SHIP

SCIENCE & TECHNOLOGY

CIENCIA & TECNOLOGÍA DE BUQUES

COTECMAR
COLOMBIA

OPV93
Offshore Patrol Vessel Class

ISSN 1909-8642 (Print)
ISSN 2619-645X (Online)

Vol. 13 - n.° 26
(1 - 70) January 2020

SHIP
SCIENCE & TECHNOLOGY
CIENCIA & TECNOLOGÍA DE BUQUES

Volume 13, Number 26 - January 2020 ISSN 1909-8642 (Print) - ISSN 2619-645X (Online)

Ship Science & Technology is a specialized journal in topics related to naval architecture, ship design, hydrodynamics, dynamics of ships, structures and materials, vibrations and noise, technology of ship construction, ocean and marine engineering, standards and regulations, oceanography, maritime and river transport, and port infrastructure. Every six months, the journal publishes scientific papers that constitute an original contribution in the development of the mentioned areas, resulting from research projects of the Science and Technology Corporation for the Naval, Maritime and Riverine Industries, and other institutions and researchers. It is distributed nationally and internationally on paper and online.

A publication of

Corporación de Ciencia y Tecnología para el Desarrollo de la Industria Naval, Marítima y Fluvial - COTECMAR
Electronic version: www.shipjournal.co

COTECMAR
COLOMBIA

Editorial Coordinators
Karen Dominguez Martínez M.Sc.;
Adriana Lucía Salgado Martínez M.Sc

Layout and design Mauricio Sarmiento Barreto

Cover image designed by Vladimir González Castiblanco

Printed by C&D Publicidad & Marketing. Bogotá, D.C.

SHIP
SCIENCE & TECHNOLOGY
CIENCIA & TECNOLOGÍA DE BUQUES
Volume 13, Number 26 - January 2020 ISSN 1909-8642 (Print) - ISSN 2619-645X (Online)

SHIP
SCIENCE & TECHNOLOGY
CIENCIA & TECNOLOGÍA DE BUQUES

Editorial Note

Cartagena de Indias, January 29^{th,} 2020.

The **Ship Science and Technology Journal** in this edition continues presenting to our specialized scientific community, some of the most outstanding articles explained on the *VI International Ship Design and Naval Engineering Congress CIDIN 2019 and the XXVI Pan-American Congress of Naval Engineering, Maritime Transport and Port Engineering COPINAVAL 2019*, developed in the historic Cartagena de Indias in March 2019.

On this occasion we present issues related to the design and construction of naval platforms for rescue maneuvers in the Colombian National Navy and a proposal of a statistical model for the estimation of resistance to the advance of this type of barges; also the digitalization processes of digital twins; the elaboration of a conceptual design of a seawater desalination system using a heat pump; and issues related to the measurement of vibrations and the estimation of maintenance costs for medium-level shipyards.

This is the right occasion to reiterate the success we achieved in the development of the aforementioned congresses thanks to the wide participation of researchers and collaborators of the business sector as well as independent researchers, who contributed with their projects and scientific capital to the achievement of this publication. To all of them, our sincere thanks and our wishes for success in all their activities.

Finally, I want to extend from now, our invitation to the scientific community for the next *VII International Ship Design and Naval Engineering Congress CIDIN 2021* to be held in Cartagena de Indias in March of the coming year. Everyone is warmly welcome from now.

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

SHIP
SCIENCE & TECHNOLOGY
CIENCIA & TECNOLOGÍA DE BUQUES

Nota Editorial

Cartagena de Indias, 29 de enero de 2020.

La revista **Ciencia y Tecnología de Buques** en esta edición continúa presentando a nuestra comunidad científica especializada, algunos de los más destacados artículos expuestos con motivo del reciente *VI Congreso Internacional de Diseño e Ingeniería Naval CIDIN 2019 y del XXVI Congreso Panamericano de Ingeniería Naval, Transporte Marítimo e Ingeniería Portuaria COPINAVAL 2019*, desarrollados en la histórica Cartagena de Indias en marzo del 2019.

En esta oportunidad presentamos temas relativos al diseño y construcción de artefactos navales para maniobras de salvamento en la Armada Nacional de Colombia y una propuesta de modelo estadístico para la estimación de resistencia al avance de este tipo de barcazas; procesos de digitalización de gemelos digitales; la elaboración del diseño conceptual de un sistema de desalinización de agua de mar utilizando una bomba de calor; para posteriormente presentar tópicos concernientes a la medición de vibraciones y la estimación de costos de mantenimiento para astilleros de nivel medio.

Sea esta la ocasión propicia para reiterar el éxito que logramos en el desarrollo de los congresos antes mencionados gracias a la amplia participación de investigadores y colaboradores del sector empresarial al igual que los investigadores independientes, quienes aportaron sus proyectos y capital científico para el logro de esta publicación. A todos ellos nuestros sinceros agradecimientos y nuestros deseos de éxitos en todas sus actividades.

Finalmente quiero desde ya, extender nuestra invitación a la comunidad científica para el próximo *VII Congreso Internacional de Diseño e Ingeniería Naval CIDIN 2021* a realizarse en Cartagena de Indias en marzo del año venidero. Todos cordialmente bienvenidos desde ya.

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

Design and construction of a prototype bongo to carry out rescue maneuvers as an instruction aid in the Diving and Salvage School of the Colombian Navy.

Diseño y construcción de un prototipo de un bongo para realizar maniobras de salvamento como ayuda a la instrucción en la Escuela de Buceo y Salvamento de la Armada Nacional de Colombia.

DOI: https://doi.org/10.25043/19098642.193

Daniel Villamizar Mantilla [1]
John Gómez Morales [2]
Wilson Ovalle Porras [3]
Lissette Casadiego [4]

Abstract

The diving and salvage school of the Colombian Navy offers training in rescue maneuvers, with the purpose that students acquire the skills and abilities required for effective surveillance, protection and attention of people and materials at sea that may involve dangerous situations or threaten human life. Therefore, the teaching and learning skills of student divers have to be improved.

The purpose of the project is to design and build a bongo that will allow the students to effectively observe the applicability of the fundamentals of physics such as: Archimedes' principle, Boyle's law and Pascal's principle, as a theoretical and practical tool that serves as effective training on rescue maneuvers in real time for students and under controlled conditions at the facilities of the Diving School of the Navy in the city of Cartagena. For its execution, exploratory research was carried out and a deductive method was applied, which began with the planning study and shipbuilding method used by COTECMAR, followed by the analysis and use of materials as a result of the experience of the Naval Base BN1 "ARC BOLIVAR" in this type of constructions. Construction manuals for rescue equipment of the United States Navy were also used as references. The existing BONGO ARC "CASA", was used as reference and its information served as an input for naval architecture calculations and finally allowed the construction of the Bongo with the technical specifications required for training in this area of knowledge. The device was put into service for the Diving and Salvage School as a learning tool, maintaining proportional and aesthetic characteristics that provide ease, comfort, safety and efficiency during the instruction and decision-making process at a low cost and minimizing the risk of accidents.

Key words: Bongo, training, Boyle's law, Archimedes' principle, Pascal's principle, rescue, simulator.

Resumen

La Escuela de Buceo y Salvamento de la Armada Nacional de Colombia ofrece capacitación en maniobras de salvamento, con el propósito que los alumnos adquieran las competencias y habilidades necesarias para la efectiva vigilancia, protección y atención de las personas y el material en el mar que pueden caer en situaciones de peligro o amenacen la vida humana, motivo por el cual se evidencia la necesidad de fortalecer las capacidades de enseñanza y aprendizaje a los buzos de la institucional que allí se presentan como alumnos.

El proyecto tiene como objetivo el diseño y construcción de un bongo que le permita al alumno observar realmente la aplicabilidad de los fundamentos de la física tales como: el principio de Arquímedes, la ley de Boyle y el principio de Pascal, igualmente, el proyecto será una herramienta teórico practica que le sirve al Alumno como entrenamiento eficaz en las maniobras de salvamento en tiempo real y bajo condiciones controladas dentro de las instalaciones de la Escuela de Buceo de la Armada Nacional en la ciudad de Cartagena; Para su ejecución se realizó una investigación exploratoria y de método deductivo, que inició con el estudio de la planeación y método de construcción naval empleado por COTECMAR, seguido del análisis y empleo de materiales producto de la experiencia de la Base Naval BN1 " ARC BOLIVAR" en este tipo de construcciones, también se usaron como referencias los manuales de construcción para equipos de salvamento de la Armada de los Estados Unidos y la comparación con el Bongo ARC "CASA", información que sirvió de insumo para los cálculos de arquitectura naval y que finalmente permitieron la construcción del bongo con las especificaciones técnicas requeridas para la capacitación en este área de conocimiento, dispositivo que fue puesto en servicio para la Escuela de Buceo y Salvamento como herramienta de aprendizaje, manteniendo características proporcionales y estéticas que generan facilidad, comodidad, seguridad y eficacia en los procesos de instrucción y toma de decisiones a bajo costo y minimizando el riesgo de accidentalidad.

Palabras claves: Bongo, entrenamiento, ley de Boyle, principio de Arquímedes, principio de Pascal, salvamento, simulador.

Date Received: April 23rd 2019 - *Fecha de recepción: Abril 23 de 2019*
Date Accepted: September 4th 2019 - *Fecha de aceptación: Septiembre 4 de 2019*

[1] Escuela de Buceo y Salvamento. Colombia. Email: daniel.villamizar@armada.mil.co.
[2] Escuela de Buceo y Salvamento. Colombia. Email: john.gomez@armada.mil.co
[3] Jefatura de Formación, Instrucción y Educación Naval. Colombia. Email: wilson.ovalle@armada.mil.co
[4] Escuela Naval de Suboficiales "ARC Barranquilla". Colombia. Email: lissette.casadiego@armada.mil.co

Introduction

This research work focuses on strengthening salvage instructions at the Diving and Salvage School, which is intended to be achieved through the construction of a prototype that will serve as a bongo simulator, with the purpose of analyzing and consider the variables of refloating maneuvers and air systems of work platforms, recreating reality during academic training in order to optimize the performance of divers in all areas of the navy.

Now, the fact that this project is carried out through the diving equipment research line provides a space for the explanation and actual application of physics fundamentals such as: Archimedes' principle, Boyle's law and Pascal's principle in the occupational role of divers, thus contributing to the training on physics and salvaging.

In the first place, the theoretical foundation of salvage maneuvers will be explained. Next, the strengthening of the instruction process will be described. Later, the results obtained in the construction of the simulator will be considered and several real examples will be analyzed. Finally, methodological training strategies will be analyzed and recommendations based on the cases analyzed and work methodologies currently used in this type of work platforms will be proposed.

It is necessary to clarify two fundamental concepts: a salvage maneuver is defined as any act or activity carried out at sea to aid a seagoing vessel, its cargo or freight (or to an aircraft at sea) that is danger; and a refloat maneuver is a salvage maneuver that consists in removing water from a compartment or storehouse using compressed air by means of a mechanical source, either a compressor or air bottles, in order to release the water encapsulated in said compartments and thus gain positive buoyancy and go afloat.

Methodology

The type of research under which this project is developed according to its objective or depth is exploratory and deductive, because there is not enough bibliography about the object of study, which purpose is the construction of a prototype bongo to be used as a simulator in salvage maneuvers, contributing as a tool to strengthen the training of the Diving and Salvage School. This type of research allows the execution of the project to be structured from the review of bibliographic information of the physical theories that support the refloating maneuvers. Likewise, it allows taking into account the opinion of experts in the subject, and therefore the participant observations of researchers, thus becoming the ideal type of research to compare the knowledge theoretically acquired with real experiences in the field.

The research method proposed is deductive because it allows researchers to infer an observed result from a general law, in this case inferences are drawn from the different laws of physics applied to this project, such as: Archimedes' principle, Boyle's law and Pascal's principle, which is why, apart from the observation, the demonstrations of these theories in the operation of the prototype bongo will be used as a research tool.

Results and Discussion

The fulfillment of the general objective through the following three steps can be considered as a result

Step 1: DESIGN THE MODEL OF THE PROTOTYPE BONGO

The analysis of the purpose of study begins with the visit to COTECMAR Design and Engineering Management, located at the Mamonal Plant, where the respective approaches were carried out with the personnel trained in the design of smaller and larger vessels. The planning process began there, analyzing all the necessary aspects to be taken into account before construction such as: type of vessel, construction material, budget and all the issues that may be necessary to carry out projects of this size. It is paramount to emphasize that said planning includes the study of all variables that may ensure that vessels have a safe, economical and adequate design or maritime or naval structure.

Visits were made to the facilities of the COTECMAR plant in BN1 where our project was also made known to the Manager of the Bocagrande Plant of COTECMAR, which is in charge of managing repair and maintenance projects for the Colombian Navy, and contributed with the identification of the specific characteristics of the most suitable materials, both in terms of costs and availability in the local market, in order to choose the materials that best suit our needs and budget in an accurate manner.

Likewise, the salvage manual of the US NAVY was used as reference, with which it was possible to demonstrate how the different salvaging maneuvers are carried out, the majority of which are carried out by refloating with compressed air since it is the most effective and efficient way to achieve it, and therefore would be the method to be implemented in the operation of the prototype bongo.

On the other hand, the measures of the Bongo ARC "CASA" were reviewed in order to have a floating structure as a reference for the construction of our prototype, based on the measures of the naval artifact which are 32.06 meters in length and 9.10 meters of beam; therefore, when dividing the length by the beam, it is evident that the ratio is 3.52. This information allowed defining a rectangular structure that would meet the conditions that are actually consistent with the original bongo.

Fig. 1. DARPA Suboff main lines.

Source: https://www.caracol.com.co/emisora/2017/10/24/cartagena

Subsequently, the location and capacity of the watertight compartments was observed based on the location and distribution in the Bongo ARC "CASA" in order to determine the location of salvage valves with their respective couplings; in order to design the model establishing the dimensions and weight that will facilitate maneuvering in different scenarios such as the pool of the Naval Base ARC "Bolivar" and the dock of the Salvage Diving Department.

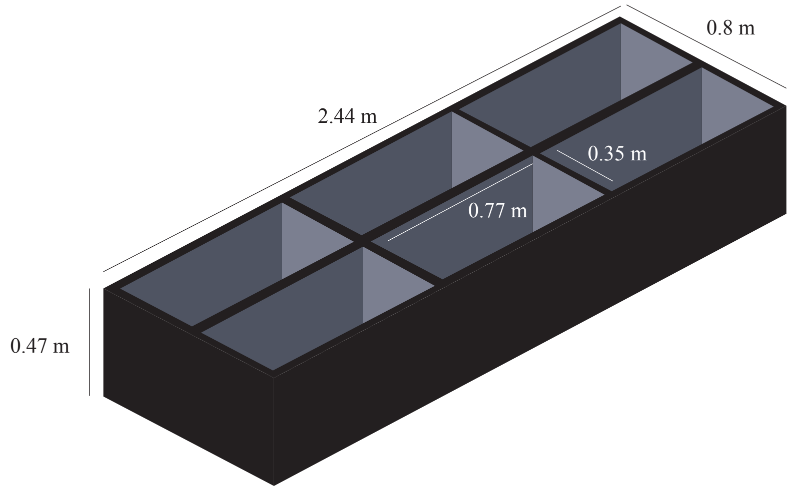
Calculations were made to select the material based on the size previously determined and according to the variables of density, plate thickness, length, width, height, weight and external volume, in order to find the pushing force and determine buoyancy.

Table 1. Pushing force calculations.

INPUT DATA FOR PROTOTYPE		
Length	2.44	m
Beam	0.8	m
Height	0.47	m
Stainless steel density	7980	kg/m^3
Plate thickness	0.002	cm
Sea Water density	1027	kg/m^3
Gravity	9.8	m/s^2
DATA OF EACH COMPARTMENT		
Length	0.77	0.77
Width	0.35	0.35
Height	0.47	0.47
Square area	0.329	0.329
Rectangle area	0.7238	0.7238
Total area	1.0528	1.0528
Compartment Volume	0.15291	0.15291
CALCULATIONS OF THE PROTOTYPE		
Bongo mass	165.2	kg
Square area	3.008	m^2
Rectangle area 1	3.904	m^2
Rectangle area 2	3.44	m^2
Total area	10.35	m^2
Material volume	0.021	m^3
Bongo volume	0.917	m^3
Bongo weight	1619	N
Pushing force	9234	N
Buoyancy reserve	7614	N
Maximum load	777	Kg
Draft displacement	0.082	m

Source: Authors.

Fig. 2. Dimensions of the Prototype.



Source: Authors.

An exercise was carried out that allowed determining the useful life of the bongo in the water and the preservation of its basic operating conditions.

These calculations allowed determining that the structure must be made of stainless steel, with the following measures: length 2.44 meters, beam 0.8 meters, plate thickness 0.2 centimeters, material density 7980 kg/m^3; thus ensuring its viability by demonstrating positive buoyancy.

Considering that the oxygen in water or air attacks iron, it has been determined to work with stainless steel to avoid any steel rust, providing greater stability and high resistance to the corrosion produced by seawater and its prolonged use in salt water, which factors allowed considering it as a better option over other metals.

Step 2: BUILD THE PROTOTYPE BONGO

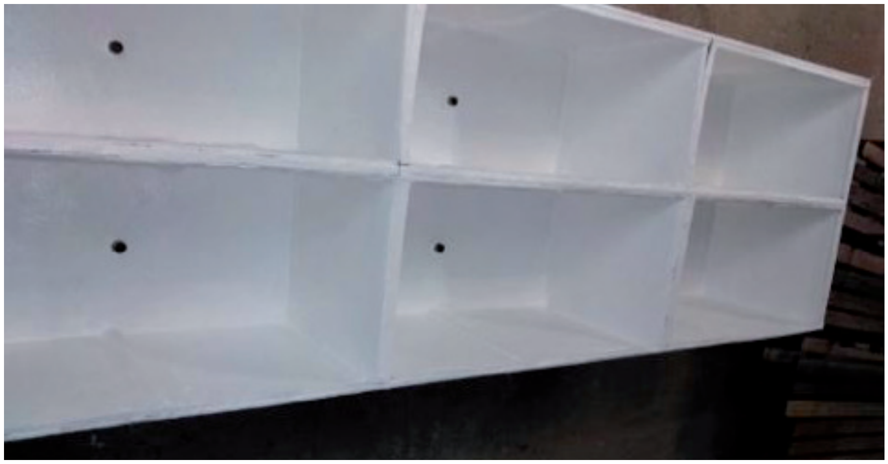
Once the materials and tools were determined, a plan was drawn, as observed in Fig. 2, where the design and dimensions are shown, minimizing any errors in the actual construction.

Based on this model, the construction of the prototype was commenced, cutting and welding in the upper part of the structure, organizing the internal system of the bongo, opening holes in the lower plate in order to weld the couplings where water outlet valves are screwed into, see Fig. 3.

Fig. 3. Cutting and welding to fix check valve couplings.

Source: Authors.

Fig. 4. Application of fiberglass on the inside of the Prototype.



Source: Authors.

Later, fiberglass was used to create a structure with six fully watertight compartments, with more stability and resistance to support the different pressures to which the prototype will be subject.

Then the lids of the compartments are individually welded and a hole is made in each one of them to connect the valves responsible for injecting air into the structure.

Fig. 5. Top lid welding.

Source: Authors.

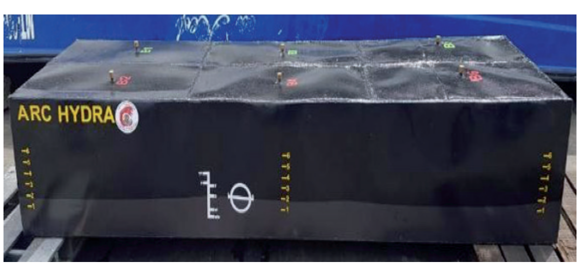
Bronze check valves were acquired, which are suitable for performing salvage maneuvers in the bongo. The holes opened in the upper lids were used to place the butterfly anchors used as pressure plugs to allow air to escape when the compartments are flooded with water.

Finally, a mechanical routine was carried out and then antifouling paint was applied on the hull, which is a special paint for the protection of the hull due to its ability to stop the development and expansion of living marine organisms that may compromise the performance, the seaworthy conditions of the structure and the durability of materials and components submerged in the ocean, thus providing a barrier to stop corrosion in metal hulls.

Fig. 6. Butterfly anchors.

Fig. 7. Application of antifouling paint.

Fig. 8. Final Prototype.



Source: Authors.

Step 3: DESIGN THE MODEL OF THE PROTOTYPE BONGO

A pneumatic test was carried out to verify the airtightness of each of the watertight compartments and to check the operation of the non-return valves located in the lower part of the prototype. To achieve this, a low pressure compressor with a maximum pressure of 180 psi was required with its respective compressed air outlet hose at 60 psi, which is the pressure needed to overcome the resistance of each check valve on the surface, and these tests determined the correct operation of such check valves, evacuating the water lodged inside each compartment.

Fig. 9. Application of antifouling paint.

Source: Authors.

