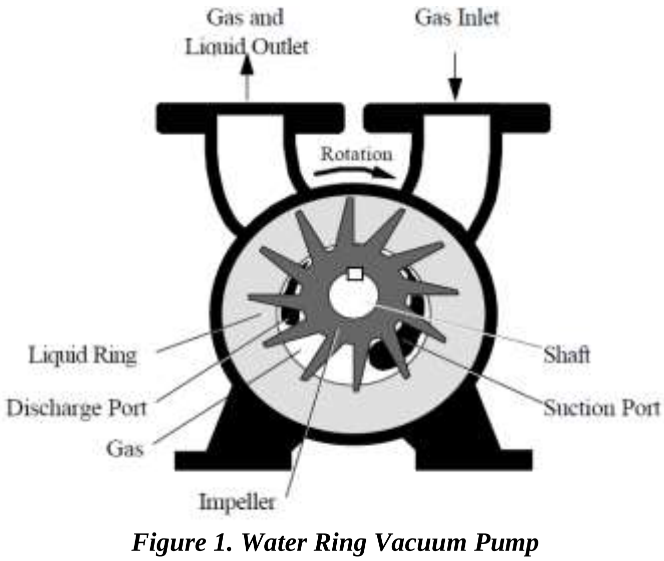


Figure 1. Water Ring Vacuum Pump

Service liquid (usually water) is introduced into the pump. As the impeller rotates, centrifugal force creates a liquid ring which is concentric to the casing. At the inlet, the area between the impeller blades increase in size, drawing gas in.As the impeller continues to rotate toward the discharge, the impeller bucket area decreases in size, compressing the gas. This gas, along with the liquid from the pump, is discharged through the outlet nozzle. In addition to being the compressing medium, the liquid ring performs two other important functions:

1) It absorbs the heat generated by compression, friction, and condensation of the incoming vapor.
2) It absorbs and washes out any process contaminants entrained in the gas.[1]

Water Ring Vacuum Pump Features

- Reliable, simple design which involves only one rotating part, which is not subject to much wear.
- Can handle condensable vapors or even slugs of liquid entrained in the gas stream without damage to pump or affecting pump performance.
- Produces a steady non-pulsating gas flow when it is used as either a vacuum pump or compressor.
- Resistant to contaminants entering with the gas stream these will be diluted and washed through the pump by the seal liquid.
- Liquid ring vacuum pumps can use any liquid compatible with the process, provided it has the appropriate vapor pressure properties, as the sealant liquid. Although the most common sealant is water, almost any liquid can be used. The second most common is oil. Since oil has a very low vapor pressure, oil-sealed liquid ring vacuum pumps are typically air-cooled.

Fields Of Application

- Chemical process technology
- Venting of steam turbine condensers
- Filter installations
- Steam and gas sterilizers
- Plastics extruders
- Vacuum calibration of plastic profiles
- Paper machines
- Vacuum driers
- Solvent recovery
- Lowering of the ground water table
- Drying and impregnation of wood
- Sludge extraction vehicles
- Mineral water production plants

Back Ground Of Company Parag Engineering is an ISO 9001-2008 quality certified company. It is a most trusted and quality manufacturer of Oil Sealed Rotary High Vacuum Pump, Water Ring Vacuum Pump, Monoblock Vacuum Pump, Fluid Couplings and Impregnation Systems since 1980.They manufacture many Products are:

- Oil Sealed Rotary High Vacuum Pump
- Water Ring Vacuum Pump
- Monoblock Vacuum Pump
- Fluid Couplings
- Impregnation Systems
- Diaphragm Pump
- High vacuum booster system
- Vacuum cum Pressure Pump

II. PROBLEM DEFINITION AND MODEL

Problem definition Water ring vacuum pump is mostly used for vacuum creation purpose in many applications. PARAG ENGINEERING company is manufacturer of water ring vacuum pump and facing problems related to this water ring vacuum pump which gives very low efficiency. In water ring vacuum pump vacuum level requirement is not achieved properly by SV-20 pump. Experiment work with accuracy take place and get vacuum level is 450 mm of hg. Pump creates very low vacuum level so not very efficient pump in its application.
So SV-20 vacuum pump not giving high efficiency as per requirement and to solve this problem and get higher vacuum using CFD analysis.

