

# [The rotor dynamic type of pumps engineering essay](https://assignbuster.com/the-rotor-dynamic-type-of-pumps-engineering-essay/)

Centrifugal pumps also called as the rotor dynamic type of pumps. Its pass on to the refrigerant by a high velocity impeller into the static pressure for the pumps by a pressure rise takes place from the continuous conversion of angular momentum. Not same as reciprocating pumps, centrifugal pumps are steady-flow devices hence they are having to low vibration and noise. Figure 2 shows the working principle of a centrifugal compressor. [1]

As the figure shown below, stage 1 the low-pressure refrigerant show as number 1 enters the compressor from the intake of the impeller at number 2. Stage 2 the impeller has a set of number of blades and forms a flow way for refrigerant at number 3. At the intake, the refrigerant flow into the flow way which rotates in very high speed. At the stage 3, the refrigerant flows through the blade pipe towards the tip of the impeller and produces many momentum and static pressure. At stage 4, coolant flows into a diffuser from stage 3. In the diffuser as number 4, the coolant is moving very slow and as a result the dynamic pressure drop is converted into static pressure and also increases the static pressure.

The conversion of velocity into static pressure takes place due to the divergent shape of the volute at the beginning vapor from the diffuser enters the volute casing as number 5. Final stage, the coolants flow out from the compressor from the volute casing. The high speed impeller blades to the coolant to keep between the blade passages, it will gain momentum. The static pressure will be increased due to the self-compression come from the centrifugal action.[2]

Figure 2. 1: Working principle of Centrifugal Pump

## 2. 2 Types of pumps

## 2. 2. 1 Hermetically sealed pumps

This done by mean of the mechanical shaft seal. The disadvantage is its poor properties when it comes to use for aggressive liquids and leakage. Seal the problems will be solved by using double mechanical shaft and it also can solve by using hermetically sealed pumps as shown Figure 2. 2.[3]

This Hermetically sealed pump can operate with fluid temperature from -120 degree Celsius up to + 480 degree Celsius. The system pressures can increase up to 1200MPa and the power can be from 1kW up to 640kW. The advantages of this kind of pump is nominal pressure 40 bar, maintenance free, can be used for water and grease free and no nonferrous metals. The area of used is refrigeration plants for production, storage and transport of refrigerants, carbon dioxide supply, dry ice producing, firefighting equipment and cooling of parts of plants

http://delta-p-online. com/wp-content/uploads/2012/03/Bornemann1. jpg

Figure 2. 2: Hermetically sealed pumps

## 2. 2. 2 Canned motor pumps

It is a hermetically sealed pump with a motor and pump integrated in a unit without seal as shown in Figure 2. 3. By thin rotor can, the pump liquid flow into the rotor chamber to separate from the stator. In between the liquid and the motor, the rotor can is a barrier. The plastic or stainless steel can withstand aggressive liquid for the material of chemical pumps. [3] The Canned Pump is a centrifugal pump, close coupled to a Canned Motor in such a way that there is no dynamic shaft seal, no couplings and no ball bearings. The motor is cooled by the pumped liquid and the sleeve type Bearings are lubricated by the same liquid. This eliminates the need for external lubrication.

The advantages of the canned motor pump are designed to enable long periods of time between pre-planned maintenance intervals, these pumps have a minimum of components that need to be monitored and serviced. Costly alignment procedures or external lubrication are never required and because it was seal less all pump can eliminate needs dynamic seal adjustments and maintenance.

http://www. hstpumps. com/images/secochem-b. jpg

Figure 2. 3: Chemical pump with canned motor

## 2. 2. 3 Sanitary pumps and Waste water pump

Sanitary pumps are usually used in the beverage, pharmaceutical and bio-technological industries placed at very important that the pumps can be clean easily. Materials of construction were using the deep-drawn rolled stainless steel as shown as Figure 2. 4. The main features of the pump are ease of cleaning and maintenance. [3]

The advantages of sanitary pumps is can be handle large sized solids without damaging the product, large range of speeds, from below 100 up to 3, 600 rpm, make it possible to convey with one pump and also use it as a conveying aggregate, super low pulsation during product transfer, very low shear and capable of pumping products with large amounts of entrained air

The wastewater pump is surround unit with pump and motor. By the reason of the construction of the pump it is not necessary to enter the pit to carry out service. Therefore they are fitted with special impeller that makes it possible to avoid blockage and clogging. There are different of impellers exist as single-channel impellers, double-channel impellers and three and four-channel impellers and vortex impellers as shown in Figure 2. 5. [3]

http://bestprocessequipment. com/images/ampco/ac-pump. jpg

Figure 2. 4: Sanitary pump

Figure 2. 5: Impeller types for wastewater

## 2. 2. 4 Immersible pumps

This kind of pump will set on the top of the tanks or containers. Immersible pumps are used in the machine tool industry for example in spark machine tools, grinding machines, machining centers and cooling units or in other industrial applications involving tanks or containers. Figure 2. 6 shown as immersible pump. [3] The immersible pumps are very innovative development of the established submersible range pump. It capable to continuous operation in a dry installation and the immersibles can be operated with equal efficiency compare with fully or partially submerged pump.

