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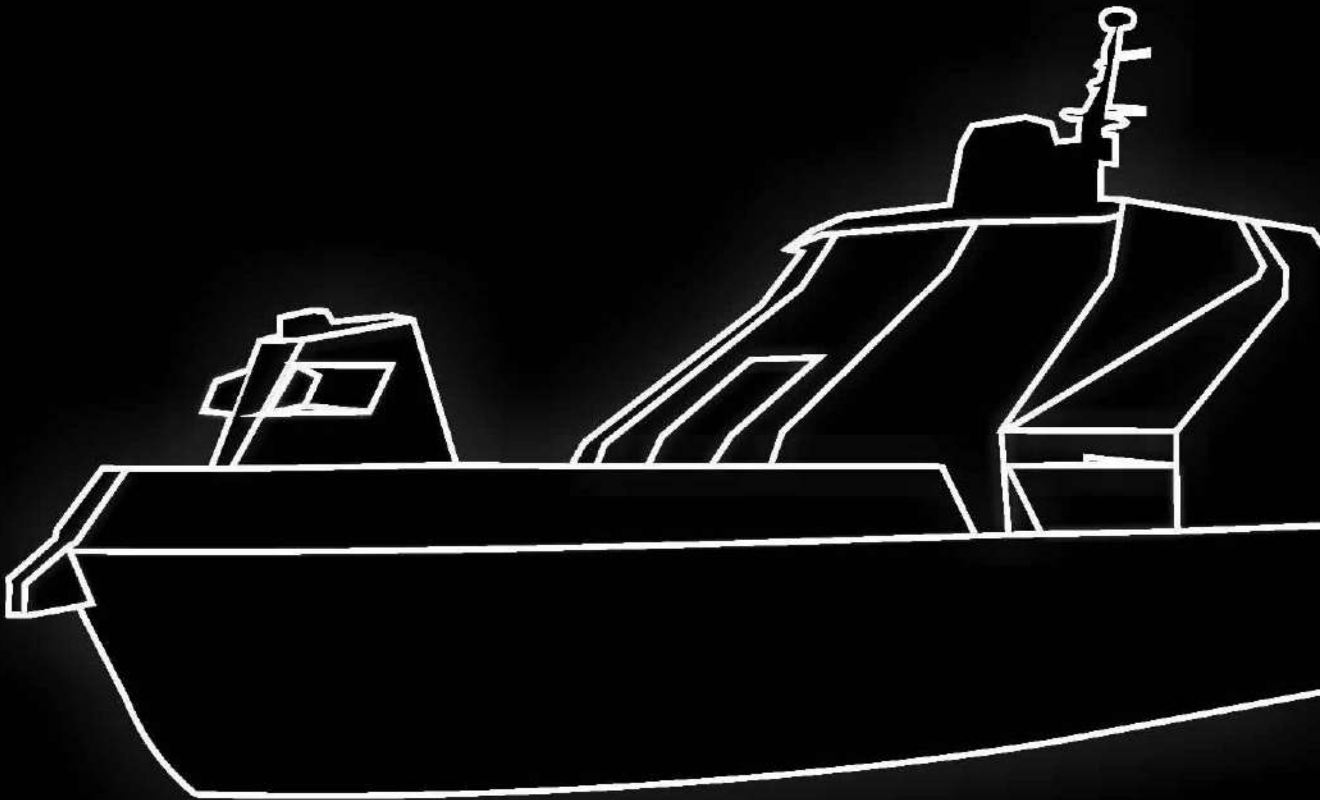

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Scientific and Technological Research Articles
Artículos de investigación científica y tecnológica

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Editorial Note

Cartagena de Indias, 21 January 2010

The year 2010 is of the upmost importance for COTECMAR since it is the year of consolidation of the Technological Development & Innovation Plan – PDTI, the vehicle through which COTECMAR expects to reach its objectives via the execution of projects in four strategic areas: (1) Research and Development, (2) Organizational Learning, (3) Information Technology, and (4) Infraestructure. In this number, Ships' Science & Technology presents the results of two research projects which will have a big impact in the achievement of this objective: (1) The development of the Decision Support System – DSS for ship repair and shipbuilding, and (2) The assessment of the FCAW welding technology in the ship repair plate replacement process. As always, we have contributions from our technological partners and our worldwide collaborators; in particular, the Escuela Naval "Almirante Padilla" – ENAP (Colombia) on the use of fuzzy logic to improve the seakeeping qualities of high speed crafts, the Escuela Politécnica del Litoral – ESPOL (Ecuador) on the development of productivity measures of merit is medium size repair shipyards, the University of Sao Paulo (Brasil) on the recent development of the maritime industry in Brasil, and Germanischer Lloyd – GL (Germany) on the effective use of simulations in the design of high performance vessels. All of these are current topics in our industry and therefore of interest to our readers.

In COTECMAR innovation is a corporate value, one that has been consolidated with the effort of many people during these years and one that has been recognized in multiple forms in our own country. In 2009, the Colombian Association for the Advancement of Science – ACAC distinguished COTECMAR with the "Price to Scientific Merit in the category of Technological Innovation" for the development of the Riverine Patrol Support Vessel – RPSV. At the same time, COTECMAR was selected by Portafolio, the main economics' diary in the country, as one of the finalists for the "Prize Portafolio in the Category of Innovation", for the design and construction of the Riverine Support Vessel – RSV, receiving a "Mention of Honor" in this category. I would like to take this opportunity to praise the team of COTECMAR that makes possible year by year the fulfillment of our responsibility in the development of the naval, maritime and riverine industry in Colombia, and to extend it to all our partners and collaborators around the world who have help us grow during these almost ten years.

Lastly, I would like to inform you that starting with this number the journal will include editorial improvements that will allow you to continue reading papers of high scientific quality in a better format.

Commander OSCAR DARÍO TASCÓN

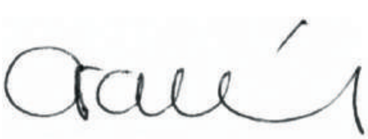
Nota Editorial

Cartagena de Indias, 21 de enero de 2010

El 2010 es para COTECMAR el año de la consolidación del Plan de Desarrollo Tecnológico e Innovación – PDTI, por medio del cual se busca alcanzar las metas corporativas a través de la ejecución de proyectos en las áreas estratégicas de Investigación y Desarrollo, Aprendizaje Organizacional, Tecnologías de la Información e Infraestructura. Esta edición de la revista Ciencia & Tecnología de Buques presenta entre otros el resultado de dos proyectos de investigación que tendrán un gran impacto en el cumplimiento de este objetivo: (1) El desarrollo del Sistema de Soporte de Decisiones – DSS para la reparación y construcción de buques, y (2) La evaluación de la utilización del proceso de soldeo FCAW en el proceso de cambio de acero. Como siempre, estos últimos están acompañados por artículos de nuestros socios a nivel nacional y de nuestros colaboradores a nivel internacional; en este caso en particular, la Escuela Naval "Almirante Padilla" (Colombia) presenta un artículo en el uso de lógica difusa para mejorar el comportamiento en el mar de embarcaciones de alta velocidad, la Escuela Politécnica del Litoral – ESPOL (Ecuador) en el desarrollo de medidas de productividad en astilleros reparadores medianos, y Germanischer Lloyd (Alemania) en el uso efectivo de simulaciones para el diseño de buques de alto desempeño. Todos estos, temas de actualidad y con seguridad de interés para nuestros lectores.

En COTECMAR la innovación es un valor corporativo que se ha consolidado entorno al esfuerzo mancomunado realizado en los últimos años y que ha sido reconocido en múltiples formas a nivel nacional. En el 2009 la Asociación Colombiana para el Avance de la Ciencia – ACAC – le entregó a COTECMAR el "Premio al Mérito Científico en la categoría Innovación Tecnológica", por el desarrollo de la Patrullera de Apoyo Fluvial – PAF. De igual forma, fue nominada por el Diario Portafolio – principal publicación económica del país – entre los finalistas al "Premio Portafolio en la Categoría Innovación", por el diseño y construcción de la Patrullera de Apoyo Fluvial Pesada (PAF-P), recibiendo una Mención de Honor en esta categoría. Deseo aprovechar esta oportunidad para extender desde la revista Ciencia y Tecnología de Buques una felicitación a todo el equipo de la Corporación que hace posible que podamos contribuir de manera determinante en nuestra responsabilidad con el desarrollo de la industria naval, marítima y fluvial del país, y a todos nuestros socios y colaboradores con quienes hemos crecido en estos ya casi diez años.

Finalmente, me complace informar que a partir de esta edición, la revista incluirá mejoras editoriales que les permitirán a los lectores seguir recibiendo artículos científicos de alta calidad en el mejor formato.



Capitán de Fragata OSCAR DARÍO TASCÓN

Design of High-Performance Ships using Simulations

Diseño de embarcaciones de alto desempeño usando Simulaciones

Fritz Grannemann Aufforth[1]
Volker Bertram[2]

Abstract

Simulation-based design increasingly replaces traditional experience-based design. This article gives an overview of techniques now used in advanced industry practice, with particular focus on navy applications. The article covers the basics of the techniques, illustrating approaches and state of the art with applications taken from the experience of Germanischer Lloyd.

Key words: CFD, ship design, simulation, structural analysis.

Resumen

El diseño basado en simulaciones crecientemente está remplazando al diseño basado en la experiencia. Este trabajo presenta una visión general de las técnicas empleadas actualmente en prácticas industriales avanzadas, con particular énfasis en el diseño de buques militares. El trabajo cubre los aspectos básicos e ilustra el estado del arte con aplicaciones tomadas de la experiencia del Germanischer Lloyd.

Palabras claves: CFD, diseño de embarcaciones, simulación, análisis estructural.

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Introduction

The word simulation is derived from the Latin word "simulare" which can be translated as "to reproduce". The VDI (Society of German Engineers) defines the technical term "simulation" as follows: "Simulation is the reproduction of a system with its dynamic processes in a running model to achieve cognition which can be referred to reality". According to the Oxford dictionary "to simulate" means "to imitate conditions of a situation or process", specifically "to produce a computer model of a process". In this sense virtually all computer models used in the design and construction of ships would qualify as simulations. Indeed, we see an ever increasing scope and importance of simulations in our work. The trend in modern classification society work is also towards simulation-based decisions, both for design and operation of ships.

Ship design is increasingly supported by sophisticated analyses. Traditionally, ship design is based on experience. This is still true to some extent, but increasingly we rely on "virtual experience" from dedicated and well chosen simulations. Scope and depth of these simulations guiding our decisions in design and operation of ships have developed very dynamically over the past decade. We describe here the state of the art as reflected in our work, building on previous work, *Fach and Bertram (2006)*, *Bertram and Couser (2007)*, but now with particular focus on applications for navy ships.

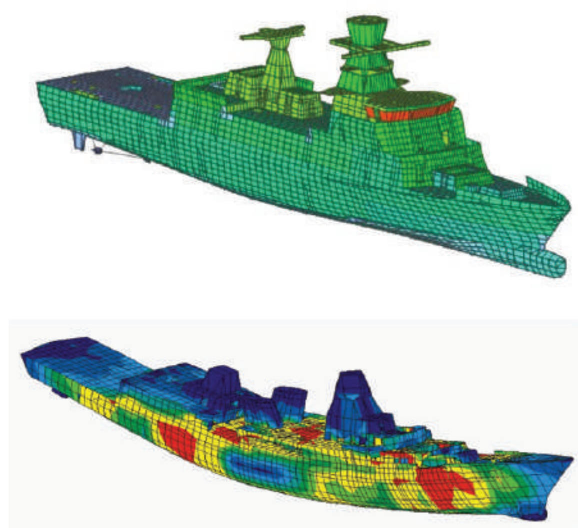
Structural Analyses

Finite-element analysis (FEA)

FEA for global strength within the elastic material domain have been standard for a long time, Fig.1. These simulations were the starting point for more sophisticated analyses, e.g. fatigue strength assessment, ultimate strength assessment, etc.

Until 1998, the SOLAS regulations on subdivision and damage stability specified damage stability requirements only for cargo ships longer than 100 meters. Since 1998, this limit has been lowered to 80 m for new cargo ships. Additional transverse bulkheads to fulfil damage stability requirements are costly and restrict operations. However, the new SOLAS regulations permit for some ships alternative arrangements, provided that at least the "same degree of safety" is achieved. This notation allows some flexibility of structural designs supported by advanced simulations. E.g. a structural design having increased collision resistance thus reducing the probability of penetration of the inner hull could eliminate the need for additional bulkheads. Based on extensive FEA simulations for ship collisions, Germanischer Lloyd developed an approval procedure which provides the first such standard for evaluation and approval of alternative solutions for design and construction of these ships, Fig.2, *Zhang et al. (2004)*. The basic philosophy of the approval procedure is to compare the critical deformation energy in case of side collision of a strengthened structural design to that of a reference design complying with the damage stability requirement described in the SOLAS regulation.

Fig.1. Global strength analysis; grid and stresses for frigate



Finite-element analyses (FEA) require load specifications which for ships involve frequently external hydrostatic and hydrodynamic loads.

Fig.2. FEA for collision of two ships

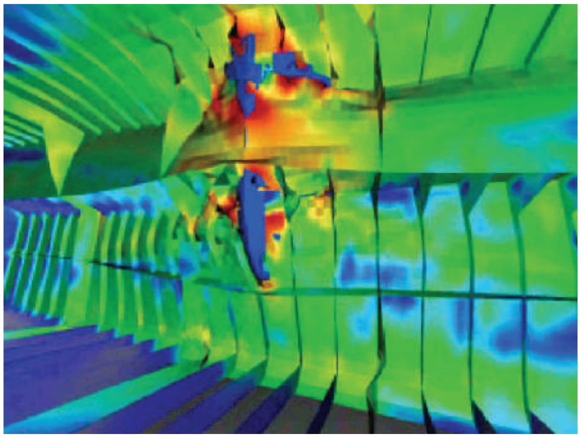


Fig.3. Global FEA of vibrations

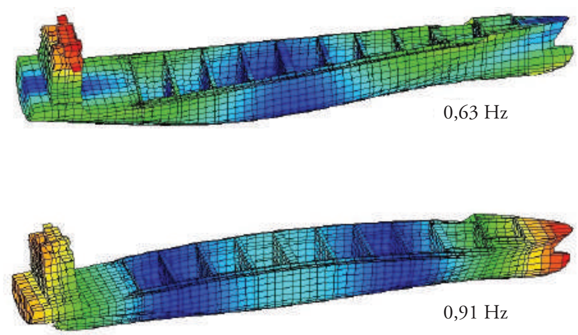
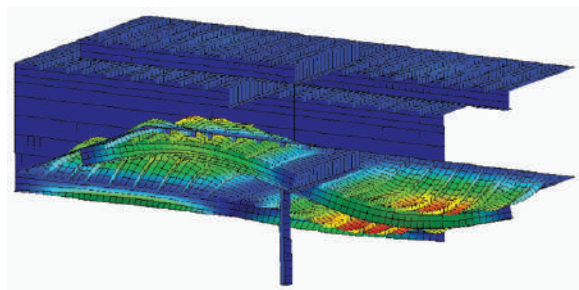


Fig.4. Local FEA of deck vibrations



GL.ShipLoad, *Cabos et al. (2006)*, supports efficient load generation for global FEA of ship structures. Hydrostatic and hydrodynamic computations are integrated into the program. GL.ShipLoad supports the generation of loads from first principles (realistic inertia and wave loads for user supplied wave parameters), but the program also aids in the selection of relevant wave situations for the global strength assessment based on bending moments and shear forces according to Germanischer Lloyd's rules. The result is a small number of balanced load cases that are sufficient for the dimensioning of the hull structure.

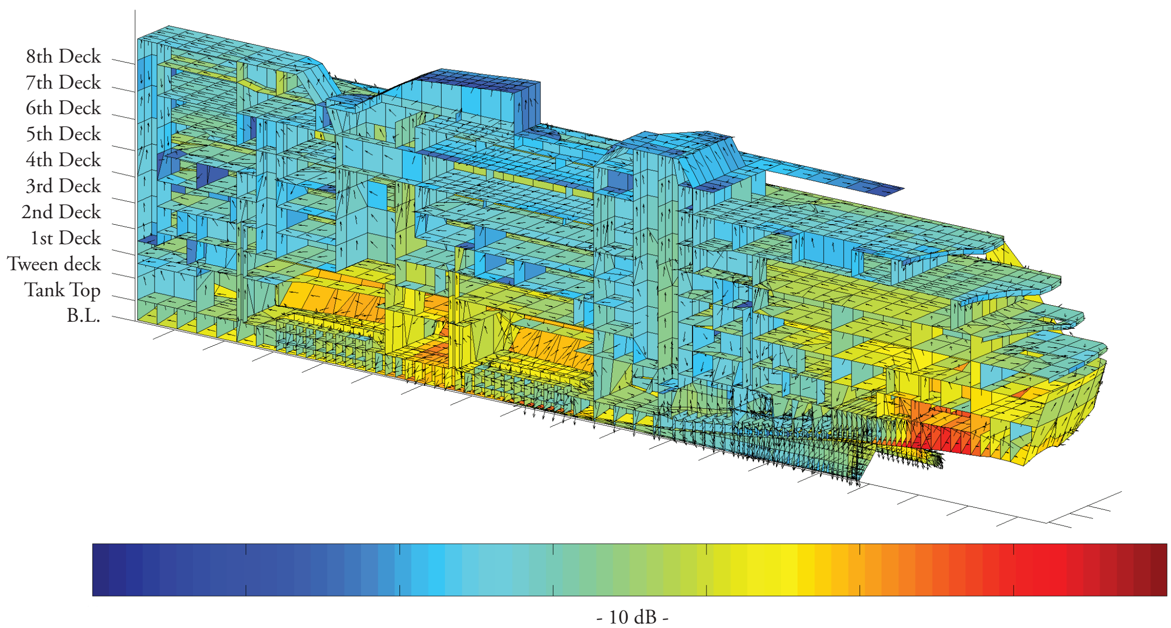
Vibration analyses

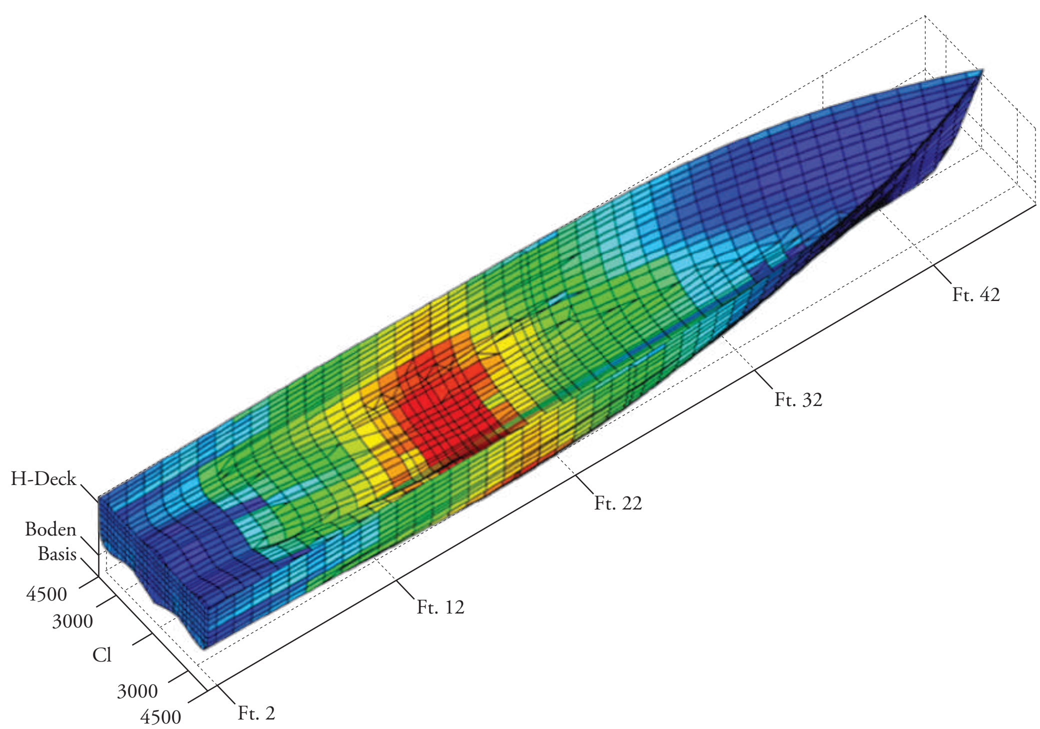
Advances in computer methods have made 3-d FEA today the standard choice for ship vibration analyses, Asmussen and Mumm (2001). The computations require longitudinal mass and stiffness distribution as input. The mass distribution considers the ship, the cargo and the hydrodynamic 'added' mass, Fig.3. The added mass reflects the effect of the surrounding water and depends on the frequency. One can either use estimates based on experience or employ sophisticated hydrodynamic simulations. For local vibrations analyses, Fig.4, added mass needs to be considered if the structures border on tanks or the outer hull plating. Because of the high natural frequencies of local structures, FEA models must be detailed including also the bending stiffness of structural elements.

Acoustics

For very high frequencies (structure-borne noise), the standard FEA approach to vibration analyses is impossible due to excessive computational requirements. For a typical passenger vessel for a frequency of 1000 Hz, a FEA vibration model would lead to several million degrees of freedom. However, the very fact that information is required only averaged over a frequency band allows an alternative, far more efficient approach based on statistical energy analysis (SEA). The Noise Finite Element Method (GL NoiseFEM) of Germanischer Lloyd, *Cabos and Jokat (1998)*, *Cabos et al. (2001)*, is based on a related approach. GL NoiseFEM predicts the propagation of noise by analyzing the exchange of energy between weakly coupled subsystems. Validation with full-scale measurements shows that the accuracy of GL NoiseFEM is sufficient for typical structure-borne sound predictions for the frequency range between 80 Hz and 4000 Hz, *Wilken et al. (2004)*. While further development is still needed, structure-borne noise analyses have been validated with good agreement on the wetted shell. Reliable prediction of the structure-borne noise is an important step towards predicting radiated noise of vessels. In the meantime, GL NoiseFEM structure-borne noise analyses are already applied to support the design of navy ships, cruiseships and customer-made yachts, Fig.5.

Fig.5. Structure-borne noise computation for Blohm&Voss cruiseship (up) and mine hunter (down)



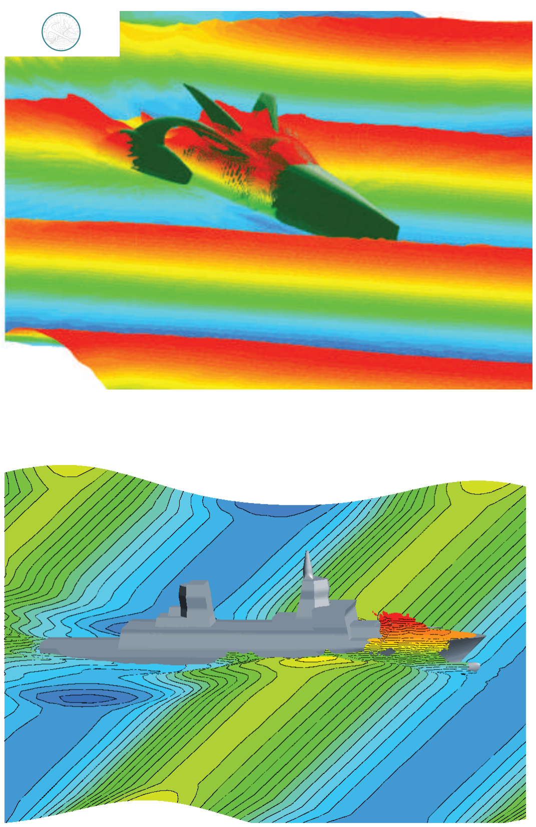


Computational Fluid Dynamics (CFD)

Seakeeping

For many seakeeping issues, linear analyses (assuming small wave height or small wave steepness) are appropriate and frequently applied due to their efficiency. The advantage of this approach is that it is very fast and allows thus the investigation of many parameters (frequency, wave direction, ship speed, metacentric height, etc.). Non-linear computations employing time-domain approaches are usually necessary for the treatment of extreme motions. These simulations require massive computer resources and allow only the simulation of relative short periods (seconds to minutes).

Fig.6. CFD simulation of ships in extreme waves; up: fast trimaran; down: frigate



Combining intelligently linear frequency-domain methods with nonlinear time-domain simulations allows exploiting the respective strengths of each approach, *El Moctar (2005).* The approach starts with a linear analysis to identify the most critical parameter combination for a ship response. Then a non-linear CFD (Computational Fluid Dynamics) analyses determines motions, loads and free surface (green water on deck). We employ the commercial RANSE solver Comet for our purposes, e.g. Fig.6.