Methodology SV-20 is WRVP which create low vacuum level so to improve that level following steps to be follows:

- Modeling of existing WRVP and its CFD analysis.
- Compare result with experimental data to validate result and to check inner flow.
- Create new modified impellers and CFD analysis of those modified impellers pump.
- Compare result of new modified impeller with existing pump vacuum level to get improve performance with high efficiency.

III. DESIGN AND EXPERIMENTATION

Experimental Work All this experiment work was done in Parag Engineering, Ahmadabad. Experimental setup is successfully developed and assembled without having any leakage problem. Experiments were carried out using water as service liquid and gas or air is trapped between impeller blades and both air and gas are thrown out by outlet at 2880 rpm and after further rotation vacuum is created in pump and system as expansion of trapped air take place.

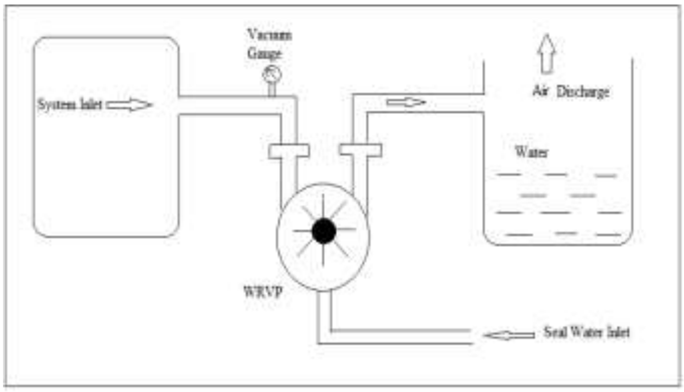


Figure 2. Experimental Set-Up

In figure we can see experiment procedure of WRVP in which to know vacuum level dial gauge or U-tube manometer is used and its range is 0-760 mm of hg. Flow-meter's range between 0-250 lpm and {system which is of 1000 liter}.

Here below given calibration data of vacuum gauge which is used during testing process in parag engineering company. By this calibration data of vacuum gauge see that very less error show vacuum gauge and it shows result ± 1to 2 mm of hg. so it is negligible and it doesn't affect to validation of WRVP.

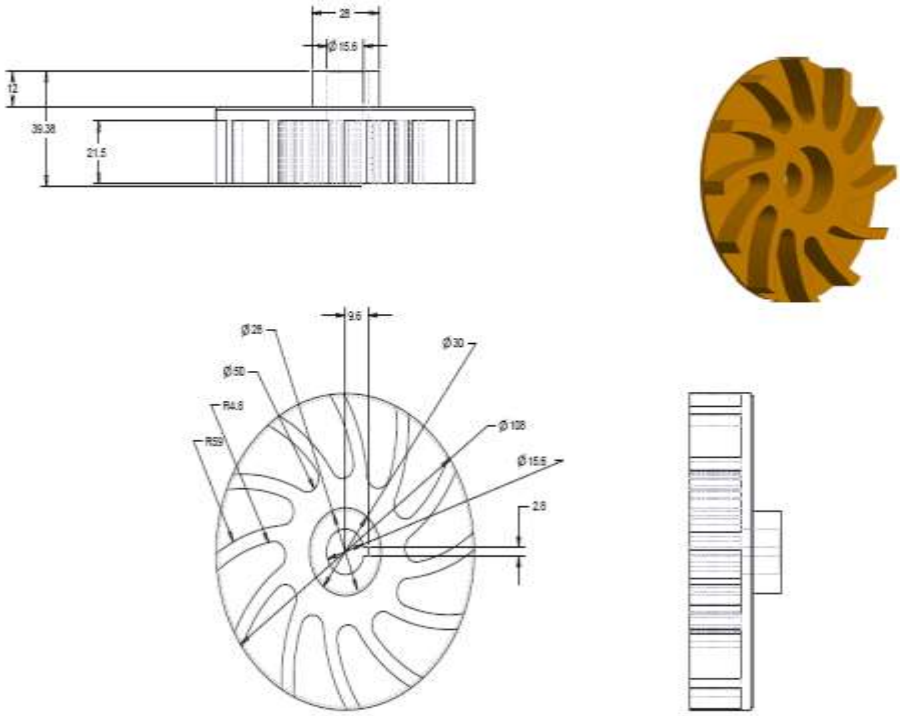


Figure 3. Existing impeller model

(all dimensions are in mm)

