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Editorial Note

Cartagena de Indias, July 26th, 2019.

In this edition, the Ship Science and Technology Journal, opens a new issue with scientific articles presented at the *VI International Ship Design and Naval Engineering Congress - CIDIN 2019*, which shared space with the *XXVI Pan American Congress of Naval Engineering, Marine Transport and Port Engineering - COPINAVAL 2019*. In addition, this number also presents articles and research carried out by the academy on topics of interest for the publication.

From March 13th to 15th, 2019, CIDIN and COPINAVAL 2019 opened their doors as a space created to promote the development of the naval, maritime and river industry, within the framework of an academic, scientific and technological scenario, destined to share and exchange knowledge about advances and new trends in this industry.

The success of the congresses has been reflected in the quality of the forums, keynote talks, scientific and technical presentations, developed in the academic setting, counting as publications of this journal issue those related to: Autonomous vessels and cybersecurity, naval architecture: from theory to practice, professional training in naval sciences and the design process of an eco-friendly catamaran.

We also contemplate in this new issue, advanced research on topics like photogrammetric evaluation of geometric tolerance standards and the design and construction of a prototype for the launch and recovery of an ROV (remotely operated vehicle).

We thank all the researchers and collaborators of the business sector who were part of the CIDIN and COPINAVAL 2019, as well as the independent researchers, who contributed their projects and scientific works to the achievement of this publication.

Captain (Ret) CARLOS EDUARDO GIL DE LOS RÍOS
Ship Science and Technology Journal Editor

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Nota Editorial

Cartagena de Indias, 26 de julio de 2019.

En esta edición, la revista *Ciencia y Tecnología de Buques*, abre un nuevo número con artículos científicos presentados en el *VI Congreso Internacional de Diseño e Ingeniería Naval CIDIN 2019*, el cual en esta oportunidad, ha compartido espacio con el *XXVI Congreso Panamericano de Ingeniería Naval, Transporte Marítimo e Ingeniería Portuaria COPINAVAL 2019*. Además se presentan artículos e investigaciones adelantadas por la academia sobre temáticas de interés para la publicación.

Del 13 al 15 de marzo del presente año, los congresos CIDIN y COPINAVAL 2019, abrieron sus puertas como un espacio creado para promover el desarrollo de la industria naval, marítima y fluvial, en el marco de un escenario académico, científico y tecnológico, destinado a compartir e intercambiar conocimientos sobre los avances y nuevas tendencias en esta industria.

El éxito de los congresos se ha reflejado en la calidad de los foros, ponencias magistrales, científicas y técnicas desarrolladas en el escenario académico, contando como publicaciones de este número de la revista, las relacionadas con: Buques autónomos y ciberseguridad, la arquitectura naval: de la teoría a la práctica, la formación profesional en ciencias navales y el proceso de diseño de un catamarán eco-amigable.

Por su parte, contemplamos igualmente en este nuevo número, investigaciones adelantadas en temas de evaluación fotogramétrica de estándares de tolerancia geométrica y el diseño y construcción de un prototipo para el lanzamiento y recuperación de un ROV (Vehículo operado remotamente).

Agradecemos a todos los investigadores y colaboradores del sector empresarial que hicieron parte del CIDIN y COPINAVAL 2019, al igual que los investigadores independientes, quienes aportaron sus proyectos y capital científico para el logro de esta publicación.

Capitán de Navío (RA) CARLOS EDUARDO GIL DE LOS RÍOS
Editor revista Ciencia y Tecnología de Buques

Photogrammetric evaluation of geometrical tolerance standards: a DARPA suboff model case study

Evaluación fotogramétrica de los estándares de tolerancia geométrica: un estudio de caso de modelo de DARPA suboff

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Abstract

A DARPA Suboff scale model was used for the development of an analysis methodology for geometric deviations of the hull, aiming the quality control of model manufacturing process. The surface three-dimensional coordinates were obtained through a photogrammetric survey and analyzed based on statistical tools.

The results were classified according to the ITTC and DIN ISO geometric tolerance standards, allowing the investigation of the compliance of the model to such criteria and the study of local geometric deviations.

Key words: Photogrammetry, DARPA Suboff, Geometric Tolerance.

Resumen

Se utilizó un modelo a escala DARPA Suboff para el desarrollo de una metodología de análisis para las desviaciones geométricas del casco, con el objetivo de controlar la calidad del modelo del proceso de fabricación. Las coordenadas tridimensionales de la superficie se obtuvieron a través de un estudio fotogramétrico y se analizaron en base a herramientas estadísticas.

Los resultados se clasificaron de acuerdo con los estándares de tolerancia geométrica del ITTC y DIN ISO, lo que permitió investigar el cumplimiento del modelo con dichos criterios y estudiar las desviaciones geométricas locales.

Palabras claves: Fotogrametría, DARPA Suboff, Tolerancia geométrica.

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Introduction

The adoption of more rigorous methods for the evaluation of small scale model's geometry is an important issue in the field of experimental methods applied to marine hydrodynamics. The experimental facilities have been improved the quality control in model's manufacturing process, in order to ensure geometrical similarity with consequent improvement in reliability and reduction of uncertainties of experimental results.

The procedure recommended by the ITTC (International Towing Tank Conference) consists of a succinct set of rules for surveying the main dimensions of the hull, which can be applied for any type of model. Length tolerance of ±0.05% Lpp or ±1.0 mm, whichever is greater; ±1.0 mm in beam dimension and ±1.0 mm in depth express a convention between model basins, stablishing minimum requirements for the accuracy of the model and for quality of test results. Each institution is independent to carry out even more restrictive procedures in order to achieve better results. A recognized standard is *(DIN ISO, 1989)*, for example, that establishes geometric tolerance classes based on a nominal size, described as "Fine", "Medium", "Coarse" and "Very Coarse" adjustments.

Based on results obtained through the use of an optical metrology technique, this work presents a procedure to evaluate the geometric deviations of the hull surface of a DARPA Suboff model, using both ITTC and DIN ISO standards.

The data used in this evaluation come from a photogrammetric survey of the hull, which, by numerical triangulations between reference targets and points located on the hull surface, is able to provide the three-dimensional coordinates of them. The algorithm used in the photogrammetry software performs a biunivocal transformation between two-dimensional and three-dimensional planes. Photogrammetry point cloud and DARPA Suboff reference mesh were aligned by means of an ICP (Iterative Closest Points) algorithm and an in-house software was used to calculate the hull deviations.

Once verified the feasibility of adopting this dimensional control technique during the manufacturing process of small-scale models, the proposed procedure can be used in experimental hydrodynamics research institutions. However, there is the need of control and standardize the measurement process itself in order to reduce its uncertainties.

Data Acquisition

This work aimed to verify the viability of the quality control of reduced model of ships according to *(ITTC, 2011)* and *(DIN ISO, 1989)*.

(Andrade et al., 2018) made the photogrammetric acquisition of a 1.5879 scale model of a DARPA Suboff submarine hull *(Groves, 1989)*. This geometry was chosen because it is defined by a set of polynomial equations, which allows the obtaining of coordinates all over the hull's surface, as shown in Fig. 1.

The photogrammetry is a metrology technique based on numerical analysis of digital images captured from targets applied to the object's surface. The images where obtained using a general purpose professional photographic camera. The procedure is relatively low cost in comparison to other optical techniques, with a 10^{-3} *mm* uncertainty for the measured coordinates. Fig.2 presents the equipment employed in this work.

Fig. 1. DARPA Suboff main lines.

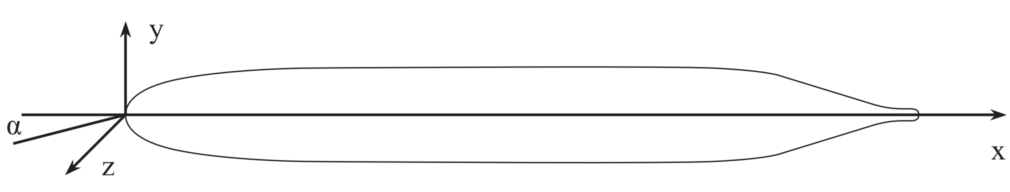


Fig. 2. Photogrammetry equipment.

At first, the model was prepared for the image acquisition by being placed in a position with adequate illumination. Adhesive targets are applied in the regions of interest, according to the model's geometry. For instance, DARPA Suboff model was filled with targets all over the circumference, as presented in Fig. 3.

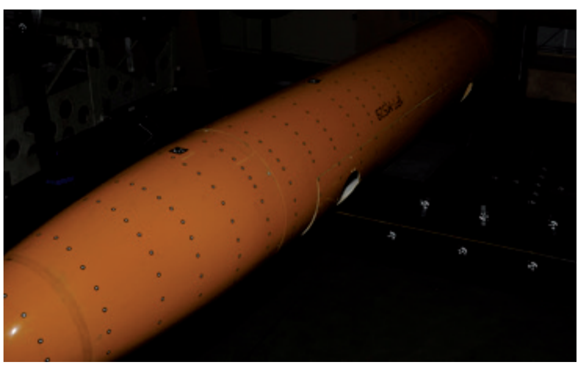


Fig. 3. Applied adhesive targets in the DARPA model for the photogrammetry procedure.

The images where analyzed by commercial software *(GOM, 2009)* which consists of a library of algorithms for estimating target distances to a reference object adopted as the origin, also registered by the photos.

The algorithms are capable of identifying the same target in different images, taken in different angles, and evaluate the point position. The quantitative output of the procedure is a point cloud represented by its 3D coordinates with the origin located in the object of reference. These points are represented in the Fig. 4, contained in an uncertainty margin.

Fig. 4. Example of point cloud (white) obtained after digital image processing.

The obtained coordinates were compared to the model's expected geometry by *(Andrade et al., 2018)*. For each obtained point, the longitudinal coordinate x was used to calculate the target radius, R_{Target}, employing the DARPA Suboff polynomials. Due to the axial symmetry, the radius measured by photogrammetry, R_{real}, is obtained as follows:

$$R_{real} = \sqrt{y^2 + z^2} \quad (1)$$

The possible definitions from R_{real} and R_{Target} comparison are: when $R_{real} < R_{Target}$ the point is an inside or interior point. On the opposite, if $R_{real} > R_{Target}$ the point is considered an outside point.

This analysis allows the verification of the geometric bias for each station, taken perpendicular from the axis of revolution of the model. The method can be thought as an analogy for the use of templates shaped with the geometry of the hull on the position of each station. Other available software for geometry comparison, CloudCompare for example, usually results in the normal distance from point to surface.

Statistics

The obtained deviations were treated in a statistical way to provide useful information regarding the model's geometry, evaluating its quality and making it possible to improve the manufacturing process.

Were evaluated 309 points on the surface of the hull, identified in the adhesive targets applied to the model. The targets were organized in transversal sections equivalent to the ship's stations, with distribution approximately uniform. Since the adhesive application is manual and there is no need, or even feasibility, for a more precise spacing control, these points do not represent stations. This organization has the objective of facilitating the image processing, especially when operator intervention is needed.

A useful way to evaluate the deviations of this model is its arrangement as a function of the longitudinal coordinate of the hull. Figs. 5 and 6 show distinct ways to visualize deviations: The first one plots the radii measured by photogrammetry over the DARPA Suboff hull reference curve. The Figure 6, in turn, shows only the deviations as a function of the longitudinal coordinate. It is possible to observe, qualitatively, greater deviations in the two extremities. In the bow, near the zero coordinate, there is greater concentration of negative amplitude big deviations. This means that the surface of the bow has a slightly smaller radius than the reference. The red markers highlight positive deviations (outside points), while the blue markers highlight the negative ones (inside points).

The region of the parallel middle body fits reasonably to the reference geometry, in the longitudinal coordinate close to 1000 millimeters. Starting

Fig. 5. Bias comparison of measured points over the reference polynomial curve.

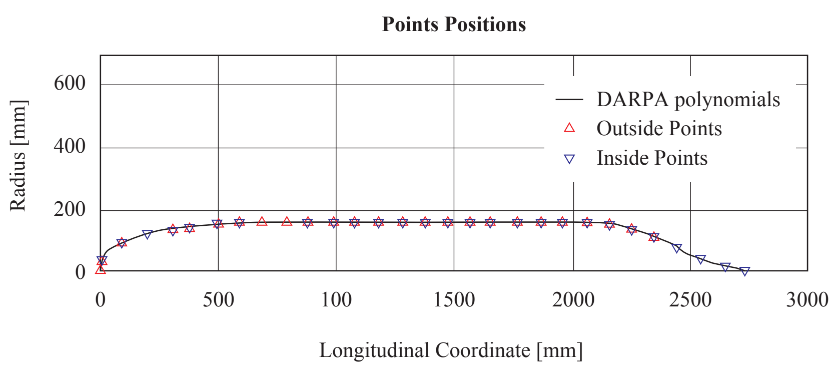


Fig. 6. Radii deviations, as function of the longitudinal coordinate of the hull.

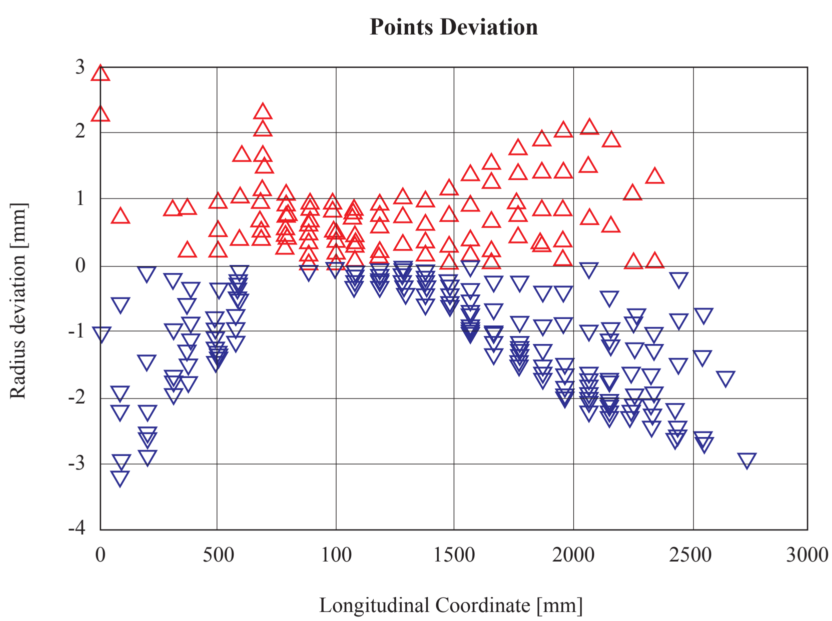
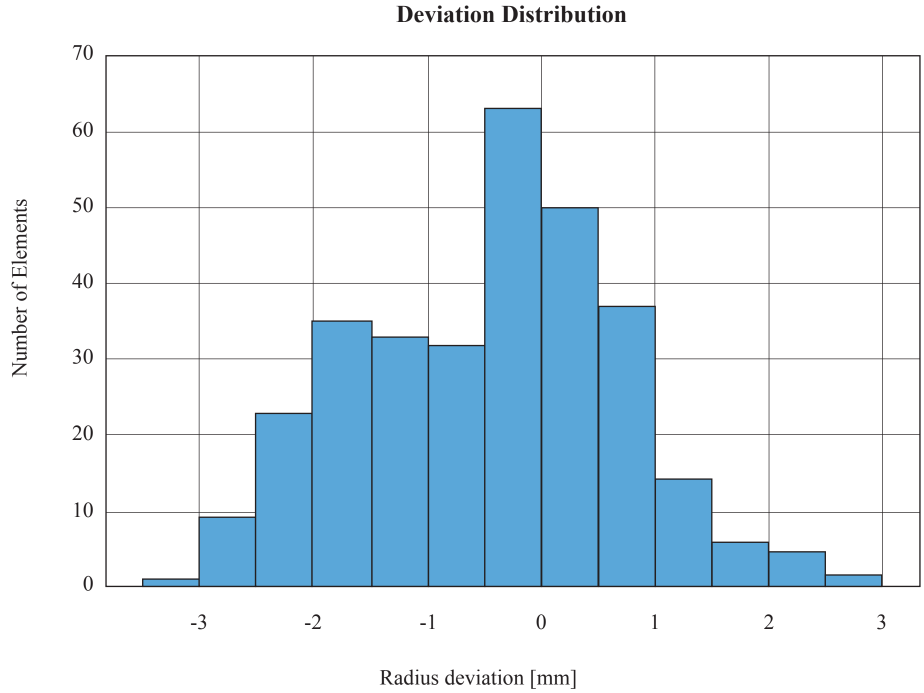


Fig. 7. Distribution of deviations.



from 1500 millimeters, there is a deviation increase to both positive (external) and negative (internal) values. The average value for the whole sample is -0.438 mm, showing a slight tendency for smaller radii than the design. In absolute values, the mean deviation is 0.968 mm.

The distribution of deviations is shown in Fig. 7. This distribution makes it clear that there is a greater density of points in the negative part of the graph, illustrating the value expressed by the simple mean. The variance for this distribution is 1.314 mm.

The International Towing Tank Conference Recommended Procedure (ITTC, 2011) does not establish a local surface tolerance, as presented in this paper. The geometric verification of the models is made by taking measurements of their main dimensions: length, depth and beam.

The recommendation for depth and beam, dimensions relevant to this work, once the radius is being checked at each point (Fig. 8), is that the principal dimensions deviations should be less than 1 millimeter. In a conservative approach, the points whose radius deviation exceeds this value were highlighted. In practice, it is verifiable that, at least due to radial symmetry, it is not possible to comply the standard with local deviation values close to 1 millimeter, since the great majority of the point's sections present values in the positive and negative half-planes of the graph. A total of 127 points (41.1%) with absolute deviation greater than 1 mm were observed and 182 (58.9%) presented deviations less than 1 mm. The first group had an absolute mean of 1.734 mm and a variance of 0.255 mm, while the second one had an absolute mean of 0.434 mm and a variance of 0.087.

The standard *(DIN ISO, 1989)* classifies the geometric tolerances in "Fine", "Medium", "Coarse" and "Very Coarse" groups. Each of these groups is related to a tolerance interval that also depends on a nominal size. Initially, were analyzed the deviations of each point, relative to the nominal value of the radius, as function of its longitudinal coordinate. In this way, it was possible to classify them according to the tolerance classes and to identify points in non-compliance with the standard.

Fig. 8. ITTC Recommended Procedures compliance to ship models manufacturing.

