



REVIEW

CENTRIFUGAL PUMP DESIGN MATERIALS AND SPECIFICATIONS

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ABSTRACT

Pumps are the machines that convert the mechanical energy they receive from the power supply into hydraulic energy. Pumps allow the fluid to reach the pump impeller by bringing the low pressure field to the suction line. The impeller directs the fluid to the outlet pipe and transmits it to the desired point. All pumps are divided into two main groups. These are displacement (positive displacement) and dynamic (non-positive displacement) type. The energy given to the flow in positive displacement pumps is periodically. In dynamic pumps, the energy supplied to increase the velocity of the fluid is continuous. Centrifugal pumps are dynamic pumps and are the most widely used pump type in agricultural irrigation. The heart of the centrifugal pump is the impeller. Centrifugal pumps consist of basic elements such as casing, impeller, diffuser, shaft, seals, stuffing box, suction and discharge ports, bearings, and couplings. Performance and lifetime are important for a successful pump. Performance relates to head, capacity and efficiency. The life span is the total running time of the pump. Pump construction material affects the performance, lifetime, operating regime and cost of the pump. In this study, the selection of materials used in making the centrifugal pump components and the factors affecting the material selection will be examined. As a result; factors such as the type of liquid to be conveyed, the substances contained in the liquid, the pumping temperature, the protection against corrosion, the amount of wear, the place of use of the pump, working pressure, working conditions, frequency of failure, operation and maintenance costs and life expectancy of the pump should be considered.

Keywords: Santrifugal pump, Materials, Material choice

1.INTRODUCTION

Pumps are machines that convert the mechanical energy they receive from the power source into hydraulic energy. By creating low pressure in the suction line, it enables the fluid to reach the pump impeller and transmits the fluid to the desired point by pressing the outlet pipe. Pumps are generally divided into positive (volumetric-volumetric-displacement) pumps and non-positive (centrifugal, dynamic) pumps according to their manufacturing methods and operating principles (Figure 1).

The volumetric displacement pumps transmits the fluid through discrete. The fluid is pushed periodically. Their efficiencies are high. Dynamic or centrifugal pumps provide continuous energy to the fluid. Fluid movement is not discrete. It is continuous. That is, while the fluid is absorbed on one side, it is pumped on the other hand. Centrifugal pumps take up less space, are light and cheap. Speeds are higher. Their efficiencies are low. Flow rate adjustment is easier. Centrifugal pumps are the most commonly used type of pumps in agricultural irrigation [1].

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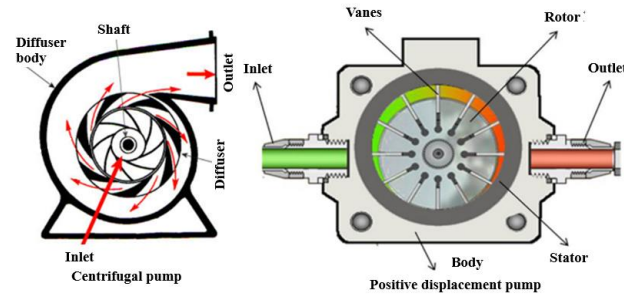


Figure 1. Non-positive displacement dynamic centrifugal pump (b) Non-positive vane pump [2] [3]

Centrifugal pump parts are examined in two sections as fixed and moving parts. Moving parts consist of pump shafts, impeller, sealing rings connected to impeller. The fixed parts consist of suction and discharge nozzles, housing, bearings, coupling, sealing elements, stuffing box and roof (chassis) (Figure 2). The centrifugal impeller is the active part of the pump and is the moving part of the pump with the shaft. The impeller transforms the mechanical energy that receives from the engine into the hydraulic energy and has a different number of curved blades on it. The volut body collects the liquid from the impeller and transmits it to the discharge pipe.

The diffuser is between the impeller and the casing. It is a spreader consisting of vanes that make the kinetic energy of the water coming out of the impeller more efficient to the pressure energy. The sealing ring or rings are located between the rotating impeller and the casing and prevent liquid from flowing from the discharge line into the suction line. Stuffing box prevents leakage between the shaft and the casing by preventing leakage of air and liquid. The movement from the motor is transmitted to the pump impeller via the shaft.

2. PUMP CONSTRUCTION MATERIALS AND FEATURES

The classification of materials can be done in different ways, but the most appropriate classification for the engineers is the classification of materials as metals, ceramics, polymers, composites and semiconductors.

