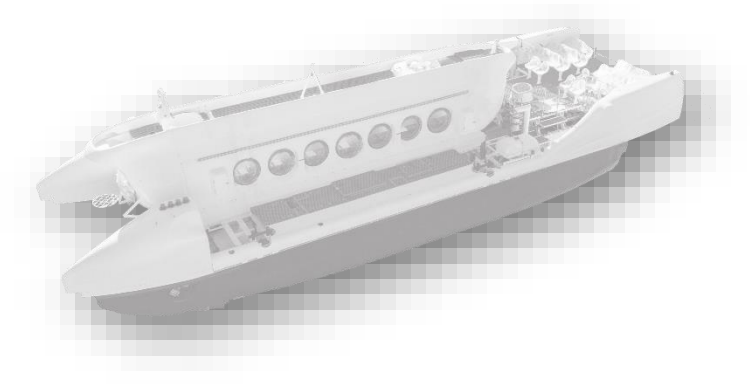
NavalSub

3 July 2023 / 3 de julio de 2023

Madrid



NavalSub, S.L.
B35686526
Avenida Victoria, 87 Piso 1.
28023, Madrid

The company NavalSub, S.L., dedicated mainly to the development of tourist submarines, specifically the catamaran submarine type "SubCat", provides below a summary of the manned underwater vehicle (MUV) industry, as well as its safety standards, in relation to the accident of the submersible Titan, owned by the company OceanGate.

1. History of the Manned Underwater Vehicle (MUV) Industry

The data below is based on information provided by the Manned Underwater Vehicle Committee of the Marine Technology Society, which monitors a total of 320 submersibles worldwide and published its latest report on safety standards in 2018[1]. NavalSub has contrasted this data with Industry[2] professionals to update it.

i. Market situation

Currently, there are between 36 and 39 tourist submarines in the world. Most of them are submarines operating at depths between 25-50m, as this is where the richest marine flora and fauna are found. Although some are designed to reach a depth of 80m, above 40m the visibility and marine richness is usually very scarce.

The two main companies that started designing tourist submarines in the 1980s are Atlantis Submarines (Vancouver, Canada) and Mobimar (Turku, Finland). These designs have conventional features (electric propulsion navigation and monohull structure). These designs have dominated the international market, with very satisfactory results in terms of safety, reliability and commercial success. However, their overall operational capability is not autonomous. In the late 1990s, Subibor (now Navalsub), began designing multi-purpose submarines, with surface and submerged navigation capabilities. It has built two R&D prototypes and three commercial units operating in different tourist areas. Finally, in the 2000s, the company Triton Submarines designed civil submarines for different applications and has a tourist unit in Vietnam.

ii. Industry Safety

Since the beginning of the commercial submarine industry, more than 30 million passengers have boarded and no incident has occurred. Navalsub has had over half a million passengers[3] throughout its SubCat operations. The tourist, exploration, research and private use submarines have more than 40 years of

1 Manned Underwater Vehicles, 2017-2018 Global Industry Review. Marine Technology Society.
2 Tarw-Trading Oy Ltd, Tarwell Ltd & Lamor Subsea, LTD.
3 Estudio de viabilidad para comercializar viajes de turismo subacuático, Escuela Técnica Superior de Ingenieros de Aeronáutica, Universidad Politécnica de Cataluña, 2014.

history, and there has been no accidents[4] at all and there has never been an implosion. This is confirmed by industry sources:

MUV Certification and Classification

The MUV industry maintains an impeccable safety record, with zero recorded fatal incidents in over 40 years. This dedication to safety and accepted design rules is reflected in the fact that 92% of all operating submersibles were designed, fabricated and tested under third party classification society review. Only 8% of operating vehicles are unclassed, and not formally documented or reviewed by a third-party agency.

The majority of submersibles in the MTS MUV database are designed to international safety standards and classed by one of the many Class societies that are part of IACS (International Assoc. of Classing Societies). The main Class societies for MUV rules include ABS, DNVGL and LR. A list of the MUVs operating per each Class society are in Table 2. The table shows the number subs operating "In Class", those operating "out of class", meaning they were designed to class but dropped out of the class survey schedule, and "un-classed" subs, including designs that were not formally documented for third party review.

