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Research Article

The Science Behind Titan Submersible Implosion - Insights From Physicists

Praveen SS[1], Aswathy Vijayan[2], Sajith Babu[3], Thulasi KPK[4]

[1,2]St. Thomas College Kozhencherry, Pathanamthittta, Kerala, India.
[3]Catholicate College Pathanamthitta, Kerala, India.
[4]St. Marys HS for Girls, Payyannur, Kannur, Kerala, India.
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I N F O

Corresponding Author:
Praveen SS, St. Thomas College Kozhencherry, Pathanamthittta, Kerala, India.
E-mail Id:
sakalyapraveen@gmail.com
Orcid Id:
https://orcid.org/0000-0003-3544-0359
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A B S T R A C T

The scientific expedition team of OceanGate company based in Canada in the North Atlantic Ocean off the coast of New found land, Canadatrip led an adventure tourism to the deeper waters of ocean for viewing the debris of Titanic ship. The expedition took off from the shores of the Atlantic Ocean on June 18,2023 which imploded on the subsequent days causing fatal causalities. Lot many discussions are engulfing around unraveling the reason behind this implosion.At this juncture,this investigation is an attempt to scientifically portray the causative factors behind this implosion.For this investigation data, reviews, opinions, newspaper reports etc were collected / collated and based on this scientific conclusions were derived. This paper is a review about titan implosion by unraveling the possible causative factors behind this, primarily based on several technical reports and news that appeared in the fourth estate.

Keywords: Submersible, Ocean Gate,Pressure, Implosion, Carbon fibre

Introduction

There is an ongoing misnomer concerned with equalizing submersible and submarine. Submersible and submarine are two different entities.The term submarine means under water or under sea. Submarine is a watercraft which is capable of propelling on the water surface or beneath the sea. But the submarines are entirely different from the surface ships in their construction, design and their physical appearance. It is a self-propelled watercraft. The submarine played a well-defined role in the first and second world war. Germany used this submarine as their primary weapon to destruct the surface merchant vessels. The submarine is also called subs. The major use of this submarine is to travel under the sea for research and military purposes. Submarines have the uniqueness to travel both beneath the ocean and on the surface of ocean. Militaries use this submarine to identify their enemies at the right time during war.

Submersible is an underwater craft which are self-supporting and capable of independent operations. Submersible find variety applications in ocean exploration, oceanography, adventure, underwater videography, equipment maintenance, oil and gas exploration. The first submersible was also constructed and designed for war. The major difference between submarine and submersible is that submersible is not fully autonomous (Caroll et.al,2015). It is a short-range watercraft and specially designed for operating in underwater environments. It has an ability to fully submerge in to the sea water and sometimes it is controlled by remote, manually or by programmed robot. It

provides human occupancy facility too. So hence the name human occupied vehicle. Most of its function is under the sea water, but it has little function on the water surface. The parts of a submarine are

1. **Pressure Hull:** It holds the submarines crew and machinery. The sea water experiences high pressure due to the depth. So this pressure hull keeps each and everything inside the submarine safely without any damage from pressure variations when it is beneath the sea.
2. **Ballast Tanks:** Ballast tank is the one of the major parts to maintain and control the buoyancy of the submarine. These are designed at each end of the submarine unit to adjust their buoyancy. This helps the submarine to get immersed or submerged in to the sea water.
3. **Diving Planes:** These are the movable surface of the submarine unit which is placed on the outside of the submarine. This diving plane control and coordinates the movements of the submarine under the sea water.
4. **Rudders:** The rudder is used to control the ship by steering. The crew men can steer the ship by turning the rudders to left and right. The crewmen control this submarine by steering the rudder to make the submarine change its front and rear directions.This rudder is situated at the bottom of the submarine to control its direction and to reach the correct destination.
5. **Hatch:** It is situated on the submarine just before the rudders and it is used to protect the cargo from the water waves without any damage and loss.
6. **Control Center:** It is located on the top of the surface of the submarine and it controls the proper functioning of the ship.
7. **Sail:** It is also known as command tower because of its function. It is the place for navigation and control equipment. This sail is situated atop of the submarine for the proper navigation.
8. **Periscope and Electronic Monitors:** It is used to monitor each and every status of the submarine when the submarine is under the sea water. Electronic monitors display surrounding condition for the safe journey.
9. **Sonar:** Sound navigation and ranging is used to detect the sea depth, fishing, sub- surface submarines, obstacles etc.
10. **Torpedo Room:** It used to load the bullets.
11. **Batteries:** It provides the power support to the submarine when it is under the sea.
12. **Nuclear Reactor**: It also provides electricity for submarine.
13. **Engine Compartment:** The main function of the engine is to control and regulate the overall activities of the submarine including their movements.
14. **Propeller:** It is used to run the ship in the correct way by spinning and it is located at the end of the submarine.