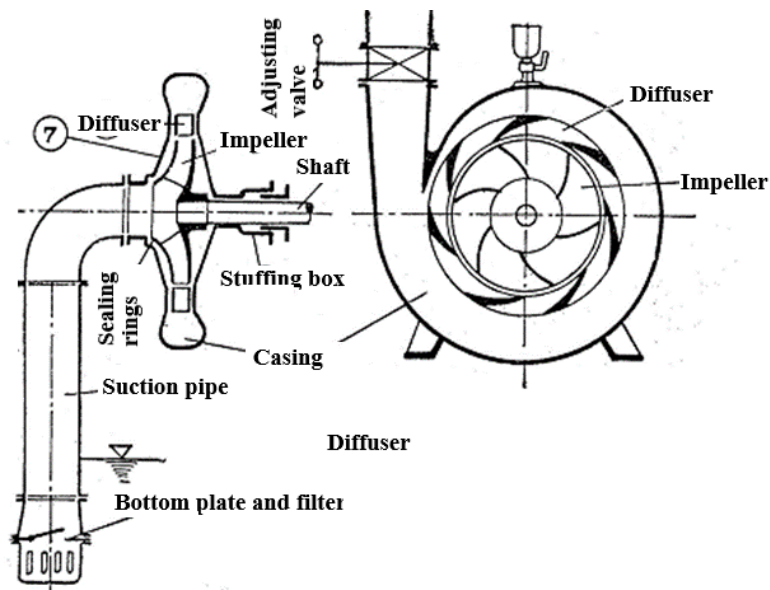


Figure 2. The parts of centrifugal pump[1]

Metals: An important part of the materials used in engineering are metals and their alloys. Generally, iron-based metals and alloys (cast iron and steels) and non-ferrous metals and alloys (aluminum, magnesium, copper, titanium, nickel, zinc and alloys) are handled under two groups. Pure metals such as aluminum, copper, zinc, iron and nickel, and other metals such as steel (Fe-C), brass (Cu-Zn) and bronze (Cu-Sn) are the most commonly used materials in the manufacturing industry.

Ceramics: Ceramic is the inorganic compound formed by the incorporation of one or more metals into a non-metal element. It is usually caused by the cracking of the rocks under external influences by cooking clay, kaolin and similar substances at high temperatures. Materials such as glass, brick, concrete, porcelain are examples of ceramics. They have high strength, brittle materials and low fracture toughness.

Polymers: Basically, carbon is a large molecular organic compound formed by non-metallic elements such as hydrogen, oxygen and nitrogen.

Composites: Materials that combine two or more materials from metals, ceramics and polymers to bring together the superior properties of these materials in the same material or create a whole new feature.

Semiconductors: It is neither a good conductor nor a complete insulator. They are very important materials used in electronics. Silicon and germanium are the most widely used semiconductors.

In general, the requirements to be considered in the selection of materials can be listed as follows.

- a) Physical properties (size, shape, density)
- b) Mechanical properties (density, yield and tensile strength, ductility, hardness, fatigue strength, friction strength, torsion, fracture toughness, brittleness)
- c) Chemical and electrochemical properties (chemical composition, solubility, oxidation, corrosion.)
- d) Electrical and magnetic properties (self-conductivity, electrical conductivity, magnetism.)
- e) Thermal properties (heat conduction coefficient, melting temperature, specific heat, heat capacity.)
- f) Optical properties (reflecting and passing light, color, light swallowing, refractive index.)
- g) Acoustic features (sound, voice, sound, reflection)
- h) Technological properties (fabricability, welding, casting, processability, compatibility)
- i) Economic features (price, reliability, availability, cost.)
- j) Estetic properties (appearance, touch, feel.)
- k) Cost

The parameters affecting the selection of materials to be used in the manufacture of centrifugal pumps; manufacturing method, operating conditions, material conformity according to the structure property, strength, corrosion, electrochemical activity, wear, cavitation, pumping temperature, load per stage, working pressure, load factor and expected life, operation and maintenance cost can be listed as [4].

Considering the long pump life, the most important parameters are operation and maintenance costs. It is expected that the pump will provide continuity on the system it operates and will not cause unexpected stoppages. It is important to select material combinations that reduce the frequency of faults and maintenance costs. The parts show different behavior depending on the type of material under load. The effects of the loads on the parts and the effects of these loads on the material must be determined correctly in the selection of materials.