ABS	American Bureau Shipping	USA	33	21%
BCS	Bulgaria Class Society	Bulgaria	1	1%
BV	Bureau Veritas	France	5	3%
CCS	China Classification Society	China	4	3%
CN	China Navy	China	4	3%
DNVGL	DNVGL	Norway/DE	21	13%
IRS	Indian Register of Shipping	India	1	1%
KR	Korean Register of Shipping	Korea	0	0%
LR	Lloyd's Register	UK	49	31%
NAVSEA	US Navy	USA	3	2%
NK	Nippon Kaiji Kyokai	Japan	4	3%
RINA	Registro Italiano Navale	Italy	3	2%
RS	Russian Maritime Register of Shipping	Russia	4	3%
None	Un-classed		12	8%
OUT	Out of Class Status		16	10%
			160	

Table 2 – 2017 MUV Industry Certification and Classification Status by IACS societies

This is because the maritime industry in general is subject to safety regulations set by the International Maritime Organization (IMO) [5], a United Nations agency responsible for safety in maritime traffic. IMO measures cover all aspects of international shipping – including design, construction, equipment, manning, operation and waste disposal – to ensure that this vital sector remains safe, environmentally friendly and energy efficient.

In addition, the industry has Classification Societies, which are non-governmental organizations or non-profit groups of professionals, with the objective of promoting the safety of human life at sea and property (vessels and platforms), as well as the protection of the natural marine environment. These Classification Societies develop specific design, construction and maintenance standards for each type of vessel. Some of the main societies worldwide are: Lloyd's Register, ABS (American Bureau of Shipping), DNV (Det Norske Veritas), BV (Bureau Veritas), RINA (Registro Italiano Navale), NK (Nippon Kaiji Kyokai).These Classification Societies are composed of engineers and technical experts, who are in charge of inspecting the vessels at the design stage, on plan, during construction, and at the time of sea trials, prior to the delivery of the class

4 Pg. 5 Manned Underwater Vehicles, 2017-2018
5 https://www.imo.org/en/About/Pages/Default.aspx

certificate. Once the class certificate is issued, the Classification Society annually inspects the vessels to maintain their approval or otherwise, thus ensuring that they remain seaworthy.

IMO regulations, as well as those of the Classification Society, are an indispensable requirement for any maritime administration to allow its registration to give it a flag and a clearance and navigation role, i.e., to allow it to legally sail.

These regulations are more rigorous when it comes to any vessel with passengers, since safety is even more necessary when the vessel is occupied by a majority of people who are not professionals of the sea.

2. OceanGate in the MUV Industry

The company OceanGate, owner of the Titan submarine, started in 2009 developing a 5-person submersible prototype, capable of reaching depths of up to 500 meters. Subsequently, it developed the Titan prototype, aiming to be capable of submerging to 4,000 meters.

In the process of research and development of the submersible, Titan pilot and operations manager David Lochridge, an employee of OceanGate, found that the Titan's safety was compromised above a certain depth[6] (1,300 m) and refused to conduct manned tests.

In addition, that same year, the aforementioned manned underwater vehicle committee issued a letter to Mr. Rush, asking him not to offer the Titan as a tourist submarine, i.e. not to market the submarine with passengers, because it did not meet the safety standards required by the industry. He warned about the serious risk this posed, not only for the Titan's crew and passengers, but also for the damage it could cause to an industry that has been working to ensure safety for 40 years.

6https://www.bbc.com/mundo/articles/cx05wn5x1e0o https://forbes.es/nautik/299739/un-empleado-de-oceangate-advirtio-de-graves-problemas-de-seguridad-con-el-submarino-titan-en-2018-y-fue-despedido/

MTS marine technology society

March 27, 2018

Oceangate Inc
1205 Craftsman Way, Suite 112
Everett, WA 98201

Dear Stockton,
This letter is sent on behalf of our industry members who have collectively expressed unanimous concern regarding the development of 'TITAN' and the planned Titanic Expedition. Our apprehension is that the current 'experimental' approach adopted by Oceangate could result in negative outcomes (from minor to catastrophic) that would have serious consequences for everyone in the industry.