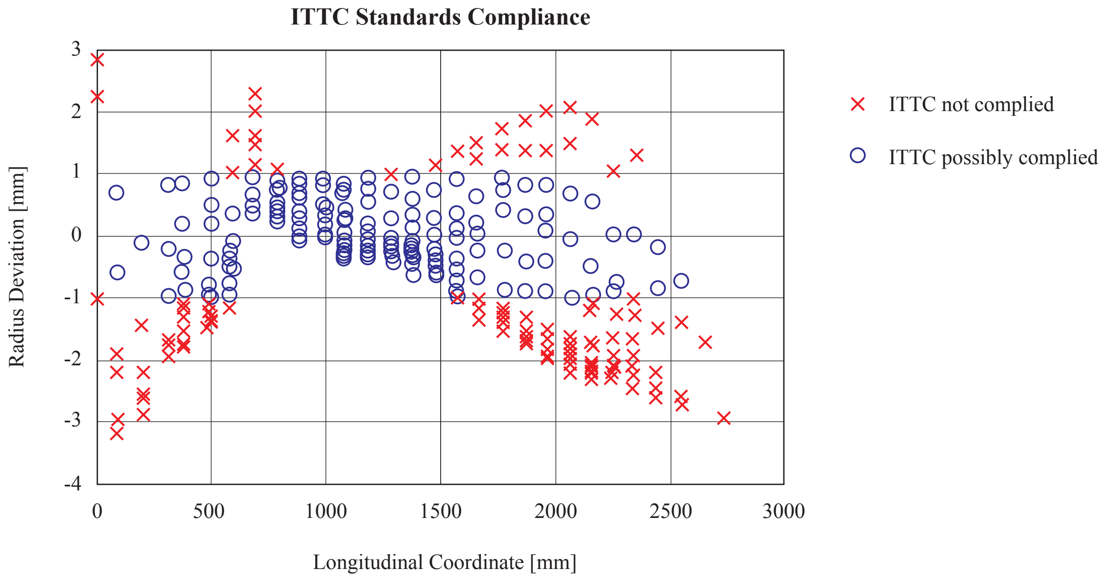
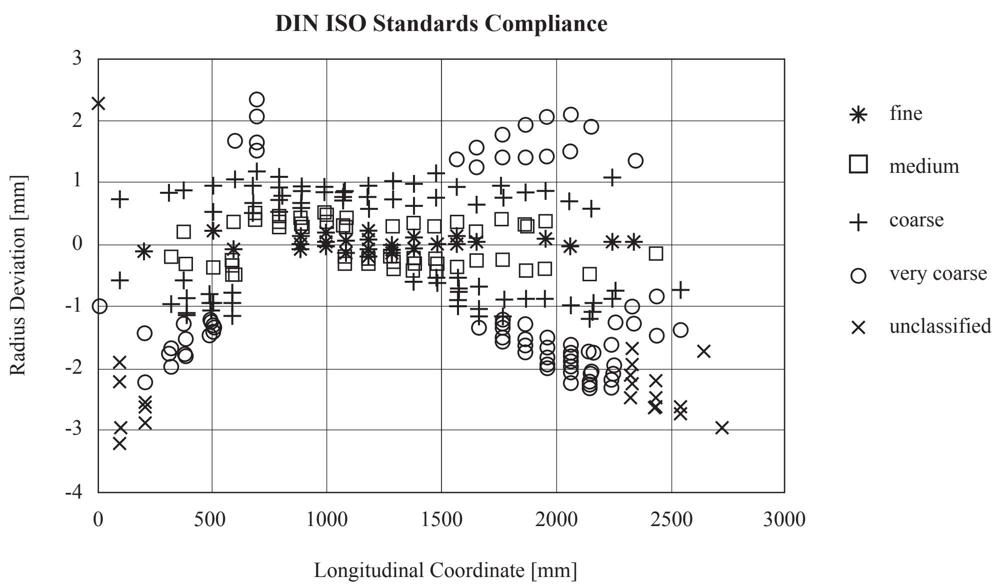


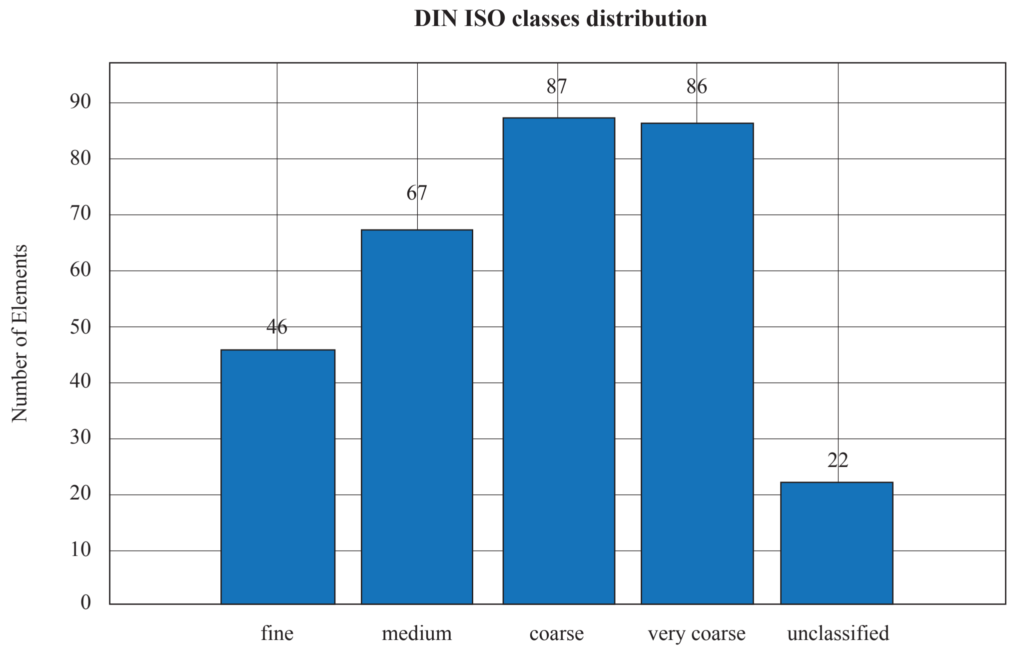
Fig. 9. DIN ISO Compliance.



The Fig. 9 shows the same distribution of deviations as a function of the longitudinal coordinate, but the points were grouped according to the class in which they fit the norm *(DIN ISO, 1989)*: "Fine" adjustment, "Medium" adjustment, "Coarse" adjustment, "Very Coarse" and points that do not fit the rules in any range of values, i.e., no class. It is possible to observe that in some cases, there may be up to three classes of deviation in the same arbitrary section at most.

The distribution among the classes can be better studied in the Fig. 10 which shows 46 points in "Fine" adjustment, 67 points in "Medium" setting, 87 "Coarse", 86 "Very Coarse" and 22 out of standard ranges.

Fig. 10. DIN ISO classes distribution.



The same procedure can be verified in the Fig.11 and Fig. 12, this time with the loosening of the rule, in order not to penalize too much the bow and stern end points, where the reference becomes smaller and smaller. In this case, it was decided to adopt the maximum radius R_{max} as nominal size for all analyzes. With this hypothesis, several points have undergone class improvement, resulting in 47 "Fine" adjustment points, 66 "Medium" adjustment, 90 "Coarse", 95 "Very Coarse" points and only 11 unclassified points, according to table presented by the standard.

Fig. 11. DIN ISO Compliance using R_{max}.

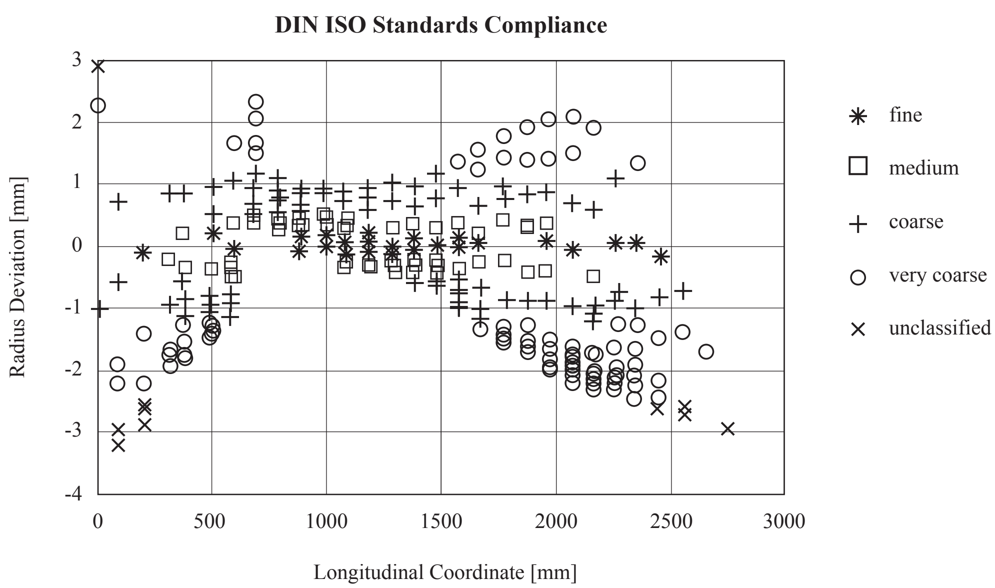
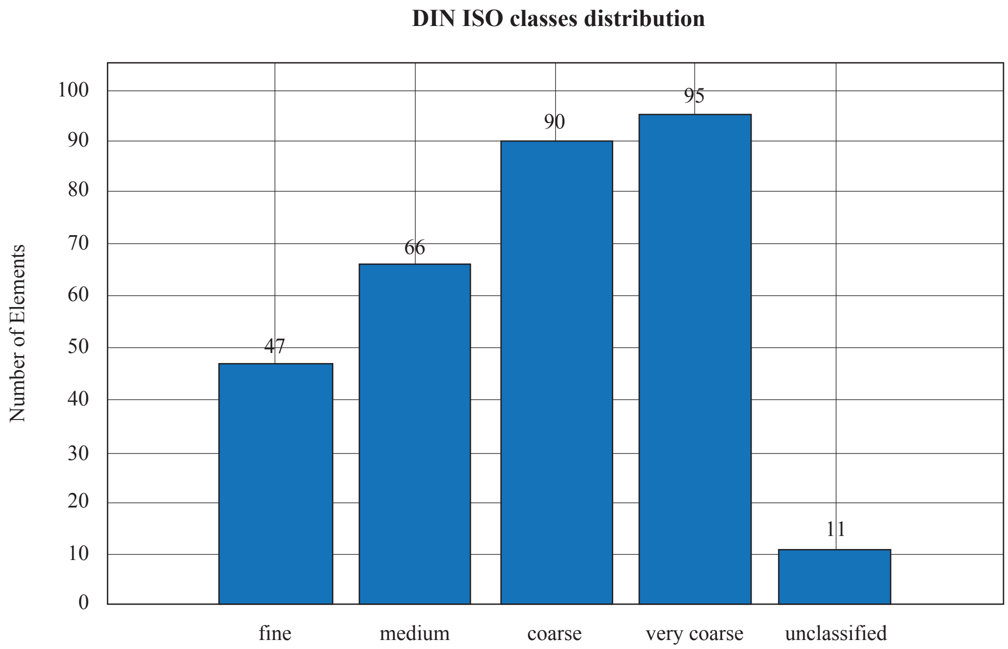


Fig. 12. DIN ISO classes distribution using R_{max}.



In addition, it was explored a way of representing deviations in dimensionless numbers. Two alternatives were studied, in both adopting a value of radius as denominator. The first one consisted in adopting the local value of radius, *i.e.*, the nominal radius for the longitudinal coordinate corresponding to the point. Again, a larger penalization was observed for smaller radius in the bow and stern regions. Also in the distribution of deviations it was possible to observe values very distant from the average.

The second alternative considered the value of the maximum radius R_{max} as denominator when making the deviation dimensionless. This option presents more significant dispersion and distribution, allowing a faster and more efficient evaluation of the results. In this way, the nominal radius was adopted equal to the maximum radius for the purposes of this work.

In this sense, the Fig. 13 shows the dispersion of the deviations as a function of the longitudinal coordinate, showing the classification of each point, according to the criterion *(DIN ISO, 1989)*, in the same color scale previously used. It is possible to observe very clear levels between the different classes, which is the advantage of having a single nominal size. In absolute values, it is possible to verify the mean of this dimensionless equal to 0.006, median equal to 0.005, maximum value 0.020 and minimum value equal to zero. The maximum value of the dimensionless, which still complies the rule, is 0.015.

In relation to the real values, were obtained the mean equal to -0.003, median equal to -0.002, maximum value 0.018 and minimum value -0.020. The maximum value of the dimensionless, which still complies the standard, is 0.014 and the minimum that obey the same rule is -0.015.

Fig. 14 shows the distribution of the dimensionless deviations in absolute values. Due to the use of the maximum radius, the shape of this distribution was preserved as in Fig. 7.

Conclusions

This work presented a statistical analysis of geometric deviation data obtained by means of a photogrammetric survey in a DARPA Suboff scale model. The results were compared to two reference

Fig. 13. Deviation / Maximum Radius dimensionless, as function of longitudinal coordinate.

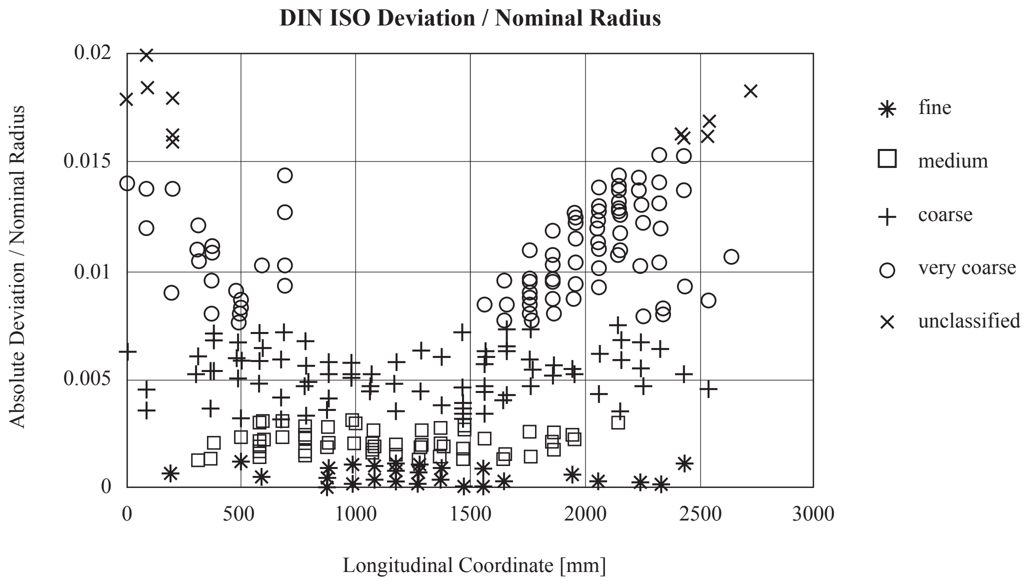
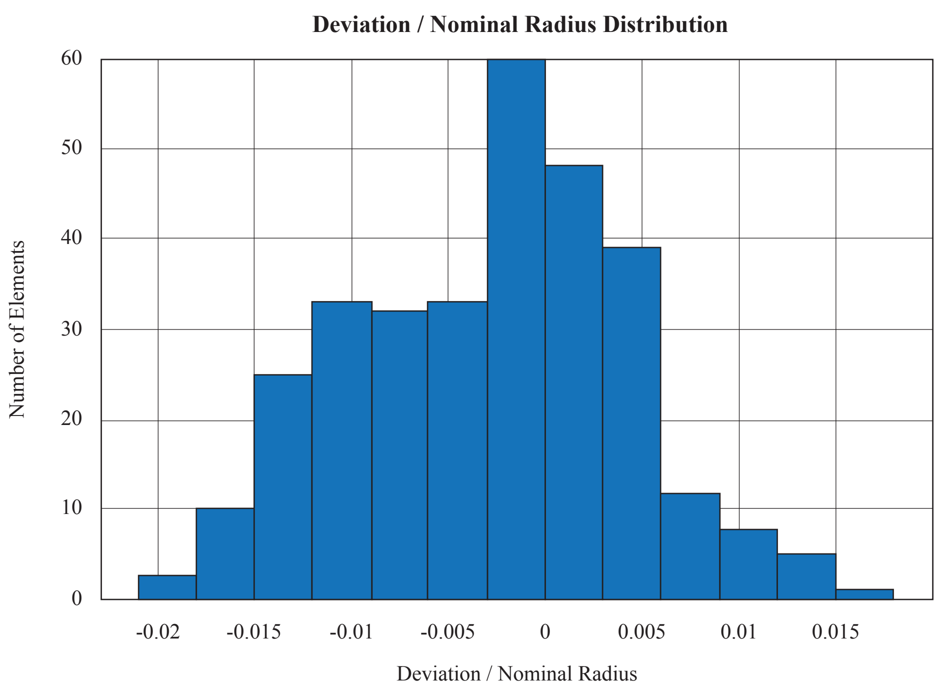


Fig. 14. Deviation / Maximum Radius dimensionless distribution.



standards for dimensional control. The first one *(ITTC, 2011)* is focused specifically on the control of the ship model manufacturing process, but does not show a very clear equivalence with the exposed method, since only the main dimensions of the hull are regulated. The *(DIN ISO, 1989)* presents geometric tolerance standards for parts in general, and its method proved to be more suitable for evaluating the points obtained by photogrammetry, organizing them according to the standardized classes of “Fine”, “Medium", "Coarse" and “Very Coarse" adjustment or rejecting values that do not fit the norm.

Dimensionless values of the deviations were also obtained, using the maximum radius of the hull as denominator. It was verified that, in this study case, points that meet the norm showed absolute values of $Deviation / R_{max}$ less than 0.015.

The presented method can still be adapted for surface hulls with the implementation of a module that calculates the beam deviation, given the longitudinal and vertical positions of the point. Multihulls should be evaluated separately and thrusters require further refinement of data collection techniques so that they can provide adequate assessment.

Acknowledgments

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Autonomous Shipping and Cybersecurity

Buques autónomos y ciberseguridad

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Abstract

Currently, as a result of new communications technologies, autonomous ships are even closer to our seas than we could think. But, besides undoubted advantages, it gives rise to uncertainties and challenges in several aspects, which include those related to the fields of cybersecurity and legislation, in relation to international regulations and national laws. The aspects of autonomous shipping are included in the information regulations of Bureau Veritas, and additional specific tags have been created to collect the cybersecurity/cyberprotection aspects of such ships.

The objective of this article is to present the current status and the foreseeable evolution of the regulations on autonomous shipping from the point of view of a Classification Society, as well as the current evolution of the methodologies concerning cybersecurity.

Key words: Connected ships, Autonomous ships / unmanned vehicles, Cybersecurity, IT/OT, Additional tags (Cybersafe/Cybersecure), Current research.

Resumen

Actualmente, y gracias a las nuevas tecnologías de las comunicaciones, los buques autónomos están aún más cerca de nuestros mares de lo que pudiéramos pensar. Pero, al igual que ventajas indudables, generan incertidumbres y retos en varios aspectos, entre los que destacan los relacionados con los campos de la ciberseguridad y legislativos, en lo referente a normas internacionales y legislación nacional. Los aspectos de los buques autónomos están recogidos en el reglamento informativo de Bureau Veritas, así como se han creado notaciones adicionales específicas para recoger los aspectos de ciberseguridad/ciberprotección de dichos buques.