Then, the low pressure compressor setup was carried out, a hose 10 meters long was connected to the air outlet valve of the compressor, then the necessary equipment was assembled so that divers could carry out the refloat maneuver.

Then the prototype is placed in the water, keeping afloat, then the plugs are removed from the top to begin filling them with water, confirming the proper performance of the filling holes.

Once the simulator was at the bottom, 2 divers entered and proceeded to connect the compressor

Fig. 10. 180 psi compressor.

Source: Authors.

hose to one of the flooded compartments. The hose was pressurized to 70psi in order to inject compressed air and thus observe the behavior and conditions of the prototype as it begins to empty the water of each compartment.

The time to evacuate all the water from a compartment is calculated and recorded (4 minutes), its ascent speed increases as it approaches the surface, this is explained in Boyle's law regarding to the increase in air volume when the absolute pressure to which the simulator is subject decreases.

It is important to highlight that the pressure required is determined according to the direct observation of the behavior of the bongo in different conditions. According to this the compressor measurements table (see Table 2) was established indicating the proper use of the prototype starting from 15 feet and in an increasing pressure scale until achieving the maximum descent of 20 feet that is the depth of the dock at the Diving and Salvage School, in which the prototype is intended to be used during instruction days.

This exercise allowed demonstrating the successful refloating of the simulator following the instructions of the procedure.

Fig. 11. Filling water into the compartments of the Prototype.

Source: Authors.

Fig. 12. Prototype submerged at 20 feet.

Source: Authors.

Table 2. Constant pressure table for each foot of seawater.

Depth in feet	Increase by Depth	Total	Unit of Measurement
Surface	N/A	60	PSI
15	6.675	67	PSI
20	8.9	69	PSI
25	11.125	71	PSI
30	13.35	73	PSI
Constant per foot of seawater increased		0.45	PSI
PSI (Pressure per Square Inch)			
Increase by Depth = Depth in feet * 045			
TOTAL = TOTAL AT SURFACE (60) + INCREASE BY DEPTH			

Source: Authors.

Fig. 13. Prototype reaching the surface in a controlled manner.

Source: Authors.

Fig. 13. Prototype reaching the surface in a controlled manner.

Source: Authors.

A manual in which the proper way to perform maneuvers with the prototype is determined is delivered together with the bongo simulator. It also describes the step-by-step maintenance required to preserve the structure in optimal conditions.

Conclusions

Once the investigation was completed and the analyzes of the data collected were carried out, refloat maneuvers were performed with the prototype bongo, from the moment in which the prototype is at the bottom of the sea until it has refloated back to the surface.

On the other hand, by making a detailed analysis of the salvage air system of the bongo ARC "CASA", it was possible to understand its structure and operation, which allowed determining the materials and tools necessary for the operation of the simulator that was later implemented in the instruction days in the Diving School of the Navy.

The studies and analyzes carried out on the materials and tools for the construction of the simulator allowed determining that stainless steel is the most suitable material, which adjusts to the shape and dimensions determined by the scale, confirming the previous calculations and ensuring the buoyancy of the structure with sufficient pushing force that serves as a support for the weight that was later added in the construction process of the simulator.

It is important to highlight the importance of caring for the structure as it is part of the training tools of the Naval School of NCOs. For this purpose, it is necessary to effectively use the checklist for the effective use of the simulator and also to follow the procedure guidelines, which instructions allow ensuring the optimal operation and development of various learning activities.

Finally, the reduction of costs with respect to the benefits of the project for the School was obvious, thus avoiding any possible damages to the bongo ARC "CASA" during salvaging instructions by using the prototype, in addition to the fact that the costs necessary to flood it are high and would require a greater amount of time and personnel to be achieved, and also because the cost of maintenance versus the maintenance of the prototype built is much higher.

References

[1] BRAVO RODRÍGUEZ, JOSÉ; ORTEGA CANTERO, MANUEL. Human-computer interaction systems. University of Castilla-La Mancha.2001.

[2] GIANCOLI, DOUGLAS. Physics: Principles with Applications. Sixth edition. Pearson Education. 2006.

[3] NEMBER SARAY. Analysis of the current situation in the refloating of sunken vessels. University of the Lagoon Polytechnic School of Engineering - Nautical, Machinery and Naval Radio Electronics Section July 2015.

[4] U.S NAVY SHIP. Salvage Manual. Submarine Salvage. Volume II. Washington D.C., 1970. P 6 12 [Online] CdS. January 27, 2017. [Revised March 25, 2018]. Available online: http://www.cadenadesuministro.es/noticias/conectando

[5 LÓPEZ, JORDI. U-history. The Ballast Tanks. OR HISTORY.COM [online]. [Revised March 12, 2107] Available online: https://www.uhistoria.com/uhistoria/te cnico/articulos/lastre/lastre.htm.

[6 PEREZ JULIAN, MERINO MARIA: Concept of Pedagogy (https://definicion.de/pedagogia/) 2012.

[7] BROWN, THEODORE L.; LEMAY, H. EUGENE, JR.; BURSTEN, BRUCE E. Chemistry. La Ciencia Central, 9th edition; Pearson Prentice-Hall: Mexico, 2004.

The "Digital twin". Digitization process from the point of view of a classification society.

El "Gemelo digital". Proceso de digitalización desde el punto de vista de una sociedad de clasificación.

DOI: https://doi.org/10.25043/19098642.194

Jaime Pancorbo Crespo [1]
Luís Guerrero Gómez [2]
Javier González Arias [3]

Abstract

The process of digitalization in our society is undeniable and unstoppable and ships are adapting more and more to this new environment. This offers great advantages, since ships can send/receive all the information on all aspects of their current status (allowing more efficient management during the ship's life and even opening the door to autonomous navigation), but this presents a number of intrinsic difficulties due to their connected state (cybersecurity).

All the above will be developed with a massive sensorization of the ships, which will indicate their condition, going from a reactive maintenance to a predictive maintenance. This requires the figure of the digital twin, which digitally represents the physical reality of the ship, and which will be a single source of information for all actors. This digital twin opens the door to "Digital Classification" by Bureau Veritas, in which traditional 2D plans are no longer necessary, but work is done directly in 3D on the Digital Twin. Bureau Veritas, as a reference classification society, has adapted to the current situation of the industry, favoring the digitalization process in all its aspects. The objective of this article is to present the current state and foreseeable evolution of the technology leading to the Digital Twin concept, its implications in the design and maintenance of ships, all from the point of view of a Classification Society while exemplifying the digitalization process of a Classification Society in different aspects.

Key words: Scanning, Digital Model, VeriSTAR AIMS3D

Resumen

El proceso de digitalización en nuestra sociedad es innegable e imparable y los buques se adaptan cada día más a este nuevo entorno. Éste ofrece grandes ventajas, ya que los buques pueden enviar/recibir toda la información de todos los aspectos de su estado actual (permitiendo una gestión más eficiente durante la vida del buque e incluso abriendo la puerta de la navegación autónoma), pero presenta una serie de dificultades intrínsecas por el hecho de estar conectados (ciberseguridad). Todo lo anterior se va a desarrollar con una sensorización masiva de los buques, que indique su estado, pasando de un mantenimiento reactivo a un mantenimiento predictivo. Para ello es necesaria la figura del gemelo digital ("digital twin" en inglés), que representa digitalmente la realidad física del buque, y que será una única fuente de información para todos los actores.
Este gemelo digital abre las puertas a la "Clasificación Digital" por parte de Bureau Veritas, en la que ya no sean necesarios los tradicionales planos 2D, sino que se trabaje directamente en 3D sobre el Gemelo Digital. Bureau Veritas, como Sociedad de Clasificación de referencia, se ha adaptado a la situación actual de la industria, favoreciendo el proceso de digitalización en todos sus aspectos.
El objetivo de este artículo es dar a conocer el estado actual y la evolución previsible de la tecnología conducente al concepto de Gemelo Digital, sus implicaciones en los diseños y mantenimiento de buques, todo desde el punto de vista de una Sociedad de Clasificación a la par que se ejemplifica el proceso de digitalización de una Sociedad de Clasificación en distintos aspectos.

Palabras claves: Digitalización, Modelo Digital, VeriSTAR AIMS3D

Date Received: January 14th 2019 - *Fecha de recepción: Enero 14 de 2019*
Date Accepted: February 25th 2019 - *Fecha de aceptación: Febrero 25 de 2019*

[1] Naval Engineer. Bureau Veritas Spain and Portugal. Madrid, España. Email: Jaime.pancorbo@es.bureauveritas.com
[2] Naval Engineer. Bureau Veritas Spain and Portugal. Madrid, España. Email: Luis.guerrero@es.bureauveritas.com
[3] Naval Engineer. Bureau Veritas Spain and Portugal. Madrid, España. Email: Javier.gonzalez-arias@es.bureauveritas.com

Introduction

Since those times (19th century) when Classification Societies worked exclusively on paper plans, a lot of time has passed, which Bureau Veritas has ceased the opportunity to continuously adapt to the information management needs of clients. This new information technology and digitalization process has been implemented in Bureau Veritas in certain aspects that fully confer the characteristics of a Classification Society in the 21st century.

Bureau Veritas' digital transformation began in 2015, leading to concrete projects in 2016 which have crystallized into the new tools available to our clients, and which will continue to evolve, along with the rest of the industry.

The changes involved in the digitization process within the work of a classification society like Bureau Veritas affect both the design and the fundamental inspections and other digital services that help and support both shipyards and shipping companies.

Digital transformation in detail

Digital transformation is based on the following 3 pillars:

1) Digital services. Digital services include the generation of a "digital twin" of the ship, which includes all the ship's information. This model will be very useful, not only for Bureau Veritas, but also for shipyards in the construction phase and shipowners in operation (facilitating groundings, etc.)
2) Customer experience. We have tried to improve the customer experience through digital certification and an array of specific applications that will facilitate the inspection and maintenance work in order to certify the fleet.
3) Operations. In this case, improvement has focused on enhancing the effectiveness and efficiency of ship interventions and Bureau Veritas' in-ternal procedures.

Table 1 shows in more detail the most fundamental aspects of the digitization process, which can

Table 1. Implementation phases of digitization at Bureau Veritas.

	DIGITAL SERVICES	CLIENT EXPERIENCE	OPERATIONS
1ST PHASE	**Digital Modelling &and AIM** *Veristar AIM 3D* **SMART SHIP** *Cybersecurity and advanced testing*	**MOBILE APPS** *My Veristar* **CAN I TAKE THIS PRODUCT?** *Veristar Dangerous Goods & Bulk* **E-COMMERCE** *My BWMP*	**CONNECTED SURVEYOR** *My Jobs* **PLAN APPROVAL MONITORING** *FIT Deadline - FIT Workload - TABLEAU* **E LEARNING**
2ND PHASE	**3D CLASSIFICATION** **ADVANCED INSPECTION METHODS**		
	VENDOR ASSESSMENT *Linked to the customer's purchasing platform* **DATA ANALYSIS AND DASHBOARD** *Fleet Performance Indicator*	**DIGITAL CERTIFICATES** **INTERFACE WITH CUSTOMER'S TOOLS** *Plans, Ship Status*	**ONLINE PLANNING** *My Chronos*
3RD PHASE	**DIGITAL MODELLING AND AIM** Veristar AIM 3D - ERP&DMS Connection **ADVANCED PANELS** *Increased PIF and mobile access*	**NEW MOBILE APPS** *PSC Checklist* *My Approval Explorer*	**CONNECTED SURVEYOR** *Complete process on board*

be divided into several phases, which have been implemented at Bureau Veritas in recent years, but all of which are operational today.

In other words, the implementation of the transformation has been done progressively. To describe this large number of developments, we will RELY on these phases:

A) Phase one

As far as the first phase implementations are concerned and have been in operation for a long time, both for Bureau Veritas and for external clients (shipyards, shipowners and equipment manufacturers), it can be said that the deeper development is already implemented at Bureau Veritas, with several pilots being executed with clients and feeding back the system with their answers, consists of digital modelling, the so-called "Digital Twin", which Bureau Veritas has implemented through the VeriSTAR AIM 3D system, which consists of Asset Integrity Management. This process will be dealt with separately in this article, and will be described in the final part of the article.

Due to the technological advances that have favored automated ship arrangements and are increasingly dependent on communications, together with new software-based technologies (dynamic positioning, electronic systems to optimize consumption, reduction of gas emissions, etc), cybersecurity (and specifically hacking), has made our hardware/software systems one of the possible "weak points" in international shipping, which must be improved and secured. In parallel with the development of the digital twin, and as a second fundamental aspect of digital services, an evaluation of cybersecurity has been carried out, both in aspects related to piracy and those to prevent unintentional accidents, as well as the evaluation of the performance of a software or system. For this, specific collaborators have been sought in each of the aforementioned tasks.

In the following table (Table 2) we can see the different lines of action of Bureau Veritas in the area of cyber security.

It is important to highlight the HWIL (HardWare In the Loop), used to standardize test procedures, reports, etc, of control systems (including

Table 2. Processes related to Cybersecurity at Bureau Veritas.

CYBER SECURITY	CYBER SAFETY	CYBER PERFORMANCE
Prevention of malicious voluntary actions	**Prevention of unintentional actions, errors or failures**	**Performance control of a certain system or software**
SYS-COM New class notation, with TAC covering remote access and data exchange in a secure manner	**IACS UR E22 & HWIL** Classification system based on the criticality of the elements of the system • Certification of critical systems • Systems integration	**Concordance with specification** Equipment for remote monitoring and control
Risk analysis consultancy: • Network • Software • Remote access	**Test Consulting** • Compliance with UR E22 • Systems integration. • Software	**Performance Consulting** • CBM (Condition Based Monitoring) • Autonomous systems • Energy efficiency fuel consumption and emissions measurement

monitoring and protection systems) in a simulated environment. The tests will be performed by a third party duly authorized by Bureau Veritas, assigned to those ships having an increased reliability of ship-to-shore communications means, so as to allow monitoring analysis as well as remote troubleshooting, increasing the reliability of the ship and its operations when using automation, support and maintenance systems.

Other tools already in place are, in terms of helping the shipowner to improve the customer experience:

1. Mobile applications (My VeriSTAR). It is an application designed for shipowners. It can be used to track the ship, both in terms of certificates, class recommendations and other information regarding classification.
2. Tools on certain products (VeriSTAR Dangeous Goods and VeriSTAR Chemicals) They can be used to check whether our ship is ready to carry a certain cargo, either of those indicated in the IMDG or in the IBC. It responds to a specific need of the ship-ping companies to verify, in a short period of time, the viability of transporting a cargo that is not in the list of products.
3. E-Commerce. The e-commerce started with the web tool "My BWMP" (Note: BWMP: Ballast Water Management Plan), in which the shipowner can submit a plan for verification, while receiving the quotation online, being able to pay by credit card. This is a further facility for shipowners, especially in view of the dates of application of this manual.

Internally, Bureau Veritas' procedures have been modified, making use of tools such as VeriSTAR Project Management (VPM), which is a tool that facilitates collaboration between shipyard/designer and Bureau Veritas, and also provides possible access for the shipowner and various tools for measuring KPI's (Key Performance Indicators):

1. Linking the number of plans received by each department in the office with the human resources available to them, creating conflict matrices that allow for the identification of subcontracting needs, etc. in advance. This program is known as FIT-WorkLoad (FIT-WL)
2. In the same way, the KPIs of each department or office are obtained through another tool that monitors the plan approval process. This data can be obtained by project, by inspector, etc., facilitating the management of the whole process. The program that monitors this process is the FIT-DeadLine (FIT-DL).

In September 2017, an internal program was launched encompassing both tools, called TABLEAU.

With regard to e-learning, it affects two fundamental fields:

a) Internally, to the training of Bureau Veritas inspectors. Under the old system of training inspectors, more than 500 New Builders or In-Service Vessel Inspectors were trained each year, which meant about 1600 days of training per year. Currently, and by means of the online training systems, the number of classroom training sessions has been reduced by more than 80%. Online training gives it a versatility and capacity to adapt to the needs of each inspector/inspection area, which would not otherwise be possible.

b) Externally: It is important to point out that Bureau Veritas is increasingly incorporating web based teaching through the Bureau Veritas Learning School, with online courses including ISM, etc. The most recent being the Master's Degree in Ship Inspection, which was conducted entirely in Spanish and was very well received in its first edition.

B) Second Phase

As far as the first phase implementations are concerned and have been in operation for a long time, both for Bureau Veritas and for external clients (shipyards, shipowners and equipment manufacturers), it can be said that the deeper development is already implemented at Bureau Veritas, with several pilots executed with clients and feeding back the system with their answers, consists of digital modelling, the so-called "Digital Twin", which Bureau Veritas has implemented through the VeriSTAR AIM 3D system, which consists of Asset Integrity Management. This process will be dealt with separately in this article and will be described in the final part of the article. In this second phase, several initiatives have been developed that include the long awaited 3D classification, which will mean not having to send plans for verification, but only a 3D model (which will be the so-called "digital twin") (NOTE: Obviously, there are plans that, due to other regulations, must be available on board, in paper format, at the disposal of the captain: Fault Management Plan and Book, Safety Plan, etc.).

Advanced inspection methods (*e.g.* visual and thermal inspection with drones), are imposing their utility and assuming within the processes of the Classification Society (with appropriate limitations). The first certification for a drone company has been delivered in the Netherlands in September, with that company (RYMS) operating as a "Service Vendor" of Bureau Veritas (*i.e.* a company performing class inspections).

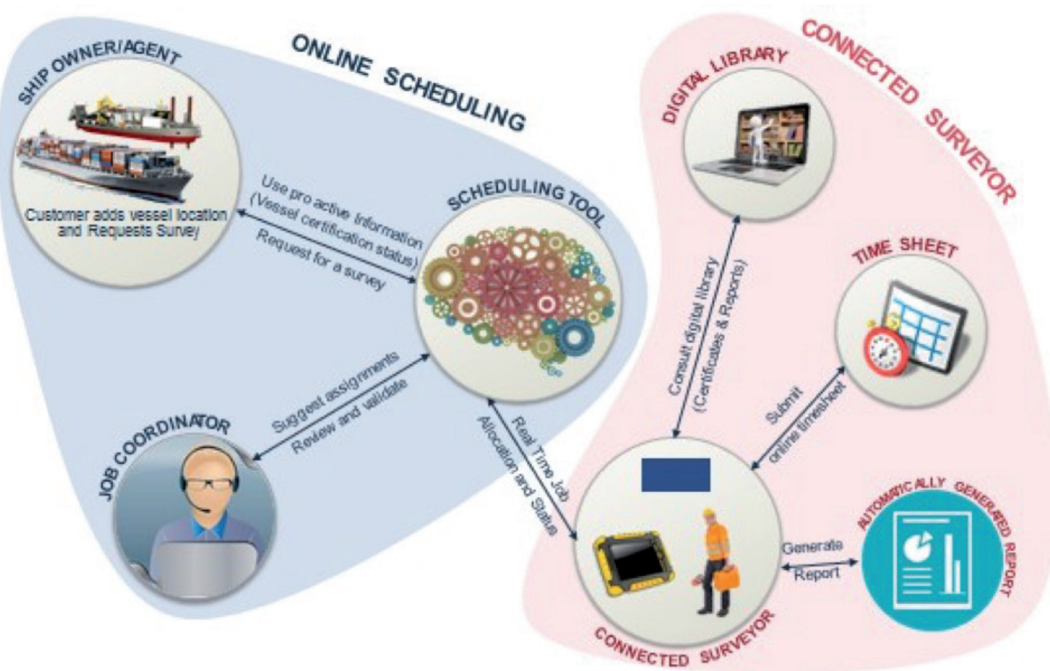
To close the circle of the classification process, the certification of the ship will be transformed into digital, which is being developed with pilot experiences together with the Danish and Dutch Maritime Authorities (DMA and NSI). Bureau Veritas inspections may be completed on the ship through the electronic signature of the inspector and verified on a verification website.

This will be complemented by tools that will interact with both:

a) Shipyard. Through the already used VeriSTAR Project Management (management tool for the approval of plans and comments, implemented in Spain in all the shipyards since 2012), it will link with the shipyards' plans management systems,
b) Shipowners: The interconnection with the shipowner's systems will be carried out, especially in order to know the state of the ship, regarding its class certification and visits.

Internally, it has been implemented from the "My Chronos" program, which is another App

Fig. 1. Bureau Veritas inspection planning tools.



that is used by planners, in order to optimize the resources of the Company giving the best possible service to the shipowner when a visit is requested. This inspection request will be managed by an inspection coordinator, who through this planning tool (My Chronos) will give the order to the inspector, who will be able to carry out the inspection and issue the corresponding certificates. In order to correctly explain how Bureau Veritas' tools work in the field of inspection planning, Fig. 1 explains the process to be followed.

C) Third Phase

The initiatives in this third phase involve, firstly, connecting the digital model with all the CAD systems on the market, through a "neutral" platform that can be fed with the models generated in the various systems and can be exported to them. Currently these "links" are already made for some software, but not for all, due to the great variety of existing design programs.

