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A CASE STUDY ABOUT SUPERCAVITATION

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Abstract - Water is the most challenging environment for an Engineer. Being 1000 times denser than air, it offers resistance roughly 1000 times higher than air. Water limits even nature's strategies, and the fastest bird moves twice as quickly the fastest fish. The phenomenon holding back the fish is the tremendous resistance that water offers to a moving object, called drag. The same drag acts on the bird as well, but the magnitude is considerably less owing to the lesser density of air.

Supersonic under Water Travel is the dream of scientists working on a bizarre technology called SUPERCAVITATION. Supercavitation is the state of the art technology that may revolutionize underwater propulsion systems

Key Words: Cavitation, Drag, Supercavitation

1.INTRODUCTION

Cavitation is the process of formation of vapour bubbles of flowing fluid in a region where the pressure of the liquid falls below its vapour pressure and then the sudden collapsing of these vapour bubbles in high pressure regions. At first small vapour filled bubbles are formed that gradually increase in size. As the pressure of the surrounding liquid increases, the cavity suddenly collapses ,a centimeter sized cavity collapses in milliseconds. Cavities implode violently and create shock waves that dig pits in exposed metal surfaces.

At first, the physical characteristics of boiling and cavitation are almost identical. Both involve the formation of small vapour-filled spherical bubbles that gradually increase in size. However, the bubbles produced by the two processes end in very different manners. In boiling, bubbles are stable: the hot gas inside either escapes to the surface or releases its heat to the surrounding liquid. However incase of cavitation, the bubble does not collapse, but instead fills with fluid as the gas inside condenses.

Since the shock waves formed by Cavitation are strong enough to significantly damage moving parts, Cavitation is usually an undesirable phenomenon. It is specifically avoided in the design of machines such as turbines or propellers, and eliminating Cavitation is a major field in the study of fluid dynamics.

When it acts upon propellers, Cavitation not only causes damage but also decreases efficiency. When a propeller induces significant Cavitation, it is pushing against a combination of liquid water and water vapor. Since water vapor is much less dense than liquid water, the propeller can exert much less force against the water vapor bubbles causing the propeller blades to "race" and spin ineffectively. With the problems it causes, it is no wonder that engineers try to avoid cavitation

Fig1: Effect of Cavitation on Propeller

1.1 Supercavitation

The scientists and the engineers have developed an entirely new solution to the cavitation problem. 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.

Supercavities are classified as: vapor or ventilated. Vapor cavities are the pure type of supercavity, formed only by the combination of a number of smaller cavities. In a ventilated cavity, however, gases are released into the bubble by the supercavitating object or a nearby water surface.

It is a means of drag reduction in water, wherein a body is enveloped in a gas layer in order to reduce skin friction. Thus Supercavitation is the use of Cavitation effects to create a large bubble of gas inside a liquid, allowing an object to travel at great speed through the liquid by being wholly enveloped by the bubble. The cavity (the bubble) reduces the drag on the object, since drag is normally about 1,000 times greater in liquid water than in a gas.

