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SUPERCAVITATION

Nirav Shah[1], Prathmesh Satam[2], Bansal Simaria[3]

[123.] *Shri Bhagubhai Mafatlal Polytechnic, Vile Parle (w), Mumbai-56, (India)*

ABSTRACT

Water limits even nature's strategies & fastest bird moves twice as quickly as the fastest fish. The phenomenon holding back the fish is tremendous resistance the water offers to a moving object, called a drag. The same drag acts on the bird as well, but the magnitude is considerably less owing to the lesser density of air. The human being has crossed the sound barrier in air & land but not underwater. Being 1000 times denser than air, water offers resistance roughly 1000 times as high as that in air. Supersonic underwater travel is dream of scientists working on a bizarre technology called SUPERCAVITATION. Supercavitation is state of the art technology that may revolutionize underwater propulsion systems. Supercavitating bodies can achieve very high speeds under water by virtue of reduced drag: with proper design, a cavitation bubble is generated at the nose and skin friction is drastically reduced.Depending on the type of device under consideration, the drag coefficient can be an order of magnitude less than that of a fully wetted vehicle.This presentation provides an overview of recent research in this topic, including the results of selected experiments with supercavitating projectiles at supersonic speeds in water, experiments involving systems suitable for self-propelled vehicles, and several topics in computational methods and simulation.

Keywords: Cavitation, Drag, Supercavitation.

I. INTRODUCTION

The considerably large density of water of over 1000 times of that of air reduces the speeds of the objects underwater by the same amount due to the drag exerted on the body of the object. Drag is simply the frictional resistance between the two contact surfaces having relative motion by virtue of the density, viscosity and molecular properties. This phenomenon limits underwater travel because of which it is difficult to achieve high propulsion speeds. This is where supercavitation comes into picture.

Supercavitation is a hydrodynamic process in which an undersea body is almost entirely enveloped in a layer of gas initiated at a cavitator mounted at the forward end. A supercavity can be maintained in one of two ways: (1) by achieving such a high speed that the water vaporizes near the nose of the body; or, (2) by supplying gas to the cavity at nearly ambient pressure. The first technique is known as vaporous cavitation; the second is termed ventilation, or artificial cavitation.

Supercavitating bodies can achieve very high speeds under water by virtue of reduced drag: with proper design, a cavitation bubble is generated at the nose and skin friction drag is drastically reduced. Because the density and viscosity of the gas are dramatically lower than that of seawater, skin friction drag can be reduced significantly. If the body is shaped properly, the attendant pressure drag can be maintained at a very low value, so that the overall body drag is also reduced dramatically: by roughly eighty percent for a self-propelled vehicle capable of executing maneuvres, to an order of magnitude for free-flying gun-launched projectiles. However, because the

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centre of pressure is typically located well forward with respect to the centre of gravity, control and maneuvering present special challenges. Also, whereas a fully wetted vehicle develops substantial lift in a turn due to vortex shedding off the hull, a supercavitating vehicle does not develop significant lift over the gasenveloped surfaces. This requires a different approach to effecting hydrodynamic control.

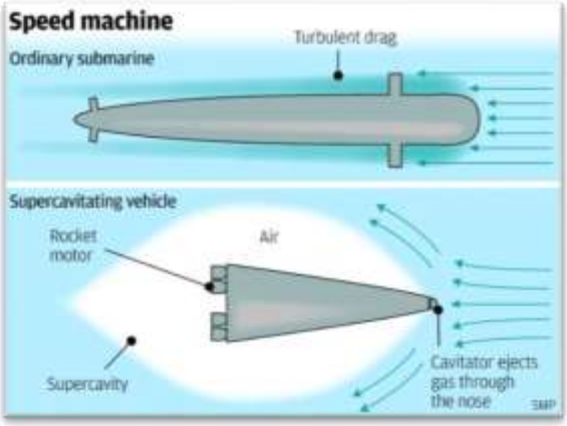

Fig. 1.difference between ordinary and supercavitating vehicle

II. CAVITATION & SUPERCAVITATION

2.1 CAVITATION

Cavitationis the formation of vapour cavities in a liquid – i.e. small liquid-free zones (bubbles or voids) – that are the consequence of forces acting upon the liquid. It usually occurs when a liquid is subjected to rapid changes of pressure that cause the formation of cavities where the pressure is relatively low. When subjected to higher pressure, the voids implode and can generate an intense shockwave.

