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CAVITATION GENERATOR DEVELOPMENT PROCESS AT RUSSIA AND ABROAD

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ПРОЦЕСС РАЗРАБОТКИ ГЕНЕРАТОРА КАВИТАЦИИ В РОССИИ И ЗА РУБЕЖОМ

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Abstract. The energy situation in the world indication a rapid increase in the consumption of natural resources. The only way out of this situation is the development of alternative environmentally friendly technologies. The research and utilization of cavitation heat generators will help ease the energy crisis and reduce exhaust emissions from fuel combustion. Therefore, it is a potential research topic.

Аннотация. Энергетическая ситуация в мире свидетельствует о быстром увеличении потребления природных ресурсов. Единственный выход из этой ситуации — разработка альтернативных экологически чистых технологий. Исследования и использование кавитационных теплогенераторов помогут ослабить энергетический кризис и сократить выбросы выхлопных газов при сжигании топлива. Таким образом, это потенциальная тема исследования.

Keywords: cavitation, heat generator, development process.

Ключевые слова: кавитация, теплогенератор, процесс разработки.

Introduction

The energy situation in the world indicates a rapid increase in the consumption of natural resources, according to world experts, almost all types of fuel can be depleted by 2025–2030. The only way out of this situation is the development of alternative environmentally friendly technologies, including technologies that use the phenomenon of cavitation.

Since the discovery of cavitation on propeller blades in the late 19th century, cavitation has caused people to attention. Examples of damage caused by cavitation in hydraulic engineering discharge structures at home and abroad after the 30s and 40s of the 20th century. Increasingly, cavitation has also aroused widespread concern. Cavitation can cause erosion, vibration, and noise, often inhibiting the performance of the machinery, and is generally considered a phenomenon that engineers should avoid.

With the advancement of computer technology. The emergence of measurement methods has led to the study of cavitation phenomena and theories through the unremitting efforts of many scholars at home and abroad. In particular, research on cavitation has made great progress in Russia and other countries. Studies have shown that transient local high temperatures (approximately 5200 K) and high pressures (above 50 MPa) occur during the collapse of a bubble, and that strong shock waves and microjets with a velocity of up to 100 m/s or more can be formed. Therefore, cavitation collapse will be accompanied by an extremely complex variety of physical and chemical effects, and the use of the energy of the collapse of cavitation is a new field for strengthening certain physical processes or chemical processes. Yet, various research involving cavitations for use in heat generators, water treatment equipment, and chemical reactors, for example, it has been conducted recently. Additionally, according to the documents written by the manufacturers of cavitation heat generators, the thermal efficiency of cavitation heat generators is purportedly higher than any other heating machine. However, little reported that the efficiency was found to be around 80% after a performance test for one of these cavitation heat generator models. In a different study, Zaporozhets et al. produced a device to generate cavitation bubbles, and the results of their experiment suggested that the amount of heat generation was 3.38 times more than the input electrical energy. Scholars at home and abroad have researched and developed many types of cavitation water jet nozzles. Rotary vane–type cavitation nozzles, center body nozzles, conical nozzles, and other shaped nozzles are successively used to generate cavitation jets. In this paper, the cavitation jets of conical nozzles are studied experimentally, and the effects of different cavitation jet nozzle cone angles on the cavitation jet cavitation effects are analyzed [1].

1. Theoretical significance and practical value of the selected topic

Cavitation is the process of the formation, development and collapse of vacuoles of vapor or gas in the liquid interior or liquid–solid interface when the local pressure is reduced. High temperature (1900 ~ 5000 K) and high pressure (up to 140 MPa ~ 170 MPa) and accompanied by a strong shock wave and micro–jet, the strong bursts of the molecular bonds that flow through the liquid will produce a strong burst.