A development mainly for the use of shipowners will be the possibility of generating personalized dashboards with the most significant data that the owner of a certain vessel or fleet wants to present. One of the most important innovations is the FPI (Fleet Performance Indicator), *i.e.* an internal indicator that considers ship recommendations, detentions, etc., so that a comparison can be made between ships in the fleet. An example of the above-mentioned PIF can be seen in Fig. 2.

More initiatives under development and that will reach the Classification Society are the use of virtual reality (VR) and augmented reality, whose integration into the usual use of the sector is not a question of if but when it will be done.

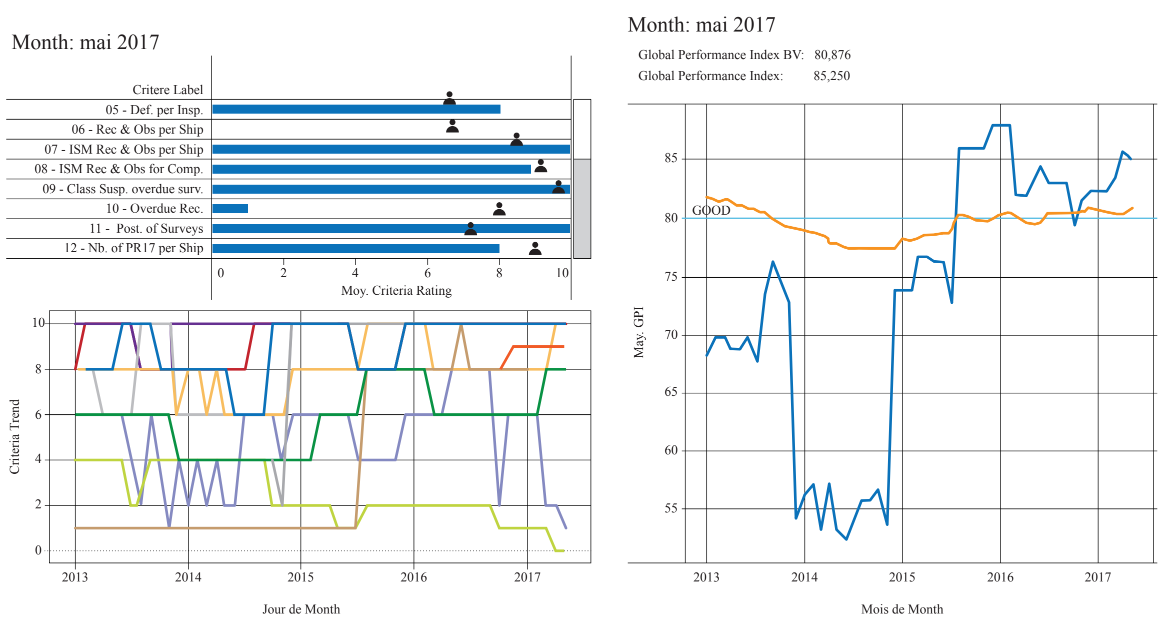
But let's focus on the digital twin and the environment in which AIMS-3D is contemplated.

VeriSTAR AIMS 3D

The AIMS 3D system aims to generate the "digital twin", which is nothing more than the digital representation of a physical model (in this case, the ship). This model will represent all the data from the physical vessel, and will be fed back through sensors and direct data input.

This model will serve in the development of the project during the new construction and

Fig. 2. Fleet Performance Indicator (FPI).

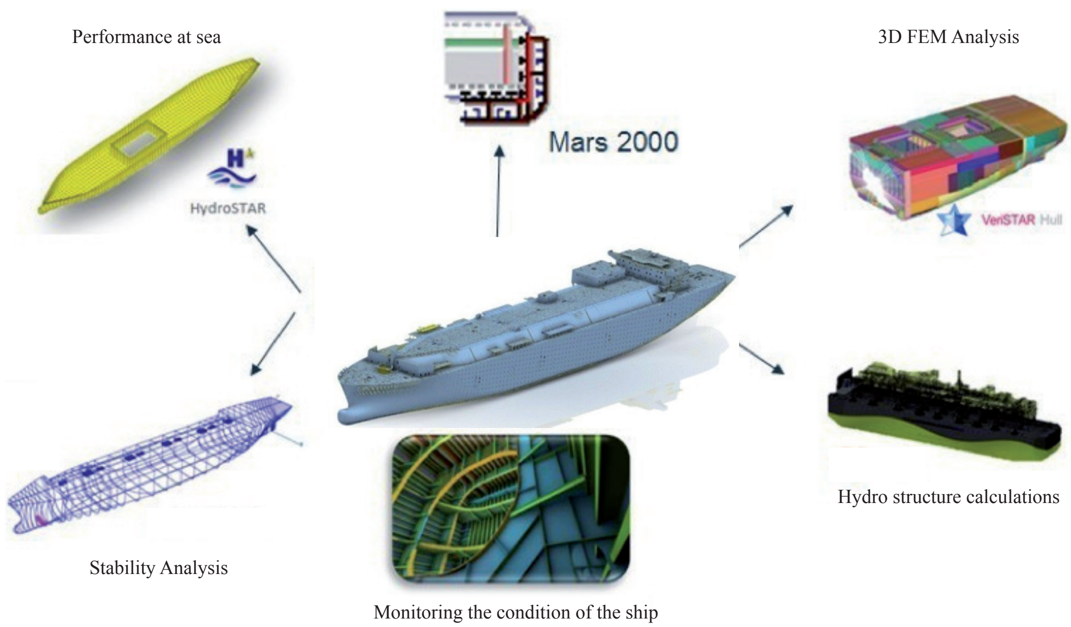


the maintenance of the ship during its life in service, covering the needs of both shipyards and shipowners.

The most important part and the one that started the development is the one corresponding to the generation of the model and the structural calculation. For this purpose, different CAD systems have been evaluated, in order to interact with existing Bureau Veritas programs, and finally, the decision has been made to collaborate in the development of a tool with the French company Dassault Systems, whose system, known as CATIA 3D EXPERIENCE, is already well established mainly in the aerospace and automotive sector.

In the first phase, work was carried out on the interaction with Bureau Veritas software regarding structure, stability and performance at sea, as can be seen in the following graph, relating the digital model to the various internal Bureau Veritas programs:

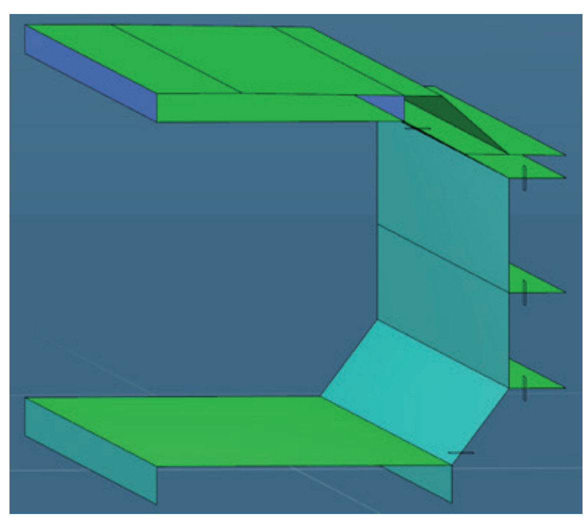
Fig. 3. Digital Twin: Single Data Source for Many Programs.



To prepare the model, the software allows the direct generation of the model, as well as the use of templates, which are already made for complete ships (classified by ship type: tankers, bulk-carriers, LNG, LPG, etc.), as well as for particular elements (*e.g.*: bulkheads, lower and upper hoppers, as well as other elements of the complete generated library)

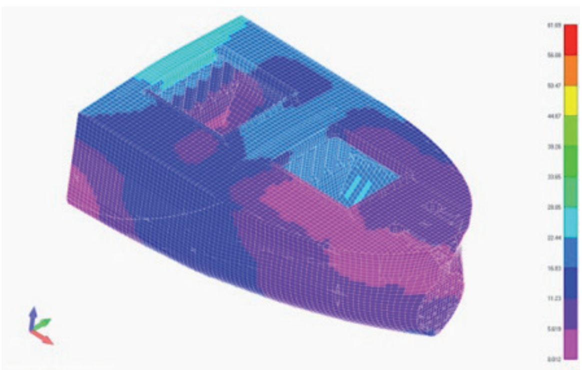
In a parametric way, these templates allow a fast and effective recreation of the ship, reducing the time needed to generate a model and avoiding possible errors due to inconsistencies between plans with different revisions, since the model is unique and all actors will feed from it. An example of a template is the following, which is a template for a membrane LNG carrier:

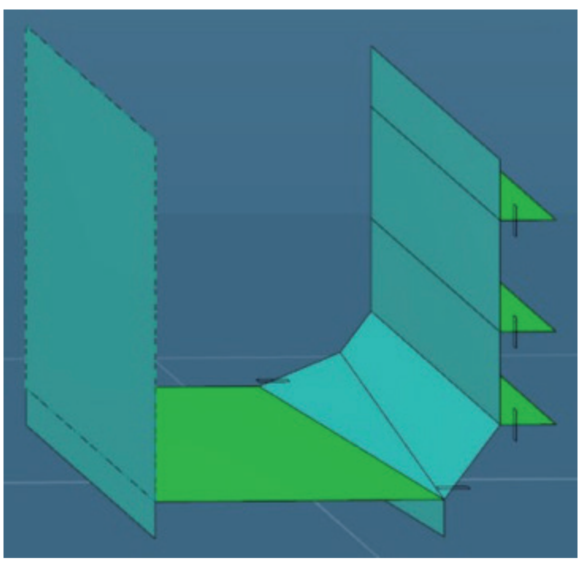
Fig. 4. LNG template.



The templates will also help us in the most complicated areas to make the model and which are the most time consuming, such as the final holds and the bow and stern ends, as you can see in the following image, as well as a template of one of these holds/end tanks:

Fig. 5. Model of a bow hold (along with the rest of the bow) and one of the templates of a bow tank.





Once the model is generated, and focusing on the structural aspect, the meshing is almost immediate, with the consequent simplification in the whole verification process. Once the model is generated, this structural model is automatically imported into VeriSTAR Hull, Bureau Veritas' finite element program, which will handle the resolution and post-processing (performance evaluation).

The comments resulting from the review will be included directly in the 3D model, which can be monitored and will be available to both Bureau Veritas inspectors and the shipyard (and eventually the shipowner), as is currently the case, but with 2D drawings.

A very important aspect of the model is that it is collaborative, wanting to indicate that all the actors involved can participate in the feedback of the model (obviously, the data needed by one and another participant in many cases are not the same). For example, Bureau Veritas inspection reports will go directly into the model, incorporating their results into the model, both in terms of thickness measurements, areas where cracks have been detected, etc. All this will allow the creation of a model that will not only be useful in the production process of the ship, but will also accompany it throughout its life in service.

Given the different needs of the different Classification Society, Shipyard and Shipowner Inspectors, a more simplified tool (a 3D model viewer) will be provided to allow all the participants to see the digital model together with all the information it contains, with a simple handling (*i.e.* no mesh generation, etc). We are currently working with a platform called SmartShape.

All these data will be integrated into the platform in such a way that they form a "Smart Data", *i.e.* data presented in a way that facilitates and assists decision-making, both in the design phase and in the service life phase of the ship.

Another substantial advantage is the access to information: all of it (status, indicators, information about visits, etc.) can be accessed from the network theough mobile/tablet apps, giving a flexibility and robustness in the information that could not be given until now. The "dashboard", represents in a graphic and simple way all the parameters that we want to know about the ship or fleet (See Fig. 6).

In addition, the AIMS 3D tool has other functionalities, which are very useful for specific purposes:

Fig. 6. Internet access and dashboards.

Offline work mode.

This way of working allows to make modifications on the model that has been previously downloaded in our computer, and once the conditions to establish a connection are restored, to overturn this data in our model. Initially it was approached solely for training purposes, so that inspections could be planned on the "digital twin", in order to increase the efficiency and effectiveness of the intervention on the physical vessel. Subsequently, the benefits that this functionality has for the information feedback (mainly from the shipowner) and the subsequent uploading on the model, have resulted in the development of specific applications, considering the internet unavailability (or sufficient bandwidth) to work directly with the model and having to do it offline mode.

Interaction with the client's IT systems.

The virtual model generated will be able to have interactions with the main management tools of our clients, mainly with

a) CMSS (Computerized Maintenance Management System)
b) ERP (Enterprise Resource Planning)
c) DMS (Document Management System)

In other words, it not only deals with document management, but also with planning and maintenance.

As an example, to summarize, the advantages of using the digital model in the classification process, for a shipowner, throughout its life, the process would be as follows:

During the construction phase of the ship, the database will be created and all the necessary interconnections will be made, both with all Bureau Veritas tools and with those of the client, so that when the ship is operating they will be operational. Once in service, the process for conducting class visits is simplified as follows:

The shipowner will be alerted on his mobile phone/computer (App My VeriSTAR) that the deadline for a visit is approaching according to the preferred notices, the shipowner will request the visit (time and place) on this same tool (My VeriSTAR), and that information will arrive in real time at Bureau Veritas. Bureau Veritas will look for the best possible inspector, with the necessary accreditations given the type of ship and according to the shipowner's request for date and place (Online Scheduling/ My Chronos), and the work order will be given to the inspector, via the mobile phone (My Jobs). The inspection will be carried out on board, either in a conventional way or with new inspection systems (drones and others), and reports will be made through the same tool (My Jobs), receiving the Digital Certificate, with the consequent saving of time in the inspection. If necessary, the measurements taken on the ship (*e.g.* thickness), would go to the digital twin which will make a recalculation of the structure of the ship as well as any other study considered necessary, giving the corresponding recommendations, thus optimizing the renovations, etc. and in the same way, it will incorporate all the notes of the inspector, issuing immediately the inspection reports with the digital seal. All this would be integrated together with the shipowner's tools, so that it would be much more comfortable for him to plan the groundings and the necessary work in each one of them.

Conclusion

We can summarize that Bureau Veritas' digitalization process has been adapting to the new needs of the 4.0 industry, focusing both on internal processes and on the interaction with clients, through new tools, among which the generation of the "digital twin" stands out, which will allow following the life of the ship from its design stage throughout its useful life.
Regarding the inspections to be carried out, Bureau Veritas has evolved in the two aspects that make up this field.

a) The request for inspections and subsequent feeding of the digital twin with this data

b) The inspection itself, using the new inspection methods available in our industry (drones, etc).

It should be noted that these inspections will be increasingly risk based (RBI = Risk Based Inspections), which are managed through specific risk analysis programs that evaluate the frequencies (probability of occurrence) and severity of the damage, generating a risk matrix that can be used to plan equipment reviews according to this index, optimizing visits and allowing for planning.

This is the first step in Bureau Veritas' ongoing digitalization, the ultimate goal of which is to be fully aligned with our clients' tools and methodologies, while offering an increasingly efficient and effective service.

The digital era has begun, as a collaborative era in which new technologies are asserting themselves and Bureau Veritas has adapted and will continue to adapt both its internal processes and methodology to the progress of the industry.

References

1. Bureau Veritas NR467 Rules for Steel Ships, July 2018.
2. Bureau Veritas presentations in the years 2017-2018.

Conceptual design of a seawater desalination system using a heat pump.

Diseño conceptual de un sistema de desalinización de agua de mar utilizando una bomba de calor.

DOI: https://doi.org/10.25043/19098642.195

Leslie L. Díaz Heyser [1]

Abstract

The present investigation is based on the development of a conceptual design of a desalination system incorporating the technology of the heat pump, for which the conceptual foundations related to water and its characteristics were addressed; a description of the different desalination systems and technical characteristics of a heat pump. The information collected allowed to start the development of the methodological framework, in which the lineal design model was applied to define the parameters and requirements that were considered to determine the conceptual design of the desalination system using a heat pump, through which, the main result was that the heat pump technology is applicable to a seawater desalination system, considering the seawater conditions on the coast of Chile and the standardized flows that the Navy could require.

Key words: *COP*: Coefficient Of Performance; the efficiency of a refrigerator or heat pump is given by a parameter, *PSU*: Practical Salinity Unit. 1[PSU]= 1 [g/kg] = one gram of salt per kilogram of water, Q_{EV} : Heat in the evaporator $[W]$, Q_T Heat in the condenser $[W]$, $\dot{W}$: Work done by the system $[W]$.

Resumen

La presente investigación se sustenta en el desarrollo de un diseño conceptual de un sistema de desalinización incorporando la tecnología de la bomba de calor, para lo cual se abordaron los fundamentos conceptuales relacionados con el agua y sus características; una descripción de los diferentes sistemas de desalinización existentes y características técnicas de una bomba de calor. La información recopilada permitió iniciar el desarrollo del marco metodológico, en el cual se aplicó el modelo de diseño lineal para definir los parámetros y los requisitos que se consideraron para determinar el diseño conceptual del sistema de desalinización utilizando una bomba de calor, a través del cual, se obtuvo como principal resultado que la tecnología de la bomba de calor es aplicable a un sistema de desalinización de agua de mar, considerando las condiciones del agua de mar en la costa de Chile y los caudales estandarizados que la Armada podría requerir.

Palabras claves: *COP*: Coeficiente de rendimiento; *PSU*: Unidad práctica de salinidad; $\dot{Q}_{EV}$: Calor en el evaporador $[W]$; $\dot{Q}_T$: Calor en el condensador $[W]$; $\dot{W}$: trabajo realizado por el sistema $[W]$.

Date Received: February 6th 2019 - *Fecha de recepción: Febrero 6 de 2019*
Date Accepted: March 10th 2019 - *Fecha de aceptación: Marzo 10 de 2019*

[1] Armada de Chile. Talcahuano, Región del Biobío, Chile. Email: ldiazh@dgtm.cl

Introduction

Water is a fundamental element for the human being: without water, there is not life. Currently, the world population has been increasing and in various parts of the world there has been water shortage, either due to long periods of drought, changes in climate, because the existing water is contaminated, among others. Of the total water in the world, around 97.5% is present in oceans and seas, and of the remaining 2.5%, 0.007% is available for human consumption. Due to the shortage of fresh water and the large amount of water available in oceans and seas, it is that, throughout history, technologies have been developed to obtain water for human consumption from salt water, emerging the concept of "desalination", for which, there are two main methods: one through the change of phase of the water, either by evaporation or freezing; and the other through the use of membranes, such as reverse osmosis or electrodialysis, on which various techniques have been developed for their execution. On the other hand, there is a technology widely used in air conditioning: the heat pump. A heat pump is a system that uses a refrigeration cycle to transfer heat energy from one place to another, generating a low temperature source and a high temperature source. From the above, the following problem arises: Is the technology of the heat pump applicable to water desalination processes?

The general objective of the present titration work is: "Conceptually design a desalination system for seawater using a heat pump".

The following specific objectives are:

1. Define the basic concepts related to the seawater desalination process.
2. Describe current systems of water production from seawater.
3. Describe basic concepts of a heat pump.
4. Describe generically a desalination process with a heat pump.
5. Determine parameters that will be considered in a water desalination process using a heat pump.
6. To theoretically calculate the technical capacities that the heat pump must have for different volumes that will be generated.
7. Identify the dimensions of the heat pump equipment.
8. Conceptually define the design of the heat pump according to the established parameters.

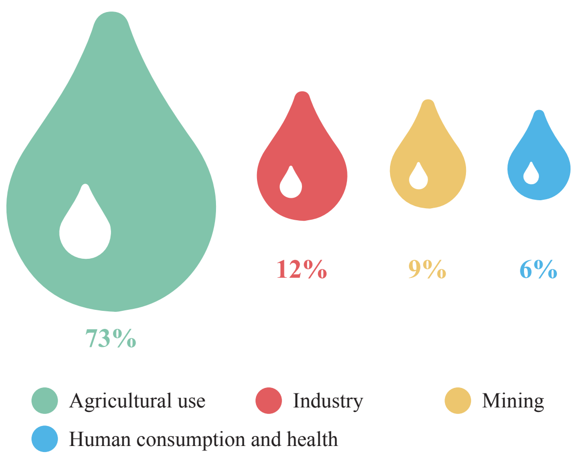
The methodology used for the present work of degree is applied research, developing in a first stage, about the conceptual foundations related to water and its characteristics; desalination; and concept of a heat pump. In the second stage, the methodological framework based on the lineal design model, which consists of five stages: identification of the idea, conceptual design, preliminary design, detailed design and final design, taking into account that, the present study is oriented finally to propose a "conceptual design". The conceptual design is defined as: "the set of tasks aimed at obtaining a solution to a problem raised from the specifications, requirements and needs" *(Alteaga, 2016)*, which involves the properties, attributes, functions, schemes and sketches of a product, in this particular case, of the conceptual design of a seawater desalination system using a heat pump.

The water and its characteristics

The first concept that must be defined is water, since it is not enough to say that it is a chemical element composed of two hydrogen atoms and one of oxygen, but that one must differentiate sea water, fresh water and drinking water. Seawater is one that has about 30 [psu] of salinity or more, that is 30 grams of salts per liter of water and is not suitable for human consumption, the average of the world salinity is 35 [psu], the Baltic Sea being the lowest salinity with a salinity of 3 to 8 [psu] and the largest one the Dead Sea with 265 [psu]. Fresh water is one that has 0.3 [psu] or less, which does not make it suitable for human consumption, since by definition it does not discriminate if it is cloudy water, with microorganisms, radioactive elements, etc. The water that is suitable for human consumption is potable water, a subdivision of fresh water that indicates that it meets the parameters of turbidity, chemical, microbiological and radioactive elements determined by each state, since the conditions must be contextualized by geographical areas. In Chile, the superintendence of sanitary services established the parameters of drinking water through the standard of water purification.