El objetivo de este artículo es dar a conocer el estado actual y la evolución previsible de las regulaciones sobre buques autónomos desde el punto de vista de una Sociedad de Clasificación, así como la actual evolución de las metodologías concernientes a la ciberseguridad.

Palabras claves: Buque conectado, Buque autónomo/buque sin tripulación, Ciberseguridad, IT/OT, Notaciones adicionales (Cybersafe/Cybersecure), Investigaciones actuales.

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Introduction

The new technologies and the inexorable advance towards the 4.0 industry has introduced the maritime industry into a new field of possibilities in the development of the business:

- Increased security, such as the decrease in the possibility of human failures, etc.

- Reduced environmental impact, due to lower emissions and lower spill probabilities

- Reduced OPEX, given the possibility for a smaller crew, as well as improved ship performance that leads to lower fuel consumption, lower maintenance, etc.

- Optimized shipping management, basically due to integrated logistics, integrity management and continuous controls, monitoring and verification.

But although this "digitalization" process will bring numerous benefits and opportunities, it also entails new threats and challenges for the industry, from several points of view, which are highlight below:

1. Technology: Systems cybersecurity, connectivity, remote access, artificial intelligence.

2. People: Training, misuse of systems, corruption, etc.

3. Processes: Supply chain and Cyber Response Plan.

4. Legal: who is responsible for unmanned vehicles?

It is important to make a distinction between what is known by cybersecurity and cybersafety, which will help us better understand the problem:

- Cybersecurity (it is the protection against the intentional attack to a ship's systems, which would be also known as Cyberprotection).

- Cybersafety (the intrinsic safety of systems, *i.e.* reliability). As the independence of human intervention becomes more important, the reliability, both of the system's own equipment and the redundancy thereof, becomes fundamental.

Currently and as result of new communications technologies, unmanned vehicles are even closer to our seas than we could think. But for the existence of autonomous ships, we must not only provide the technical means to make feasible its materialization, but also cover legal aspects, regulations and the issues indicated above.

Current situation and Cybersecurity

In the results of the survey published by the specialized marine magazine IHS Fair play among 300 participants, 34% of them acknowledged that they had suffered cyber attacks in the previous 12 months (we must bear in mind that these participants are only those who were aware of being attacked!!!). Regarding these attacks, the greatest vulnerability was represented by the workers of companies, which accounted for 47% of them, while suppliers represented 19%.

The attacks have caused companies to consider the need to train their workers, both in preventive aspects as in how to react upon any risk or attack. 51% of companies have trained their workers in this regard, but only 23% are certified.

The following case is an example of what cyber attacks represent today: in June 2017, Maersk was attacked by malware as part of a global attack. The virus stopped the company's operations in ports such as Rotterdam, Los Angeles and Auckland and interfered with operations worldwide. Maersk reported losses close to 250-300 million dollars as a result of the operations that took place in July and August.

But as mentioned above, most cyber attacks are carried out by company personnel: an example of this is the cyber attack suffered in a MODU oil rig with a dynamic positioning system. A worker on the platform, completely unintentionally, introduced a malware through a USB stick inserted into a computer. This caused a loss of dynamic positioning and made the platform go adrift, so for security reasons, the well had to be temporarily closed. This could have resulted in a disaster not only for the workers but also for the environment!!

A final example would be that of the Clarksons magazine, in which the attackers gained unauthorized access to their computer systems and to the information contained in them, to then request a ransom for that information under the threat of disclosing it. The company's shares fell 2.71%.

This situation makes nonnegotiable the need to increase the security of the systems against external attacks and system failures due to reduced crews.

Autonomous Shipping

Autonomous ships should not be confused with unmanned vehicles. The definition of both is the following:

1. Autonomous ship. A ship that is capable of making decisions and executing actions with or without human intervention in the chain of decision. An autonomous ship can be manned with a reduced crew or no crew.
2. Unmanned vehicle. A vehicle that does not physically contain human life on board and is capable of executing controlled movements.

Internationally, autonomous ships are known as MASS (Maritime Autonomous Surface Ships).

To define their degree of independence with respect to human beings: data collection, data interpretation, decision assistance or completely autonomous, Bureau Veritas classifies autonomous ships according to who executes each step in the decision-making process (see Fig. 1).

It is important to emphasize that the previous classification is not homogeneous internationally, and different organisms represent the current situation in more or less levels, but the philosophy is common.

The aspects of autonomous shipping are included in the specific information regulations Bureau Veritas NI 641 "Guidelines for autonomous shipping" *(December 2017 Edition)*, and additional specific tags have been created to collect the cybersecurity aspects of such ships.

This process of autonomy and independence from human interference leads to different benefits, such as:

- Reduced crew costs

Fig. 1. Bureau Veritas classification of autonomous ships

Category	Level of Autonomy		Manned?	Control Method
Conventional	0	Human operated	Yes	Manual or automated operations under human control
Smart	1	Human assistance	Yes/No	Support in decisions. Humans take actions and decisions
Autonomous	2	Human delegated	Yes/No	Humans must confirm decisions
	3	Human supervised	Yes/No	The system awaits confirmation. Human are always informed of decisions and actions
	4	Completely autonomous	No	The System does NOT await confirmation. Humans are only informed in case of emergency

- Reduced human errors (let's remember that almost 80% of incidents/accidents are caused by human errors!)
- Reduced ship weight, by eliminating human support weight in superstructures
- Reduced fuel consumption (6%)
- Increased spaces dedicated to cargo
- Reduced construction costs (approximately 5%)

But there are other aspects to be taken into account and that have not been resolved yet, such as:

- Increased system reliability, which will result in a redundancy of many systems, increasing construction CAPEX by 10% for this reason.
- Technology. The current state of the art does not allow considering fully autonomous ships without the evolution of artificial intelligence systems, etc.
- Legal aspects. We must take into account the legal responsibilities that these ships represent, since they lack crew, and above all, the highest authority on the ship: the captain
- Regulatory aspects: the current rules assume the existence of an onboard crew and must adapt as the industry develops in this direction, taking into account the possible solutions to the problems that will be faced. Some of the regulations to take into account are the following:
    - o STCW. Crew training. The treatment of the new "crew" of the vessel and its training should be appropriate to this new situation.
    - o COLREG. The prevention of boarding attacks becomes even more important in the case of unmanned ships. Surveillance and identification systems must be increased.
    - o SOLAS. Security of Human Life at the Sea... without crew? Firefighting safety systems must be installed in those places that are subject to fire risks, or automatic extinguishing systems that replace manual systems.
    - o ISM. There must be a communication channel between the Company and the people onboard the ship.

Cybersecurity

Given the current trends of increasingly "connected" ships, it is essential to provide protection given the possibility of cyber attacks. Such protection is even more important, if possible, when taking into account the possibility of increasing the autonomy of ships.

With respect to cybersecurity, it is worth highlighting two widely used regulatory standards:

a) On the one hand, the international regulations of the International Maritime Organization (IMO), through MSC 428 (98), adopted in 2017. It is titled "MARITIME CYBER RISK MANAGEMENT IN SAFETY MANAGEMENT SYSTEMS". In this MSC, it is indicated that cyber risks must be correctly taken into account before the first annual visit for the issuance of the Company's Compliance Document, after January 1, 2021. In addition, this item must be included in the ISM.

b) On the other hand, the regulations of the European Union, which have two sources:

b.1) EU Directive 2016/1148 (This Directive concerns the security of information networks and systems). It is called NIS Directive. It includes the ports but not the ships.

b.2) The GDPR Directive (corresponds to EU 2016/679). This directive is already applicable (since May 2018) and includes ships.

It is important to highlight the creation of a specific cybersecurity-dedicated agency in the European Union, which is called ENISA (EU Cybersecurity Agency).

Another widely used standard, which is not in any case in the field of regulation, is the benchmark framework established by NIST (NIST = National Institute of Standard and Technology, part of the US Department of Commerce).

They are a very important reference framework, and are based on the current BIMCO guidelines (which acronym stands for "The Baltic and International Maritime Council").

Among the standards indicated by NIST, it is important to highlight that it establishes a series of parameters that must be solved sequentially in order to provide proper security. These parameters are the following:

a) Risk Identification. Among the corresponding categories, it should be emphasized the need to conduct risk analyses, not only for the formalization of the system used but also for its execution, affecting the entire company's logistics chain.

b) Protection of systems in the event of a cyber attack. This section includes all the protection related to maintenance, the formation of teams, data protection, etc.

c) Attack detection. The detection process must be taken into account, as well as the consideration of possible anomalies and a continuous monitoring system, in order to be able to detect an attack early.

d) Response to the attack. The purpose is to stop the impact of the incident, and involves actions to plan the response, plan correct communications, as well as the analysis of the attack, including mitigation systems and improvements.

e) Recovery of systems/data/etc. To this end, planning should be done on the possible recovery of information and systems, as well as on any improvements.

Other standards correspond to ISO, IEC, etc.

Once the problem has been identified, it is important to make a distinction about which ship system is being attacked. This division will be defined according to whether it will affect an IT or OT system of a ship:

a) *IT (Information Technologies).*
When an attack takes place on the IT systems of a ship, in which the financial and commercial aspects will be mainly affected, from the point of view of the reputation lost.

An example would be electronic mail systems, electronic certificates, etc.

b) *OT (Operation Technology)*
In this case not only monetary and commercial aspects are affect, but human life, the ship or platform are endangered and there is a possibility of environmental con-tamination.

The following are some examples of OT systems: ship navigation systems, dynamic positioning systems, etc.

Solutions of Bureau Veritas

The solutions found consists of additional tags that will provide additional benefits in terms of security and reliability.

a) Regarding the reliability of systems, the safety thereof is affected by three terms which together may cause an accident. These terms are: Systems, Software and Human Intervention. To deal specifically with these aspects, it is worth highlighting 2 additional tags in this regard:

a. SW-Registry. Software registration and maintenance.

b. HWIL (Hardware In The Loop), for

testing complex systems. It is developed through regulations Bureau Veritas NR 632 and NR 467.

b) Regarding cybersecurity, it is also affected by the intersection of 3 systems: Objective, Protection and Attacker.

To solve this issue, Bureau Veritas has created 2 specific tags, both included in Regulatory Note 659 (NR 659) (Cyber Managed and Cyber Secure), but without leaving aside the importance of certifying the logistics chain, which is established in Regulatory Note Bureau Veritas 642.

The CYBER SECURE tag is especially directed to newly built ships and affects both equipment (and their certifications) as well as the design of all aspects related to a possible cyber attack (physical access, such as cables, etc., as well as remote accesses both onboard and onshore). This tag not only affects the shipbuilder, but also equipment suppliers, shipyards and the systems integrator. Security control is carried out by means of automatic software. Equipment can be certified or not depending on the level requested in this same tag (certified equipment can be requested or not).

The CYBER MANAGED tag has been created especially for ships that are currently in service, and for those in which a design evaluation cannot be carried out, since it has not been taken into account in construction. In this tag, the roles of each one of the participants are detailed and explained. Likewise, the procedures used will be taken into account. Crews must receive adequate training on issues against a cyber attack. The organization must have a change management policy to ensures the proper management in terms of IT and OT systems. Similarly, through this tag, an adequate response must be given to incidents (both locally and remotely) and the status of vulnerabilities must be monitored. In this case, security control is achieved through manual procedures, unlike in the CYBER SECURED tag.

Furthermore, Bureau Veritas has created the SYSCOM tag, which is directly aimed at the prevention of malicious attacks. It is also a voluntary tag that protects data exchanges onboard and onshore.

Current research on Autonomous Shipping

Currently, Bureau Veritas is participating in the development of projects, both financed by public bodies and by industry consortia, in the field of unmanned ships. The following are currently the most important:

Bourbon Smart Ship Program

The consortium formed by the shipping company Bourbon, the manufacturer of dynamic positioning systems Kongsberg and Bureau Veritas, is developing a program that increases the automation level both in operations and in processes.

It allows a ship to transmit data onshore so that it can be analyzed and resolved, which translates into a reduced crew and reduced time onboard.

A pilot system is being developed and implemented on the ship Bourbon Explorer 508 (you can consult the website https://youtu.be/tCXe1eXJElM).

The next steps in this project will consists of the development of continuous testing and remote verification systems in relation to the ship's dynamic positioning system.

NOVIMAR Program

The NOVIMAR project is a H2020 European project with EU funding. It consists of the development of a new concept of marine transport called Vessel Train (see https://vimeo.com/263869758). The vessel train consists of a leading ship (L) followed by a series of ships with reduced crew and digitally connected to the leader, which are called follower ships (F).

This concept will reduce operational costs and increase economies of scale due to its use of existing infrastructures.

Fig. 2. NOVIMAR Concept

Source: NOVIMAR Webpage.

Twenty-two companies participate in this Consortium, from logistics operators, industry, public and research agencies belonging to 7 EU countries and two associated countries.

Autonomous shipping JIP

The Dutch marine cluster, according to its planning, will carry out a first test of an autonomous ship in 2019. The vessel will be an existing offshore operation ship facilitated by SeaZip Offshore Services and built at the Dutch shipyards Damen. The demonstration will be part of a much more extensive 2-year program that includes a consortium of 17 members, which includes, in addition to Bureau Veritas and Damen, the Marin Channel, the Dutch University, TU Delft, etc.

This project is co-financed by the Ministry of Economic Affairs of the Netherlands.

Conclusions

Completely autonomous ships, to this day and in spite of the pilot projects created with small ships, seem a utopia in large ships, but which will be reached as the technology develops. What is sure and more immediate is the possibility of reducing crews given the current technology, although the equivalence of safety aspects with respect to minimum crews must be verified.

Cybersecurity is a fundamental aspect not only for the development of autonomous shipping technology, but also a navigation need, to accommodate the increased vessel connectivity, or through increases in automation with smart aids for operations such as the monitoring of various parameters and remote assistance to solve problems and incidents, while providing protection against attacks to both systems and communications.

Cybersecurity, together with the development of unmanned vehicles and autonomous ships, is a great opportunity for our entire sector and offers many different R&D opportunities in different aspects that will surely be implemented in the maritime sector.

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Naval Architecture: From Theory to practice

Arquitectura Naval: De la Teoría a la Práctica

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Abstract

The complexity of projecting and designing a ship requires a work sequence that covers at least three main areas: (1) Concept engineering; (2) Basic engineering; (3) Detail engineering. This paper explains the design transition that exists (or should exist) between concept engineering and the final product, emphasizing the existing contractual relationship with the shipbuilder, especially in the initial definition of the project and the influence on construction aspects.

Key words: Design; naval architecture; mission profile; shipbuilding.

Resumen

La complejidad del proyecto y diseño de una embarcación obliga a plantear una secuencia de trabajo que abarca al menos tres grandes áreas: (1) Ingeniería de concepto; (2) Ingeniería básica; (3) Ingeniería de detalle. El presente trabajo explica la transición de diseño que existe (o debería existir) entre la ingeniería de concepto y el producto final, poniendo énfasis en la relación contractual existente con el armador, especialmente en la definición inicial del proyecto y la influencia sobre los aspectos constructivos.

Palabras claves: Diseño; arquitectura naval; perfil de misión; construcción naval.

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Introduction

The development of a naval architecture project, unlike a traditional project, requires taking into consideration the complexity existing in the autonomy that a final work must have, in the broadest meaning of the word. The basic premise of the initial approach must ensure that the project must be capable of complying with construction and regulatory requirements, which on are often contradictory (especially in special ships), either due to the safety of human life at sea or simply due to aspects related to physics and mathematics.

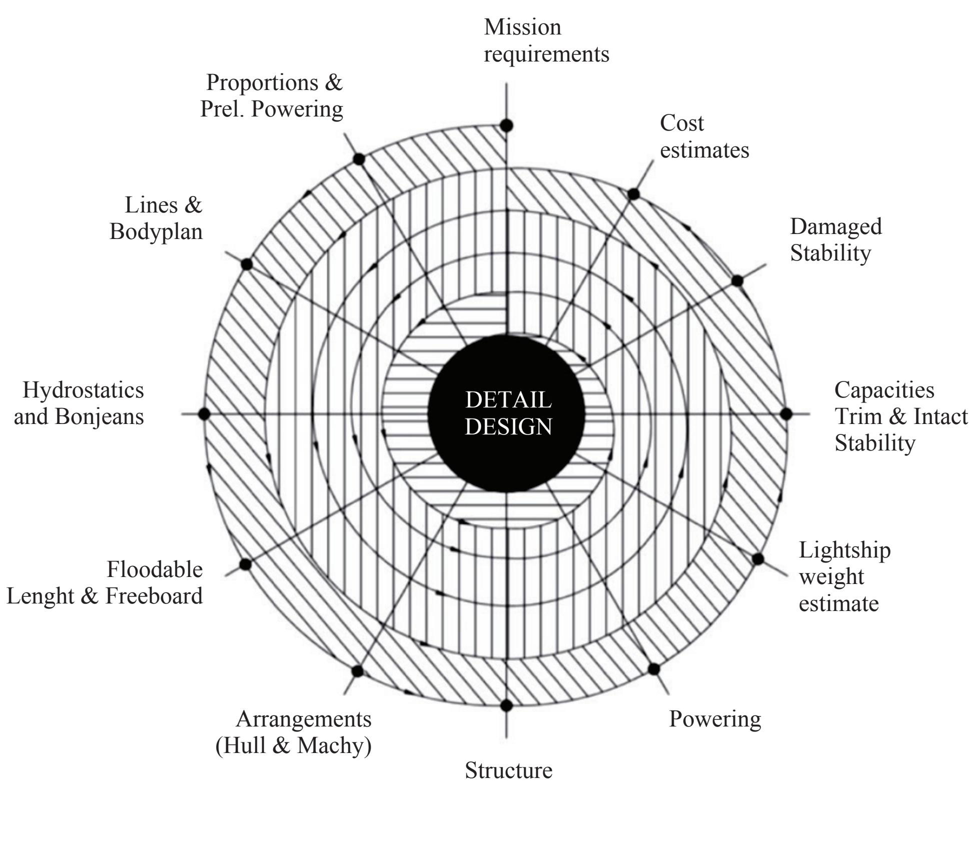
Therefore, it is important to correctly state in the early stages the concept that contains the construction requirement, which would allow obtaining a higher level of success. However, all modifications and corrections required must be applied, surely delaying the project substantially, although allowing the completion of the work in a satisfactory manner.

Certain aspects of ship design

Each of these stages has a "defined function" in the project and in the design. For example, basic engineering allows having sufficient information for the technical and economical assessment of the project, its reliability, feasibility of construction and complexity from the engineering point of view. On the other hand, construction engineering involves details of the project that must be applied according to the shipyards, especially because not all shipyards operate in the same way, either due to training or resources. The problem arises in the early stages of the project, especially in the vague line that separates concept engineering from basic engineering.