Advantage of these kind of pump is very efficient, high in capacity, require very little maintenance and are generally very economical for wells that are 80 feet or more in depth.

http://www. weirpowerindustrial. com/images/wh\_immersible\_640x480. jpg

Figure 2. 6: Immersible Pump

There are two groups of pump for machine tools: Pumps for the clean side of the filter and pumps for the dirty side of the filter. Closed impellers pumps are usually used at the clean side because they can produce high efficiency and high pressure. Opened or semi-opened impeller pumps are used at dirty side because can use for metal chips and other small particles.

## 2. 3 Impeller

An impeller is a rotating iron or steel disc with blades in a centrifugal pump. Impellers transfer energy from the motor that drives the pump to the fluid being pumped by accelerating the fluid out from the center of rotation. The velocity gain by the impeller transfers into pressure when the output movement of the fluid is confined by the pump casing as the Figure 2. 7. Impellers are available as vortex or channel impellers.

http://www. lawrencepumps. com/images04/news\_FLS-Wear%20Rings-Fig-7. gif

Figure 2. 7: Flow of the fluid in Impeller

The impeller transfers energy from the motor that drives the pump to the fluid by increasing the speed of the fluid out from the center of rotation. Impellers are usually used short cylinders with an open inlet to get intake fluid, blades to push the fluid radially and a turned the bore to drive the drive-shaft. The impeller may be called rotor [4]

## 2. 4 Types of Impeller

## 2. 4. 1 Axial Flow Fan Turbine and Screw Centrifugal

Impellers have multiple fins at the pumped media in the direction along the revolve axis of the impeller. Axial flow impellers are used at high speeds to produce rapid dispersion and used at low speeds for keeping solids in suspension. Figure 2. 8 shows as axial flow fan turbine. [5]

http://www. machsources. com/productimages/24752/aluminum-axial-flow-impeller. jpg

Figure 2. 8: Axial Flow Fan Turbine

It is used for pumping liquid with solid objects and fibrous materials. The impeller has a single blade, extended at the inlet and developed around its axis much like a screw as shown in Figure 2. 9. Linking this to a centrifugal outlet allows pumping with the minimum of agitation and shear. [5] The features of the screw centrifugal impeller are energy saving of up to 50% compared with conventional centrifugal pumps and same high efficiency with immersible, submersible and end suction pumps. Non-clog impeller suitable for pumping high consistency media, easy to adjust of the impeller clearance and continuity of high efficiency performance and low maintenance costs.

http://www. weirpowerindustrial. com/images/hidrostal\_cutaway\_850x817. jpg

Figure 2. 9: Screw centrifugal

## 2. 4. 2 Vortex

An Impeller used within a pump used for pumping liquid. With a vortex pump, flow through the hydraulic unit is produced not by the actual impeller, but rather by a rotating vortex created by the impeller. Because the pumping action is created by the vortex, particles in the liquid do not come in contact with the impeller itself as shown in Figure 2. 10. [5]

This combination, of low flow and high head, is posing a particular problem to most pump manufactures. Until now there was no ideal pump type for this kind of demanding pumping situation. Some manufactures are offering high speed pumps (2 pole) equipped with channel impellers but with small ball passage (30-40mm) and a duty point that is located left of the curve. The channel impeller is fitted with wear rings or wear plates, (open channel impeller), so they can reduce the gap between the impeller and the volute. Eventually when the gap widens significantly the pump performance drops dramatically and the duty point is starting to move to the left of the curve.

The advantages of vortex impeller are high clog resistance, it flow under impeller and passes large solid and resistant to grit and sand damage that means no tight wear ring clearances. The efficiency of a pump with a vortex impeller is typically lower than a pump with a channel impeller.

http://www. commonwealth-engineers. com/media/20982/slideimage7. jpg

Figure 2. 10: Vortex

## 2. 4. 3 Low speed sweep impeller

Sweep impellers usually have three blades but occasionally on laboratory models two blades are used as shown in Figure 2. 11. The impellers come in a great variety of configurations and sixes. Each basic design has certain advantages. Open impellers for example provide added shearing actions especially if double risers are used. Here there is more surface shear as the material is forced through the open prongs. The open impellers can run faster. These blades pump more efficiently as they are configured for uniform product flow at all points of the circumference. [5]

Advantages for the low speed sweep impeller are faster pigment loading that means less splashing, less heat buildup the high speed dispersion blade can be engaged for a shorter period than with a single shaft machine and less air entrapment. For large slow speed sweep impeller with its pumping action, tends to reduce the deep vortex of the high speed dispersion blade so less air will sucked in.