The MUV industry has earned itself an enviable safety track record over the past 40 years. This is partly due to the diligent engineering discipline and professional approach exercised by members of the industry, but also due to the collective observation of (and adherence to) a variety of safety standards. This reputation is solid because it was hard won over many years of diligence application and has resulted in a safe and successful record of operation. Our members are all aware of how important and precious this standing is and deeply concerned that a single negative event could undo this.

However, the company's founder and CEO, Stockton Rush, considered the industry to be exaggeratedly safe, and that this prevented innovation according to his statements on twitter in 2019, published in various media[7]:

Mr. Rush has spoken publicly in the past about what he viewed as regulatory red tape in the industry.

"There hasn't been an injury in the commercial sub industry in over 35 years," he told Smithsonian magazine in a profile published in 2019. "It's obscenely safe because they have all these regulations. But it also hasn't innovated or grown — because they have all these regulations."

In a CBS report last year, David Pogue, a former New York Times technology columnist, joined one of OceanGate's Titanic

In short, the Titan submersible operated outside the industry and in international waters precisely to avoid complying with state regulations requiring it to follow certified safety protocols.

i. Causes of the Titan implosion

In 2021, the Titan made two underwater trips to the Titanic with passengers. According to the company, they had made several dives during the previous years.

7 https://www.nytimes.com/2023/06/20/us/oceangate-titanic-missing-submersible.html

However, last June 22, the implosion of the submersible's hull was confirmed, while it was making its third voyage with passengers.

The pressure at which the submarine found itself when it was in the vicinity of the Titanic was 400 atmospheres, a weight of 400 kg/cm2. In order to withstand that pressure, the structure of the submersible has to meet certain characteristics of thickness, strength, shape and watertightness. Normally, depending on the depths at which each submarine sails, safety tests are carried out, which analyze the fatigue suffered by the hull, among other things, in order to be able to correct it. In this case, everything points to the fact that these tests had not been carried out.

The Titan's hull was made of carbon fiber and titanium, a material widely used in aircraft because it is lightweight and more resistant and adaptable than steel, but without as much resistance to compression, which makes it lose strength at greater depth, where it suffers more pressure. This means that a carbon fiber hull suffers more fatigue than steel, and therefore requires greater control over its wear. This is emphasized by director James Cameron, who developed a research submarine in which he has dived up to 33 times to the depth of 4,000m[8].

OceanGate had installed a sensor that was supposed to monitor the condition of the hull, so the pilot would have information to activate the emergency system if necessary. However, this sensor does not monitor in real time, but warns of impending problems, therefore unavoidable once detected.

The accumulation of these circumstances: material with a more vulnerable pressure-bearing capacity, exposed to greater fatigue; the failure to check under regulatory process the condition of the hull and its wear or hull stress, delegated to a system that was not monitoring, are the most likely cause of the Titan's implosion.

3. SubCat in the MUV industry

The submarine type SubCat was developed during the 1990s by the company Subibor, S.A. [9] (later Gran Azul Lanzarote, S.L., now NavalSub, S.L.). During the research and development process, Subibor worked in close and permanent collaboration with the classification society ABS and the Dirección General de la Marina Mercante Española (representative of IMO/OMI) to build the first submarine

8 https://www.nytimes.com/2023/06/22/science/james-cameron-titanic-submersible.html
9 With the idea of making up for the lack of navigation and autonomy of conventional submarines, in the nineties a group of naval engineers, businessmen and professionals in the sector, led by Borja Oriol (businessman, graduate and civil submarine commander), Alfonso Romo Garza (businessman and engineer), Mariano Perez-Sobrino (Doctor of Naval Engineering), and Jorge Flores (Naval Engineer), began to develop the idea of a submersible vessel with multipurpose navigation capabilities (surface/immersion).

with design and performance characteristics never seen before: multipurpose capability (surface and submersible). As an example, one of the operational SubCats with the certification in force can be found in the official page of the classification society[10].

During 14 years of operations, three SubCat submarines have embarked more than half a million passengers. There have never been any technical or operational incidents.