Design Specification Of Impeller

Diameter of shaft	**108 mm**
Inlet Angle	**15˚**
Outlet Angle	**52˚**
Thickness of blade	**5 mm**
Blade No.	**12**
Diameter of shaft	**16 mm**

Figure 4. impeller

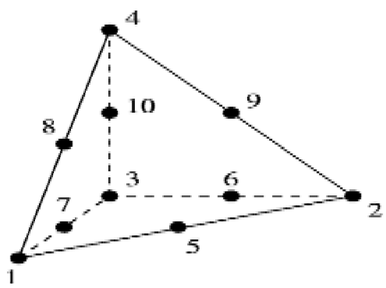
IV. CFD ANALYSIS OF WATER RING VACUUM PUMP

Pump outline and execution forecast process is as yet a troublesome assignment, for the most part because of the immense number of free geometric parameters, the impact of which can't be specifically assessed. The critical cost and time of the experimentation procedure by building and testing physical models lessens the overall revenues of the pump makers. Consequently CFD investigation is right now being utilized as a part of the outline and development phase of different pump sorts. To enhance the productivity of pump, Computational Fluid Dynamics (CFD) examination is one of the propelled apparatuses utilized as a part of the pump business.

A definite CFD examination was done to anticipate the stream design inside the impeller which is a dynamic pump segment. From the consequences of CFD examination, the speed and weight in the outlet of the impeller is anticipated. These outlet stream conditions are utilized to figure the productivity of the impeller. From the CFD investigation programming and propelled post handling devices the mind boggling stream inside the impeller can be broke down. The mind boggling stream attributes like delta pre-twirl, stream detachment and outlet distribution can't be pictured by the exploratory method for pump test. In any case, on account of CFD examination the above stream characters can be imagined obviously. Also outline change should be possible effortlessly and accordingly CFD investigation diminishes the item advancement time and cost. The numerical reenactment can give very exact data on the liquid conduct in the machine, and along these lines helps the architect to get an exhaustive execution assessment of a specific outline.

Meshing of Water Ring Vacuum Pump The geometry and the work of a twelve bladed pump impeller space is created utilizing Ansys Workbench. An unstructured work with tetrahedral cells is utilized for the zones of impeller and cavity of WRVP as appeared in Fig. An aggregate of 469681 components are created for the cavity of water ring vacuum pump. Work measurements are exhibited as following.

No. of Nodes	**104035**
No. of Elements	**469681**
Meshing Type	**3D**
Type of Element	**Tetrahedral**