Submersible have a limited propulsion system and power system to their movements. It has external cameras to observe the surrounding environment to identifying the obstacles, direction etc (Caroll et.al,2015). It doesnot have any ballast system to control the buoyancy. The pressure vessel of the titan submarine has five major components. It contains two hemispherical end cap, two interface ring and a cylindrical hull made up of carbon fiber. The hemispherical end cap helps the crew members to enter into the submersible and exit from the submersible (Caroll et.al,2015). Titan submersible also contains landing skid and shell (Oleson et.al,2020). These two are already attached to the interface ring.The parts of the Titan submersible are shown in Figure1.

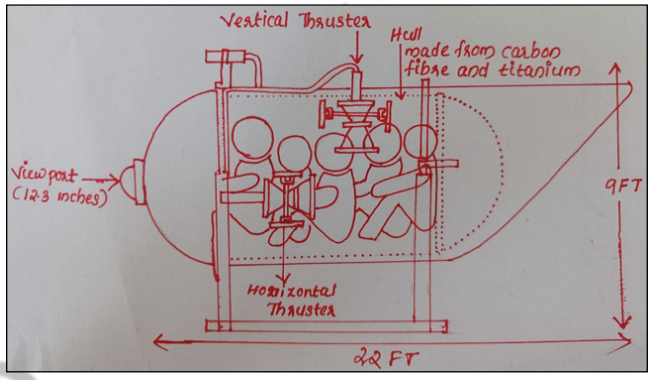

Figure 1.Parts of the Titan submersible

Ocean Gate Company

It is an American based company. The headquarters of this company is in Everett ,Washington(US) and it was established in 2009 by Stockton rush and Guillermo Sohnlein. This submersible is used for tourism, underwater diving, research, exploration etc. The first submersible of Ocean Gate was named as Antipodes and the very first tourist journey was started in the year 2010(Oleson et.al,2018). It is having a steel hull where five occupants can reside. The main activity engulfs around renting this submersible mainly for research, tourism and other adventures.

Titan was earlier called Cyclopes2. It imploded on 18 June 2023 on the voyage to visit the shipwreck debris of Titanic. It was created and fully controlled by Ocean gate and it was completed in 2018. Four innerspace thrusters were used for the propulsion.The test depth of the titan submersible was up to 4000 m. The capacity of the titan submersible is five and it includes one pilot, one technical expert, three mission specialists besides having researchers and tourists in payment basis. The company built two submersibles namely cyclops I and Titan. They charged 250,000 US$ (Around 2 crore INR) on an Ocean Gate expedition to titanic shipwreck destination to the passengers to explore the underseas. On June 18 (2023), Titan started their voyage to the shipwreck site and killed 5 people including one

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of its founders. The rescue operation teams reached on June 22,2023 at the shipwreck site and they discovered its damaged debris about 500 m from the Titanic wreck site.

Features of Titan Submersible

The general features of Titan submersible can be summarized as follows. It is having a length of 6.7 m and height of 2.5 m. It is having four inner space thrusters and its maximum velocity is 5.6 Km/h. It can traverse a depth of 400 m with a carrying capacity of 5 nos. Its weight is around 9600 Kg with a maximum payload of 685 kg. It has a major pressure vessel and the pressure vessel consists of 5 major components. The submersible is equipped with a real time monitoring acoustic system for communication. The monitoring systems in the submersible continuously monitor the strength of the hull with different backup systems including balloon thrusters, pneumatic pumps and sand bags . OceanGate company used to organize multiple time period excursions and it was the fifth adventurous trip which got imploded. The voyage and disappearance can be summarized as follows. The descent started on 18 June at 9:30 a.m with the help of parent ship Polar Prince. Soon after the descend Titan , communicated with the parent ship during every 15 minutes. That communication continuously happened for the first 90 minutes. Thereafter communication stopped and it did not resurface at the expected time that was 4.30 PM. Subsequently rescue operations were held involving United States Coast Guard, United States Navy, Canadian Coast Guard. Besides Aircrafts from the Royal Canadian Air Force and United States Air National Guard, too participated in this search operation. Several commercial / research ships and remotely operated underwater vehicles (ROVs) also participated extensively in the rescue retrieval operation as reported by Wikipedia. Finally on 22 June the U.S. Coast Guard's reported the presence of Titan debris near the wreck of the Titanic killing all five tourist occupants.