It is also necessary to know the erosion and corrosion properties of the selected material at the flow rates of the pump. In highly corrosive working environments, it is to be expected that the parts in contact with the fluid during the life of the pump will need to be replaced and replaced. The size, shape and hardness of the particles present in the liquid are the determinants of the determination of both the material and the structural properties of the parts such as the impeller and body. The presence of different substances in the liquid, even in trace amounts, significantly changes the corrosive effect of the solution. For example, liquids containing trace amounts of chlorine and salt compounds increase the corrosive effect on the metal, the presence of such materials as chromate and dichromate in the liquid reduces the corrosive effect. The choice of the right materials in the pump manufacturing will reduce both the energy consumption and the harmful effects on the environment due to wastes.

2.1. MATERIAL SELECTION FOR TYPES OF WEAR IN PUMPS

Due to the substances contained in the irrigation water used in agriculture (such as silty substances, sand, organic substances), various physical damages or abrasions occur in the parts of the water contact of the centrifugal pumps used for irrigation. The types of wear on the pumps can be classified as wear, corrosion and cavitation.

Wear: Abrasion is the loss of undesired material formed by friction effect on the surfaces of friction objects that touch each other and move relative to each other [5]. The wear rate depends on the materials of the rotating and stationary parts of the pump. Although the hardness of the material is not a single measure for mechanical wear resistance, it is a very suitable indicator in the selection of ductile materials used in centrifugal pumps. It is important to note that the brittle materials, for example cast iron, have a much lower mechanical wear resistance than steel or bronze material of the same hardness. The mechanical wear rate of the ductile materials is proportional to the square of the solid component velocity. In brittle materials, there are indications that this ratio can be as high as the sixth force of the part velocity.

Although the pump impellers are composed of many different materials in terms of construction material, aluminum material is used in the application. Aluminum is a cubic surface centered crystal lattice with a density of $2,7 \text{ kg / dm}^3$, melting degree of $660 \text{ }^\circ\text{C}$. The elements of manganese, magnesium, silicon, copper and zinc are added into aluminum. In this way, the yield limit of aluminum is reduced without decreasing the easy formability.

The strength of the alloying is significantly increased [6]. In addition, anodizing (anodic oxidation), which is an electrochemical process to aluminum, can be improved by applying the surface coating method [7]. Yüksel and Eker [8] run a monobloc centrifugal pump (with an aluminum wheel) running an average of 7-8 days a day and a total of 180 hours a day during an irrigation season. Water containing sand was used. At the end of the study, abrasion and corrosion traces were detected in the aluminum impellers of the water pumps but no major damage was observed. They concluded that the pump could adversely affect the operation of the pump.

Corrosion: Metals lose their metallic properties by chemical or electrochemical reaction in liquid or gas environment. This is called corrosion. Bronze, brass, stainless steel, zinc and aluminum without protection is expected to last for a long time under the conditions of very slow corrosion. The structural corrosion of iron and steel advances rapidly if the metal is not properly protected. Corrosion is a significant increase in the load and heat on the metals are the factors [9]. Coating the surfaces of metals with materials such as boron or chromite significantly reduces the wear of these substances [10] [11].

Appropriate material selection is one of the methods of preventing or reducing corrosion. The most important materials used for this purpose are stainless steels. High corrosion resistance of stainless steels is due to the thin oxide film on the surface. When this layer is broken, it spontaneously re-forms in air or oxygen. Corrosion can be examined under 4 headings. These are intergranular corrosion, erosion corrosion, fatigue and galvanic corrosion.

Intergranular corrosion is the corrosion of the internal structure of the material. The most typical example of intergranular corrosion is found in stainless steels. Erosion corrosion occurs under slip and friction stresses between metal and liquid. It is known as erosion corrosion which is in contact with the metal surface and acts as a relative corrosive fluid. Erosion corrosion is one of the most fundamental problems of centrifugal pumps. Centrifugal pumps are particularly sensitive to impeller erosion corrosion. The pump body is also subject to erosion corrosion, but less than the wheel. The diffuser casings with a large number of blades are subjected to much more erosion corrosion than the volute

casins with only one wings. Wear rings are also subject to erosion corrosion. If proper material is not selected, excessive wear may occur due to the effect of high speed flow in narrow gaps [12].