Water is a vital resource for living beings, either directly, through the consumption and daily use of the resource, or indirectly, through its use in the mining industry and agriculture, the Fig.1 shows the distribution of water use in Chile.

Fig. 1. Water use in Chile (Cáceres, 2016).



According to a study carried out by Aguas Andinas, a Chilean family of 5 people consumes an average of 30,000 [L] of water in a month, which refers to direct uses of water (see detail in Table 1), which is equivalent to a monthly consumption of approximately 6,000 [L] per person, that is 200 [L] per day.

Table 1. Water consumption of a family of 5 people in Chile (Aguas Andinas, 2017).

USE	WINTER [L]	SUMMER [L]
Shower	250	350
Toilet flushing	300	300
Preparation of meals and washing dishes	80	90
General washing	200	245
Water plants	5	165
Total per day	835	1.150
Total per person in one day	167	230
Total in a month	25.050	34.500

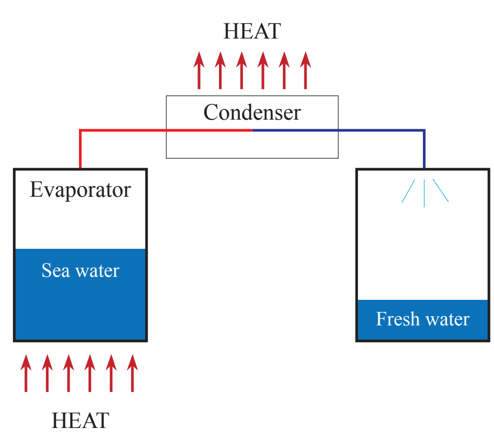
The World Health Organization (WHO) warns that, due to various factors such as climate change, demographic changes and the same advances in urbanization, by 2025 half of the world's population will live in areas with water shortages, what is really important is to look for alternatives to generate water for a sustainable future.

Desalination

The desalination of seawater is the action of separating water from its salts and for this there are different methods, the main ones being through the change of phase of the water, either by evaporation or freezing; or through membranes, such as electrodialysis or reverse osmosis. On board the units of the Chilean Navy, reverse osmosis and evaporation are mainly used, for the present study the concept of desalination by evaporation will be explained, since it will be used later for the development of the conceptual design.

A system of desalination by evaporation is composed of two main elements, an evaporator and a condenser (Fig. 2). In the evaporator the water changes from liquid phase to vapor, separating from the salts, for this it needs an external source of heat. Subsequently, the steam passes to the condenser where energy is extracted to achieve the change of phase from vapor to desalinated liquid. Currently, the most commonly used heat sources are boilers and heat reuse of engine exhaust gases.

Fig. 2. Evaporator (La desalinización, 2017).



Concept of a heat pump

A heat pump is a thermodynamic system whose function is to move heat energy from one environment to another and for that uses a refrigeration cycle, is composed of a condenser, an evaporator, a compressor and an expansion valve.

The thermodynamic cycle that occurs in a heat pump per compression cycle will be explained step by step through the case of a heat pump designed for the production of domestic hot water (Fig. 3), because the thermodynamically functioning is the same as in the heat pumps used in other applications.

In point (1) the refrigerant fluid is in a phase of mixing of liquid with a certain percentage of vapor and at low pressure, because it comes from the expansion valve, therefore its temperature is also low; in this state the refrigerant enters the evaporator, where it absorbs heat from the outside and changes its phase to saturated dry steam (2). In point (2) the refrigerant is found as saturated dry steam and thus enters the compressor, where it is compressed raising its pressure and therefore, its temperature (3), for this the compressor needs external energy which obtains it from an electrical or thermal source. From point (3) to (4) the refrigerant flows through the condenser, yielding energy to another contact fluid, which in the case of Fig. 3 corresponds to sanitary water. Finally, the coolant flows from point (4) to point (1) through the expansion valve, decreasing its pressure and temperature, remaining in the ideal condition to start the cycle again.

Methodological Framework

Once the theoretical concepts have been explained, the identification of the idea of the present study will be explained. A process is proposed that begins by separating the seawater from its salts through the evaporation of seawater, by means of the heat input it receives from the heat pump condenser. In other words, the heat transferred by the refrigerant will be used in the condensation process, in the change of the seawater phase from liquid to vapor, obtaining as products, desalinated water vapor and brine waste. To obtain desalinated water, the water vapor obtained from the condenser of the heat pump must be condensed. For this, an exchange of heat in the evaporator of the system is proposed between the coolant, which is at a low temperature, and the water vapor, which is at a high temperature. In other words, the refrigerant liquid will absorb the heat of the water vapor and will pass from the liquid to the gaseous phase, while, at the same

Fig. 3. Thermodynamic cycle of a heat pump (Calor y frío, 2015).

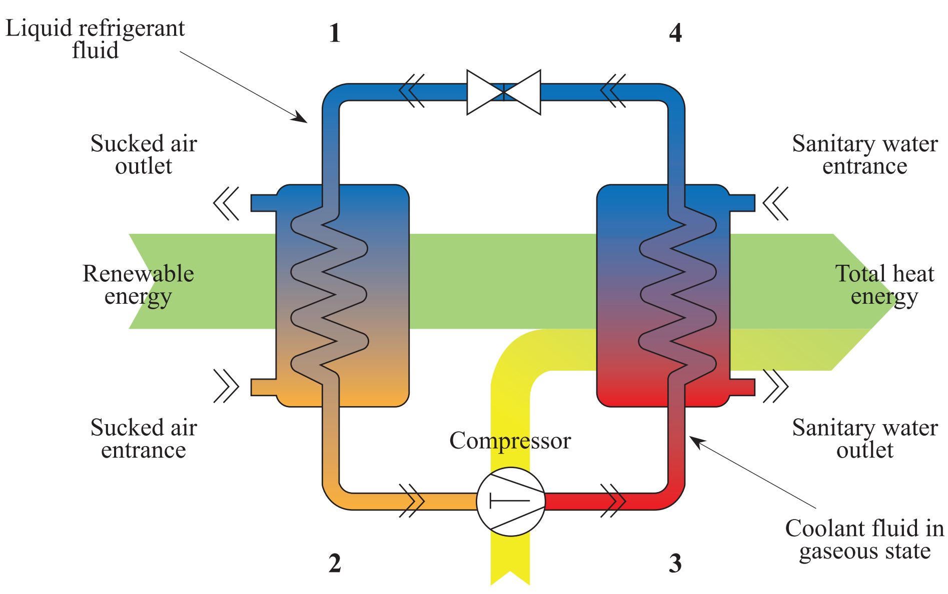
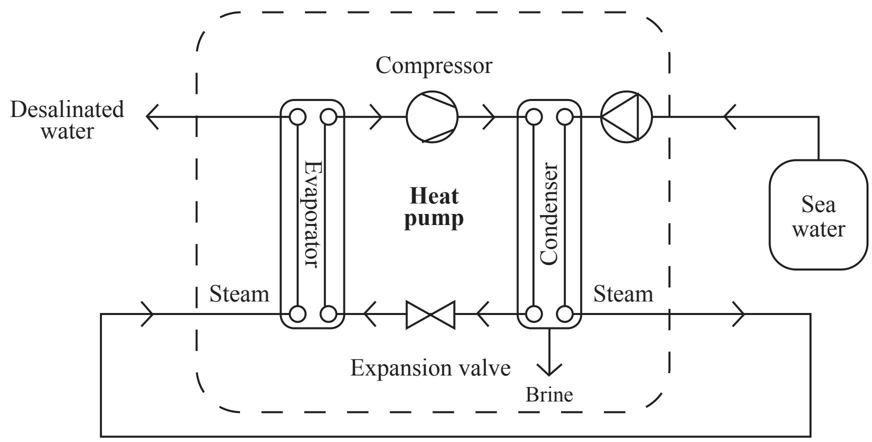


Fig. 4. Diagram of a seawater desalination heat pump (own elaboration).



time, the water vapor will condense, obtaining as final product: desalinated water (Fig. 4).

To determine that the proposal described in the previous paragraph is really viable, different parameters had to be established such as: the application area and the desalinated water flows for each case, the geographical delimitation of the study and, accordingly, to establish the parameters of the seawater; determine the most suitable refrigerant and calculate the capacity that each component of the heat pump must possess.

It was established that the application area of the desalination system would be oriented to the Chilean Navy, for it was thought of three fields of action that are seen or could be affected by the scarcity of water. First, a unit afloat, since eventually a vessel may have its autonomy restricted due to the lack of potable water on board. Second the Marine infantry, especially in its operations in desert areas and finally the lighthouses inhabited in the extreme zone. And finally, the lighthouses inhabited in the southern area.

Within the afloat Units, a Chilean frigate was chosen, which has reverse osmosis as a desalination system and has a maximum desalination capacity of 25 [m3] per day. Its endowment is 160 people and to satisfy the normal water requirements they need to desalinate 15 [m3] per day, for the present study they will be considered the latter conditions, which is equivalent to 625 [L] per hour.

For the Marine Corps, the Logistic Battalion, generally distributes the water requirements by Marine Companies, the Marine Company are composed of 132 people and are considered 23 [L] per person per day, which equals 126.5 [L] per hour.

In the case of inhabited lighthouses, the Maritime Signaling Service indicated that the lighthouses: Evangelical Islets, Fairway Islets, Felix Bay and Diego Ramirez Islands are currently facing water supply problems, as they are collected through rainwater, which together with the bad conditions of wind and sea, most of the time is salty and unfit for human consumption. The endowments of these four lighthouses on average is 5 people, as mentioned at the beginning, a person consumes approximately 200 [L] of water per day, which gives a total of a consumption of 1000 [L] per day per lighthouse, equivalent to 42 [L] per hour. Table 2 shows a summary of the flows that will be considered in the present study according to the area of application.

The geographical delimitation of the study was centered in Chile according to the northern, central and southern zones, and statistical studies were carried out to determine the representative data of the surface measurements of seawater delivered by the Hydrographic and Oceanographic Service of the Navy. Density, specific heat, salinity and temperature of the coast of Iquique, for the northern zone, an average between Valparaíso and Talcahuano, for the central zone and Punta

Table 2. Flows of desalinated water according to number of people (own elaboration).

		PEOPLE	VOLUME FLOW RATE	VOLUME FLOW RATE
Flow 1	Living lighthouse	5	1.000	42
Flow 2	Marine company	132	3.036	127
Flow 3	Frigate	160	15.000	625

Arenas for the southern zone. Table 3 indicates the results obtained.

For the refrigerant, hydrofluorocarbons or HFCs were studied, since they do not have chlorine in their composition, an element that directly affects the destruction of the ozone layer, within the HFCs those of classification A1 were chosen, this means that It is not flammable and has low toxicity, and among those selected, refrigerant gas 134a is the most suitable because it is regularly used in heat pumps and works at medium and high temperatures, that is to say at 0ºC.

Table 3. Parameters representative of sea water according to geographical area (own elaboration).

ZONE	PORTS	TEMPERATURE [ºC]	SPECIFIC HEAT CAPACITY	DENSITY [Kg/m^3]	SALINITY [PSU]
NORTH	Iquique	15,23	3,89	1025,09	34,86
CENTER	Valparaíso/Talcahuano	13,74	3,89	1025,53	33,97
SOUTH	Punta Arenas	8,58	3,9	1025,53	32,95

Finally, the calculation of the capacities for each component of the heat pump, that is, the heat transferred by the condenser, the heat absorbed by the evaporator and the power required by the compressor, through the procedure indicated below:

In the condenser of the heat pump, as its name indicates, the refrigerant will be condensed, but at the same time, the seawater will evaporate, with the objective of obtaining as product, steam, brine and condensed refrigerant liquid, but how much heat do you need to achieve it? The total heat is the sum of the sensible heat and the latent heat and it's equal to the sum of the heat of evaporation plus the power of the compressor (equation 1).

$$\dot{Q}_T = \dot{Q}_S + \dot{Q}_L = \dot{Q}_{Ev} + \dot{W} \quad (1)$$

$\dot{Q}_T$: Total heat *[W]*
$\dot{Q}_S$: Sensible heat *[W]*
$\dot{Q}_L$: Latent heat *[W]*
$\dot{Q}_{Ev}$: Evaporation heat *[W]*
$\dot{W}$: Compressor power *[W]*

To calculate the sensible and latent heat equations 2 and 3 were used.

$$\dot{Q}_S = \dot{m} * c\,(T_f - T_i) \quad (2)$$

$$\dot{Q}_L = \dot{m} * h_{fg} \quad (3)$$

m : Seawater mass flow *[Kg/s]*
c : Specific heat of seawater *[KJ/ºC*Kg]*
T_f : Final temperature of seawater *[ºC]*
T_i : Initial temperature of seawater *[ºC]*
h_{fg} : Difference of water saturation enthalpies *[J/Kg]*

The variables that have not yet been determined are: the seawater mass flow rate, the final evaporation temperature and the water saturation enthalpies difference, since the initial temperature and the specific heat of seawater are indicated in the Table 3. The mass flow of seawater will be calculated through equation (4), from the volumetric flow of desalinated water indicated in Table 2 and, depending on the geographical area, the densities and salinities determined in Table 3 will be used.

$$\dot{m} = \dot{q}_a * \frac{\rho}{1000} \quad (4)$$

$$\dot{q}_a = \frac{\dot{q}_f}{\left(1 - \frac{S_a}{\rho}\right)} \quad (5)$$

$\dot{q}_a$: Volumetric flow of seawater *[L/h]*
ρ : Seawater density *[Kg/m³] = [g/L]*
$\dot{q}_f$: Volumetric flow of desalinated water *[L/h]*
S_a : Salinity of seawater *[psu] = [g/L]*

To determine the evaporation temperature of seawater, it must first be indicated that it depends on the pressure of the circuit. The idea is to establish a boiling temperature of sea water less than that corresponding to atmospheric pressure, for this the circuit must be empty. For the present study to be adjusted to reality, the evaporation temperature was considered equal to that used in the on-board evaporators, that is 70 [° C] *(Salinas, 2015)*, corresponding to a pressure of 31,202 [kPa] *(Cengel, 2011)*.

With the mass flow rate and the established evaporation temperature, the h_fg equivalent to 2.333,0 [*kJ/kg*] *(Cengel, 2011)*, from the above you can calculate the sensible heat, the latent heat and therefore the total heat ($\dot{Q}_T$).

On the other hand, equation (6) was used to calculate the heat of evaporation.

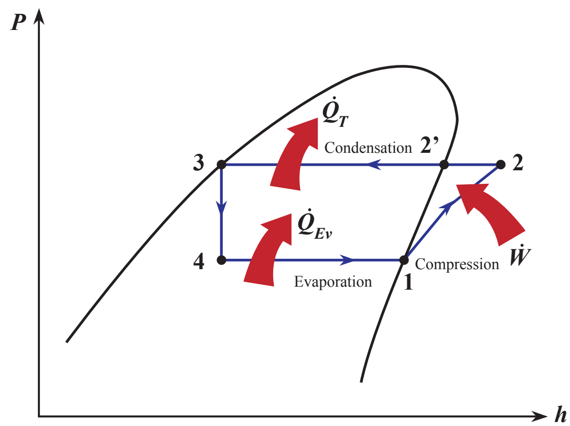
$$\dot{Q}_{Ev} = \dot{m}_{RF} * (h_1 - h_4) \quad (6)$$

$$\dot{m}_{RF} = \frac{\dot{Q}_T}{h_{2-3}} \quad (7)$$

m_{RF} : Mass flow coolant *[Kg/s]*
$h_{1,2,3,4}$: Enthalpy coolant according to Fig. 5. *[W]*

To set the value of h_{2-3} The temperature of the refrigerant must be determined upon entering the compressor. "A common value that is taken into account for the condenser is a temperature difference of 20 ° C" *(Silva, 2012)*, between the medium (sea water) and the refrigerant; that is, a temperature of 90 [°C] will be considered for the refrigerant, which corresponds to an enthalpy of 82.35[*kJ/kg*] *(Cengel, 2011)*.

Fig. 5. Pressure-enthalpy diagram of the refrigeration cycle (Cengel, 2011).



To determine h_4, it should be mentioned that the enthalpy in point (4) is equal to that of point (3) (Fig. 5), so you must enter the refrigerant table R-134a *(Cengel, 2011)* with the T_{rf}= 90 [°C] and verify the enthalpy of saturated liquid, which equals $h_3 = h_4$= 194,76[*kJ/kg*]. While to establish enthalpy h_1, first determine the temperature of desalinated water that you want to obtain as a product. "The water for the drink should not be cold or hot, in both cases it affects the muscles of the stomach and all the movement of the digestive system, the ideal temperature should oscillate between 10[°C] y 22[°C] " *(Costas, 2002)*. On the other hand, according to Silva (2012), in an evaporator, the difference of the temperature of the coolant with the medium (water vapor), is recommended 10[°C].

Therefore, for the present titration work, a temperature will be established for the desalinated water of T_{ad}= 20[°C], therefore, the coolant temperature will be 10[°C]. To get the enthalpy h_1, you must enter the refrigerant table R-134a *(Cengel, 2011)* with the T_{rf} = 10[°C]and verify the enthalpy of saturated dry steam, which equals h_1 = 256,16[*kJ/kg*]. The power of the compressor was established (equation (1)) and through this the size of the heat pump will be dimensioned and it will be determined, conceptually, if it is an effective system to desalinate seawater according to the conditions of the coast From Chile. In addition, the coefficient of performance (COP) was established through equation (8).

$$\dot{Q}_T = \dot{Q}_S + \dot{Q}_L = \dot{Q}_{Ev} + \dot{W} \quad (1)$$

$$COP = \frac{Q_T}{\dot{W}} \quad (8)$$

Table 4 shows the results obtained, which indicates that the power of the heat pump is not affected significantly by the differences in the parameters according to geographical area, therefore standardized characteristics were established according to Table 5. The COP of 3.93 indicates that the total energy that the refrigerant gives to the seawater in the condenser and almost four times the power required by the compressor, which implies efficiency greater than any other thermal machine.

As a technical proposal, real commercial-level components that complied with the proposed specifications were selected, with which the viability of the project will be indicated, but it will not be determined that the chosen component is the most appropriate.

In the case of the evaporator and the condenser, heat exchangers of the shell and tube type were investigated, for which the heat transfer area had to be calculated, with these data it was verified that there are shell heat exchangers and tubes that meet with the requirements, an example of this is the SSCF or EF model of the company Standard Xchange.

For the selection of a compressor that meets the specified specifications, the United Technologies Corporation (UTC) Spare Parts Catalog was chosen, Table 6 shows some of the compressors that meet the requirements necessary to be part of the desalination system using a heat pump, also

Table 4. Capacities per component of the heat pump.

CASES	ZONE	VOLUME FLOW RATE qf [L/h]	Q_T [KW]	Q_{EV} [KW]	W [KW]
Living lighthouse	NORTH	42	31,52	23,5	8,02
	CENTER		31,58	23,54	8,03
	SOUTH		31,8	23,71	8,09
Marine company	NORTH	127	95,31	71,07	24,25
	CENTER		95,48	71,19	24,29
	SOUTH		96,16	71,7	24,46
Fragata	NORTH	625	469,07	349,73	119,33
	CENTER		469,91	350,36	119,54
	SOUTH		473,23	352,84	120,39

Table 5. Standardized capacities per component of the heat pump.

CASES	VOLUME FLOW RATE [L/h]	Q_T [KW]	Q_{EV} [KW]	W [KW]	COP
Living lighthouse	42	32	24	10	3,93
Marine company	127	97	72	25	
Frigate	625	475	353	120	

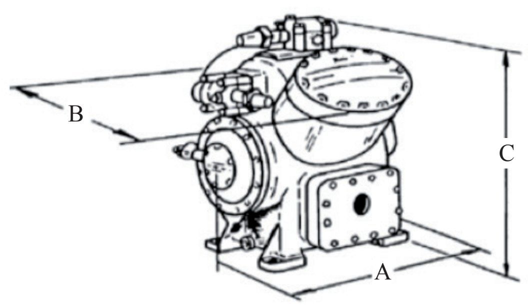
Table 6. Compressor selection according to catalog (own preparation).

CASES	VOLUME FLOW RATE qf	W [KW]	COMPRESSOR	DIMENSIONS* [cm]	WEIGHT [Kg]
Living lighthouse	42	11	Open Alternative Carlyle-Carrier model 5F40	A= 54,61 B= 48,26 C= 51,12	161
Marine company	127	29	Open Alternative Carlyle-Carrier 5H46	A= 77,47 B= 62,23 C= 73,66	277
Frigate	625	136,5	Rotary Screw Carlyle-Carrier model 06N	Not available	380

Information obtained from: Catálogo de repuestos (UTC). *Dimensions according Fig. 6.

indicating the dimensions and / or the weight in each case (Fig. 6).