Reasons behind Titan Submersible Implosion

The layers of Ocean can be Broadly Classified as

1. **Epipelagic Zone:** This is the outer surface layer of the ocean so it is also called sunlight zone. This is extended from the surface to 200m.This layer is in direct contact with the surface. So it experiences variations in temperature. The wind allows the heat to distribute vertically over the surface.
2. **Mesopelagic Zone:** This is located just below the Epipelagic zone extending from 200 m to 1000m. It is called twilight zone or mid water zone because this layer receives only feeble sunlight. This layer also experiences temperature changes as per varying seasons and years.
3. **Bathypelagic Zone:** The depth of this layer ranges from 1000 to 4000m. Due to this depth this layer experiences darkness. So, it is called midnight zone. The only light evolved here is due to the presence of bioluminescence. The pressure in the bathypelagic zone is extreme.
4. **Abyssopelagic Zone:** This is extended from 4000 to 6000m. This is considered as a pitch black bottom layer of the ocean. Only few creatures live here because the temperature is constantly near freezing.
5. **Hadalpelagic Zone:** This is the deepest zone of the ocean and extends from 6000 to the bottom of the ocean. Here the temperature is constant at just above the freezing point.
6. **Pressure:** Pressure variations happen for objects/ humans while comparing the positions above the ocean and beneath the ocean. It means that a person sitting on the land and a person beneath the ocean water will experience huge pressure variations. A human being sitting on the land terrain will experience a pressure of 1 atm that is equal to 1 kg/cm^2.It indicates that for a square area of 1cm in human body, the pressure weight will be as equivalent to that of placing 1 kg weight box (Figure 2). It all depends upon the layers of ocean and its equivalent depth with reference to the surface of water level If that person is moving deep into the ocean up to 20 m the pressure will be 2kg/cm^2.Likewise, 3 m-3kg/cm^2.1000m-100kg/cm^2. At 3800m where the debris of the Titanic is supposed to be there and where the submersible is expected to land, the pressure will be around 380kg/cm^2 that means very much greater in dimensions. Figure 3 represents the pressure variations in different depth layers The passengers of Titan submersible and the submersible were defending themselves from this huge pressure during this expedition and it attributes towards the first causative factor behind this implosion.

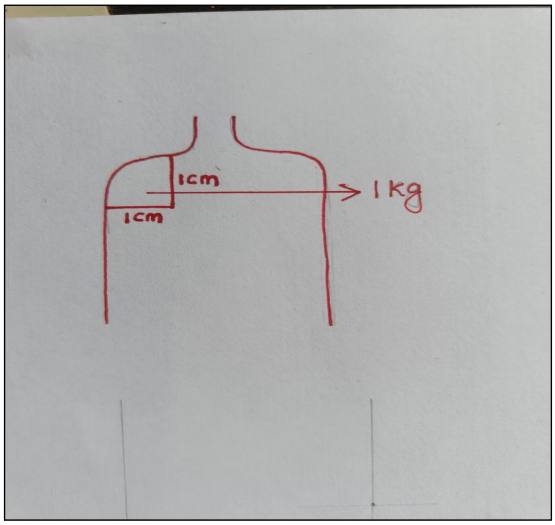

Figure 2.Representation of atmosphere pressure acting on human

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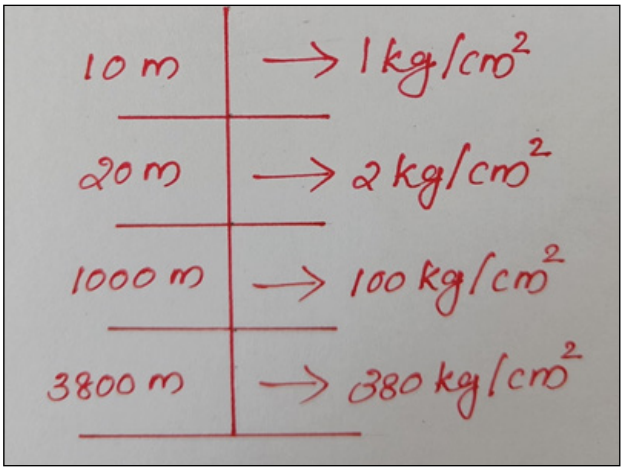