Fatigue can occur in all materials prone to simple corrosion under periodic loading. Corrosion fatigue is seen in the grain size (trans-granules) of the material. When selecting material of the pump parts exposed to variable loads, the full variable stress limit of the material must be taken into account. The full variable stress limit is the maximum total variable stress value upon which the material rests without distortion even though it is subjected to an infinite number of unstable stresses. The full variable stress limit of the steel is about 50% of the tensile stress. With tensile stress of 400 MPa, the steel is relieved in a very short period of time under the variable load which causes the same tension in the static state. If the stress value is reduced to 200 MPa, the material will not deteriorate as the full variable stress limit is not exceeded. However, if the same steel is exposed to full tensile stress of 200 MPa in a corrosive environment, it will deteriorate in a short time. The pump shaft is subjected to full load at every turn and will have a certain life span depending on the fatigue corrosion resistance and rotational speed of the material. The best way to prevent the reduction of shaft life is to prevent the shaft from contacting with the liquid using the shaft bushings.

Galvanic corrosion includes cast iron, iron and graphite. Graphite is in the form of lamellae and gives a characteristic gray appearance of cast iron. The presence of graphite provides a lubricating effect during processing. In addition to this feature, easy breakage of sawdust allows easy machining of cast iron. These properties and very low casting costs are the most commonly used material in the production of cast iron pumps. If the tensile stress and elasticity, which are low compared to steel, are left aside, the corrosion resistance properties of the cast iron should be carefully examined. The presence of graphite in the structure of the cast iron causes corrosion known as graphite corrosion. The effect of graphite corrosion on the cast casting impellers of the pumps working in sea water has been very significant. The same impellers do not have non-electrolytic fluids such as clean water, and graphite corrosion when pressed. Experiments have shown that cast iron impellers should never be used to light salt water or sea water. Otherwise, the result is definitive degradation by graphite corrosion.

Cavitation: In centrifugal pumps, rapid evaporation occurs because the pressure in the suction line is equal to or lower than the vapor pressure depending on the temperature of the water. Water bubbles occur at low pressure and these bubbles burst into the high-pressure zone when they reach the wheel, and they concentrate in a very short time. Pressure increases to 300 atm. It's called cavitation. Sound and noise are generated in the pump. The efficiency is reduced, the pump looks like it is pressing sand particles. The high pressure caused by the explosion of steam bubbles causes wear in the pump parts, especially the suction mouth and the impeller. Blows on hammer impulses are formed on the impeller blades and cavities are opened on the wheel surface.

In order to prevent cavitation in terms of pump material, the types of materials used in the pump impellers must also be considered. The materials with the highest cavitation resistance are aluminum bronze, monel metal, hardened martensitic steel and titanium alloy steel. In addition, cavitation-resistant materials used in pump construction can be used as cast iron, bronze, steel casting, manganese bronze, martensitic steels (400 series steels), austenitic steels (300 series steels) and nickel-aluminum bronze, respectively, utilizing laboratory data and practical experience [12].

2.2. MATERIAL SELECTION IN METAL PUMPS

The cast iron used in the pumps can be grouped into three groups as gray cast iron, spheroidal cast iron and white cast iron according to the distribution of carbon in the composition. The tensile strength of gray cast iron is low and brittle. Its compressive strength, ductility and vibration damping ability are good, wear resistant, casting ability is very suitable. Hardenability and good workability are also available. Spheroidal graphite cast iron is also known as ductile iron casting on the market.

The strengths, rupture elongations and toughness of the spherical graphite cast irons are higher than the coverslip graphite cast irons. Strength and ductility are higher than gray cast iron. The cast surface of white cast iron appears white. It contains a high proportion of cementite instead of carbon graphite. Therefore it has high hardness and brittleness. It is used due to its excellent wear and tear resistance properties. It cannot be machined but processed as grinding. Temper is used in the production of cast iron. Temper cast iron can be divided into black and white temper cast iron.

When selecting the body material in centrifugal pumps, criteria such as corrosion resistance, strength, abrasion resistance, casting and processing properties and cost should be taken into consideration. High pressure resistant cast iron (GG 18-22-25), ductile cast iron (GGG 40-50) and steel casting (Ni-Cr) can be used as the body material. In addition, cast iron and spheroid cast iron are used in the manufacture of parts such as diffuser stage, end stage diffuser, impeller end stage, roller bearing and bearing cover. The cast iron used generally contains more than 2% carbon and is obtained using scrap iron. It is resistant to high pressure.

