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An overview on cavitation in centrifugal pump

D.B. Jani[1], Mistry Yash[2], Suthar Mit[3], Suthar Ajay[4], Shah Jeel[5], Patel Pritesh[6]
[1,2,3,4,5,6] *GEC, Dahod-389151, Gujarat Technological University, GTU, Gujarat, India*

***Abstract*- Cavitation is one of the most challenging fluid flow abnormalities leading to detrimental effects on both the centrifugal pump flow behaviors and physical characteristics. Centrifugal pumps' most low pressure zones are the first cavitation victims, where cavitation manifests itself in form of pitting on the pump internal solid walls, accompanied by noise and vibration, all leading to the pump hydraulic performance degradation. In the present article, based on the literature survey, some light were shed on fundamental cavitation features; where different aspects relating to cavitation in centrifugal pumps were briefly discussed. Methods to stop or prevent cavitation were also presented in the article.**

Index terms- Cavitation, Centrifugal pump, Performance characteristics, Vapor pressure

I. INTRODUCTION

Pump is a mechanical device mostly used for raising liquids from a lower level to a higher one. This is done by creating a low pressure at the inlet and high pressure at the outlet of the pump. However, initially work has to be done by a prime mover to enable it to impart mechanical energy to the liquid which ultimately converts into pressure energy. It is mostly in used in industries and residential applications. A centrifugal pump is a non-positive displacement pump that imparts energy to a liquid. Centrifugal pumps are the machines, which utilizes centrifugal force in order to lift fluid from a lower level to a higher level by developing pressure. The centrifugal pump moves liquid by rotating one or more impellers inside a volute casing. The liquid is introduced through the casing inlet from the eye of the impeller where it is picked up by the impeller vanes. In other words, the fluid turbo machinery essentially consists of an impeller rotating in a casing [1-3]. Fluid enters from the eye of the impeller (at the center of the impellers) and exits though the space between the impeller blades to the space between the impeller and casing walls [4]. The velocity of fluid elements is in both tangential and radial directions, as the impeller start rotating. The velocity as well as the pressure, both increases, relatively, as the fluid flows from the impeller [5-6]. A centrifugal pump consists of a set of rotating vanes enclosed within a housing or casing that is utilized to impart energy to a fluid through centrifugal force (Fig. 1).

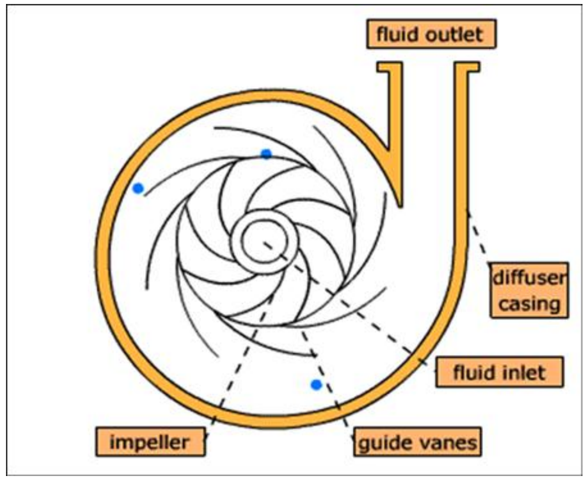

Fig. 1. Constructional features of centrifugal pump

The vanes are usually slope backwards, away from the direction of rotation. The blades of the rotating impeller transfer energy to the fluid & thus increase velocity. The fluid is sucked into the impeller through impeller eye and flows through the impeller channels formed by the curved blades between the shroud and hub. The fluid is accelerated by pulse transmission while following through the curvature of the impeller vanes from the impeller Centre (eye) outwards. It reaches its maximum velocity at impeller's outer diameter and leaves the impeller into a diffuser or volute chamber [7-8].

