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Wear and its Effects in Centrifugal Pumps

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Abstract: Wearing means the abrasion of machinery or other materials because of a lot of use and over time. Wearing can be examined under 4 different groups. These are mechanical wear, corrosion, cavitation and fatigue. Mechanical abrasion is the mechanical removal of metal by cutting or the abrasion of suspended solid particles carried in the liquid, which is a loss of material. Corrosion is the change in the physical, chemical and mechanical properties of materials as a result of the chemical and electrochemical effects of the environment they are in. Cavitation is the result of the formation of vapor bubbles in the liquid subjected to intense local pressure changes and the detonation resulting from the explosion in the high pressure zone. Wearing which occurs in machine elements under variable stresses is called fatigue. Centrifugal pumps are from the dynamic pump group and are the most widely used pump type in agricultural irrigation. They work in very difficult and critical environments. They encounter many wear-out problems throughout their lifetime. In this study, the types of wearing observed in centrifugal pumps were investigated and the effects on the centrifugal pumps were investigated.

Santrifüj Pompalarda Yıpranma ve Etkileri

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Anahtar kelimeler

Aşınma,
Kavitasyon,
Santrifüj pompa,
Korozyon,
Yıpranma,
Yorulma.

Öz: Yıpranma; zamanla veya çok kullanılma sonucu aşınmak, eskimek, makine veya diğer malzemelerin aşınıp bozulması anlamına gelir. Yıpranma 4 farklı grup altında incelenebilir. Bunlar mekanik aşınma, korozyon, kavitasyon ve yorulmadır. Mekanik aşınma, mekanik olarak metalin kesilerek kaldırılması veya basılan sıvı içinde taşınan askıdaki katı parçacıkların aşındırması olup malzeme kaybıdır. Korozyon, malzemelerin içinde bulundukları ortamın etkisiyle kimyasal ve elektrokimyasal etkiler sonucunda fiziksel, kimyasal ve mekanik özelliklerinde değişim meydana gelmesidir. Kavitasyon, yoğun yerel basınç değişimlerine maruz kalan sıvı içinde buhar baloncuklarının oluşması ve yüksek basınç bölgesinde patlamasıyla ortaya çıkan yıpranmadır. Değişken zorlanmalar altında makina elemanlarında meydana gelen yıpranmalara yorulma denir. Santrifüj pompalar dinamik pompa grubundan olup tarımsal sulamada en yaygın kullanılan pompa tipidir. Çok zor ve kritik ortamlarda çalışırlar. Santrifüj pompalar, ömürleri boyunca birçok yıpranma kaynaklı problemlerle karşılaşır. Bu çalışmada santrifüj pompalarda görülen yıpranma tipleri incelenmiş ve santrifüj pompalara etkileri araştırılmıştır.

1. Introduction

Centrifugal pumps are used for transferring water from ground and ground water sources to other places. Centrifugal pumps enter the dynamic pump group used for irrigation (Fig. 1). They continuously give energy to the fluid. Fluid movement is continuous. It is not discontinious. On the other hand, the fluid is absorbed while the other hand is pressed. As the flow rate of centrifugal pumps increases, the pressure remains to a certain extent. Speeds are higher. The speed of these pumps can be 6000 rpm and larger. In centrifugal pumps, the relationship between the flow rate and the speed is not linear. There is an inverse relationship between flow rate and head. They are simple machines. Their aging, even in the event of a decrease in efficiency, but they perform their functions. The efficiency in centrifugal pumps is highly dependent on the ratio between flow and pressure. With centrifugal pumps, the flow rate can be easily adjusted with a regulating valve. Centrifugal pumps have virtually no air absorption capabilities. The suction pipe must be filled with water for the pump to operate. Centrifugal pumps take up less space, are light and cheap. Their efficiency is low at low flow rates and high pressures (Keskin and Güner, 2012).

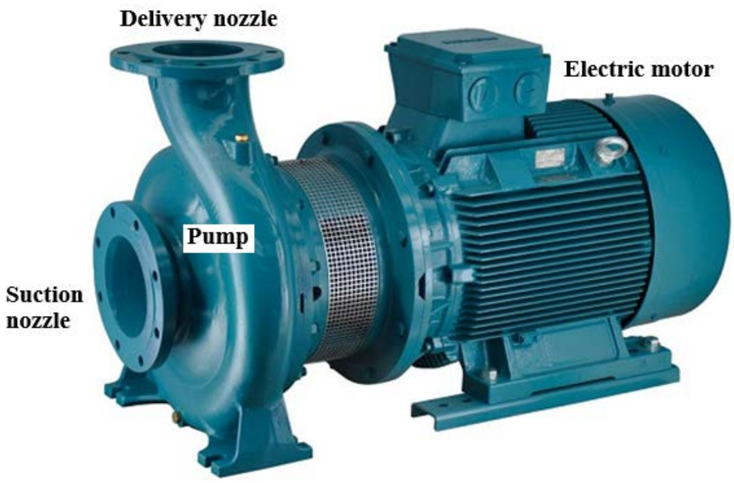

Figure 1. Centrifugal pump.