Fluid-structure interaction is a topic of increasing importance in our experience. In a weak coupling, the computed pressures from the seakeeping analyses are used to compute the structural response to these forces. In a strong coupling, the hydrodynamic and the structural problem are solved simultaneously. The hydrodynamic model then considers the deformation of the hull, the structural model the loads from the hydrodynamics, *Oberhagemann et al. (2008).*

Rudder flows

CFD is the most appropriate tool to support practical rudder design, Fig.7 (see page 12). The propeller is typically modelled in a simplified way using external forces distributed over the cells which cover the location where the propeller would be in reality. The sum of all axial body forces is the thrust. The body forces are assumed to vary in radial direction of the propeller only. This procedure is much faster than geometrical modelling of the propeller (by two orders of magnitude) at a negligible penalty in accuracy (about 1%). The procedure has been extensively validated for rudder flows both with and without propeller modelling. The same approach for propeller and rudder interaction can be applied for podded drives, *Junglewitz and El Moctar (2004).* Comet allows also the treatment of cavitating flows, Fig.8 (see page 12). The extensive experience gathered in the last 5 years has resulted in a GL guideline for rudder design procedures, *GL (2005), El Moctar (2007).*

Fig.7. CFD model for hull-propeller-rudder interaction

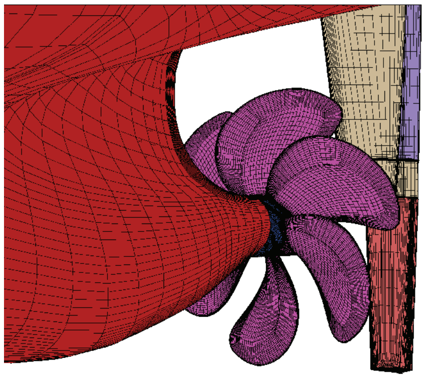
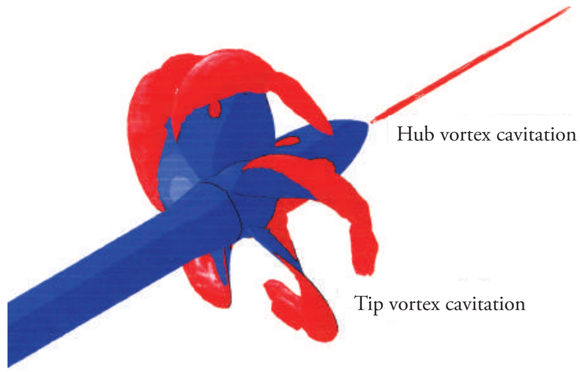


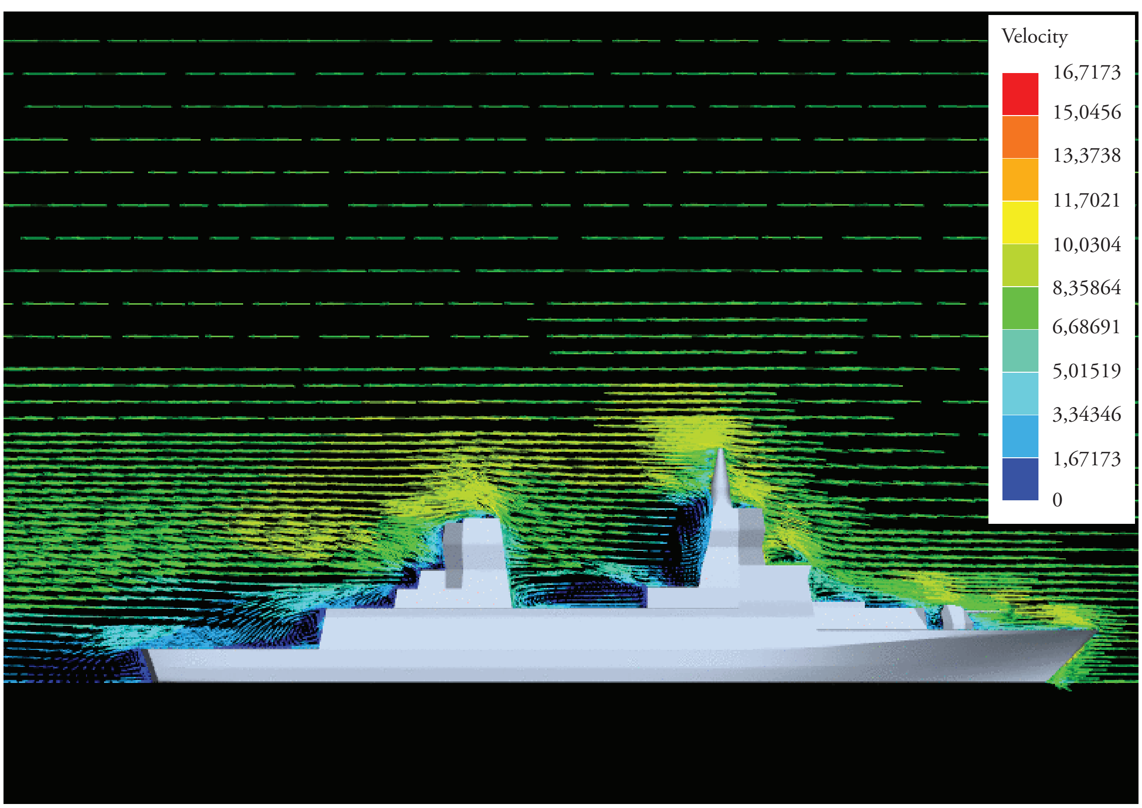
Fig.8. Cavitation predicted at propeller



HVAC and fire simulations

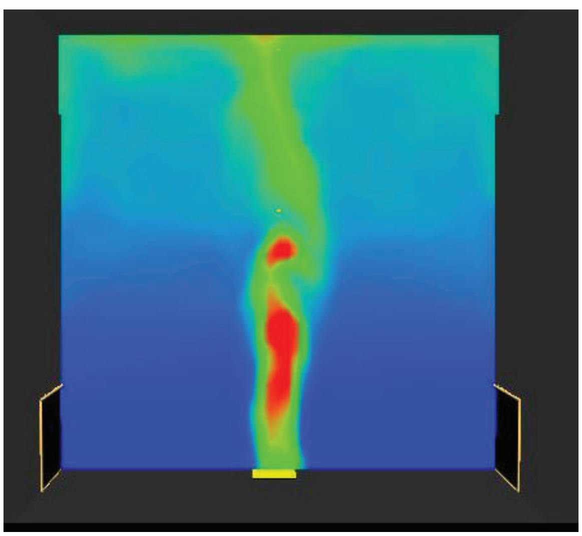
Aerodynamic flows around ship superstructures can be computed by CFD, Fig.9, although wind tunnel tests still are popular and widely used. CFD offers the advantage of overcoming scale effects which can be significant if thermodynamic processes are involved, *El Moctar and Bertram (2002)*. HVAC (heat, ventilation, air condition) simulations involve the simultaneous solution of fluid mechanics equations and thermodynamic balances, often involving concentrations of different gases. Navy applications include for example the smoke and heat (buoyancy and turbulence) conditions on helicopter decks affecting safe helicopter operation.

Fig.9. CFD aerodynamic simulation



At present, zone models and CFD tools are considered for fire simulations in ships. Zone models are suitable for examining more complex, time-dependent scenarios involving multiple compartments and levels, but numerical stability can be a problem for scenarios involving multi-level ship domains, HVAC systems and for post-flashover conditions. CFD models can yield detailed information about temperatures, heat fluxes, and species concentrations, Fig.10. However, the time penalty of this approach currently makes CFD unfeasible for long periods of real time or for large computational domains. Nevertheless, applications have graduated from preliminary validation studies to more complex applications for typical ship rooms (accommodation, atrium, engine room), *Bertram et al. (2004)*.

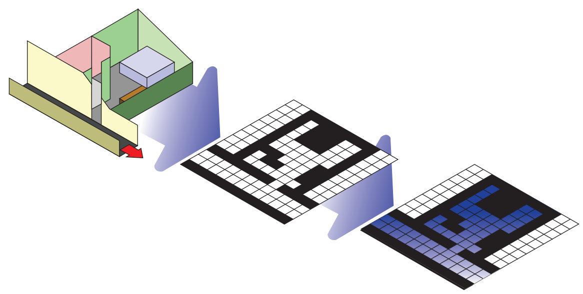
Fig.10. CFD fire simulation

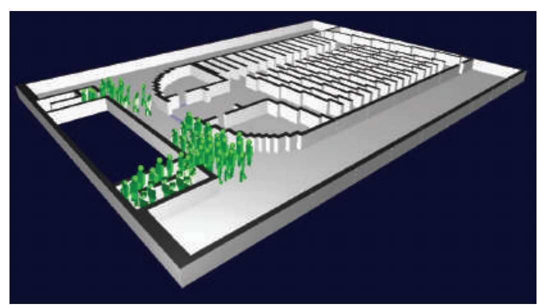


Evacuation simulation

Evacuation assessment became a major topic at the International Maritime Organization (IMO) after the loss of the 'Estonia', resulting in new requirements for evacuation analyses in an early stage of the design process, *IMO (2002)*. Germanischer Lloyd and TraffGo have developed the software AENEAS for this purpose. Evacuation analyses focus on safety, but the tool can be used also for the optimization of boarding and de-boarding processes, *Petersen et al. (2003)*, or space requirements for promenades on cruise ships and large RoPax ferries. These simulations are very fast, allowing typically 500 simulations within one hour, to gain a broad basis for statistical evaluation. The ship is represented by a simplified grid of different cell types (accessible floor, doors, stairs, obstacles/walls), Fig.11. Passengers and crew are represented by intelligent agents. The same approach can be used to simulate crew movement on board of navy ships, e.g. time to man battle stations.

Fig.11. Steps to AENEAS model from CAD model to cells with assigned information





Germanischer Lloyd has developed an integrated methodology called NESTOR, *Petersen and Voelker (2003)*, combining fire simulations with the Multi Room Fire Code, evacuation simulation with AENEAS and an Event Tree Analysis for risk assessment. *Meyer-König et al. (2005)* coupled seakeeping simulations and evacuation simulations in a semi-empirical approach to find the influence of ship motions on evacuation times. Since trim and pitch angles are usually relatively small, their effect is mostly negligible. Roll motions were found to be less critical than static heel for evacuation time.

Final remark

The technological progress is rapid, both for hardware and software. Simulations for numerous applications now often aid decisions, sometimes 'just' for qualitative ranking of solutions, sometimes for quantitative 'optimization' of advanced engineering solutions. Continued validation feedback serves to improve simulation tools as well as it serves to build confidence.

However, advanced simulation software alone is not enough. Engineering is more than ever the art of modelling, finding the right balance between level of detail and resources (time, man-power). This modelling often requires intelligence and considerable (collective) experience. The true value offered by advanced engineering service providers lies thus not in software licenses or hardware, but in the symbiosis of highly skilled staff and these resources.

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Analysis of the current stage of the Brazilian Maritime Industry and study of clusters features in this industry - Naval construction, repair, offshore and nautical

Análisis de la etapa actual de la Industria Marítima Brasilera y estudio de las características del agrupamiento en esta industria – La industria de la construcción naval, reparación, en altamar y náutica

Rui Carlos Botter[1]
Delmo Alves de Moura[2]

Abstract

The present work aims to analyze the Brazilian maritime industry. The core of the work is making an analysis of which are the basic elements to insert this system in the national maritime industry and how it is structured nowadays. The focus of the work is to analyze the four larger segments of this industry in Brazil: shipbuilding, construction of off-shore platforms and ship repair. The research included fieldwork in each national shipyard and other actors in the supply chain of that industry, as well as unions and associations.

Key words: brazilian maritime industry, european maritime clusters, competitiveness.

Resumen

El presente trabajo tiene como objetivo el análisis de la industria marítima brasilera. El núcleo del trabajo es el hacer un análisis acerca de cuáles son los elementos básicos que se necesitan para introducir este sistema dentro de la industria marítima nacional y acerca de la forma en que está estructurado hoy en día. El enfoque del trabajo es analizar los cuatro segmentos más grandes de esta industria en Brasil: los astilleros, la construcción de plataformas marítimas, reparaciones náuticas y navales. La investigación incluyó trabajo de campo en cada astillero a nivel nacional y demás actores dentro de la cadena de suministro de dicha industria, al igual que las asociaciones y sindicatos.

Palabras claves: industria marítima brasileña, clusters marítimos europeos, competitividad.

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Introduction

One of the focuses of this article is to analyze if there is some indication of cluster formation in the Brazilian maritime industry when all its segments are analysed. Another focus is to check whether it is possible to be competitive in the global market. Also, the article tried to observe if Brazilian maritime segments have potential for becoming competitive and developing into a business management model for other segments.

Theoretical review of concept of clusters

One of the most important mentors who treated the subject was Marshall (1985), who dealt with the industrial concentration and the advantages these types of companies could get. He noted that the concentration of industries in one specific geographic region could lead to scale profits, consequently, transforming the economy of that region. Marshall's studies on British industrial districts have inspired many authors to enrich literature, searching on the agglomerations of small companies located in the same geographical area.

Based on Marshall, *Krugman (1995)* says that the geographic concentration originates itself in the interaction between increasing returns, costs of transport and demand and it is based on the resulting agglomerations of the local externalities. Krugman's hypothesis is that the main focus to occur geographic concentration of companies is essentially the economy of scale. This would justify the tendency of costs reduction of transport.

Clusters are formed only when the sectorial and geographical aspects are present. Therefore, cluster or agglomerations are companies of the same segment that are found installed in a nearby geographic area, with legalized and integrated relations, generating knowledge and development for all the actors of this industry *(Amato Neto, 2000)*.

Clusters started to have a larger repercussion after Michael Porter presents its studies in 1990 which originated the base for the competitive advantages of nations. Cluster is the geographic concentration of interconnected companies and institutions in a particular area *(Porter, 1998)*. Cluster is also characterized for involving important approaches of companies and other important institutions for the competition. In that system, all the actors of a specialized supply chain are involved, such as producers of machines and equipments, or suppliers of services and infrastructure. Clusters must consider not only the upstream or downstream, but all the support chain to the consumer, like the companies that complement the products offered to the market, the institutions and other businesses which participate with their specialties and/or abilities in technologies. Clusters also must include the Government and the universities, providing specialized training, education, information, research and technical support.

According to Porter *(Porter, 1999; p. 211)*, a cluster or agglomerate is: '*a grouping of geographic concentration of interrelated companies, and correlated institutions in a determined area, connected for common and complementary elements*'.

Porter based on his Diamond Model for the competitive advantage of nations. In this model, the dynamic interaction between demand conditions, strategy, structure and rivalry of the companies are analyzed on a systemic way *(Porter, 1991)*.

According to *Suzigan (2006)*, Porter accomplished his studies in the analysis of the regional agglomerations, contributing in the area of business economics to the financial health of the companies. That way, he has approached that the competitiveness of the companies in clusters are based on four sets of favourable conditions that predominate in the local environment of business: production factors; demand; presence of suppliers and service industries; and rivalry and strategies of competition from the local companies. *Suzigan, et al. (2006)* make a vast review on the literature referring to the definition of clusters, agglomerations and local systems of production and describe their peculiarities and the variables inherent to each model.

Garcia (2006) analyzes the vision of Marshall, Krugman and Porter about the benefits of the agglomeration of the companies, focusing only the local externalities that emerge spontaneously from the concentration of the producers. The conclusion of the work stands out the importance of these externalities to the local producers that can access a set of knowledge, abilities and services, reduction of costs and increment of the competitive capacity. The elements that corroborate the externalities are: the presence of qualified labour, raw material suppliers, components and equipments suppliers and the occurrence of spill-over of technologies, abilities and knowledge.

Thus, a cluster aims at an increase of reliability, dissemination of know-how, technological qualification of the actors and innovation in the productive processes of the products and services offered. The result is the increase in value of the industries and institutions of the sector.

Gordon & Mccann, (2006) approached that the second model of space cluster which emerged of the traditional economy or neoclassical economy is the industrial complex. The first model was agglomeration. They told that the industrial complex is characterized by the term of business relation among the companies, in what refers to the purchases and sales of products or service. Another aspect analyzed by Gordon & Mccann is the reduction in costs of transport, because of the proximity among the companies. The reduction in costs of communication is other important factor in the proximity among the companies in an industrial complex.

In the ideal cluster, the economy of scale is reached by the total cooperation among the actors of the agglomeration, bringing mutual benefits to all the productive chain. The objective of a cluster is to be able to, physically, have companies close one to the others, promoting contribution. However, it is not always possible *(Dijk; Sverrisson, 2003).*

Physical proximity is only one of several items which characterize a cluster. The other features are: technological cooperation among the companies, long term contracts, shared ethics in businesses, presence of a reasonable number of companies with similar or subsidiary activities. Items related to the characteristics called 'constructed', also corroborate the formation of cluster, as a mutual process of collective learning, relationship created by the transactions among producers and traders, the function of the region in the institutions nearby, such as schools, universities, research and development centres, the function of the municipal, state and federal agents, the level of technology of the region, labour, etc.

There are three forms related to the formation of a cluster and they are characterized as follow. The first one mentions the pure agglomeration, proceeding from the economy of scale and target that flows from the companies located in the same geographic area. This brings three main benefits: the companies can get more prepared labour, can access a larger range of products and services with superior quality and they can get profits related with the information flow and ideas generated inside the complex. The second form of cluster refers to the industrial complex. In this case, the companies are situated next to each other for minimizing the costs of communication, transport and logistic system. The third form of cluster is the social chain where the companies relate themselves, searching for cooperation, aiming to promote loyalty and mutual interest in the businesses, long-term contracts and interpersonal relationship *(Turok, 2003, Simmie; Sennett, 1991).*

There is a variety of definitions in literature, but there is the tendency of using terms such as agglomeration, industrial district etc. *Sennet, Simmie (1991)* make a vast review in literature on different types of implemented clusters in several countries, and describe variables necessary to characterize clusters related to the innovation, therefore these variables can be the competitive differential for the companies faced their competitors and can signify profitability and survival along the time *(Sennett, 2001, Simmie; Sennett, 1991).*
Not all grouping of companies from the same branch can be considered a cluster, and, sometimes, it can only be considered as an industrial district *(Meyer-Stamer; Altenburg, 1999).*

Schmitz (2000) analyzes four clusters: in Guadalajara, Mexico; in Vale dos Sinos, Brazil; in Sialkot, Pakistan; and in Agra, India. Schmitz studies the behaviour of the variable cooperation in these clusters and verifies whether this variable collaborates for the competitiveness of the searched clusters. In some clusters, the variable is a competitive differential for the success, while in other ones it has average relevance for the businesses.

When a cluster is analyzed, it is essential to evidence the presence of local externalities related to the size of the market, specialized labour and technological spill-over (overflow) which could favour the local specialization, besides linkages of production, commerce and distribution. There must be cooperation in marketing, promotion of the exportations, supplying of essential inputs and also research and development, in order to reach balance between competition and the cooperation. All the companies of a cluster must benefit themselves with the support from the local institutions. There are private and public actions that can corroborate the development and the promotion of a cluster. The engagement of adjusted policies, social and cultural identity can all promote confidence and exchange of information among the companies, benefiting the set of organizations *(Suzigan, et al. (2006)*.

The external economies can be called of services or profits that a producer provides to another one without any compensation *(Igliori, 2001)*. The external economies can, thus, be classified in three great groups: technological economies, market economies and economies of organization. The technological economies involve impacts in the function production and become directly related with technological standards (innovation in the market and in the production process) adopted: physical conditions - climate and ground, etc. - offer of raw materials, infrastructure of transport, etc. *(Machado, 2003)*.

Implementation of clusters

Waits (2000) approaches the composition of the essential agents from the aerial-space segment and the formation of the three main levels, such as leader companies in the exportation, support companies and the specialized foundations that compose the plan of economic and strategic development from Arizona. In the State of Arizona, a programme called ASPED was implemented, that means, Strategic Plan for the Economic Development of Arizona, and nine groups of clusters have been implemented.

Each cluster had an economically representative leader company for the sector in study. Arizona's Government has chosen a representative for each cluster that is responsible in selecting actors that represent several levels of each cluster formed of small, medium and large companies related with the final production, as well with the supply chain. Each cluster also had a representative from Universities, from chambers of commerce, lawyers and marketing companies. The member was responsible for pointing out the necessities and inherent opportunities of each segment to the groups. Each cluster had five great demands to be executed:

- Cataloguing the main components of each segment as well as mapping the inter-relationship among the companies;
- Articulating a vision that could be reached over what each cluster could become in the next 10, 20 years;
- Identifying chances of growth of each cluster in a direction desired for the expansion of the companies and preferably attracting new ones from other regions;
- Identifying chances of larger synergy inside of each cluster; and
- Identifying necessities of specific economic justification and proposed strategies.

According to *Waits (2000)*, the concept of industrial clusters has been contributing immensely to the policies of the State of Arizona, with the educators and the economic development of the region, fortifying the enterprises and adding value to the clients. After the implementation of the ASPED, the authorities that elaborate the policies in the State of Arizona started to understand the importance of being competitive, developing economic strategies for the 21st Century, focused on the industries guided for the global market. Consequently, with the new strategies of industrial policies for the State of Arizona, some specific objectives hve been also lined up, as more qualified works and high standard of living to the citizens of the State.

Altenburg; *Meyer-Stamer, (1999)* tell the experience of clusters in Latin America and emphasize that these agglomerations are characterized by small and micro companies with low entrance barrier, little specialization of labour and products with low technology. Altenburg; Meyer-Stamer also success cases as the one from Chile, called Proyectos de Fomento (PROFOs), which is a three-year contract among a group of five or more from small companies and agencies of public or private support, considered as a network broker. These groups receive assistance for integrating its activities, such as market research, studies of economic viability, or to participate commercial missions or fairs.

There is the experience from Denmark in the implementation of the first studies about cluster *(Drejer, et al., 1999)*. They approach several clusters that were analyzed and implemented, as well as state that among the ten countries used for Porter in its research on competitive advantage; clusters implemented in Denmark has served as study base.

Floysand; *Jakobsen (2001-2002)* analyzed the internal factors related with cluster of fishery in Norway, and told the potential problems inherent to the system focused on the social ambit. The research mentions the degree of rivalry between the competitors of cluster and the way they duel for inserting and keeping their products in the international market. The article shows another side of the cluster, different from several authors regarding to the cooperation among the companies, exchange of information and team work.

Worldwide maritime clusters

All clusters must have, at least, one company that is considered a leader, for being able of multiplying the knowledge for the other ones of the chain. The leader company should have the following characteristics: to be engaged with Research and Development and to have access to the international market *(Langen, 2002).*

The Norwegian maritime cluster is composed of Norwegian associations of navigation, Norwegian federacy of engineering and industries, associations of metallurgic workers and maritime associations, of companies that own boats, shipyards, industry of maritime equipments, brokers, financial companies, insurance companies, consultancies, etc., totalizing over 600 members, including governmental representatives. They have these goals: defining the industrial policies; promoting the cooperation among the members of different sectors inside of the maritime chain; and promoting the international businesses, benefiting the Norwegian maritime industry.

The Norwegian maritime sector employs around 75 000 people in the following maritime sectors: naval construction; repairs; industrial equipment; industry of oil and offshore; the association of the companies of maritime navigation; coastal shipping companies; ports; consultancies; institutions and research centres; training and education institutions; brokers; financial companies and banks; insuring and engineering *(Langen, 2002).*

In Norway, the maritime cluster begun around the year of 1990 and was opened for all the companies and organizations that, somehow, were related to the maritime industry. It was necessary the commitment for the employers to the employees, so that the idea of cluster was implemented successfully. Organizations such as the association of companies of the Norwegian navigation, federacy of the Norwegian industries of engineering, association of workers of metallurgic industry and Norwegian association of workers of the maritime sector, shipyards and repair, industry of oil and offshore, research institutes, maritime equipment companies, brokers, financial companies, insurance companies, and consultancies, eight regional organizations, ports, education centres, training institutes and governmental agencies, were some of the 600 members that participated in an integrated way for the discussion of the problems and implementation of the maritime cluster concept for benefiting the local maritime industry *(Lahnstein, 2004).*

The initial objectives defined for implementation of the Norwegian maritime cluster were: defining industrial policies, promoting cooperation among the companies of the segments related to the maritime industry and inserting the Norwegian products in the international market.

The maritime cluster was implemented in the country in 1996, after six years of discussion with all of the actors involved with the Norwegian maritime industry. But it was only in 1996, that the industrial policies were, in fact, used by Norway. For a cluster to be a case of success, it is basic to follow some steps, such as: defining cluster, establishing its importance, promoting visibility in the domestic scene, defining industrial policies, establishing the demand of the sector and promoting commitment of the supply chain, monitoring and keeping the defined levels and the strategies, promoting exportation and internationalization, promoting innovation, research and development, mainly for the leader companies, and establishing goals for reaching the necessary education for the labours, supplying the market *(Lahnstein, 2004).*

The case of Panamanians maritime clusters started at the construction of The Panama Canal that has assisted in the competitive necessity of the horizontal and vertical maritime industry. The service segment is directly related with the Panamanian maritime industry that is the great stimulus to the economy in the country. Panama's GDP in 2001 was of 10.25 billion of dollars. This year, the businesses related with the maritime industry have represented 1,971 billion of dollars, approximately, 19.22% of the GDP, and have employed 26,875 employees connected to the sector *(Maucci; Lugo, 2002).*.

There are five large central activities which support the economy: The Panama Canal, Ports, Register of Vessels, Free Zone of Colon and Fishery. About the related industry and the other maritime services, it can be cited: Maritime industry; Pilotage; Fuel supplying; Maritime research; Dredging; Companies of navigation; Logistic operators; Services of repairs; Centre of maritime training; Travel agents); Other Sectors; Hotels; Restaurants; Centres of specialized training; Airports; Banks; Financial companies; Tourism; Insurances; Activities of recreation and Commerce, in general *(Maucci; Lugo, 2002).*

In The Panama Canal, approximately, 4 000 ships per year generate 14 000 tickets, which generate activities related with supply of fuel, repairs of boats, ports specialized in the movement of containers and liners *(Maucci; Lugo, 2002).*

The flag registration of vessels also involves an enormous contingent of companies and people directly involved with the maritime service. The Free Zone of Colon is a worldwide logistic centre, generating thousands of jobs and stimulating the economy of the Country. The industry of fishery also generates thousands of direct and indirect jobs.

The Belgian maritime cluster is characterized by a small number of companies that are considered of great deadweight, and these ones occupy prominent position inside of certain specific segments of the market, or are companies of large international repercussion, as in the case of the sector of hydraulic engineering. Belgium has perceived that it was necessary to have companies of prominence inside specific niches that have corroborated, excessively, the implementation of maritime clusters in the country.

The Danish specific sectors that form the maritime cluster are: the waterway transport, maritime services, naval construction, maritime equipment, offshore for gas and oil extraction. The companies are supported by institutions related with the governmental authorities of the country, universities and centres of technological research, technical schools, centres of training and associations of class, companies related with the productive chain of each maritime segment and financial or insurance companies. There is integration among the actors that participate of the Danish maritime cluster with focus in promoting the national development, and the country can be competitive in the world-wide maritime activity, inside some specific niches *(Drejer, et al., 1999).*

In the year of 2004, Denmark had: 17 companies of navigation; one shipyard; 12 companies of ship; three companies related with the port authority; 13 education and research centres; four institutions related with the governmental authority; ten companies of maritime commerce; 27 consultancies and service; and, five companies related with the financial sector and insurance *(Drejer, et al., 1999).*

In the year of 1999, 37 out of 1 000 people acting in the work market were related with the activity of inland trade, 78 were related with the segment of maritime services, 24 with the segment of naval construction, 54 with the segment of maritime equipment, three with offshore, representing approximately 7.2% from the total of the Danish economy. Therefore, the Danish maritime cluster is highly meaningful for that country when compared to its economy *(Drejer, et al., 1999).*

After the year of 2004, the cited numbers above grew more, stimulating the Danish economy, since there has been a bigger integration among the pertinent actors of the maritime sector. An association was created to approach the actors, to organize the segments and to discuss the common particularities that they had the common interest. Several conferences and meetings were necessary to promote the synergy among the integrated actors. A strong campaign of international marketing was carried out to promote the image of the country related with the maritime segments. The association which was created had also the objective to promote and stimulate the research, to develop products and services with technological value, specially, with the education of superior and technical schools. It was necessary to have partnerships with many related European associations with the maritime area and with excellence centres in research for development of qualified and specialized labour *(Drejer, et al., 1999).*

The Dutch maritime cluster was one of the pioneers in Europe, initiating its activities in 1996; and, in 1997, it was established an association called Dutch Maritime Network for managing this activity and to give the total support to its implementation in Holland. The Dutch maritime cluster started its implementation with the following maritime segments: sector of navigation, naval construction, ports, inland trade, dredging, offshore activities, equipments suppliers, Dutch navy, maritime services, nautical and fishery industry.

An intense work in all Dutch community for implementation of cluster was carried through, with the participation of the society, the government and the actors of the maritime segments. This spreading has involved means of communication such as journals, specialized publications in the maritime segments, television programmes, advertisements in schools, visits to the ports, electronic media and websites. That was the initial form to promote this type of discussion for all the society and to integrate all the Dutch maritime actors for the growth of the Dutch maritime industry *(Nijdam; Langen, 2003).*

The competitiveness of a cluster depends on the interaction among the companies related with it. From the total of € 70 billion of aggregated value produced by the European maritime industry in the year of 2001, 10% of this value was generated by cluster of the Dutch maritime industry. To structure a cluster, it is necessary to have a leader company in the market that attracts the other companies related with the segment. In Holland, the implementation of maritime cluster has always had as starting point, the adhesion of a leader company *(Nijdam; Langen, 2003).*

A leader company is likely to be the one that possess a definite impact in the other ones related to the cluster in analysis. It must be capable to contribute with the competitiveness of its partners, sharing knowledge, adding many companies of the sector, contributing to add value in all supply chain of the sector. It also must occupy a central position due to its relationship with the supply chain and final customers. The one must surpass for the changeable innovation, as much in the process as in the products.