SubCat's hull is constructed of high-pressure resistant naval steel (EH32 grade), designed to withstand depths of up to 50 m (164 ft). In relation to the SubCat hull, the Classification Society examines (and, in this case, approves/certifies), the following aspects:

- Size and thickness calculations
- Steel material/quality
- Manufacturer's quality assurance and quality control procedures (e.g.: welding procedures with ABS approved welders guaranteeing watertightness).
- X-ray and ultrasonic inspection results. The weld seams of the pressure hull (the pressure-bearing structure) are 100% X-ray and ultrasonic tested.
- Pressure test results. Once completed, the pressurized structure undergoes heat treatment to release the weld stress. The complete pressure hull is pressure tested to 1.5 times the maximum operating depth.

The condition of the pressure hull is inspected annually by ABS, among other things, to certify that it maintains safety conditions. It also has several emergency systems, which to date have never had to be used in a passenger operation (they have only been used in overhaul tests to check that they are working properly). They are as follows:

1) Life support system, according to IMO/OMI regulations, to ensure oxygen and ventilation inside the cabin in the event of a technical failure. Legally, this system requires a 24-hour support capacity.
2) Emergency plan approved by the Capitania Maritima (local IMO/OMI representative). This plan provides for the rescue of passengers and the submarine within a period not exceeding two hours, in case of any incident in which the submarine cannot surface by its own means.
3) Mechanical emergency system (drop weight). This system is mandatory and classic in all submersibles, in order to be able to surface in case of failure of the submarine's engines or electrical system.

10 https://www.eagle.org/portal/#/absrecord/details

4) Hydropneumatic emergency system, to surface in case of any incident. The SubCat has seven tanks per catamaran hull, and by activating just one of them, the submarine would surface. This feature is unique to the SubCat design.
5) Emergency air bag system, exclusive to the SubCat, which allows surface emersion in the event of a water leak or water ingress in the engine rooms and the installed bilge systems do not work.
6) Exhaustion of gases: since the batteries are outside the cabin and located in the hulls, there is no risk of gas exhaustion, which means a significant increase in passenger comfort and safety.
7) SubCat's communication systems, like all tourist submarines, are redundant. It has a UWT system, wireless, with the support ship and UVHF systems, with land and the support ship. In the event of failure of both, which has never happened, the support diver, by means of appropriate signals, will communicate the corresponding incident to the support ship.

In addition to the required safety measures, the SubCat design significantly increases these measures as it is a bicamaran design (catamaran-submarine), improving the parameters of the center of gravity and hull.

Being able to sail on the surface, it has an extra range of several hundred miles, being able to operate at adequate distances from the coast without the need for trawlers and transfers. It also allows the passenger to enjoy a tourist boat on the surface, and to access the cabin through a central hatch (eliminating the inconvenience of doing it through the upper part of the cabin), complying with the regulations for passengers with disabilities. This is the reason why the degree of satisfaction is much higher than the experience of a conventional submarine, and is an element that significantly reduces the possible fear or resistance of passengers to embark on a submarine.

La empresa NavalSub, S.L., dedicada principalmente al desarrollo de submarinos turísticos, en concreto el tipo submarino catamarán "SubCat", desglosa a continuación un resumen de la industria de vehículos submarinos tripulados, (MUV según sus siglas en inglés), así como sus estándares de seguridad, en relación con el accidente del sumergible Titán, propiedad de la empresa OceanGate.

1. Historial de la Industria de Vehículos Sumergibles Pilotados (MUV)

Los datos que exponemos a continuación están basados en la información ofrecida por el Comité de Vehículos Submarinos Tripulados, de la organización Marine Technology Society, que da seguimiento a un total de 320 sumergibles en el mundo y que publicó su último informe sobre normas de seguridad en el año 2018[1]. NavalSub ha contrastado estos datos con profesionales de la Industria[2] para actualizarlos.

i. Situación del mercado

Actualmente, existen entre 36 y 39 submarinos turísticos en el mundo. En su mayoría son submarinos que operan en cotas de entre 25-50m, por ser donde está la mayor riqueza de flora y fauna marina. Aunque algunos están diseñador para alcanzar los 80m de profundidad, a partir de los 40m la visibilidad y riqueza marina suele ser muy escasa.