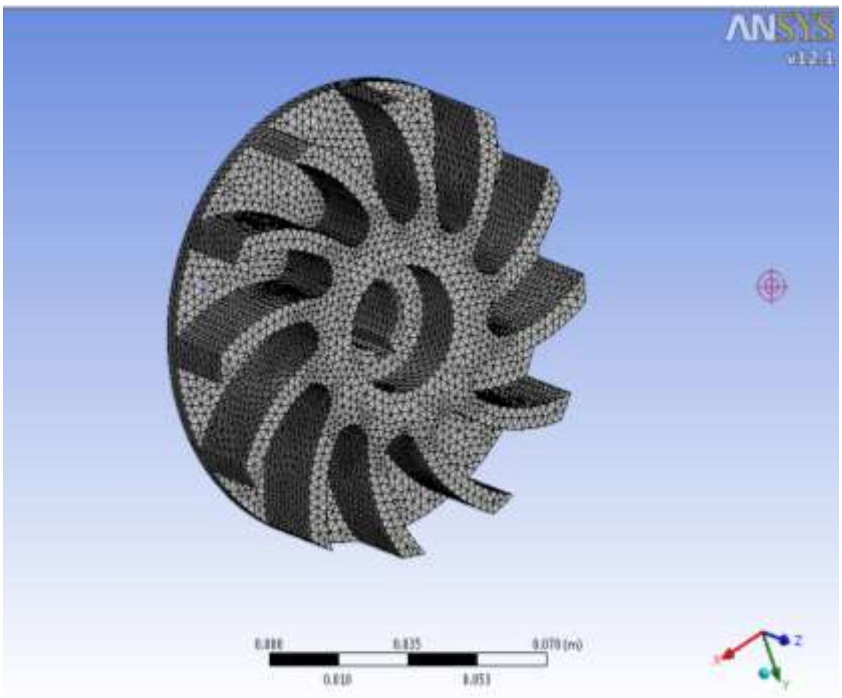


Figure 5. Meshed Model of Impeller

Now to define impeller domain it is solid domain and select its material as steel and impeller is rotating part of WRVP so domain motion is rotating and its angular velocity is 2880 RPM.

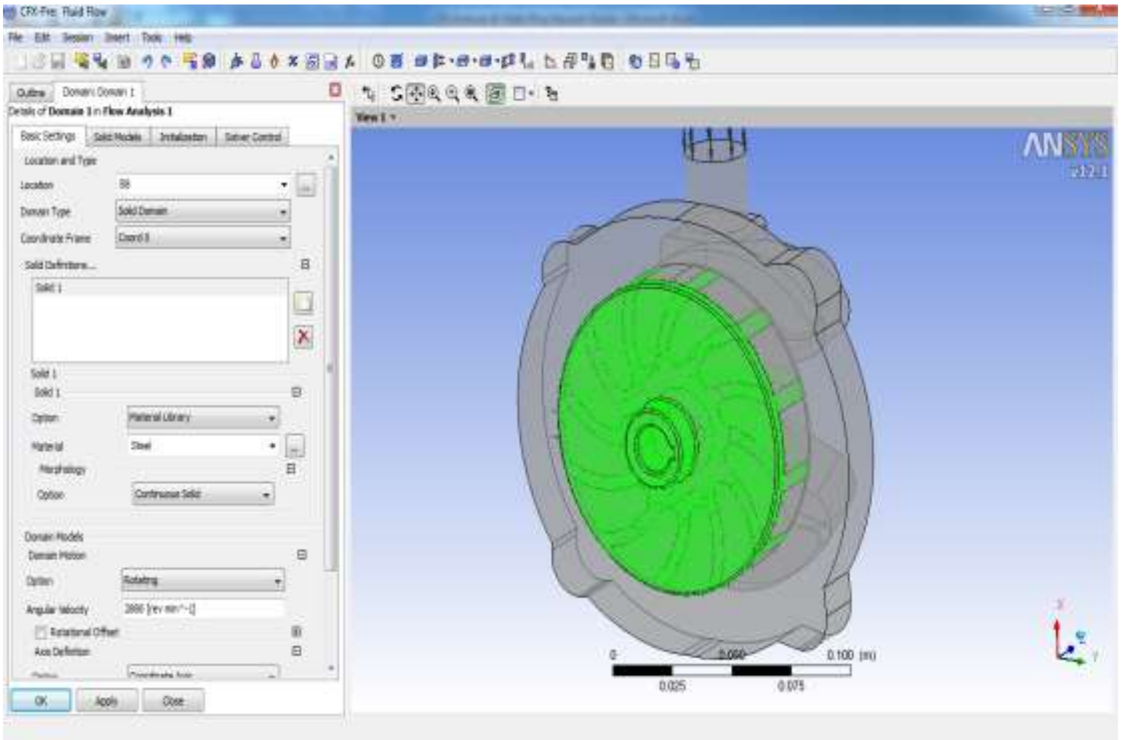


Figure 6. Window of impeller domain

To define heat transfer and Turbulence model is select as thermal energy as shown as figure below.