Cavitation becomes a blessing under a condition called Supercavitation i.e., when a single cavity called supercavity is formed enveloping the moving object almost completely. In Supercavitation, the small gas bubbles produced by cavitation expand and combine to form one large, stable, and predictable bubble around the supercavitating object.

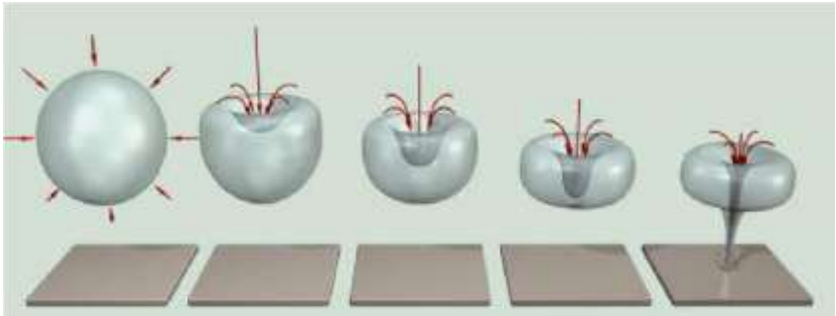

Fig. 2 effect of cavitation

Fig. 3 damaged component due to cavitation

2.2 Supercavitation

A SUPERCAVITATING OBJECTis a high speed submerged object that is designed to initiate a cavitation bubble at the nose which extends past the end of the object substantially reducing the skin friction drag that would be present if the sides of the object were in contact with the liquid in which the object is submerged. A key feature of the supercavitating object is the nose (cavitator), which may be shaped as a flat disk or cone behind which the cavitation bubble forms. If the bubble is of insufficient length to encompass the object, especially at slower speeds, the bubble can be enlarged and extended by injection of high pressure gas near the object's nose.

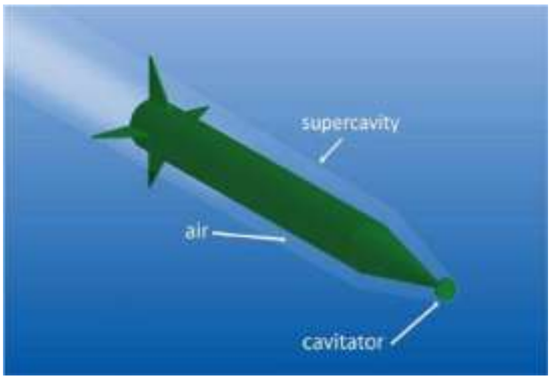

Fig 4 Supercavitation Model

There are two types of Supercavitation captive models used:

2.2.1 Disk Caviator

2.2.2 Conical Caviator

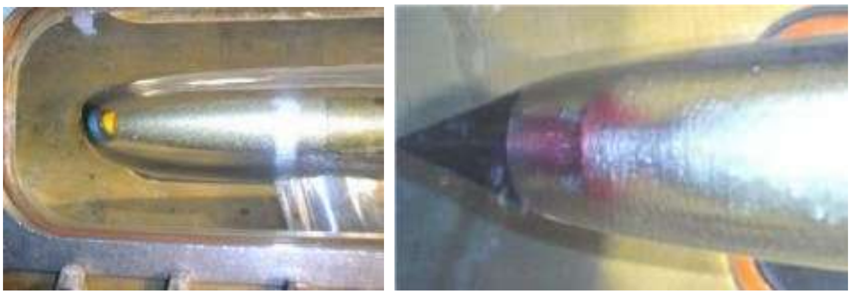

Fig 4 & 5 Disk & Conical Caviator

III. APPLICATIONS

3.1 Supercavivitating Torpedos

The nose of a supercavitating torpedo uses gas nozzles that continually expel an envelope of water vapor around the torpedo as it speeds through the ocean. This bubble of gas--a 'super cavity'--prevents the skin of the torpedo from contacting the water, eliminating almost all drag and friction and allowing the projectile to slide seamlessly through the water at great velocity. Some people have described supercavitating torpedoes as the first true underwater missiles.