The design of the ship, as it is the result of a set of specialties that are transformed into a product, requires the integration of such specialties through logical coordination, which at least is proposed and represented by what is known as the "design spiral"[1] (Fig. 1).

Fig. 1. Design Spiral



The "design spiral" is the most basic expression in the organization of a ship design, following the detail of each one of the process stages, the programming of the execution of works, either by means of a Gantt Chart or another system that allows adequate control, etc.

It is of special interest to refer to the critical design stages, such as for example the following:

a) *Definition of the mission profile:* It represents the life of the ship, which is closely associated with the participation of the shipbuilder. The proper definition of the mission profile, with the details required, will avoid later design problems.

b) *Definition of forms:* Stage associated with an adequate selection of the main dimensions, supported by a database based on the mission profile. The use of modern tools for the development of forms not only provides a high degree of accuracy, but also speed, allowing to provide a response within appropriate time frames.

c) *Hydrodynamic studies:* It is considered as one of the most complex stages where aspects that in many cases are contradictory are interwoven, for example, the relation of load capacity, hull volumes and speed. The use of numerical methods supported by tests carried out at marine hydrodynamic laboratories make this task one of the most representative of the world of naval architecture and the application of advanced tools.

d) *Structural design:* This stage is subordinated to hydrodynamic aspects and is very important in the design process, especially in ships with a special layout.

e) *Estimation of costs:* This stage allows determining the feasibility of a project, defining the size of the ship and the level of finishing, associated with the profitability sought by the shipbuilder.

Concept engineering

The concept engineering defines the subsequent development of the entire project, in the understanding that this stage will at least define the mission profile, the power to be installed on board, the general plan, preliminary weight estimation and certain preliminary costs.

The above can be discussed or not, depending on what is understood by concept engineering. Some authors define it as the first loop of the design spiral and the execution of which must be closely related to the shipbuilder. The problem arises when trying to define the line that divides concept engineering from basic engineering, since a "greater definition" of the concept will always be required before going to the next stage, which in many cases implies the conclusion or no of the design agreement. The number of engineering hours invested in this stage is difficult to quantify, depending on the type of ship and the work method of the design office or design department of the shipyard.

Fig. 2a shows concept engineering using the "design spiral" as a basis[2]. In turn, Fig. 2b shows a proposal regarding the order of priorities in the concept stage, while Fig. 2c shows the limits of all stages, concept engineering, basic engineering, contract engineering and detail engineering.

The level of depth of each one of the stages of concept engineering is subject to the resources available and the programmatic framework of the project, i.e. engineering hours are directly related to the project development program.

As indicated above, a deeper concept definition will allow the project to be developed more easily, since decisions regarding the concept will not be made in advanced stages of the project.

Table 1 shows the proposed scope of concept engineering.

Fig. 2a. Concept engineering.

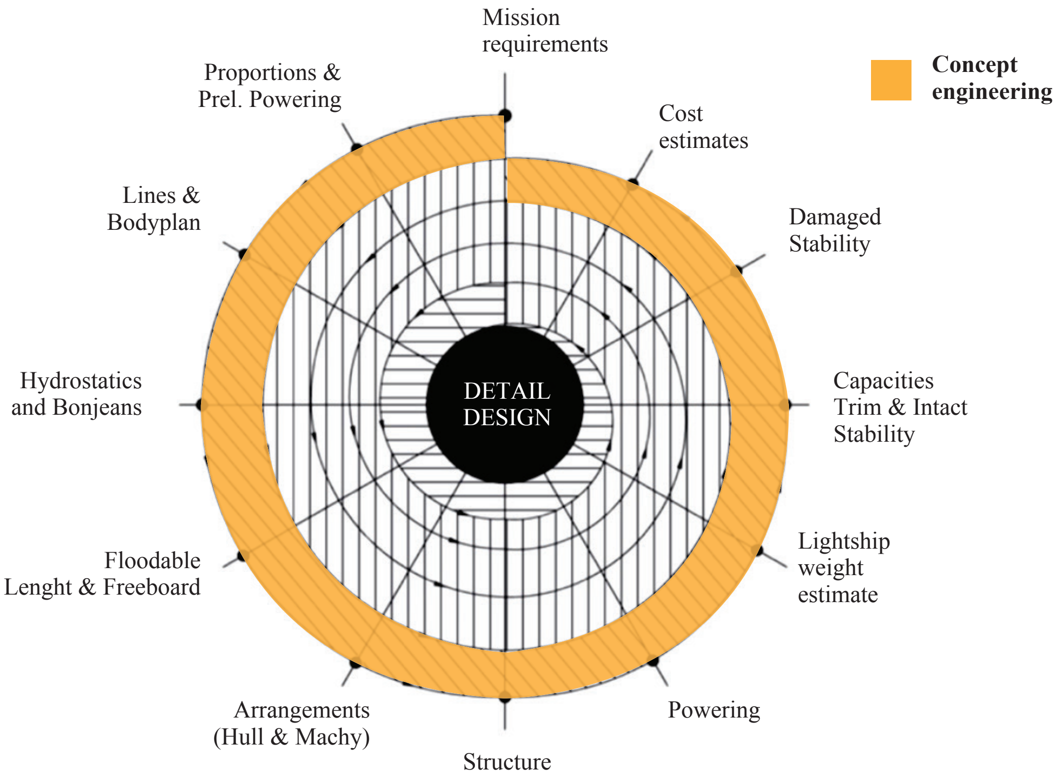


Fig. 2b. Order of priorities.

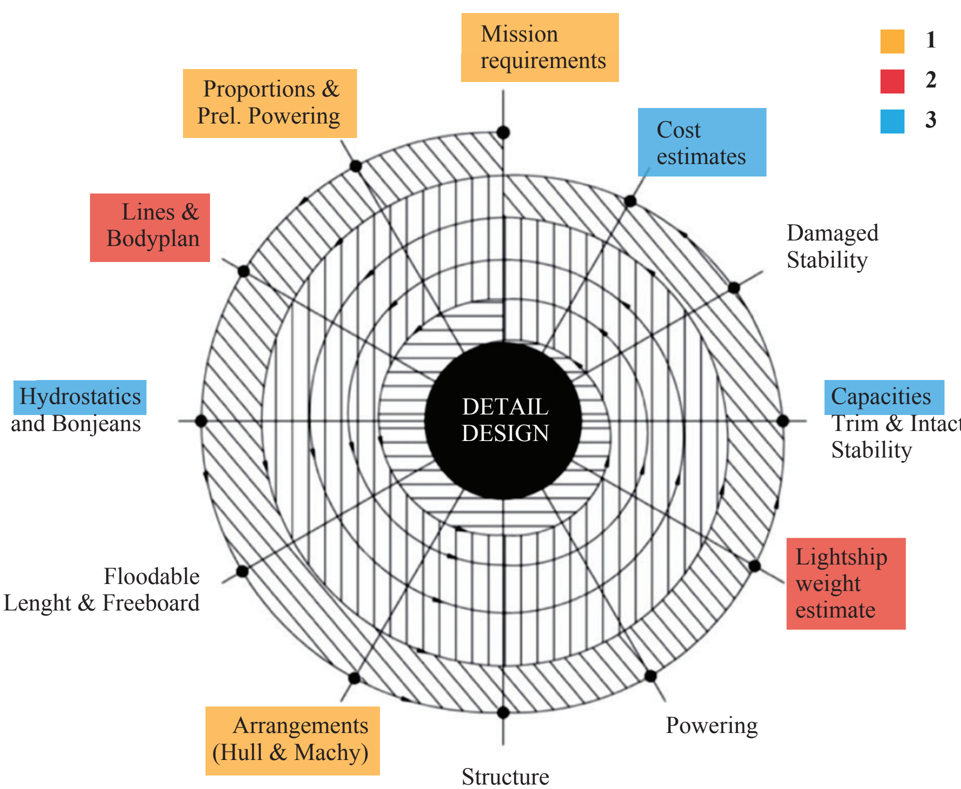


Fig. 2c. Limits of engineering stages.

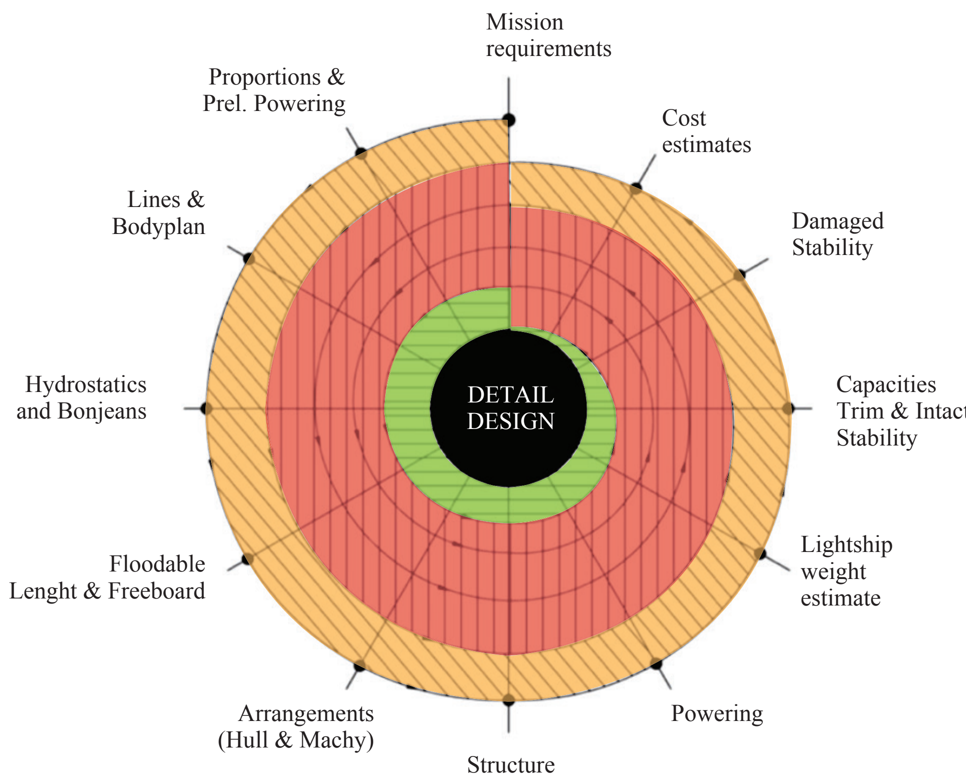


Table 1. Proposed scope of the concept engineering stage.

Stage	Scope
Mission Profile	Definition of the purpose of the ship and its technical characteristics depending on the area of operation, required capacities and specific needs to be met.
Main dimensions	Definition of the preliminary main dimensions using iterative methods and databases of "similar ships".
Design of preliminary forms	Generation of the preliminary forms of the hull, adapting the necessary volumes and the hydrodynamic characteristics associated with the mission profile, using approximate methods for the definition of geometric coefficients.
General layout	Definition of the general plan based on construction requirements, complying with the mission profile and considering a fine level of detail, which allows facing the rest of the project with the ease of having detailed information.
Power estimation	Association of the preliminary estimate of power with the preliminary hull forms using approximate methods and/or systematic series suitable to the type of ship.
Structure	It is recommended to carry out a preliminary scantling based on the rules of Classification Houses, drawing at least a sketch of the master frame, which allows proposing the structural distribution based on this structure.
Weight and displacement estimation	An estimation of weights is made using approximate methods, correlating this stage with the preliminary main dimensions and the development of forms, adjusting the preliminary design draft and the estimated displacement.
Costs estimation	There are several approximate methods for estimating costs in the early stages of the project, although the experience of the designer and the history of the shipyard will be paramount at this stage.

From theory to practice: case studies

Projects usually go through a critical initial definition stage and are successful when they manage to overcome this stage and be fully developed. This section describes some critical and/or breaking points in the conceptual development of successful projects.

Main dimensions and work scale of the project

The order, which in principle is very simple, deals with a recreational ship to be built in wood and which target image is the traditional (historical) ships of southern Chile. The original ships, as shown in Fig. 3, are only sailing boats and their mission profile is directed to work functions, but mixed propulsion is requested and its mission profile is mainly pleasure navigation.

The original main dimensions are circumscribed to what has been defined in templates from Europe. It has a length not exceeding 9 meters and with a running roof, which is only interrupted by a sliding hatch cover that allows access to the cargo and/or accommodation area, which in most cases is precarious. These ships have a generous beam and a sailplane composed of a larger main sail and a jib.

The mission profile, in this case, begins with the definition of accommodation requirements, which leads to estimating preliminary dimensions that exceed the traditional length. The first approach resulted in a length of 10 meters, considering a cabin with private toilet, a visitor cabin with capacity for three people, dining room, visitors toilet, full kitchen, crew cabin and engine room. The dimensions of the accommodations required by the shipbuilder require an increase in the length of the ship, being finally limited to 12 meters.

The main problem faced from the design point of view is the management of the scale required by the project, specifically in regards to indoor spaces and of course the handling of rigging, maneuverability and rudder, structural design and equipment on board, considering that it is a ship constructed using artisan methods and which dimension rations are outside the ranges normally used.

From the theoretical point of view the project does not pose major difficulties, but from the practical point of view it faces two aspects that must be considered: the construction system and the finishing level required by the shipbuilder, which are not traditional in an artisanal ship. The concept engineering presented to the shipbuilder was limited to aesthetic aspects, both exterior and interior, which in many points of the project resulted contradictory with other requirements. However, it was possible to bring the concept to reality, as shown in Fig. 4.

Fig. 3. Original ships.

Fig. 4. Full-scale ship.

Compromise solution for support ship

The order arises from the need of the shipbuilder to have a boat that must mainly fulfill two roles, in addition to the normal roles of a ship. It must be considered that in naval architecture the definition of "multipurpose" restricts the project in some areas to enhance others. The project presents a ship that will perform tasks such as LEP and REM, highlighting the difficulty of combining the values required by the standard in certain aspects, for example the freeboard and the heel at the time of the pulling action.

The design process focused on two aspects:

a) Design of forms
b) Strength and position of the pulling point associated with stability criteria

These two aspects are directly related to the requirements of the Maritime Authority, regarding the criteria of stability and what has been defined in the Rules of Classifying Houses as the method for calculating the heeling moment.

The methodology used consisted of a calculation matrix composed of the parametric variation of the ship's beam, force and pulling position. The flooding angle was defined as a constant in the analysis, considering that the hull models were adjusted, thus achieving a considerable reduction in the models to be studied.

Table 2 shows the main features of the ship.

Table 2. Main characteristics of the ship.

Characteristic	Unit (m)
Total length	16.50
Maximum beam	5.20
Moulded depth	3.15

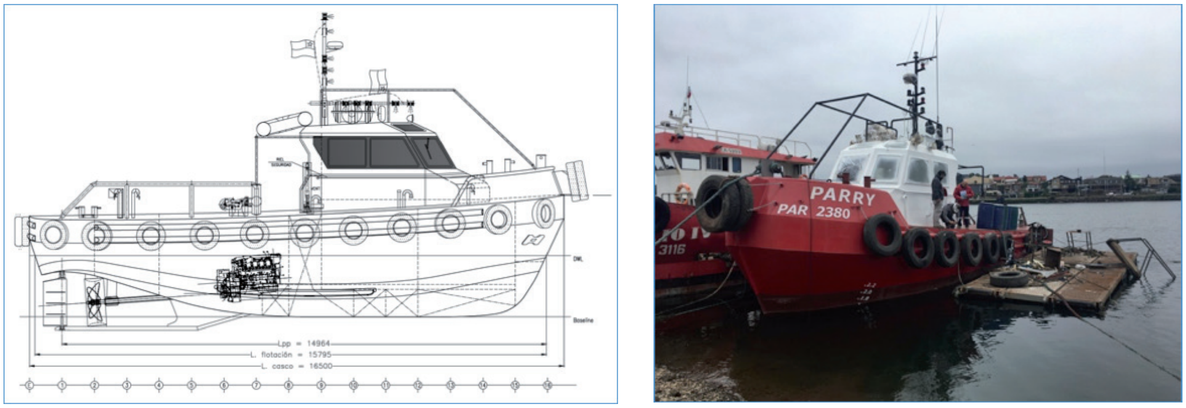
Fig. 5 shows the general planimetry of the ship during its finishing phase.

In theoretical terms, compliance with stability criteria can be covered in the design stage. Although it implies a laborious analysis process, the objective of the mission profile was achieved in this stage. In practical terms, a careful control of weights is required during the construction process, ensuring that the modifications are the minimum possible so as not to alter the draft or trim of the ship. There are other restrictions and requirements arising from concept engineering associated with regulatory requirements, thus making the project complex and requiring thorough control on each stage.

Prediction of failures in design stages

Sailing ships pose design challenges additional to propelled ships. In this case, the ship is a mini-coastal vessel 6 meters in length. From the theoretical point of view, the design is framed in traditional lines but with a greater hull volume,

Fig. 5. General planimetry and finishing phase.



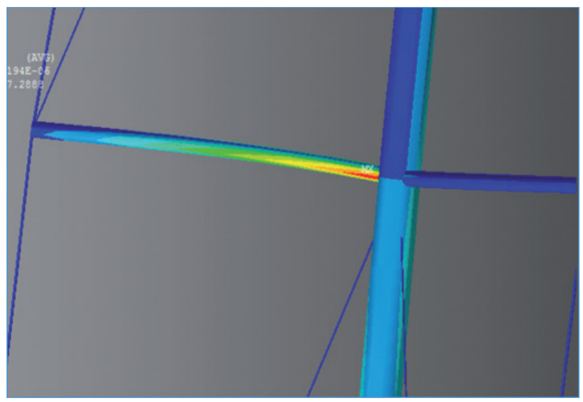
which provides a generous freeboard for this boat size segment. The need to provide the boat with a safety range that will allow it to face demanding regattas resulted in the improvement of the position of the ship's center of gravity with respect to the original design and in the redesign of the sailplane. The structure broadly complies with what was proposed by the Classification Houses and the yacht design literature.

Fig. 6 shows what was built and installed on the ship and Fig. 7 [3] shows the failure area that takes place in the case of a "forced" maneuver with a spinaker.

Fig. 6. Built part of the ship.

The prediction of the structural behavior of the different component parts of the ship, allow, among other things, recommending the operation of the ship by limiting some maneuvers in order to avoid possible structural failures.

Fig. 7. Failure area.



In theoretical terms, a load condition was defined that would cause mast failure. This load condition is produced by a forced maneuver of the spinaker. In practical terms, this was fully demonstrated by removing the mast while navigating, which is shown in Fig. 8.

Conclusions

Although the initial notes and the cases presented are specific and limited to small ships,[4] the experience of going from theory to practice can be extrapolated to larger ships and naval artifacts, especially in relation to conceptual engineering. The implementation of state-of-the-art tools to simulate the behavior of the ship in the different design stages, either through numerical codes for the simulation of flows around the hull or the

Fig. 8. Removed mast.

structural behavior of the hull, allow narrowing the distance between theory and practice.