The leader company should have an outstanding position in the market, stimulates the development of new abilities and knowledge for the sector, and stimulates new investments permeating this knowledge to the other companies related to the sector, making, thus, the natural growth of cluster in which is placed. The benefits of the externality transmitted to all the companies related to a determined cluster is a principle that characterizes a cluster, therefore when only some companies of any segment are benefited due to this externality (acquired knowledge), this do not characterize a cluster, but an industrial district or something similar to that *(Nijdam; Langen, 2003)*.

Investment in externality of the leader company includes investments in innovation and internationalization. The knowledge must be permeated to all the companies of the cluster. Other essential factors for a cluster to obtain success are: investment in training and education, knowledge and information related to the necessary infrastructure aspects to all the companies related with cluster. This set of factors assists, excessively, the competitiveness of the cluster *(Nijdam; Langen, 2003)*.

To determine the leader companies in each Dutch maritime segment, in order to carry through the conception of cluster, the following methods were used: interviews with the associations of class from each maritime segment to get information about the leader companies in the vision of the associations because they needed to be based on some criteria. They are: first, the size of the company analyzed by its turnover, the number of employees and its invoicing; second, the number of subsidiaries outside the country, because it measures the internationalization of the company; third, number of patents, because it measures the ability that the company has for innovation; and fourth, number of companies inside of an association in which one organization is admitted, because that fact is linked with the negotiation power with the governmental agencies (*(Nijdam; Langen, 2003)*.

The actors related with the maritime industry were heard for the implementation of the Finnish cluster. Moreover, it had the intense support of the Ministry of the Communication of that country and the Ministry of the Finances, Commerce and Industry as well as the Centre of Finnish Maritime Studies. The preliminary studies for implementation of cluster in Finland initiate in the year of 1991, after the country had been invited to participate on a research developed by Michael E. Porter in 1987 and 1988, referring to a study on competitiveness in ten countries *(Viitanen, 2003)*.

Viitanen (2003) says that the cooperation among the companies in a cluster is very important, therefore, the innovation and the development can be permeated through all the companies, benefiting the set and not one or another company. This would be a way to assure the competitiveness among the companies and with this, the possible threats related with cluster would be better managed and eliminated or minimized.

The structure of a cluster must contain, at least, one company that is considered leader or a set of companies that produce products considered essential. There must be support companies considered suppliers of the leader companies and, also, associations of class, universities, educational centres, research centres, financial institutions and government [26].

Finn maritime cluster has developed itself around of two main segments: naval construction and construction for transport of passengers. During the Second World War, the Finnish shipyards were requested to supply the fleet of the old Soviet Union and, also after the Second World War. They have also specialized in naval repair segment *(Viitanen, 2003)*.

In the end of 1985, big groups of naval construction were in difficulties, and it was necessary to structure this industry. With the economic contraction of that period and the end of the order of naval construction from the extinct Soviet Union, the scenery of the Finnish naval industry was summarized in a shipyard focused in the products of offshore construction, a specialist in the construction and development of projects focused in the area of vessels construction in the transport of passengers, luxury cruises, ferryboats, vessels boats for patrol and defence and ice breaker ships, and another one in the naval construction, such as, for example, LNG ships. In the segment of passenger liners, Finland is ones of the first in the world, when it refers to the exportation of products. These are the main products that are produced in the Finnish maritime industry: cruise ships, ferryboat for the transport of automobiles, cargo ships, ice breakers, special patrol ships, special ships for research, special tanks and offshore. Factors that has contributed to the maritime industry of this country are: know-how of engineering, know-how of the technology required, know-how of development and projects, quality systems, the environmental and the security technology *(Viitanen, 2003).*

Several other segments contributed to structure the Finn maritime cluster, such as: steel industry, metal mechanics industry, industry of pieces for ships, industry of interior projects in vessels, electronic industry, hydraulically engineering, among others. Services were also part of this process, such as: financing sector, insurance sector, research centres, workers associations, and repair and maintenance services.

European maritime clusters

The aggregate value of cluster from the European maritime industry (European Community) in the year of 1997 was approximately € 159 billion. The direct value generated by the industry of cluster from the European maritime industry was of, approximately, € 70 billion, as shown in table 1 *(Wijnolst et al., 2003).*

Table 1: Direct aggregate value generated by cluster from the European maritime industry

Cluster	Direct medium aggregate value (billion in €)	Indirect medium aggregate value (billion in €)	Medium generation of labor in the sector (thousand)
Navigation Transport	15,7	15,7	16
Ports	15,8	2,5	15,5
Maritime Equipments	9,3	7,2	8,7
Offshore	7	4,5	7
Fishery	7	1,5	7
Naval Construction	7	10,3	7
Maritime Services	6	1,5	6,1
Inland Trade	2	0,2	1,8
Nautics	1	0,5	1
Dredging	1	0,5	1

Source: *(Wijnolst et al., 2003).*

Navigation/Transport: the financial movement was of, approximately, € 48 billion in 1997. The navigation/transport is the biggest maritime sector in Europe, and Norway was the country that was more benefited from this type of financial movement, followed by Denmark, Germany, the United kingdom, France, Italy, Sweden, Holland, Greece, Finland, Belgium and with really small parcels in this analysis sector, there are Portugal, Ireland and Spain.

In accordance with the European Commission, the cluster in study (Navigation/Transport) has obtained € 15,7 billion in financial profits, and the most benefited countries, ordered by monetary value in €, were: Germany, the United Kingdom, Norway, Denmark, Italy, France, Greece, Holland, Sweden, Finland, Belgium, and with really small parcels, we have Portugal, Spain and Ireland *(Wijnolst et al., 2003).*

- Naval construction: the financial movement in 1997 was of, approximately, € 10,3 billion in new constructions, € 5,7 billion in repairs and conversions, and € 3,4 billion in the naval construction. The leader countries were: Germany, Italy, Norway, Finland, Holland, Denmark, France, the United Kingdom, Spain, Portugal and Sweden.
- Maritime equipments: the financial movement, in 1997, was of, approximately, € 22,4 billion. The countries that were more benefited were: Germany, the United Kingdom, Norway, Italy, France, Holland, Spain, Denmark, Finland, Sweden and Greece.
- Port and Ports Services: the financial movement was of, approximately, € 15,2 billion in 1997. The most benefited countries benefited were: Belgium, Italy, Holland, Spain, Germany, the United Kingdom, France, Denmark, Sweden, Finland, Portugal, Greece, Ireland and Norway.
- Offshore: the financial movement was of, approximately, € 16,4 billion in 1997, concentrated, practically, in four countries: The United kingdom, France, Norway and Holland.
- Inland trade: the financial movement was of, approximately, € 3 billion in 1997. Two countries dominated the sector: Holland and Germany, due to its localization next to the River Reno basin.
- Fishery and Aquiculture: the financial movement was of, approximately, € 11.7 billion in 1997. It is one of the biggest sectors in Europe. Four countries have the biggest sectors of fishery and aquiculture: Italy, Spain, Norway and France.
- Dredging: the financial movement was of, approximately, € 2,9 billion in 1997, practically concentrated in two countries: Holland and Belgium.
- Maritime services: the financial movement was of, approximately, € 10 billion in 1997. The United Kingdom possesses the biggest parcel, followed by Denmark, France, Germany, Italy, Holland and Norway.
- Yachting: the financial movement was of, approximately, € 3 billion in 1997. Three countries dominated: France, the United Kingdom and Italy.

The direct value generated by the European maritime industry was estimated in € 70 billion and constituted almost 1% of the European gross domestic product in 1997. The aggregate value corresponded to 44% of the invoicing in the maritime sectors (total of € 159 billion). The total labour, estimated, was of 1 545 000 people. Around 33% (about € 23 billion, out of the € 70 billion), generated by the direct aggregate value returned to the governments in the form of taxes and social contributions. The sum generated by the direct aggregate value of the maritime industry was used in investments in the private sector. The private sector has consumed € 16 billion, from the € 70 billion, and the investments were of € 19 billion. But only 17%, of the € 70 billion - (€ 12 billion) were expended in services and goods outside of the European Union *(Wijnolst et al., 2003).*

Europe, in order to become world-widely competitive and to face the Asians, such as Japan, South Korea, China, Singapore etc., has adopted the strategy to compete in the segment of ship construction with sophisticated ships, in special, the ones of passengers, besides the emphasis in the industry of ship pieces, with products of high technological value. In 2004, the total production of Europe, in terms of delivery in CGT, was inferior to the production in South Korea, nearly three times smaller; however, in terms of revenue, the European shipyards obtained almost 10% more (€ 1 billion) than the ones from South Korea *(Coutinho, 2006)*.

Methodology

For the research, 31 shipyards were visited in Brazil. From this total, 14 shipyards are from the segment of nautical construction, tourism and leisure. There are 20 shipyards which belong to an association of class from the nautical segment. The most representative shipyards, in terms of sales, for domestic and international market, and in terms of volume of production were visited personally for data collection (research in field).

In the segment of ship construction, there are, currently, nine shipyards in Brazil and seven were visited for application of the questionnaire. In the platform segment, there are five shipyard/ EPC (Engineering, Procurement and Construction Contracts) and all had been visited. In the segment of ship repair, all the five shipyards were visited personally.

The methodology consisted in the qualitative type research *(Mattar, 1999; Cooper; Schindler, 2003; Babbie, 2001; Selltiz Et. Al., 1987; Botelho; Zouain, 2006)*. It was carried through by means of personal interviews, with entrepreneurs, presidents, directors and managers of the maritime industry. The criterion used for election of the companies in the qualitative research was based on the importance of the company inside its segment. Therefore, the questionnaire was applied exclusively in the 31 visited shipyards. However, other data had been collected personally in the other actors of the national maritime industry.

Current scenery of the Brazilian maritime industry

In the State of Rio de Janeiro there is a concentration of shipyards focused on the segments of the ship construction, repair and offshore platform construction. Analyzing the geographic localization aspect, these segments of the Brazilian maritime industry have a strong characteristic of cluster *(Porter, 1999)*. However, the geographic aspect is not enough to evidence the cluster. When it is analyzed the integration factor among the shipyards of these segments in the State of Rio de Janeiro, the research has pointed out that is almost inexistent the exchange of experience, know-how, technology or knowledge among the companies. Few are the suppliers that participate on the development phase of products from the shipyards and when this occurs, it is generally in the offshore platform segment where there is the PROMINP programme and the leadership of Petrobras, that contributes for the small integration among the companies of this specific segment (offshore platform construction). The integration with the other actors of these segments, such as universities, research and development centres, government, etc. is isolated and without industrial policies that contribute for the development of the Brazilian maritime segments. Most of the supply chain of these segments is geographically distant from the state of Rio de Janeiro.

When the segment is analyzed, it is evident that there is not a cluster; therefore the shipyards are installed in several places in the country, with enormous distances among them and also with their supply chains. There is not any kind of integration among them, not even integration with universities, research and development centres, government, and the other actors from the nautical segment. There isn't currently any industrial policy which contributes for the development of this segment in Brazil and of its supply chain, despite being a promising segment to the insertion of products in the North American and European market *(Moura, 2008; Moura; Botter, 2009)*.

There is in Brazil a programme called PROMINP - programme of Mobilization of the National Industry of Oil and Natural Gas, coordinated by the Ministry of Mining and Energy, with the objective of maximizing the participation of the Brazilian industry of goods and services, in competitive and sustainable bases, in the implementation of projects of oil and natural gas in Brazil, and also abroad.
PROMINP project is focused on implementation in the areas of exploration and production,

maritime transport, supplying, gas and energy and ductway transport. The focus is to identify and to implement qualification actions of the industry, on a way to take care of the demands of the projects in investment from the operators of the oil and natural gas sectors. It has the participation of the Ministry of Mining and Energy (MME), of the Ministry of Development, Industry and Foreign Trade (MDIC), of Petrobras, of The Brazilian Development Bank, of the National Organization of Oil Industry (ONIP) and the Brazilian Institute of Oil and Gas (IBP), that congregates all the Brazilian operators. The National Confederation of Industry (CNI) and the following class associations also participate: Brazilian Association of Industrial Engineering (ABEMI), Brazilian Association of Engineering Consultants (ABCE), Brazilian Association of the Infrastructure and Base Industries (ABDID), Brazilian Machinery Builders' Association (ABIMAQ), Brazilian Association of the Electric and Electronic Industry (ABINEE), Brazilian Association of the Industry of Pipes and Metal Accessories (ABITAM) and National Union of the Industry of Construction and Naval Repair and Offshore (SINAVAL).

PROMINP developed its first studies in the years of 2003/2004. In that period, it was evidenced the necessity of qualification of an enormous number of labour. The results identified by the diagnosis system, pointed to the necessity of a demand for qualified labour, until the end of 2007. Thus, a huge effort became urgent aiming at specialization and professional education.

After many months of study, it was conceived, then, the Plan of Professional Qualification of PROMINP, which has the objective to structure actions for qualification of labour in the 150 job categories considered critical in the diagnosis.

In order to take care of the total demand of 70 thousand qualified professionals until the end of the year of 2007, 64 thousand professionals of basic and technician levels, and 6 thousand of graduate education will be trained, involving more than 40 education institutions. 580 courses and 3 800 groups in several Brazilian states, It is foreseen an investment around US$ 110 million *(Moura, 2008; Moura; Botter, 2009).*

PROMINP project in Brazil is much similar to the cluster system of the maritime industry implemented in Holland and Norway and, it is a model that can be expanded to the other segments of the Brazilian maritime industry; therefore, it involves many agents who are direct or indirectly related with the national maritime industry.

As this programme involves an expressive number of organizations, and there is enormous demand for products with assured quality by Petrobras (the final customer), it is observed the existence of a bigger demand for qualification of the suppliers of parts and equipments.

It is important to stand out that in the segment of platform/UEP/FPSO construction, it is a requirement of Petrobras that the supplier possesses products/components/parts with assured quality and this factor collaborates so that 100% of construction companies (EPC), or shipyards have qualification. That way, two negative points inherent in the domestic maritime industry could be eliminated with the implementation of models similar to PROMINP and to the other segments of the maritime industry: qualification of the suppliers and qualified labour.

Being competitive in the maritime industry demands the necessity of qualified labour, and, currently, only the segment of platform/UEP carries through some type of investment with this purpose. The shipyards train this specialized labour directly in its physical installations to supply, exclusively, their necessities. A school such as Senai (National Service for Industry), is a great generator of labour for the sector, the Armory of Rio de Janeiro's Navy also possesses professionalizing courses that prepare specialized labour for the sector. Inside of the PROMINP programme, the qualification of the labour, for the sector of platform/UEP construction is foreseen, due to the necessity of constructing platforms for Petrobras.

Fig. 1 demonstrates on a punctual form, the strong, weak and very weak points of the Brazilian maritime industry. For Brazil to become world-wide competitive in this industry, it is necessary to have a national plan of development that involves all or the main direct and indirect actors from all the segments. It will be necessary to have an involvement and commitment of governmental spheres, unions, associations, owners, universities, research and development centres, technical schools, industry federations, confederation of industries, services, agencies of research and technology *(Moura, 2008; Moura y Botter, 2009).*

Fig. 1. General characteristics of the Brazilian maritime industry

Item	ST	WK	TWK
Qualification of the Suppliers.	X		
Outsourcing Products/Services.		X	
Pieces Produced in Brazil.		X	
Integration between Shipyards and Supply chains.		X	
Technological Partner between Shipyards and Supply chains.			X
Participation of the Suppliers in the Project Developing Phase.		X	
Existence of Control Mechanisms with Delivery Term of the Suppliers.	X		
Suppliers with Long Term Relationship.		X	
Horizon of Production Planning.	X		
Integration of the Information of Production Planning between Shipyards and Supply chains.	X		
Domestic Vessel Project.		X	
Supplier participating in the Project of Vessel Development Phase.		X	
Service of Technical Assistance.		X	
Integration between Shipyards and National Universities.		X	
Industrial Policies.		X	
Qualified Labor in the Maritime Industry.		X	
Dredging			X

Captions: Strong (ST); Weak (WK) e Too Weak (TWK)

Fig. 2 presents the division for segments of the Brazilian maritime industry and describes the characteristic of these sectors in relation to the following points: whether the segment is on a strong, medium or weak phase in relation to the critical points for being competitive in the sector. The conclusions refers to the descriptive analyses from the statistical inferences proceeding of the research in field carried through in the Brazilian shipyards *(Moura, 2008; Moura; Botter, 2009).*

Fig. 2. General characteristics of the Brazilian maritime industry

Item	Yachting Segment	Naval Construction Segment	Platform Segment	Naval Repair Segment
Qualification of Suppliers.	Medium	Medium	Strong	Strong
Suppliers participating of the Project Developing Phase.	Weak	Medium	Strong	Weak
Technological Partner between Shipyard and Supply chain.	Weak	Weak	Strong	Weak
Mechanisms to Measure the Delivery Term of the Suppliers.	Weak	Strong	Strong	Weak
Integration of the Planning Production Information.	Strong	Strong	Strong	Weak
The Supply chain supplies: Raw material (RM); Subsets; Pieces/Components or All the Products.	Strong	Strong	Strong	Strong
Supplying of National Products in the Agreed Terms between the parts.	Strong	Strong	Strong	Strong
Supplying of Imported Products the Agreed Terms between the parts.	Strong	Strong	Strong	Strong
Standardization of Products Deriving from the Supply chain (National and Imported).	Strong	Strong	Medium Customi-zation	Strong
Suppliers Actuating Physically in the installations of the Shipyards.	Weak	Strong	Strong	Few
Domestic Vessel Project.	Weak	Medium	Strong	There is nothing
Imported Project Contemplates Acquisition of Pieces/Components.	Weak	Strong	Não há	There is nothing
Participation of the Suppliers (National/International) in the Project Development Phase.	Weak	Strong	Strong	Strong
Existence of Supplier Groups to straighten out the Problems of the Shipyards (National and International).	Weak	Strong Imported	There is nothing	There is nothing
Use of Turnkey System between Shipyards and Suppliers (National and International).	Inexistent	Strong	Strong	Strong
Sending of Production of Shipyards Program with antecedence to the Suppliers.	Medium	Medium	Weak	Medium
Qualified Labor for Supplying the National Maritime Industry	Weak	Weak	Weak	Weak
Technical Assistance in Brazil.	Weak	Medium	Strong	There is nothing
Technical Assistance in Brazil.	Weak	Weak	There is nothing	There is nothing
Partnership in the Exterior for Services of Technical Assistance.	Medium	Medium	There is nothing	There is nothing
Integration between Shipyards and Universities.	Weak	Medium	Medium	There is nothing

Importance of the Integration between Shipyards Universities.	Strong	Strong	Strong	Strong
Existence of Governmental Subsidies.	There is nothing	Strong	Weak	Weak
Industrial Policies	There is nothing	Weak	Strong	Weak
Using of the Merchant Navy's Fund.	There is nothing	Strong	Medium	Weak
Tax of interests in Brazil.	Strong	Strong	Strong	Strong
Financing of BNDES.	There is nothing	Strong	Medium	Medium
Exportation.	Medium	Weak	Strong Services	There is nothing
International Barriers for the Insertion of Products.	There is nothing	Medium	There is nothing	There is nothing
International Certificates to Insert in Products in the Exterior.	Strong	Weak	Strong	Medium

Source: *(MOURA, 2008).*

Some important points that can be inferred originated from the analysis carried through in figure 2 and of the descriptive statistics, are:

- Competitiveness of the Brazilian products could increase with larger participation of the suppliers in the project development phase of the shipyards/EPC. The integration could result in benefits to eliminate or to reduce problems related to the production phase of the shipyards/EPC and to increase the degree of partnership among the parts. Suppliers would better understand the businesses of shipyards/EPC and could produce products focused on the necessity of the maritime industry. Also, the integration of the parts could develop suppliers to fill up international markets.
- When the participation of the suppliers in the project development phase by segment is analyzed, it is noticed that in the platform/UEP/FPSO segment, there is more integration among companies that acts in the EPCs system (Engineering, Procurement and Construction Contracts - Contracts related with a specialized company in the engineering of the project management, in the purchase of parts and components management and in the construction of the enterprise management). Some companies that act in the construction sector of Platforms/UEP are not shipyards, but, they are managers of EPCs enterprises [34].
- As there are few companies that produce, exclusively, for the Brazilian maritime industry segment, and, even though for international maritime segment, there is a small integration between suppliers and shipyards. Another relevant factor is the fact that, the demand related to the maritime industry, being small, many times, does not justify to the supplier to invest time for a bigger integration with the shipyards. The percentage of suppliers that participates as technological partner in the Research and Development area with the shipyards or companies of enterprises/EPCs management is more representative in the Platform/UEP/FPSO construction segment than in the other segments, because of PROMINP programme and, certainly, the power of the biggest customer of these types of products, Petrobras. Even in the maritime segment of platforms/UEP/FPSO construction, still, there is a field for wider integration among companies, universities, research centres to improve the participation of the companies in the products development

phase, according to the opinion of the proper interviewed companies. This percentage is relatively low for the yachting segment, naval construction and Naval Repair with values of 30.8%; 33.3% and 25.0% respectively.

- The technological partnership in the Research and Development area in the Naval Repair segment is mentioned in the research because there is a shipyard which has recently signed a partnership with a South Korean shipyard and some results related with the Research and Development area has already affected positively its activities in Brazil.

By its own characteristic, the Platforms/UEP/FPSO construction segment, is much well evident, because it is clearly noticed the integration with universities, research centres, technical schools, Government, society, associations, etc. In the Naval construction segment, there is partnership when it deals with suppliers with great bargaining power in the supply chain or when it is considered strategic suppliers for the shipyards, such as supplying of maritime engines and other vital components for the shipyards business (MOURA, 2008).

There are Brazilian companies searching for bigger integration with the shipyards in Brazil, to understand, with more details, which is the real necessity of the market in terms of demand and specific products. In the Nautical construction segment, this fact also happens with the suppliers considered strategic for the shipyards and, in its majority they are suppliers of imported components.

Conclusion

As for the item cluster, the experience of implementation in some European countries can be used. It is necessary to raise all the related actors aware of having companies leading this project for integration of all the actors from the domestic maritime industry. There is the necessity of participation of the government, universities, research and development centres, employers associations, unions, workers, governmental or private financial companies, the companies of maritime and waterway transports, associations of machines and equipment producers, suppliers of essential raw material, the society, etc.

Through the bibliographic review carried through in this work, in the topic about cluster and maritime cluster, it can be concluded that the segments of ship construction, naval repair and Offshore/UEP, as in Fig. 3, installed in the State of Rio de Janeiro, have potential for cluster development, compared to the shipyards installed in other States of the country. For having a bigger concentration of shipyards in one specific region of Rio de Janeiro, as it is in the case of Niteroi, this factor contributes to the cluster development *(Moura, 2008; Moura y Botter, 2009).*

With the exception of the PROMINP programme, there is nothing structured among the actors of Brazilian maritime industry that characterize a cluster in Brazil but the proximity of localization among the shipyards. There are employers' associations searching for approximating to actors related with the maritime industry, but yet, slowly. There is the necessity of having larger participation of the society, government, suppliers of machines and equipment, parts and components, universities, technical schools, research centres, etc.

PROMINP programme is much similar to the model of cluster implemented in Norway and Holland which has been succeeding. However, an enormous differential is that in the two European countries, the cluster model implemented has corroborated the increase of the competitiveness of the companies and their insertion in the globalized market, disputing considerable market share world-widely, mainly with products and services of high aggregate value and, in Brazil, the PROMINP model does not possess this characteristic and purpose.

Brazil needs to discuss with the society the successful models implemented in Europe, not imitating them, but taking advantage of the great profits and adjusting the domestic reality providing growth for the Brazilian maritime industry inside the Brazilian market, as well as inserting products and services in the international market.

Fig. 3. Possible potential of the maritime cluster in the national maritime industry

Source: MOURA y BOTTER.

In the construction of a platform, where PROMINP programme is implemented there are still products of high aggregate value or with high technology being imported, and it can be thought about the local development of some of these products, with bigger integration among shipyards, EPC, universities, research and development centres, promotion agencies, association with international universities and, mainly, qualified and specialized labour *(Moura, 2008)*.

In the bibliographical review, it becomes evident that the European maritime clusters has always searched to the integration among the companies related with the maritime industry of its respective countries along to universities and research centres for generating specialized labour, for supplying the needs of the sectors and, moreover, for sensibilizing the society in the necessity of investments in the labour with ability and enabled to the new challenges, aiming at facing the huge competition world-wide. The proximity of research and development centres, universities and technical schools is one of the bases to initiate an implementation process of maritime clusters, such as the successful experiences in Europe.

Therefore, having leader companies that mobilize the other actors of the maritime industry of a country to work as a team in favour of all the industry, having support and integration among universities, research and development centres and technical schools and government (collaborating with public and industrial policies that promote the development of all the industry) are essential conditions to increase the businesses of shipyards, the whole supply chain, the companies of support and service and the government, because, they reflect directly on better economic and social conditions for the people, and provide foreign currency for the country, as pointed in the bibliographical review, in the cases of the European countries experiences.

In the segment of nautical construction, tourism and leisure, there isn't any indication of formation of cluster in Brazil. The companies are generally separated physically; there isn't a concentration on a specific area, as showed in Fig. 4. There are shipyards spread among the States of Rio de Janeiro, São Paulo, Santa Catarina, Rio Grande do Sul and Ceará. The biggest production is found in the South-eastern and South regions, specifically, in the States of Rio de Janeiro, São Paulo and Santa Catarina. In the construction of luxury yachts, the biggest production is in the States of São Paulo and Santa Catarina, being the State of São Paulo the biggest producer.

Taking into account that the proximity factor does not characterize the cluster formation in the nautical construction segment in Brazil, and also because it does not have anything similar in this segment as it has in the platform/UEP construction segment (PROMINP programme), it could be thought about implementing the cluster system like the one implemented in Holland. One or more leader companies of the nautical segment would be defined, and they could be responsible for integrating the other actors of the nautical segment with participation of the government, universities, research and development centres, technical schools, associations of all kinds, etc. PROMINP programme is led by Petrobras Company who is

Fig. 4. Localization of the main shipyards in the nautical segment in Brazil.

the agent to nationalize items for the construction of platform/UEP in Brazil, and to promote the development of the local industry.

In the nautical segment, the leader companies would have to play the same role, however, they would have to be more proactive and to integrate the greatest possible number of shipyards, suppliers of the supply chain, agencies, universities, research and development centres, the associations, etc.; to also focus on exportation, services and other specific niches that can be explored *(Moura, 2008).*

In the nautical construction segment, there is very little integration among shipyards and universities, practically isolated cases, when the complete segment, in Brazil, is studied. In what refers to the research and development centres, it is practically inexistent any type of integration among the main shipyards of this segment and the well-known centres in the country. When the specialized labour is analyzed, with competence and ability to act in this segment, it is noticed the total unpreparedness of the country, and that there isn't so far universities or technical schools that enable the professionals for acting in this segment in Brazil *(Moura, 2008; Moura; Botter, 2009).*

In the nautical construction segment, few shipyards have some kind of partnership with the universities. It is necessary to increase this kind of partnership to promote the development of the sector and to make Brazil globally more competitive. There are products with quality, competitive costs, technology, however, with very small volume of production to supply the demand of some markets, such as the North American one.