Las dos empresas principales que comenzaron a diseñar submarinos turísticos en la década de 1980 son Atlantis Submarines (Vancouver, Canadá) y Mobimar (Turku, Finalandia). Estos diseños tienen características convencionales (navegación con propulsión eléctrica y estructura monocasco). Estos diseños han dominado el mercado internacional, con resultados muy satisfactorios en términos de seguridad, fiabilidad y éxito comercial. Si bien su capacidad operativa integral no es autónoma. A finales de los años 1990, Subibor (actualmente Navalsub), comienzan los diseños de submarinos polivalentes, con capacidad de navegación en superficie e inmersión. Ha construido dos prototipos de I+D y tres unidades comerciales operando en diferentes zonas turísticas. Finalmente, en los años 2000, la empresa Tritón Submarines diseñó submarinos civiles para diferentes aplicaciones y tiene una unidad turística en Vietnam.

ii. Seguridad en la Industria

Desde que comenzó la industria de submarinos comerciales, se han embarcado más de **30 millones de pasajeros**, y **no se ha producido incidente** alguno. Navalsub

1 Manned Underwater Vehicles, 2017-2018 Global Industry Review. Marine Technology Society.
2 Tarw-Trading Oy Ltd, Tarwell Ltd & Lamor Subsea, LTD.

ha tenido a lo largo de sus operativas con SubCat más de medio millón de pasajeros[3]. Los submarinos turísticos, de exploración, investigación y de uso privado cuentan con más de 40 años de historia, y en ningún caso ha habido algún accidente[4] y nunca se ha producido una implosión. Así lo confirman las fuentes del sector:

MUV Certification and Classification

The MUV industry maintains an impeccable safety record, with zero recorded fatal incidents in over 40 years. This dedication to safety and accepted design rules is reflected in the fact that 92% of all operating submersibles were designed, fabricated and tested under third party classification society review. Only 8% of operating vehicles are unclassed, and not formally documented or reviewed by a third-party agency.

The majority of submersibles in the MTS MUV database are designed to international safety standards and classed by one of the many Class societies that are part of IACS (International Assoc. of Classing Societies). The main Class societies for MUV rules include ABS, DNVGL and LR. A list of the MUVs operating per each Class society are in Table 2. The table shows the number subs operating "In Class", those operating "out of class", meaning they were designed to class but dropped out of the class survey schedule, and "un-classed" subs, including designs that were not formally documented for third party review.

ABS	American Bureau Shipping	USA	33	21%
BCS	Bulgaria Class Society	Bulgaria	1	1%
BV	Bureau Veritas	France	5	3%
CCS	China Classification Society	China	4	3%
CN	China Navy	China	4	3%
DNVGL	DNVGL	Norway/DE	21	13%
IRS	Indian Register of Shipping	India	1	1%
KR	Korean Register of Shipping	Korea	0	0%
LR	Lloyd's Register	UK	49	31%
NAVSEA	US Navy	USA	3	2%
NK	Nippon Kaiji Kyokai	Japan	4	3%
RINA	Registro Italiano Navale	Italy	3	2%
RS	Russian Maritime Register of Shipping	Russia	4	3%
None	Un-classed		12	8%
OUT	Out of Class Status		16	10%
			160	

Table 2 – 2017 MUV Industry Certification and Classification Status by IACS societies

Esto se debe a que la industria marítima en general se somete a la normativa de seguridad establecida por la Organización Marítima Internacional (OMI, o IMO según sus siglas en inglés)[5], una agencia de las Naciones Unidas, responsable de la seguridad en el tráfico marítimo. Las medidas de la OMI abarcan todos los aspectos del transporte marítimo internacional -incluidos el diseño, la construcción, el equipamiento, la dotación, la explotación y la eliminación de residuos- para garantizar que este sector vital siga siendo seguro, respetuoso con el medio ambiente y eficiente desde el punto de vista energético.