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Naval professional qualification in the Amazon state

Formación profesional naval en el estado amazónico

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Abstract

This article aims to report the efforts that have been made in the Amazon State for Naval professional qualification from 2007 up to now. And it is justified by the position of the Amazon State as one of largest Naval Brazilian Poles, so it is necessary to qualify professionals to meet the demands of construction, repair and maintenance of fluvial vessels in the shipyards. Partnerships with government institutes for education qualified shipbuilding technicians; and partnerships with private universities and other nongovernmental organizations sought to provide a new way of thinking for engineers and architects who were unaware of the naval market. The standards applied in the trainings and their respective focuses will be presented here. And the results will show the synergies created with other universities, the market, the shipyards and the professionals who were qualified.

Key words: Amazon, Professional Qualification.

Resumen

Este artículo tiene como objetivo presentar los esfuerzos que se están haciendo en el Estado de Amazonas para la formación profesional naval, desde 2004 hasta la actualidad. Teniendo en cuenta la situación de que el Amazonas está ubicado entre los más grandes polos navales de Brasil, se hace entonces necesario formar al personal para las demandas de construcción, reparación y mantenimiento de las embarcaciones fluviales en los astilleros. Las alianzas con institutos de educación profesional del gobierno, formaron técnicos en construcción naval y las alianzas con instituciones de enseñanza superior privadas y otras organizaciones no gubernamentales, buscaron formar nuevas visiones para los ingenieros y arquitectos que desconocían el mercado naval. Se presentarán en el artículo los modelos de cursos aplicados y sus respectivos focos, y los resultados de las sinergias con otras instituciones de enseñanza superior, con el mercado, con los astilleros y con los profesionales formados.

Palabras claves: Amazonas, formación profesional.

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Introduction

A Brief History of the Naval Sector in Brazil

Sivar Hoepner Ferreira, from the Paulistana Academy of History, in the work "Note on Naval Construction in Brazil in the XVII and XVIII Centuries", describes that, at the time of the great navigations, Brazil was contemplated with the installation of shipyards for repair and maintenance of wood vessels in its coastal, due to its strategic geographical location in relation to the “Route to India” and also for having wood in abundance to be used as input for the shipyards.

In 1549, Tomé de Souza, a Portuguese military and politician, came to Brazil and brought in a group of qualified professionals to work in the shipyards, such as: construction masters, naval carpenters, calligraphers, blacksmiths and other ones able to teach the Portuguese workers and “mestizos” who already lived in the country.

In the end of 1500th year, in Bahia, by that time the capital of Brazil, the first shipyard called Ribeira das Naus was settled to repair and maintain the Portuguese´s vessels.

In 1663, the capital of Brazil was transferred to Rio de Janeiro and it was created the Navy Arsenal of Rio de Janeiro.

In 1767, the first ship built in Brazil, named “São Sebastião”, at the Navy Arsenal of Rio de Janeiro was launched.

In 1770, the Ribeira das Naus Shipyard, located in Salvador, was renamed for the Navy Arsenal, and was extinguished in 1899. A plant dating from the 18th Century indicated an imposing set of buildings of approximately 300,000m^2 in size, including paths of raw logs, workshops, warehouses, barracks and boilers (closed basin).

In 1874, according to information from the Santa-Anna Nery Baron the first European vessel, with Danish flag, arrived in Manaus from Hamburg. It was a sailing boat weighing 263 tons.

In 1937, the São João Shipyard was settled in Manaus, Capital of the Amazonas State, it is considered the oldest shipyard in operation in Brazil.

In 1945, after the II World War, the West began to use more iron and steel vessels, thus opening up new demand for shipyards that had previously worked almost exclusively with wood.

Since 1970 many shipyards have been opened in Manaus, which began not only to manufacture wooden vessels, but also iron and steel vessels; the ferries, tugs and pushers are not only the most manufactured ones, but also the most suitable ones for the transportation of cargoes to the inland navigation.

In 1996, a new option of transport was created, aiming to serve the country side of the Amazon. It is exclusive for passengers and hand luggage, it is made of aluminum hull and it´s called “Expresso”, as its speed is well above the regional boats, thus reducing travel time.

In 2000, forced by the difficulty in obtaining the wood from legal origin for the construction of the hulls in the state of Amazonas, the shipyards began to renew the fleet of mixed vessels (transport people and cargo) to the iron and steel hull.

And from 2010 on, due to the demand of agribusiness, called “Arco Norte”, in the country side of Brazil, the vessels needed to be modernized again to bring the grains in their rafts and pushers through the Amazonian rivers.

The range of the Naval sector

The naval sector has three major divisions that strongly complement each other: the transport of cargo and people, the terminals and ports, and shipbuilding. As this article is about professional qualification in the naval sector, we will focus specifically on this topic. Following:

- The transportation of cargo and people in waterway or waterway modal is carried out in boats. In the Amazon there is the mixed transportation, that is, in the same boat loads and people can be transported. In addition, there is the cargo transport that carries both general loads and bulk. The crew that works on the vessels is qualified in the Instruction Centers of the Brazilian Navy; there is one these in Manaus and another one in Belém in Pará;

- Terminals and ports are the places where vessels dock to leave people, luggage and cargo. In Manaus there is a Public Port that serves mixed vessels and cruises. And there are 2 private terminals that serve the vessels that do cabotage or long haul, bringing cargoes. There is a Port Labor Management Organization (OGMO) that develops the professionals who work both in the warehouse and in the wharfage. However, the Private Terminals began to promote internal training, thus bringing more productivity to the port activities; and

- Shipbuilding occurs in shipyards that offer the services of manufacturing, maintenance and repair of vessels. Thus, it requires Professional, supervisors, engineers, architects, etc., who need to be experts in the building vessels that are certified and classified according to Brazilian Navy standards in order to be approved for sailing.

In this article we are going to talk about the Naval Construction Professional.

Navigation in the Amazon

In the Amazon State most of the existing highways are non-transitable, besides BR 174 that goes from the Amazon to Venezuela, thus the waterway is the most used modal of transportation. The Amazonas is the best river known but there are several other tributaries that also need to be navigated.

In this way in the Amazonas states several modals of navigation, such as: long haul, cabotage, inland and crossing navigation:

a) The cabotage and long-distance vessels usually transport unitized cargo to the Industrial Pole of Manaus (PIM);

b) The vessels that do inland navigation come from the States and Countries surrounding the Amazon State, and they perform mixed transport (load and people). There are also the ones that are exclusive to bulk transport from the center of Brazil to the ports of the North, performing the inland navigation;

c) In the inland navigation, there are also those that only transport passengers; those travel in a very high speed, as a result the duration of the trips between the cities in lower;

d) There are boats that do crossing navigation. Those are propelled boats that transport cars and people from one shore of the river to another, thus facilitating road trips; and

e) Finally, there boats used for sports and leisure, they are minority, but they make small inland routes on the weekends and holidays.

Demand for the Naval Sector

According to the ANTAQ (National Agency for Water Transport) there has been a significant increase in what we call "Arco Norte", that is, transportation of grains (soy and corn), which passes through the private port of Hermasa, in the city of Itacoatiara, 269 km of road from Manaus, according to Fig. 1.

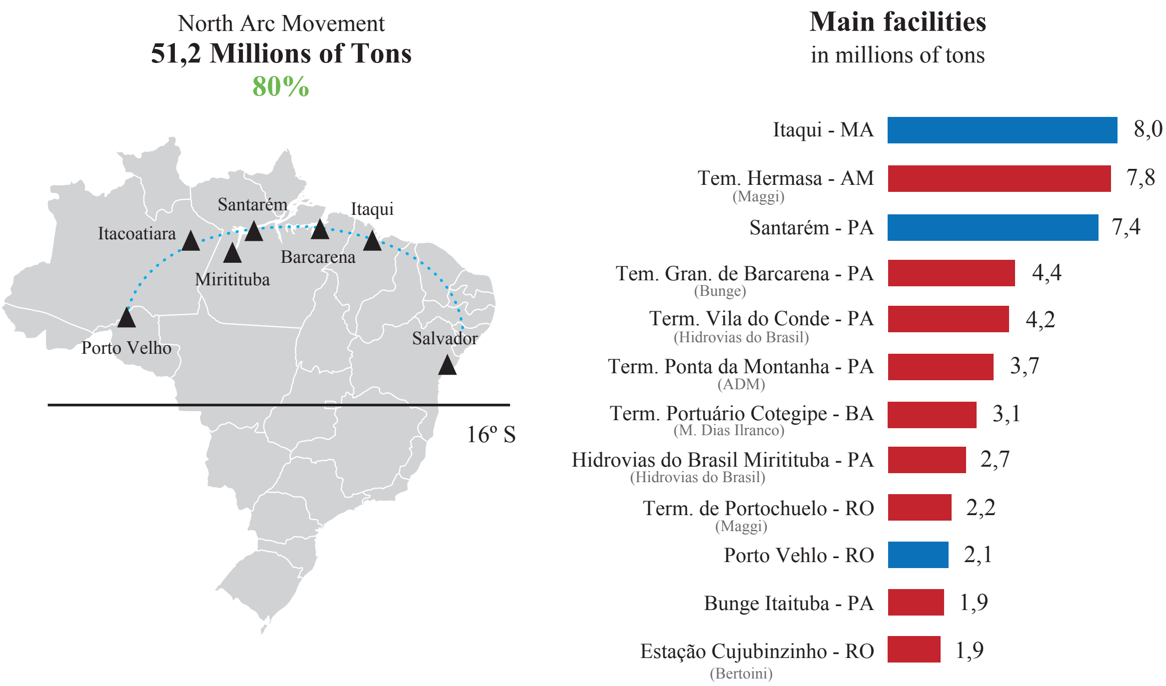
Data from 2017 show that Brazil handled 64% of in bulk solid cargo. Iron ore, soybeans, containers and corn were the four main goods exported to China, the Netherlands and Japan.

The data show that from 2010 to 2017 the "Arco Norte" went up from 23% to 41%; That is, all the indicators show that this demand is notorious and it has to be covered meaning that manufacture, maintenance and repair of vessels must be supported.

In order to drain the grains the rafts and the pushers need new technologies and maintenance.

As per what was seen above, there is demand for the naval sector, mainly coming from the

Fig. 1. North Arc Movement in 2017.



Source: ANTAQ.

transportation of grains (soy and corn), better known as "Arco Norte".

Material and Methods

The material for this work is the technical qualification courses of the naval sector that have started in 2004 with qualification courses in Naval Construction technology, then the technical qualification courses, the undergraduate course and the extension courses. All of them run in partnerships with educational institutions. Some of them are still in place in the institutions.

The method used was ethnography, which is based on observation and hypothesis analysis, where observers sought to describe what is happening in the context (naval sector) with the subject researched (professional qualification).

Due to lack of information, quantitative data were not available; therefore, the analyzes and results were qualitative.

The SWOT Analysis tool will be used to identify the characteristics of each variable (naval sector training course). This technique was founded by Kenneth Andrews and Roland Christensen and was intended to aid and improve business strategic planning in the 1960s and 1970s. The term "SWOT" stands for strengths, weaknesses, opportunities, and threats. It is a management tool which main purpose is to evaluate the internal and external environments of the business.

Results

The Naval Sector qualification training in the Amazon Chronology

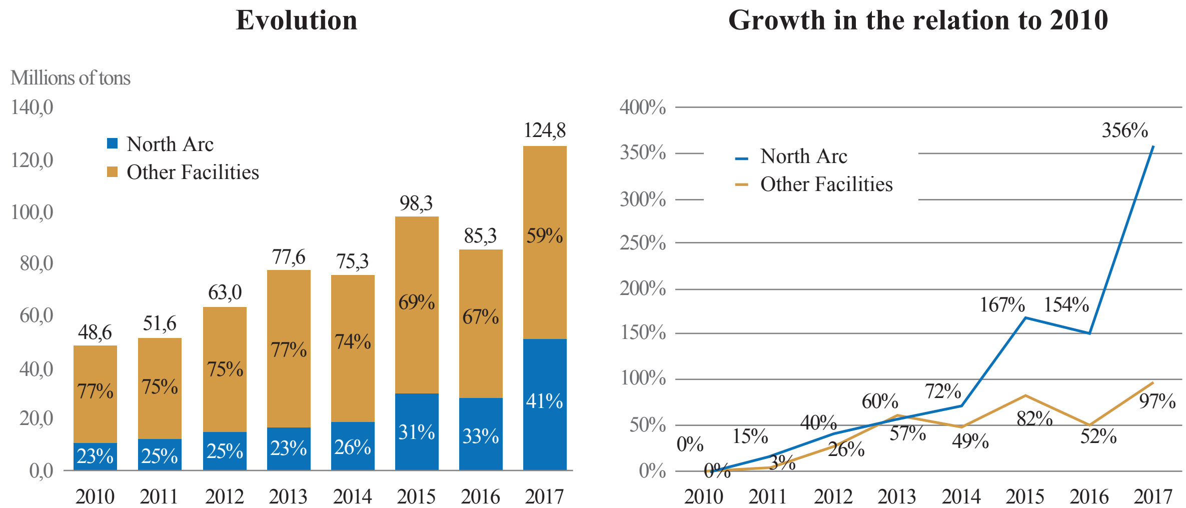
2004

ULBRA (Lutheran University of Brazil) launched the first course in **Naval Construction Technology**, in Manaus.

Duration: 3 years.

Strength: pioneer in training professionals to work

Fig. 2. Evolution of the Northern Arc.



Source: ANTAQ.

in the shipyards in Manaus.
Weakness: difficulty in getting teachers; It was a paid course.
Threat: value of benefits, little interest, profession not valued; for this reason, it was terminated in the 3ª. Class.
Opportunity: could have partnered with shipyards or other institutions.

2007

UEA (University of the Amazonas State) in partnership with **Hermasa Navegação da Amazônia**, a company of cargo transportation through the Amazonian rivers, aiming to train their own labor for the maintenance of their rafts and pushers, launched the Naval Construction Technician qualification course in Itacoatiara, a city 270 km distant from Manaus.
Duration: 3 years.
Strength: Pioneer in the technical training courses of naval construction and in the formation of employees for the sector.
Weakness: the teachers were the staff themselves, however, due to the inability to deliver the classes, they had to hire teachers.
Threat: the distance from Manaus made it difficult for the teachers to teach the courses in the city. As a result, the course was delayed and completed only in 2012.
Opportunity: They could have done more classes to qualify more employees of the company.

2008

UEA (State University of the Amazonas State), in partnership with the Secretariat of Planning of the Amazonas State (SEPLAN), aiming to attend the fishing production chain, launched the Naval Construction Technology training course in Novo Airão, a city located 194km from Manaus.
Duration: 3 years.
Strength: First course of Naval Construction Technology in the inland.
Weakness: difficulties to have teachers travelling all the distance to teach.
Threat: as it was a project, the training course was unique to these students.
Opportunity: courses were later opened in Tefé (522 km distant from Manaus) and Itacoatiara (270 km distant from Manaus).

2013

CETAM launched, (Technological Education Center of Amazonas) in partnership with the Brazilian Navy (**MB**), aiming to train technicians to work on shipyards in the construction, repairs and maintenance of vessels in the region, at the same time the **Naval Construction Technician training course** in Manaus and Tabatinga

(1,106km distant from Manaus).
Duration: 2 years.
Strength: First Naval Technician course in the Capital and states country side.
Weakness: difficulties to teachers to go to teach classes, both in Manaus and in the country side.
Threat: The target audience has low level of education, as at least a high school degree is required and those who had interest often had no such educational level.
Opportunity: Classes were offered in Manaus from 2013 to 2017, up to now 4 classes have graduated.

2013
UEA (State University of the Amazonas State) launched the **graduate course in Naval Engineering in Manaus**, in order to meet the needy naval engineers demand in the State. The first class of naval engineers graduated in 2017.
Duration: 5 years.
Strength: Manaus had less than 10 naval engineers registered in the Regional Engineering Council and needed to train these professionals.
Weakness: difficulty to find teachers qualified on the area demands.
Threat: student avoidance for other engineering courses.
Opportunity: creation of specialization courses in Naval Engineering.

2014
CETAM (Technological Education Center of Amazonas) aiming to train technicians to work in ports and waterway terminals launched a 2-year Technical Course in **Freight Transportation in Manaus**.
Strength: First Technical Course of Freight Transportation in Manaus.
Weakness: Difficulties with qualitied teachers in the area.
Threat: The target audience has low level of education, as at least a high school degree is required and those who had interest often had no such educational level.
Opportunity: Partnerships with port and terminal companies could have been made. Only one class graduated.

2016
UNIAMAZONIA (Free University of the Amazon) aiming to present the naval architecture to the engineering and architecture courses academics and professionals who work or wish to work in the naval sector, launched the Extension Course in Naval Architecture in Manaus.
Duration: 32 hours.
Strength: First extension course in naval architecture in Manaus.
Weakness: short course load.
Threat: lack of incentive for institutions to promote extension courses.
Opportunity: to do other extension courses exploring all areas of the naval sector.

2018
FACULDADES LA SALLE aiming to present the naval architecture to academics of the engineering and architecture courses and professionals who work or wish to work in the naval sector, launched the **Extension Course in Yachts**, in **Manaus**.
Duration: 32 hours.
Strength: Second extension course in naval architecture in Manaus.
Weakness: short course load.
Threat: lack of incentive for institutions to promote extension courses.
Opportunity: to do other extension courses exploring all areas of the naval sector.

2019
UEA (State University of the Amazonas State) will launch a specialization course in Naval Engineering in Manaus. Up to the moment there is no detail of the course.

OTHERS
In 2017 the Naval Institute of the Amazon ministered the course of Maritime Transport and Port Logistics in Manaus.
Duration: 8 hours

Over the years there has always been qualification courses offered by some shipping companies that train and advertise their product *(Caterpillar and Cummins)*. The quantitative results can be seen in Table 1, which presents the number of vacancies offered by courses since 2004, that is, 15 years. Showing that 692 positions were offered in all categories. The technician's category was most attended one.

Table 1. Number of vacancies offered by courses since 2004.

Institutions	Technical	Technology	Engineering	Extension
ULBRA		150		
UEA/HERMASA	40			
UEA		120		
CETAM/MB	80			
UEA			60	
CETAM	200			
UNIAMAZONIA				15
INSTITURO NAVAL DA AMAZONIA				12
FACULDADE LA SALLE				15
TOTAL	**320**	**270**	**60**	**42**
PERCENTAGE BY CATEGORY	**46%**	**39%**	**9%**	**6%**

Conclusions

Since 2004, the Amazon has been active in order to train professionals for the naval sector, however, the results achieved still not promptly meeting the needs of the existing shipyards in Manaus.

The negative aspects are numerous, but the ones that most stand out are:

a) The lack of specialist teachers in the naval sector, it is noteworthy that we had help from FATEC-JAHÚ technologists who lived in Manaus and contributed considerably as teachers in the courses;

b) The target audience, students, with low level of educational degree. The Technical level requires that you have at least a high school degree;

c) The low investment of educational institutions in this branch. Colleges do not open courses for the naval sector;

d) The Shipbuilding Union of Amazonas does not undertake to participate in this initiative; and

e) The informality of the shipyards makes them accept unqualified professionals and certifications, promoting themselves training for the employee's adequacy to the work.