Cast iron bodies are rarely used in pump design above 68-75 atm pressure and 177 °C. Pumps with steel bodies are preferred at high temperatures and pressures. Steel is an iron-carbon alloy that is hot and cold formed and has less than 2% carbon content. Pumps made of steel are used for the transmission of highly corrosive liquids with corrosion effects. The molten steel is called cast steel if it is formed by casting. The cast steel material is used in cases where the discharge pressure or pumping temperature or both are important together and the use of cast iron material is not suitable. There are also pumps made of stainless steel body (AISI 304). It is used in the production of stainless steel (AISI 304 diffuser and diffuser dish).

The selection of the construction materials of the pump impellers must take into account criteria such as wear, cavitation and corrosion resistance, casting and processing properties and cost. The size, shape and hardness of the particles present in the liquid are effective in determining the construction properties of both the material and the parts. The presence of different substances in the liquid, even in trace amounts, significantly changes the corrosive effect of the solution. The trace amounts of chlorine and salt compounds increase the corrosive effect of liquids. Cast iron (GG 22-25), bronze casting (G-CuSn10), stainless steel (AISI 304-316), steel casting, aluminum, bronze, brass, molded rubber, glass fiber are used as impeller material.

The sensitivity of austenitic stainless steel (containing Cr and Ni) to intergranular corrosion can be reduced by controlling the amount of carbon in the alloy. Standard austenitic stainless steel (AISI304, AISI316, etc.) has more than 0.08% carbon. Due to improper heat treatment, this steel is prone to intergranular corrosion. In the 300 series, there are very low carbon steels indicated by the L symbol and contain less than 0.03% carbon. These steels are much less sensitive to intergranular corrosion. Considering the austenitic stainless casting for the impeller and body in the pumps, the possibility of intergranular corrosion should be considered. In medium-sized castings, low-carbon steel is sufficient only if the correct heat treatment is applied. It is not necessary to use 0.03% carbon steels which are much more expensive. However, it is necessary to think about 0.03% carbon steels in larger castings. This is especially true in open and semi-open impellers used in mixed-flow and axial pumps.

In general, all alloys of copper except brass are called bronze. As the tin content in the alloy increases, the corrosion resistance increases. Bronze material is not suitable for temperatures exceeding 120 °C. The loss of material surface in a bronze pump is only half the loss of the casting pump. Bronze often leaves heavy gray metals into the pumped liquid, so it can only be used in special applications. In case of using stainless steel instead of cast iron as impeller material, zinc anodes will be consumed faster and require more frequent replacement due to the corrosive environment. Corrosion protection or abrasion resistance in terms of any specific need for waste water applications suitable for the most widely used impeller material is gray cast iron. Bronze casting is frequently used in pumps with low corrosion effects such as sea water.

Durability, corrosion resistance and notch precision should be taken into account when selecting material for pump shafts. Pump shafts are generally made of steel, stainless steel (300-400) or corrosion resistant material. Sleeves are made of high carbon steel, stainless steel or brass. Stainless steel is expensive but long-lasting, brass is cheap but short-lived. High carbon steel has a life between brass and stainless steel [1]. Stainless steel (AISI-304-316-410-420) is used in the production of parts such as spindle, intermediate bushing, impeller, bush, bushing, seal bush, coupling, coupling, wedges and studs used in centrifugal pumps.

Stainless steels can be used at low or high temperatures and pressures, as well as easy forming and high corrosion resistance. These steels are more expensive than other steels, but they are easy to maintain and long-lasting. As it increases the risk of galvanic corrosion, it is not recommended for wastewater applications. The bearings used in centrifugal pumps are made of high-carbon stainless steel and cast iron (GG25). Rubber, bronze, cast iron and plastic materials are used to strengthen the bearings.

The wear rings are placed between the body and the impeller in the centrifugal pumps and provide sealing. Factors such as wear resistance, corrosion resistance, casting and processing properties should be considered when selecting materials for wear rings. Wear rings are made of bronze and 300-400 stainless steel. The seal provides sealing between the shaft and the body and prevents water leaks. Stuffing elements can be made of synthetic material, cotton, linen, teflon, carbon graphite. Materials are used by knitting. Linen and cotton are used for the delivery of cold liquids. In practice, more Teflon (PTFE) and bronze casting (RG-5) are used as seal material. Teflon seals are recyclable without any chemical treatment. Therefore, they eliminate the risk of hazardous waste. Bronze casting gaskets ensure long-term use, corrosion resistance is good and easy to handle.