In centrifugal pumps; there are impeller, pump shaft, casing, chasis, suction and discharge port, diffuser, sealing elements (stuffing box), impeller and wearing rings connected to the body. The impeller provides transmission of the energy from the engine to the water by means of the shaft and sends the water in the suction mouth to the discharge line. The impeller increases the kinetic energy of water. Water from the impeller loses its kinetic energy in the expanding body and converts its kinetic energy into pressure energy. The diffuser allows the kinetic energy of the water from the impeller to be changed more effectively to the pressure energy between the impeller and the volute. The wearing rings are located on the impeller, on the body or on both the impeller and the body. These rings prevent fluid from passing through the discharge line into the suction line. Stuffing box prevents leakage between air and liquid leaks between shaft and body (Keskin and Güner, 2012).

2. Wear and its Effects in Centrifugal Pumps

Centrifugal pumps are the most widely used indispensable dynamic type pump in industry and agriculture. Centrifugal pumps are used for the extraction and transport of under-ground water above and below ground, transport of clean water in cities, transmission of fire extinguishing water, hot water circulation, sewage systems, food industry, dairy enterprises, pharmaceutical industry, chemical industry, fruit juices used in different environments and temperatures. Centrifugal pumps are used in the most demanding work in the industry and in the most critical jobs. There are many physical and chemical mechanisms that damage the pump elements. Most of the damaging mechanisms occur at the same time and have the potential to accelerate each other. The centrifugal pump and its elements are exposed to different substances with different liquids and the transmission of materials at different temperatures cause the wear and tear to be affected by chemical factors. Wear means erode or tear as a result of over time or a lot of use. It is generally used for the machine or machine parts.

The centrifugal pump elements are subject to wear due to friction, chemical and electrochemical effects, and high pressure formation. Pump elements wear, break, break down and as a result yield decreases, pump life is shortened, manufacturing and operating costs increase. It puts endangering human health and life in addition to the significant harm to the country's economy. It causes waste of metal resources. Labor's knowledge leads to loss of experience. A centrifugal pump is subjected to numerous harmful physical and chemical processes including service degradation during service. Each factor that damages the pump is wear.

The requirements for a successful pumping plant are performance and life. The performance is related to the pressure, flow rate and efficiency of the pump. Life is the sum of hours of operation before the replacement of one or more parts for the pump to operate with acceptable performance. The pump manufacturer is responsible for the initial performance of the pump. It is connected to the design of the pump. The life of the pump affects the operating conditions of the pump. It depends on the resistance of the pump elements to wear under different operating conditions. Factors affecting the long life of pumps in centrifugal pumps are as follows (Tural, 2011).

- Neutral liquids at low temperatures,
- The absence of abrasive particles,
- The pump works at the maximum efficiency point, ie the pump operating point,
- $NPSH_A$ (the absolute pressure at the suction port of the pump) must be greater than $NPSH_R$ (the minimum pressure required at the suction port of the pump) for the pump system to operate without cavitating.

A pumping facility providing all these conditions will be long-lasting. Pumps for water distribution networks are a typical example. Some water mains pumps with bronze wheels and cast iron bodies last 50 years or longer. On the other hand, transmission of fluids with abrasive particles can shorten pump life considerably. The biggest factor that reduces wear, corrosion and cavitation as well as pump life due to abrasive particles in the liquid is the operation of the pump outside the operating point. Damage of the impeller blades resulting from cavitation is particularly evident at the entrance of the impeller. The reason is that the impeller input is the lowest pressure point in the pump and the vapor bubbles formed in the suction line explode and generate high pressure (Karassik et al., 1985). The types of wear in centrifugal pumps can be classified under 4 headings (Tural, 2011).

a) Mechanical wear
b) Corrosion
c) Cavitation
d) Fatigue

2.1. Mechanical wear

Mechanical abrasion is the loss of material by mechanical removal of the metal, or abrasion of the suspended solid particles carried in the conveyed liquid. The amount of wear depends on the type of material, the mass, the shape and roughness of the friction surfaces, the friction conditions and the chemical effects of the environment. Wear on the surface of the materials with a wavy mat surface is generally defined as mechanical wear (Arikan, 2007; Tural, 2011).

Centrifugal pumps are used in many fields from agriculture to industry and they transfer their liquid and solutions of different properties from one place to another. The liquid and the solutions and the colloidal substances present in them cause friction with the pump parts (Fig. 2). The transmission fluid velocity and the high pressure in the centrifugal pumps are also the factors that constitute and increase the wear.

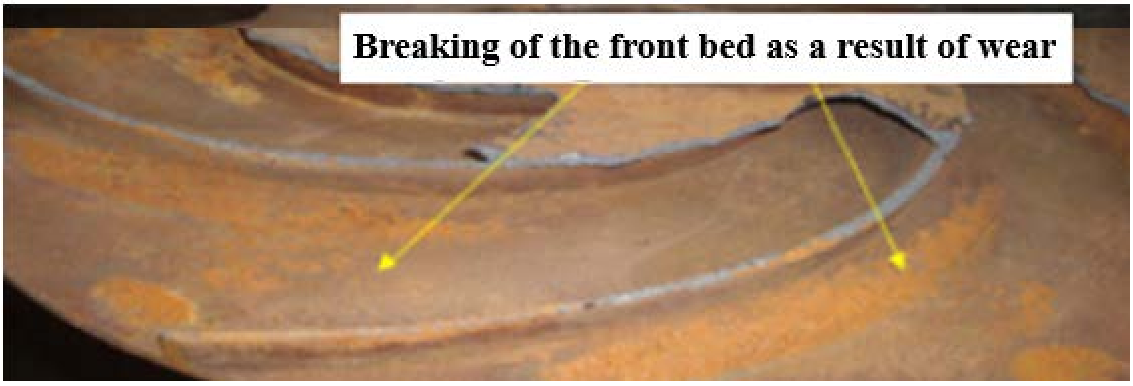

Figure 2. Wear pump impeller as a result of wear and bearing problems (Tural, 2011).