The good aspects are:

a) The formation of several levels of professionals, from the technician through the technologist to the naval engineer with quantitative limitation, but that already have awakened another look for the professional that chooses this branch of the naval sector. Whereas, in the last century, workers were not even valued as professionals;

b) At the Bertolini Construção Naval Shipyard, considered one of the best in the northern region, several professionals, technicians and engineers were hired; and

c) Students who have already completed the technical courses continued studying, graduating in engineering and related areas.

We have verified that the opportunity we have to be in the region where the “Arco Norte”, which transports grain from the country side of Brazil to the outside, can be the door to open more courses in our region to meet the construction of vessels, but mainly maintenance and repairs on the sailing vessels.

But for this to happen, it will require a partnership between academia and the market so that professionals can be trained here in the state of Amazonas.

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Design and construction of a prototype for the launch and recovery of a "SAAB SEAEYE FALCON" ROV for the diving and salvage department of the Colombian Navy

Diseño y construcción de un prototipo para el lanzamiento y recuperación de un ROV Tipo "SAAB SEAEYE FALCON" para el departamento de buceo y salvamento de la Armada Nacional de Colombia

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Abstract

The divers of the Colombian Navy carry out search and salvage operations of equipment that are submerged in maritime or fluvial areas. To be effective, the diving and salvage department must have appropriate equipment to ensure the completion of the inspections carried out; however, since underwater dive inspections are carried out in difficult access or dangerous places, it is necessary to use specialized equipment such as remote operation vehicles - ROV, where the urgent need to implement a launching system for the immersion and subsequent extraction of such equipment is identified.

As a result of the existing problem, the project is built with the purpose of creating a prototype for the immersion and extraction of a "SAAB SEAEYE FALCON" ROV, thus facilitating inspections and reaching depths of 300 meters. For its construction, exploratory research was carried out and a deductive method was applied; modeling was performed using SolidWorks software as a tool for its construction that allowed identifying the best electromechanical structure, and the component to be used for its construction was identified through the study of pure and composite materials, which processes allowed designing and building a LARS prototype that met the operational objectives for which it was proposed.

Key words: Diver, Launch, Lars (launch and recovery system for ROV), Recovery, ROV (remote operation vehicle).

Resumen

Los buzos de la Armada Nacional de Colombia desarrollan operaciones de búsqueda y rescate de equipos que se encuentran sumergidos en zonas marítimas o fluviales, y para su efectividad el departamento de buceo y salvamento debe contar con los equipos correspondientes que garanticen el funcionamiento de las inspecciones realizadas; sin embargo, al desarrollarse inmersiones de inspecciones subacuáticas en lugares de difícil acceso o peligrosos, es necesario usar equipos especializados como el vehículo de operación remota - ROV, donde se identifica la necesidad apremiante de implementar un sistema de lanzamiento para su inmersión y posterior extracción.

Como resultado de la problemática existente, el proyecto se construye con el objetivo de crear un prototipo para la inmersión y extracción de un ROV tipo "SAAB SEAEYE FALCON" facilitando las inspecciones y alcanzando a llegar a 300 metros de profundidad. Para su ejecución se realizó investigación exploratoria y método deductivo; como herramienta para su construcción se realizaron modelaciones a través del software SolidWorks que permitieron identificar la mejor estructura electromecánica y mediante un estudio de materiales puros y compuestos se identificó el componente a usarse para su construcción, procesos que permitieron diseñar y construir un prototipo LARS, que cumplió con los objetivos operacionales para los cuales fue proyectado.

Palabras claves: Buzo, Lanzamiento, Lars (sistema de lanzamiento y recuperación para el Rov), Recuperación, Rov (vehículo de operación remoto).

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Introduction

An underwater inspection is an activity in which the conditions of a place, vessel or structure submerged in an aquatic environment are verified. Over time, this type of activity, which was initially carried out only by specialized divers, has been evolving with the development of new technologies, such as underwater cameras and the use of remotely operated vehicles (increasingly with greater capabilities). It must be taken into account that a series of tools or systems are required for the effective operation of this type of equipment, in order to carry out the immersion, deployment, recovery, extraction, and the fixed umbilical administration, launch and recovery systems of the submarine vehicle.

Based on the above, the research has been based on the characteristics required for a launch and recovery system that can be adapted to the vessels of the Colombian Navy, such as frigates or pilot, which is characterized by its versatility, easy transportation and handling in the operations and inspections carried out by the Diving and Salvage Department. Additionally, it contributed to the generation of knowledge in the "Diving equipment" research line is geared towards the field of underwater inspections carried out by the divers of the Colombian Navy.

The mission of the Diving and Salvage Department of the Colombian Navy includes the following operations: underwater inspections, maintenance operations, maritime salvage and assistance, which purpose is to recover and/or prevent the loss of afloat units, aircraft, war and quartermaster materials; which is why the divers of the entity are constantly performing underwater operations of this nature.

Some ROV launch and recovery systems available in the market

These types of systems can be found in different models and there are companies such as Saab Seaeye and Rolls Royce that manufacture them; such equipment operate with a hydraulic system that allows moving the arm from its resting position to its working position and provides the load capacity, it also has an electrical system that consists of a gearmotor that moves ROV up and down; the materials with which such equipment are manufactured must be exposed to load resistance tests and a previous use study.

For the design of the prototype launch and recovery system, the model must be adapted to the needs and characteristics of the afloat units of the Colombian Navy, which include the following:

Fig. 1. Saab Seaeye Launch & Recovery Systems.

Fig. 2. Saab Seaeye Launch & Recovery Systems.

Source: SAAB SEAEYE LTD. ALL RIGHTS RESERVED [Consulted on 03-30-2018]; [online] https://bit.ly/2GGuRMh

Determination of the technical specifications required for the prototype ROV immersion and extraction system

The Diving and Salvage Department identified the need to have a system for the immersion and extraction of ROVs with the following characteristics: high tensile strength and rated strength; it must be capable of being disassembled to facilitate transport; it must have the ability to be attached to the roof of frigate units such as the ARC "ANTIOQUIA" and Pilot units such as the ARC "ISLA TESORO"; it must have a mechanical source for the lowering and hoisting of the ROV, easy maintenance, affordable spare parts in the local market , low costs and its operation must requires little personnel participating in the maneuver without affecting the safety of operators and the equipment.

The technical specifications that the prototype must have are indicated below:

Material strength: Taking into account that the ROV has a weight of 78 kg, a safety factor of 3 was considered, equivalent to a load of 234 kg. The material with which the structure was built has technical characteristics that provide a tensile strength of 400 Mpa and a yield strength of 317 Mpa.

Electric motor: The motor must have at least ¼ horsepower, providing the necessary torque to move the structure for the operation of the ROV. The proposed engine has an input of 1700rpm with a 40:01 gearbox and uses a crown worm, which works as a brake in case of loss of electrical power or when disengaging. It has a 110V AC power supply which provides greater ease when powering it up (which is voltage mostly used in afloat units and portable power plants used in the Colombian Navy).

Design of the prototype using 3D modeling software for the ROV immersion and extraction system according to the operation and use needs of the equipment

For the design of the prototype, it was necessary to make field visits to the Frigate "ARC ANTIOQUIA" and "ARC ISLA TESORO", taking measurements and identifying the place where the system could be used.

After determining that the useful space for the prototype was insufficient, since there were more deck fixtures such as bitts, cleats, eyebolts and heavy armament, with a space on the port side of 110cm wide aft to the bow, which is arranged for the location of the gate while at the dock, and from the rail to the amidship line there is a space of 350 cm using one of the eyebolts to fix the structure to the roof.

The modeling market was verified for this type of systems that allowed contributing to the investigation of the prototype proposed and giving way to the design of the device. SolidWorks software was used for building a 3D model taking into account the needs and characteristics that

Table 1. Material Comparison Table.

COMPARATIVE TABLE			
Item	**Characteristics**	**Carbon Steel**	**Galvanized Steel**
1	Square Tube	YES	YES
2	Outer Measurements	2" x 2"	2" x 2"
3	Thickness	2.5 mm	2.5 mm
4	Yield Stress	3522 Kg/cm²	3522 Kg/cm²
5	Breaking Strength	4348 Kg/cm²	4348 Kg/cm²
6	Corrosion Resistance	NO	YES
7	Cost (in dollars) for 6 meters	$ 21.95	$48.07

Source: Authors.

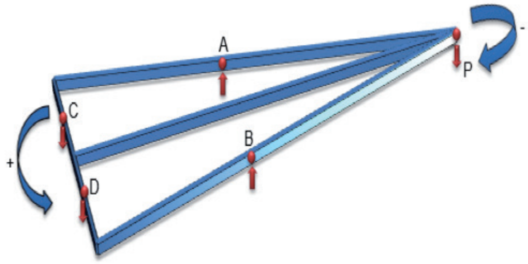
were sought, in which procedure new ideas were identified that allowed favoring the prototype and ensuring a more reliable and secure system.

Construction of the prototype using the technical specifications for the "SAAB SEAEYES FALCON" ROV immersion and extraction system

For the construction of the prototype, the space available on the vessels was first taken into account, followed by the selection of the material with which the structure was built, comparing the prices and durability of carbon steel with and without galvanized coating. Carbon steel was chosen without galvanized coating, since its durability depends on the maintenance of the structure and its price is lower in relation to carbon steel with galvanized coating, and they have the same yield stress and breaking strength properties.

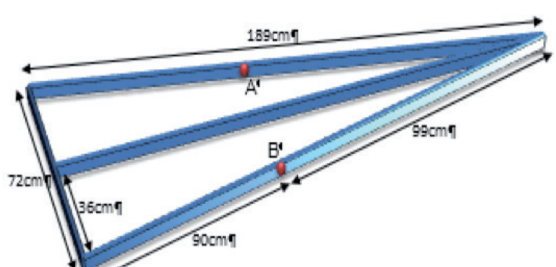
After having selected the material and built the structure, the free body diagram was then made.

Fig. 3. Free Body Diagram.



Source: Authors.

Fig. 4. Dimensions and Measurements.



Source: Authors.

Once determined the dimensions, distances and forces at play on the piece, the reactions at C and D were calculated at the time of suspending a load equal to the ROV with a mass of 80 kg.

Since the sum of momentums is equal to 0.

$M = F * D;$

$$\sum M = 0; \quad -P(99\ cm) + D(90\ cm) + C(90\ cm) = 0 \tag{1}$$

By symmetry, it is established that the forces present at point C are equal to the forces at point D.

$F_C = F_D;$

$$-P(99\ cm) + 2D(90\ cm) = 0 \tag{2}$$

$P = mg;$

$$D = \frac{P(99\ cm)}{2\ (90\ cm)} \tag{3}$$

$m = mg;$

$$D = \frac{mg\ (99\ cm)}{180\ cm} \tag{4}$$

$g = 10\ m/s^2;$

$$D = \frac{80\ kg\ *\ 10 m/s^2\ (99\ cm)}{180\ cm}$$

$$D = \frac{79200 Ncm}{180\ cm} \tag{5}$$

$$D = 440N$$

Knowing what the forces are at points D, C and P at the time of suspending a load of 80 kg, the forces on the Y axis were added to calculate the forces on the vertical axis at points A and B, which are the most vulnerable points of the structure.

$\sum Fy = 0;$

$$-C - D - P + By + Ay = 0 \tag{6}$$

By symmetry, it was established that the forces present at point *B* are equal to the forces at point *A*.

By = Ay;

$$-C - D - P + 2\,By = 0$$

$$By = \frac{C + D + P}{2}$$

$$By = \frac{440N + 440N + 800N}{2} \tag{7}$$

$$By = \frac{1680N}{2}$$

$$By = 840N$$

The momentum that the force *P* produces at point *A* and *B* is found when a weight of 80 kg is suspended. By symmetry, it was considered that the momentum is the same in both points.

$$M_B = P\,(99\ cm)$$

$$M_B = 800N\,(99\ cm) \tag{8}$$

$$M_B = 79200Ncm$$

Taking into account the physical properties of the square carbon steel tube of 2"x 2" provided by the supplier according to the technical sheet, the strength of the material was calculated to verify that it meets the safety characteristics.

Moment of Inertia (I) = $16.94cm^4$

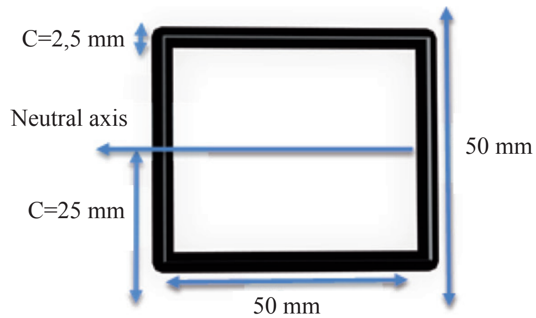
σStrength = $4368kg/cm^2$

σYield = $3522kg/cm^2$

Then the allowable stress was determined according to the safety factor of 3 used.

FS = 3;

Fig. 5. Physical Characteristics of the Material.



Source: Authors.

$$\sigma_{Perm} = \frac{\sigma_{Ultimo}}{FS}$$

$$\sigma_{Perm} = \frac{4368\ kg/cm^2}{3} \tag{9}$$

$$\sigma_{Perm} = 1456\ kg/cm^2$$

The above shows that the allowable stress is less than the yield stress, allowing the tube to remain in the elastic range to work safely.

With the information provided by the supplier and the parameters established for this type of work, the calculation was made to find the bending moment of the tube.

$$\sigma_{Perm} = \frac{Mf * C}{I}$$

$$Mf = \frac{\sigma_{Perm} * I}{C}$$

$$Mf = \frac{4368\ kg/cm^2 * 16{,}94\ cm^4}{2{,}5\ cm} \tag{10}$$

$$Mf = 9865.85\ kgcm$$

$$M = Mf * g$$

$$M = 9865.85\ kgcm * 10\ m/s^2$$

$$M = 98658.56\ Ncm$$

To find the maximum momentum to which the structure can be subject with such safety factor, the bending moment was multiplied by gravity and it was determined that M = 98658.56Ncm > MB = 79200Ncm, which is the momentum produced by the 80 kg load, which means that it is much higher and the structure can work safely.

However, it was decided to calculate what would be the maximum load that could be supported by the structure with the established allowable stress, and what would be the limit load for the breaking point of the structure, based on the previous data.

The momentums on the piece were added considering that points C and D have the same momentum and that points A and B are subject to the same stress.

$M_C = M_D$;

$$-P\,(99\ cm) + 2D\,(90) = 0 \tag{11}$$

M_D = 98658.56 Ncm ;

$$-P\,(99cm) + 2\,(98658.56Ncm) = 0$$

$$-P\,(99cm) + 197317.12\ Ncm = 0$$

$$P = \frac{197317.12\ Ncm}{99\ cm} \tag{12}$$

$$P = 1993.1\ Ncm$$

$P = mg$;

$$m = \frac{P}{g}$$

$$P = \frac{1993.1\ kgm/s^2}{10\ m/s^2} \tag{13}$$

$$m = 199{,}31\ kg$$

This is the limit work mass according to the safety factor of 3 and the allowable effort established.

The breaking stress was used to calculate the bending moment, in order to determine the momentum in which the piece would break, then the momentums were added, the force that should take place was calculated and the mass of the breaking point was found.

I = 16.94 cm^4 ;

$$Mf = \frac{\sigma_{Strenght} * I}{C} \tag{14}$$

$\sigma_{Strength}$ = 4368 kg/cm^2 ;

$$Mf = \frac{4368\ kg/cm^2 * 16{,}94\ cm^4}{2{,}5\ cm} \tag{15}$$

C = 2,5 cm ;

$$Mf = 29597.56\ kgcm$$

$$M = Mf * g$$

$$M = 9865.85\ kgcm * 10\ m/s^2 \tag{16}$$

$$M = 295975.68\ Ncm$$

$M_D = M_C$;

$$-P\,(99\ cm) + 2D\,(90) = 0 \tag{17}$$

M_D = 295975.68 Ncm ;

$$-P\,(99\ cm) + 2\,(295975.68\ Ncm) = 0$$

$$-P\,(99\ cm) + 591951.36\ Ncm = 0$$

$$P = \frac{591951.36\ Ncm}{99\ cm} \tag{18}$$

$$P = 5979.3\ N$$

$P = mg$;

$$m = \frac{P}{g}$$

$$m = \frac{5979.3\ kgm/s^2}{10\ m/s^2} \tag{19}$$

$$m = 597.93\ kg$$

The previous calculation allows establishing the breaking mass of the most vulnerable piece of the structure and ensuring the work with the ROV with the allowable stress and the safety factor of 3.

Based on the above calculations, the materials were quoted again, choosing 2x2-inch square carbon steel tubes for the framework of the structure. The first thing that was built was the structure of the arms that would be responsible for lifting and lowering the ROV, taking into account that it should be versatile and disassemblable. Cuts were made at 45°, 13° and 90° on the tubes to shape the structure.

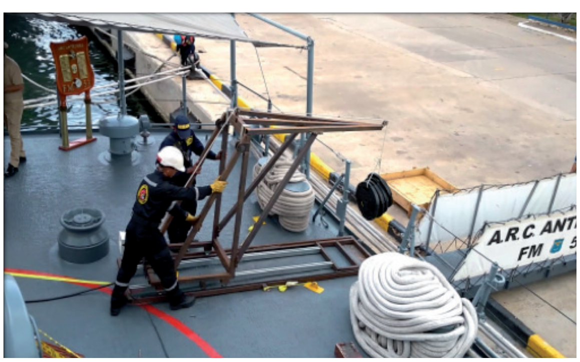
Conclusions

When the characteristics of the prototype were assessed and the study of loads to which the device would be subject was commenced, it was possible to identify that the strength, versatility, easy transportation, easy operation, disassemblable structure and ease of use in the vessels mentioned above were some of the criteria to be taken into account at the time of designing and building the prototype ROV launch and recovery system.

It was possible to identify the possible designs according to the characteristics established.

A first prototype was developed in the construction stage, but it was observed that the system was too robust and it was decided to focus the project on the construction of the following design in order to ensure that the requirements established at the onset were fulfilled and that the prototype would be used in future operations with the ROV, thus facilitating and ensuring the work of the personnel.

Fig. 6. Prototype tests.



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Process of design an eco-friendly catamaran to extract aquatic plants

Proceso de Diseño de un Catamarán eco-amigable para extraer plantas acuáticas

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Abstract

This paper presents the design of an eco-friendly catamaran that follows two design methodologies, one focusing in the importance in the needs of future users and the other the spiral boat design methodology. The prototype is going to take advantage of the unique form of a catamaran and use the space available between the points of flotation for the process of extracting small plants and light plastics from the surface of recreational lakes. With the prototype the esthetics and also the aquatic ecosystem of the lake would be better preserved. The application of the prototype, could improve the time required to recollect the duckweed and only required one operator; however, the potential of this project is significantly bigger as it could be used as a method to extract superficial contaminants in garbage patches in the ocean and lakes without harming the species still in the zone of operation. Good practices of engineering are going to be use for the design of the catamaran, as well as for the selection of the necessary components.

