

CHAPTER FOUR

CORROSION

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Selecting the right pump type and sizing it correctly are critical to the success of any pump application. Equally important is the selection of materials of construction. Choices must be made between metals and/or non-metals for pump components that come into contact with the pumpage. In addition, gaskets and O-ring material selections must be made to assure long leak-free operation of the pump's dynamic and static sealing joints. To assist in proper selection, included in this section is a brief discussion of specific types of corrosion and a general material selection guide.

4.1 Corrosion

Corrosion is the destructive attack of a metal by chemical or electro-chemical reaction with its environment. It is important to understand the various types of corrosion and factors affecting corrosion rate to properly select materials.

4.1.1 Types of Corrosion

1. Galvanic corrosion is the electro-chemical action produced when one metal is in electrical contact with another more noble metal, with both being immersed in the same corroding medium called the electrolyte. A galvanic cell is formed and current flows between the two materials. The least noble material called the anode will corrode while the more noble cathode will be protected. It is important that the smaller wearing parts in a pump be of a more noble material than the larger more massive parts, as in an iron pump with bronze or stainless steel trim. Following is a galvanic series listing the more common metals and alloys sorted from least noble to most noble.

Magnesium	
Magnesium Alloys	
Zinc	
Aluminum 2S	
Cadmium	
Aluminum 175T	
Steel or Iron	
Cast Iron	
Stainless Steel, 400 Series	(Active)
Stainless Steel, Type 304	(Active)
Stainless Steel, Type 316	(Active)
Lead-tin Solders	
Lead	
Tin	
Nickel	(Active)
Nickel base alloy	(Active)
Brasses	
Copper	
Bronzes	
Copper-Nickel Alloy	
Monel	
Silver Solder	
Nickel	(Passive)
Nickel Base Alloy	(Passive)
Stainless Steel, 400 Series	(Passive)
Stainless Steel, Type 304	(Passive)
Stainless Steel, Type 316	(Passive)
Silver	
Graphite	
Gold	

2. Uniform Corrosion is the overall attack on a metal by a corroding liquid resulting in a relatively uniform metal loss over the exposed surface. This is the most common type of corrosion and it can be minimized by the selection of a material which offers resistance to the corroding liquid.
3. Intergranular corrosion is the precipitation of chromium carbides at the grain boundaries of stainless steels. It results in the complete destruction of the mechanical properties of the steel for the depth of the attack. Solution annealing or the use of extra low carbon stainless steels will eliminate intergranular corrosion.
4. Pitting Corrosion is a localized rather than uniform type of attack. It is caused by a breakdown of the protective film and results in rapid pit formation at random locations on the surface.
5. Crevice or Concentration Cell Corrosion occurs in joints or small surface imperfections. Portions of the liquid become trapped and a difference in potential is established due to the oxygen concentration difference in these cells. The resulting corrosion may progress rapidly leaving the surrounding area unaffected.
6. Stress Corrosion is the failure of a material due to a combination of stress and corrosive environment, whereas the material would not be affected by the environment alone.
7. Erosion-Corrosion is the corrosion resulting when a metal's protective film is destroyed by high velocity fluids. It is distinguished from abrasion which is destruction by fluids containing abrasive solid particles.

4.2 pH Values

The pH of a liquid is an indication of its corrosive qualities, either acidic or alkaline. It is a measure of the hydrogen or hydroxide ion concentration in gram equivalents per litre. pH value is expressed as the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration. The scale of pH values is from zero to 14, with 7 as a neutral point. From 6 to zero denotes increasing hydrogen ion concentration and thus increasing acidity, and from 8 to 14 denotes increasing hydroxide ion concentration and thus increasing alkalinity.

The table below outlines materials of construction usually recommended for pumps handling liquids of known pH value

pH Value	Material of Construction
10 to 14	Corrosion Resistant Alloys
8 to 10 6 to 8 4 to 6	Iron, Stainless Steel, Bronze, Carbon Steel
0 to 4	Corrosion Resistant Alloys

The pH value should only be used as a guide with weak aqueous solutions. For more corrosive solutions, temperature and chemical composition should be carefully evaluated in the selection of materials of construction.