Brazil does not possess anything of prominence that allows it to be recognized world-widely for developing high technology in the nautical construction segment, result of the partnership between shipyards and universities. With a few exceptions, there is a couple of suppliers of products to the nautical segment that stands out for having carried through the partnership between shipyard and university for the product development; however, they can be classified as isolated cases. There is also the necessity of industrial policies which promote this partnership between shipyards, universities and research centres in Brazil.

The segment of nautical construction has potential markets like the European and North American ones. On the other hand, the shipyards have low production to supply these markets, specially the United States. It would be important a bigger integration between shipyards and universities for generation of research that would contributed for products and services development, promoting also, the growth of the supply chain of this sector, in the domestic territory. That way, Brazil could explore the world-wide parts and components market, besides of the nautical services.

In the naval construction segment, there is integration with the universities located in the South-eastern region of the country, predominating the States of São Paulo and Rio de Janeiro, however, this integration can still be bigger. Together with the construction of a new shipyard in the Northeast region of the country, it is searched to increase the integration with local universities; however, still, it is incipient and it does not demonstrate to be something that will promote research and development. Some advances have already happened in this segment of the Brazilian maritime industry, but, there is space available for much more integration. However, that very much depends on industrial policies that stimulate all the agents of the maritime industry for mobilizing themselves of reaching common objectives, benefiting all the set of related companies in direct or indirect way with the segment.

In the platform construction segment, there is this integration between universities and shipyards/EPC, but it must be better explored. The benefits generated still are punctual and small, knowing that the segment can be offered to all actors of the sector. This partnership should be increased so that Brazil could develop essential abilities in specific niches and gain market share.

This also could promote the growth of the economy, generating more employment and income distribution among the population and, increasing the entrance foreign currency, besides of the international recognition.

In the ship repair segment, the integration between university and shipyards is inexistent. In this segment, it would be important the integration between these two actors, because, world-widely, this market is very promising; and, Brazil could be structured to explore international markets that, nowadays, are dominated by Singapore and other countries that already appear among the great players, such as Dubai, in the United Arab Emirates.

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Validating the weldability with flux core arc welding "FCAW" for deteriorated naval steels (FLUX CORED ARC WELDING)

Validación de la soldabilidad mediante alambre tubular con núcleo de fundente "FCAW" para aceros navales deteriorados (FLUX CORED ARC WELDING)

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Abstract

Repairs and changes of steel plates in the structure of the vessels where it is possible to find steels with a high degree of deterioration need reliable welded joints in naval steel of the type ASTM A–131 Gr. A new to old. Due to the fact that the variables associated to the weldability of the materials to be repaired are not known, it is necessary to make a study on the weldability of steel ASTM A131 Gr A, in full penetration seams or junctures, under the various parameters involved in the welding process, to determine the influence of the corroding residues that affect the application of welding compounds through the analysis of the metallurgical reactions of liquid condition in order to select the contributing materials with the alloy elements that are able to prevent these phenomena and to recommend the best practices for the electric arc welding process with tubular electrode with FCAW flux core.

Key words: Weldability, corrosion, flux Cored Arc Welding.

Resumen

Las reparaciones y cambios de láminas de acero en la estructura de los buques donde se presentan aceros con alto grado de deterioro, requieren uniones soldadas confiables en el acero naval ASTM A–131 Gr. A nuevo a viejo. Debido al desconocimiento de las variables asociadas con la soldabilidad de los materiales a reparar, es necesario realizar el estudio de la soldabilidad del acero ASTM A131 Gr A, en uniones o juntas de penetración completa, bajo los diferentes parámetros del proceso de soldeo, determinar la influencia de los residuos de corrosión que afectan la aplicación de la soldadura, mediante análisis de las reacciones metalúrgicas de estado líquido para seleccionar los materiales de aporte con elementos de aleación capaces de evitar estos fenómenos y recomendar las mejores prácticas del proceso soldeo por arco eléctrico con electrodo tubular con núcleo de fundente FCAW .

Palabras claves: soldabilidad, corrosión, flux Cored Arc Welding.

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Introduction

Studies on the weldability of ASTM A-131grams, naval steel with a high degree of deterioration are scarce. The objective of this study is to establish the behavior of these steels when they are subject to the FCAW (Flux Cored Arc Welding) processes. This process stands out for its high productivity and welding reduction costs as compared to manual processes. It is based on the fact that FCAW is a semi automatic process that reduces the periods of using welding, welding costs and also, they increase productivity by improving several indicators as compared to the SMAW process.

In order to validate the weldability, mechanic practices, micro structural behavior studies as well as studies on the behavior of several commercial tubular wires in Colombia will be conducted.

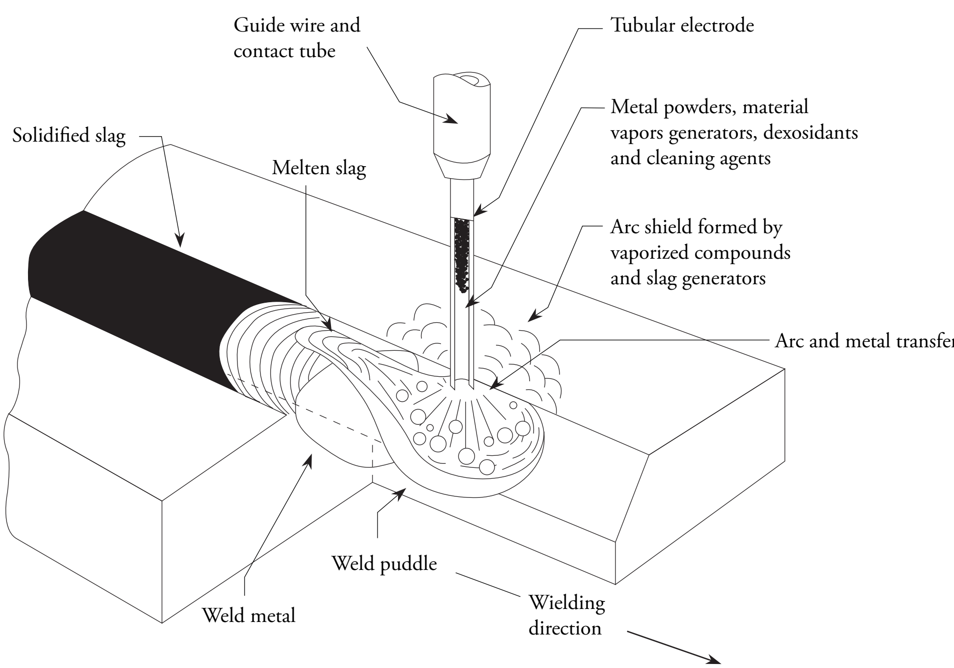
Basics of the process

Welding with an electric arc with tubular electrode with flux core FCAW (Flux Cored Arc Welding) is a semi automatic welding process that takes advantage of an electric arc between a continuous electrode of filler metal and the welding electrode and the welding puddle. This process is used with the protection from a flux that can be found into the tubular electrode, with or without an additional gaseous protection from the outside, and without applying any pressure to it.

Experimental Design

The method that has been used to assess the weldability conditions of Steel of the type ASTM A–131 Gr. A, through the FCAW process in the manufacture and repair of vessels, by Cotecmar and Centro de Materiales y Ensayos del SENA, has been based on the characterization of steels of the type ASTM A–131 Gr. A with steel samples of ships built on different years. The following tubular wires were selected for this study in order to be assessed in terms of their behavior before weldability of the naval steel as per the classification ANSI / AWS A 5.20; E71T-1, E71T-8 and E71T-11, which was encoded in this document as **-1**, **-8** y **-11** respectively.

Fig. 1. A diagram of self- protected FCAW.



Source: Lincoln Electric.

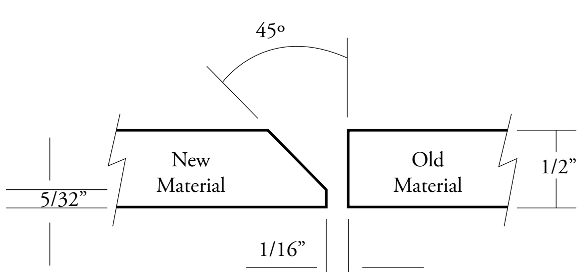
Three stages were followed here: characterization of the naval steel, selection of the filler materials and the assessment of the weldability.

Creating the parameters of the welding equipment was performed in order to qualify positions 2G and 3G correspondingly as per code number AWS D1.1:2004

The seam junctures were made with base materials according to the production years and service condition of the vessel. The nomenclature for the base material was set as follows: new material (N), old material (V) and old- welded material (VS); and the resulting combinations were N-VS, V-V and N-V for each one of the junctures part of the research.

The design of groove butt joints with root size face equivalent to 0 a $^{5}/_{32}$" root opening equivalent to $^{5}/_{64}$" a $^{1}/_{16}$" and bevel angle and chamfer of 45°.

Fig. 2. Design of a typical joint.



The result analysis was done by ***simple comparison*** with: 18 observations in the tension test which corresponded to the 3 combinations per each one of the designation and 2 test tubes per coupon as per the Regulation, 36 observations in the side 3 combinations and 4 test tubes per coupon according to code AWS D1.1 and in the hardness test 36 observations for a total of 720 points obtained, 20 points per test tube). The metallographic analysis had 27 metallographies (3 for each combination and designation), for the base material, welding jobs and the area that had been affected by heat, done in the old material (V) and old welding jobs (VS) whose interest is to verify the weldability behavior in them for the FCAW process.

Fig. 3. ASTM A131 G A. Naval steel flame-cutting process.

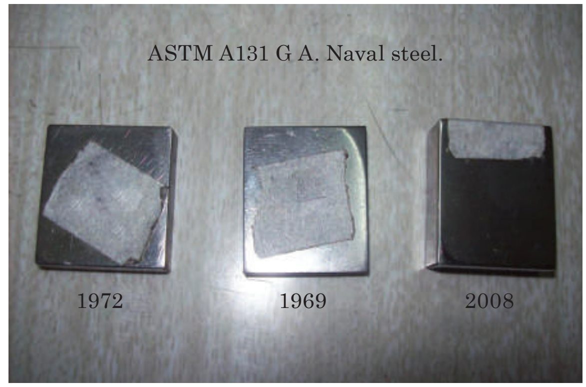


Fig. 4. Cutting and tagging the test tubes for chemical and metallographic analysis of the base metals.

Fig. 5. Test coupon for Naval Steel of the type ASTM A131 Gr A of Steel made in 2008 and steel made in 1972. Prior to welding.

Fig. 6. Test coupon of naval steel of the type ASTM A131 Gr A, steel manufactured in 2008 and one from 1972.

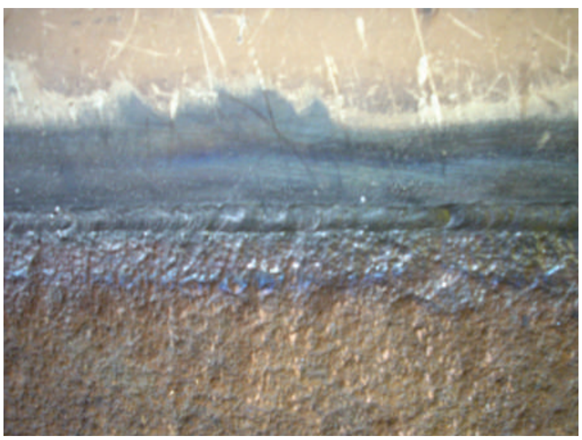


Fig. 7. Performing the tension tests on the test specimens.

The AWS D1.1 code criteria were applied here, obtaining the design of the joint of Fig. 2 for which the flame- cutting process was performed in order to generate the coupons on which the welded joints were done following the FCAW process with three electrode wires -1,-8 and -11.

Parameter creation of the Welding Process and calculation of the Heat input (H)

Heat input H

Where:

$$H = \frac{A.V.\ 60_{\ (1)}}{Va} \tag{1}$$

H = Heat input in J/centimieters
A = amperes
V = electrical potencials in volts
Va = Advancing speed in inches / minutes
A = current in amperes
V = voltage in volts
va = advancing speed in inches per minutes
60 = constant

Heat input for position 2G

- Root pass = 64,8 KJ/cm
- Filler pass = 61,8 KJ/cm
- Presentation pass = 60.800,11 J/m

Heat intake for position 3G

- Root pass = 53.647,05 J/m
- Filler pass = 52.258,06 J/m
- Presentation pass = 49.241,37 J/m

Base material characterization

The base material of the test tubes obtained from the plates was characterized during the research, to verify it with ASTM A131 Gr A for Naval Steel, according to what is shown in Fig. 3. Chemical analysis tests were performed by spectrometry thus generating the chemical composition of Table 2, from where it is easy to conclude that the naval steels manufactured in 1969, 1972 and 2008, are typical steels of designation ASTM A131 Gr A.

Table 1. Parameter classification FCAW process.

Input	Pass	Amperes	Volts	Advancing Speed	Polarity
-1	1	160 - 190	18 - 21	3,0	Negative
	2	140 - 170	19 - 23	3,1	N
	3	140 - 170	19 - 23	3,7	N
-8	1	160 - 195	19 - 23	3,2	N
	2	155 - 180	18 - 21	2,8	N
	3	155 - 180	18 - 21	3,2	N
-11	1	150 - 180	18 - 21	3,5	N
	2	140 - 170	17 - 20	3,3	N
	3	140 - 170	17 - 20	3	N

Table 2. Chemical composition of the base material naval steel.

Element	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	V	Nb
Steel vessel built in 1969	.2098	.0242	.7724	.0175	.0181	.0010	.0010	.1526	.0167	.0010	.0026
Steel vessel built in 1972	.2490	.0342	.7621	.0123	.0215	.0010	.0010	.1878	.0492	.0010	.0027
Steel vessel built in 2008	.1549	.2227	.6974	.0106	.0295	.0199	.0010	.1804	.0785	.0010	.0028

Later, a metallographic analysis was performed and finding bead like segregation bands in the naval steel from 1969 and 1972, (see Figs. 8 and 9) (boxes 1 and 4) on a ferritic matrix (box 3), supposedly due to the aging process due to the precipitation and migration of carbon on ferrite. Also sphere- shaped oxides were found in the ferritic structure (box 2), probably generated by corroding environments in an aqueous or gaseous environment.

Fig. 8. Metallography ASTM A 131 Gr A steel from 1969.

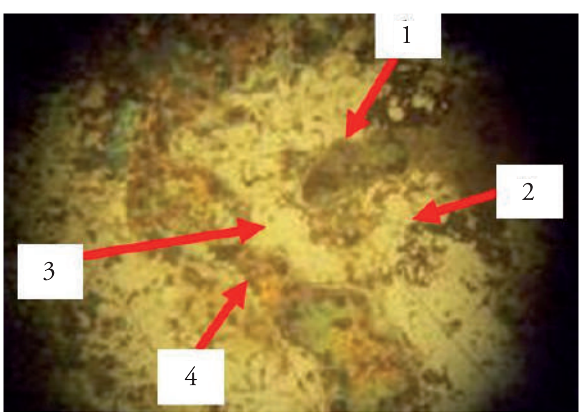
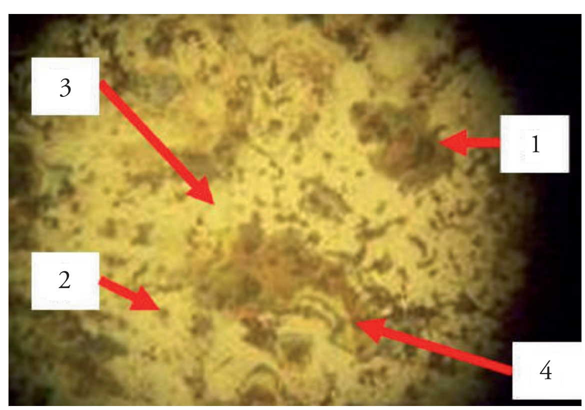
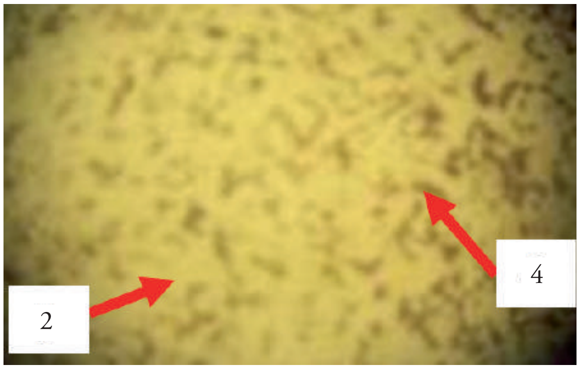


Fig. 9. Metallography, ASTM A 131 Gr A steel from 1972.



As compared with the micro structure of naval steel from 2008, that shows an evenly distributed beaded ferritic structure as can be seen in Fig. 10.

Fig. 10. Metallography ASTM A 131 Gr A steel from 2008.



The average Vickers analysis of hardness of the samples of the naval steel from 1969, 1972 and 2008, is consistent with the metallographic analysis. It was possible to obtain hardness indexes greater than that of the steel from 2008, supposedly due to the aging phenomenon due to the precipitation and migration of carbon on ferrite.

Table 3. Hardness Comparison.

Year	1969	1972	2008
Vickers Hardness	143,51	143,41	134,45

Characterization of a Welded Joint

By applying the parameters in Table 1, and the design of the joint in Fig. 2, the FCAW welding process was applied with input -1, -8 and -11, according to what was stated during the experimental design the Joints welded using the visual inspection techniques, colored penetrating fluids, tension destructive test, side crease, metallography and hardness profile.

Regarding the side crease tests, the test tubes with the various combinations had a good behavior and the behavior is acceptable under the criteria in Code AWS D1.1.

Table 4. Maximum load, tension practice.

Input	Joint	Amperes
-1	V-V	68
	N-VS	68
	N-V	72
-8	V-V	59
	N-VS	58
	N-V	69
-11	V-V	73
	N-VS	68
	N-V	76

Table 5. Parameters of the Vickers hardness test.

Load (gmf)	300
Load Constant	1854,4
Occular Constant 20 X	0,6234

Fig. 11. Behavior of the hardness profile for welded joints.

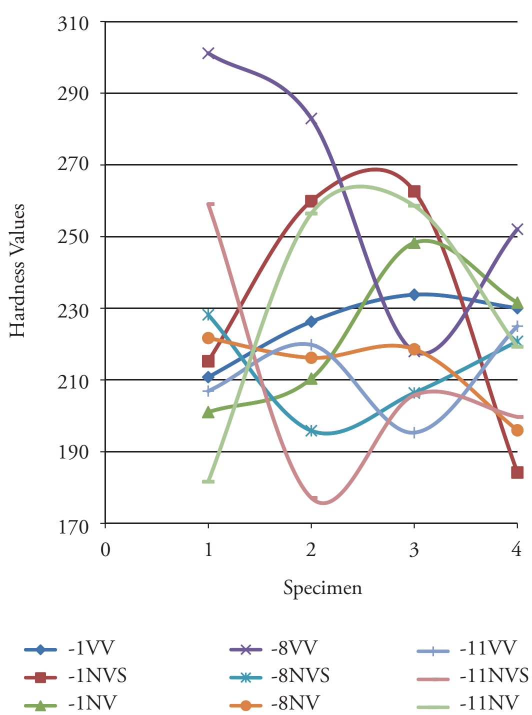


Fig. 12. Metallography - Input - 1 VV Joint.

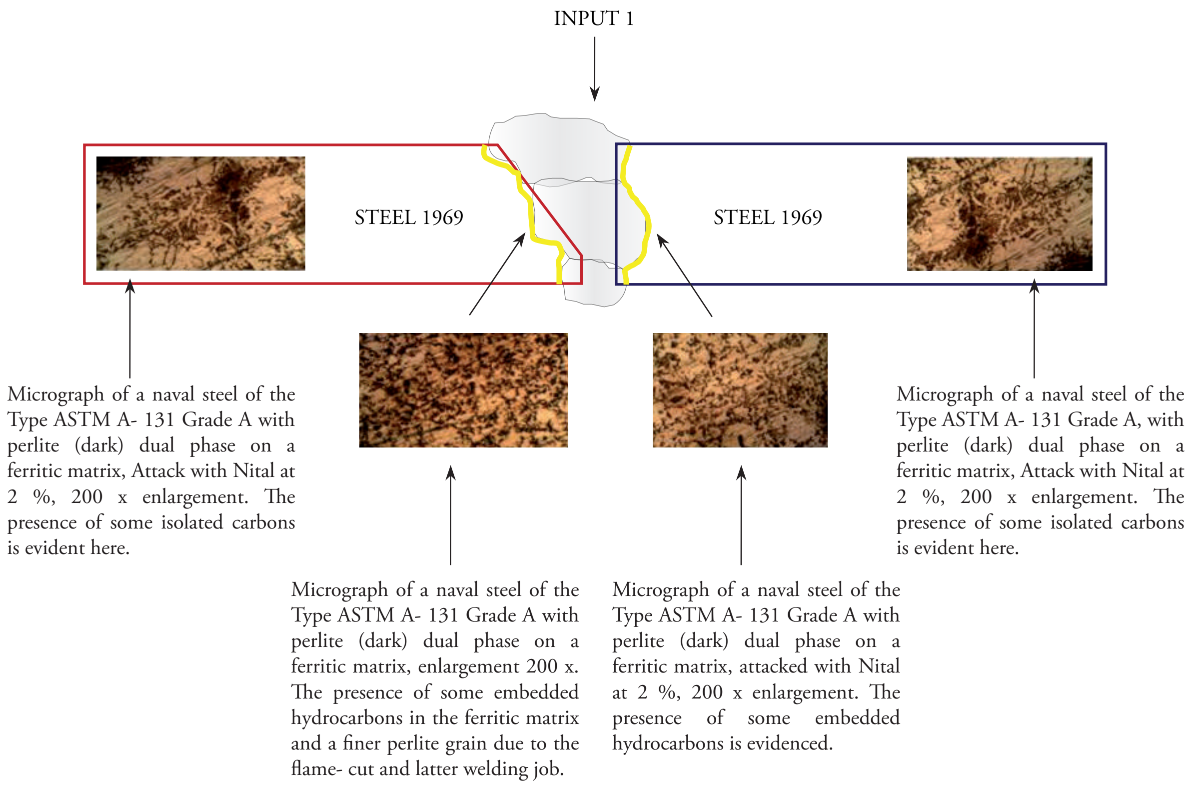


Fig. 13. Metallography - Input - 1 Joint NV.

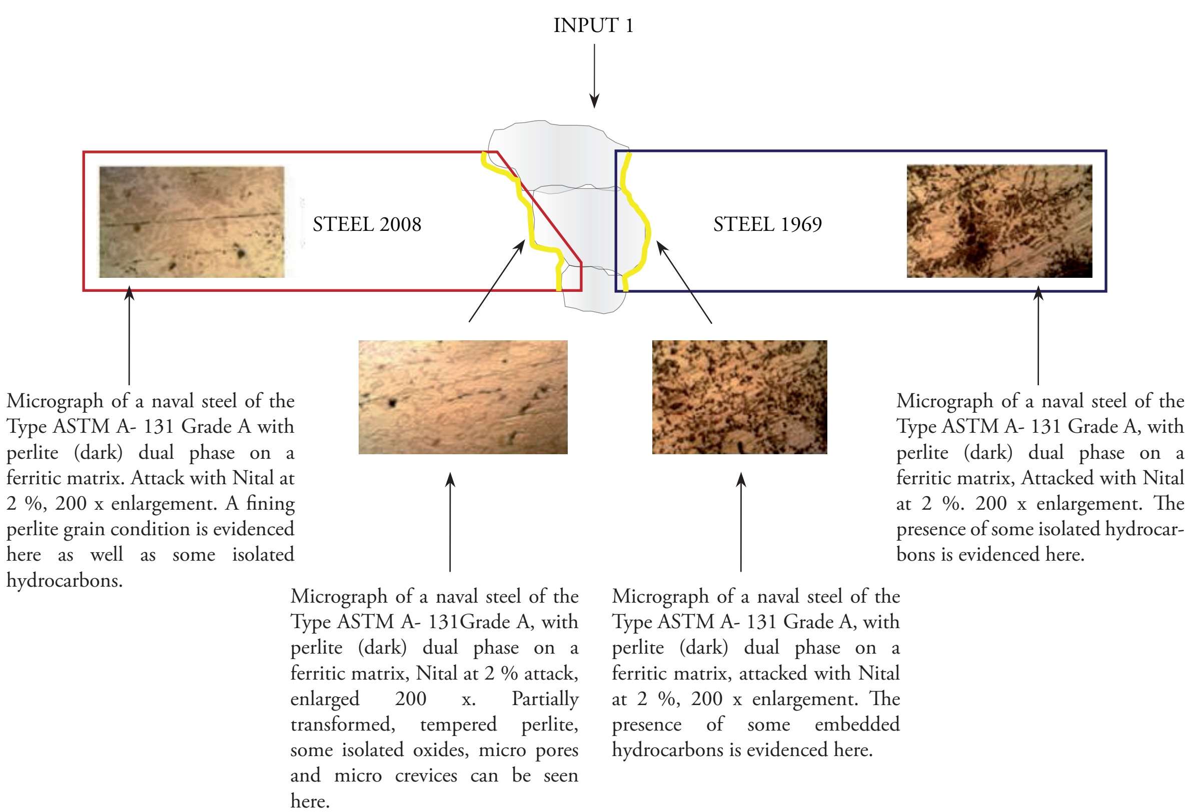
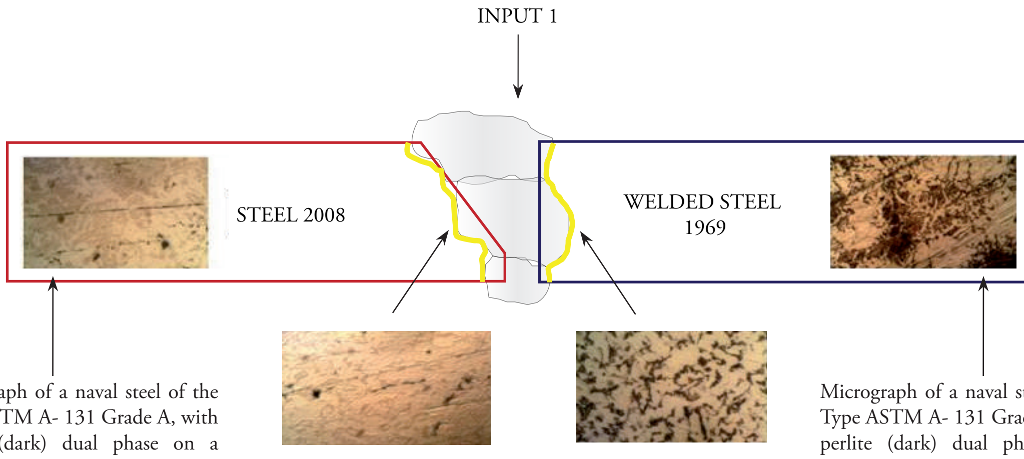


Fig. 14. Metallography - Input - 1 NVS Joint.