Key words: Design, catamaran, eco-friendly, spiral boat design methodology.

Resumen

Este documento presenta el diseño de un catamarán eco-amigable que sigue dos metodologías de diseño, una que se centra en la importancia de las necesidades de los futuros usuarios y la otra en la metodología de diseño de embarcaciones en espiral.

El prototipo aprovechará la forma única de un catamarán y utilizará el espacio disponible entre los puntos de flotación para el proceso de extracción de pequeñas plantas y plásticos ligeros de la superficie de los lagos recreativos. Con el prototipo se preservarían mejor la estética y también el ecosistema acuático del lago. La aplicación del prototipo, podría mejorar el tiempo requerido para recolectar la lenteja de agua y solo se requiere un operador; sin embargo, el potencial de este proyecto es significativamente mayor, ya que podría utilizarse como un método para extraer contaminantes superficiales en parches de basura en el océano y lagos sin dañar a las especies que aún se encuentran en la zona de operación. Se utilizarán buenas prácticas de ingeniería para el diseño del catamarán, así como para la selección de los componentes necesarios.

Palabras claves: Diseño, catamarán, eco-amigable, metodología diseño en espiral.

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Introduction

Nonmoving water always cause certain problems in recreational lakes or in considerable size open field deposit of water, where an aquatic plant named duckweed manages to grow due to bacteria presence [14]. The main problem with this plant is that it doesn't allow the sunlight to enter to the aquatic environment, degrading the ecosystem and also because his fast decomposition it generates not pleasant smells [14]. The plant is necessary in the lake in order to maintain the food chain in the aquatic ecosystem, however his overpopulation bring the previously mentioned problems.

Currently, in recreational lakes, the duckweed doesn't give a good aspect when the lake is opened to the visitors, the way of removed it is manually by at least 2 employees, taking at least six labor hours (Number given by the City Hall of Santiago de Surco).

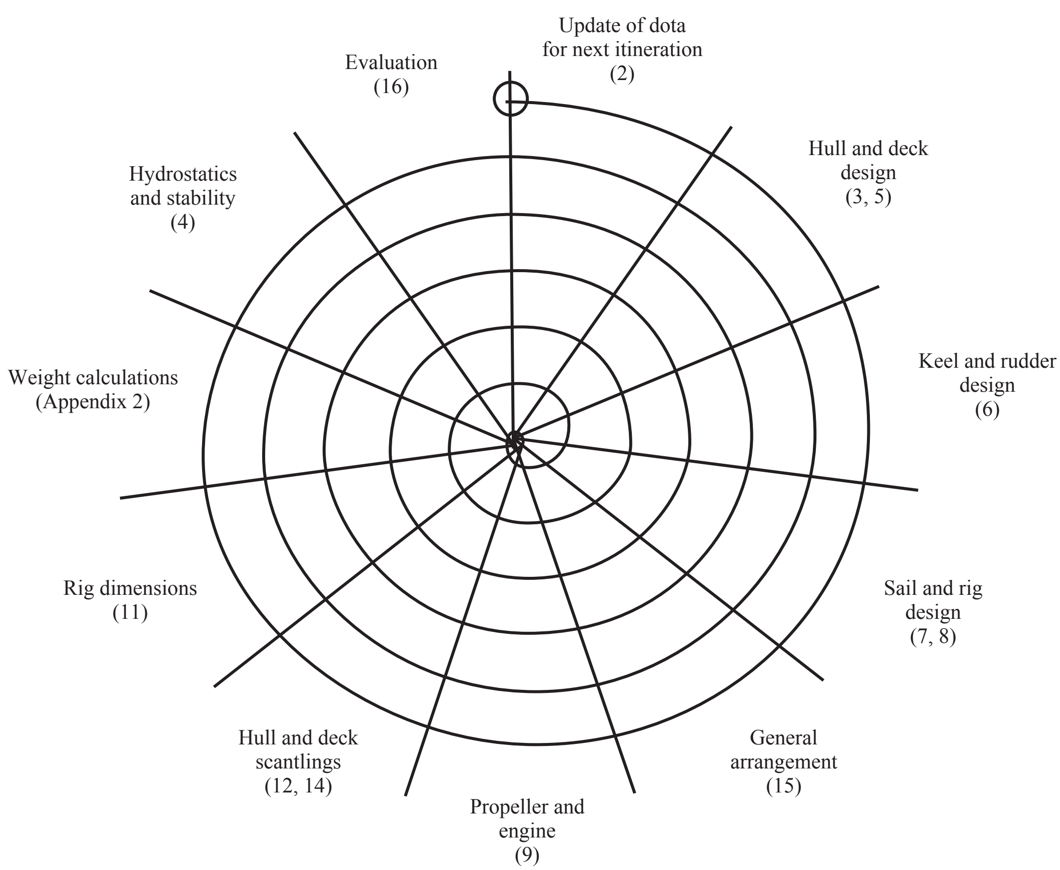
An eco-friendly catamaran with an extraction system could clean a lake in a at least 40% faster way, without making a lot of noise [1].

The objective of the project is to learn, design and simulate an eco-friendly vessel capable of recollect superficial plants; this means that the ways of generate power and the material of the hull constructions had to be ecological.

Design Methodology

In the design process of any type of boat, there is always going to be certain problems such as re-design the boat structure or changing the dimensions when the weight distribution of the components is already done. So is important to keep in mind the spiral methodology [1], [15].

Fig. 1. Spiral design methodology mostly used in boats [1].



Functional Analysis

Knowing the principal objective of the project, is important to collect and measure certain necessities from a possible customer. The city hall of Santiago de Surco – Lima which administrate a recreational lake called "Lago de la Amistad", manifest that the vessel should accomplish certain necessities to them being interested, Table 1.

The white box

The methodology offers the option to perform the analysis of the white box, this helps to consider the objectives of the project and focusing entirely in solving them. The box in Fig. 2 stablishes as input data (the problems to solve) and an output data (the project objectives). Inside the "white box", are the variables to succeed with the input data. Using the white box guarantees the usability of the project [15].

Preliminary considerations

One initial step in the spiral methodology in vessel is to select the type of boat looked-for to achieve the necessities. A catamaran was the most suitable option due his unique form, his reduce draught compared with a monohull (33.3% better) and his 15% superior transversal stability [5], [7].

Table 1. Necessities charts.

Necessities	Metric	Units	Value	Importance	Should / Shouldn't Have
Eco friendly materials	Construction with natural fibers	kg	8-14	HIGH	Should
Low cost of operation	Operation with renewable energy	$	0.5	HIGH	Should
Easy to maneuver	On a catamaran	Turning radius	20° - 45°	MEDIUM	Should
Few Components	In motors and solar panels	Quantity	4-10	HIGH	Should
Stable	-	-	-	HIGH	Should
Safe	With safety standards	Level of risk	3	HIGH	Should
Light Weight	Over all weight	kg	20-40	LOW	Should Not
Quiet	In operation	decibels	30	MEDIUM	Should

Fig. 2. White box diagram.

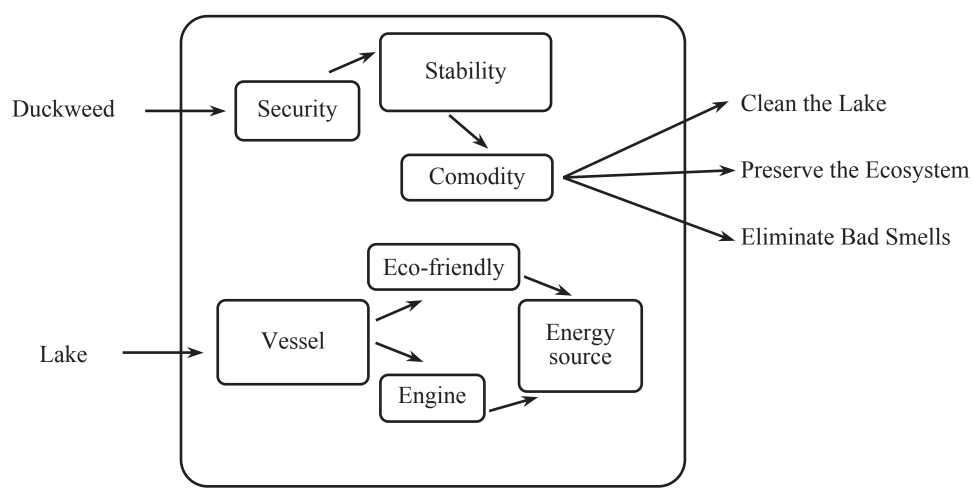
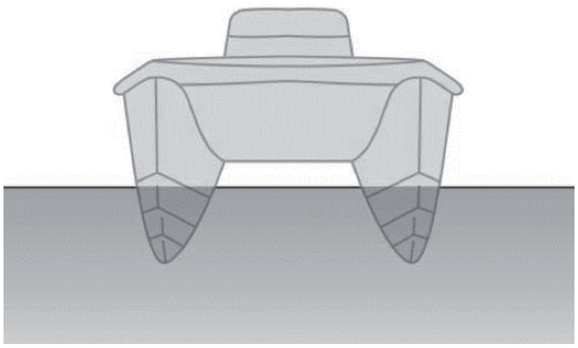


Fig. 3. Symmetrical catamaran [9].



Also in this part is important to know the type of propulsion the boat would use, due to the objective and requirements of the consumer (Table 1) an electric motor is the best option, in Section 8 is specified the type and power required from the engine.

Hull Geometry

In the industry there are two types of hulls the displacement and planning hull. The first one is designed to go through the water and second one is designed to glide on the surface of the water as the boat gains speed [2]. Since the objective of the project is to extract aquatic plants, both hulls of the catamaran are being the displacement type.

Once establishing the type of hull, the next thing is to select the hull style, in the industry they use different types like round bottom, flat bottom, v bottom and other; for the project was selected a multi displacement hull with convex round bottom style, because it present better longitudinal stability, better pressure resistance and more displacement capacity [12].

Lines drawing

The first step before start designing the catamaran is to establish the dimensions, where the facts considered where, the maximum lengths value of a design category, the amount of duckweed estimated to recollect and an analysis of the dimensions of the boat commonly found in recreational lakes [3], [4].

Table 2. Vessel dimension.

Length (m)	Width (m)	Depth (m)	Width of each hull (m)
1.85	1.52	0.5	0.32

By knowing the specs of the hull (Table 2) is possible with the help of a software CAD to generate the hull mesh in different points of view. The importance of this part is to saw in perspective the design model and change or adjust different parameters.

Fig. 4. Displacement and planning hull [1].

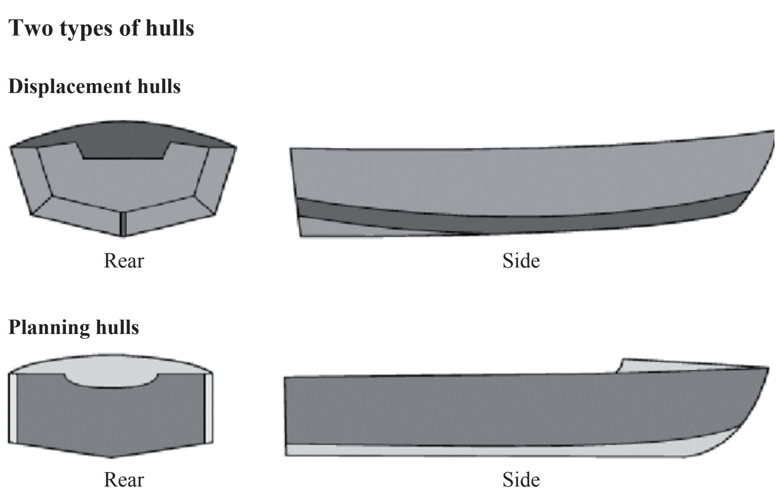
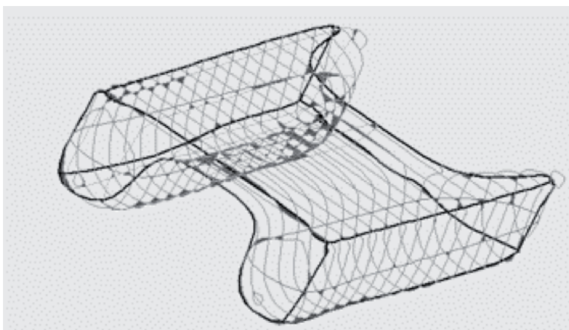


Fig. 5. First catamaran design in a software CAD.

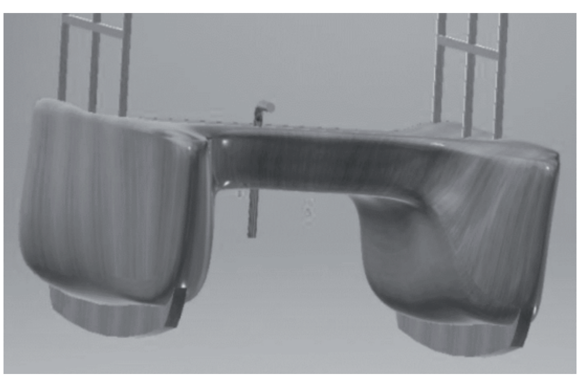
Fig. 6. Lines of the design in the software CAD.



Process design

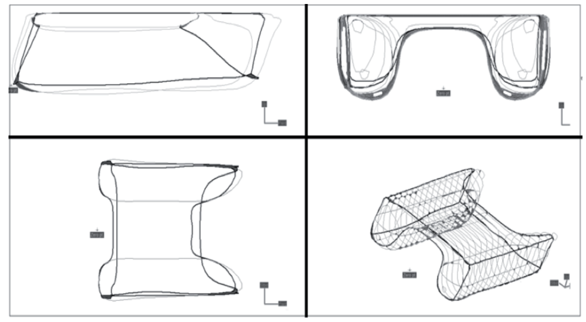
The CAD software used was Inventor, which presented the best tools to represent and export the model of the catamaran. The tool used in the program was FreeForm, which offers symmetry and mesh generation functions.

Fig. 7. Freeform catamaran design.



Having the hull design ready is necessary to opened the design in the software Maxsurf, to analyze his stability; for this the help of the software Rhynoceros was important to scale the design and correct the tridimensional position of the vessel model. And finally export it to Maxsurf to analyze.

Fig. 8. View in maxsurf of the catamaran.



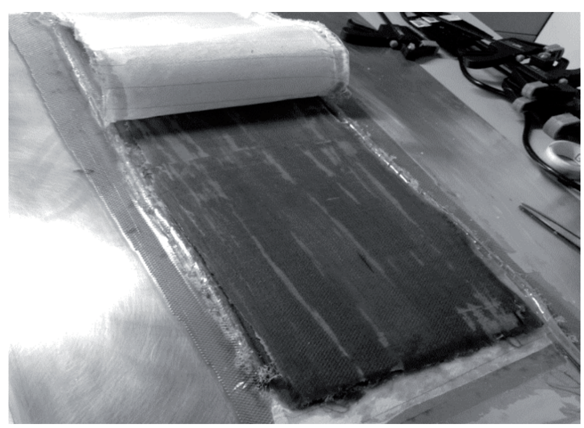
Hydrostatics and stability

Calculation of areas

The software CAD can calculate the total area of the catamaran, this is important to know the weight of the hull and the amount of material needed.

The hull weight was interpolated by a piece of the composite material proposed in Image 17. The piece manufactured in the laboratory was of (25 * 70 cm), Fig. 9.

Fig. 9. Piece of composite material witch ichu.



The total area of the hull of the catamaran was estimated in 6.121 m^2, obtained by software Maxsurf.

The estimated weight of the hull was obtained as 29.845 kg.

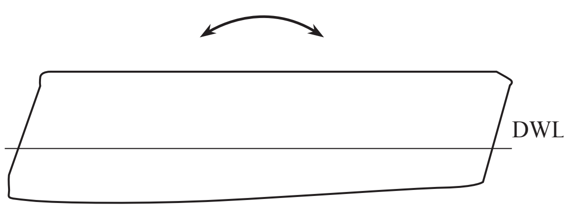
Center of Gravity

This process represents a challenge not only because some software required a manually calibration, because after include all the components that are going to be on the boat it must state in equilibrium in the water [16].

This conditions in boats greater than 10 meters is not a problem, but in small recreational boats present some challenges. [5]

With the correct distribution of the components the problems of trim, where solved. The center of gravity of the hull, and the center of gravity of all the components had to be close to succeed in this part.

Fig. 10. Longitudinal instability (TRIM).



Weight distribution on the boat

This process is crucial to determine all the component that are going to be or could be on the boat and knowing the total weight.

The length of the catamaran was only 1.8 meters and due to the presence of solar panel, a high weight it was necessary to add against weight and a keel to balance the boat longitudinally.

Where *Lc*, is longitudinal coordinate and *Vc*, is the vertical coordinate; Dead Weight, total amount of weight that is always on the boat; Dry Weight, total weight that depend of crew and Load. The draught for condition is in Table 4.

In Table 3, is considering as 5 kg the aquatic plants expected to extract, this is because the catamaran it's not going to be carrying any undergrowth, instead the designed system installed in the bottom on the hull is going to drag the vegetation (Fig. 23).

Wetted surface

Helped by the Archimedes principle it was determined the water line (Draught), in two circumstances, with the dead and dry weight for freshwater (density 1000 kg/m^3), considering the regulation of minimum bulkhead [10].

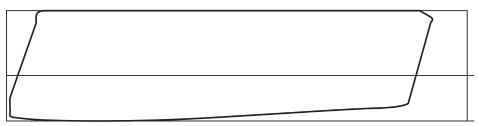
Table 4. Weight and distance from the baseline.

Catamaran Condition	WEIGHT (kg)	Draught or Water lines (m)
Dead Weight	227	0.17
Dry Weight	307.6	0.23

Table 3. Catamaran Components.

	Components	Mass (kg)	Lc (m)	Vc (m)
Dead Weight	Hull	30	0.85	0.23
	Motor	15	0.1	0.25
	Battery	25	0.2	0.1
	Solar Panels	28	0.6	0.95
	Support Structure	14	0.5	0.8
	Keel	57	1.2	-0.065
	Props	20	0.3	0.55
	Against Weight	38	1.7	0.23
Dry Weight	Crew	75	0.85	0.25
	Aquatic plants	5*	0.6	0.25
TOTAL		307	0.76	0.267

Fig. 11. First catamaran design in a software CAD.



Transverse stability

A concept in terms of boat stability, in which it explains the distance from the center of gravity (G) should be always above the center of buoyancy (B). This is because when the boat make a heel move, a moment arm given by the distance (GZ) from center of buoyancy and the new center of buoyancy (B') formed when the boat moved transversally; when the moment arm is 0 o negative the boat lost the lateral stability [1], [5], [6].