Además, la industria cuenta con Sociedades de Clasificación, que son organizaciones no gubernamentales o grupos de profesionales sin ánimo de lucro, con el objetivo de promover la seguridad de la vida humana en el mar y propiedades (buques y plataformas), así como la protección del entorno natural

3 Estudio de viabilidad para comercializar viajes de turismo subacuático, Escuela Técnica Superior de Ingenieros de Aeronáutica, Universidad Politécnica de Cataluña, 2014.
4 Pg. 5 Manned Underwater Vehicles, 2017-2018
5 https://www.imo.org/en/About/Pages/Default.aspx

marino. Estas Sociedades de Clasificación desarrollan normas específicas de diseño, construcción y mantenimiento para cada tipo de embarcación. Algunas de las principales sociedades a nivel mundial son: Lloyd's Register, ABS (American Bureau of Shipping), DNV (Det Norske Veritas), BV (Bureau Veritas), RINA (Registro Italiano Navale), NK (Nippon Kaiji Kyokai). Estas Sociedades de Clasificación están compuestas por ingenieros y técnicos expertos, que se encargan de inspeccionar las embarcaciones en la fase de diseño, sobre plano; durante su construcción, y en el momento de las pruebas de mar, antes de la entrega del certificado de clase. Una vez emitido el certificado de clase, la Sociedad de Clasificación inspecciona anualmente las embarcaciones para conservar su aprobación o no, asegurando así que se mantiene en las condiciones correctas para navegar.

Las normas de la OMI, así como las de la Sociedad de Clasificación, son un requisito indispensable para que cualquier administración marítima permita su registro para darle una bandera y un despacho y rol de navegación, es decir, para que pueda navegar legalmente.

Esta normativa es más rigurosa cuando se trata de cualquier embarcación con pasajeros, ya que la seguridad es todavía más necesaria cuando la embarcación está ocupada por una mayoría de personas que no son profesionales del mar.

2. OceanGate en la Industria MUV

La empresa OceanGate, propietaria del submarino Titán, comenzó en 2009 desarrollando un prototipo sumergible para 5 personas, capaz de alcanzar profundidades hasta de 500 metros. Posteriormente, desarrolló el prototipo Titán, capaz de sumergirse hasta los 4.000 metros.

En el proceso de investigación y desarrollo del sumergible, el piloto del Titán y director de operaciones, David Lochridge, empelado de la empresa OceanGate, detectó que la seguridad del Titán se veía comprometida[6] a partir de cierta profundidad (1.300 m) y se negó a efectuar pruebas tripuladas.

Además, ese mismo año, el ya mencionado comité de vehículos submarinos tripulados emitió una carta al Sr. Rush, pidiéndole que no ofreciese el Titán como submarino turístico, es decir, que no comercializara el submarino con pasajeros, porque no cumplía con los estándares de seguridad exigidos por la Industria. Alertaba sobre el grave riesgo que esto suponía, no solo para los tripulantes y

6https://www.bbc.com/mundo/articles/cx05wn5x1e0o https://forbes.es/nautik/299739/un-empleado-de-oceangate-advirtio-de-graves-problemas-de-seguridad-con-el-submarino-titan-en-2018-y-fue-despedido/

pasajeros del Titán, si no por el daño que podía provocar en una Industria que ha trabajado por garantizar la seguridad durante 40 años.

MTS marine technology society

March 27, 2018

Oceangate Inc
1205 Craftsman Way, Suite 112
Everett, WA 98201

Dear Stockton,
This letter is sent on behalf of our industry members who have collectively expressed unanimous concern regarding the development of 'TITAN' and the planned Titanic Expedition. Our apprehension is that the current 'experimental' approach adopted by Oceangate could result in negative outcomes (from minor to catastrophic) that would have serious consequences for everyone in the industry.

The MUV industry has earned itself an enviable safety track record over the past 40 years. This is partly due to the diligent engineering discipline and professional approach exercised by members of the industry, but also due to the collective observation of (and adherence to) a variety of safety standards. This reputation is solid because it was hard won over many years of diligence application and has resulted in a safe and successful record of operation. Our members are all aware of how important and precious this standing is and deeply concerned that a single negative event could undo this.

No obstante, el fundador y CEO de la empresa, Stockton Rush, consideraba que el sector era exageradamente seguro, y que eso impedía la innovación según se ha podido averiguar por sus declaraciones en twitter en 2019, publicadas en varios medios[7].