Figure 2. 11: Sweep impeller

## 2. 5 Performance calculation

Calculating the centrifugal pump theoretical pressure head with broad flow areas, uses the method of Stodola-Meisel, taking into account the finite number of the impeller blades:

HT = (2. 1)

Where – the tangential component of absolute velocity at the outlet of the impeller which can be obtained by:

(2. 2)

– Circumferential velocity at the exit; – constraint factor of fluid flow at the exit of the impeller; z – number of blades; – radial component of absolute velocity.

(2. 3)

The value of the coefficient taking into account only the geometrical dimensions of the blades at the exit :

(2. 4)

Where – blade thickness along the diameter at the outlet of the impeller.

In case of a constant thickness of the blade :

(2. 5)

Where – the blade angle at outlet. Based on theoretical considerations and experimental researches, it is recommended to determine the flow constriction at the outlet of the impeller with consideration of the forming separation zones in the inner surface of the blades.

(2. 6)

In addition, when determining the parameter, taking into account a finite number of blades of the impeller, a correction to the angle, is made at the outlet blade stream. The amendment part of formula (2. 1) has the form (2. 7):

(2. 7)

(2. 8)

Based on (proceeding of) experimental studies and analysis, the theoretical pressure head of the model pump with different impellers is calculates as:

(2. 9)

Where – pump hydraulic efficiency:

Pump hydraulic efficiency is calculated as follows:

(2. 10)

Pump mechanical efficiency:

(2. 11)

Where – pump efficiency; – volumetric efficiency; – mechanical power loss of the pump.

## 2. 6 Effect by number of the impeller blades

The performance characteristics and cavitations characteristics of a pump are influenced by the blade number, which is one of the most important design considerations of pumps. If blade number is too more, the come out effect at the impeller is serious and the velocity of flow will be increases and also the increase of interface between fluid streams and if blade number is too few, the diffuser loss will increase with the extent of diffuse extent of flow passage. [6]

According to the research from Center of Fluid Machinery Engineering and Technology, the increasing of the blade number, the limitation between blade and flow gets more obvious, the phenomenon of “ jet and wake” in impeller did become unobvious which is prominent in the flow channel against tongue of volute. As the conclusion for the increased of blade number was to reduce the mixture loss of “ jet “ and “ wake” in centrifugal pump and it also increased the power of output. [7] The clog phenomenon became in flow passage of impeller with the more blade number. With the increased of blade number, the area of low pressure region at the suction of blade inlet will be increasing and at diffusion section become better and better. [8]

The blade number of impeller is an important design of pumps, which most affects the characteristics of pump. At present, the investigation focused mostly on the performance characteristics of axis flow pumps, the influenced of blade number on inner flow field. [7] With the increase of blade number, the head of the model pumps increases too, the variable regulation of efficiency and cavitation characteristics are complicated, but there are optimum values of blade number for each one. The research results are helpful for hydraulic design of centrifugal pump. [8] For example of the impeller blades shows as Figure 2. 12. On the other hand, if the blade of impeller is too many, the crowding out effect phenomenon at the impeller is serious. The area of the impeller will be increase cause the fluid hard to flow through the gap but the velocity of flow increases. Besides that it also increases of interface between fluid stream and blade will cause the increasing of hydraulic loss in the fluid flow and will affect the performance of the centrifugal pump. [22]

http://www. flaktwoods. com/be5f5868-1d4e-4931-8a07-a64315bc4709

(a) 2 blades (b) 3 blades (c) 4 blades (d) 6 blades

Figure 2. 12: Different number of impeller blades

## 2. 7 Effect by angle of the impeller blades

There are a reviewed journal by Fard and Boyaghchi entitled “ Studies on the Influence of the Various Blade Outlet Angles in a Centrifugal Pump when Handling Viscous Fluids”, [12] in year 2012 as shown in Figure 2. 13. The focus of this researched is to study the performance and flow field of centrifugal pump with different blade outlets angles using water and viscous fluids to show the comparison between experimental and numerical results. It was used to test the pump performance and to measure the flow within the pump impeller when the pump was pumping water and viscous oil. [12]

https://www. sharcnet. ca/Software/Fluent13/help/ice\_ug/graphics/g\_ice\_ug\_fig\_blower\_swirl. png