Fig. 6. Open reciprocating compressor Carlyle-Carrier models 5F & 5H (United Technologies Corporation (UTC), 2017)



Conclusions

1. The variation of the parameters due to their geographic location does not significantly affect the power required by the heat pump to desalinate a certain water flow, so that the same conceptual design can be used throughout the coast of the country.

2. It is not possible to determine that the proposed conceptual design constitutes a more or less adequate system than the reverse osmosis plants or evaporators that exist on board the units of the Chilean Navy.

3. Theoretically it can be concluded that the desalination system using a heat pump is more efficient than another evaporation desalination system, because its coefficient of performance equal to 3.93 is greater than that of any other thermal system, since that these have an efficiency lower than one.

4. According to the parameters and requirements established for the proposed conceptual design, it is established that it is possible to use commercial compressors, condensers and evaporators as basic components of the heat pump.

5. 5. Finally, through the established conceptual design, it is concluded that the technology of the heat pump is applicable to a seawater desalination system, considering the conditions and properties that the sea has in the studied zones of Chile.

References

CÁCERES, Ó. (2016). *Reforma al Código de Aguas: los efectos del proyecto que limita los derechos de uso*. Retrieved from http://www.biobiochile.cl/noticias/nacional/chile/2016/11/22/reforma-al-codigo-de-aguas-los-efectos-del-proyecto-que-limita-los-derechos-de-uso.shtml

AGUAS ANDINAS. (2017). *Aguas Andinas*. Retrieved from https://www.aguasandinas.cl/la-empresa/que-hacemos/consumo

MARTIN, G. &. (2017). *What is diffusion?* Retrieved 5 3, 2017, from http://qcpages.qc.cuny.edu/~instr%5Cjgao104/diffusion.html

CENGEL, B. (2011). *Termodinámica*. New York, Estados Unidos: Mc Graw Hill.

CALOR Y FRÍO. (2015). *Funcionamiento de la bomba de calor para calefacción y agua caliente*. Retrieved 08 25, 2017, from https://www.caloryfrio.com/calefaccion/bomba-de-calor/bomba-de-calor.html

UNITED TECHNOLOGIES CORPORATION (UTC) . (2017). *Carrier*. Retrieved 09 22, 2017, from http://www.carrier.es/manuales/CATALOGO_UTC.pdf

ALTEAGA, J. A. (2016). *Diseño conceptual*. Retrieved Julio 31, 2017, from https://www.coursehero.com/file/17966444/Dise%C3%B1o-conceptual/

SILVA, G. G. (2012, 02 12). *Cero grados celsius*. Retrieved 09 20, 2017, from https://www.0grados.com/diferencia-de-temperatura-en-sistemas-de-refrigeracion-y-aire-acondicionado/

COSTAS, M. (2002). *H2O Agua*. Retrieved 09 20, 2017, from Asesoría Nutricional: http://asesorianutricional.com.ar/h2oagua.htm

SALINAS, R. (2015). *Análisis comparativo de plantas de osmosis inversa y evaporadores a bordo de la Escuadra*. Valparaíso, Chile.

Measurement and analysis of vibrations - Evaluation of the criteria of acceptance ISO Standard 10816-6

Medición y análisis de vibraciones – Evaluación del criterio de aceptación Norma ISO 10816-6.

DOI: https://doi.org/10.25043/19098642.196

Roger Arévalo Gómez [1]

Abstract

During the reception and / or delivery tests of a ship, vibration measurement and analysis is made to the propulsion line in order to evaluate and predict the condition of the machinery. The values taken during the measurement of the vibrations are evaluated with the acceptance criteria provided by the standards. International Standard ISO 10816-6 (1995) focuses on reciprocating machinery with power of greater than 100kW, is used by both analysts and manufacturers of propulsion machinery for ships. Through this work, we intend to evaluate the acceptance criteria of this norm in boats smaller than 100 meters. At the end of this work it is concluded that the standard must be updated, indicating and differentiating the acceptance criteria for machinery taking into account its type of anchorage to the structure (flexible or rigid), boats with length less than or greater than 100 meters and the Ship building material (Aluminum, Steel or Composite material).

Key words: Reciprocant, Vibration level.

Resumen

Durante las pruebas de recepción y/o entrega de un buque se realiza medición y análisis de vibración a la línea de propulsión con el fin evaluar y predecir la condición de la maquinaria. Los valores tomados durante la medición de las vibraciones son evaluados con los criterios de aceptación que entregan las normas. La norma Internacional ISO 10816-6 (1995) se enfoca en la maquinaria reciprocante con potencia de rateo mayor a 100kW, es utilizada tanto por analistas como por fabricantes de maquinaria propulsiva para buques. Por medio de este trabajo se pretende evaluar los criterios de aceptación de esta norma en embarcaciones menores a 100 metros. Al final de este trabajo se concluye que la norma debe ser actualizada, indicando y diferenciando los criterios de aceptación para maquinaria teniendo en cuenta su tipo de anclaje a la estructura (flexible o rígida), embarcaciones con eslora inferior o superior a 100 metros y el material de construcción del buque (Aluminio, Acero o Material compuesto).

Palabras claves: Reciprocante, nivel de vibración.

Date Received: January 17th 2019 - *Fecha de recepción: Enero 17 de 2019*
Date Accepted: March 3rd 2019 - *Fecha de aceptación: Marzo 3 de 2019*

[1] COTECMAR. Cartagena, Colombia. Email: rarevalo@cotecmar.com

Introduction

ISO 10816-6 "Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts - Part 6: Reciprocating machines with power ratings above 100 kW", specifies the conditions and general procedures for the measurement and evaluation of the linear vibrations, in measurements made on the non-rotating parts of reciprocating machines with powers greater than 100 kW.

Typical examples of application are marine propulsion engines, Diesel engine generator sets, gas compressors and diesel engines for locomotives. This standard does not apply to machines installed on road vehicles.

ISO 10816-6 in Annex A "Classification of vibration in machinery" indicates a qualification of reciprocating machinery. In said classification, the standard establishes that diesel and industrial marine engines can be classified either 5, 6 or 7.

Since 2013, COTECMAR has acquired the technological and human capacity to carry out with its own force the measurement and analysis of the linear vibrations of the ships belonging to the Colombian Republic Navy (ARC) and private customers.

In these more than four years the experience in the measurement and analysis of linear vibrations in the propulsion lines of ships has been strengthened, which includes an internal combustion engine, a power transmission box and revolutions to the transmission shaft and finally to the propeller.

In more than 63 ships served in this period (2013 to 2018) measurements and analysis of linear vibrations were made to diesel engines of ARC and private vessels, totaling approximately 150 services. At the beginning there were many inconveniences and complaints from the client because although the global vibrations did not reach the minimum level, level 5, required by ISO 10816-6 to consider an alarm in the diesel machinery, in reality, there were developments in the engines, which affected the credibility of the client.

Therefore, it was determined to reclassify the machinery at least to level 3 indicated by the standard. By doing this, we had a more accurate alarm of the novelties presented by the diesel machinery and determined through the measurement and analysis of linear vibrations.

Presentation of the problem

Before COTECMAR, had the ability to meet the service of measurement and analysis of vibrations lines with its own strength, this was executed by means of contractors, local companies specialized in measurement and analysis of vibrations, but who did not have the knowledge in the area ship, the behavior of the marine combustion machinery and the standards used by these companies were not adequate.

The ignorance in the behavior in marine diesel machinery and the lack of use of an adequate norm in multiple occasions caused complaints and complaints on the part of the final client due to a bad concept or conclusion on the part of the analyst.

By training personnel in the naval area, certifying it in vibration analysis under the guidelines of ISO 18436-2 in level II and acquiring equipment for the measurement and subsequent analysis of the linear vibration measurement, gave COTECMAR a better answer. customers, reducing the number of complaints and claims, which was seen in a significant increase in the number of services that went from 9 in 2014, 42 in 2015, 46 in 2016, 40 in 2017 and 46 services in 2018.

For the analysis of measured vibrations, the criteria of ISO 18816 and its six different parts are taken as acceptance criteria:

- Part 1: General guidelines.
- Part 2: Large steam turbine generator sets on land exceeding 50 MW.
- Part 3: Industrial machines with nominal power greater than 15 kW and rated speeds between 120 r / min and 15 000 r / min when measured in situ.
- Part 4: Sets powered by gas turbines, excluding aircraft derivatives

- Part 5: Sets of machines in hydraulic generating and pumping plants.
- Part 6: Reciprocal machines with nominal powers greater than 100 kW.

In order to evaluate the vibrations measured in the propulsion lines of the ships, ISO 10816-3[2] standards are adopted for gearboxes, support points and bearings and ISO 10816-6 [1] for the evaluation of propulsion engines.

The norm ISO 10816-3 [2] establishes criteria for the levels of the linear vibrations measured according to the power, revolutions per minute of rotation and type of support or anchoring of the equipment (flexible, rigid or semi-rigid).

The norm ISO 10816-6[1] classifies the vibration of the machinery in seven levels. The standard does not indicate how to classify the machinery that is being measured. It only indicates that as an example many industrial and marine Diesel engines are classified 5, 6 and 7. But it does not give more details. Manufacturers of marine engines such as Wartsilla and MTU give a rating of 5 to their engines.

Measured Data

Between 2013 and 2018, more than 150 diesel combustion engines from different manufacturers and models have been vibrated. The following is a summary of the brands and models of diesel combustion engines serviced.

Table 1. Summary of Brand and Model of Diesel Engines serviced.

BRAND - MODEL
MTU - 12V M70
MTU - 1163 TB93
CATERPILLAR - 3412
CATERPILLAR - 3056
CATERPILLAR - C18
DETROIT DIESEL - 6L 2T
DETROIT DIESEL - 6L 71T
DETROIT DIESEL - 16-645 E2
MAN B&W - 6L23/30A
CUMMINS

The values of the vibration measurements were taken in the diesel combustion engines according to ISO 10816-6 [1].

Fig. 1. Diesel engine in L.

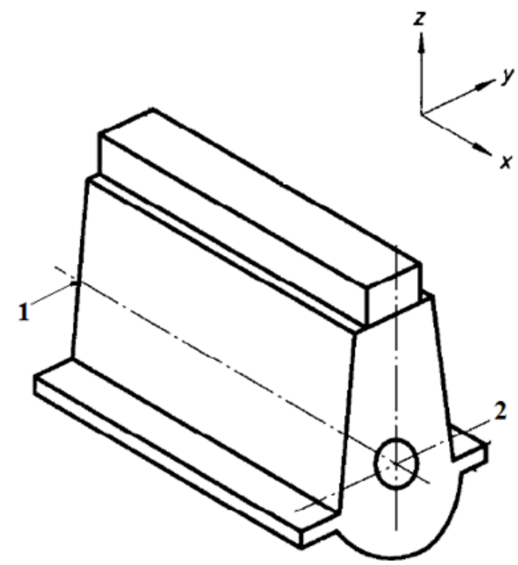
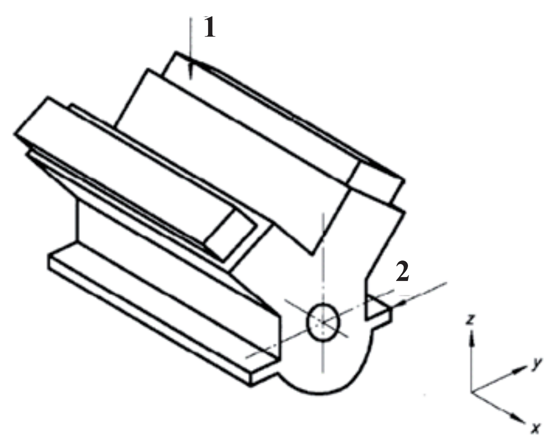


Fig. 2. Multi-cylinder Diesel engine in V.



Points 1 and 2 are called free side and side coupling respectively. At each point the measurement is made in the three directions Vertical (V), Horizontal (H) and Axial (A).

The data taken is compared with the classifications and acceptable levels given in ISO 10816-6 [1].

Fig. 3. Comparison of global vibration values with the acceptance criteria according to ISO 10816-6.

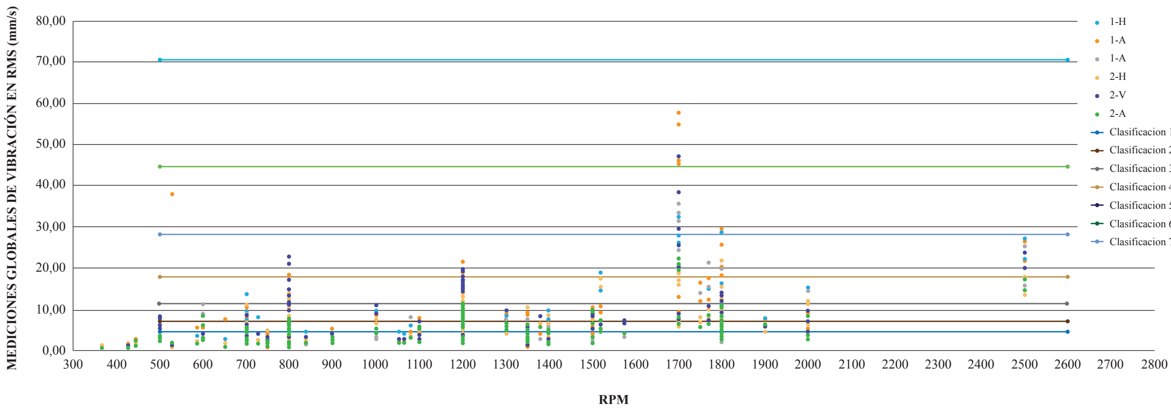
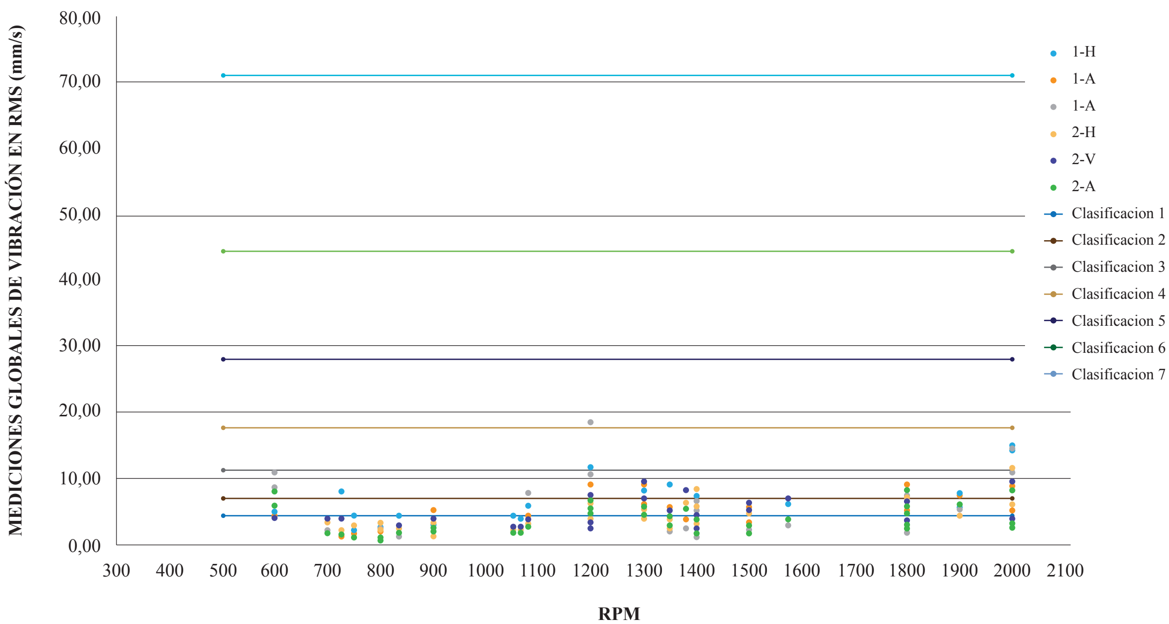


Fig. 4. Comparison - Values Of Global Vibration Vs Classification Levels - Motors Without Failure.



For the analysis, 23 vessels were taken into account, each of which possesses two propulsion lines, so in total 46 engines were examined. As shown in illustration 6, of the 48% of the ships to which the global vibration measurements were taken, their engines present failure even with vibration magnitudes below the classification 5 indicated in ISO 10816-6 [1]. These failures are related to sources other than poor installation or misalignments of engine parts, such as high levels of cooling water temperature or low oil pressure, associated with a lack of maintenance.

If marine diesel engines continue to be evaluated under ISO 10816-6[1] in the considerations that this indicates, failures could arise due to an erroneous decision, for example a propulsion engine could be presented with vibration levels

Fig. 5. Comparison - Global Vibration Values Vs Classification Levels - Faulty Engines.

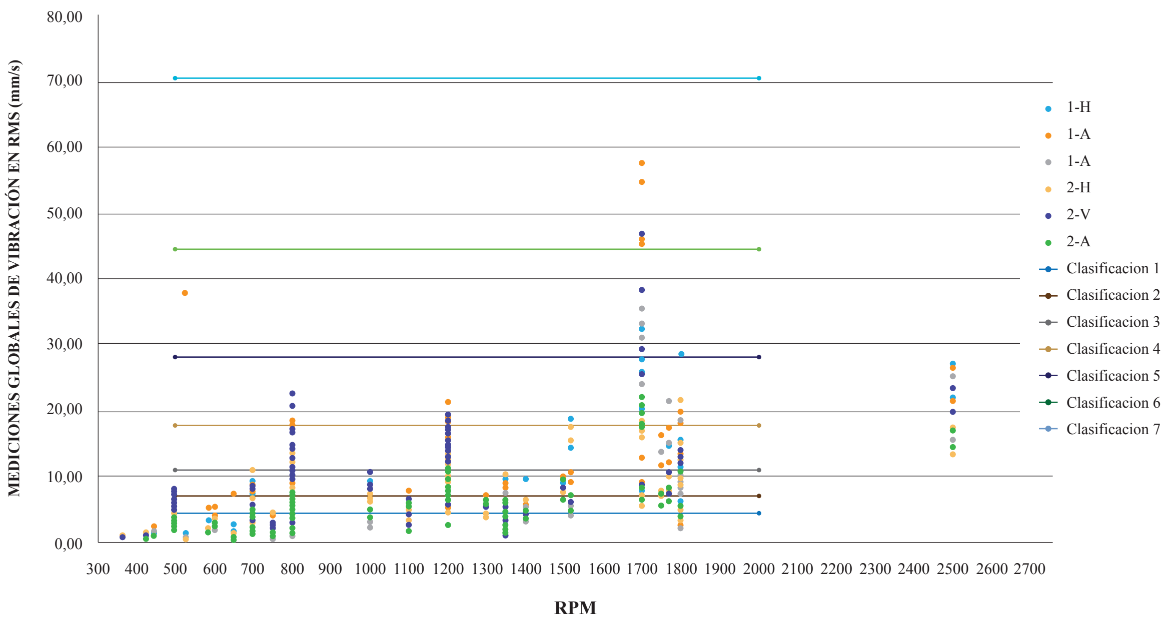
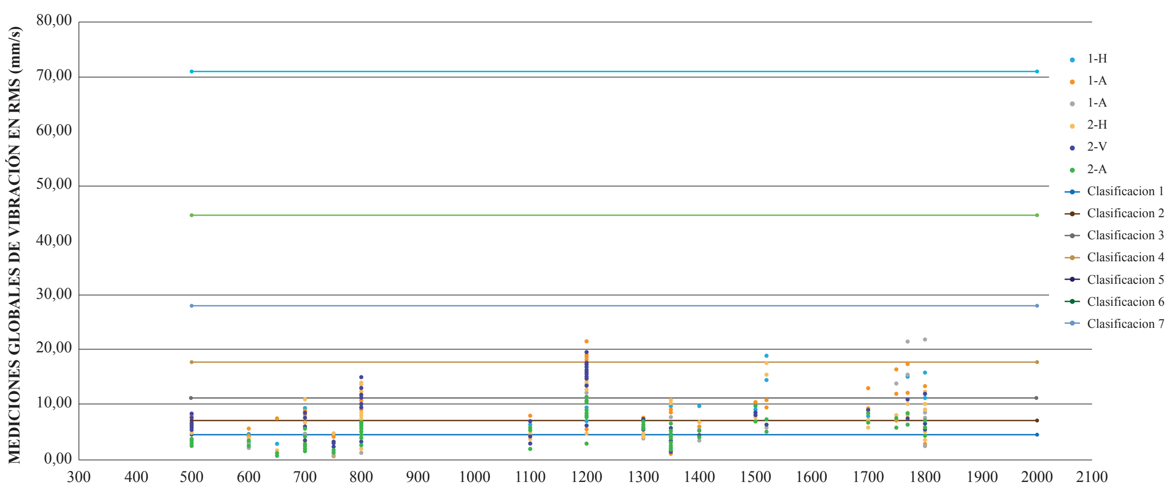


Fig. 6. Comparison - Global Vibration Values Vs Classification Levels - Faulty Engines with Values below the Qualification 5.



above the classification 4 that was affecting the structural integrity of the vessel. Or have a diesel combustion engine whose levels of vibration were above classification 5 but that did not present problems of mechanics, simply the base where it is supported is flexible and the material of the vessel is made of aluminum or composite material.