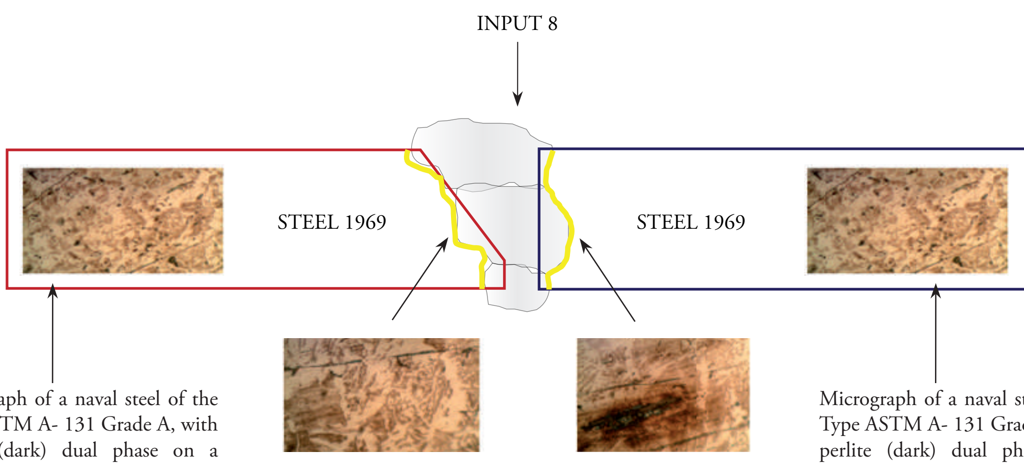
Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, Attacked with Nital at 2 %, 200 x enlargement. A fining perlite grain trend is evidenced here as well as some isolated hydrocarbons.

Micrograph of a naval steel of the Type ASTM A- 131Grade A, with perlite (dark) dual phase on a ferritic matrix, Nital at 2 % attack, enlarged 200 x. Partially transformed, tempered perlite, some isolated oxides, micro pores and micro crevices can be seen here.

Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, Attacked with Nital at 2 %, 200 x enlargement. A fining perlite grain trend is evidenced here, some isolated hydrocarbons in the perlite grains limits.

Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, attacked with Nital at 2 %, 200 x enlargement. The presence of some isolated hydrocarbons is evidenced here.

Fig. 15. Metallography - Input - 8 VV Joint.



Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, Attacked with Nital at 2 %, 200 x enlargement. The presence of some hydrocarbons is evidenced here.

Micrograph of a naval steel of the Type ASTM A- 131Grade A, with perlite (dark) dual phase on a ferritic matrix, Nital at 2 % attack, enlarged 200 x. Partially transformed perlite as well as some isolated hydrocarbons can be seen here.

Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, Attacked with Nital at 2 %, 500 x enlargement. The inclusion of slug together with some hydrocarbons and grouped oxides is evidenced here.

Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, attacked with Nital at 2 %, 200 x enlargement. The presence of some hydrocarbons is evidenced here.

Fig. 16. Metallography - Input - 8 NVS Joint.

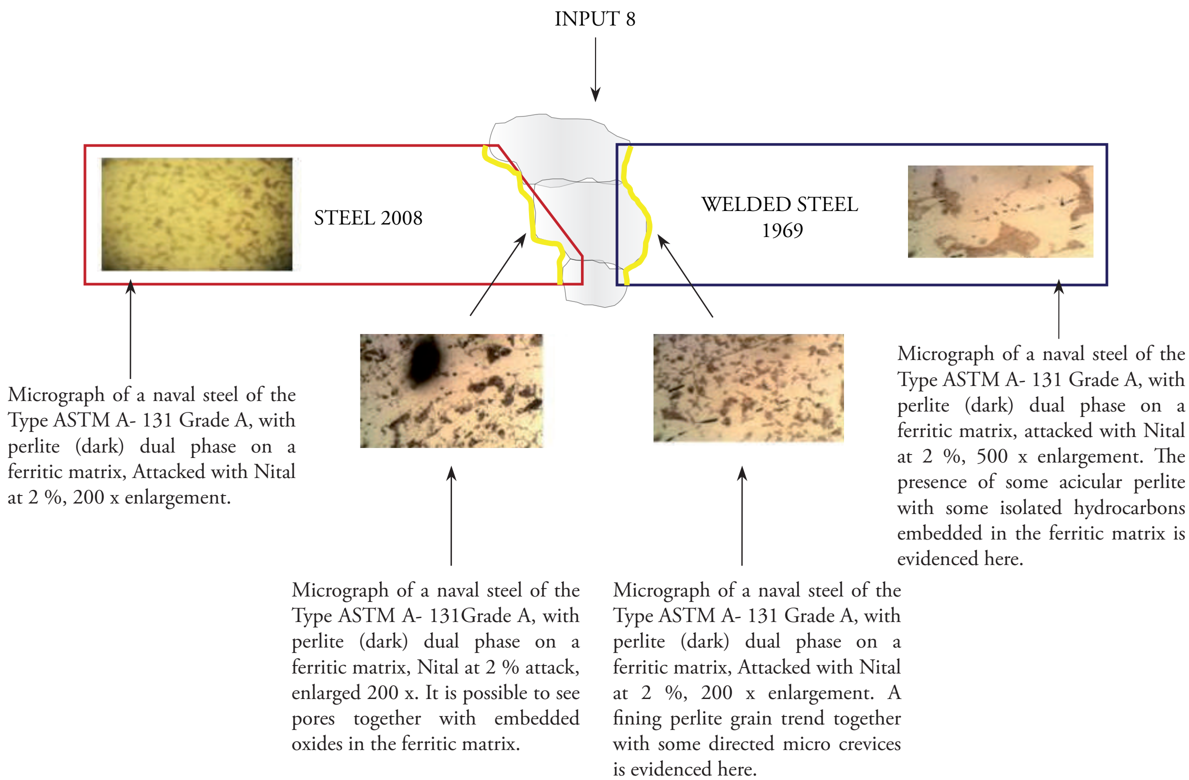


Fig. 17. Metallography - Input - 8 NV Joint.

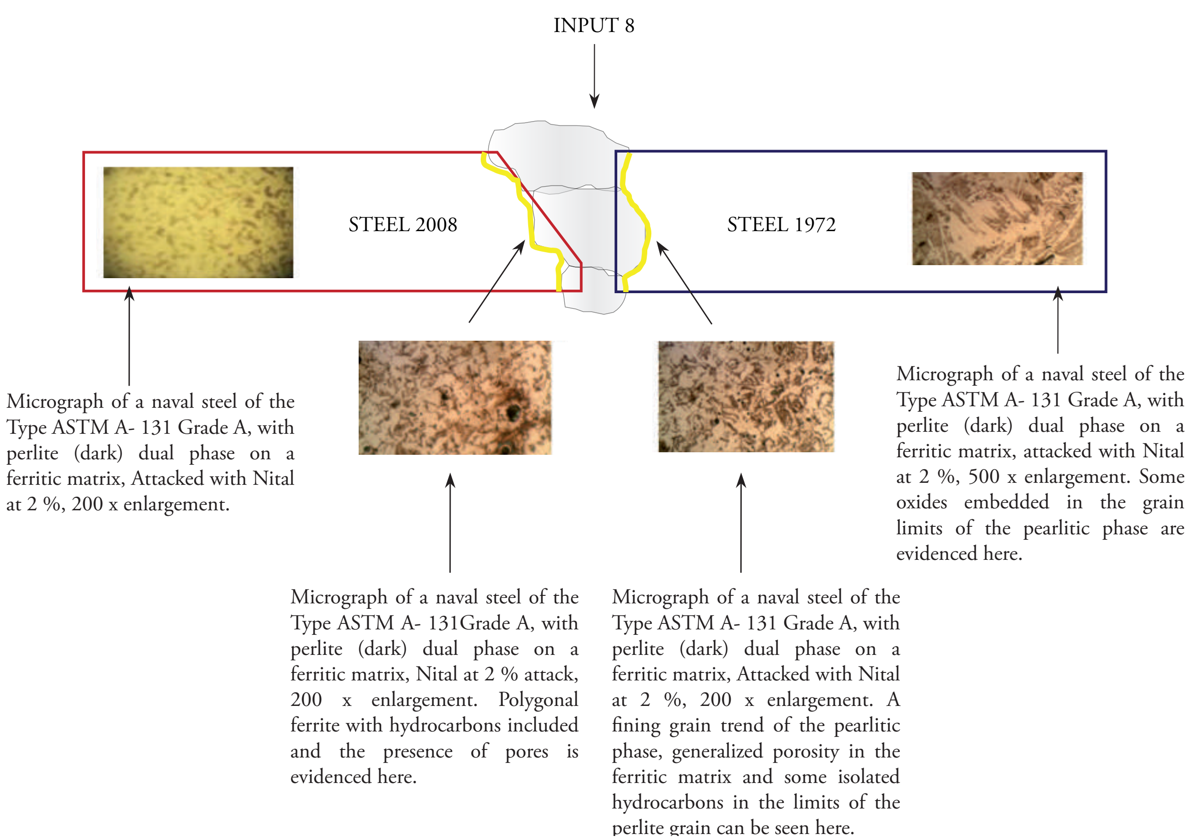
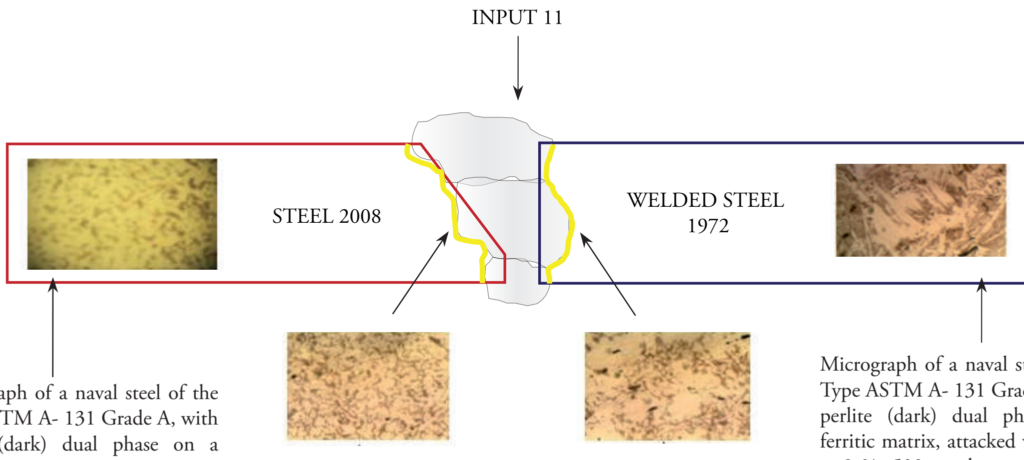


Fig. 18. Metallography - Input - 11 NVS Joint.



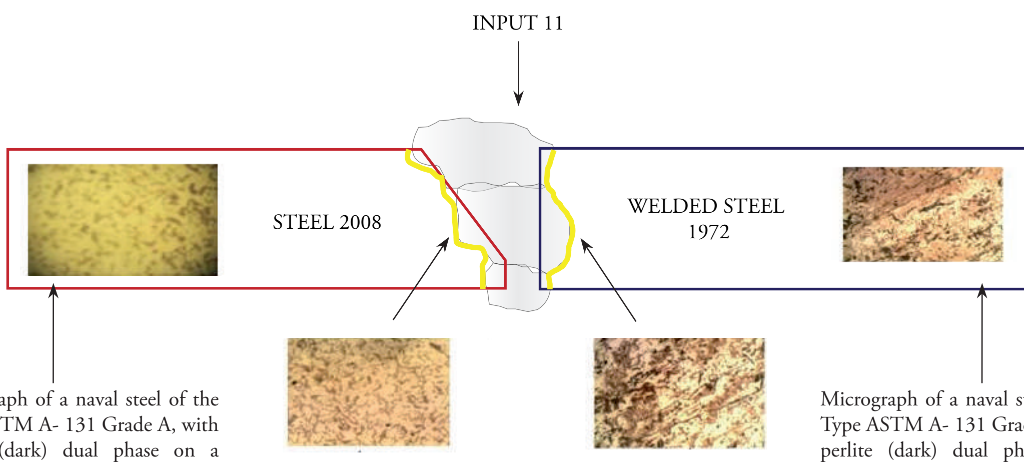
Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, Attacked with Nital at 2 %, 200 x enlargement.

Micrograph of a naval steel of the Type ASTM A- 131Grade A, with perlite (dark) dual phase on a ferritic matrix, Nital at 2 % attack, enlarged 200 X. It is possible to see acicular perlite as well as some isolated oxides in the grain limits.

Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, Attacked with Nital at 2 %, 200 x enlargement. A fining grain trend of the pearlitic phase is evidenced here.

Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, attacked with Nital at 2 %, 500 x enlargement. Some oxides embedded in the grain limits of the pearlitic phase are evidenced here.

Fig. 19. Metallography - Input - 11 NVS Joint.



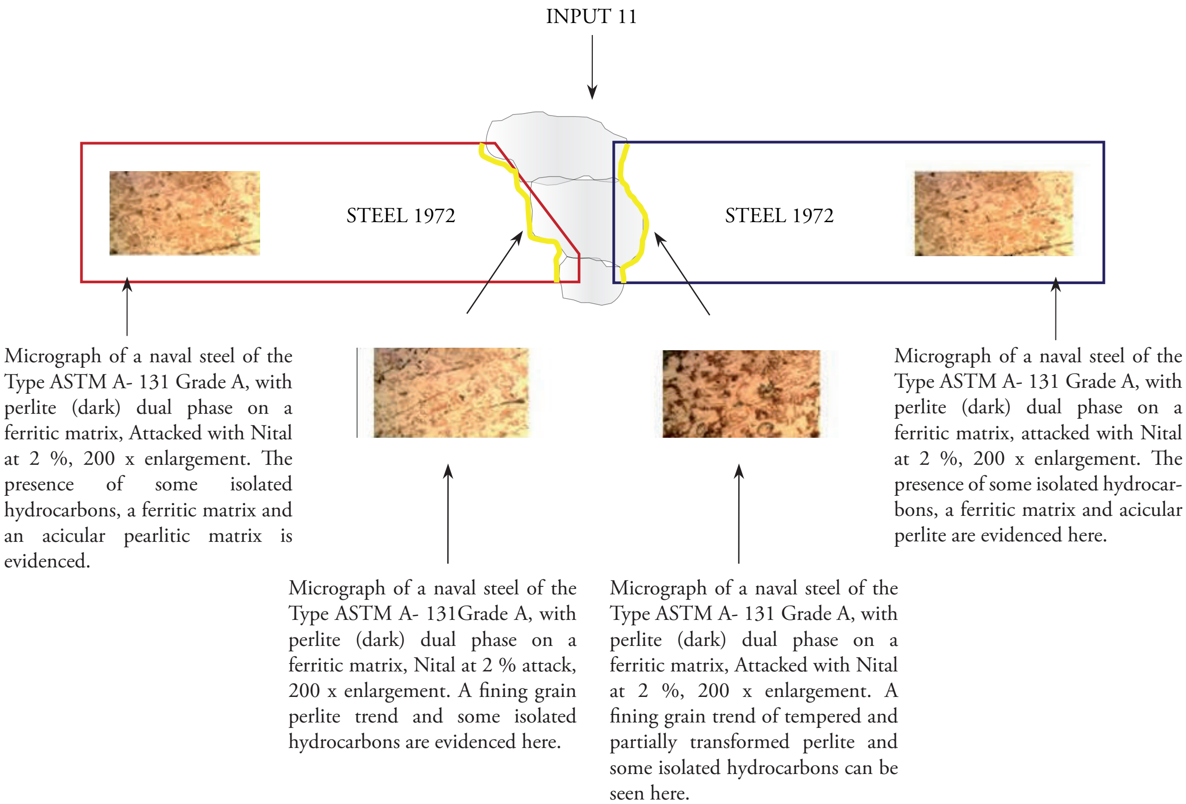
Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, Attacked with Nital at 2 %, 200 x enlargement.

Micrograph of a naval steel of the Type ASTM A- 131Grade A, with perlite (dark) dual phase on a ferritic matrix, Nital at 2 % attack, enlarged 200 X. It is possible to see acicular perlite as well as some isolated oxides in the grain limits.

Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, Attacked with Nital at 2 %, 200 x enlargement. A fining pearlitic grain trend, ferrite grain limit veins as well as some isolated hydrocarbons are evidenced here.

Micrograph of a naval steel of the Type ASTM A- 131 Grade A, with perlite (dark) dual phase on a ferritic matrix, attacked with Nital at 2 %, 200 x enlargement. The veins on the ferrite grains limits are evidenced here.

Fig. 20. Metallography - Input - 11 VV Joint.



Source: research results.

Analysis and Conclusions

The average Vickers hardness for all base materials, shows that for years 1969-(143,51) and 1972-(143,41), it is relatively similar and they are higher when compared to the year 2008-(134,45). This is due to the probable hardening caused by its micro component precipitation and the years the materials have been used in the vessel.

The base materials used in this study exhibited a ferritic matrix with perlite as the second micro component. Mechanical tension tests showed maximum load values, maximum effort values, rupture load and rupture effort within the ranges set by regulation ASTM A131 Grade A for designation -11. Designations -1 and -8 are below the values stated by the regulation and especially -8 whose rupture occurred in the input material.

During welding process FCAW, some welding procedure specifications were generated, as well as the qualification of the welders. The conclusions were that the input materials designated as -1 and -8, require highly trained welders, because managing the welding puddle and especially the slag fluency result in inclusions and lack of penetration in the root of the joint.

The Best behavior was exhibited by the input material designated as -11, since it generates clean welded joints and the welder needs an intermediate training level. It is possible to go from manual coated electrode applications SMAW, to the FCAW process.

Calculating the input heat for inputs -1,-8 and -11 generates heat affected areas that are typical in clean steels like ASTM A 131 Gr A.

The metallographic analysis concluded that the steels from 1969, 1972 and 2008, even though the first two exhibit pearlitic segregations, this does not affect the welded joints, including the old welding jobs found. A NV welding process should be graded for maintenance cases.

FCAW welding process with AWS E71T-11input material exhibits the best welding results. It developed clean full penetration joints. This behavior allows for unilateral welds in vessels, thus displacing the SMAW welding methods which have partial penetration and root clean up.

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Determination of Productivity Parameters in ship maintenance works in a medium-size shipyard

Determinación de los Parámetros de Productividad en los Procesos de Carenamiento en un Varadero Mediano

José L. Barberán Nazareno[1]
José R. Marín López[2]

Abstract

Productivity parameters were determined in maintenance works of 16 ships in the slipways of ASTINAVE, a medium-size shipyard at Guayaquil, Ecuador, in the period between April 2008 and January 2009. Typical processes applied during ship maintenance, its units for evaluation and a classification chart are presented. With the registered time (Man-Hour, M-H), mean values, standard deviations and variation coefficients were calculated for each process. Mean value results for each work were: Plating replacement: 0.220 M-H/kg, Hull cleaning: 0.435 M-H/m^2-machine, Painting: 0.027 M-H/m^2-machine, Cathodic protection: 0.116 M-H/Kg, Thickness measurement: 0.030 M-H/test, Propulsion system: 130.92 M-H/line, Steering system: 54.89 M-H/line, Ship docking/undocking: 43.97 M-H/maneuver, Bottom Valves: 15.83 M-H/#valve, and, Fuel tank cleaning: 0.0093 M-H/gal.

Key words: ship maintenance.

Resumen

Se determinaron Parámetros de Productividad en los trabajos de mantenimiento de 16 embarcaciones en el varadero de ASTINAVE, en Guayaquil, Ecuador, en el periodo Abril 08 hasta Enero 2009. Se describen, definen las unidades para su evaluación y se clasifican los procesos típicos que se desarrollan para el mantenimiento de buques. Con los tiempos (hombres-hora) registrados se calcularon los valores medios, desviaciones estándar y Coeficiente de Variación de los parámetros de cada proceso. Los valores medios resultantes son: Cambio de planchaje 0.220 H-H/kg, Limpieza del Casco 0.435 H-H/m^2-máq, Pintado 0.027 H-H/m^2-máq, Protección catódica 0.116 H-H/Kg, Medición de espesores 0.030 H-H/prueba, Sistema de Propulsión 130.92 H-H/línea, Sistema de Gobierno 54.89 H-H/línea, Varada/Desvarada 43.97 H-H/maniobra, Válvulas de Fondo 15.83 H-H/#válv, y, Tanques de combustible 0.0093 H-H/gal.

Key words: mantenimiento de buques.

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Overview

Time intervals between ship maintenance works are established usually by the classification societies, maritime authority, or, insurance companies, and to satisfy those requirements shipowners must coordinate entrances in dock according to the availabilities of them. Shipowners desire that the time periods for maintenance works be short to satisfy his previous commitments, and to reduce costs, while the shipyard may not have enough area to receive all ships that require its services. These limitations in time and area, force the shipyard to keep an effective control for the fulfillment of the programmed tasks.

The determination of the parameters for each activity during ship hull maintenance, may only be obtained in the working area, in a specific manner. Besides, each one of these activities is evaluated in a different manner.

The present work will provide real information about the methodology that is followed in the maintenance work of ship hulls in an ecuadorian shipyard, and also will allow to have productivity parameters, that permit comparison with processes and efficiency parameters in other locations. As it is established by a American proverb, "what cannot be measured cannot be evaluated, what cannot be evaluated cannot be controlled, and, what cannot be evaluated cannot be improved".

In the slipways of ASTINAVE, Guayaquil, Ecuador, eight ship hulls may receive maintenance simultaneously, with four of them under cover. The shipyard posses of a platform in slipways 35 meter long, 10 meter wide, a 4000 m^2 area of

Table 1. Classification of maintenance tasks, equipment and units.

	Area		Process	Machinery	Parameters	Notes
1	Hull related processes	1	Gangplank change	Flame- cutting equipment, welding machines, pulling hoists, crane, "pulleys"	M*H/Kg.	4- 12 mm Thicknesses
		2	Clean- up	Compressor, sandblasting machine, diving helmet	M*H/m^2	Quick work
		3	Painting	Compressor, painting machines and measuring tools	M*H/m^2- Layer- Machine	Quick work
		4	Cathodic Protection	Flame – cutting gear, welding machines, pulling hoists, cranes	M*H/Kg.	Anodes up to 10 Kg
		5	Thickness Measurement	Gage audio gear, & salt pick	M*H/Test	External part of hull
2	Maneuver related processes	1	Propulsion System	Crane, pulling hoists, "pulleys", mass, hammer wrenches, forklifts, calibrator, micrometer, strobes, hydraulic jacks, mergollar extractor	M*H/Line	Does not include repairs
		2	Rudder Systems	Crane, pulling hoists, "pulleys", mass, hammer wrenches, forklifts, calibrator, micrometer, strobes, hydraulic jacks, mergollar extractor	M*H/Line	Does not include repairs
		3	Grounding and Leaving Grounding	Forklift, crane, grounding cars, winch, grounding platform, rigging, strips, winches, turnbuckles, depths, boards, wood wedges	M*H/Maneuver	Ships of up to 400 tons
3	Processes related to the inside part of the hull	1	Bottom valves	Spanners, screw wrenches, Stilson wrenches, compressor, valve testing circuit	M*H/Valves	Valves of up to 127 mm
		2	Tank clean- ups Comb	Wippe, coarse cotton, cloth, degasifying liquid, waste disposing containers	M*H/Gallons	Waste disposal

transference, a winch with pulling capacity of 700 tons, six cars for transferences, and five cars to dock with extensions. Besides this, the shipyard counts with two semiautomatic machines for painting, a stationary electric compressor, five sandblasting machines, a portable compressor, two forklifts, a 2-ton telescopic crane, among other facilities.

Classification of Hull maintenance tasks. In the present work, hull maintenance tasks, which are described in the appendix, have been grouped in three areas, and for each one it has been established measurement units, as it is following explained (see Table 1.)

Equipment limitations, (ASTINAVE CAR-C, 2008) and (ASTINAVE, 2008b). Following the characteristics and limitations of the available equipment used in the different tasks are presented.

Equipment for steel plating replacement (Group 1/1). It consists of oxygen cylinders and acetylene, of 10 m3 and 9 kg, respectively, pressure regulators, torches for plate cutting, welding machines, with service cycles of 60%. One of the limitations is the time loss, when cylinders are unloaded.

Equipment for hull surface cleaning ("sandblasting") (Group 1/2). It consists of five 1 m^3 boxes, and 5 sandblasting machines, each of $0.08m^3$ of capacity. The equipment receives compressed air at 125 psig. The limitation is that each machine must have a compressor, so when two machines are operated, a portable compressor must be installed.

Equipment for painting (Group 1/3). It consists of a painting machine with 180 cm^3 output per cycle. This equipment receives compressed air from an stationary electric compressor at 125 psig. In the painting gun a nozzle is installed, discharging with the most common model, 0.77-0.88 gals/min when operates at a pressure of 3800 psi, (HEMPEL).

Equipment for cathodic protection (Group 1/4). It is the same as that used for plating replacement.

Equipment for Thickness measurement ("Audio Gage") (Group 1/5). The equipment for measurement of thickness (Ultrasound) has a simple crystal probe, and it is capable of measuring over painting; it does not need to be calibrated when working with different materials. The main disadvantage is that the delay line is damaged when working on rough surfaces.

Equipment for Propulsion system (Group 2/1). It is composed of tackles and pulleys with a 2 ton capacity, a crane with maximum lift of 2 tons, forklifts, packing extractors and tools for gap measuring. The main limitation of the equipment is the fact that part of the pulling process is manual and that the boom of the crane can be extended a maximum distance of 6 m.

Equipment for steering gear (Group 2/2). It is composed of tackles and pulleys with a 2 ton capacity, a crane with maximum lift of 2 tons, forklifts, packing extractors and tools for gap measuring. The main limitation of the equipment is the fact that part of the pulling process is manual.

Equipment for hull docking and undocking (Group 2/3). This includes a 200 hp power engine. The Buckan winch, has a cable drum diameter of 2.04 m. The platform for docking is 35 meter long, and 10 meter wide. The cars on which ships are docked are 4, and two of them dispose of hydraulic arms to secure the hull. To increase the draft of the ship to be docked, extensions may be installed at the end of the platform. The main limitation of the equipment is the draft above the platform, which depends on the water level of the tide. Another limitation is the winch pulling capacity.

Equipment for bottom valves (Group 3/1). It consists of spanners, screw wrenches, and a compressor of 150 psi. The main limitation of the equipment is that the tasks depend heavily on worker skill.

Equipment for cleaning fuel tanks (Group 3/2). The equipment for disposing, cleaning, and degasification consists of buckets, scrapers and hooks. The main limitation is that tasks depend on the size and configuration of the tank.

Determining productivity parameters

Data registration. Following a summary of the main characteristics of the analyzed ships is presented. They are ships with length between 20 and 45 meters, and with light load draft between 1.2 and 2.8 meters. In Table 2, ships classified as *Armada* belong to the Ecuadorian Navy but are not of war type (for example tugs or barges). It must also be noted that ship #7 (Tanq 86) was not docked, but she was tied to the pier and took place some steel plate changes.