The studs, bolts and nuts used in the pump manufacturing are made of steel (ST 42-50). ST 42 steel is a material that does not harm the environment due to its high recyclability. Brass alloys used in centrifugal pumps are used in the manufacture of hoodstones and greases. Brass materials have very good machinability, forging, high strength and recyclable properties.

O-ring used in the body cover is made of rubber and silicone. The silicone material has high strength, flexibility, high recyclability and its ability to maintain its elasticity between -60°C and 200°C . Rubber has high flexibility, high strength, low deformation, easy processing, good tear and abrasion resistance.

2.3. MATERIAL SELECTION IN NON-METALLIC (PLASTIC) PUMPS

Plastics are chemically incorporated into the group of polymers. The general characteristics of plastic materials are their low resistance to amorphous structure and heat. Plastics (polymer) materials have been widely used because of their low production costs, lightness, high resistance to corrosion, ease of forming and suitable production. Polymers are materials whose heat and electrical conductivity are low but adversely affected by high temperatures. Polymer materials have become an important engineering material recently due to their lightness and easy processing [13]. Polymer materials are divided into three groups: thermoplastics, thermosets and elastomers.

Thermoplastics: They are linear polymers. Thermoplastics are generally ductile, they change plastic shapes before they break. Its mechanical properties are significantly dependent on the loading speed, loading time and temperature. They continuously change their shape under constant stress at room temperature. Thermoplastics are soft and plasticized when heated. Once cooled, they can return to their initial hardness. Most commonly used thermoplastics: polymethyl methacrylate (PMMA), acrylonitrile-butadiene-styrene (ABS), polyethylene (PE), polyphenylene (PPO), polycarbonate (PC), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) is polytetrafluoroethylene (Teflon) and nylon.

Polyvinyl chloride (PVC) and polypropylene (PP) are used as pump construction materials rather than thermoplastics.

Thermoset plastics: Thermosets are more hard and durable polymers that cure with temperature. Thermoset plastics are superior to thermoplastics in terms of their strength, rigidity, usage temperature limits and resistance to external influences, but they are not used again. The damage caused by the temperature is permanent. Thermosets are brittle, plastic is broken without deformation. When the temperature increases, their strength decreases, but they do not soften. They decompose at extreme temperature and roast. Thermoset plastics; phenoplasts, aminoplasts, polyesters, polyethers and polyurethanes.

Elastomers: Elastomers have elastic-plastic behavior. The structure is not rigid, the material can be stretched. They can be extended too much, then stretched back to their original length by stretching elastically. This feature is clearly visible on the tire. Elastomers are amorphous. While the elastomers which are not stretched on them are wound or curved, the elastomers stretched on them are elongated during deformation.

Plastic body pumps can be used in fish farms, large aquariums, marine and mining industries. They are suitable for working under water. Provides protection against freezing in cold water. They're not magnetic. They are used for the transmission of flammable and non-greasy liquids due to their excellent corrosion resistance due to their non-ignition and insulating properties. They are also used for pumping deionized and demineralized water. It is suitable for preventing gaskets caused by hazardous chemicals. Usually plastic pumps are cheaper than metal pumps. Operating and maintenance costs are low. Plastic pumps work less noisy. Operating temperatures range from 66 °C to 121 °C. Plastic pumps with working pressure of 620 kPa, temperature 170 °C and flow rate 320 m³ / h were manufactured.

Centrifugal pump body and impeller are made of thermoplastic materials. The thermoplastic wheel is lightweight and does not rust or decay. Suitable for working in sea water and corrosive environments. Works without vibration. In this way, the motor bearings and the mechanical ceramic seal do not deteriorate. Porcelain or glass body pumps are used in very special applications.

Polypropylene (PP), PVDF (kynar), polycarbonate (PC), noryl (mixed form of polyphenylene oxide and polystyrene polymers) and teflon are used as plastic material. Teflon, rubber and kynar strengthens the strength of metallic bodies. Polypropylene and PVDF plastic pumps are suitable for applications where the pressure is not high (max. 6 bar). Pumps made of nylon reinforced rubber and teflon material are also available. Tensile strength is increased by using PVC, sintered carbon and thermoset plastics.