The rate of wear depends on the materials selected for the rotating and stationary parts of a centrifugal pump. Although the hardness of the material is not the only criterion for mechanical abrasion resistance, it generally provides a suitable indicator for the selection of ductile materials available for centrifugal pumps. It should be noted that a brittle (brittle) material, such as cast iron, will have a much lower mechanical wear resistance than bronze or steel with the same hardness. While the wear rate for a ductile material is proportional to the square of the velocity of the abrasive particles, there is some evidence that the wear rate of a brittle material can be as high as the sixth force of the part velocity.

It is impossible to establish a direct connection between the life of the pump elements and the characteristics and number of abrasive particles in the pumped liquid. However, according to the increase of mechanical abrasion resistance, materials can be listed as cast iron, bronze, manganese bronze, nickel-aluminum bronze, steel casting, austenitic steels (300 series steels), martensitic steels (400 series steels) (Karassik et al., 1985).

Pumped acidic, drinking or utility water, sewage, etc. liquids containing solid particles cause wear in materials and lead to a decrease in pump efficiency. Yüksel and Eker (2010) also found that wear and corrosion occurred in the impeller of a monoblock centrifugal pump, which was operated for a total of 180 hours during an irrigation period (Fig.3).

Figure 3. The wear on the impeller after 180 hours of operation (Yüksel & Eker, 2010).

2.2. Corrosion

Corrosion is a wear of metallic materials. It leads to significant loss of income. Corrosion is the change in physical, chemical and mechanical properties of materials due to chemical and electrochemical effects. In general, corrosion metal and its alloys are degraded by their environment and chemical and electrochemical reactions. Corrosion is a chemical, electrochemical and metallurgical reaction that occurs wherever there is metal and cannot be stopped. The materials forming the centrifugal pumps are mostly metal. For this reason, their use areas are in contact with continuous liquids and their solutions put the centrifugal pumps at risk. Metals are corroded in the natural environment. Corrosion pollutes the environment.

Examples of corrosion-resistant materials without protection include bronze, brass, stainless steel, zinc and aluminum. Load and heat are factors that increase corrosion. Coating the surfaces of metals with materials such as boron or chromium significantly reduces the wear. Economic loss due to corrosion is 1% in developed countries and 5% in developing countries. The annual loss in the USA is 70 billion USD (Yüksel and Eker, 2010).

Due to corrosion, the material breaks down and loses its function, this is an irreversible deterioration. Even though pump manufacturers choose materials and design suitable for their working environment, unexpected damage can occur due to corrosion and erosion in the pumps. Even the presence of trace amounts of different substances in the liquid greatly 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. Chromate and dichromate reduce the corrosive effect. In the manufacturing and design stages of the pump elements, it is particularly desirable to select materials that reduce the corrosion for the pump impeller and body. The size, shape and hardness of the particles in the liquid are effective in determining the constructive properties of the parts such as impeller and body.

Corrosion according to the mechanisms; physical, chemical and electrochemical. Organic liquids or molten metals cause physical corrosion. Chemical corrosion is the reaction of metal materials with direct environment. Electrochemical corrosion occurs in the aqueous environment by the deterioration of metal and its alloys (Akdoğan, 2009). Corrosion according to other classification; It is classified as erosion corrosion, stress corrosion, intergranular corrosion, graphite corrosion.

2.2.1. Erosion corrosion

It is the physical abrasion of metals, pipes and other equipment by moving solids, liquids and gases. Erosion-corrosion, erosion and corrosion are combined with rapid deterioration. Also called accelerated high flow corrosion. Erosion-corrosion is affected by the type of fluid, the dynamic properties of the fluid, the thermodynamic properties of the fluid and the environment, the properties of the material, the size of the material, the manufacturing and the assembly. High flow rate causes oxidation on the metallic surface. The most important factor is the fluid velocity. The erosion rate is directly proportional to the cube of the fluid velocity. Speeds below the threshold fluid velocity do not cause erosion-corrosion. It increases in proportion to temperature and chemical variables. The rate of erosion growth decreases when the weight ratio increases by increasing the solid particle erosion effect in the fluid first.

Pipes, valves, propellers, pumps, conduits, grooves, and conduits with moving fluids are visible on material surfaces that are open to the environment. Erosion corrosion is one of the most fundamental problems of centrifugal pumps. Erosion corrosion causes abrasion on the surfaces, which are uniformly distributed, such as wall loss, groove, groove, wave, creek bed and drop. The pits in the form of horseshoe in the direction of flow and the bright surface structure are the most obvious erosion corrosion indicator. Figure 4 shows the stages of erosion-corrosion.