4.3 Cavitation

Generally, the bubbles that form inside the liquid are of two types:
Vapor bubbles or Gas bubbles:

1. Vapor bubbles are formed due to the vaporisation of a process liquid that is being pumped. The cavitation condition induced by formation and collapse of vapor bubbles is commonly referred to as Vaporous Cavitation.
2. Gas bubbles are formed due to the presence of dissolved gases in the liquid that is being pumped (generally air but may be any gas in the system). The cavitation condition induced by the formation and collapse of gas bubbles is commonly referred to as Gaseous Cavitation.

Both types of bubbles are formed at a point inside the pump where the local static pressure is less than the vapor pressure of the liquid (vaporous cavitation) or saturation pressure of the gas (gaseous cavitation).

4.3.1 Vaporous Cavitation

Vaporous cavitation is the most common form of cavitation found in process plants. Generally it occurs due to insufficiency of the available NPSH or internal recirculation phenomenon. It generally manifests itself in the form of reduced pump performance, excessive noise and vibrations and wear of pump parts. The extent of the cavitation damage can range from a relatively minor amount of pitting after years of service to catastrophic failure in a relatively short period of time.

4.3.2 Gaseous Cavitation

Gaseous cavitation occurs when any gas (most commonly air) enters a centrifugal pump along with liquid. A centrifugal pump can handle air in the range of ½ % by volume. If the amount of air is increased to 6%, the pump starts cavitating. The cavitation condition is also referred to as Air binding. It seldom causes damage to the impeller or casing. The main effect of gaseous cavitation is loss of capacity.

4.3.3 Cavitation Process Steps

The phenomenon of cavitation is a stepwise process as shown in Figure 4.1.

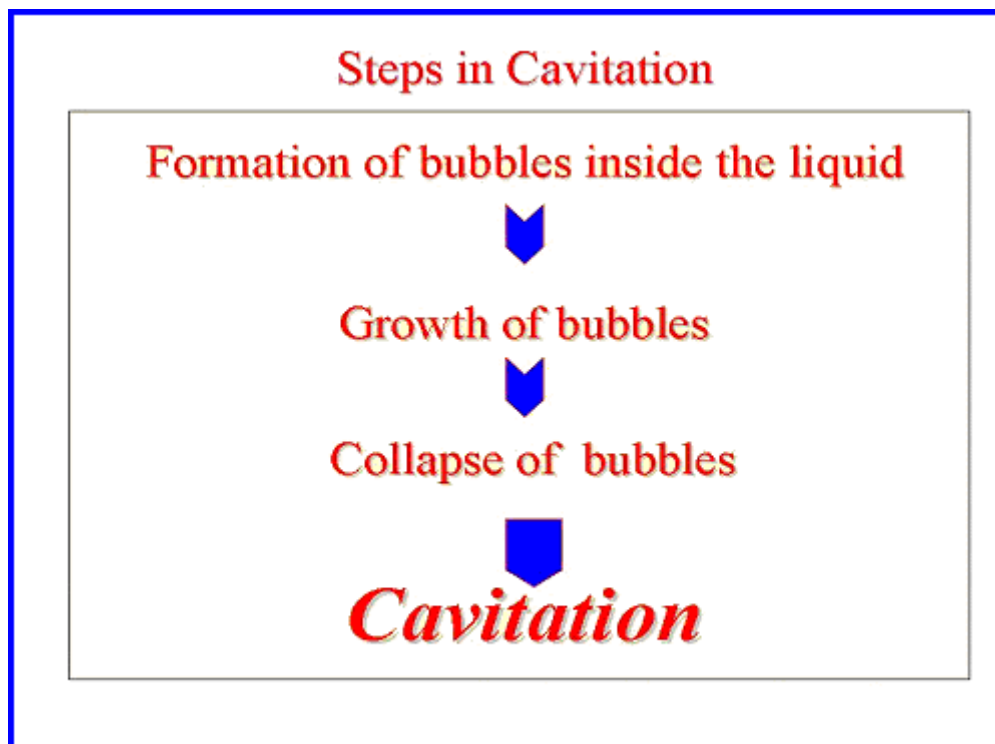


Figure 4.1 – Phenomenon of cavitation

Step One, Formation of bubbles inside the liquid being pumped:

The bubbles form inside the liquid when it vaporises i.e. phase change from liquid to vapor. But how does vaporization of the liquid occur during a pumping operation?