Cavitation is a physical phenomenon that occurs in a liquid medium. Under normal circumstances, if the temperature does not change and the small surface tension of small bubbles is neglected, when the local absolute pressure of the liquid drops below the saturated vapor pressure of the environment, the tiny gas core contained in the liquid will expand due to the pressure drop. Eventually develop into a bubble with a certain diameter containing water vapor, thus forming a cavitation phenomenon. After cavitation is born, the liquid gas nucleus grows up into a vacuole in the low–pressure zone. As the mainstream moves into an area where the pressure rises, the pressure inside and outside of a certain moment becomes unbalanced and the vacuole is squeezed by the outside pressure, instant contraction collapse. The cavitation collapse produces a very high pressure and acts on the solid surface to cause the material to deform to a certain degree elastically. As shown in Figure 1–2, the whole process of development of vacuoles in water is depicted. Therefore, the process of cavitation can be summarized in three stages, namely, the primary development, development, and collapse of vacuoles. Each stage is related to the internal dynamics of fluids. Changes in water pressure are related [2].

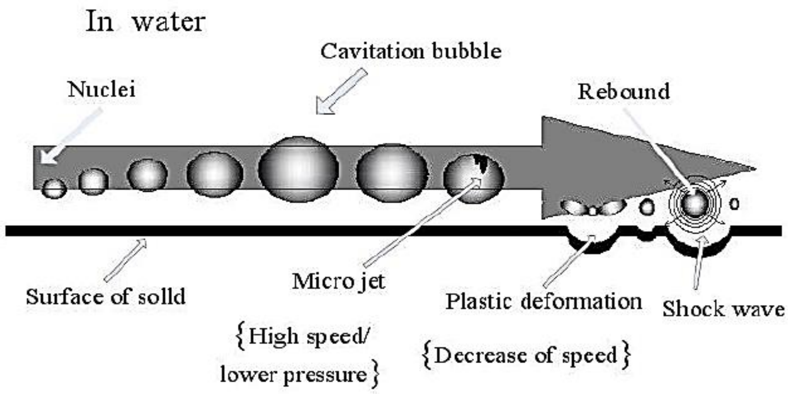

Figure 1. The development of Cavity.

In general, the occurrence of cavitation will bring a series of hazards to engineering practice, such as changes in equipment characteristics and performance degradation, reduce mechanical efficiency, causing vibration, resulting in noise. Cavitation of the collapse of the surrounding space will also produce a very high temperature, high pressure, micro–jet, bubble collapse, the pressure on the solid wall and micro–jet, and thus erosion and erosion to form cavitation phenomenon. Figure 1–2.

Figure 2. The cavitation of centrifugal pump impeller.

For a long time, people have tried to avoid and mitigate the harm caused by cavitation. In recent years it has been recognized that cavitation can also benefit mankind. With the continuous improvement of the understanding of the cavitation mechanism and the continuous optimization of the forming method, the application prospect will be more extensive. On the cavitation generation mechanism, because the liquid structure is not very clear, there is no obvious theoretical description. Some scholars have made some assumptions, more acceptable for people to accept Harvey's stable bubble nucleus mechanism hypothesis. Harvey believes that the undisclosed gas core may be present in a hydrophobic solid gap because in such cases the surface tension will act to reduce the pressure so that the gas is not forced to dissolve and may also remain in the gas phase status [3].

Cavitation is a fluid–specific compound hydrodynamic phenomenon, and the study of cavitation mechanism is of great significance. Most people have long been committed to suppressing the cavitation process, leading to the positive effect of cavitation has been ignored. The cavitation occurs with the collapse of the cavitation bubble, and instantly can release a lot of energy, the use of the energy can be achieved on the chemical and physical processes to enhance the effect, to achieve efficiency, energy saving, energy consumption effect. The study shows that the energy released by the cavitation process is many times higher than that of the same cost.

Typically, heaters are devices that require a large power source to operate and to provide an adequate amount of heat. For example, an electric space heater is continuously supplied with power from an electric power plant. Also, for example, a home's or building's heating system draws its heat from either a water boiler or a furnace. Other heaters need to burn consumables, such as oxygen and fuel, in order to generate an adequate amount of heat. The aforementioned heaters are cumbersome to operate in a variety of situations, one of which is in space exploration. The limited resources and storage space on a spaceship would make any of the aforementioned heaters difficulty to use in space exploration [4].