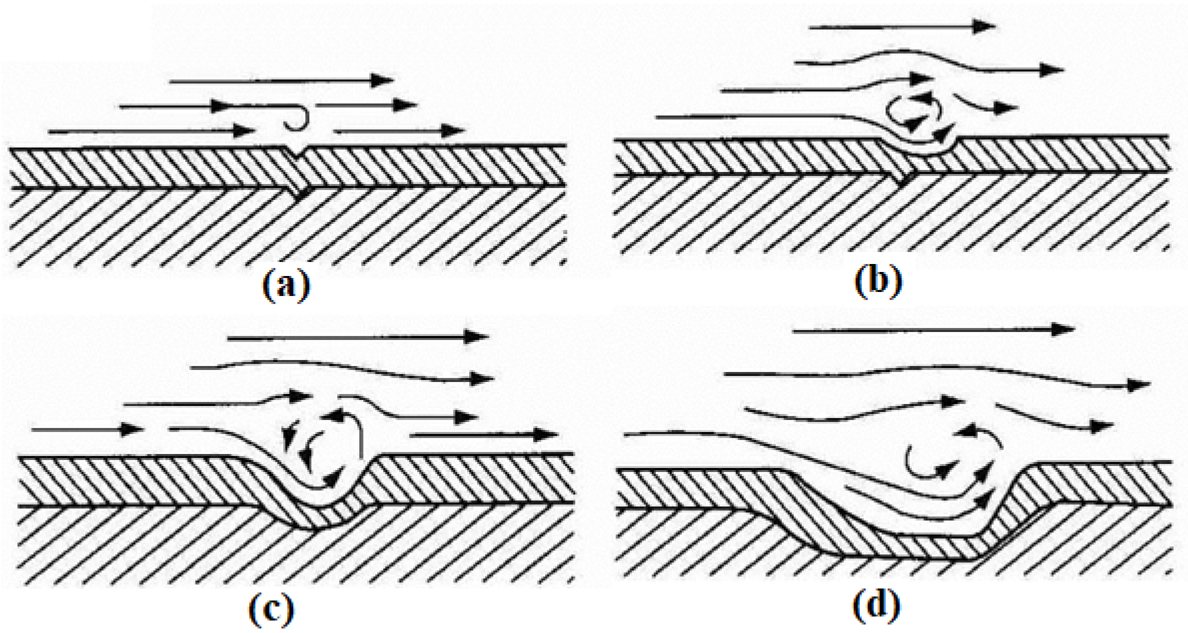

Figure 4. Erosion-corrosion stages.

The corrosion rate of many metals increases when the liquid flow depends on the component. The corrosion rate is also dependent on the angle of attack of the part according to the direction of flow. As a general rule, as the angle of attack, which is the angle between the flow lines of the aerodynamic flow line and the line of the wing, increases, the corrosion rate increases, ie the fraction of the fluid from the metal surface is greater. The greater the breakout, the more severe the turbulence and therefore the speed of metal breakage is greater.

Corrosion rate in most metals and alloys in any liquid environment under static conditions depends on the resistance of the film formed on the surface and the protection of the base metal from further attack. Damage to or destruction of this film by erosion leaves the base metal unprotected in a corrosive environment and continues to reduce metal removal.

In centrifugal pumps, the impeller is particularly sensitive to erosion corrosion. Although the pump body may be damaged by erosion corrosion, the problem is usually secondary compared to the wheel (Fig. 5). The diffuser type body is more susceptible to erosion corrosion as a barrier to the flow line compared to the single-wing volute type body with its multiple blades.

Figure 5. Waveform erosion-corroded impeller (Oluk & Ozturk, 2011).

Wear rings are also susceptible to erosion corrosion and should be considered in particular for material selection. If the appropriate material is not selected, high fluid velocities through the small ring openings can result in a high wear rate.

When considering any material for pump service, the characteristics, size and geometric structure of the material, manufacturing and assembly quality should be evaluated. This can be a difficult task, as many of the characteristics and characteristics of the liquid and the material to be pumped are not so detailed as to permit an optimum solution. Most of the materials used in pump construction have been subjected to corrosion testing under various conditions in a variety of liquids, but very few have been tested in a high-speed environment. For example, the corrosion rate of austenitic stainless steels 300 series remains virtually unchanged in a wide range of seawater velocities, while the corrosion rate for bronze is rapidly increasing in the same range. However, the corrosion rate is only part of the problem in the evaluation of erosion corrosion.

The corrosion resistance of a metal or alloy depends mainly on the hardness of the material. However, the hardness of a material is not necessarily compatible with its corrosion resistance. The 300 series of austenitic stainless steels are not curable, but most exhibit low corrosion rates in the liquid. On the other hand, 400 series stainless steels can harden up to 500 Brinell, but have higher corrosion rates than austenitic stainless steels in much more fluid.

While most of the pump elements are designed as standard, their hardness is limited to about 350 Brinell. Above 350 Brinell, standard operations such as turning, hole drilling, drilling and tapping are not economical. Higher hardness can be achieved for the stuffing box and the wear rings and the finishing of the cylindrical parts can be performed by grinding.

As a general rule, for the transmission of liquid without free abrasive solid particles, the material must first be selected based on the speed-corrosion resistance of the pumped liquid. If the liquid contains abrasive solid particles, acceptable speed-corrosion resistance properties are to be provided; firstly the construction material for mechanical abrasion resistance should be selected (Karassik et al., 1985).