Vaporization of any liquid inside a closed container can occur if either pressure on the liquid surface decreases such that it becomes equal to or less than the liquid vapor pressure at the operating temperature, or the temperature of the liquid rises, raising the vapor pressure such that it becomes equal to or greater than the operating pressure at the liquid surface. For example, if water at room temperature (about 77 °F [25 °C]) is kept in a closed container and the system pressure is reduced to its vapor pressure (about 0.52 psia), the water quickly changes to a vapor. Also, if the operating pressure is to remain constant at about 0.52 psia and the temperature is allowed to rise above 77 °F [25 °C], then the water quickly changes to a vapor.

Just like in a closed container, vaporization of the liquid can occur in centrifugal pumps when the local static pressure reduces below that of the vapor pressure of the liquid at the pumping temperature. The pressure reduction profile within the pump is depicted in Figure 4.2.

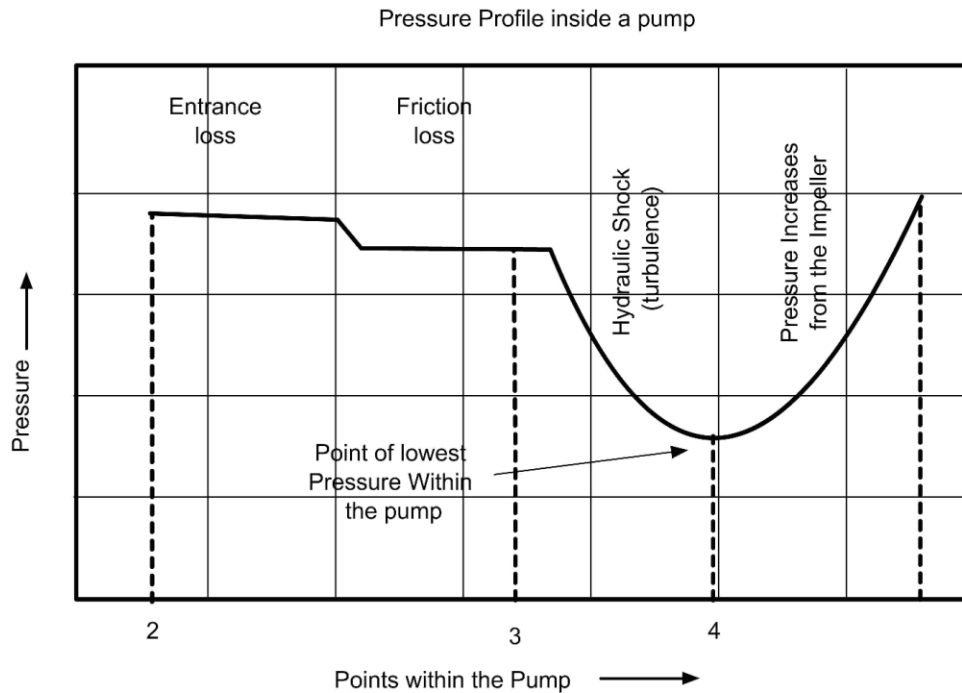


Figure 4.2 – Pressure Profile in a Pump

Cavitation occurs at the beginning of the trailing edge of the vanes near the impeller eye, where the pressure actually falls to below the liquid vapor pressure. The region of bubble formation is shown in Figure 4.3.