Cavitation–induced heating has a number of advantages in heating fluids. In the petroleum industry, cavitation–induced heating allows petroleum products to be heated directly in storage tanks in the field, on pipelines, or on barges to facilitate pumping and unloading in cold weather, and heavy oil products could be heated for processing without heat exchanger scaling. In ethanol production, cavitation–induced heating eliminates the need for a steam boiler and allows up to four steps in the distillation process to be combined, which reduces production time and cost. In dairy production, cavitation–induced heating results in reduced maintenance, since pasteurization would occur without direct contact between the milk and a heat exchanger surface. This is particularly beneficial in the pasteurization of high–fat dairy products. Cavitation–induced heating has also shown promising ability in generating relatively high concentrations (up to 40%) of hydrogen peroxide (H_2O_2) from tap water.

One of the most popular current applications, however, is a use of cavitation–induced heating to heat water. Therefore, an objective of the task is to produce heat without carbon dioxide (CO_2) pollution or dangerous radiation. Another objective of the present task is to produce heat without a large power source or without using consumables such as fuel or oxygen. The cavitation heat generator is a simple device for transferring the mechanical energy to the thermal energy in the working fluid, which realizes the effective conversion of energy and makes full use of the new energy way!

As early as the 1950s, the former Soviet Union, China, and the United States began to use low–pressure and large–flow water jets for hydropower coal mining experiments and applications and conducted a series of experimental and theoretical studies on continuous jets. Since then, developed countries have gradually extended their jet technology to other industrial fields. By the 1980s, jet technology has been widely used in industrial cutting, oil drilling, and chemical cleaning. With the further development of research and practice, many new high–efficiency jet technologies have emerged, such as abrasive jets, polymer drag reducing jets, and Cavitation jet.

Among these new types of jets, cavitation jets are among the more typical high–efficiency jets because of their high efficiency in cleaning and cutting, especially the potential advantages of oil drilling, underwater cleaning and cutting under submerged conditions. Researchers favor. Among them, Russia's research on hydraulic pulsed cavitation jet generators has significant implications for the heating of domestic or industrial water. There is no need to consume traditional fuels and eliminate exhaust gases. Using only the cavitation effect induced by cavitation nozzles to heat water is a potential research direction, which is of great significance for energy conservation and environmental protection [5].

2. Present situation and international research progress

The phenomenon of cavitation is a common phenomenon in nature. In 1753 Euler once pointed out: “If a certain pressure in a water pipe falls to a negative value, water separates from the wall, and a vacuum space will form in this place. Phenomenon should be avoided” [8]. This is the earliest description of the cavitation phenomenon. As early as more than 100 years ago, Parsons et al. studied propeller performance and found that when the propeller speed reached a certain limit, the motor power was increased, and the submarine forward speed did not increase but decreased [9]. The reason was that cavitation occurred at the propeller blades. Reduced propulsion, so Parsons for the first time, et al. proposed and used the term ‘cavitation’ C cavitation [6].

In 1917, Rayleigh theoretically analyzed the cavitation phenomenon, deduced the kinematics equation of the spherical vacuole in an incompressible fluid, and calculated the bursting time, the collapse velocity and the maximum pressure pulse in the liquid. Since then, many scholars have made unremitting efforts to continuously develop and improve cavitation theory [10]. In the past 100 years, cavitation (or cavitation) has been notorious for the cavitation damage of hydraulic machinery, hydraulic components, and many water conservancy projects. How to prevent and avoid cavitation erosion has always been an important research topic for scholars at home and abroad. With the development of research on cavitation mechanism, scholars at home and abroad are gradually realizing that if the huge damage energy released by cavitation is used, this will provide a new kind of physical and chemical process that is difficult or impossible to achieve under general conditions. Because of the special physical environment, how to make better use of the cavitation effect to benefit mankind has drawn increasing attention from scholars at home and abroad.

In the 1970s, with the development of waterjet technology research, people consciously combined cavitation and water jet technology to form a new theory of science — a cavitation jet theory. Among them, the most specific personage is Johnson and Kohl et al. [11]. Cavitation water jet is a new type of environment–friendly technology with high potential and high efficiency. The structural parameters design of the cavitation nozzle is one of its key technologies. In order to increase cavitation energy, researchers at home and abroad have developed various forms of cavitation nozzles. Chahine and Kalumuck improved the cavitation jet device to reduce the cavitation effect pressure from the original tens of MPa to less than 1 MPa [12].