Pump impellers are made of polycarbonate (PC), noryl (PPO), molded rubber and glass. Noryl is much lighter compared to other impeller materials. Noryl provides superior wear resistance. It is seen that the risk of resonance decreases when the noryl material is used instead of the cast iron as a fan material [14]. Bearing and diffuser are made of noryl.

When exposed to abrasive fluids at high pressures, Noryl diffusers and bearings are determined in tests where they are less worn than those made of stainless steel. There are also plastic pump wheels reinforced with vinyl or epoxy material made of fiberglass. The diaphragm is made of teflon (polytetrafluoroethylene) material. Other parts of plastic pumps are made of glass, vinylester and epoxy. Graphite, teflon and ceramic materials are used as coating and interior coating materials. The pump bearings are reinforced with teflon and thermoset plastic materials.

3. CONCLUSIONS

Iron-based metals and alloys (cast iron and steel) and non-ferrous metals and alloys are used in the manufacture of metallic material centrifugal pump parts. When cast parts such as cast iron, bronze casting and steel are used, they can be melted into new products. Plastic materials cannot be recycled. When cast iron parts are removed or replaced, they can be reused elsewhere. In this case, both the formation of environmental waste and the costs are reduced. Metal structures are corroded in certain degrees in the natural environment.

Plastics are characterized by low production costs, lightness, high resistance to corrosion, ease of forming and suitable production. The reasons for the use of plastic pumps compared to metallic pumps are the cost savings for even corrosion resistance, the contamination of the pumped liquid and the lighter weight. Due to their light weight they can be easily moved and repaired. The building materials of the pump parts can be summarized as follows [15].

- a) Cast iron materials; body, impeller, pump shaft, bearing housing, wear ring, mechanical seal, diffuser and coupling are used in the construction.
- b) Steel materials; body, impeller, wear ring, pump shaft, suction and outlet are used in making.
- c) Stainless steel materials are used in pumps, pump shaft, body, impeller, wear ring, diffuser and mechanical seal.
- d) Bronze material is used in pumps, body, impeller, wear ring, pump shaft, mechanical seal, suction and outlet port.
- e) Used for aluminum impeller and electric motor body. Rice is used in suction and outlet.
- f) In the construction of plastic pumps; plastics, ceramics, glass, rubber, nylon and elastomers are used.
- g) Elastomers are recommended for gaskets and packing rings. They are used as coating and lining as well as body material.

Materials used in the construction of pump impellers:

Prairie (gray) casting,

Ductile iron,

316 quality austenitic stainless steel

304 quality austenitic stainless steel

Steel casting,

Aluminum,

Bronze,

Brass

Pump body materials:

Generally cast iron, high pressure steel,

Alloy cast iron or cast steel at very low temperatures (such as salt water),

High pressure resistant (peak) casting,

Steel casting (exceeding 177°C temperature, 13.8 mPa pressure)

Bronze, copper, aluminum

Diffuser materials:

Prairie (peak) casting,

Ductile iron,

Steel casting,

Bronze,

Stainless steel

Pump shaft and sleeve materials:

Shaft 304-316-410-420 quality stainless steel,

Shaft 1050 stainless chrome steel,
Shaft chrome steel,
Shaft cast iron,
Most hives are bronze,
Sleeve rice,
Sleeve high carbon steel,
Hive seldom cast iron

Packing materials:

Cotton (in the transmission of cold liquids),
Flax (in the transmission of cold liquids),
Teflon (PTFE) (liquid temperature above 105° C),
Graphite (liquid temperature over 105° C temperature, low pressure pumps),
Asbestos
Nylon
Asbestos saturated with graphite and teflon (2000 ° C temperature and 25 bar pressure hot water)

Mechanical seal materials:

Steel alloys,
Cast iron,
Stainless steel,
Bronze,
Silicon carbide, ceramic or tungsten carbide combinations

Plastic pump housings supplies:

Polypropylene (PP), (low pressure max. 6 bar),
Polyvinyl chloride (PVC),
Polyethylene (PE),
PVDF (kynar), (low pressure max. 6 bar),
Polycarbonate (PC),
Noryl (mixed form of polyphenylene oxide and polystyrene polymers)
Teflon (Polytetrafluoroethylene)

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