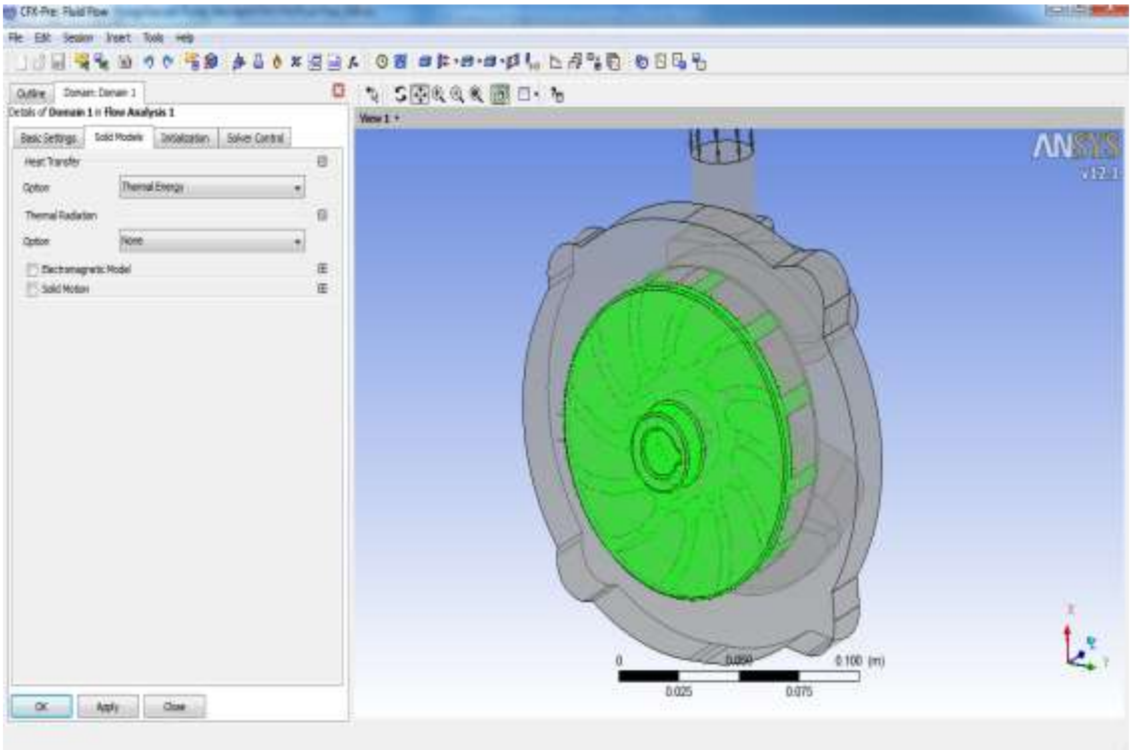


Figure 7. Heat transfer and Turbulence model

To define water ring , domain type is fluid and that fluid is water and its motion is taken as stationary for define it.