2.2.2 Intergranular corrosion

Corrosion between grains is the corrosion of grain boundaries in the material body. Corrosion occurs as a result of condensation of material near grain boundaries. The most important feature of this type of corrosion is that despite the very small weight loss, the corrosion rate can reach high values near the grain boundaries. This condition can corrode parts of the cross-section along the entire cross-sectional area quickly. While the grains retain their integrity and shape, the intergranular bond is degraded. As a result, mechanical strength is reduced to zero in areas where corrosion is a factor. For example, it is possible to ground a piece of austenitic chromium-nickel steel which has been damaged by grain boundaries between the fingers. There is no significant change in the appearance and dimensions of the parts. These conditions make it difficult to monitor and control the grain boundary corrosion. Intergranular corrosion is especially observed in austenitic chromium-nickel steels and aluminum-copper alloys (Zeren, 2017).

In contrast to direct or galvanic corrosion of the metal surface, intergranular corrosion is hidden because it can be seen as a minor amount of surface damage, which can significantly reduce the mechanical properties of the material. Because only the grain boundaries are affected, the material appears good in the audible surface inspection. However, intergranular corrosion can proceed to the point where the material is completely fragmented (Fig. 6).

Figure 6. Centrifugal pump seal bed with intergranular corrosion (Cebeci, 2016).

Intergranular corrosion of austenitic stainless steels results from the precipitation of carbides at grain boundaries during slow cooling of the casting. When exposed to the corrosive environment, the carbides first attack and the strongly bonded matrix structure of the metal grains is destroyed. Carbide precipitation, heating up to 1 100 ºC and then quenching by quenching can be controlled. Carbide is kept in 1 100 ºC solution and carbide precipitation is prevented by rapid quenching.

The sensitivity of austenitic stainless steels to intergranular corrosion can also be reduced by controlling the carbon content of the alloy. Standard austenitic stainless steels of 300 series contain more than 0.08% carbon. These steels are susceptible to intergranular corrosion when proper heat treatment is not performed. Extra-low-carbon steels are available in the 300 series and are identified by the letter L. The carbon content of these steels is less than 0.03% and is much less sensitive to intergranular corrosion.

Castings of austenitic stainless steels, fluid for the end of piston pumps, or intergranular corrosion for cavities and impellers of centrifugal pumps must be considered. When heat treatment is applied for medium-sized castings, low carbon grades are sufficient; there is no need for applications after heat treatment. In this case, it is not correct to use 0.03% carbon steels which are more expensive. However, in larger, more complex castings, 0.03% carbon steels should be considered. This is particularly true for open or semi-open impellers used in mixed flow and axial pumps. Here, large, cheek-free wings can be severely damaged during cooling. In this case, steel with 0.03% carbon reinforced by air cooling is the preferred choice.

If the ends of the impeller wings damaged by erosion-corrosion are to be restored during the life of the pump, the impeller break should be determined with a maximum of 0.03% carbon content. If this is not the case, carbides will collapse at the grain boundaries at the next welding process and rapid damage from intergranular corrosion may occur in welded areas (Karassik et al., 1985).

2.2.3. Graphite corrosion

The iron (gray) structure of gray cast iron contains iron and graphite. The graphite is in the form of thin layers (lamella) and reveals the characteristic gray appearance of cast iron. The presence of graphite also provides a lubricating effect during processing. In addition to this feature, the breakage of small pieces should be taken into account as the perfect processing quality for cast iron (Fig.7).

Apart from these properties, gray cast iron is widely used in pump manufacturing due to very low casting costs. The low tensile stress and ductility of cast iron as well as corrosion resistance properties should be taken into account. The presence of graphite in the interior of the cast iron has the effect of corrosion, which is called graphite corrosion or, more simply, graphite. In graphite corrosion, iron leaves weak spongy graphite. The porous structure consists of iron soluble, backward graphite, gaps and paste remains.

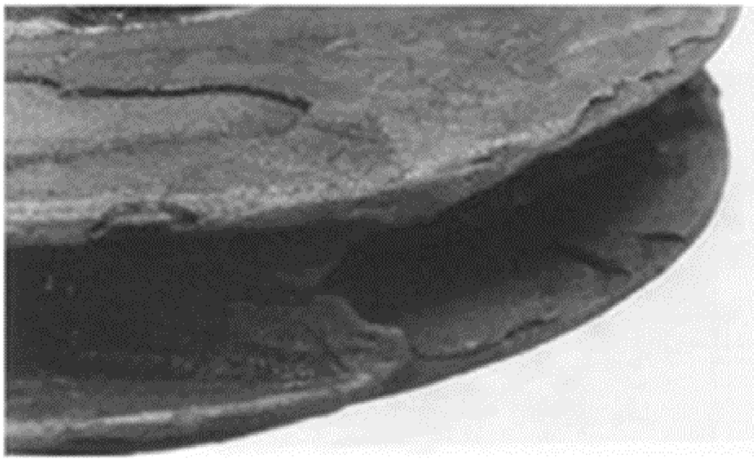

Figure 7. Graphite corrosion of centrifugal pump impeller made of gray cast iron material (Cebeci, 2016).

In the presence of an electrolyte, galvanic batteries are formed between the iron and graphite pieces. Iron and graphite composition are iron anode and graphite cathode. Iron-to-graphite is galvanic and iron is mixed into the solution. The result is the slow depletion of the matrix structure of the iron until only the graphite remains. In this case, the structure of the original cast iron is reduced to a porous graphite structure, where the corrosion products are sprinkled. The physical properties of the graphite structure are much lower than the properties of cast iron and this structure rapidly fails. In fact, the effect is so noticeable that even though the casting material looks good from the outside, it can be torn apart by touching it with the fingers.