The first such weapon in this class, the Shkval ("Squall"), was in development by the Soviet Union throughout the latter half of the Cold War but was not recognized in the West until the 1990s. Using powerful solid rocket motors, the Shkval is capable of speeds exceeding 230 mph, over four times the velocity of most conventional torpedoes. The Shkval also has a reported 80% kill rate at ranges of up to 7000 meters.

The US navy is seeking to build its own version of the Shkval, but one with a much higher velocity. This is mostly in response to Russia selling stripped down versions of the Shkval on the open international weapons market. However, a US combat-ready version is not expected for at least another 10+ years.

The technology does have one great weakness--maneuverability. The bubble of water vapor generated by the gas nozzles tends to become asymmetrical and breaks up along the outer side of the turn if the torpedo alters its course significantly. At the speeds such a torpedo would typically be travelling, the sudden re-assertion of water pressure and drag on it could not only severely knock it off course, but may even rip the projectile apart. A new, improved version of the Shkval has been reported in use by the Russian Navy, one that can maneuver and track its intended target. However, it was also reported that in order to do so, this improved Shkval had to slow down significantly once in the general area of the target so it could scan and home in on its prey like a normal torpedo. While a genuine improvement, the true goal of current research is to have the torpedo maneuver and home in on a target without the need to decrease its velocity. Both Russian and US Navy researchers are striving toward this end.

One means of making sure the gas bubble does not wear down upon a turn would be by having the gas-ejection nozzles pump more water vapor into the side of the bubble that's on the outside of the turn, to provide the torpedo with a thick enough "buffer" for the turn without any more parts of it exiting the cavity. Another option might be to magnetically charge the vapor used in the torpedo’s bubble, and use a magnetic field to hold the bubble cohesive while it turns.

Another weakness of the technology is that the Shkval is both very noisy and shows up very readily on sonar. Whereas some long-range conventional torpedoes might be able to stealth relatively close to their targets before going active, the target of a supercavitating torpedo will know right away if they're in the bulls-eye. However, the supercavitating torpedo may also be travelling fast enough to give its intended victim much less time to take effective countermeasures.

A drawback that had been pointed out in several articles is that the Shkval and its peers only have ranges of several kilometers, whereas a number of modern torpedoes, like the US Mark 48, has a range of over 30 nautical miles. It’s possible that a US submarine could just sit outside of Shkval-equipped submarine's range and pound on such an enemy with impunity.

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The downside to that strategy is, of course, that most subs are unlikely to be equipped only with supercavitating projectiles. Like most modern combat subs, they will likely carry a variety of different weapons for different purposes, and the Shkval will just be one of the weapons it has in its arsenal. One can assume at long ranges they will likely employ conventional torpedoes, but once within the effective kill-range of a Shkval, they will use their supercavitating weapons to fullest possible effect. Also, it is almost a certainty that all parties engaging in research are striving to increase the weapon's range as much as possible.

Submarines, even with minimal warning, can evade a supercavitating torpedo by blowing some ballast and quickly ascending. However, an enemy submarine captain may anticipate this, and may launch a second or even a third Shkval simultaneously, aimed above the target submarine, in order to keep the enemy vessel from attempting this maneuver.