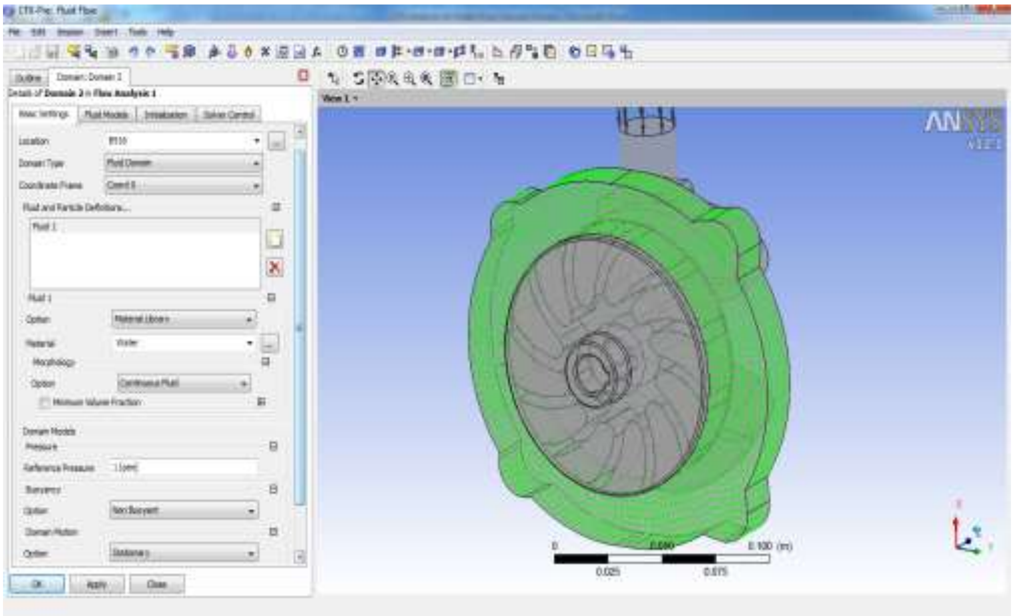


Figure 8. Window of water ring domain

Presently we select warmth exchange demonstrate as aggregate vitality and turbulence show as K-epsilon, Where k is the turbulence active vitality and is characterized as the difference of the vacillations in velocityand ε is the turbulence vortex scattering (the rate at which the speed changes dissipate).The k-ε display brings two new factors into the arrangement of conditions. The progression Equation is:

$$\frac{\partial \rho}{\partial t} + \nabla \bullet (\rho U) = 0$$

and the momentum equation becomes:

$$\frac{\partial \rho U}{\partial t} + \nabla \bullet (\rho U \otimes U) - \nabla \bullet (\mu eff \nabla U) = \nabla P' + \nabla \bullet (\mu eff \nabla U) T + B$$

V. RESULTS AND DISCUSSION OF ANALYSIS

In this CFD analysis we can see different pressure contours generated are as shown below figure and we can see result obtained using CFD analysis. Here by using CFD analysis of existing vacuum pump get result in terms of vacuum pressure which is shown in figure below that at inlet of WRVP get generated vacuum pressure is 6.134 e^4 Pa which means that460.087mm of hg in terms of vacuum.