Conclusion

There are engine failures, even if these have global vibration levels below the minimum classification suggested by ISO 10816-6[1], so the classification indicated by ISO 10816-6[1] should be modified, the standard should have the ability to indicate, as is the norm ISO 10816-3[2], the levels of acceptance according to their power, the type of anchoring of the engines, whether rigid or flexible and also the construction material of the vessel.

The way of obtaining the accepted levels of vibration for marine diesel engines could be in two ways:

- Establish a list of the linear vibration levels in Diesel internal combustion engines installed in new vessels, tabulating power, number of banks (1 or 2), propulsion line numbers, type of anchoring of the bases (Flexible, Rigid or Semi-rigid)) and material of the vessel (Steel, Aluminum or Composite Materials) and create a tendency to depart from said primary values by handling a first alarm (Caution) of 25% of the initial value.

- Set up a list of linear vibration levels in diesel internal combustion engines after maintenance tabulating power, number of benches (1 or 2), propulsion line numbers, type of anchoring of the bases (Flexible, Rigid or Semi-rigid) and material of the vessel (Steel, Aluminum or Composite Materials) and register the vibration values when the operating parameters (Temperature, Pressure) exceed the alarm value. This is because for the vibration levels to be considered high or harmful, it is because the machinery is suffering some affectation reflected in its temperature and operating pressure of Oil, Fuel, Cooling Water.

With these values of vibration lines would be created more real acceptance levels and would help to make a more assertive diagnosis to diesel propulsion engines.

References

1. ISO. (15 de Diciembre de 1995). ISO 10816-6. Mechanical vibration -- Evaluation of machine vibration by measurements on non-rotating parts -- Part 6: Reciprocating machines with power ratings above 100 Kw.
2. ISO. (15 de Mayo de 1998). ISO 10816-3. Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ.

Statistic Model for the Estimation of the Resistance of Landing Craft Hulls

Modelo estadístico para la estimación de resistencia al avance de barcazas.

DOI: https://doi.org/10.25043/19098642.197

Cristian P. Vargas M. [1]
Gonzalo Tampier B. [2]
Marcos Salas I. [3]
Cristian Cifuentes S. [4]

Abstract

One of the most important challenges in the development of the preliminary project of a ship is the estimation of propulsive power. This calculation can become a challenge for landing craft projects, since no specific estimation method for these ships is available, considering their special form characteristics. Using a systematized test database carried out in the ship model ba-sin of Universidad Austral de Chile, a statistical model was generated through a multiple linear regression process to obtain an expression that serves to estimate the resistance for landing craft in preliminary stages of the project. Finally, the results of the regressions were compared with field measurements of 3 vessels in operation, showing a good agreement.

Key words: Landing craft, Ship resistance, Multiple linear regression.

Resumen

Siendo la resistencia al avance de una embarcación uno de los puntos principales a determinar en el proyecto, no se conoce una metodología específica para este especial tipo de buques. Utilizando una base de datos sistematizada de ensayos de barcazas efectuados en el Canal de Ensayos Hidrodinámicos de la Universidad Austral de Chile, los cuales fueron sometidos a una correlación modelo – buque siguiendo las recomendaciones de la ITTC-78, con algunos cambios; y mediante la utilización de modelos estadísticos basados en regresión lineal múltiple se obtuvieron 2 formulas, las que fueron comparadas con mediciones a bordo de 3 barcazas operativas.

Palabras claves: Barcazas, Resistencia al Avance, Regresión Lineal Múltiple.

Date Received: January 25th 2019 - *Fecha de recepción: Enero 25 de 2019*
Date Accepted: February 28th 2019 - *Fecha de aceptación: Febrero 28 de 2019*

[1] Astilleros ACN. Valdivia, Chile. Email: cristianpvargasm@gmail.com
[2] Universidad Austral de Chile. Valdivia, Chile. Email: gonzalo.tampier@uach.cl
[3] Universidad Austral de Chile. Valdivia, Chile. Email: msalas@uach.cl
[4] Universidad Austral de Chile. Valdivia, Chile. Email: cristiancifuentes@uach.cl

Introduction

The estimation of ship resistance in early project stages is of great importance, allowing the designer to evaluate hull shape, and estimate the propulsive power required. In the case of landing craft and barge-shaped forms, this initial estimate is difficult, due to the limited information and methods available to be used.

The present work seeks to develop a statistical method to estimate the total resistance landing craft, using an estimation method prepared with information obtained from 520 model tests, which took place at the Hydrodynamic Test Facility (Canal de Ensayos Hidrodinámicos) of Universidad Austral de Chile (CEH-UACh). The proposed estimation method systematizes these data and processes them. Once the data is processed, multiple linear regressions were carried out, comparing these results with field measurements of barges in operation. These comparisons confirm the proposed formula for the estimation of ship resistance in calm waters for similarly shaped ships in preliminary design stages of vessels of this type.

Landing Craft use for commercial applications

Landing craft are usually small and medium vessels used for both military and civilian use. Their main characteristic is their ability to land on beaches using a lowerable ramp in their bow. First accounts of landing craft in Chile were given during the landing in Pisagua (1879), where flat-bottomed landing craft called "chalanas" were built to transport troops to the shore. During World War I, motorized landing craft with a ramp at the bow "X-lighters", were used for the mobilization of troops. Besides military use, landing craft have found different applications in regions with limited port infrastructure, limited water depth and/or the need of a large deck area. In Chile, landing craft vessels are widely used today for transportation of goods and support of aquaculture activities in the sheltered waters of the southern regions. These vessels provide large stability, large deck area, low draft and can land on beaches or ramps, providing ease of operation, despite their less optimal hydrodynamic performance. In Fig. 1, an example of a typical commercial landing craft is shown. As of today, around 300 landing craft vessels operate only for the aquaculture industry in Chile, being the most used vessel type in the aquaculture industry.

Database consolidation and data processing

The experimental data used for the preparation of the database came entirely from landing craft tank tests from the Hydrodynamic Test Tank

Fig. 1. Civilian landing craft for aquaculture support activities

Table 1. Descriptive statistics of the landing craft database (dimensional data).

Description	L_{WL} (m)	B_{WL} (m)	T (m)	C_B	S (m²)	Δ(t)	∇(m³)	V_S (m/s)
Minimum	14,080	2,400	0,260	0,472	46,000	15,990	15,600	0,000
Maximum	20,000	12,000	1,900	0,840	322,400	322,834	314,960	7,155
1st Quartile	16,150	4,000	0,700	0,737	84,840	39,379	38,419	2,236
Median	17,000	5,000	1,060	0,771	107,600	66,152	64,538	3,578
3rd Quartile	18,720	5,000	1,360	0,805	129,280	93,683	91,398	4,472
Mean	17,302	5,603	1,055	0,748	128,117	79,053	77,125	3,304
Variance (n-1)	3,081	10,032	0,162	0,008	4878,577	4170,302	3969,354	2,971
Typical deviation (n-1)	1,755	3,167	0,403	0,087	69,847	64,578	63,003	1,724

from Universidad Austral de Chile (CEH-UACh), carried out between 1990 and 2016. Part of these tests correspond to early systematic series [1] [2], [3]. Another part came from tests for landing craft projects built by Chilean shipyards. 520 tests were used , which were consolidated in a database. The descriptive statistics of the database are shown in Table 1 (full scale dimensions) and in Table 2 (nondimensional coefficients).

Modeling and regression process

A multiple linear regression model was used, due to the presence of more than one independent variable. Since most parameters are linear within the scope of this work, a linear regression was considered adequate at this stage. To solve the regression model, the method of ordinary least squares or linear least squares was used. To work with this method, it must be verified that the database does not present multicollinearity or autocorrelation. Additionally, independent variables must be exogenous to the dependent variables [4].

A total of 8 regressions were performed. By changing independent variables and delimiting the database to different parameters, different expressions were obtained to compare and select. From an error analysis and considering the

Table 2. Descriptive statistics of the landing craft database (non-dimensional data).

Description	F_N	R_N	C_{TM}	C_{FM} (ITTC-57)	CR
Minimum	0,000	0,000	0,000	0,000	0,000
Maximum	0,556	1,397E6	4,846E-02	7,504E-03	4,278E-02
1st Quartile	0,171	0,371E6	1,324E-02	4,751E-03	7,654E-03
Median	0,260	0,571E6	1,607E-02	5,154E-03	1,070E-02
3rd Quartile	0,351	0,780E6	2,061E-02	5,648E-03	1,556E-02
Mean	0,254	0,570E6	1,642E-02	4,790E-03	1,163E-02
Variance (n-1)	0,017	9,982E10	6,39E-05	2,988E-06	5,03E-05
Typical deviation (n-1)	0,131	0,316E6	7,994E-03	1,729E-03	7,097E-03

Table 3. Multiple linear regressions for CR estimation.

	DATASET	N° OBS.	INDEPENDENT VARIABLES
1	Full database	520	F_N, $L/\nabla^{1/3}$, C_B, L_{WL} / B, L_{WL} / T, B / T
2	Full database	520	F_N, C_B, L_{WL} / B, L_{WL} / T, B / T
3	$0.22 \le F_N \le 0.4$	247	F_N, $L/\nabla^{1/3}$, C_B, L_{WL} / B, L_{WL} / T, B / T
4	$0.22 \le F_N \le 0.4$	247	F_N, C_B, L_{WL} / B, L_{WL} / T, B / T
5	$0.22 \le F_N \le 0.4$ and $L/\nabla^{1/3} < 6$	226	F_N, C_B, L_{WL} / B, L_{WL} / T, B / T
6	$0.22 \le F_N \le 0.4$ and $L/\nabla^{1/3} < 6$	226	F_N, $L/\nabla^{1/3}$, C_B, L_{WL} / B, L_{WL} / T, B / T
7	$0.22 \le F_N \le 0.4$ and $L/\nabla^{1/3} < 6$	226	F_N^2, $L/\nabla^{1/3}$, C_B, L_{WL} / B, L_{WL} / T, B / T
8	$0.22 \le F_N \le 0.4$ and $L/\nabla^{1/3} < 6$	226	F_N^2, $L/\nabla^{1/3}$, C_B, C_M, L_{WL} / B, L_{WL} / T, B / T

limitations of certain data, a subset limiting the Froude number $0.22 \le F_N \le 0.4$ and the slenderness coefficient L/∇^(1/3) < 6 was preferred, considering 7 independent variables, as shown in dataset 8 (last row) of Table 3.

The recommended minimum and maximum values of the independent variables for the selected dataset are given in Table 4. The obtained formula for the estimation of the residual resistance coefficient is given in section 5.

Resistance prediction

For the present investigation, Froude's method is used for the total resistance coefficient estimation using the following workflow.

Table 4. Recommended limits for the independent variables.

	Variable	Min.	Max
1	F_N	0,22	0,40
2	$L/\nabla^{1/3}$	3	6
3	C_B	0,5	0,8
4	C_M	0,6	1
5	L_{WL} / B	3	7
6	L_{WL} / T	12	30
8	B / T	1,5	10

a) Residual resistance coefficient estimated according to the expression:

$$C_R = 0{,}060119 - 0{,}054478\, C_B + 0{,}026896\, C_M - 0{,}017670\, L/\nabla^{1/3} + 0{,}004886\, L_{WL}/B + 0{,}001687\, L_{WL}/T - 0{,}0016367\, B/T + 0{,}101304\, F_N^2 \quad (1)$$

b) Friction correlation line according to ITTC-57:

$$C_F = \frac{0{,}075}{(\log(R_N) - 2)^2} \quad (2)$$

c) Wind resistance according to the expression:

$$C_{AA} = 0{,}001\, A_T/S \quad (3)$$

d) Correlation allowance [5]

$$C_A = 0{,}105\left(k_S/L\right)^{1/3} - 0{,}00064 \quad (4)$$

e) Total resistance coefficient is then defined:

$$C_T = C_R + C_F + C_{AA} + C_A \quad (5)$$

Appendages, added resistance in waves, and other effects can be added if required.

Determination of model effectiveness

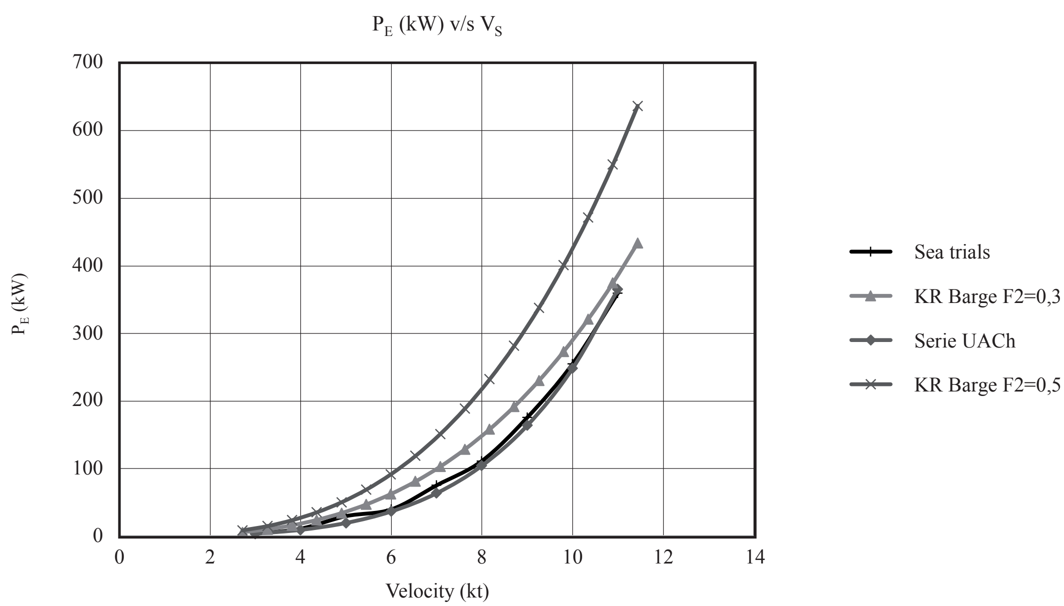
To verify the effectiveness of the obtained model, results were compared with data from real vessels in which power versus speed measurements were available. Additionally, results were compared with results from an estimation for barges proposed by KR [6]. Although the KR method is proposed as an estimation for the towing force needed for unpropelled barges, it is widely used today by naval architects in early design stages for landing craft, mainly due to the lack of more adequate methods. Data from 3 vessels of similar characteristics as those contained in the database were used (see Table 5).

In Fig. 2, results for the selected model are compared with data from sea trials for one of the analyzed vessels (Isla Picton). Additionally, resistance results from the KR method are shown using two bow shape factors (F2 = 0,3 and 0,5). These shape factors represent the limits for landing craft shaped bows according to the KR method. From results, a good agreement can be seen for the presented method, although more validation is necessary.

Table 5. Characteristics of landing craft used for model verification.

	ISLA LENNOX	ISLA PICTON	ISLA MAILLEN
L_{WL}	18,172 m	20,586 m	21,010 m
B_{WL}	6,47 m	6,22 m	6,652 m
T	1,05 m	1,03 m	1,01 m
∇	105,4 m^3	109,7 m^3	123,55 m^3
C_B	0,689	0,659	0,68
L_{Wl} / B_{Wl}	2,808	3,3	3,16
L_{Wl} / T	17,3	19,98	20,8
B_{Wl} / T	6,1619	6,039	6,58
$L_{WL} / \nabla^{1/3}$	3,85	4,3	4,22
P_B	240 HP x 2	240 HP x 2	360 HP x 2

Fig. 2. PE v/s VS, from sea trials and proposed method for "Isla Picton" landing craft. Simi-lar results were obtained for the remaining ships.



Conclusions

Although there are numerous methods to empirically obtain the total resistance of a ship, none of them incorporates landing craft vessels. The presented methodology can still be improved by considering more form parameters (*e.g.* bow and stern shape), data reanalysis, and a deeper validation process. Nevertheless, results can be considered as encouraging and, within the limitations of the considered form parameters, useful in early stages of design. It is important to emphasize that results should be interpreted with care and should not replace experiments or numerical simulations at later stages of design.

References

[1] C. FONFACH, *"Resistencia al avance en barcazas con diferentes secciones transversales"*, Universidad Austral de Chile, 1991.

[2] J. GONZÁLEZ, *"Influencia en la Resistencia al avance de algunas formas de proa en una barcaza"*, Universidad Austral de Chile, 1990.

[3] J. MIÑO, "Serie sistemática de gabarras I.," Universidad Austral de Chile, 1993.

[4] C. P. VARGAS MUÑOZ, *"Estimación de Resistencia al Avance de Barcazas en las Etapas preliminares del Diseño utilizando un Modelo Estadístico Basado en Series Sistemáticas"*, Universidad Austral de Chile, 2018.

[5] B. S. BOWDEN AND DAVISON N.J., *"Resistance Increments Due to Hull Roughness Associated with Form Factor Extrapolation Methods"*, 1974.

[6] K. KOREAN REGISTER, *"Rules for the Towing Survey of Barges and Tugboats"*, 2014.

Maintenance costs estimation for a mid-tier Shipyard

Estimación de costos de mantenimiento para un astillero de nivel medio

DOI: https://doi.org/10.25043/19098642.198

Miguel Calvache Ramírez [1]
Andrés Eloy García Barón [2]

Abstract

This document presents a detailed shipyard maintenance cost analysis. The first step was to gather information on some industries maintenance studies, to estimate the adequate maintenance budget for a medium size shipyard. A methodology to calculate the approximate maintenance budget is proposed, through a benchmarking of recommended maintenance costs.

Key words: Shipyard, maintenance cost, maintenance, costs methodology.

Resumen

Este documento presenta un análisis detallado de los costos de mantenimiento del astillero. El primer paso fue reunir información sobre los estudios de mantenimiento de algunas industrias, para estimar el presupuesto de mantenimiento adecuado para un astillero de tamaño mediano. Se propone una metodología para calcular el presupuesto de mantenimiento aproximado, a través de una evaluación comparativa de los costos de mantenimiento recomendados.

Palabras claves: Astillero, costo de mantenimiento, mantenimiento, metodología de costos.

Date Received: December 1st 2019 - *Fecha de recepción: Diciembre 1 de 2019*
Date Accepted: January 30th 2020 - *Fecha de aceptación: Enero 30 de 2020*

[1] COTECMAR. Cartagena, Colombia. Email: mcalvache@cotecmar.com
[2] COTECMAR. Cartagena, Colombia. Email: eloygarcia08@hotmail.com

Objective

Estimate the annual cost of the medium shipyard building plant maintenance, as a rule of thumb, with few information available in order to get an approximate and preliminary value.

Introduction

In Colombia, industries have a great challenge to estimate maintenance costs and its effectiveness. Although, there's different authors that propose different methods to calculate maintenance budget, it is not known which should be the ideal or adequate quantity to obtain the greatest Return On Assets (ROA) whit the lower maintenance cost, in a general manner. What does exist is historical data series that put in evidence the evolution of maintenance since its beginning until present [1].

Currently, many companies in developing countries tend to invest great amounts in technological advancement, innovation, plant staff training and process improvement. Nevertheless, inside this organization chart it is common to find that these companies exclude very relevant areas to maintain the company, as it is maintenance itself [2].

Despite global advancement over maintenance, as the instrumentation technology implementation, the automation software development and the strict maintenance plans creation, in Colombia only a few companies invest the right amount on it. According to Patiño [3] one of the greatest limitations is that companies do not have access to maintenance information systems in general and there is not an specific organization chart that could be suited to any company. In the same way it concludes that for this reason each company seems to be forced to create its own department, which will be in charge to bring technical support to the plant.

Another aspect that limits the maintenance management is the corporative assets control, which is the biggest obstacle that Colombian companies face. The result of a survey made by ACIEM[1] to 410 companies in Colombia, shows that 64% of these industries manages the maintenance information manually or through a third party, making this task more strenuous and inefficient in decision making [2].

There is 3 principal maintenance kinds [4]: corrective, preventive and predictive, also evolved as RCM (reliability-centered maintenance). Among those, our country focuses in a single one: Corrective maintenance, or “reactive” [3]. This maintenance is performed when affected equipment gets repaired and bring it to its normal operation state. This methodology results more expensive at the end, if we count the consequences of equipment stops and the repair itself.

Preventive maintenance is performed before the failure occurs. Programmed stops are performed according to a maintenance plan previously assigned for the equipment. Worn parts get replaced, lubrication and inspection, among other practices to avoid big corrective maintenance costs is performed.

Luisa Patiño [3, p. 29] affirms that the metalworking industry is implementing new technologies and machines that in most cases are expensive. This has been confirmed in the last industry fairs [5]. This state of the art machinery is being acquired by shipyards, for that reason preventive maintenance is necessary to protect this costly equipment.