Table 2. Main characteristics of the analyzed vessels, (ASTINAVE, 2008a)

	Main Characteristic							
#	Vessel	Length (m)	Wind Sale (m)	Draft (m)	Entry Date	Leaving Date	Type	Form of Grounding
1	LG 23, 4	23,40	4,10	1,50	July 7th, 08	Aug. 4th, 08	Naval	Cars
2	Catam 26,8	26,80	10,80	1,52	Sep. 19th, 08	Sept. 26th, 08	Pleasure	Platform
3	Gabarra 37,5	37,50	9,20	1,00	June 26th, 08	Sept. 27th, 08	Commercial	Cars
4	LM 44, 9	44,90	7,00	1,95	July 7th, 08	Oct. 1st, 08	Naval	Cars
5	LG 36	36,00	5,80	1,60	July 9th, 08	July 30th, 08	Naval	Cars
6	Yacht 24 ,5	24,50	7,30	2,40	Sept. 17th, 08	Oct. 1st, 08	Pleasure	Cars
7	Tang 86	86,00	13,00	5,00			Commercial	
8	Rem 24, 4	24,40	7,10	2,59	Aug. 6th, 08	Aug. 13th, 08	Naval	Platform
9	Yacht 32, 93	32,93	6,30	2,44	Sept. 9th, 08	Sept. 15th, 08	Pleasure	Extension
10	LG 32	32,00	6,86	1,88	Oct. 15th, 08	Oct. 29th, 08	Naval	Cars
11	Yacht 37, 89	37,89	6,92	1,85	Sept. 18th, 08	Nov. 30th, 08	Pleasure	Cars
12	Tang 40, 24	40,24	7,62	2,45	Nov. 14th, 08	Nov. 17th, 08	Naval	Platform
13	Barge 28, 45	28,45	9,15	1,25	April 1st, 08	June 26th, 08	Naval	Cars
14	Yacht 29, 90	29,90	6,60	1,98	Nov. 27th, 08	Nov. 28th, 08	Pleasure	Extension
15	Yacht 26, 00	26,00	5,96	1,80	Jan. 14th, 09	Jan. 24th, 09	Pleasure	Cars
16	Rem 21, 95	21,45	6,33	2,79	Jan. 25th, 09	Jan. 27th, 09	Naval	Platform

Data summary. Table 3 presents a summary of the registered productivity parameters, including also mean, μ, standard deviation, σ, and the variation coefficient as a percentage of the mean, defined as *(Zurita, 2008)*:

$$C_V = \frac{\sigma}{\mu} 100, [\%] \qquad (1)$$

The reported values correspond to the different tasks developed on different ships, in the period between April/2008 and January/2009. In the appendix of this paper, registered values for each parameter are presented for all analyzed ships, *(Barberán, 2008)*.

It must be mentioned that in the case of ship 16, *Rem 21.95*, for the steel plating change a overtap process was utilized (no cutting was involved), and as a result, the time for that job was reduced considerably. In the case of ship 8, *Rem 24.4*, tasks developed in the propulsion system consisted only of dismounting/mounting the propeller. And in the case of ship 14, *Yacht 29.90*, because of the urgency of the shipowner, the shipyard had to work continuously for 24 hours, with a reduction in dead times because of task reinitialization.

Table 3. Calculated productivity parameters, (ASTINAVE, 2008b)

		HULL					MANEUVERS			INSIDE PART OF THE HULL	
		Gangplank Change	Clean - up	Paint Job	Cathodic Protection	Thickness Measurement	Propulsion System	Rudder System	Grounding and Refloating	Bottom Valve	T K Comb Clean- Up
#	Ship	[M*H/Kg]	M*H/m²-Mach	M*H/m²-Mach-Layer	M*H/Kg	M*H/Test	M*H/Line	M*H/Line	M*H/Maneuver	M*H/Valve	pulleys/Gallons
1	LG 23, 4	0,200	0,286	0,032	0,100	0,025	152,00	72,00	48,00	16,00	0,0080
2	Catam 26,8			0,030	0,071		130,00	60,00	48,00		
3	Gabarra 37,5	0,214	0,500	0,026	0,135	0,030	140,00	56,00	50,00	17,50	0,0080
4	LM 44, 9	0,259			0,110	0,035	204,00		55,00	16,57	0,0090
5	LG 36		0,474	0,030	0,100	0,025	192,00		40,00	17,50	0,0084
6	Yacht 24 ,5	0,243		0,027	0,150	0,030	130,00	62,00	50,00	17,20	0,0087
7	Tang 86	0,222	0,258								
8	Rem 24, 4	0,236	0,444	0,028	0,109	0,038	35,00	68,00	51,50	15,00	0,0090
9	Yacht 32, 93		0,429	0,027	0,157	0,031	105,00	40,00	54,00		
10	LG 32	0,212	0,482	0,021	0,074	0,030		36,00	35,00		
11	Yacht 37, 89	0,269	0,540	0,024	0,145	0,035	150,00	40,00	35,50	16,66	0,0133
12	Tang 40, 24	0,265	0,500	0,027	0,128	0,025	120,00		38,50	12,00	0,0100
13	Barge 28, 45						148,00	60,00	32,00		
14	Yacht 29, 90						65,00		49,00		
15	Yacht 26, 00			0,027		0,028			26,50	14,00	
16	Rem 21, 95	0,075							46,50		
	Average	**0,220**	**0,435**	**0,027**	**0,116**	**0,030**	**130,92**	**54,89**	**43,97**	**15,83**	**0,0093**
	Stand. Dev.	**0,0560**	**0,0980**	**0,0030**	**0,0292**	**0,0043**	**47,28**	**13,08**	**8,71**	**1,85**	**0,0017**
	Coeff. Variat.	**25,5**	**22,5**	**11,1**	**25,1**	**14,4**	**36,1**	**23,8**	**19,8**	**11,7**	**18,7**

Analysis of results

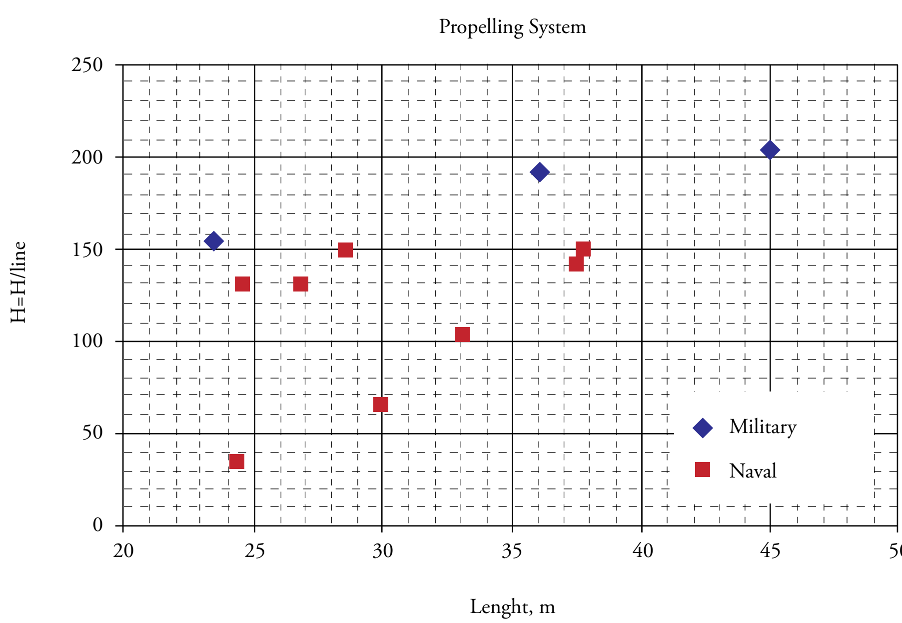
The usefulness, for planning and control purposes, of the productivity parameters in the ship hull maintenance works depend on the low variation of the reported values. As a function of the calculated variation coefficients, in the present paper, processes were classified as with High (C_V>20%), Intermediate (12-20%), and, Low (<12%) variation, with the results presented in Table 4.

According to the calculated results, the process with the highest variation is related to the maintenance of propulsion systems. In this variability, influences the different in size of the system that forces to manipulate different weights; also, because of the design of warships, very small spaces are available in the bottom region of the hull, obstructing the access and increasing the required time to complete

Table 4. Classification of processes according to the variation coefficient.

	Process	Variation Coefficient	Productivity Parameter	Standard Deviation
High Variation	Gangplank Change	23,40	4,10	1,50
	Hull Clean – up	26,80	10,80	1,52
	Cathodic Protection	37,50	9,20	1,00
	Propulsion System	44,90	7,00	1,95
	Rudder System	36,00	5,80	1,60
Intermediate Variation	Thickness Measurement	24,50	7,30	2,40
	Grounding / Refloating	86,00	13,00	5,00
	Fuel Tank Clean- up	24,40	7,10	2,59
Low Variation	Paint job	32,93	6,30	2,44
	Bottom Valves	21,45	6,33	2,79

Fig. 1. Productivity of the tasks related to propulsion systems classified by ship type.



the tasks. In the previous topic of this paper, it was mentioned that two of the analyzed ships (8 and 14) required uncommon tasks, and if they are not included in the calculations, the variation coefficient reduces to 20.8%, with a mean value of 147.10 M-H/line.

In Fig. 1 productivity parameter related to the propulsion system work versus length of the ships are plotted, differentiating between civil (including navy tugs and barges) and war vessels. It may be noted that naval ships require longer repairing time periods than commercial or pleasure, and in both cases it may established a tendency line with positive slope; this is thought to be reasonable since with the length of the ship the size of the mechanical element of propulsion system increase, and with them, their weights and the time to manipulate them.

Productivity parameter for the rudder system also shows high variation, however when plotted against the length of the ship it was not found the expected relationship, as may be noted in Fig. 2. It seems that the high variation of this parameter is mainly influenced by the type of construction: with or without sternframe solepiece, the type of top support, either liner or roller bearing, and, the watertightness device, with packing or retainer.

Another task with high variation coefficient is the cleaning of the hull, which is influenced by the difference in adhesion of the painting to be removed. Also, in the high variation of the cathodic protection, influences the fact that some ships have bolted anodes while others are welded, and between these last ones, some have two legs while others have four.

Finally in Fig. 3, required time for ship docking/undocking are presented versus length of the ship, classified in the three possible ways: using the cars, directly on the platform, and, using an extension to the platform. Because the number of analyzed data is small, a definitive conclusion cannot be reached, but it may be noticed that this process is more efficient when cars are used, and this is expected since in this case the system has hydraulic

Fig. 2. Productivity parameter for the steering system tasks versus ship's length.

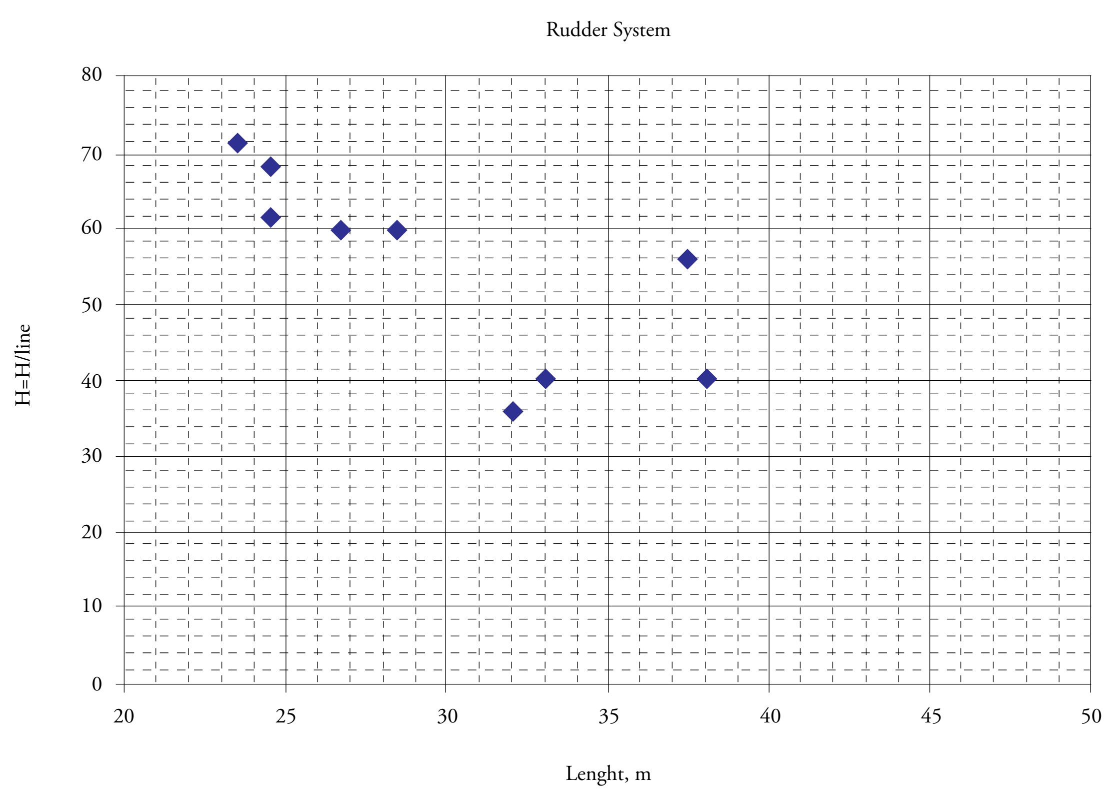
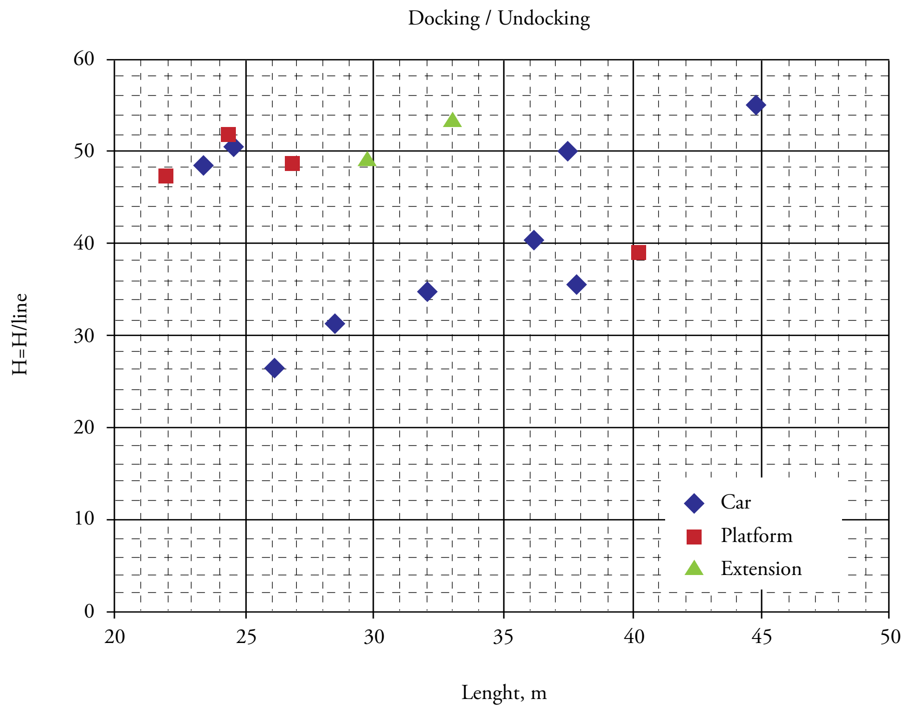


Fig. 3. Productivity of the different forms of ship docking/undocking.



arms to secure the ship being docked when she is in the adequate position. Also, considering only ship docking using the cars upon the platform, it may be noticed an almost linear relationship between the time to complete the task and the length of the ship, a fact which is also reasonable.

Unfortunately it was not possible to find reports on productivity of shipyards similar to ASTINAVE for comparison purposes, so following some comments will be presented about the relationship of the registered values as compared with those presented in Butler's book (Butler, 2000). It must be emphasized that the times to develop tasks reported in the above mentioned reference are related to works developed in dry docks, which include blocks around one meter height, which influences the required execution times because the need to install scaffold and platforms. In the case of tasks to replace cathodic protection anodes, Butler reports values of 0.33 M-H/kg to replace slabs of up to 3 kg, and of 0.20 for those of 5 kg; in the present work, the average value for that parameter is 0.12 M-H/kg, with a variation of 25.1%. In the case of steel plating replacement works, the above mentioned reference presents values according to the thickness, for example, for plates up to 6 mm, they need 250 M-H/ton, and for those of 8 mm, 245; in the present paper it was estimated for plating changes an average value of 0.22 M-H/kg (or 220 M-H/ton), with a variation of 25.5%. For the removal of propulsion tail shafts with diameters below 150 mm, if it is towards the exterior of the hull, the reference mentions 90 M-H, while if the pull is towards the interior, 140 M-H; in the present report, it was estimated a mean value for removal of tail shafts of 130.9 M-H/line, with a variation of 36.1%.

Conclusions and Recommendations

The required times for maintenance works in a shipyard have been registered and from them productivity parameters were calculated, for sixteen ships in the slipways of the Astilleros Navales Ecuatorianos, ASTINAVE, at Guayaquil, Ecuador, in the period between Abril 2008 and January 2009. The analyzed ships are in a range between 20 and 45 meter length. It can be mentioned, remembering that the reduced number of data does not permit definitive conclusions, the following:

The classification of ship maintenance work proposed in this paper, includes three areas: related to the hull (plating replacement, surface cleaning, surface painting, cathodic protection, and measuring of plate thickness), related to ship handling (propulsion systems, steering systems, and docking/undocking), and, related to hull interiors (bottom valves and fuel tanks). Also, before proceeding to calculate each productivity parameter it was necessary to define units to be used to measure those quantities, and determine the limitations taken in each process. It was found that the classification employed for the calculations facilitated the registration and control of the process for the final estimation of the productivity parameters.

The analysis of results presents processes with values of standard deviations, s.d., which allowed us to group them in three categories, see chart 4. The values of s.d. considered as high, are those with a variation coefficient above 20%; in this group you may find works related to propulsion systems, 36.1%, plating change, 25.5%, cathodic protection, 25.1%, steering systems, 23.8%, and, hull cleaning, 22.5%. Processes with intermediate deviations were considered those with a variation coefficient between 12-20%; in this group we found: hull docking/undocking with 19.8%, fuel tanks cleaning, 18.7%, and, measuring of plate thickness, 14.4%. Finally processes with low standard deviations are considered those with variation coefficients below 12%, and include: bottom valves, 11.7%, and, painting, 11.1%.

Finally maintenance works with low variation values of the productivity parameters have the following means values and are: painting, 0.027 M-H/(m^2*layer*machine), and bottom valves, 15.8 M-H/valve. Given these low variations, it is thought that these values may be used to compare with productivity standards from other shipyards, for process control, and eventually for planning purposes. The authors commit themselves to keep the register of the time required for ship hull maintenance works in the slipways of ASTINAVE shipyard to determine in the future productivity parameters with higher statistical confidence.

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Apendices

A. Work description for ship maintenance, (ASTINAVE 2008b)

Steel plating replacement: It includes the process from visually inspecting hull plating and structural parts, going through deciding the areas where the plating needs to be replaced based on the recommendation that resulted after measuring the thickness, up to performing the leak tests (hydraulic or pneumatic) after having performed the welding jobs in the inner part of the water or fuel tanks.

Hull cleaning- up (sand blasting): It includes the process from cleaning up the hull by scraping it in order to eliminate the pieces of small sea shells, up to verifying the requirements for sandblasting of the SA 2 ½ degree, while comparing it with photographic patterns.

Surface painting: Once the technicians from the painting company and the customer have verified that the treated surface has the required degree of cleanliness, (Hempel, 2008), they move on to authorizing the paint job, not before verifying the environmental temperature, relative humidity factor and dew point parameters. The process ends when the equipment is washed. This includes washing the nozzle and the gun with thinner, after applying each coat of paint.

Cathodic Protection: This process begins by dismounting all the zinc plates by using flame-cutting equipment, when the anodes have been welded or by using the appropriate wrenches when they are bolted. The process ends with the installation through the welding or mounting of the bolts of the new zinc anodes.

Thickness Measurement: It begins by coordinating, together with the representative of the vessel shipowner, the areas where the thickness measurements will be performed. The process ends with the writing of the technical report on the thicknesses that includes the recommendations on the plating changes that are required.

Propulsion system: The process begins by taking off the fenders, the thimbles and safety devices in the shaft lines. Then perform gap measurement and analysis, and it ends with reassembling of the fenders and safety devices. Shafts or propeller repair works are not included.

Steering System: This process starts by taking off the bumpers and safety devices. It then continues with logging and analyzing the measured gaps. The process ends when the clamp clans are reassembled.

Ship docking: It begins with the preparation of the docking plan, then the manufacturing of the docking bed according to the characteristics of the process (on top of transference cars, platform, or, with extensions) all the way up to the positioning of the vessel to its final position in the transference yard.

Vessel undocking: Once having checked that all works carried out in the hull, bottom valves, propulsion and steering systems have been completed, then developing a technical stop when the vessel has a sufficient level of water, and finishes when it floats out of the slipway entrance.

Bottom Valves: It goes from dismantling the valve tower, checking what condition the stem and the hatch are in (in order to detect any pitting or scratches), verifying the leak tests of the valve by means of a hydrostatic test, to the reinstallation in its original position.

Fuel tanks (clean-up and degasification): From opening the tank covers in the fuel tanks, then performing the degasification process, then pumping out the mud and fuel residues, to the verification of the cleaning process performed.

B.Variation of the registered values

Fig 4. Gangplank change.

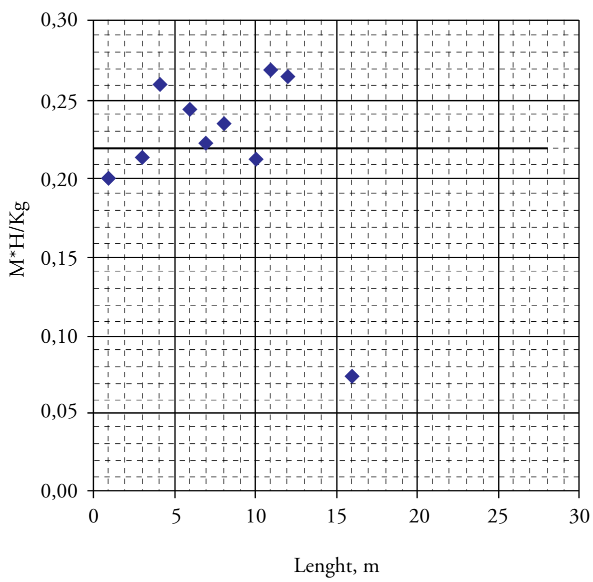


Fig. 5. Hull clean up.

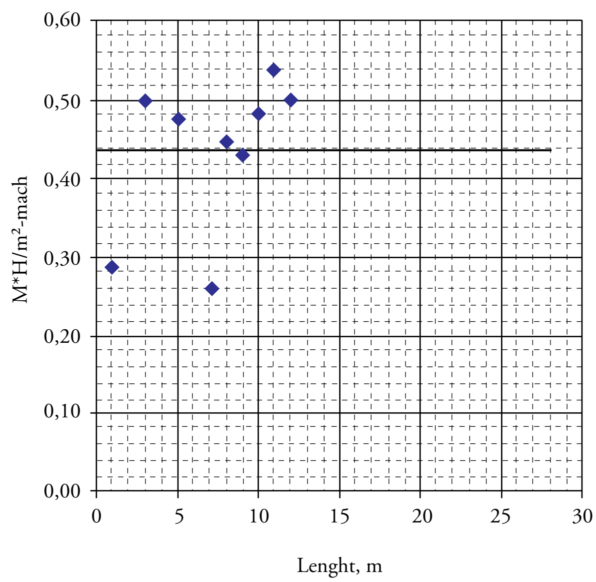


Fig. 6. Hull paint job.

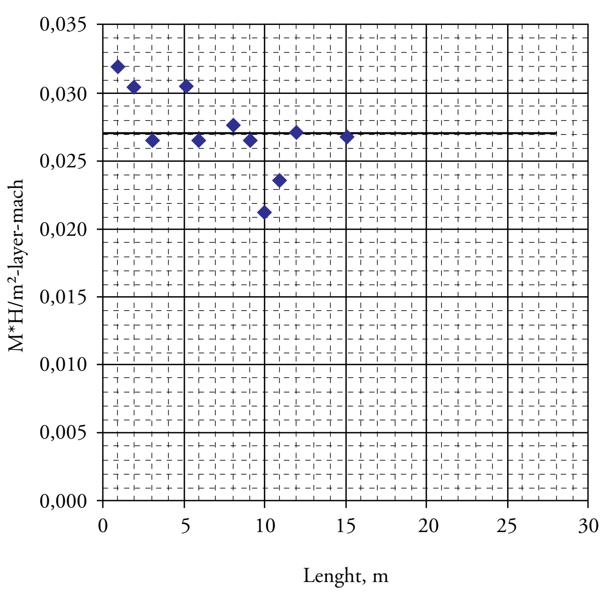


Fig. 7. Cathodic protection.

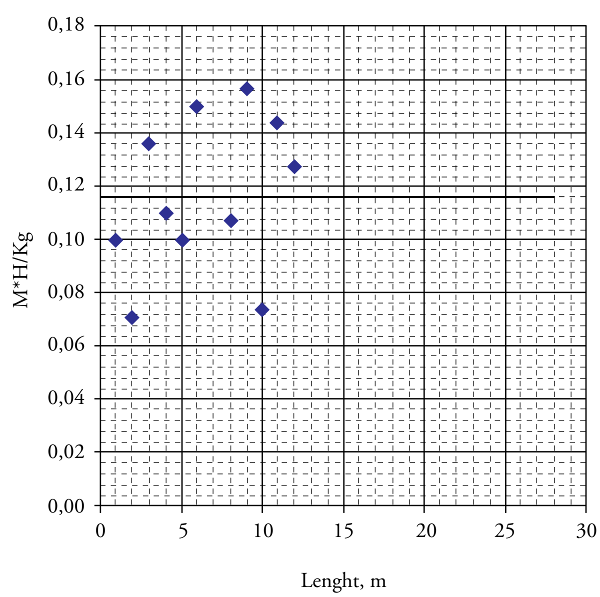


Fig. 8. Thickness measurement.

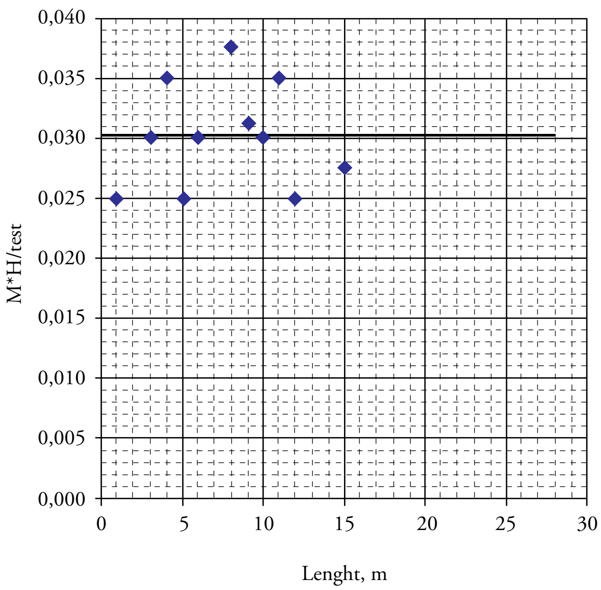


Fig. 9. Propelling system.