Mr. Rush has spoken publicly in the past about what he viewed as regulatory red tape in the industry.

"There hasn't been an injury in the commercial sub industry in over 35 years," he told Smithsonian magazine in a profile published in 2019. "It's obscenely safe because they have all these regulations. But it also hasn't innovated or grown — because they have all these regulations."

In a CBS report last year, David Pogue, a former New York Times technology columnist, joined one of OceanGate's Titanic

En definitiva, el sumergible Titán operaba fuera de la industria y en aguas internacionales precisamente para evitar cumplir con la normativa estatal que le exigiera seguir protocolos de seguridad certificados.

7 https://www.nytimes.com/2023/06/20/us/oceangate-titanic-missing-submersible.html

i. Causas de la implosión del Titán

En 2021, el Titán realizó dos viajes submarinos al Titanic con pasajeros. Según la empresa, habían realizado varias inmersiones durante los años anteriores. No obstante, el pasado 22 de junio se confirmó la implosión del casco del sumergible, mientras realizaba su tercer viaje con pasajeros.

La presión a la que se encontraba el submarino cuando se situaba en las cercanías del Titanic era de 400 atmósferas, un peso de 400 kg/cm2. Para poder soportar esa presión, la estructura del sumergible tiene que cumplir con determinadas características de espesor, fuerza, forma y estanqueidad. Normalmente, en función de las profundidades a las que navega cada submarino, se pasan unos exámenes de seguridad, que analiza la fatiga sufrida por el casco entre otras cosas, para poder corregirlo. En este caso, todo apunta a que esos exámenes no se habían realizado.

El casco del Titán estaba construido de fibra de carbono y titanio, un material muy usado en aeronaves porque es ligero y más resistente y adaptable que el acero, pero sin tanta resistencia a la compresión, lo que le hace perder fuerza a mayor profundidad, donde más presión sufre. Esto significa que un casco de fibra de carbono sufre más fatiga que el acero, y por eso necesita un mayor control sobre su desgaste. Así lo destaca el director James Cameron, que desarrolló un submarino de investigación en el que se ha sumergido hasta 33 veces a la profundidad de 4.000m[8].

OceanGate había instalado un sensor que se suponía que monitorizaba el estado del casco, así el piloto tendría información para activar el sistema de emergencia si fuera necesario. No obstante, este sensor no monitoriza en tiempo real, si no que alerta de problemas inminentes, por lo tanto, inevitables una vez se detectan.

La acumulación de estas circunstancias: material con una capacidad de soportar la presión más vulnerable, expuesto a mayor fatiga; la no revisión legal del estado del casco y su desgaste, revisado por un sistema que no monitorizaba, son la causa más probable de que haya sucedido una implosión del Titán.

3. SubCat en la industria MUV

El submarino tipo SubCat fue desarrollado durante la década de 1990 por la empresa Subibor, S.A[9] (después Gran Azul Lanzarote, S.L., ahora NavalSub, S.L.).

---

8 https://www.nytimes.com/2023/06/22/science/james-cameron-titanic-submersible.html

9 Con la idea de suplir las carencias de navegación y autonomía de los submarinos convencionales, en la década de los noventa un grupo de ingenieros navales, empresarios, y profesionales del sector ,encabezados por Borja Oriol (empresario, licenciado y comandante de submarinos civiles), Alfonso Romo Garza (empresario e Ingeniero), Mariano Perez-Sobrino (Doctor Ingeniero Naval), y

Durante el proceso de investigación y desarrollo, Subibor trabajó en estrecha y permanente colaboración con la sociedad de clasificación ABS y la Dirección General de la Marina Mercante Española (representante de IMO/OMI) para construir el primer submarino con características de diseño y prestaciones inéditas hasta el momento: capacidad polivalente (navegar en superficie e inmersión). A modo de ejemplo, en la página oficial de la sociedad de clasificación se puede encontrar uno de los SubCat operativos con la certificación en vigor[10].

Durante 14 años de operativas, tres submarinos SubCat han embarcado a más de medio millón de pasajeros. Nunca ha habido ningún incidente técnico u operativo.