Type of design category

The strictness and limit values to achieve in the stability and safety simulations are going to be determined by the design category of the boat [4], [6]. In Table 5 is shown the common operation areas and wave height depending of the design category.

The catamaran is going to operate in recreational lakes in optimal conditions, because of that the boat is going to be ruled by the design category **type D**.

Fig. 12. Important components in transverse stability.

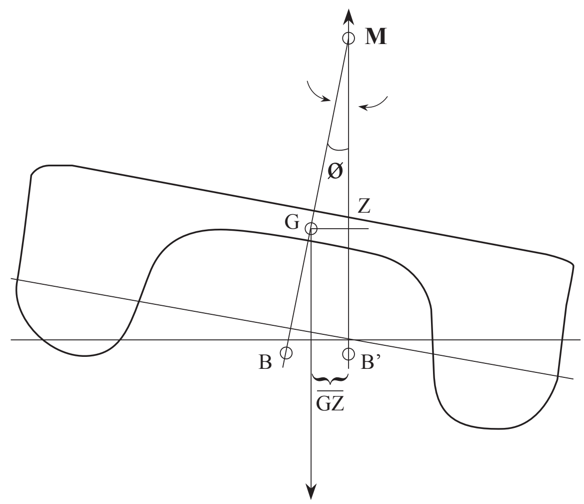
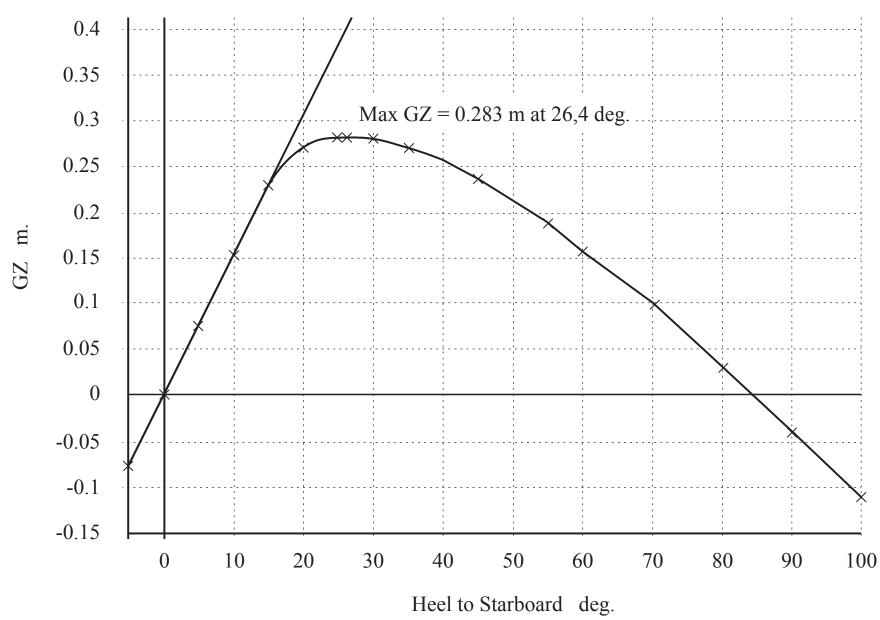


Table 5. Boat Design Category Conditions [4].

Design Category	Operation	Wave Height
A	Oceanic	< 8 m
B	High Seas	< 4 m
C	Coastal Waters	< 2 m
D	Protected Waters	< 0.3 m

Fig. 13. Stability Graph of the design.



STRIX Analysis

One important criteria for different types of boats is the STRIX analysis, these criteria analyze the form of the boat with the stability, this calculation take as inputs the dimensions of the boat, righting moment curve, as well as the approximate weight with the lines where the water is gone reach [2].

After solving the parameters, the number obtained should be greater that Minimum STRIX value, given by each design category.

The STRIX values of the catamaran obtain by software was 5.7, so it passed the STRIX analysis (Table 7).

With the main dimensions of the yacht and its righting moment curve, STRIX uses the demotions of the boat to proposes a formula which the answer must grated that a value determined by each one of the design category of boats to accomplish stability.

Table 6. Limit alues of STRIX depending of the design category [16].

Design Category	A	B	C	D
Minimum STRIX value	32	23	14	5

The IMO standard, code intact stability

Imo, a regulation standard that has a long develop in stability criteria for different types of yachts, such fundamental principles of precaution and righting level. They develop different types of precaution to take care depending of the vessel you are designing.

Eco – Friendly manufacture

As part of the eco-friendly solution that the project purpose, the hull is being made of natural fibers of ichu, a plant that grown above 3000 m.a.s.l. However, to be able to use this plant as a material is necessary a process where the lignite is removed of the plant by an alkaline process that requires about 5 hours and the final result in longitudinal fiber of ichu Fig. 16 [18].

The boat hull using natural fiber in his configuration, Fig. 15, is planned to be fabricated in a laboratory with a determined process to adhere the fibers with the polyester resin, that is compatible with the fiber of ichu. Nowadays there are different methods to the adhere the mention materials, each one achieving better uniformly properties around the surface, like vacuum chamber, spray lay-up and hand lay-up [17].

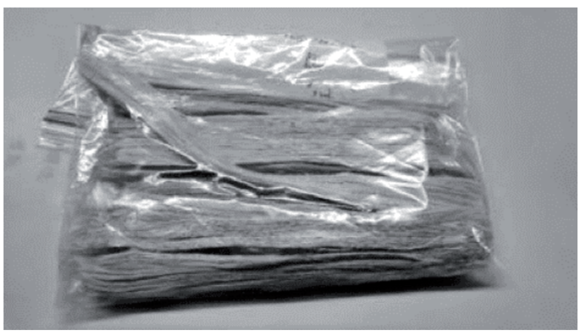
However, because due the size of the catamaran and that the hull itself doesn't handles critical forces, the method of manufacture recommended is the hand land lay-up (In case of increasing the dimensions or interacting with more critical forces the manufacture method selected would be under vacuum test) [17].

Table 7. Values of the stability simulations, considering the design category and de catamaran design.

Test	Value Obtain	Value by standard	Status	Margin	Units
STIX	5.7	5	PASS	0.7	
Angle of maximum GZ multi hull	26.4	25	PASS	1.4	deg.
Initial GMt	0.869	0.15	PASS	0.7	m
Area 0 to 30 or GZ max	5.7609	3.1513	PASS	2.6	m.deg
Area 30 to 40	2.6848	1.7189	PASS	1.0	m.deg
Range of positive stability	84	7	PASS	77.0	deg
Passenger crowding	1.4	10	PASS	-8.6	deg

Fig. 15. Ichu growing in Cusco, Perú.

Fig. 16. Longitudinal natural fiber of ichu in seal package [18]



Organization of the materials

One of the functions of the hull of the vessel is to displace water, so that the vessel by hydrostatic principles could float, the displaced volume generates a pressure on the hull and the composite material, the material must handle this pressure. This pressure generated by the water to the vessel is obtained by the following formula [1].

$$Pb = \frac{0.1 * m}{Lwl * Bc} * (1 + ncg) * kar * kl \; \frac{kN}{m^2} \qquad (1)$$

The maximum value of *Pb* was obtain in the lower part of the stern, the bottom of the ship, after analyzing in different points.

The maximum pressure that the vessel requires to handle is 7.83 kPa.

Using the configuration un Fig. 17, the next procedure was to determine if it was going to handle the pressure obtained. Considering a surface of 25 * 70 cm and the unitary properties the Ichu as 350 MPa (longitudinal fiber with alkaline process) [18]. Using a software of finite elements and stablishing the orientation of the fibers (Fig. 17) it was obtained that the surface could handle approximately 20 KPa.

Fig. 17. Sandwich proposed configuration.

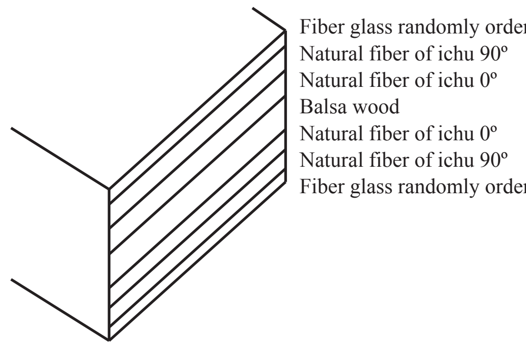
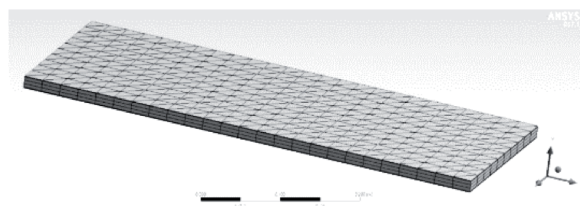


Fig. 18. Analysis in finite element software.



Structural Resistance

In order to conserverd the structural resitance thought time and use, the catamaran have an intern structure, that helps the composite material exterioir layers to resist side collitions, front and impact with other boats or plataforms.

Fig. 19. Structural frame of the catamaran.

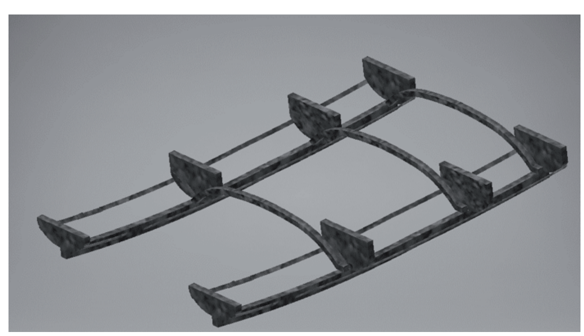
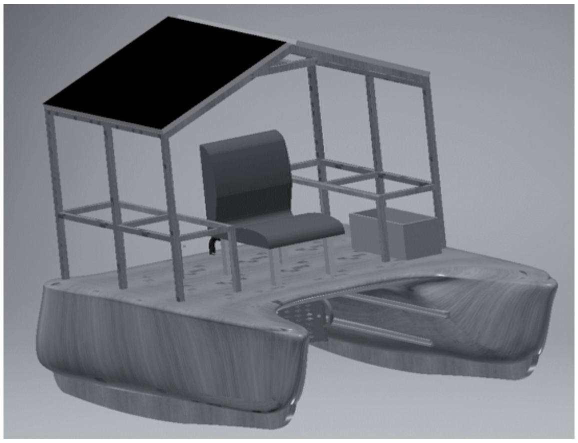


Fig. 20. Final design of the catamaran.



Extraction system

With the extraction and recollection system, is planned to use a mesh strainer, and take advantage of the particular form of the catamaran.

Fig. 21. Extraction system.

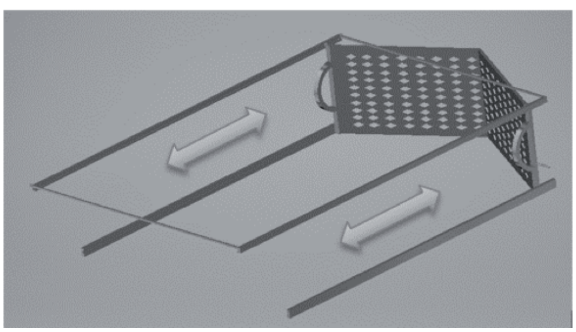
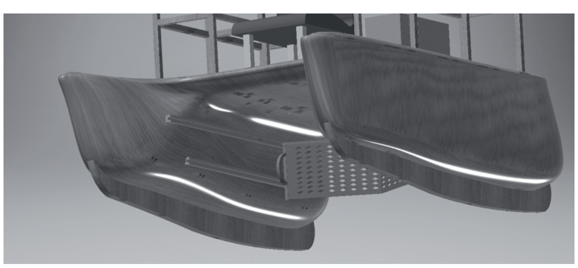


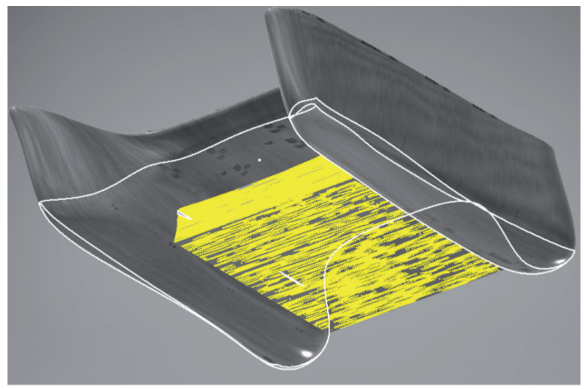
Fig. 22. Extraction system installed the catamaran.



The system takes advantage of the forward inertia of the boat to position itself to the back of the catamaran and while the catamaran moves around the lake it collect and displace the duckweed, until the volume between the keels is full. To extract the aquatic waste, the crew member just need to pull the frame of the mesh and collocate the duckweed in plastic bags to use them as fertilizer.

The maximum volume of seaweed that the catamaran could manage to extract is 0.0614 m^3, this value depends of the size of the duckweed.

Fig. 23. Volume of duckweed planned to extract.



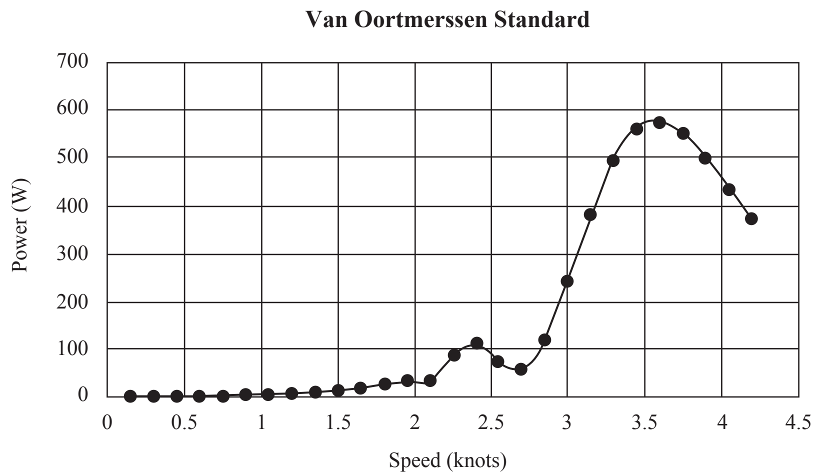
Motor Estimation Power

To estimate the power required in the boat, first is important to establish the velocity that it has to reach. Mostly in small lakes, the maximum speed reached by small vessel is four knots [16].

From that point, it was necessary to use a power prediction method. It could be used a monohull power prediction method as Van Oortmerssen to small dimensions catamarans [13], [19]. The method consists in the resistance of the water, the

Fig. 24. Van Oortmerssen deduces a factor from the wave pattern along the hull and consider the length of the boat.

Fig. 25. Graphic, speed of the boat vs power required.



displacement capacity, the form of the wave made by the ship passing through [13].

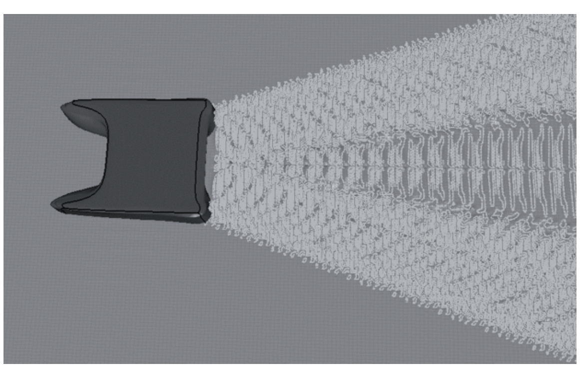
After applying the method, with the tool of Maxsurf, Resistance, is obtained a graph where is stablish the amount of power required from the engine to achieve different speeds, Fig. 25. Is important to considerate the maximum speed of the boat could handle equation 2 [1].

$$Vmax = 2.4 * (L)^{0.5} \tag{2}$$

The maximum speed the catamaran could achieve is 3.29 knots.

Having the power needed and searching in the market for a motor with the amount of power required, it was determined that an electric outboard propeller motor of 480W, manufactured by Intex accomplish the specs required.

Fig. 26. Wave pattern when the catamaran pass thought.



Solar Panels

In order to achieve one of the most important objectives of the project, the boat must have a power system that is energy friendly to the environment, for this the use of solar energy was chosen. Once selecting solar panels as the main source of power, it is important to consider the number of hours that the ship is going to operate.

By using a boat for the labor of extracting the duckweed of a lake could be much faster, the estimated time of operation for the cleaning consider the dimensions of the catamaran is in Formula 3.

$$0.02 \; \frac{hours}{m^2 \; of\; the\; lake} \tag{3}$$

The recreational lake selected is located in the city of Lima and has a surface area of 125 m^2.

The catamaran will be equipped with 2 conventional 12 volt batteries, Table 8.

Table 8. Selection of battery voltage considering power requirements [11].

POWER REQUIRED (W)	NOMINAL TENSION OF THE BATTERY (V)
0 - 800	12
800 – 1600	24
1600 - 3200	48

To select the capacity of the solar panel, it wsa used the Formula 4. The variables where the consumption per day, a safety factor of twenty-five percent, the amount of radiation present in the place (HSE) and the efficiency of the electrical components (90% was used) [11].

$$\text{Power of the solar panel (Wp)} = \frac{1.25 * Consume\left(\frac{Wh}{day}\right)}{Hse\left(\frac{h}{day}\right) * (Efficiency)} \quad (4)$$

Table 9. Variables for the Formula 4.

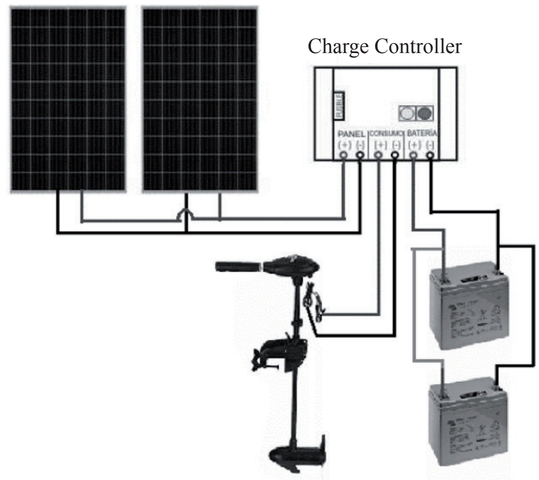
Data required		Units
Use	2.5	h
Power required	480	W
Consume	1200	Wh/day
HSE min.	4.35	h/day
Solar panel power required	**362.97**	**W**

The minimum value of power required to satisfy the needs of the project is 363 W. For a correct distribution of weight, it was decided to use two panels and between them achieve the required power.

In the market, there is a panel which offers 265 W, two of these panels would be used for the catamaran.

The electrical components necessary for the boat to move, are the electric motor, batteries, electric cable and charge controller, Fig. 27.

Fig. 27. Electric diagram of the components in the ship.



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