II. CAVITATION PHENOMENA IN PUMP

Within a centrifugal pump, the flow area at the eye of the pump impeller is usually smaller than either the flow area of the pump suction piping or the flow area through the impeller vanes. When the liquid being pumped enters the eye of a centrifugal pump, the decrease in flow area results in an increase in flow velocity accompanied by a decrease in pressure. The greater the pump flow rate, the greater the pressure drop between the pump suction and the eye of the impeller. If the pressure drop is large enough, or if the temperature is high enough, the pressure drop may be sufficient to cause the liquid to flash to vapor when the local pressure falls below the saturation pressure for the fluid being pumped. Any vapor bubbles formed by the pressure drop at the eye of the Impellers are swept along the impeller vanes by the flow of the fluid. When the bubbles enter a region where local pressure is greater than saturation pressure farther out the impeller vane, the vapor bubbles abruptly collapse [9-10]. This process of the formation and subsequent collapse of vapor bubbles in a pump is called cavitation (Fig. 2).

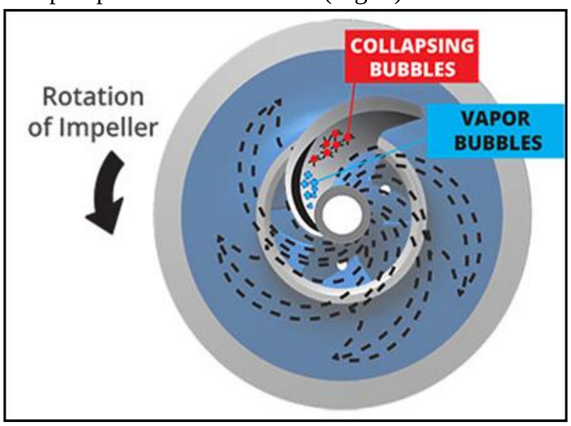

Fig. 2. Formation and collapsing of vapor bubbles

Some of situations where cavitation phenomenon is more likely to occur in the fluid flow through centrifugal pump.

1. The wall geometry at the fluid flow zones imposes high velocities and a subsequent pressure drop due gradual decrease in flow area. This is the case of flow constriction in fluid ducts and pump impellers.
2. The shearing between two neighboring flows having very different velocities entails large turbulent fluctuations of the pressure: that is the case for jets and wakes.
3. The high unsteadiness character of certain flows which as a result increase the fluid flow temporal acceleration terms, thus pressure drop in the fluid flow.
4. The roughness at the fluid flow wall boundary, which results in formation of wakes and subsequent attached cavities.
5. Presence of water in interstices due the inaccurate joining between two or more pieces in a mechanical system. There is high probability of cavitation occurrence when the interstice walls start to move.
6. The influence of moving solid bodies having sharp edges immersed in the liquid. The acquired fluid acceleration at these edges produces a pressure drop, thus high chances of cavitation occurrence.

Cavitation is a major concern in centrifugal pump because it can result in reduced pump performance and conduits and fixtures damage. Cavitation can be dependent upon the fluid flow rate and its fluid temperature. Most centrifugal pumps are not designed to withstand sustained cavitation. Noise is one of the indications that a centrifugal pump is cavitating. A cavitating pump can sound like a can of marbles being shaken. Other indications that can be observed from a remote operating station are fluctuating discharge pressure, flow rate, and pump motor current. The cavitation in centrifugal pump can be identified by the following techniques (Fig. 3). The effect of flowing water temperature and flow rate on cavitations inception in the centrifugal pump may be studied using flow visualization technique and pressure prediction [11-12].

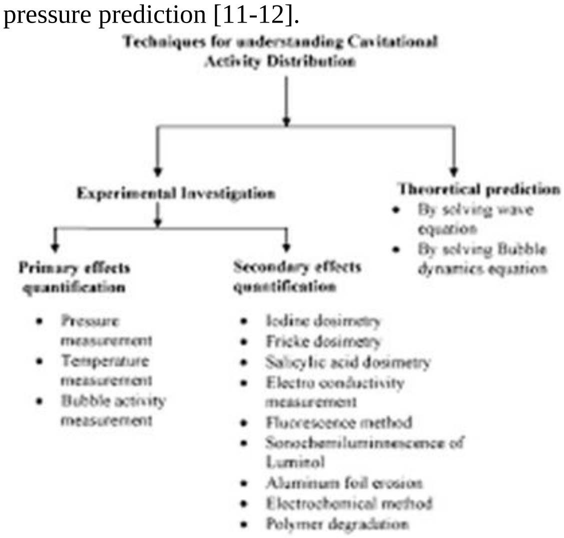

Fig. 3. Various techniques for identification of cavitation in centrifugal pump

III. TYPES OF CAVITATION

The cavitation phenomenon is generally characterized by the formation and growth of vapor bubbles in the fluid flow. The fluid-vapor interface can be under different shapes on which cavitation classification is based. Different cavitation patterns are presented here [13-14].