El casco de SubCat está construido con acero naval resistente a alta presión (grado EH32), diseñado para soportar profundidades de hasta 50 m. En relación al casco del SubCat, la Sociedad de Clasificación examina (y, en este caso, aprueba/certifica), los siguientes aspectos:

- Cálculos de medidas y espesores
- Material/calidad del acero
- Los procedimientos de garantía y control de calidad del fabricante (e.j.: procedimientos de soldadura con soldadores homologados por ABS que garantizan la estanqueidad).
- Los resultados de la inspección por rayos X y ultrasonidos. Los cordones de soldadura del casco a presión (la estructura que soporta la presión) se comprueban al 100% con rayos X y ultrasonidos.
- Los resultados de las pruebas de presión. Una vez terminado la estructura a presión se somete a un tratamiento térmico para liberar la tensión de la soldadura. El casco a presión completo se somete a una prueba de presión 1,5 veces superior a la profundidad máxima de funcionamiento.

Anualmente ABS inspecciona, entre otros aspectos, el estado del casco a presión, para certificar que mantiene las condiciones de seguridad. Cuenta, además con varios sistemas de emergencia, que hasta la fecha no ha sido necesario utilizar nunca en una operativa de pasajeros (solamente se han utilizado en las pruebas de revisión para comprobar que funcionan correctamente). Son los siguientes:

1) Sistema de soporte a la vida, según la normativa IMO/OMI, para asegurar el oxígeno y ventilación dentro de la cabina en el caso de que hubiera un fallo técnico. Legalmente, este sistema exige una capacidad de soporte de 24 horas.

Jorge Flores (Ingeniero Naval), comienzan a desarrollar la idea de una embarcación sumergible con capacidad de navegación polivalente (superficie/inmersión).
10 https://www.eagle.org/portal/#/absrecord/details

2) Plan de emergencia aprobado por la Capitanía Marítima (representante local de IMO/OMI). Este plan contempla el rescate de los pasajeros y el submarino en un plazo no superior a dos horas, en caso de cualquier incidente en que el submarino no puede emerger por sus propios medios.
3) Sistema de emergencia mecánico (drop weight). Este sistema es obligatorio y clásico en todos los sumergibles, para poder salir a la superficie en caso de que fallen los motores o el sistema eléctrico del submarino.
4) Sistema de emergencia hidroneumático, para salir a la superficie en caso de cualquier incidente. El SubCat tiene siete tanques por cada casco de catamarán, y al activar tan solo uno de ellos, el submarino saldría a superficie. Esta característica es única del diseño SubCat.
5) Sistema de emergencia air bag, exclusivo del SubCat, que permite la emersión a superficie en caso de que haya una vía o entrada de agua en las cámaras de máquinas y no funcionen los sistemas de achique instalados.
6) Exhaustación de gases: al llevar las baterías fuera de la cabina y situadas en los cascos, no hay riesgo de exhaustación de gases, lo que supone un incremento notable en el confort y seguridad de los pasajeros.
7) Los sistemas de comunicación en SubCat, al igual que todos los submarinos turísticos, son redundantes. Dispone de un sistema UWT, inalámbricas, con el barco de apoyo y sistemas UVHF, con tierra y el barco de apoyo. En el caso de que fallaran los dos, lo cual nunca ha sucedido, el buzo de apoyo mediante señales oportunas, comunicará al barco de apoyo la incidencia correspondiente.

Además de las medidas de seguridad exigidas, el diseño SubCat incrementa significativamente dichas medidas al ser un diseño bicasco (catamarán-submarino), mejorando los parámetros del centro de gravedad y carena.

Al poder navegar en superficie, dispone de una autonomía extra de varios cientos de millas, pudiendo operar a distancias de costa adecuadas sin necesidad de barcos de arrastre y *transfers*. También permite al pasaje disfrutar de una embarcación de turismo en superficie, y acceder a la cabina por una escotilla central (eliminando los inconvenientes de hacerlo por la parte superior de la cabina) cumpliendo con la normativa para pasajeros con discapacidades. Esto es la causa por la que el grado de satisfacción es muy superior a la experiencia de un submarino convencional, y es un elemento que disminuye notablemente el posible temor o resistencia de los pasajeros a embarcarse en un submarino.

***