Graphite corrosion has been observed on cast iron impeller of a pump used in sea water transmission. The impeller blades, which are more exposed to new metal attacks, result in rapid deterioration due to wear of the soft graphite structure. The same impeller does not show any electrolyte liquid, for example graphite corrosion when clean water is pressed. Experience has shown that it should never be used for cast iron impeller, low salt water or sea water because of the inevitable damage caused by graphite corrosion.

Again, it has been shown that cast iron bodies are more resistant to abrasive graphite corrosion than cast iron wheels. When examining the inner surface of the hull, a layer of graphite may be exposed, the flow velocities encountered by the hull are not very effective on graphite abrasion and the main material is protected against further attacks. However, the pumps only have a height of 30 m or less. In case of low saline or seawater applications, alternative casing materials should be considered for headings exceeding 30 m (Karassik et al., 1985).

2.2.4. Pitting corrosion

Pits are defined as cavity or hole where the surface diameter is equal to or less than the depth. In this type of corrosion, holes or pits occur on the material surface. It is an electrochemical event. The mechanism that causes pitting corrosion is an electrochemical process that occurs when a protective passive film is allowed to break-down on a susceptible metallic surface. Therefore the phenomenon is most common on metals that rely on a protective oxide for corrosion resistance such as stainless steels. The pits are formed by breaking the protective film in the small point regions on the metal. As the protective film does not regenerate, metal dissolution starts. Protective film for protection against corrosion is more common in metals such as stainless steel. It may take a long time for the pits to become visible. It develops insidiously, often noticeable when the material is drilled. Since the anode and cathode regions are separated from each other, the anode is a narrow region inside the pit that opens from any point of the surface, while the cathode is a large area around the pit. As a result of corrosion, the pit grows increasingly and causes the metal to be punctured from that point in a short time. Material loss is low but dangerous corrosion type. For liquids with low pH and high chlorine, the growth rate of the pits is quite high. This is the property that separates the corrosion from the gap corrosion itself. This type of corrosion is mostly observed in NaCl, $CaCl_2$, $MgCl_2$, AlC_3 and NaBr (Fig.8).

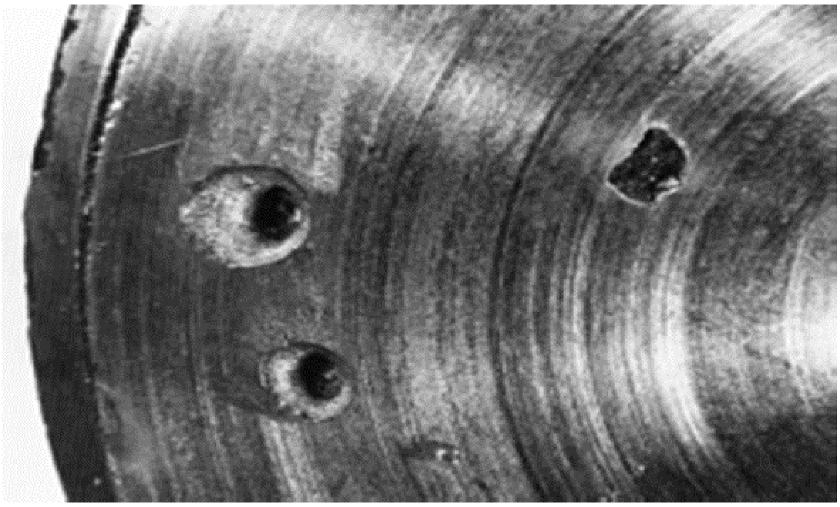

Figure 8. Pitting corrosion on the impeller (Cebeci, 2016).

2.2.5. Crevice Corrosion

This type of corrosion is the corrosion of metal-metal or sometimes metal-nonmetal (gasket, wood, glass, rubber, aspest, and concrete) that is tightly bonded together by fastening elements such as rivets. Crevice corrosion is a corrosion form that occurs when one metallic component is tightly fitted (but not welded) to another metallic (or in some cases a nonmetallic) component to form a microscopic cavity or crevice. It is necessary condition that the crevice be able to be penetrated water – even microscopically. Such crevices are numerous in the construction of a typical centrifugal pump. The spacing between the interconnected parts causes corrosion. This range is less than mm. If the gap rises above mm, no corrosion occurs. It occurs at intervals between two stainless steel parts of the same or different types. A limited battery is present in the narrow ranges and the condensate battery is not repaired. At these intervals, foreign substances accelerating corrosion accumulate. It is suitable to be completely sealed. Crevice corrosion is an electrochemical event. Water enters the crevice first. Water, oxygen and metal react to the general type of corrosion. Then the crevice corrosion occurs. Crevice corrosion is common in centrifugal pumps. This type of corrosion is frequently seen in cascade pumps, pump inlet-outlet fittings and sealing rings.

2.2.6. Galvanic and concentration cell corrosion

Corrosion occurs in the form of macro and micro contact corrosion in stainless steels. Concentration battery, which is frequently seen in stainless steel, is the ventilation battery which is caused by the fact that the oxygen input to the electrolyte is different in various regions and that the surface passivity is deteriorated in some places (Aran and Temel, 2004).