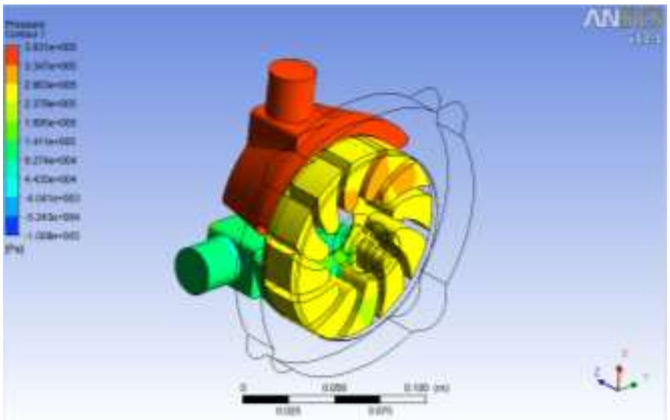


Figure 9. Pressure contour in WRVP

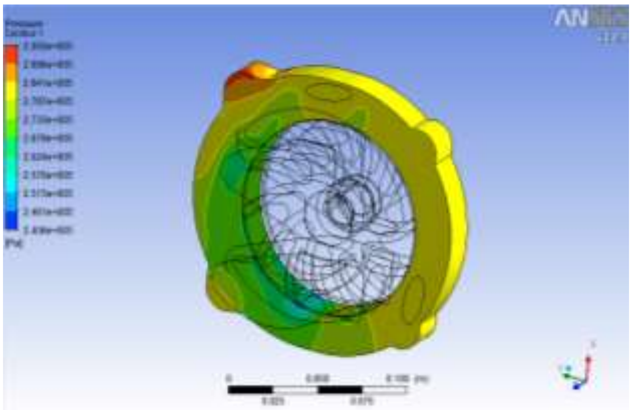


Figure 10. Pressure contour

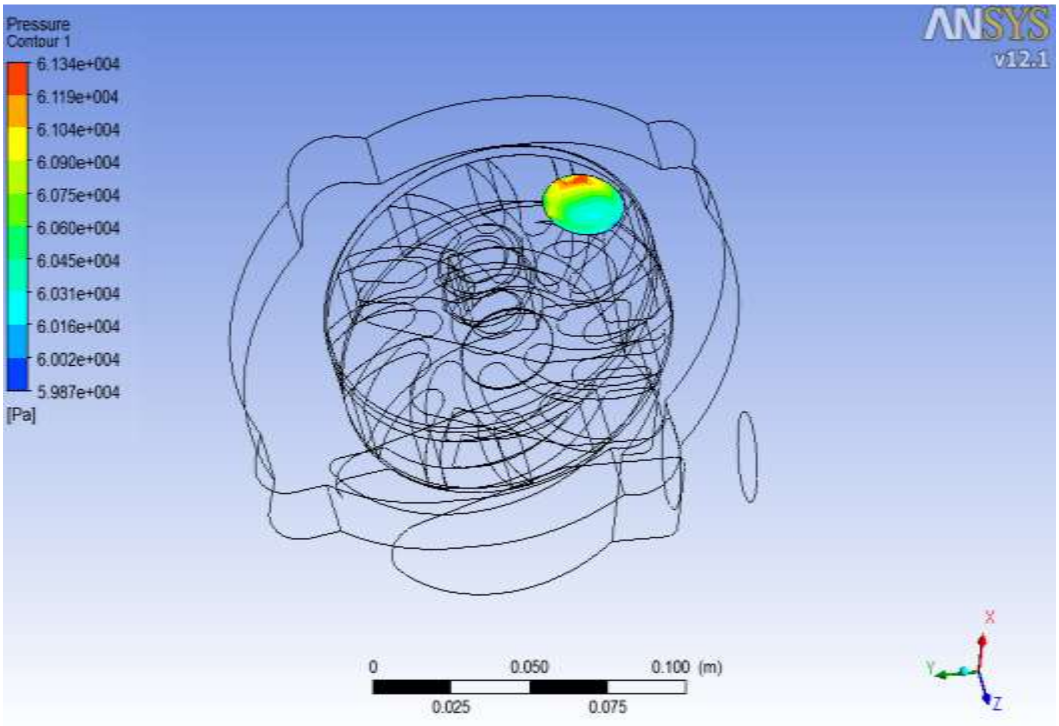


Figure 11. Generated Vacuum at Inlet

Table 1. Validation of Experimental Results with CFD Analysis Results

	Experimental Results	CFD Analysis Results	% Deviation
Original (Existing Case)	450 mm of Hg	460.087 mm of Hg	2.241 %

Trial is completed and same situation when investigated utilizing programming the result obtained is practically fulfilling. This demonstrates the exactness of CFD and Experimental methodologies. Here by test and CFD investigation result has 2.24 % deviation which is low and insignificant, which contrast appeared in above in table. So for the further investigation to enhance execution of the pump we can utilize CFD examination.

Conclusion A water ring vacuum pump which is used for purpose of creating vacuum. In WRVP all parts of that pump are very important for performance of pump and also affect directly to the performance of 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 here we see in the chapter 3 about pump parts model and how it works. In WRVP it is very difficult task to find out fault and improve design of pump by experimental and also very costly to improve performance. So introduced CFD analysis which very friendly software to finding fault and for improve design of vacuum pump. We have seen CFD analysis of existing vacuum pump in chapter 4,in that chapter for design improvement using CFD analysis, validation of CFD result of existing vacuum pump with experimental results take place.

WRVP in which impeller is most critical part so choose it for modification in its design and to get higher effect in performance. In chapter 5 we have seen that changes in inlet angle and outlet angle of impeller and also blade thickness based on empirical relation and also these three parameters are critical parameters of impeller and they are very important parameters to improve performance so these three parameters are modified in existing impeller which is shown in chapter 5 and all these modified impellers are used in existing pump model and took place CFD analysis of all those pumps. After CFD analysis of those all modified impeller pumps getting different results in terms of vacuum. In existing Vacuum pump generated vacuum is 460 mm of hg, in existing impeller model thickness of blade is 5 mm,15˚ inlet angle and 52˚ outlet angle. But when modification in outlet angle of impeller and angle is 49˚,in that model After CFD analysis generated vacuum pressure is 485.88 mm of hg vacuum. So result is improved in terms of vacuum using CFD analysis of water ring vacuum pump.

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