Predictive maintenance: for this, exhaustive equipment monitoring is performed to know the current status and in this way draft a timely maintenance plan. The RCM integrates Preventive Maintenance (PM), PredictiveTesting and Inspection (PT&I), Repair (also called reactive maintenance), and Proactive Maintenance to increase the probability that a machine or component will function in the required manner over its design life-cycle with a minimum amount of maintenance and downtime [6]. Although is and old concept of the 80’s, still its apllication is made mainly by the aeronautical, spacecraft, nuclear indusries and the DoD. The problem of this kind of maintenance is

[1] ACIEM: Asociación Colombiana de ingenieros.

that trained personnel and specialized tools that are required, which increases the initial cost. For this reason, predictive maintenance is still scarce in the Colombian industries.

Approximate Maintenance Annual Budget in Colombian Companies

According to ACIEM report [2, p. 41] concludes:

1. Colombian companies expend 22.5% of their annual budget in their plant maintenance, which gets close to the best maintenance practices where companies invest 20%.
2. In average, the Colombian industries invest 12% of the value of their assets; In particular, this percentage is different for each company according to its size:
   - Micro company 13%.
   - Small and medium company 8%.
   - Big company 11%.

How maintenance cost is estimated?

Based on the methodology proposed by Juan Díaz Navarro in his book *"Técnicas del Mantenimiento Industrial"* [7] the next costs structure arises:

1. "... each kind of company will require an adequate maintenance service to their production, but not separated from it on any case..." [8]. Quoting the previous sentence, the maintenance activity is started agreeing with the production department, certain strategic parameters to not lose time in unsuccessful debates. Such parameters are:

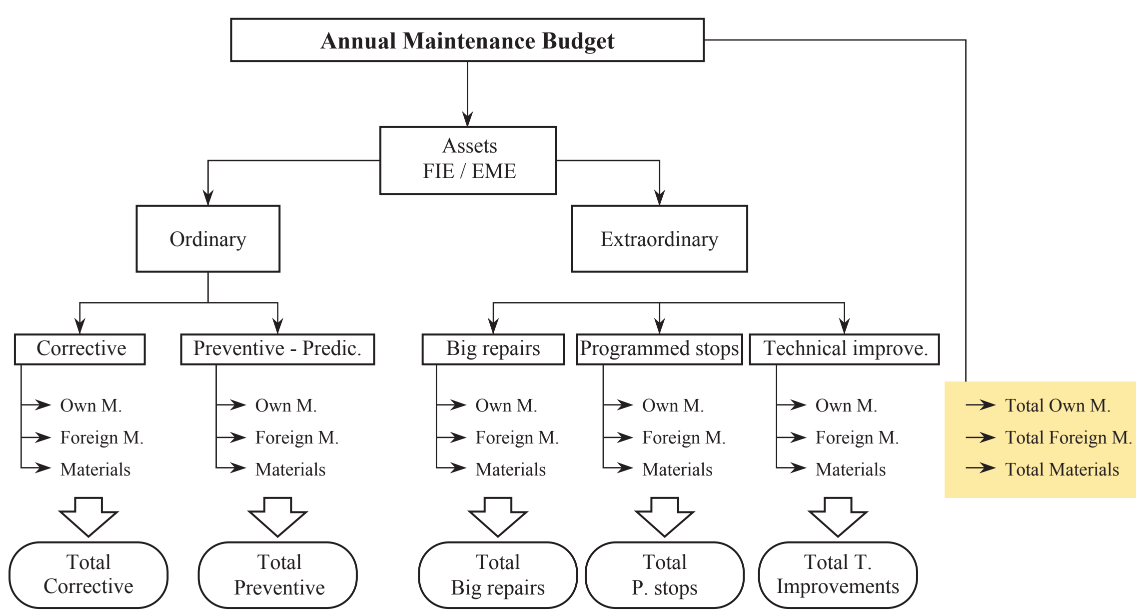
- What is expected from the maintenance service?
- What way is needed to perform such maintenance labours?
- How performance will be measured?
- How will maintenance activities be controlled and followed in the plant?
- What is the annual production program in the plant.

2. The assets will be classified in the next category groups:

FIE: Fixed and Infrastructure Equipment (Pipes, Superstructure, tanks).
EME: Electrical and Mechanical Equipment (welding machines, polishers, combustion engines).

Then proceed to find the maintenance budget following the next structure:

Fig. 1. Maintenance Cost Organization Chart. Source: [7, p. 51]. Edited by the author.



The own maintenance cost can be found as follows:

Maintenance staff hours multiplied by its own cost. The maintenance hour in each specialty is conformed by:

- Operating work force (salaries plus social tax charges).
- Maintenance supervisor and management or intermediary personnel.
- Another maintenance expenses:
- Water, steam, power.
- Training, management.
- Maintenance installations and workshops (this is omitted if is worked inside the same plant to simplify the operation).
- Non distributed materials, job specific.
- Tools.
- Measurement instruments.
- Supplies and minor materials.

The maintenance cost per hour in Colombian pesos (COP/h) is made adding these 4 costs and dividing them by the maintenance performed hours.

According to Diaz. J [7], the previously proposed belong to the maintenance direct costs; nevertheless, could be far from its real cost. To improve this calculation, maintenance indirect costs must be included, that could at the end be higher than the direct costs if they are not checked and controlled in detail. These indirect costs are related to:

- Production cost loss by equipment stop.
- Penalties on delivery delays.
- Extra hours due to low equipment productivity.
- Negative effects on personnel and environmental safety.
- External equipment rentals due to own equipment failures.

On this idea, the total maintenance cost is given by the direct plus indirect maintenance costs, this is known as the integral cost.

On the other hand, we must keep in mind that is not always recommended to make maintenance to an equipment. In some cases, this is not profitable, and it has to be with the machine's life cycle. On this same way, Diaz proposes that the life cycle cost is given by:

$$C = A + F + M + r \tag{1}$$

Where
A is the purchasing cost.
F is the working cost (raw materials, energy, etc.)
M is the maintenance cost.
r is the residual value (if it has any).

Being I the generated income by the equipment, the profit is given by:

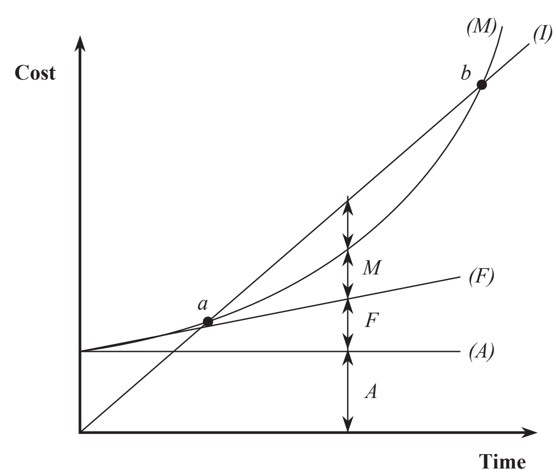
$$R = I - C$$

$$R = I - C\,(A + F + M + r) \tag{2}$$

If $R < 0$ it means that the equipment is generating losses to the company.
If $R > 0$ it means that the equipment is generating profits to the company.

Ignoring the value of r, the prior equation can be represented in the next graph:

Fig. 2. Maintenance Effectiveness.



Source: (Navarro,2007).

Where R is positive between a and b.

Before to reach the investment return point (a), the operation is non profitable because the spending is larger than the income, due to the purchasing cost.

From (*b*) the same problem shows, given that the maintenance costs exponentially increase, because most of the parts will be very worn or it will have an old technology.

Finally, to find an equipment failure periodicity, a yearly average for each kind of failure is estimated and the time of the year in which the failure happens.

All these variables used to find the maintenance cost, could vary so much that makes this estimation a real challenge. As Komonen [9] mentioned, the maintenance cost can vary from 0.5% to 25% in a study made on companies in Finland. Nevertheless, in the Spanish companies that uncertainty has being reduced and is evident the improvement in the maintenance practices, that bring as a result the decrease in associated costs over the years [10]. This improvement tendency on Spanish companies is shown in Fig. 3.

In that same way, the distribution of maintenance in Spanish companies is presented in Fig. 4, assuming that the total maintenance is 100% and is divided between preventive and corrective maintenance. The percentage of preventive maintenance is shown. The corrective maintenance is the complement.

From Fig. 4 we could conclude that more than 70% of Spanish companies have more than 50% corrective maintenance [10]. Is evident then, that there's an inclination on this companies to distribute maintenance as: 30% to 40% preventive and 60% to 70% corrective.

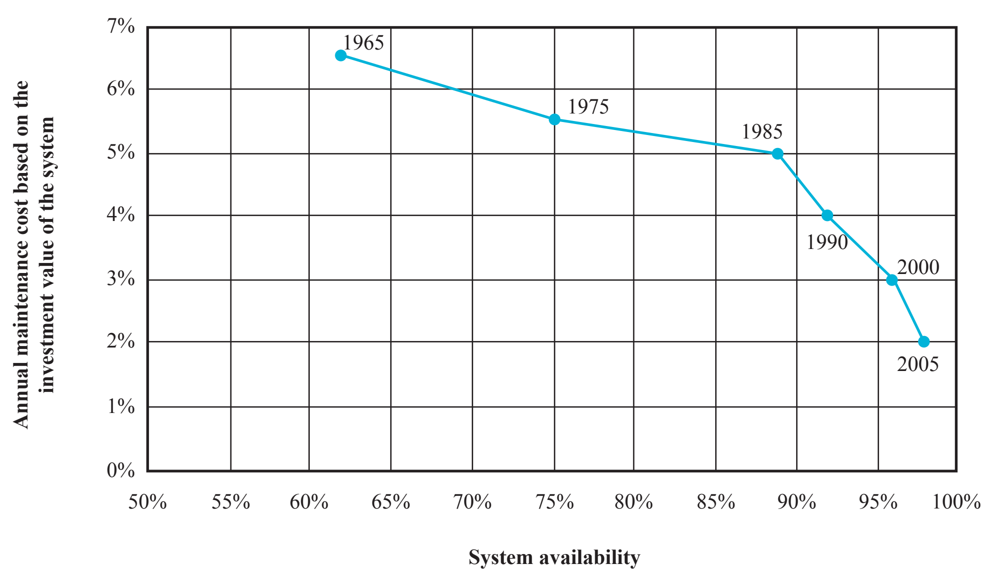
Is important that companies have clear towards what kind of maintenance aim. Garcia [11] explains in his blog, the focuses of the maintenance over the years:

There are 5 maintenance generations, being consequently one better than the previous one. The first generation perform corrective maintenance. In the second the term "preventive maintenance" arises, this is shown by a higher demand in production continuity. The third generation is focused in equipment availability, so it gives birth to predictive maintenance. The fourth generation integrate all the prior knowledge, adding the customer expectations. The fifth generation is focused in the systems energy efficiency.

Maintenance cost rule-of-thumb

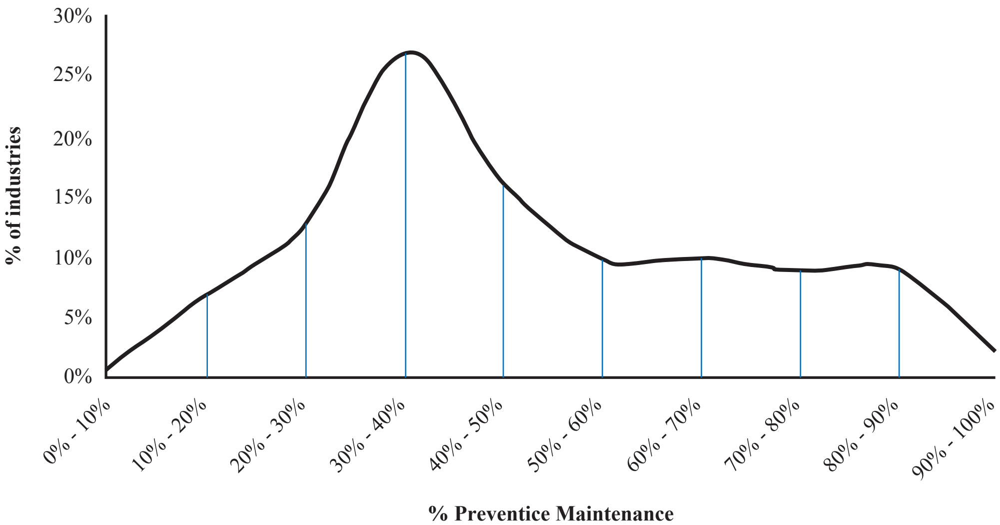
As shown before, a detailed analysis and cost estimation must include many facts and values to

Fig. 3. Maintenance Effectiveness Evolution in Spain Companies.



Source: [10]

Fig. 4. Preventive Maintenance Distribution against corrective in Spanish Companies.

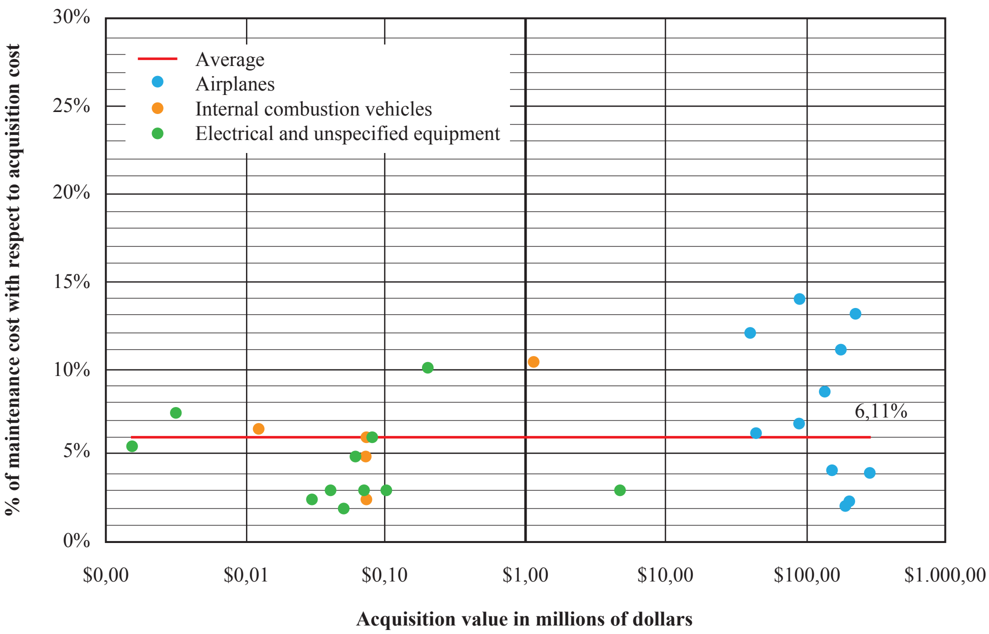


Source: [10]

get a exact amount for the annual maintenance budget. However, most of this information is not know or very difficult to get, not to say the amount of time (and so money) that it would require. This is why is important to have an approximate amount to start a budget, and then make it more specific for each company or shipyard.

For this purpose, many literature and sources were consulted, in order to get a general percentage that should be expended in maintenance, regarding the acquisition value of the assets. In Fig. 5 is shown the maintenance cost of some industrial equipment and transportation means. The horizontal axis is in logarithmic scale.

Fig. 5. Companies Maintenance Cost.



Source: The author based this on researched information. See Table 1.

Table 1. Industries Maintenance Cost.

Machinery/ Infrastructure	*Category*	*Asset Type*	*Maintenance Value (% acquisition value)*	*Source*
Machinery	Electrical Equipment and non specific	Pumps	15%	[12, p. 117]
		Non Specific	3 - 6%	[12, p. 49]
		Non Specific	3 - 5%	[2, p. 42]
		Electric Locomotive	3.08 %	[13]
		Compressors	7.4%	[14]
		Non Specific	2 – 3%	[15]
		Conventional Lathe	5.5%	[16]
		Non Specific	2.05 – 10%	[9]
	Internal Combustion Equipment	Fighter planes	6.41% - 10.79%	[17]
		ICV (Internal combustion vehicle)	6.54%	[18]
		Lift Truck	2.4%, 4.99%, 6.01%	[19]
		Machinery	11%	[2]
		Tipper Trucks	10.4%	[4] [20]
Infrastructure	Static Equipment	Railways	1.52 – 2.11%	[21] [22]
		Pipelines	0.2%	[23]

Source: Author, with different sources data.

According to Fig. 5 is estimated that industries invest in machinery maintenance an annual average of 6.11% of their assets value. For infrastructure there is an average of 1.27%.

Mid-Tier Shipyard

A shipyard is an industrial factory aimed to build and repair vessels, and it is a labor intense type. It includes the intensive use of mechanical and electrical tools, big size facilities, shops and hangars.

As an example, we will consider an generic and imaginary mid-tier shipyard, in order to calculate how big should be is annual budget for maintenance. We consider a general asset distribution as the presented in Table 1.

Table 2. Acquisition value of the assets Mid-Tier Shipyard [USD].

Asset Type	Present Value
Infraestructure – buildings	$ 4.300.000
Equipment - Machinery	$ 1.900.000
Manual tools	$ 1.100.000
General Total:	**$ 7.300.000**

Considering these values, we apply the gotten percentages estimated for maintenance, and get the approximate annual maintenance cost. This calculation is made to get the approximate percentage of the acquisition cost that should be invested yearly to maintain the company assets.

Table 3. Projected maintenance annual cost.

	Assets value		Annual maintenance cost	
	[M USD]	[%]	[%]	[USD]
Infraestructure – buildings	4.3	59	1.27	54.610
Equipment - Machinery	1.9	26	6.11	116.090
Manual tools	1.1	15	6.11	67.210
Total	7.3	100	3.26	237.910

As a result, the annual maintenance cost of this virtual shipyard is around $238.000 and this equals to the 3.26% of the total asset value. This could be used as a rule of thumb to plan the budget for the mid-size shipyards, as long as the proportion of infrastructure, equipment and tools be similar.

This value could also help to improve the pricing of the offered services considering a proper level of maintenance. For example, considering an annual revenue of this shipyard for $25 M USD, the planned maintenance cost ($238.000 USD) is equal to the 0,95% of this revenue, and this percentage should be charged for every order made, with specific destination to maintenance.

Furthermore, a more detailed control on the life cycle costs for every machine and equipment, can lead to decide which processes and services are more profitable, and which don't, so is better to outsource.

Conclusion

The maintenance management is one of the core issues that any industrial factory must address. Its importance has no doubt about, and in the last years many formal education, new techniques, methods and technologies are available.

However, the cost maintenance estimation still is a matter that most organizations keep secret. From the manufacturer point of view, does not worth to disclose the studies about the required cost of maintenance while the competitors are not forced to. From the companies point of view, the optimal maintenance cost is a commercial secret that took many years to get, so it makes no sense to reveal it. All this issues are the same for the shipbuilding industry. However, in order to make an estimation of investment in new machinery, a relocation on the layout, or to evaluate the estimated profit for a new shipbuilding project, it is of great importance to know how much the maintenance of the facilities will cost. For this reason this research was conducted, in order to find a rule of thumb about what is the ordinary cost of maintenance of a mid-tier shipyard or similar industries composed by infraestructure (buildings) and machinery. Then would be a better understanding of how much the maintenance cost can be reduced keeping a good rate of operativity and security, in order to increase the overall profit.

References

[1] I. M. O. G. PALENCIA, "Tendencias actuales del mantenimiento industrial," Reportero industrial, April 2014. [Online]. Available: http://www.reporteroindustrial.com/temas/Tendencias-actuales-en-mantenimiento-industrial+97221?pagina=1. [Accessed 09 August 2019].

[2] ACIEM, Diagnostico del mantenimiento en Colombia, Capitulo Cundinamarca ed., Bogota D.C., 2018.

[3] L. F. C. PATIÑO, "Mantenimiento industrial: La columna vertebral de su empresa," in Aceros Antiabración: una batalla contra el desgaste, 2009, pp. 28-33.

[4] Arquitectos especializados del Noroeste, "Clasificación de los tipos de mantenimiento," Arquitectos especializados del Noroeste, [Online]. Available: https://aen.mx/clasificacion-de-los-tipos-de-mantenimiento-industrial/. [Accessed 15 July 2019].

[5] D. LUNA, "Metalmecanica Internacional," December 2007. [Online]. Available: http://www.metalmecanica.com/temas/Cuales-son-las-maquinas-y-tecnologias-que-estan-transformando-la-industria-metalmecanica+122977?pagina=1.

[6] NASA, «Reliability-Centered Maintenance Guide,» September 2008. [On line]. Available: https://www.nasa.gov/sites/default/files/atoms/files/nasa_rcmguide.pdf. [Último acceso: 20 January 2019].

[7] J. D. NAVARRO, Técnicas de Mantenimiento industrial, Calpe Institute of Technology, 2007.

[8] L. N. ELOLA, A. C. P. TEJEDOR AND J. M. M. LACABRERA, Gestión integral del Mantenimiento, Marcombo Boixareu, 1997.

[9] K. KOMONEN, "A cost model of industrial maintenance for profitability analysis and benchmarking," international journal production economics, 2000.

[10] F. J. G. FERNÁNDEZ, Teoría y práctica del mantenimiento industrial avanzado, 2 ed., FC editorial, 2011.