In the 4th circum–Pacific International Water Jet Conference (https://goo.gl/y1T1rK), Erdmann et al. published experimental results for a variety of conical nozzles. Erdmann’s study showed cavitation nozzles with O.SD cylindrical parallel sections and 60° conical shrink angle structures under submerged conditions. Erosion works best Corm and Johnson et al. developed acoustically independent cavitation jet nozzles based on the principle of hydroacoustics. Helmholtz oscillating cavity nozzles (Helmholtz) and organ nozzles (Organ) are two of the most commonly used, self–resonant cavitations. Jet nozzles can generate cavitation jets in hundreds or even thousands of meters of deep wells and have a strong cavitation effect [13].

In the 1980s, scholars at home and abroad began to study more about the effect of nozzle outlet shape on cavitation. Prof. Yanaida of Japan showed that under the submerged condition, the angle nozzle's erosion volume to the target is an order of magnitude higher than that of the ordinary linear nozzle, and it is considered that the optimal half angle of the angled nozzle is 30 °C [14]. Academician Shen Zhonghou of the China University of Petroleum Research has shown that: When the pump pressure is fixed, the diffusion angle of the self–resonating cavitation jet nozzle is 120°, and the rock breaking volume is more than 3 times that of the ordinary conical nozzle. The combination of cavitation nozzles designed by Professor Yang Yongyin and the center body has improved the efficiency of rock fragmentation. Prof. Liao Zhenfang of Chongqing University studied the influence of the shape of the outlet runner of a self–oscillating pulsed cavitation jet nozzle on the cavitation effectiveness of cavitation jets both theoretically and experimentally [15]. It was applied to assisted cone drilling and the average penetration rate and bit footage were respectively Increase by 30% and 11%.

At the beginning of the new century, because the orifice plate has the advantages of simple structure, relatively small energy consumption and large cavitation range, it is favored by many scholars at home and abroad. At the same time, the study of vortex cavitation has also aroused great interest. The vortex cavitation invented by Georges (2011) and others uses the principle of negative pressure formed by the vortex center to greatly reduce the initial pressure of cavitation (less than MPa), thereby effectively reducing energy consumption. Wang Jingang and others used vortex cavitation to degrade rhodamine and received good results [7].

3. The theoretical basis of cavitation

Cavitation is the vaporization of liquid due to local low pressure in the liquid (below the saturated vapor pressure of the liquid at the corresponding temperature). The resulting microbubble (or gas core) explosive growth phenomenon. The process of cavitation can be divided into the following four stage：

(1) Initial cavitation: only very tiny vacuoles appear, and there is no obvious separation of the boundary layer;

(2) Flaky cavitation: At this time, the cavitation number decreases, and the continuous gas phase begins to appear. From the appearance, the flaky cavitation is like a finger;

(3) Cloud cavitation: The cavitation number is further reduced, a large number of cavitation bubbles appear, and there is a large cluster of white mist;

(4) Supercavitation: it is at the final stage of the development of cavitation, the pressure dropped to a very low level and eventually collapsed with the recovery of pressure.

After the initial growth of vacuoles, as the time increases, the vacuoles will develop and expand, and when the liquid pressure around the vacuoles increases, it can be seen that the vacuole will shrink or even collapse. Because the vacuole generally contains a small amount of non-condensing permanent gas, it is empty. The bubble will not completely disappear and disappear immediately, but the collapse and rebound regeneration alternately occur. The size of the vacuole is regenerated every time. Decrease once until it does not vanish with the naked eye. Initial, expansion, contraction, collapse, regeneration of vacuoles until the most the process that disappears later is called cavitation or cavitation.

Overall, cavitation has the following characteristics:

(1) There is a large amount of energy released during cavitation, which can produce high temperatures. Extreme conditions such as high pressure, high turbulence, high jet, etc;

(2) Cavitation is a dynamic process in stationary or flowing liquids. Without helium solids or gas shutoff, this phenomenon does not occur under normal conditions;

(3) Cavitation It is the result of the pressure drop in the liquid. As long as the monthly pressure is reduced, and the critical pressure determined by the nature of the liquid is determined by r, the cavitation may occur. Therefore, it is possible to control the pressure to control the occurrence of cavitation and its change;

(4) Cavitation is a physical change process that involves the whole process of growth, compression and collapse of a vacuole.

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