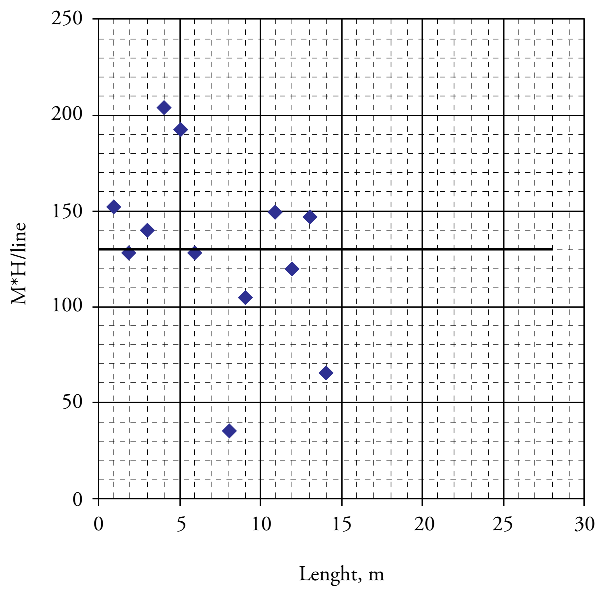


Fig. 10. Rudder system.

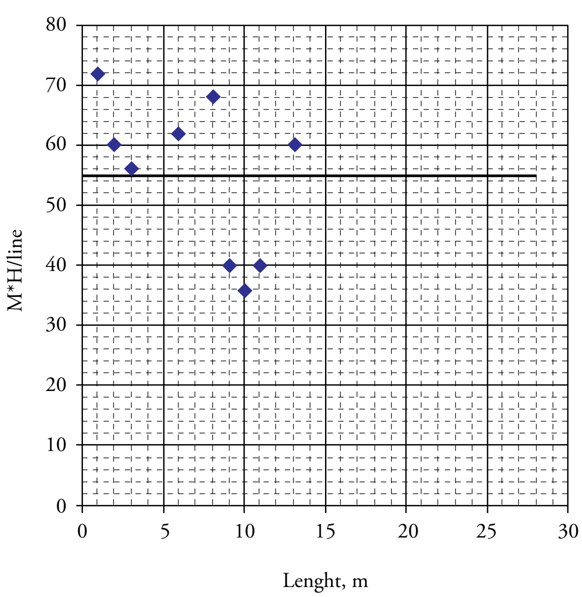


Fig. 11. Grounding and refloating.

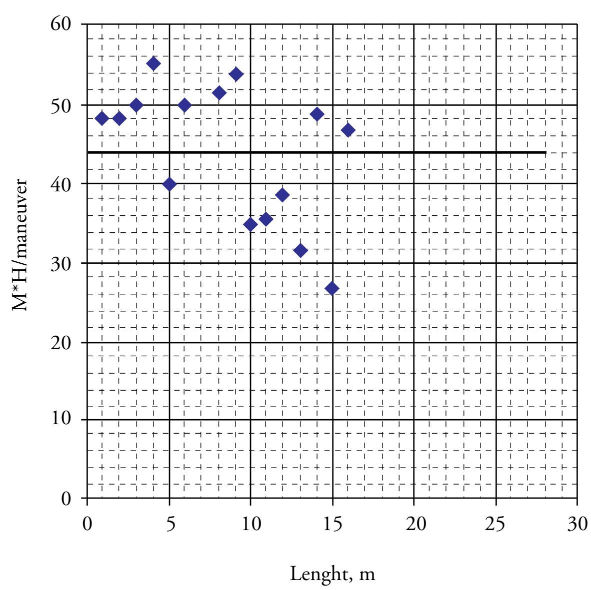


Fig. 12. Bottom valves.

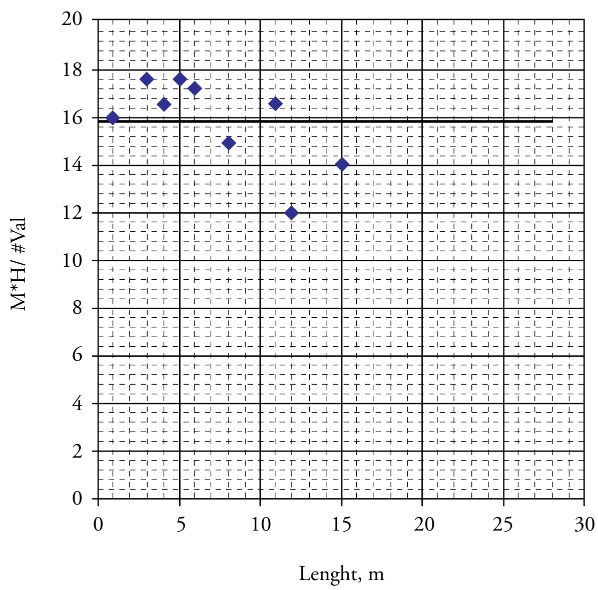
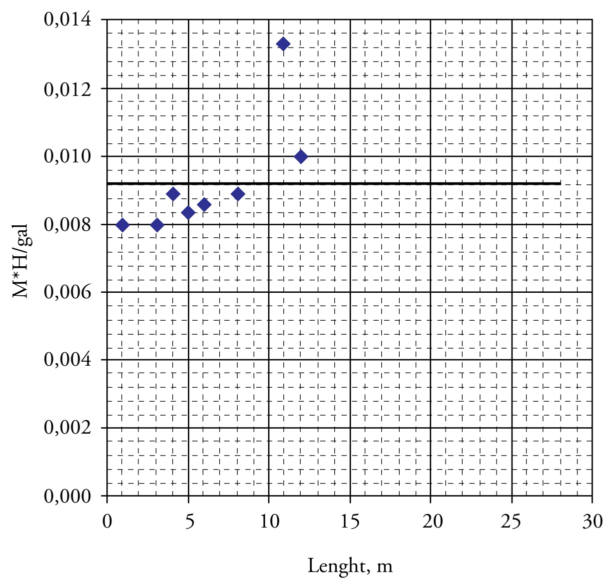


Fig. 13. Fuel tank clean up.



Fuzzy Predictive Model of the Vertical Acceleration of a High Speed Vessel in Pitch Motion

Modelo Predictivo Borroso de la Aceleración de Cabeceo de Buque de Alta Velocidad

Francisco Gil Navia[1]
Juan Contreras Montes[2]

Abstract

An adaptable fuzzy inference technique is being described in order to generate predictive models of the acceleration of the pitching of a high speed vessel, from the data obtained from the web on an experiment conducted by the University of Iowa. The geometry of interest in the experiment is a scale model of the type 1/46.6 of the DTMB model 5415 (DDG-51). The fuzzy algorithm for the generation of the predictive model uses a triangular partition with a 0.5 overlapping and consequents of the Singleton type. The consequents are adjusted in an automatic fashion by using recursive least squares. The algorithm shows a very low computational complexity rate which allows for it to be used for on line identification.

Key words: fuzzy identification, vessel pitching, fuzzy predictive model, recursive least squares.

Resumen

Se describe una técnica de inferencia borrosa adaptativa para generar modelos predictivos de la aceleración de cabeceo de un buque de alta velocidad, a partir de datos obtenidos de la web de un experimento realizado en la Universidad de Iowa. En el experimento, la geometría de interés es un modelo a escala 1/46.6 del DTMB modelo 5415 (DDG-51). El algoritmo borroso para la generación del modelo predictivo emplea partición triangular con solapamiento de 0.5 y consecuentes tipo singlenton. Los consecuentes son ajustados de manera automática empleando mínimos cuadrados recursivos. El algoritmo presenta una baja complejidad computacional lo que permite su empleo para identificación en línea.

Palabras claves: identificación borrosa, cabeceo de buque, modelo predictivo borroso, mínimos cuadrados recursivos.

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Introduction

Thanks to the current use of lighter materials in the construction of vessels great growth has been achieved in the development of high speed vessels. However, the high speeds that have been achieved generate in turn vertical accelerations which result in dizziness and fatigue for the members of the crew and to the passengers as well, thus affecting the safety and comfort. In order to get a decrease in vertical accelerations, control surfaces are used in high speed vessels which through the appropriate control system vary the attacking angle presented by the ocean in its advance, thus generating a reaction to the vertical forces actuating upon the ship. *(Santos et al, 2005).*

To design the pitching control system it is necessary to have a model capable of predicting the vertical acceleration value from the previous data taken from the input variables related to the dynamics of the waves. Modeling complexity is due to the fact that we are dealing with a dynamic that is highly non - linear.

Fuzzy logics have proven to be greatly useful to represent the behavior or dynamics of the systems through diffuse rules of the IF-THEN type. The first systems that were based on diffuse rules were supported on the information as supplied by an expert; however, in the case of complex systems the rules that had been built that way did not allow for an acceptable simulation of the system. In the search of fuzzy systems that approximate in an acceptable manner the dynamics of complex systems has lead to the development of a research in extraction techniques of fuzzy rules from the input and output data; that is, the development of fuzzy identification techniques (*Sugeno and Yasukawa, 1993).*

One of the first proposals for the automatic design of fuzzy systems from experimental data is the technique called the look-up table scheme *(Wang and Mendel, 1992).* Other important methods use the descending gradient, grouping or clustering techniques and evolutionary algorithms. Except for the last one, all methods require a previous design of the membership functions.

Building a fuzzy model requires the selection of a great number of parameters: number, form and distribution of the membership functions, construction of the rule base, selecting the logical operators, selecting the inference method, among others. All these needs for a systematic criterion to be applied in order to make an accurate selection *(Espinosa and Vandewalle, 2000).*

Fuzzy cluster algorithms represent the most appropriate technique to obtain fuzzy models. The Fuzzy C-Means *(Bezdek, 1987)* and *Gustafson-Kessel (1979)* methods are the most used ones. Several variations have been done to these cluster algorithms. *Nauck and Kruse (1995, 1999)* suggest neuro- diffuse cluster techniques; *Espinosa and Vandewalle (2000)* present a methodology to extract rules from the data within a linguistic integrity frame including fusion algorithms to group sets whose modal values are at a very close distance. *Sala (1998, 2001)* introduces a novel technique based on the inference error to approximate functions by using partition sum1 with triangular sets; *Díez et al (2004)* propose introducing variations to the cluster algorithms in order to improve the ability to interpret them and find local structures that are similar within the fuzzy models obtained. *Paiva and Dourado (2004)* present a model that has been generated through the training of a neuro- diffuse network which was implemented in two phases: during the first phase, the structure of the model is obtained by using a subtractive clustering algorithm, which allows for the extraction of the rules from input and output data; during the second phase, the parameters of the model are tuned in by means of a neural network that uses back propagation. *Guillaume and Charnomordic (2004)* propose a strategy to generate interpretable diffuse partitions from the data in which they incorporate an algorithm they call hierarchic fuzzy partition (HFP) which adds fuzzy sets instead of incorporating data in each iteration. They also present a fusion algorithm of the fuzzy sets based on the appropriate metrics that ensure semantic interpretability.

The methodology used in this paper to obtain the fuzzy model from the input and output data is based on Sala's (1998) error inference method and is presented in three phases: during the first phase, the inference error is used to detect possible types or clusters within the data; during the second phase, rules are generated; during the third one the form, number and distribution of the fuzzy sets are generated. Using an ideal inference method is another proposal that has been made.

Characteristics of the Data Collection Experiment

The following study is supported on the work done by *Irving et al (2006)*, on the experimental tests carried out at the test tank of IIHR (Hydro science & Engineering from the University of Iowa, Iowa City, USA) using a DTMB (David Taylor Model Basin) a 5512, as the geometry of interest. The data was taken from the following web page: (http://www.iihr.uiowa.edu/~shiphydro/efd_vdata_5512_pitch_and_heave.htm).

The tests are carried out in the test tank at Iowa University IIHR. The tank has 100 m of length, a width equivalent to 3.048m and a depth of 3.048m and it is equipped with a wave generator of the automated plunger type. The towing car is equipped with 2 data acquisition computers, circuit speed and signal conditioning to measure analog voltages measured from the speed of the vessel, speed of the carriage and wave elevation.

The geometry of model 5512 scale 1:46.6 with Lpp=3.048m is made of reinforced fiber with CB=0.506. This model is a symmetrical geometric scale (geosim) of the DTMB 5415 (scale 1:24.8, Lpp=5.72m), that has been conceived by the US Navy as a preliminary design of a combatant.

The tests are conducted for 5 Froude Numbers *Fr* and 3 wave steepnesses Ak, where

$$Fr = Uc / \sqrt{gL} \qquad \mathrm{Ak} = 2\pi \ \mathrm{A}/\lambda \tag{1}$$

from where:
Uc = speed of the towing carriage
A = wave amplitude
Fr = 0.28 corresponds to the cruising speed
Fe = wavelength

Data collection occurs at 80, 106.7, 160 Hz / channel, for 30, 20, 15, 10 seconds correspondingly, for those cases where Fr = 0.19, 0.28, 0.34, 0.41, correspondingly. The parameters for the collection of data are the same for Fr = 0 and 0.19, Uc = 0 m/s. The data includes ballasting parameters, the encounter frequency, time histories, Fourier series amplitudes and pitch and heave transfer functions and phase.

Fuzzy Modeling Algorithm

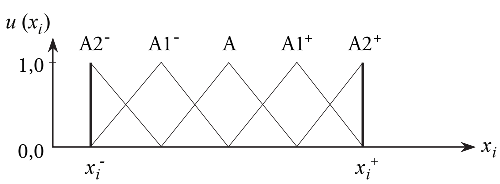
The algorithm for fuzzy systems that can be interpreted from the data available is based on minimization process of the inference error. All the user needs to do is to introduce the data of the input and output variables. The algorithm determines the ranges of each variable, distributes the membership functions within the universes of each input variable, locates the consequents of the Singleton type in the outlet space, determines the rules and adjusts the location of the consequents, by using the least squares in order to minimize the approximation error. The algorithm stops once it has an error measurement that is lower than the one required by the user or when the number of fuzzy sets per input variable is greater than 9. The distribution of the membership functions in each input universe is done in a uniform fashion in order to guarantee that the resulting partition is sum 1; that is, the sum of all the degrees of membership of a data within an input variable will always be equal to 1 *(Gil and Contreras, 2008)*.

Given a collection of experimental input and output data $\{x_k^{(i)}, y^{(i)}\}$, with $i = 1...N$; $k = 1..., p$, where $x_k^{(i)}$ is the input vector of input p-dimensional $x_1^{(i)}, x_2^{(i)},... x_p^{(i)}$ e $y^{(i)}$ is the output one dimensional vector.

1. Organization of the set of N pairs of pieces of input - output data $\{(x_i, y_i) \mid i = 1,2,...,N\}$, where $x_i \in \Re^p$ are input vectors and y_i are output scaling.
2. Determining the ranges of the universes of each variable as per the maximum and minimum values of the data associated $[x_i^-, x_i^+]$, $[y^-, y^+]$
3. Distribution of the triangular membership functions on each universe. As a general condi-

tion the vertex with a membership value of one (modal value) falls in the center of the region that is covered by the membership function while the other two apexes, with a membership value equal to zero, fall in the center of the two neighboring regions. In order to be able to efficiently approximate the lower and upper ends of a function that is being represented by the data it is necessary for the membership functions covering the beginning and end of the universe that in the triangular partition to coincide their apexes with their membership values of one with their left and right apexes correspondingly, as shown in Fig. 1.

Fig. 1. Distribution of the triangular membership functions



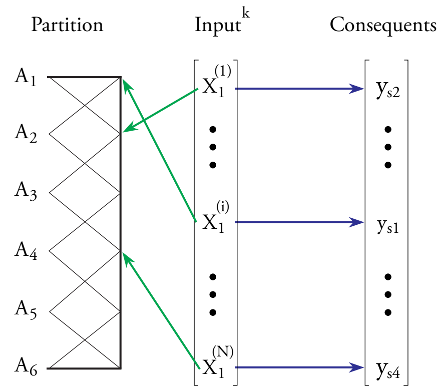
4. Calculating the position of the modal values of the input variable (s), as per the following:

$$\begin{aligned} &\text{if} \quad u_{A_k^{(n)}}(x_k^{(i)}) = 1 \\ &\text{End} \quad ys_k^{(n)} = y[i] \end{aligned} \tag{2}$$

where $ys_k^{(n)}$ corresponds to the projection on the outlet space of the assessment of data $x^{(i)}$ de la k-th input variable in the n-th corresponding partition set. The value of the output that corresponds to the said projection is given by the value of the i-th position of the output vector y.

5. Determining the rules. The number of rules as initially obtained is the same as the number of sets of each input variable multiplied by the number of variables; that is, it is equal to $n \times k$. The membership functions associated to each consequent will form the antecedents of the rules. An algorithm to reduce the number of rules will be introduced later on. (see Fig. 3)
6. Validation of the model, or calculating the approximation by using the inference method as described by

Fig. 2. Determining the consequents.



$$f(x^{(i)}) = \frac{1}{N}\sum_{j=1}^{L} \bar{y}^{j} m_j\left(x^{(i)}\right) \tag{3}$$

where $\bar{y}^{j}$ is the solitary value that corresponds to rule j

7. Adjusting the parameters by relocating the output solitaires, using the least squares method. In order for that to be possible, the equation (2) is presented as

$$f\left(x^{(i)}\right) = \sum_{j=1}^{L} \bar{y}^{j} w_j(x^{(i)}) \tag{4}$$

where

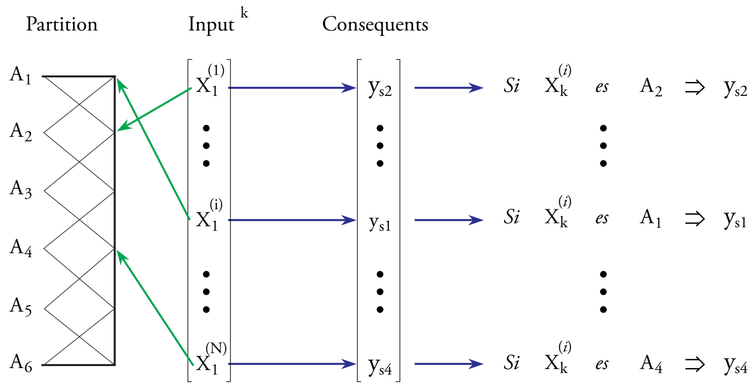
$$w_j\left(x^{(i)}\right) = \frac{m_j\left(x^{(i)}\right)}{\sum_{j=1}^{L} m_j\left(x^{(i)}\right)} = w_j^{i} \tag{5}$$

As per the inference process, the output n values may be represented with the form $Y = W\Theta + E$, which in a matrix form is given by

$$\underbrace{\begin{bmatrix} y^1 \\ y^2 \\ \vdots \\ y^n \end{bmatrix}}_{Y} = \underbrace{\begin{bmatrix} w_1^1 & w_2^1 & \cdots & w_L^1 \\ w_1^2 & w_2^2 & \cdots & w_L^2 \\ \vdots & \vdots & \ddots & \vdots \\ w_1^n & w_2^n & \cdots & w_L^n \end{bmatrix}}_{W} \underbrace{\begin{bmatrix} \bar{y}^1 \\ \bar{y}^2 \\ \vdots \\ \bar{y}^L \end{bmatrix}}_{\theta} + \underbrace{\begin{bmatrix} e_1 \\ e_2 \\ \vdots \\ e_n \end{bmatrix}}_{E} \tag{6}$$

where E is the approximation error that has to be minimized, and Θ is the consequent vector.

Fig. 3. Determining the rules.



When using the norm of the root square error we have

$$E^2 = (Y - W\theta)^2 = (Y^2 - 2YW\theta + (W\theta)^2) \quad (7)$$

The solution to this least squares problem, by adjusting the consequents, is given by

$$\frac{\partial E^2}{\partial \theta} = 0 = -2Y^T W + 2W^T W\theta \quad (8)$$

from where the following has been obtained

$$\theta = \frac{Y^T W}{W^T W} = (W^T W)^{-1} Y^T W \quad (9)$$

This solution is valid if ($W^T W$) is not singular, what this means is that all the rules need to receive sufficient excitation (persistent excitation) during training. This is not always possible in practice, which is why it is recommended to go to the application of recursive least squares, seeking to guarantee that the adaptation process will affect the rules that have been excited *(Contreras, 2006; Espinosa and Vandewalle, 2000, 2005)*.

8. Determine whether the measurement of the root mean square error MSE is lower than a measurement that has been previously established. Otherwise, increase in 1 the number of sets of the income variable and go back to step 3.

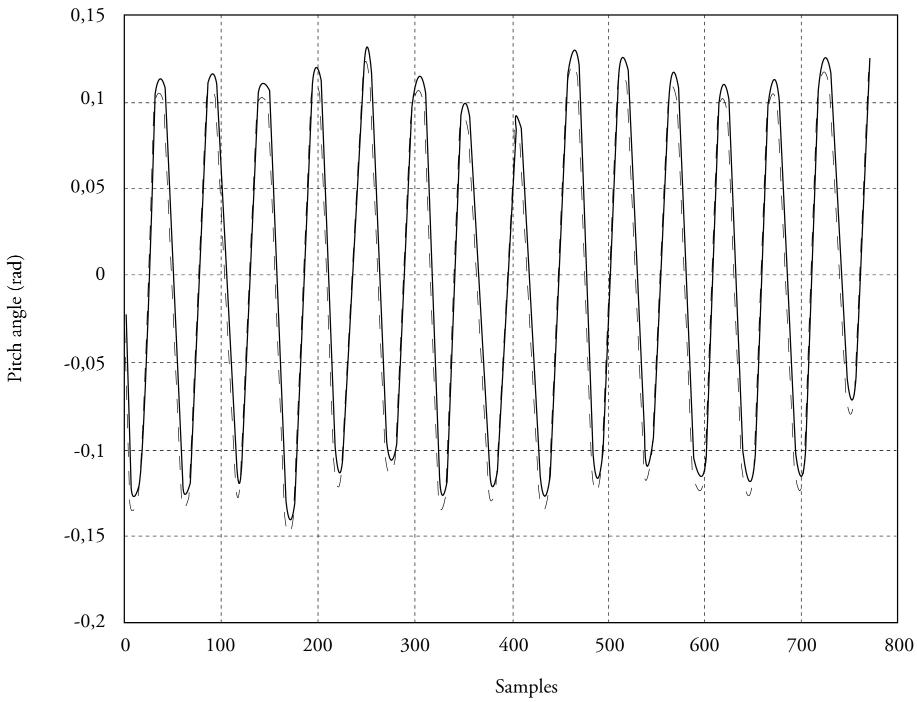
With the method that has been proposed it is possible to obtain a fuzzy model that can be interpreted with some degree of accuracy and the only thing needed is to adjust the parameters of the consequent, which are of the solitary type. This results in a decrease of the training time. It is possible to achieve a greater approximation ("fine adjustment") if upon finalizing the said process the decreasing gradient method were to be applied only to adjust the location of the modal values of the triangular sets of the antecedent, keeping the partition sum 1 and, therefore the interpretation ability of the system.

Results

The suggested method was applied to the experimental data found on the web page of the University of Iowa (http://www.iihr.uiowa.edu/~shiphydro/efd_vdata_5512_pitch_and_heave.htm), and that was taken from tests made to the model DTMB 5512, which is on scale of 1/46.6 of model DTMB 5415 (DDG-51) with L_{pp} = 3.048 m. The experiments were carried out in a towing tank that was 3 x 3 x 100 m and that was equipped with a wave generator of the plunger type. Several tests or series of tests were carried out, all of them at constant speed. The sampling speed was 53.3 samples per second. In order to obtain the model, all series were taken, regarding the wave signal at the following times: w(k-12) and w(k-6), as well as the pitch angle y(k) as input variables to predict the pitch angle at instant y(k+6).

The fuzzy model that was obtained has 3 triangular sets per variable (Low, Intermediate and High) which are evenly distributed and 12 rules. 800

Fig. 4. Comparison between the actual pitching signal and the prediction.



pieces of data were used for the identification and 800 pieces of data for validation. The root mean square error MSE reached was equivalent to 0.0012. Fig. 4 shows the comparison made between the actual process and the fuzzy model.

Conclusions

A method based on minimizing the inference error for the identification of systems from the data available is being presented here. The suggested strategy includes the use of fuzzy models that can be interpreted with the adjustment of the consequent parameters of the Singleton type, by using least squares. The method does not require the use of other artificial intelligence techniques.

Using the experimental data with a model replicated on a scale of 1/46.6 of model DTMB 5415 (DDG-51) a predictive fuzzy model has been obtained for the acceleration of the pitching.

Applying the method in the identification of classical dynamic processes has allowed for the obtainment of fuzzy models with a high accuracy rate without being forced to sacrifice the interpretation ability, as happens with most of the available methods.

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Multi objective support system for the decisions to plan scheduling of operations

Sistema multiobjetivo de soporte a decisiones para planificación de programación de operaciones

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Abstract

This research shows the design and construction of a multi objective optimization support system for decision making, DSS-SCHEDULER, in order to effectively perform naval shipbuilding operations, by managing to have a rational usage, under a limited capacity, of the installed capacity. The system creates the operational plan for the scheduling of operations as well as the allocation of all the resources related to the processes carried out at the plant, and, taking into account all the restrictions this type of service entails, generate a set of optimal solutions in order to comply with the objective functions as planned, such as costs and the promise for delivery dates to support the decision making process in scheduling Cotecmar's industrial operations.

Key words: DSS decision support system, multi-objective optimization, operation scheduling, operational planning, and evolutionary algorithms.

Resumen

La presente investigación muestra el diseño y construcción de un sistema de optimización Multiobjetivo de soporte a toma de decisiones, DSS-SCHEDULER, para realizar de manera efectiva la actividad de programación de operaciones en planta de astilleros navales, logrando una utilización racional, bajo capacidad finita, de la capacidad instalada, el cual realiza la creación de la planificación operativa de programación de operaciones y la asignación de todos los recursos asociados a los procesos que se realizan en la planta, y teniendo en cuenta todas las restricciones que conlleva estos servicios, generar un conjunto de soluciones óptimas cumpliendo con las funciones objetivo propuestas, como costos y promesa de fechas de entrega para apoyar la toma de decisiones de la programación de las operaciones industriales de Cotecmar.

Palabras claves: DSS Sistema de apoyo para la toma de decisiones, Optimización multi-objetivo, programación de operaciones, planificación operativa, Algoritmos evolutivos.

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Introduction

Planning the operations at the plants of the companies nowadays requires to be carried out through efficient and strong optimization techniques, which not only affect the development as well as the behavior of the company itself, but also, the tactical and strategic decisions this type of solutions entail such as cost estimation, policies, levels of service, priorities, machinery, among others.

Besides, the competition level for the company is increased since by having systems as the one presented by this research, a high technological development is obtained at the Information System (SI) because it is about systems that are at the top of the organizational pyramid due to the type of solutions the system is able to generate.