Figure 3.Pressure variations in different layers of ocean bathymetry

The pressure can be bifurcated into two areas. Inside the cavity and outside the cavity.Inside the cavity is termed as system and outside the cavity is termed as surroundings (Fig. 4).If the system is having high pressure and surroundings is having lesser pressure, explosion will take place and it will be directed outwards to the surroundings. But if the system is having low pressure and the surroundings is having high pressure, the pressure will be acting in the inward direction towards the system and implosion will be happening. In the case of titan the surrounding pressure was 380kg/ sqcm in the surroundings and the system pressure was normal. So pressure from the exterior acted towards the submersible and implosion happened. Figure 4 depicts the pressure difference in system and surroundings.

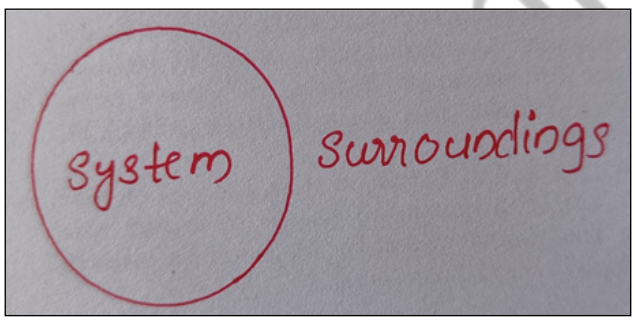

Figure 4.Pressure difference in system and surroundings

Modulus of Elasticity: In modulus of elasticity there are many effects in which two of them are pertinent. They are tensile effect and compressive effect. The detailed pictorial descriptions of both effects are shown in the figure 5. Take a string. Stretch it from both ends. There will be a break on the centre of the string. It is called Tensile effect. But if we apply force from both ends, there will be a deformation which will be happening at the centre of the wire. This is called compressive buckling (Figures 5 and 6). With reference to these two, buckling deformations emanating from compressive effect is more dangerous leading to implosion when coupled with pressure.