1. Traveling cavitation

In this type of cavitation, the micro bubbles otherwise called cavitation nuclei are curried along the flow field until they get to the flow's lower pressure zones, where they become macroscopic cavitation bubbles before collapsing at pressure recovery zones. The developed bubbles are usually in complex shapes mainly from their interactions with neighboring walls or other bubbles as shown in Fig. 4.

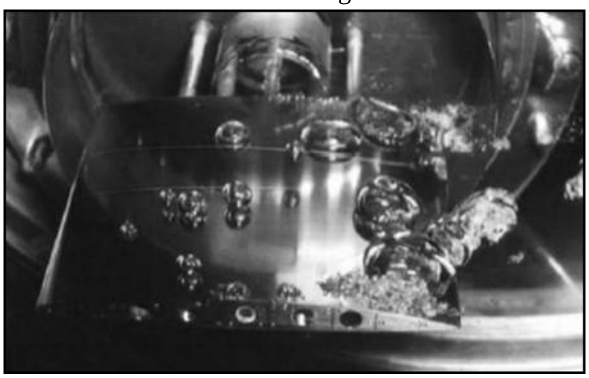

Fig.4. Traveling bubble cavitation

2. Attached cavitation

Contrary to the above presented traveling cavitation, the attached cavitation stays at the same location attached on a wall. This does not mean that the flow is steady. Actually, cavitation is almost always the source of unsteadiness which may be quite strong. In the down presented case of attached cavitation, the main source of unsteadiness originated in the rear part of the cavity as shown in Fig. 5.

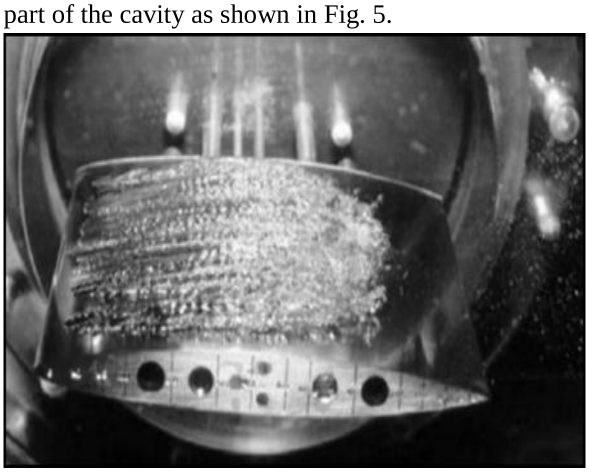

Fig.5. Attached cavitation

3. Vortex Cavitation

This type of cavitation is the mostly found in marine propellers. It is found at the vortex core generated by the secondary flow at the blade tip as illustrated in Fig. 6. The blade tip second flow is a result of the pressure difference between the vane pressure and suction side. The pressure at the generated tip vortex is much lower than pressure far away in the same fluid making it vulnerable to cavitation phenomenon.

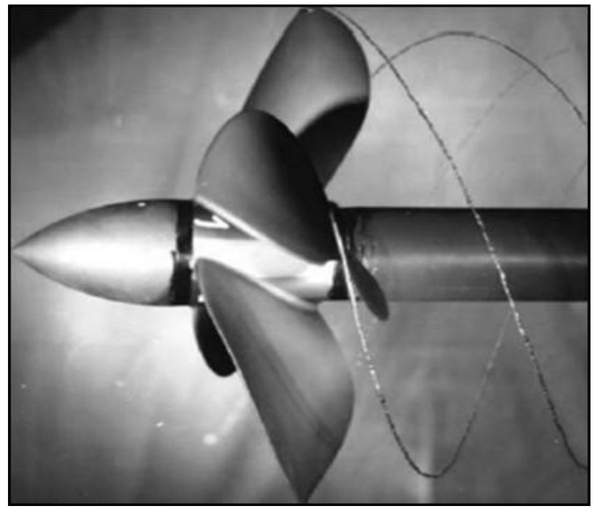

Fig. 6. Vortex cavitation

4. Shear Cavitation

Such a cavitation is observed in the wake of bluff bodies or in submerged liquid jets; Fig. 7 below presents a typical image of cavitation in the wake of a wedge.