Figure 2. 13: angle of the blade

The effects of impeller’s blade angle on the efficiency of a centrifugal pump had analysis when the centrifugal pump pumps the water in the process. The hydraulic losses in the pump test by using a designed model of impeller on the fluid mechanics base. The result shows that the blade discharge angle has a high influence on the efficiency of the centrifugal pump. The hydraulic and mechanical efficiencies are responsible for the pump performance with increasing of the angle of the impeller fan blades. [23]

## 2. 8 Effect by thickness of the impeller blades

## 2. 9 SolidWorks

## 2. 9. 1 Introduction

SolidWorks is a solid based model design and use all the parametric feature-based approach to create parts of the model and assembly’s model shown as Figure 2. 14. Parameters refer to constraints whose values determine the shape, dimension of the model and assembly. Design Intent is how the designer of the part wants it to changes and updates. [13]

http://www. cfturbo. de/fileadmin/content/pic/cft/imp/solidworks. jpg

Figure 2. 14: SolidWorks impeller design

The Shape based features typically begin with 2D or 3D sketch such as bosses, holes, slots and many more. [14] This shape can be extruded, cut-extruded, add or remove material from the part. The Operation based features are not sketch-based and include features such fillets, chamfers, shells, applying draft to the faces of the part. [15]

User build model usually starts to sketch with a 2D part sketch in SolidWorks software. The sketch consists with geometry dimension such as points, lines, arcs and other features. The size and location of the geometry with sketch dimension feature with dimensions are added to the sketch to be defined. Relations function can be used to define the design model with tangency, parallelism, perpendicularity and concentricity usually the user will click the shift button on the keyboard because it can save user’s time in modeling. The dimensions of the design model can be controlled independently or relationships to other parameters whole part of the sketch. [16]

SolidWorks pioneered the ability of the user to roll back through the history of the part in order to make changes, add additional features or change to sequence in which operations are performed. Feature-based solid modeling software also has same functionality.

In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism and concentricity with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts allowing the easy constructions of assemblies. SolidWorks also includes additional advanced mating features such as gear mate, cam follower mates, belt/chain mate and rack pinion which allow user’s modeled assemblies to accurately reproduce the rotational movement of an actual gear train. Views are automatically generated from the solid model, notes and dimensions can be easily added to the drawing when user needed. [16]

## 2. 9. 2 Advantages of SolidWorks

The benefit of this software was included with excellent computer aided design’s tools that can automates design the detailing work in modeling and help user to solve the problem related to mechanical relationships. It also help user ti generates parametric of the 3D models from design sketches that can allow the user to used for presentations, sales proposals or material analysis before it start to developed any component of the design. With all this benefit it can helps in saving time and cost compared with making a prototyping.

## 2. 10 Computational Fluid Dynamics

## 2. 10. 1 Introduction

The Computational Fluid Dynamics (CFD) Module is the premier tool in the fluid flow simulations. Compressible as well as incompressible flows can be combined with advanced turbulence models and forced and natural convection. The characteristic of the Computational Fluid Dynamics Module is its capability of precise multiphysics-flow simulations for example conjugates heat transfer with non-isothermal flow, fluid-structure interactions and non-Newtonian flow with viscous heating and fluids with concentration-dependent viscosity. Figure 2. 15 was an example of CFD.

http://www. comsol. com/shared/images/products/cfd/intro. jpg

Figure 2. 15: Turbine test in Computational Fluid Dynamics software

The CFD Module’s interfaces for two-phase flow include a mixture model for fine particle suspensions and a bubbly flow model for macroscopic gas bubble flow. For interface tracking two-phase flow, formulations are provided using the level-set and phase-field methods. The tools available in the CFD Module for advanced transport and reacting flow simulations are automatically extended when combined with the Chemical Reaction Engineering Module. For fluid-structure interactions, the Structural Mechanics Module interacts with the CFD Module’s flow models and makes available elastic solid-fluid couplings as well as lubricating flow. [18]

Computational Fluid Dynamics (CFD) was a design tool that has been developed over the past few decades and will be continually developed as the understanding of the physical. The objectives of CFD are to be able to predict ¬‚ uid ¬‚ ow in accuracy, heat transfer and chemical reactions in complex systems. As a design tool, CFD presently sits behind experimental analysis due to the fact that CFD does not produce absolute results. The reason for this is that the numerical methods, which govern the solutions in a CFD problem, depends on several modeling assumptions that may not have been validated to a satisfactory level.

## 2. 10. 2 Advantages of Computational Fluid Dynamics

CFD was a very useful and very powerful software because it can simulated dangerous or expensive trial and error experiments, computers are becoming even more powerful and less expensive, thus allowing larger CFD simulations to be calculated in more detailed and accurately simulations of present CFD problems. If a CFD model can be established accurate results on one particular design, then the model can be used as a tool of prediction for that design under many different operating conditions and It can be also used for analysis heat transfer, fluid flows and air flows.