Galvanic corrosion is the most common type of electrochemical corrosion that occurs in centrifugal pumps. Centrifugal pumps are the most important corrosion types due to the variability of the materials used. Electrode potentials occur when two different metals or alloys are present in the same electrolytic environment. The cathode, which is more lineage than the material in the environment, acts as an anode. The metal, which is an anode, is corroded faster than the other metal. The corroded metal is anodic and the other metal has a cathodic structure (Gall, 2013).

2.3. Cavitation

If the pressure of the water moving in a closed system (pipelines) at any point falls below or below the vapor pressure depending on the temperature, the molten gases are separated and water vapor bubbles are formed. When these bubbles are moving together with water, they break down when a high-pressure zone is found and the vapor condenses into water. This event is called cavitation (Keskin and Güner, 2012). Cavitation erosion is the material wear that occurs as a result of very high local pressures on the metal surface by condensation of vapor bubbles. In corrosive environments, the damaged parts are continuously removed to increase the wear rate and the corrosion continues without slowing down (Fig. 9).

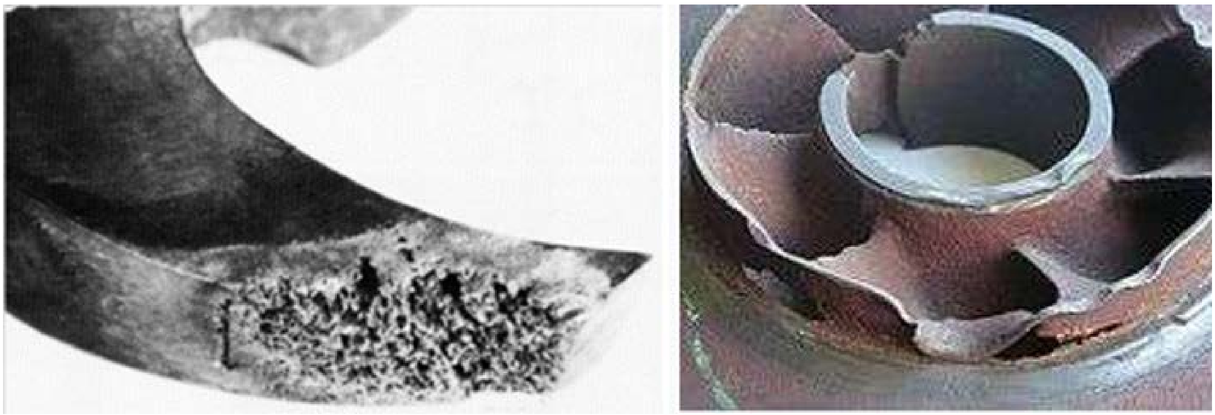

Figure 8. Cavitation corrosion at the impeller (Cebeci, 2016).

Although every effort has been made to prevent cavitation in the design and use of centrifugal pumps, it is not always possible to prevent cavitation if the pump is operated at lower flow rates than at the point where the highest efficiency is achieved. In a low flow study, it should be noted that the net positive suction head (NPSH) in the declared suction is generally not sufficient to suppress all cavitation damage. The net positive suction head (NPSH) in the declared suction is required to ensure the head, flow and efficiency shown in the performance curves. It is to be expected that there will be some cavitation damage at low flow rates. While the net positive suction head (NPSH) is often the best yield point required, it would be impractical to provide a net positive suction head (NPSH) that will suppress all cavitation in low flow flows. Therefore, it should be expected that there will be some cavitation in the low flow operation and should be taken into consideration when evaluating the material for the impellers.

Open-type mixed-flow impellers, which deliver a top height of 10.7 m, are particularly sensitive to cavitation corrosion in spaces between the fixed body and the rotating blades. This is often referred to as wing tip erosion and causes cavitation vents in the openings between the body and the wings. In this case, it would be impractical to provide a net positive suction head (NPSH) to eliminate cavitation. The evaluation of any impeller and body material for such a pump should be included in the possibility of wing tip cavitation (Fig. 9).

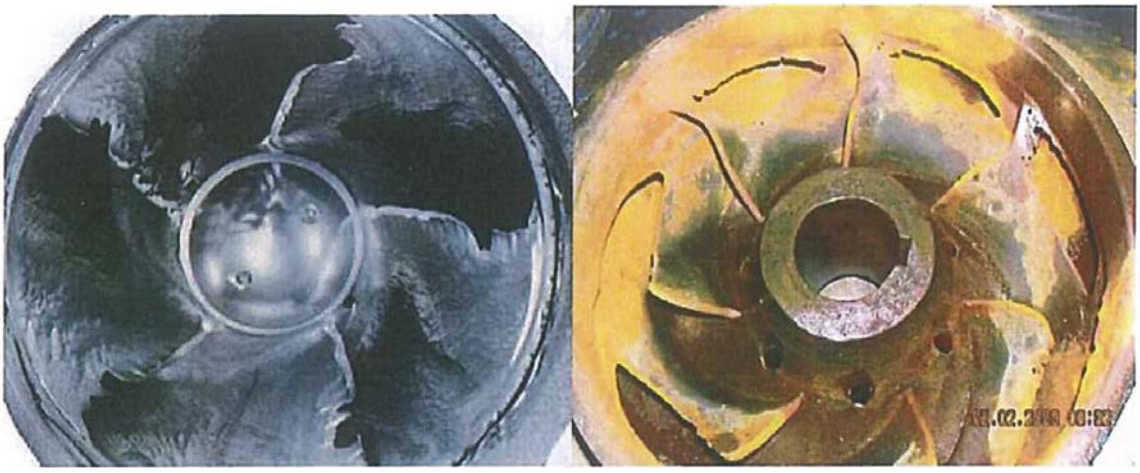

Figure 9. Cavitation-wear austenic-ferritic stainless (left) and cast iron (right) impeller (Tural, 2011).