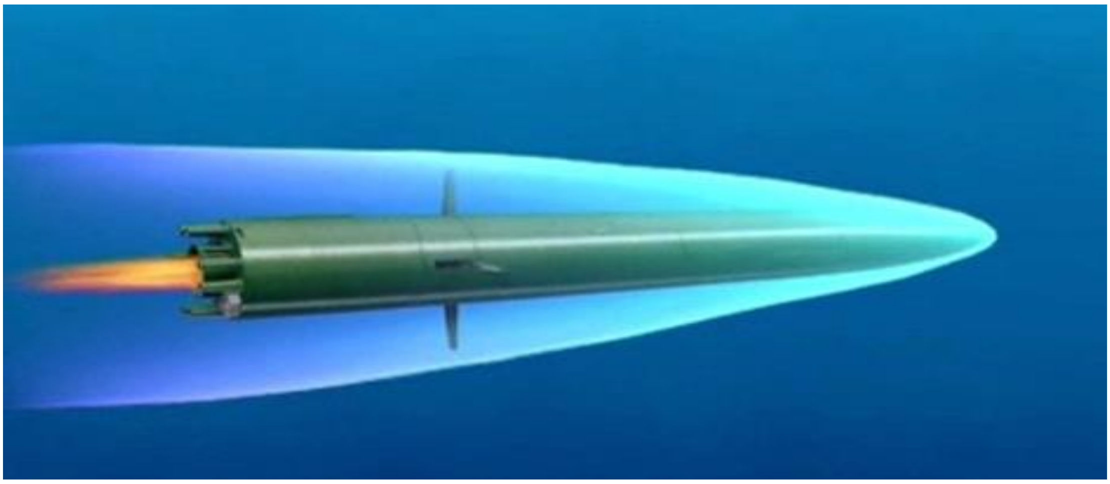

Fig 2: A supercavitating Torpedo

Fig3: Supercavitating Boat 'Ghoast'

2. Disadvantages of Conventional Underwater Propulsion systems

The problem holding back conventional propulsion systems from high speeds is the drag. No matter how streamlined an object is, it suffers resistance as it moves through a fluid. One source of friction is the skin friction, the force that is required to shear the thin layers of fluid lying against the moving body's surface. This happens in air too, but water being thousand times denser than air generates a drag thousand times more than air. Moreover, the power required to overcome drag is proportional to the cube of its velocity. So, each incremental improvement in propulsion technology produces only a meager increase in speed.

Torpedoes are mostly the fastest propelled objects moving under water. It is drag which is the main factor that limits the speed of conventional torpedoes. At high speeds drag is so enormous that efficiency of propulsion is very low. Modern torpedoes can reach speeds below 180 km/hr. The idea of an entirely new under water propulsion system owes its birth to the cold war. In the early 60's Russian torpedoes were inferior to those of Americans in speed. Rather than trying to improve the conventional technology, the Russians decided to try to leapfrog the Americans with a radical solution.

3 A Supercavitating Projectile

For a body to be supercavitating, it has to be cruising very fast at least with a speed of 180km/hr. which is far faster than ordinary torpedoes. The nose rather than being streamlined should be flat. Thus, at high speeds water is forced to flow off the edge of the nose at such an angle that it cannot wrap around the surface of the body. As it passes over the edge it vaporizes due to high velocity. Thus, a big cavity is formed which encloses the front part of the object. If we could make this cavity enclose the entire body most of the drag could be eliminated. This is possible by two ways. If the body is fast enough so that the entire length of the body passes through before the cavity collapses, it will appear as if the cavity is traveling along with the body. If the object is not fast enough to travel through the vapor cavity before it collapses, then artificial ventilation into the cavity can keep it open until the object moves past. Once a super cavity is formed which completely encloses the object, the drag force is nearly eliminated as the only portion in contact with liquid is the nose. Only the leading edge of the object actually contacts liquid water. The rest of the object is surrounded by low-pressure water vapor, significantly lowering the drag on the supercavitating object. With an appropriate nose shape and a speed over 180 km per hour, the entire projectile may reside in the vapor cavity. Since drag is proportional to the density of the surrounding fluid, the drag on a supercavitating projectile is dramatically reduced, allowing supercavitating projectiles to attain higher speeds than conventional projectiles. In water, a rough approximation predicts that a supercavitating projectile has 200,000 times less skin friction than a normal projectile. Thus, the potential applications are impressive.

4 Making a supercavitating projectile

Although the idea may seem simple, making a supercavitating projectile is a daring challenge. The technological hurdles to be overcome are many. The most important question is how to propel the body if no other part except the nose is in contact with the surrounding fluid. Also, the enormous drag exerted on the blunt nose would literally crush any material.