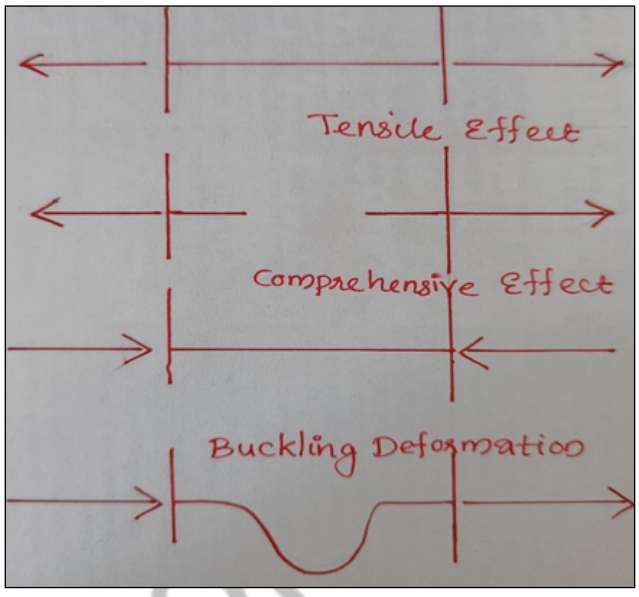

Figure 5.Different elastic effects

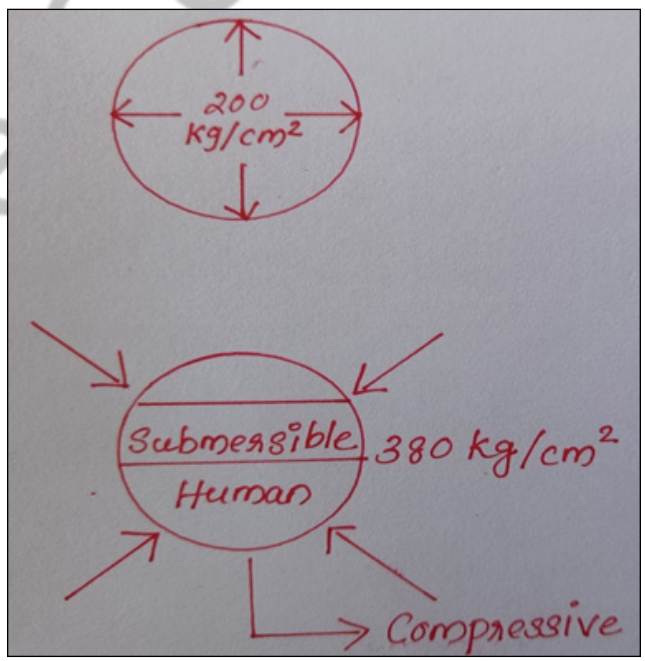

Figure 6.Representation of Pressure acting in wards to cause implosion

Shape: The parts of a submersible can be divided into two. Two surfaces one on the front and the other on the back with a middle surface.The front and back surfaces are spherical in shape whereas the middle surfaces is cylindrical in shape. The spherical shape will be symmetrical in all directions , so it is less vulnerable to compressive effects whereas cylindrical shape is not at all symmetric and so it is vulnerable to compressive effects. The middle portion of titan submersible where passengers were seated was

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spherical in shape and it became vulnerable to compressive bucking due to its non spherical shape. This is the second causative reason for this implosion.

Material Used

For constructing the body of submersibles, many materials are considered. The materials include aluminium, steel, titanium and carbon fiber. The properties of these materials can be summarized as follows.

1. **Properties of Aluminum:** Aluminum is a 13th group element. Aluminum has lower density and it is light in weight. It is a good conductor of heat and electricity. Melting point of aluminum is 660^{0}C. It is a good reflector for UV radiation.It is a silvery white metal. It is malleable and ductile.
2. **Properties of Steel:** Steel is an alloy of iron. The tensile strength of steel is high and it not easily breakable.It has an ability to change their shape when a force is applied on it.It is ductile. It is malleable by hammering. It is long lasting and its hardness is high. So, it is a durable material. It is a good conductor of heat and electricity. It is silvery and shiny(lustrous). The rust resistance of this material is very high.
3. **Properties of Titanium:** It is an alloy with high tensile strength. It is light weight with corrosion resistance. So, it has many applications in aircraft, pipes for power plants, naval ships spacecraft and missiles.Titanium is a heat resistant material. It is denser with having high melting point, low elasticity and good oxidation capability.
4. **Properties of Carbon Fiber:** Carbon fiber is a collection of large number of carbon filaments and waves in the form of a mat of fabric. The carbon fibers are lighter and stronger than the steel. This carbon fibre is used in different application in the field of aerospace, medical sports, 3D printing, marine and militaryindustries. Its strength to weight ratio is appreciable, but the cost is very high. Carbon fiber is electrically conductive, corrosion resistant, nonflammable and nontoxic.

Carbon fibre material was used for the making the cylindrical middle portion of submersible. Multiple carbon fibre materials were wrapped in good resolution and it was converted into thick sheets. Likewise multiple sheets were merged and made as a wrapping material of the submersible. The titan submersible carried out multiple trips to the ocean layers. It is learned that carbon fibre materials on multiple usages have good water absorbing property and such absorptions will reduce the defensive mechanism of the submersible against huge pressure values. This too contributed towards the implosion of titan submersible

Accostic Signals : The communication of submersible to the parent ship was with the help of acoustic signals. Acoustic signals are very weak compared to other signals. It is based primarily on sound transmission. Soon after the descent the sound emanating from the propeller was very noisy and it masked the acoustic signals. This was the basic reason for the lost of communication of titan ship and the parent ship.

Conclusion

The implosion of Titan ship which happened off the coast of Atlantic on 18th June 2023 was reviewed and its causative factors are mentioned in this investigation. The major causative factors included pressure variations, shape pattern of the submersible, the used material of husk, elastic buckling and various other contributed towards the implosion. The sound of propeller too masked the acoustic signals and that attributed towards the loss of communication between the submersible and the parent ship. More technical details of this implosion should be estimated. For that a detailed scientific and technical survey should be carried out incorporating physical modelling, numerical modelling and various other engineering aspects.

Acknowledgements

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