The extensive laboratory tests for the resistance of materials to cavitation erosion provided data for all materials used in the construction of centrifugal pumps. Despite the complexity of the cavitation process and the large number of useful laboratory data, it is possible to develop the following chart regarding the cavitation resistance properties of the pump materials by establishing a relationship between laboratory data and field experience. According to the increase in cavitation resistance materials; cast iron, bronze, steel casting, manganese bronze, monel, martensitic steels (400 series steels), austenitic steels (300 series steels) and nickel-aluminum bronze (Karassik et al., 1985).

2.4. Fatigue

The wear of the machine elements under variable stresses is called fatigue. The final wear in fatigue occurs when small microcracks within the material grow over time as a result of varying stresses. This type of wear is a kind of abrasion that occurs with the simultaneous action of corrosive and mechanical factors. Stress corrosion begins on the surface of the component with cracks and geometric irregularities (Fig.10). The deterioration on the surface progresses into the material over time. Material comes to such a point that it cannot carry stresses and sudden breaks occur. Chemical and mechanical effects must be affected at the same time in order to prevent wear. If they do not have corrosive and mechanical effects, they do not occur in the wear. In order for the wear to occur, sensitive material, favorable environment, stress and time must be present. The wedge slot, invoice, screw thread, pin hole, ring slot and similar factors found in the machines have the effect of fatigue. It was determined that 22% of the breakage in the machines was caused by fatigue wear. Ambient temperature increases fatigue. 100 °C and above are considered to cause fatigue wear (Zeren, 2017).

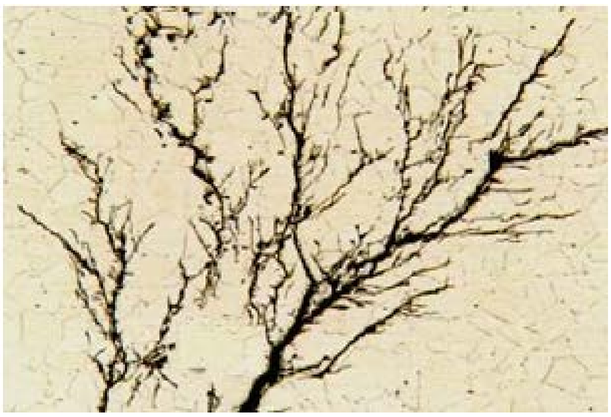

Figure 10. Wear as a result of fatigue (Zeren, 2017).

When evaluating the material for a pump component exposed to repeated loads (periodic), the durability limit of the material must be taken into account (Tural, 2011). The endurance limit is the maximum repetitive stress that the material may be exposed to and will not fail even after an infinite number of reverse repetitive loads. The endurance limit of the steel is, for example, about 50% of the tensile stress. 690 MPa tensile steel can be subjected to static load to produce 690 MPa tension in case of stress, but will fail shortly if the same steel is subjected to 690 MPa repeated load. However, if the strain is reduced to 345 MPa, the endurance limit will not be exceeded and the metal will be subjected to reverse tension of 345 MPa and will not fail. If the same steel is subjected to 345 MPa of repeated stress in a corrosive environment, the failure will be very fast. This failure causes fatigue. As a result of repeated stretching of the part, small capillary cracks occur on the surface. The metal surface exposed to cracks in a corrosive environment is rapidly corroded. Then the crack penetrates deeper, the corrosion develops even more and the piece will eventually become inoperable (Fig.11).

Figure 11. Stressed corrosion centrifugal pump impeller (Cebeci, 2016).

Experience has shown that the maximum combined stress in a pump shaft for sections that come into contact with the pumped liquid should not exceed 52 MPa. Above this value, the early deterioration of the shafts increases significantly. Since the fatigue strength of any metal depends on the corrosion resistance of the metal rather than the tensile strength of the metal, the life of any pump element can only be estimated based on the repeated loads to which it is exposed. The pump shaft will, for example, be subjected to a full stretch in reverse for each turn and in certain applications will have a certain life time based on the fatigue resistance of the material and the rotation speed of the pump. The best way to provide protection against short spindle life is to prevent the shaft from contacting with the liquid through the bushings (Karassik et al., 1985).

3. Conclusions

Pumps are the machines that convert the mechanical energy from the power supply to the corresponding liquid and convert them into hydraulic energy. Centrifugal pumps are the most commonly used type of pumps in agricultural irrigation. Metals wear up to a certain degree in their natural environment. Wear means wear or tear, wear and tear of machinery or other materials due to wear or tear. The amount of moisture, the acidity and alkalinity of the environment, the temperature, the selected material, the salinity, the amount of oxygen, the liquid content and the speed, the air pollution and the like are effective. Damage caused by material loss and pollution, labor and capital loss and plant out-of-service due to wear. For the pump elements, it is necessary to select the materials that will reduce the wear and take measures to prevent wear.

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