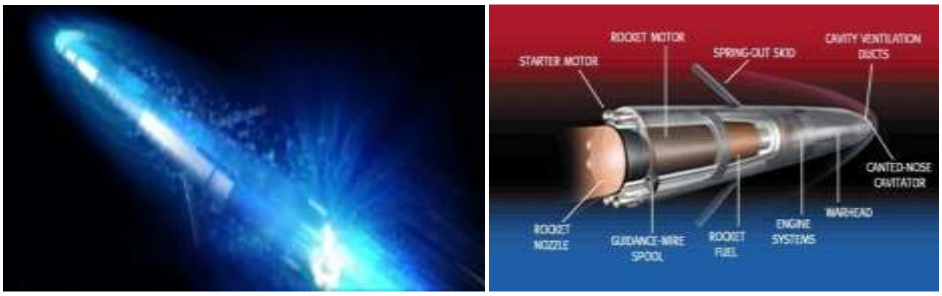

Fig.6&7 shkval torpedo

3.2 Supercavivitating Propellers

The supercavitating propeller is a variant of a propeller for propulsion in water, where supercavitation is actively employed to gain increased speed by reduced friction. In general, subcavitating propellers become less efficient when they are running under supercavitating conditions.

The supercavitating propeller is being used for military purposes and for high performance boat racing vessels as well as model boat racing.

The supercavitating propeller operates in the conventional submerged mode, with the entire diameter of the blade below the water line. The blades of a supercavitating propeller are wedge shaped to force cavitation at the leading edge and avoid water skin friction along the whole forward face. The cavity collapses well behind the blade, which is the reason the supercavitating propeller avoids the erosion damage due to cavitation that is a problem with conventional propellers.

An alternative to the supercavitating propeller is the surface piercing, or ventilated propeller. These propellers are designed to intentionally cleave the water and entrain atmospheric air to fill the void, which means that the resulting gas layer surrounding the propeller blade consists of air instead of water vapour. Less energy is thus used, and the surface piercing propeller generally enjoys lower drag than the supercavitating principle. The surface piercing propeller also has wedge shaped blades, and propellers may be designed that can operate in both supercavitating and surface piercing mode.

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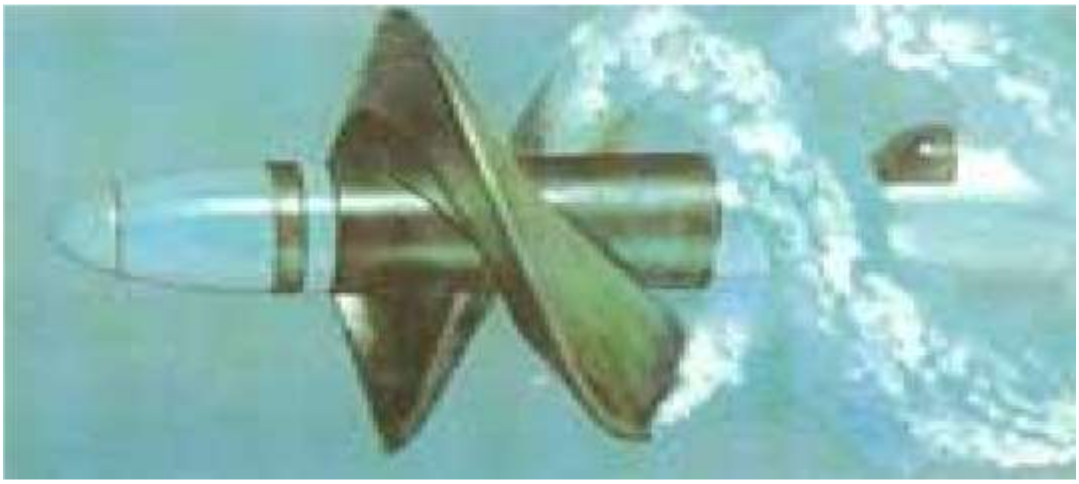