[11] J. L. GARCÍA, "Las cinco generaciones del mantenimiento," 21 February 2013. [Online]. Available: http://gestionmantenimientoeficiente.blogspot.com/2013/02/las-cinco-generaciones-del-mantenimiento.html. [Accessed 17 July 2019].

[12] J. GAMARRA, Tecnicas de mantenimiento industrial, 2013.

[13] B. VILA ARAICO, "Plataforma de mantenimiento basado en condición CBM de material rodante," El blog de innovación y tecnología de Altran España, 10 February 2016. [Online]. Available: https://blog.altran.es/industria-energia/mantenimiento-basado-en-condicion-cbm/. [Accessed 29 June 2019].

[14] MACHINE TOOLS WORLD, "ELGI: Costo de ciclo de vida para compresores," [Online]. Available: https://www.mtwmag.com/energy-efficiency-compressors/elgi-lifecycle-cost-for-compressors/#noopener%20noreferrer/4/. [Accessed 24 July 2019].

[15] S. GARCIA GARRIDO, "EL PRESUPUESTO ANUAL DE MANTENIMIENTO," RENOVETEC, 2012. [Online]. [Accessed 9 July 2019].

[16] R. LOPEZ GUARANGO, "Instituto Tecnológico Superior "Carlos Cisneros"," 2015. [Online]. Available: https://es.slideshare.net/jcaminos2/tesis-cepilladora-2015. [Accessed 8 June 2019].

[17] P. CERVERA, «Este caza es una ruina: los brutales costes de volar cada hora un avión de combate,» El confidencial, 9 May 2016. [On line]. Available: https://www.elconfidencial.com/tecnologia/2016-05-09/caza-avion-combate-costes-ruina_1196165/. [Último acceso: 12 July 2019].

[18] B. PROPFE, M. REDELBACH, D. J. SANTINI AND H. FRIEDRICH, "Cost analysis of Plug-in Hybrid Electric Vehicles including," Institute of Vehicle Concepts, German Aerospace Center (DLR), Los angeles, California, 2012.

[19] WIDMAN INTERNATIONAL SRL, "El Costo de Mantenimiento de Equipo Pesado," 6 October 2019. [Online]. Available: https://www.widman.biz/mantenimiento/pesado.php.

[20] M. R. BECERRA GUZMAN, Y. P. BOHORQUEZ FARFAN AND E. FAJARDO OSPINO, "Diseño e implementación de un programa de mantenimiento preventivo para la maquinaria de la Empresa Mejía Villegas Constructores S.A.," 2007. [Online]. Available: http://repositorio.unicartagena.edu.co/handle/11227/763. [Accessed 16 May 2019].

[21] FERROPEDIA, "Costos de mantenimiento de infraestructura," 2014. [Online].

[22] FERROPEDIA, "Ferropedia," 3 January 2017. [Online]. Available: http://www.ferropedia.es/mediawiki/index.php/Costos_de_construcci%C3%B3n_de_infraestructura. [Accessed 22 June 2019].

[23] F. S. ALAA CHATEAUNEUF, "Maintenance Cost Models," 16 Jun 2014. [Online]. Available: https://hal.archives-ouvertes.fr/hal-01007484/document. [Accessed 5 Jun 2019].

Editorial Guidelines for Authors

Thematic Interest

The *Ship Science and Technology* Journal accepts for publication original engineering contributions in English language on ship design, hydrodynamics, dynamics of ships, structures and materials, vibrations and noise, technology of ship construction, ocean and marine engineering, standards and regulations, oceanography, maritime and river transport, and port infrastructure, results of scientific and technological researches. Every article shall be subject to consideration of the Editorial Council of The *Ship Science and Technology* Journal deciding on pertinence of its publication.

Typology

The *Ship Science and Technology* Journal accepts to publish articles classified within the following typology (COLCIENCIAS 2006):

- *Scientific and technological research articles*. Documents presenting detailed original results of finished research projects. Generally, the structure used contains four important parts: introduction, methodology, results, and conclusions.
- *Reflection Articles*. Documents presenting results of finished research as of an analytical, interpretative, or critical perspective of the author on a specific theme, resorting to original sources.
- *Revision Articles*. Documents resulting from finished research in the field of science or technology in which published or unpublished results are analyzed, systemized, and integrated to present advances and development trends. These are characterized by presenting an attentive bibliographic revision of at least 50 references.

Format

All articles must be sent to the editor of The *Ship Science and Technology* Journal accompanied by a letter from the authors requesting their publication. Every article must be written in *Microsoft Word* in single space and sent in magnetic form.
Articles must not exceed 10,000 words (9 pages).
File must contain all text and any tabulation and mathematical equations.
All mathematical equations must be written in *Microsoft Word Equation Editor*. This file must contain graphs and figures; additionally, they must be sent in a modifiable format file (soft copy). Also, abbreviations and acronyms have to be defined the first time they appear in the text.

Content

All articles must contain the following elements that must appear in the same order as follows:

Title
It must be concise (no more than 25 words) with appropriate words so as to give readers an idea of the contents of the article. It must be sent in English and Spanish language.

Author and Affiliations
The author's name must be written as follows: last name, initial of first name . Affiliations of author must be specified in the following way and order:

- Business or institution (including department or division to which he/she belongs).
- Street mailing address.
- City (Province/State/Department).
- Country.

Abstract
A short essay of no more than one hundred fifty (150) words, specifying content of the work, scope, and results. It must be written in such a way so as to contain key ideas of the document. It must be sent in English and Spanish language.

Key Words
Identify words and/or phrases (at least three) that recover relevant ideas in an index. They must be sent in English and Spanish language.

Introduction
The text must be explanatory, clear, simple, precise, and original in presenting ideas. Likewise, it must be organized in a logical sequence of parts or sections, with clear subtitles to guide readers. The first part of the document is the introduction. Its objective is to present the theme, objectives, and justification of why it was selected. It must contain sources consulted and methodology used, as well as a short explanation of the status of the research, if it were the case, and form in which the rest of article is structured.

Body Article
It is made up of the theoretical framework supporting the study, statement of the theme, status of its analysis, results obtained, and conclusions.

Equations, Tables, Charts ang Graphs
All of these elements must be numbered in order of appearance according to their type and must have their corresponding legends, along with the source of the data.

Equations must be numbered on the right hand side of the column containing it, in the same line and in parenthesis. The body of the text must refer to it as "(Equation x)". When the reference starts a sentence it must be made as follows: "Equation x". Equations must be written so that capital letters can be clearly differentiated from lower case letters. Avoid confusions between the letter "l" and the number one or between zero and the lower case letter "o". All sub-indexes, super-indexes, Greek letters, and other symbols must be clearly indicated. All expressions and mathematical analyses must explain all symbols (and unit in which they are measured) that have not been previously defined in the nomenclature. If the work is extremely mathematical by nature, it would be advisable to develop equations and formulas in appendixes instead of including them in the body of the text.

Figure/Fig. (lineal drawings, tables, pictures, figures, etc.) must be numbered according to the order of appearance and should include the number of the graph in parenthesis and a brief description. As with equations, in the body of the text, reference as "(Fig. X)", and when reference to a graph is the beginning of a sentence it must be made as follows: "Fig. x".

Charts, graphs, and illustrations must be sent in modifiable vector file format (*Microsoft Excel, Microsoft Power Period*, and/or *Microsoft Vision*).

Pictures must be sent in TIF or JPG format files, separate from the main document in a resolution higher than 1000 dpi.

Foot Notes
We recommend their use as required to identify additional information. They must be numbered in order of appearance along the text.

Acknowledgment
Acknowledgments may be made to persons or institutions considered to have made important contributions and not mentioned in any other part of the article.

Bibliographic References

The bibliographic references must be included at the end of the article in alphabetical order and shall be identified along the document. To cite references, the Journal uses ISO 690 standards, which specify the mandatory elements to cite references (monographs, serials, chapters, articles, and patents), and ISO 690-2, related to the citation of electronic documents. We also use IEEE standard for the bibliographic references.

ISO 690

Quotations

They must be made in two ways: at the end of the text, in which case the last name of author followed by a comma and year of publication in the following manner:

"Methods exist today by which carbon fibers and prepregs can be recycled, and the resulting recyclate retains up to 90% of the fibers' mechanical properties" (*Davidson, 2006*).

The other way is:

Davidson (2006) manifests that "Methods exist today by which carbon fibers and prepregs can be recycled, and the resulting recyclate retains up to 90% of the fibers' mechanical properties".

List of References

Bibliographic references of original sources for cited material must be cited at the end of the article in alphabetical order and according to the following parameters:

In the event of more than one author, separate by commas and the last one by an "and". If there are more than three authors write the last name and initials of the first author and then the abbreviation "*et al.,*".

Books

Last name of author followed by a comma, initial(s) of name followed by a period, the year of publication of book in parenthesis followed by a comma, title of publication in italics and without quotation marks followed by a comma, city where published followed by a comma, and name of editorial without abbreviations such as Ltd., Inc. or the word "editorial".

Basic Form:
LAST NAME, N.I. *Title of book*. Subordinate responsibility (optional). Edition. Publication (place, publisher). Year. Extent. Series. Notes. Standard Number.

Example:
GOLDBERG, D.E. *Genetic Algorithms for Search, Optimization, and Machine Learning.* Edition 1. Reading, MA: Addison-Wesley. 412 p. 1989. ISBN 0201157675.

If a corporate author

Write complete name of entity and follow the other standards.

Basic form:
INSTITUTION NAME. *Title of publication*. Subordinate responsibility (optional). Edition. Publication (place, publisher). Year. Extent. Series. Notes. Standard Number.

Example:
AMERICAN SOCIETY FOR METALS. *Metals Handbook: Properties and Selection: Stainless Steels, Tool Materials and Special-Purpose Metals*. 9th edition. Asm Intl. December 1980. ISBN: 0871700093.

When book or any publication have as author an entity pertaining to the state, write name of country first.

Basic form:
COUNTRY, ENTITY PERTAINING TO THE STATE. *Title of publication*. Subordinate responsibility (optional). Edition. Publication (place, publisher). Year. Extent. Series. Notes. Standard Number.

Example:
UNITED STATED OF AMERICAN. EPA - U.S. Environmental Protection Agency. Profile of the Shipbuilding and Repair Industry. Washington D.C. 1997. P. 135.

Journal Article

Basic form:
Last name, N.I. Title of article, *Name of publication*. Edition. Year, issue designation, Pagination of the part.

Graduation Work

Basic form:
Primary responsibility. *Title of the invention*. Subordinate responsibility. Notes. Document identifier: Country or issuing office. *Kind of patent document*. Number. Date of publication of cited document.

Example:
CARL ZEISS JENA, VEB. *Anordnung zur lichtelektrischen Erfassung der Mitte eines Lichtfeldes. Et-finder*: W. FEIST, C. WAHNERT, E. FEISTAUER. Int. Cl.3 : GO2 B 27/14. Schweiz Patentschrift, 608 626. 1979-01-15.

Presentation at conferences or academic or scientific event

Basic form:
LAST NAME, N.I. Title of the presentation. In: Sponsor of the event. *Name of the event*. Country, City: Publisher, year. Pagination of the part.

Example:
VALENCIA, R., et al. Simulation of the thrust forces of a ROV En: COTECMAR. P*rimer Congreso Internacional de Diseño e Ingeniería Naval CIDIN 09*. Colombia, Cartagena: COTECMAR, 2009.

Internet

Basic form:
[1] LAST NAME, N.I. *Title of work*, [on-line]. Available at: http://www.direccion_completa.com, recovered: day of month of year.

Example:
[1] COLOMBIA. ARMADA NACIONAL. COTECMAR gana premio nacional científico, [web on-line]. Available at: http://www.armada.mil.co/?idcategoria=545965, recovered: 5 January of 2010.

IEEE

IEEE Publications uses Webster's College Dictionary, 4th Edition. For guidance on grammar and usage not included in this manual, please consult The Chicago Manual of Style, published by the University of Chicago Press.

Books

Basic form:
[1] J. K. Author, "Title of chapter in the book," in *Title of His Published Book*, *x*th ed. City of Publisher, Country if not USA: Abbrev. of Publisher, year, ch. *x*, sec. *x*, pp. *xxx–xxx*.

Example:
[1] B. Klaus and P. Horn, *Robot Vision*. Cambridge, MA: MIT Press, 1986.

Handbooks

Basic form:
[1] *Name of Manual/Handbook*, *x* ed., Abbrev. Name of Co., City of Co., Abbrev. State, year, pp. *xx-xx*.

Example:
[1] *Transmission Systems for Communications*, 3rd ed., Western Electric Co., Winston-Salem, NC, 1985, pp. 44–60.

Reports
The general form for citing technical reports is to place the name and location of the company or institution after the author and title and to give the report number and date at the end of the reference.

Basic form:
[1] J. K. Author, "Title of report," Abbrev. Name of Co., City of Co., Abbrev. State, Rep. *xxx*, year.

Example:
[1] E. E. Reber *et al.*, "Oxygen absorption in the earth's atmosphere," Aerospace Corp., Los Angeles, CA, Tech. Rep. Angeles, CA, Tech. Rep. TR-0200 (4230-46)-3, Nov. 1988.

Conference Technical Articles
The general form for citing technical articles published in conference proceedings is to list the author/s and title of the paper, followed by the name (and location, if given) of the conference

publication in italics using these standard abbreviations. Write out all the remaining words, but omit most articles and prepositions like "of the" and "on." That is, *Proceedings of the 1996 Robotics and Automation Conference* becomes *Proc. 1996 Robotics and Automation Conf.*

Basic form:
[1] J. K. Author, "Title of paper," in *Unabbreviated Name of Conf.*, City of Conf., Abbrev. State (if given), year, pp. xxx-xxx.

For an electronic conference article when there are no page numbers:
[1] J. K. Author [two authors: J. K. Author and A. N. Writer] [three or more authors: J. K. Author et al.], "Title of Article," in [Title of Conf. Record as it appears on the copyright page], [copyright year] © [IEEE or applicable copyright holder of the Conference Record]. doi: [DOI number]

For an unpublished papr presented at a conference:
[1] J. K. Author, "Title of paper," presented at the Unabbrev. Name of Conf., City of Conf., Abbrev. State, year.

Online Sources

The basic guideline for citing online sources is to follow the standard citation for the source given previously and add the Digital Object Identifier (DOI) at the end of the citation, or add the DOI in place of page numbers if the source is not paginated. The DOI for each IEEE conference article is assigned when the article is processed for inclusion in the IEEE Xplore digital library and is included with the reference data of the article in Xplore. See The DOI System for more information about the benefits of DOI referencing.

The following sources are unique in that they are electronic only sources.

FTP

Basic form:
[1] J. K. Author. (year). Title (edition) [Type of medium]. Available FTP: Directory: File:

Example:
[1] R. J. Vidmar. (1994). *On the use of atmospheric plasmas as electromagnetic reflector*s [Online]. Available FTP: atmnext.usc.edu Directory: pub/etext/1994 File: atmosplasma.txt.

WWW

Basic form:
[1] J. K. Author. (year, month day). Title (edition) [Type of medium]. Available: http://www.(URL)

Example:
[1] J. Jones. (1991, May 10). Networks (2nd ed.) [Online]. Available: http://www.atm.com

E-Mail

Basic form:
[1] J. K. Author. (year, month day). Title (edition) [Type of medium]. Available e-mail: Message:

Example:
[1] S. H. Gold. (1995, Oct. 10). *Inter-Network Talk* [Online]. Available e-mail: COMSERVE@RPIECS Message: Get NETWORK TALK

E-Mail

Basic form:
[1] J. K. Author. (year, month day). Title (edition) [Type of medium]. Available Telnet: Directory: File:

Example:
[1] V. Meligna. (1993, June 11). *Periodic table of elements* [Online]. Available Telnet: Library.CMU.edu Directory: Libraries/Reference Works File: Periodic Table of Elements

Patents

Basic form:
[1] J. K. Author, "Title of patent," U.S. Patent x xxx xxx, Abbrev. Month, day, year.

Example:
[1] J. P. Wilkinson, "Nonlinear resonant circuit devices," U.S. Patent 3 624 125, July 16, 1990.

Standards

Basic form:
[1] Title of Standard, Standard number, date.

Example:
[1] IEEE Criteria for Class IE Electric Systems, IEEE Standard 308, 1969.

Theses (M.S.) and Dissertations (Ph.D.)

Basic form:
[1] J. K. Author, "Title of thesis," M.S. thesis, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

Example:
[1] J. O. Williams, "Narrow-band analyzer," Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, 1993.

Unpublished
These are the two most common types of unpublished references.

Basic form:
[1] J. K. Author, private communication, Abbrev. Month, year.
[2] J. K. Author, "Title of paper," unpublished.

Examples:
[1] A. Harrison, private communication, May 1995.
[2] B. Smith, "An approach to graphs of linear forms," unpublished.

Periodicals
NOTE: When referencing IEEE Transactions, the issue number should be deleted and month carried.

Basic form:
[1] J. K. Author, "Name of paper," *Abbrev. Title of Periodical*, vol. *x*, no. x, pp. *xxx-xxx*, Abbrev. Month, year.

Examples:
[1] R. E. Kalman, "New results in linear filtering and prediction theory," J. Basic Eng., ser. D, vol. 83, pp. 95-108, Mar. 1961.

References
NOTE: Use *et al*. when three or more names are given.

References in Text:
References need not be cited in the text. When they are, they appear on the line, in square brackets, inside the punctuation. Grammatically, they may be treated as if they were footnote numbers, e.g.,
as shown by Brown [4], [5]; as mentioned earlier [2], [4]–[7], [9]; Smith [4] and Brown and Jones [5]; Wood et al. [7]
or as nouns:
as demonstrated in [3]; according to [4] and [6]–[9].

References Within a Reference:
Check the reference list for ibid. or op. cit. These refer to a previous reference and should be eliminated from the reference section. In text, repeat the earlier reference number and renumber the reference section accordingly. If the ibid. gives a new page number, or other information, use the following forms:
[3, Th. 1]; [3, Lemma 2]; [3, pp. 5-10]; [3, eq. (2)]; [3, Fig. 1]; [3, Appendix I]; [3, Sec. 4.5]; [3, Ch. 2, pp. 5-10]; [3, Algorithm 5].

NOTE: Editing of references may entail careful renumbering of references, as well as the citations in text.

Acceptance

Articles must be sent by e-mail to the editor of The *Ship Science and Technology* Journal to otascon@cotecmar.com or in CD to the journal's street mailing address (COTECMAR Mamonal Km 9 Cartagena Colombia), accompanied by the "Declaration of Originality of Written Work "included in this journal.

The author shall receive acknowledgement of receipt by e-mail. All articles will be submitted to Peer Review. Comments and evaluations made by the journal shall be kept confidential. Receipt of articles by The Ship Science and Technology

Journal does not necessarily constitute acceptance for publishing. If an article is not accepted it shall be returned to the respective author. The Journal only publishes one article per author in the same number of the magazine.

Opinions and declarations stated by authors in articles are of their exclusive responsibility and not of the journal. Acceptance of articles grants The Ship Science and Technology Journal the right to print and reproduce these; nevertheless, any reasonable petition by an author to obtain permission to reproduce his/her contributions shall be considered.

Further information can be obtained by:
Sending an e-mail to sst.journal@cotecmar.com
Contacting Carlos Eduardo Gil De los Rios (Editor)
The Ship Science and Technology (Ciencia y Tecnología de Buques) office located at:
COTECMAR Bocagrande Carrera 2da Base Naval A.R.C. Bolívar
Cartagena de Indias – Colombia.
Phone Number: +57 (5) 653 5511

SHIP
SCIENCE & TECHNOLOGY
CIENCIA & TECNOLOGÍA DE BUQUES

Statement of Originality of Written Work

Title of work submitted

____

____

I hereby certify that the work submitted for publication in The Ship Science and Technology journal of Science and Technology for the Development of Naval, Maritime, and Riverine Industry Corporation, COTECMAR, was written by me, given that its content is the product of my direct intellectual contribution. All data and references to material already published are duly identified with their respective credits and are included in the bibliographic notes and quotations highlighted as such.

I, therefore, declare that all materials submitted for publication are completely free of copyrights; consequently, I accept responsibility for any lawsuit or claim related with Intellectual Property Rights thereof.

In the event that the article is chosen for publication by The Ship Science and Technology journal, I hereby state that I totally transfer publication and reproduction rights of such to the Science and Technology Corporation for the Development of Naval, Maritime, and Riverine Industry - COTECMAR, which will be simultaneously subject to the Creative Commons Attribution License (CC -BY) that allows the license to copy, distribute, display and represent the work and to make derivative works as long as it recognizes and cites the work in the manner specified by the author or licensor, without territorial limitation.

This assignment of rights does not obligate Cotecmar to pay for the article and in retribution of it I agree to receive two issues of the journal number where my article is published.

In witness thereof, I sign this statement on the ______ day of the month of _______________ of year ______________, in the city of _______________ .

Name and signature: _________________________________

Identification document: _________________________________

Level of Education: _________________________________

Institutional Affiliation: _________________________________

COTECMAR
COLOMBIA

Km. 9 Vía Mamonal - Cartagena, Colombia
www.shipjournal.co

Vol. 13 - n.° 26
January 2020