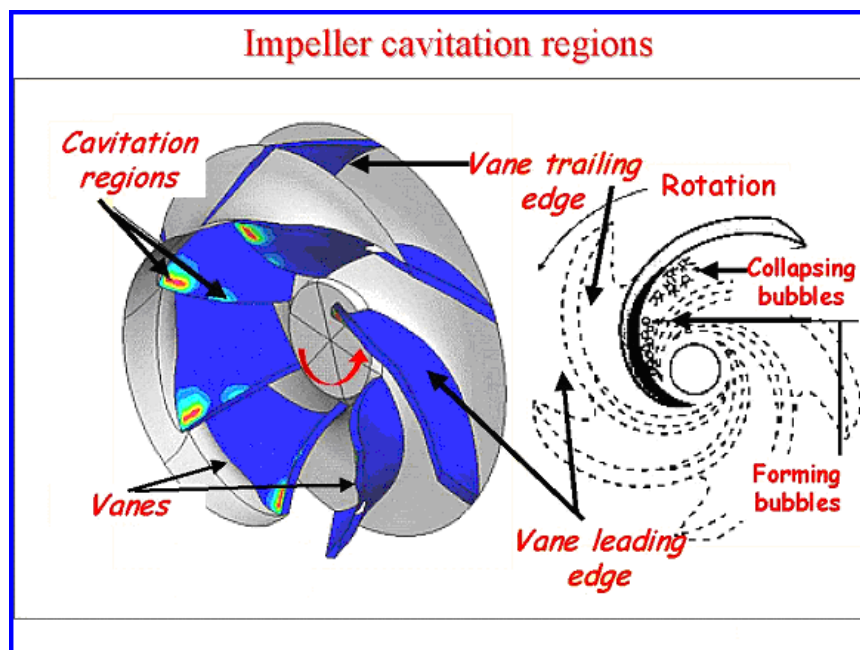


Figure 4.3 – Impeller cavitation regions

In summary, vaporization of the liquid (bubble formation) occurs due to the reduction of the static pressure to a value below that of the liquid vapor pressure. The reduction of static pressure in the external suction system occurs mainly due to friction in suction piping. The reduction of static pressure in the internal suction system occurs mainly due to the rise in the velocity at the impeller eye.

Step Two, Growth of bubbles:

Unless there is no change in the operating conditions, new bubbles continue to form and old bubbles grow in size. The bubbles then get carried in the liquid as it flows from the impeller eye to the impeller exit tip along the vane trailing edge. Due to impeller rotating action, the bubbles attain very high velocity and eventually reach the regions of high pressure within the impeller where they start collapsing. The life cycle of a bubble has been estimated to be in the order of 0.003 seconds.

Step Three, Collapse of bubbles:

As the vapor bubbles move along the impeller vanes, the pressure around the bubbles begins to increase until a point is reached where the pressure on the outside of the bubble is greater than the pressure inside the bubble. The bubble collapses. The process is not an explosion but rather an implosion (inward bursting). Hundreds of bubbles collapse at approximately the same point on each impeller vane. Bubbles collapse non-symmetrically such that the surrounding liquid rushes to fill the void forming a liquid micro jet. The micro jet subsequently ruptures the bubble with such force that a hammering action occurs. Bubble collapse pressures greater than 1 GPa (145×10^6 psi) have been reported. The highly localized hammering effect can pit the pump impeller. The pitting effect is illustrated schematically in Figure 4.4.

Collapse of a Vapor Bubble

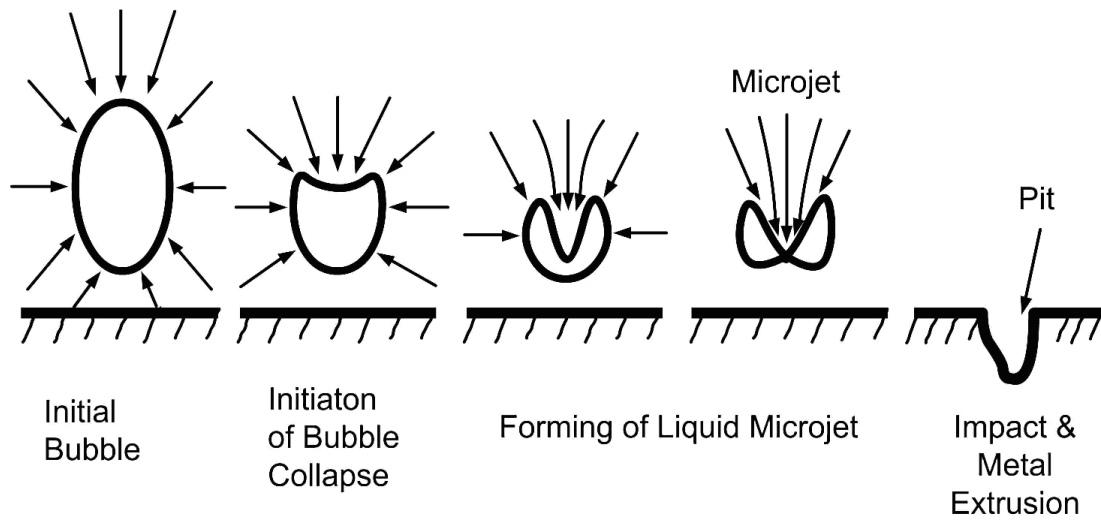


Figure 4.4 – Collapse of a Vapor Bubble

After the bubble collapses, a shock wave emanates outward from the point of collapse. This shock wave is what we actually hear and what we call "cavitation".