Fig. 4 supercavitating propeller

3.3 Supercavivitating Vehicles:

Recent investigations into high-speed underwater vehicles have focused attention on providing vehicles which ride a cushion of air to achieve high speeds in water. For a nominal prior art streamlined, fully-wetted underwater vehicle, 70% of the overall drag is skin friction drag; the remainder is pressure or blockage drag. Supercavitation allows for much higher speeds to be sustainable by eliminating, or drastically reducing, skin friction drag at the higher speeds. The conditions for supercavitation require that enough energy be put into the water to vaporize a given volume of water through which an object can travel. This is done by accelerating fluid over a sharp edge, usually the nose of a vehicle, such as a torpedo, so that the pressure drops below the vapor pressure of water. If the speed of the object is not fast enough to travel through the vapor cavity before the cavity collapses, artificial ventilation into the cavity can keep the cavity "open" until the object moves past. When a cavity completely encapsulates an object, by vaporous and/or vented cavitation, it is referred to as "supercavitation". The vehicle nose, or "cavitator", is the only part of the object in constant contact with the water through which the vehicle travels. The cavity closure is positioned behind the vehicle.

When the cavitator and artificial ventilation generate the necessary cavity properties, i.e., sufficient length and diameter of air cushion, it results in a larger air gap between the vehicle and water than is otherwise necessary at the after end of the vehicle. The air, or other selected gas, is drawn through the gap by a propulsion jet plume, and escapes into the ambient water. It has been found desirable to minimize the downstream entrainment effect of the propulsion plume, to thereby minimize loss of air and to increase life expectancy of a reservoir of ventilation air on-board the vehicle.

A supercavitating vehicle is an advanced concept for achieving very high speeds underwater with significantly less drag than a conventional vehicle. The idea behind this concept is the enshrouding of a vehicle moving through water in a gas cavity. A vehicle is said to be supercavitating when the cavity extends from around the nose to just beyond the tail of the vehicle. Part of the nose of the vehicle, called the cavitator–and, possibly, some control fins–would be in wetted contact with liquid water, but the rest of the surface of the vehicle would remain in contact with gas only (inside the cavity). The gas is much lower in density and viscosity than the surrounding water. Depending on the design, the gas could be water vapor, air, or something else. Due to the lower density and viscosity of the gas, this conceptually results in significantly less drag than a similar, but fully wetted vehicle.

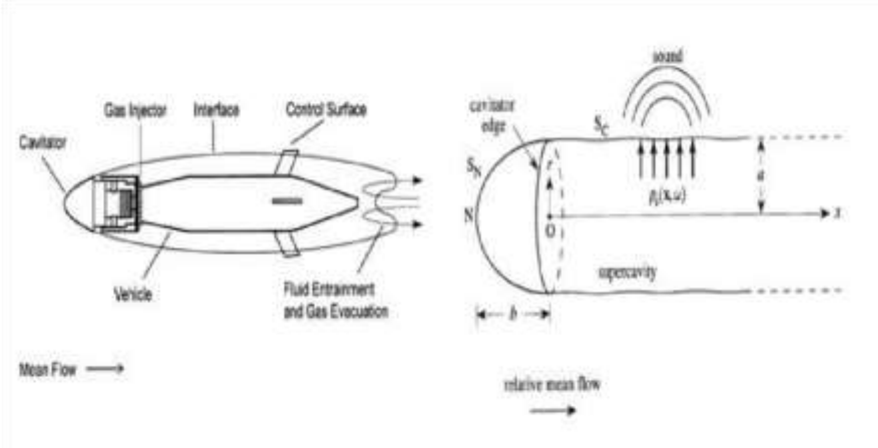

Fig. 7 Schematic Diagram of Supercavitating Vehicle

IV. CONCLUSION

This is an overview of recent basic research and exploratory development results in the topic of supercavitating high-speed bodies. The focused effort by a nationwide team of scientists and engineers over the last decade has resulted in an improved over the last decade has resulted in an improved understanding of the physics of these devices, as well as an enhanced capability to predict their performance and assess their utility. The confidence gained in overcoming the many technical challenges associated with vehicle and projectile operation at very high speeds underwater has positioned the Navy to set more challenging objectives for the next few years, including field testing of free-flying vehicles in maneuvers. Continued development of the resources established to date will help ensure that such activities can be carried out safely and cost-effectively.

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