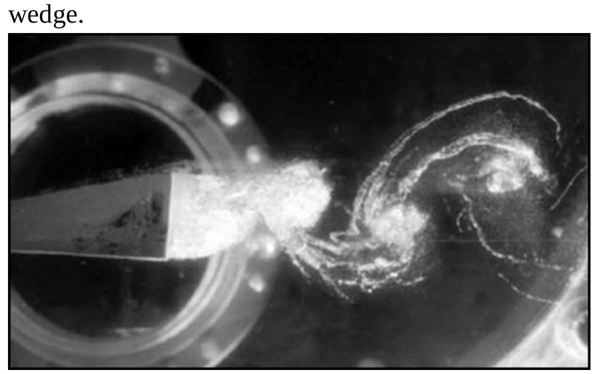

Fig.7. Shear cavitation.

IV. EFFECTS OF CAVITATION IN PUMP

Cavitation in a centrifugal pump has a significant effect on pump performance. Cavitation degrades the performance of a pump, resulting in a fluctuating flow rate and discharge pressure. Cavitation can also be destructive to pumps internal components. When a pump cavitates, vapor bubbles form in the low pressure region directly behind the rotating impeller vanes. These vapor bubbles then move toward the oncoming impeller vane, where they collapse and cause a physical shock to the leading edge of the impeller vane. This physical shock creates small pits on the leading edge of the impeller vane. Each individual pit is microscopic in size, but the cumulative effect of millions of these pits formed over a period of hours or days can literally destroy a pump impeller. Cavitation can also cause excessive pump vibration, which could damage pump bearings, wearing rings, and seals. A small number of centrifugal pumps are designed to operate under conditions where cavitation is unavoidable. These pumps must be specially designed and maintained to With stand the small amount of cavitation that occurs during their operation [15]. The following are the damages in pump due to cavitation.

- Erosion of impeller due to cavitation will cause unbalance of the impeller.
- Cavitation produces high vibration and damage bearings.
- Due to cavitation, pump life will reduce and also cause premature failure of the pump.

V. PREVENTION OF CAVITATION IN PUMP

While designing a pumping system or selecting a pump, one must thoroughly evaluate Net Positive Suction Head (NPSH) margin to prevent cavitation. Proper analysis of both the net positive suction heads available in the system (NPSHA) and the net positive suction head required by the pump (NPSHR) will reduce the formation of cavitation. It is a measure of the pressure drop as the liquid travels from the pump suction range along the inlet to the pump impeller. This loss is due primarily to friction and turbulence. Turbulence loss is extremely high at the low flow of the pump and then decreases with flow towards the best efficiency point of the pump. Friction loss usually increases with the increase in pump flow rate. As a result, the internal pump losses will be high at low flow, dropping at generally 20–30% of the best efficiency flow, then increasing with the flow. The NPSH margin required will vary with pump design and other factors, and the exact margin cannot be precisely predicted. For most applications, the NPSHA will exceed the NPSHR. Normally the NPSH margin will be of 1 meter is considering for pump selection to avoid cavitation [16-17].

- NPSH available shall be higher than then the NPSH required by the pump.
- Provide a straight run of three to five times the length of the pipe diameter (D) to the pump suction Range to prevent added turbulence at the impeller eye.
- Avoid boil-off vapor mixing with pumping liquid.
- The absolute pressure must not be allowed to drop below the vapor pressure of the fluid. This will prevent boiling which will cause cavitation.

VI. CONCLUSIONS

Cavitation phenomenon is globally understood like formation of vapor bubbles in the fluid flow from a pressure drop below its vapor pressure. Due to its speedy and complex nature, cavitation detection requires sophisticated methods; otherwise it can only be noticed by its effects on the equipment like unusual noise, vibrations and material damage. In fluid machinery, based on the system physical and working conditions, Cavitation can appear under different forms, which after getting to its full development, present almost similar effects on the system characteristics. In centrifugal pumps, cavitation performance mostly depends on the impeller geometrical design such that, any geometry modification can result in a totally different performance. Therefore, the design process requires a more careful control, such that, through experimentally the centrifugal pump's performance can be well determined where cavitation can be decreased to acceptable levels if not completely eliminated.

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