4.1 Propelling the Object

When a supercavitating projectile is enclosed by a cavity conventional propulsion technique cannot be used. A rocket engine is a solution. As the cavity encloses the vessel it is similar as flying in the air. Therefore, by using a rocket engine high speed can be attained which in turn helps for retaining the cavity.

When the projectile is fired from above water it pulls along with it a ventilated cavity which is unstable but as supercavitation starts this ventilated cavity is converted to vapor cavity. Then the rocket motor is fired and using the exhaust the cavity can be stabilized. A rocket motor also provides an immensely powerful thrust, enabling the object to achieve high velocities. The overall drag reduces enormously once it reaches the supercaviting regime and then increases only linearly with speed.

An aluminum burning rocket is an answer to a compact and efficient propulsion system. It would use water as its oxidizer and so would not need to carry oxygen. The problem with aluminum has been that unreacted fuel quickly becomes coated with aluminum oxide, inhibiting any further reaction. To avoid this, powdered aluminum can be injected to a vortex of water, which keeps the molten drops apart.

Using a rocket motor has another advantage. The exhaust from the motor can be used to ventilate the cavity and stabilize it. The exhaust can be ducted round from just behind the nose which strengthens the existing cavity and expands it to a bigger one. Thus, the cavity can be retained much longer.

4.2 The Nose

The nose being the only part in contact with water is subjected to extremely high stresses. Ordinary materials under these conditions will buckle and eventually crush. So, in order to withstand such high stresses nose must be made of materials hard as well as light weight. Lightweight materials like carbon composites in honey comb structure can be used.

Unlike conventional noses, a supercavitating body has a rather blunt nose. Water is forced to flow off the edge of the nose at such an angle that it cannot wrap around the surface of the body.

If the projectile is of the correct shape, a bubble of air starts to form around the object... This extends to cover the entire projectile, and hence the cavitating object is no longer moving through water, but through air which creates but a fraction of the friction! Hence supercavitating projectiles can travel with a speed of about 200 knots.

4.3 Other Challenge's

At the present time only supercavitating weapons are under development. The major challenges in the implementation of this technology are the following.

I. Inside the cavity the projectile is very unstable. A projectile dropped into water draws a column of air down with it, creating a temporarily ventilated cavity that reduces drag on the torpedo. The air eventually leaks out, but if the torpedo is moving fast enough the collapsing ventilated cavity is replaced by a vapour cavity.

II. The splashing tail problem can be solved by making the cavity bigger by ventilating it by the exhaust of the rocket engine from just behind the nose at the front and from the rear. But my making the cavity bigger we are increasing the instability. Since only the nose touches the water, the maneuvering is tough.

III. Another big challenge is how to steer a supercavitating vehicle. Specially designed retractable control fins that come in contact with water only when required to steer are a solution. However, there are technological hurdles yet to be overcome.

IV. The pressure that the nose has to withstand at high speeds will be very high. So, the right selection of the material is another challenge. The use of composite lightweight materials like graphite epoxy or aluminum honeycomb will be effective.

5 Future Scope of Supercavitation

Far from now this simple cavitating theory could bring us the ultimate fighting machines. Sub fighters racing around beneath the waves at thousands of kilometers per hour... Massive underwater sub fighter carriers silently gliding through the deep blue. It may seem like fantasy, but it's the future.

Supercavitation does not only have tremendous scope in military developments and applications but it is also sure to revolutionize underwater travel. The day is not far away when pencil shaped, rocket powered vehicles break the sound barrier underwater.

6 Conclusion

As is the case of most cutting-edge technologies, supercavitation is largely concentrated around military developments and applications. Very little is known outside about the recent advancements in detail, as they are closely guarded military affairs. However, this technology is sure to revolutionize underwater weaponry and travel. Under water bullets have already broken the sound barrier in water. The day is not far away when pencil shaped, rocket powered vehicles break the sound barrier underwater

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