The theory of complexity shows us that for problems such as the planning and controlling of operation scheduling with a large number of restrictions and various objective functions, there are no exact methods through which it is possible to obtain feasible – optimal solutions. The use of heuristic techniques (EDD, LPT, SPT, etc.) allows us to find sub optimal methods in reasonable calculating times. Notwithstanding, it is the meta heuristic techniques the ones that take the biggest portion of the literature devoted to solving strong combinatory problems as well as the ones that have suggested the Best solutions.

Included here and among the so called meta heuristic types, are all the procedures that, within an iterative process, lead an ordinary heuristic by intelligently combining certain concepts that have been taken in analogy with nature, and explore the solution space by utilizing the learning strategies to structure the information to efficiently find solutions that are very close to the global optimal of a problem as an objective.

It is due to the reasons mentioned above, that it was necessary to implement an evolutionary meta-heuristic that would help, from the seed generating heuristic, to obtain optimal multi- objective plans for the solution of the problem.

Description of the problem and solution

Operation programming in industrial companies is a fairly complex job, due to the great number of variables, restrictions and objectives the entrepreneurs, operators and customers of the company have. The following items show the specific problem to be solved as well as the solution that has been suggested in this research.

Description of the Problem

Within the naval production environments, the ways in which we are able to make a product, be it a repair, empowerment or manufacture, the processes involved face a great deal of restrictions, such as, a product may have more than one production phase, it requires different processing times, etc. The way to assign: materials, human resources, dates, amounts to be produced by each one of the material resources or machines in order to comply with a delivery plan, has become a multiplicity of options from which choosing the best option is a difficult task. The result of this process is better known as the making of a sequencing plan or programming the operations. In various productive systems, the operation programming process takes on great significance, due to the incidence it has on both, the competitiveness and productivity of the company.

Operation programming is the process involving the allocation of resources that are limited to the tasks within a certain deadline, in order to optimize one or more objectives. These resources may very well be machines or people. Some examples of the said tasks include machine operation, moving, transportation, loading, unloading, etc.

Using heuristics and meta-heuristics in the operation programming process, helps deliver programs that are very close to the optimal objective. These mathematical models, used to schedule operations, depend on the way the company has been organized, as far as the physical structure and product flow the company has is concerned.

This company organization goes from the easiest one form a simple machine where just one type of product enters, to the problems of the type of a Flexible Job Shop Flexible that have a high level of complexity to be solved up to the programming of projects, where it is possible to find assembling activities and both machines and workers can be found working in one common activity.

Several different references can be found to use productive configuration. If the business environment were to be studied, it would be easy to find a variety of production systems at manufacturing and service rendering companies.

All tasks may have a deadline and some of the tasks may have priority over others. Among the operation programming objectives it is relevant to take into account the one that aims to reducing to the minimum level possible the time it takes to finalize all tasks (MAKESPAN) by maximizing the number of finalized tasks in a given period of time and reducing the inventory in process.

An Approach to the Solution

In order to find a solution to the problem that has been stated it could be approached from three specific fields, among which we can find:

Good information management: This solution is suggested due to the deficiencies encountered within the productive system when the time comes to store all production related information. Most of the companies only handle the information related to large amounts in long periods of time (days or weeks), but they do not have the information so it can be known in an accurate fashion what time the good enters the company, when it is being processed and an order is issued for its further study.

Good Planning: Companies do not have a system that helps them to plan production, that is, they do not have systems that by using logic works generate the best way to produce an item, which makes organizing the production a more difficult task upon receiving the orders. For this specific problem it would be a good idea if models were generated to help in the decision making process at the time of organizing the production schedule.

Adequate Technology: In order to give a solution to the production scheduling problems it would be useful to develop a systematic model (software) that helps in the operation programming activities at the company.

A combination of the three solutions would be the most appropriate option to solve the problem that has been stated, because with the aid of a tool that facilitates the task scheduling process, information management and besides uses the correct logic to program, a great contribution would be made in decreasing delayed deliveries, eliminating inventory and minimizing costs.

Decision Support System (DSS)

Description of DSS

Architecture of DSS

The decision support system (DSS) is supported on a two- level- architecture Client – Server, this supplies for the general sustainability of the system, among other aspects. The general architecture of the system can be seen in Fig. 1.

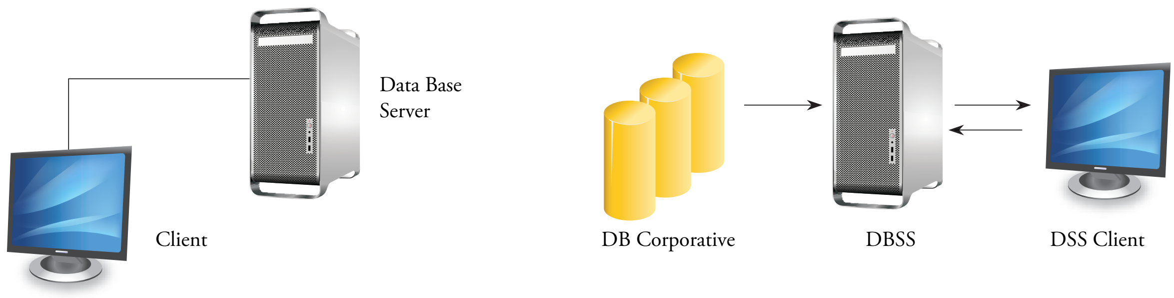
The Stand –Alone application which supports the system GUI can be found at the client's side. On the other side it is possible to find the Data Base server, which allows for persistence and the search for information.

Structural Components for the Programming Algorithm

The system information is supported on data structures (see Fig. 2) which facilitate the execution of the programming. These structures are linked and match their behavior to that of the portrayed reality, defining a programming algorithm that is as real and natural as possible.

As a whole, the programming model being proposed upon loading the information on these

Fig. 1. General architecture of the DSS.



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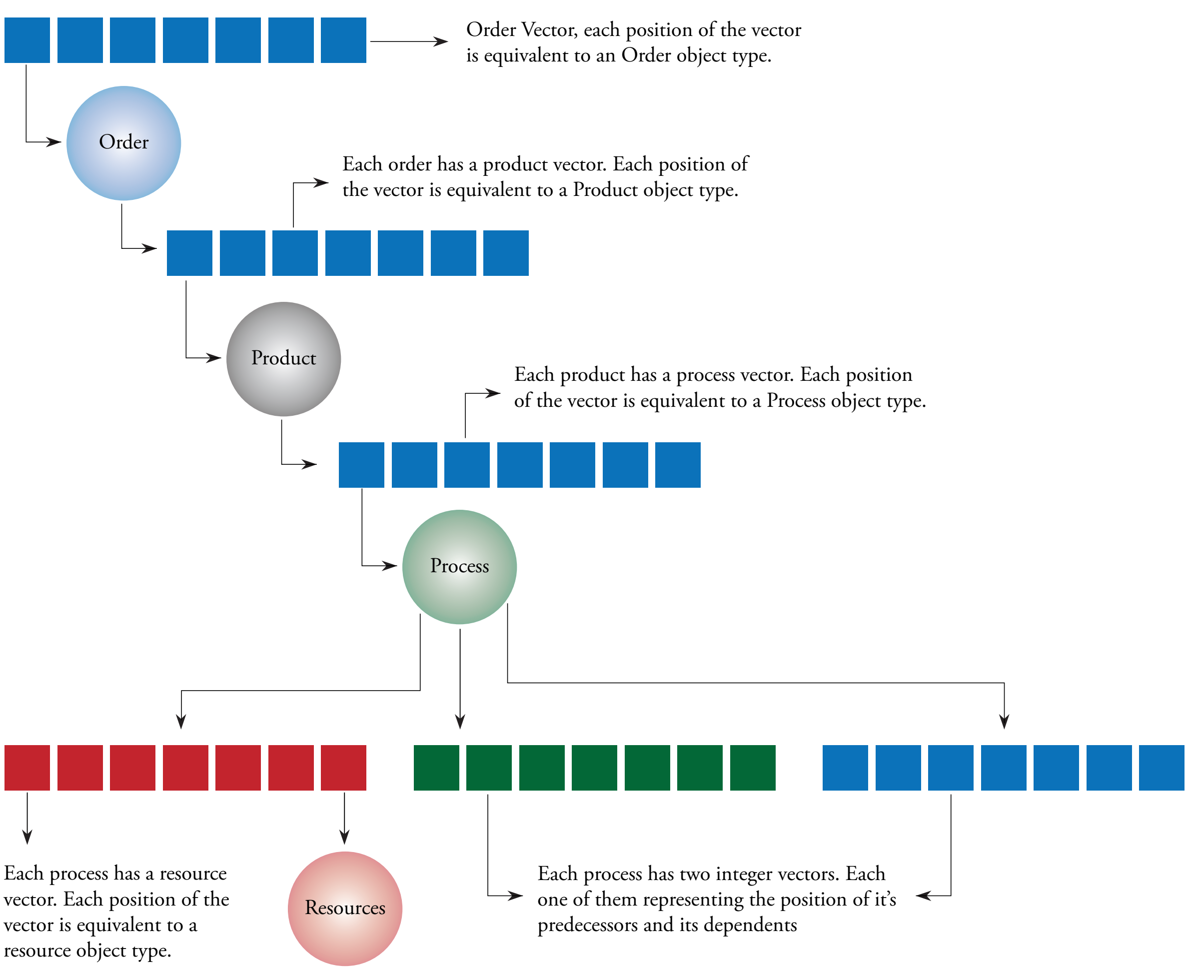
structures has the following Multi-objective function:

- Minimizing costs and the total processing time. Subject to these restrictions:

1. Validate the working day for $(\text{Processes})_k$
2. Validate the execution time $(\text{Processes})_k$
3. Validate the availability of $(\text{Resources})_j$

Fig. 2. Data structures as implemented on a logical and DSS programming level.



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Preliminary Heuristics

The DSS operates by means of a programming algorithm which in order to issue schedules that are as optimized as possible regarding cost vs. time suggests four mechanisms before the execution of the programming algorithm, as follows:

- Organize all production order by applying heuristics for EDD, SPT, SMPT, and LPT.
- Apply the heuristics that were mentioned in the previous item to the products in each one of the orders.
- Organize the internal processes of each one of the products according to their levels
- Randomly select the resources needed to carry out a process.

Scheduling Algorithm

There are two main objectives to the algorithm that has been described in Fig. 3, one is to minimize the idle time of the resources which will implicitly result in the optimization of the time needed to schedule the various activities that are part of the production process of the company and minimize costs by randomizing the selection of the resources involved in the operation of the process.

As a whole the DSS operates with heuristic techniques that from the beginning start contributing new solutions to the scheduling process, by determining each one of these and thanks to the randomization of the selection process of the resources as well as the minimization of the time needed to carry out the processes, various solutions can be obtained through one same heuristic such as EDD, SPT, among others, the general work flow of the system can be seen in the Fig. 3.

Fig. 3. Design and scheduling algorithm as implemented in the DSS.

```
Procedure performScheduling()
  Obtain (Production Order)_j  1 ≤ j ≤ number of orders
    Obtain (Product)_j  1 ≤ j ≤ number of products in production order i
      Obtain (Process)_k  1 ≤ k ≤ number of processes of product order j

      Select _ Resources_ on a Random basis (Process)_k
      Time = StartingTime (Process)_k
        Perform
          As long as (Process)_k does not comply with the restrictions in Time
            Increase Time
          End while
        InitialTime = Time
          As long as (Process)_k complies with the restrictions in Time and Time (Process)_k > 0
            Increase Time and Decrease Time (Process)_k
          End while
        FinalTime = Time
        Schedule the resources used by (Proceso)_k between the InitialTime and the FinalTime
        Up to Time (Process)_k = 0

      ∀(Process)_v that depend on (Process)_k to do StartTime( (Process)_v )= FinalTime
      End
    End
  End
End performScheduling
```

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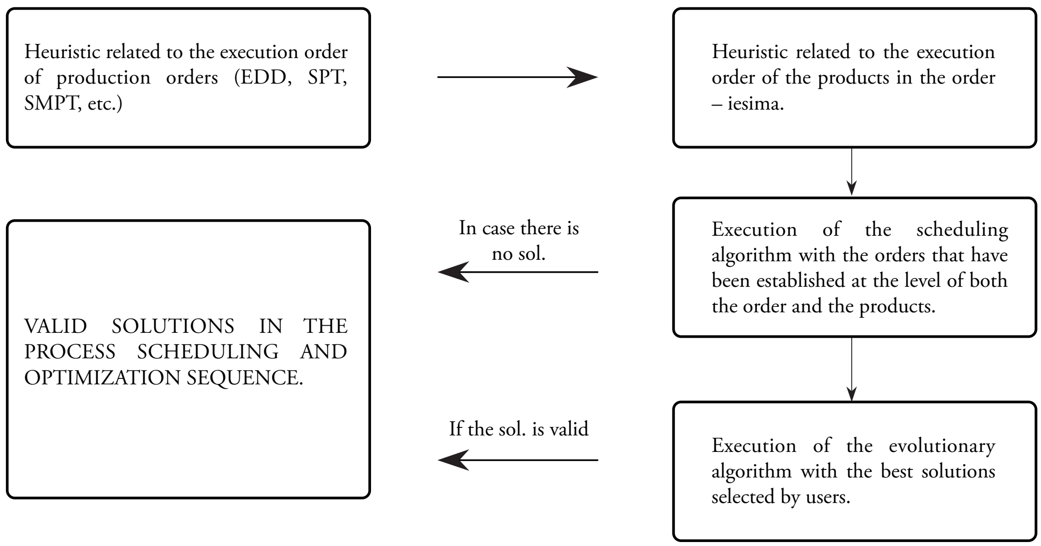
Fig. 4. DSS performance sequence.



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Evolutionary Algorithm

Once having finalized the scheduling process, by getting the end user to select the best solutions the evolutionary algorithm is carried out. This algorithm has been specified in Fig. 5. The main objective of the algorithm is to obtain new solutions that somehow get to excel the ones suggested by the said algorithm through cross operators with Solutions that are generated from the scheduling algorithm.

DSS Interfaces

Productive system configuration

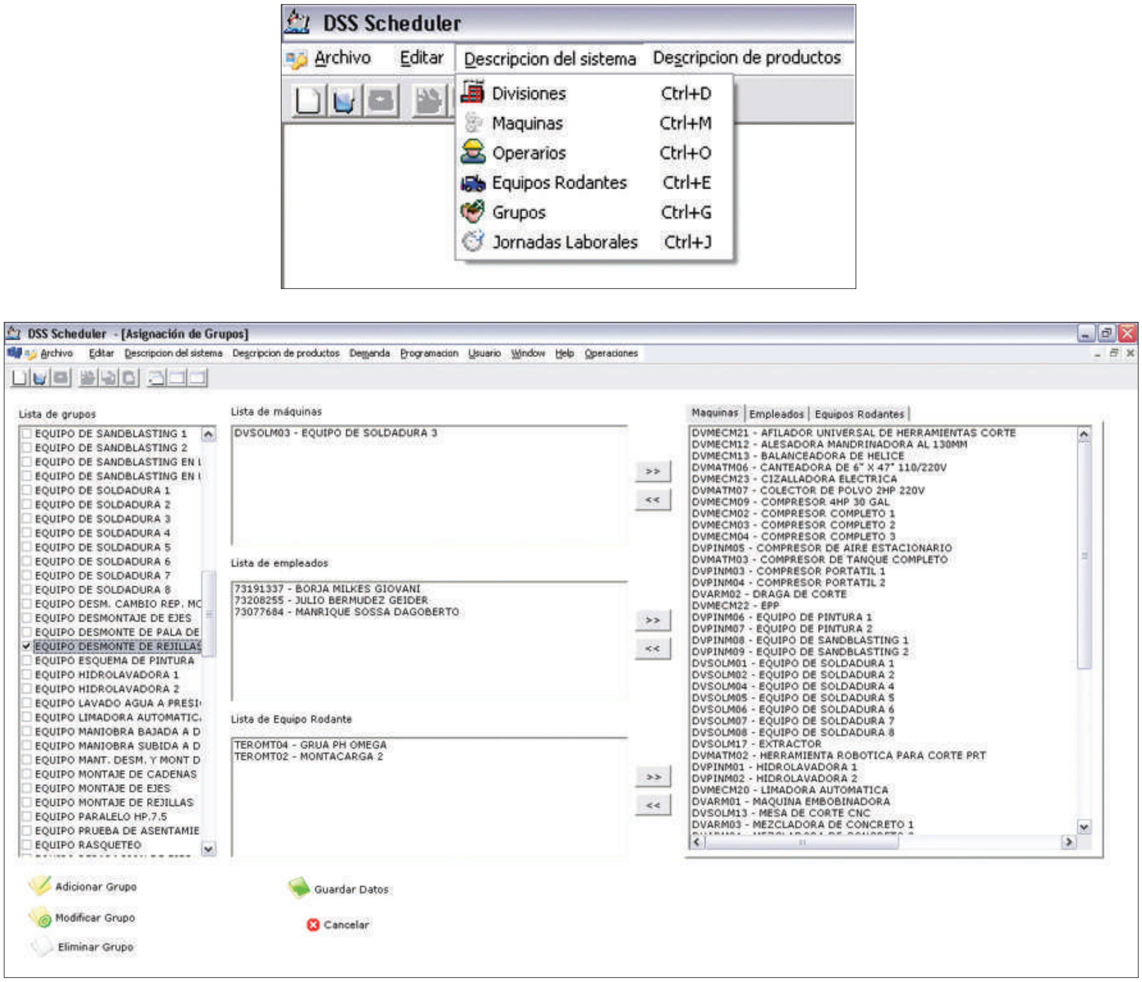
In this module you will find the definition of all the topics related to how the plant is doing, where the processes are going to be performed, the company's divisions or areas are also defined here, and so are the resources and resource associations for the creation of work teams and work days.

Fig. 5. The structure of the optimization evolutionary algorithm.

```
Scheduling optimization Procedure()
  As long as the solution does not improve in θ ggenerations and the maximum iteration number is not over passed do Mi
    Obtain (Solution)k  1 ≤ j ≤ number of solution
      Obtain (Solution)j  1 ≤ j ≤ number of solution
    Load solution (Solution)k
    Load solution (Solution)j
      New Solution = Perform Crossing  ((Solution)k ,(Solution)j)((Solution)k ,(Solution)j)
      If it is valid New Solution then Save (Solution)new solution
      End
    End
  End
End Optimize Scheduling
```

Source: Personal creation

Fig. 6. System Configuration.



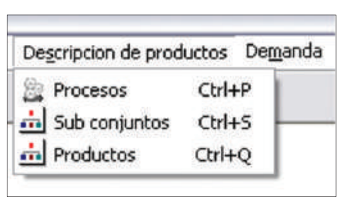
Source: DSS-SCHEDULER Modules.

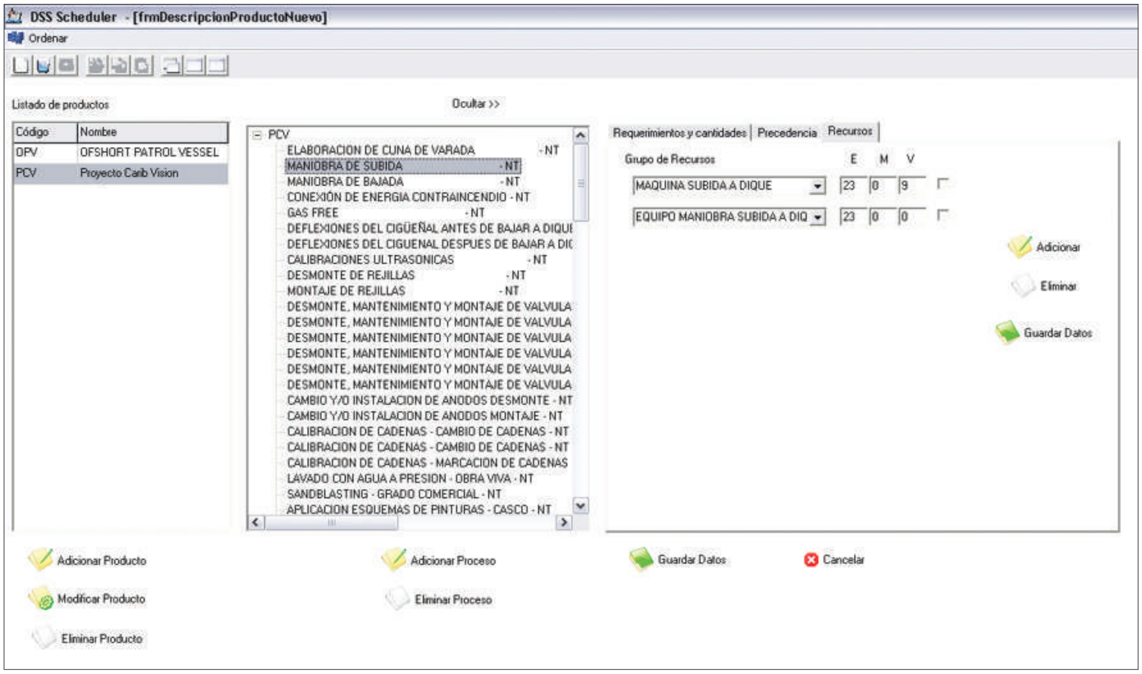
Product configuration within the system

This module specifies the requirements needed to make a product. The product tree is done representing what is needed to make a product, the processes, and requirements for by- products or raw materials, priorities and resource groups.

In the Fig. 8 we are able to see the configuration of the product tree, where we can find the finished product at the root. This finished product may very well be the unit. The finalized product, naval device or a service to be rendered, and if we go down each one of the levels we can see how each sub level

Fig. 7. Product description.

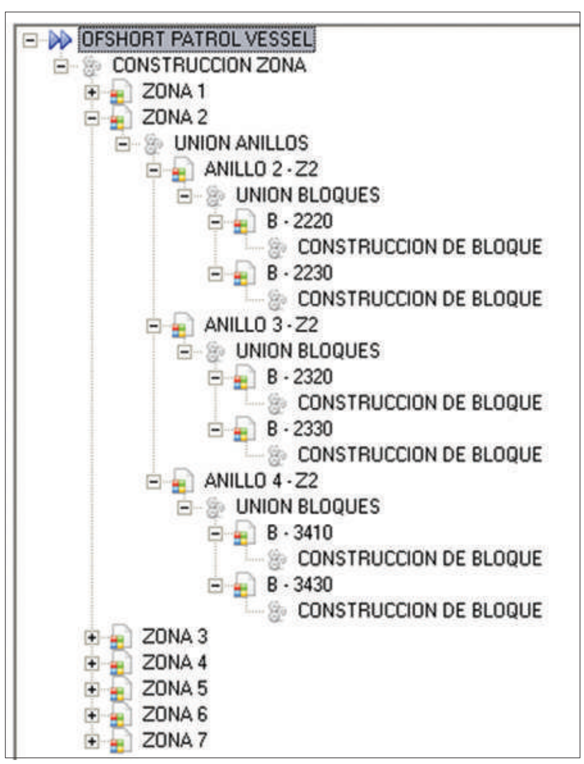


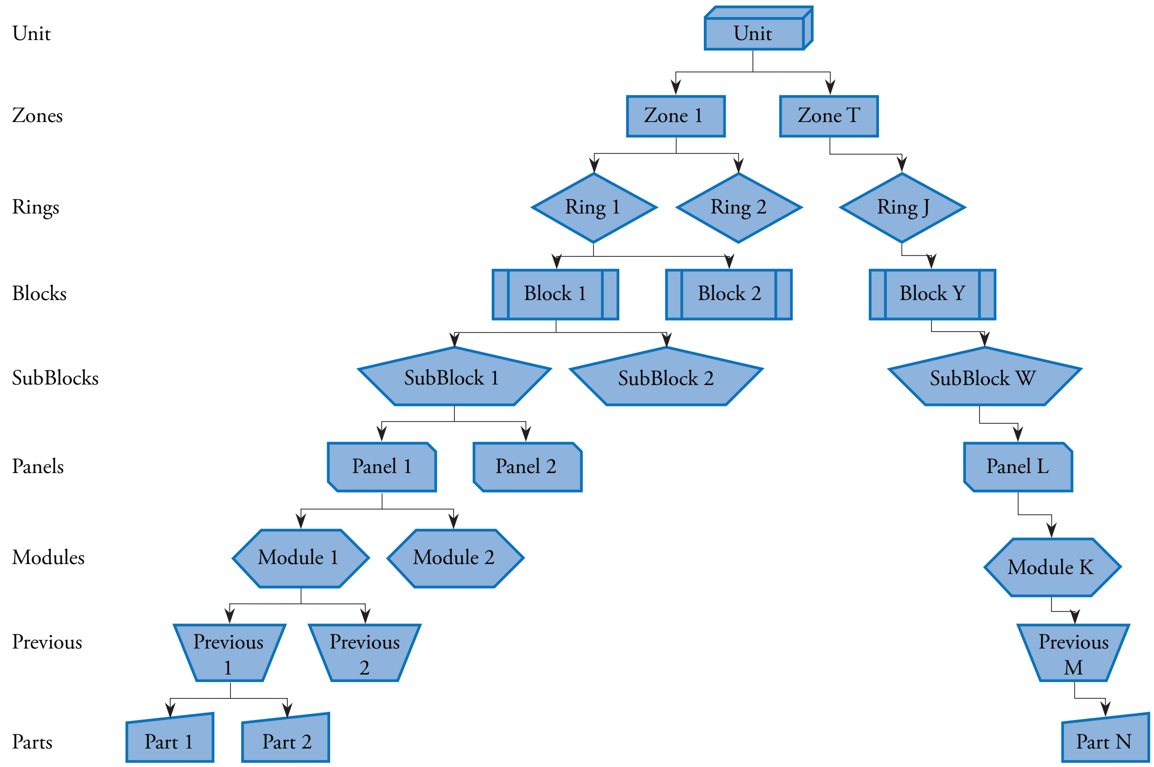


Source: DSS-SCHEDULER Modules.

of the tree is made up that refers to intermediate products until we reach the leaves of the tree where the requirements for raw materials can be found as well as some intermediate products. The processes required to be performed in order to complete a level and keep moving on until we get to the root of the tree, which is the final product to be developed, are associated to these levels.

Fig. 8. Description of the tree of the product.





Source: Personal creation

Description of the Orders
This module defines the customers, priorities, orders of purchase and production orders.

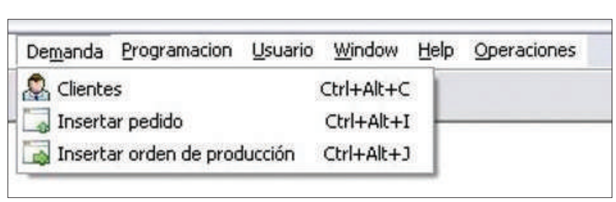
Reports
DSS-Scheduler has text reports where all the optimal solutions can be visualized as found by the optimizer and it allows for the exploration of each one of them in a detailed fashion. There are also graph reports in Gantt diagram with several filters for the user to be able to generate the reports as needed. Besides these reports, DSS lets us export the schedule as chosen to Microsoft Project where it can have a manipulation that is familiar with the various users the tool has.

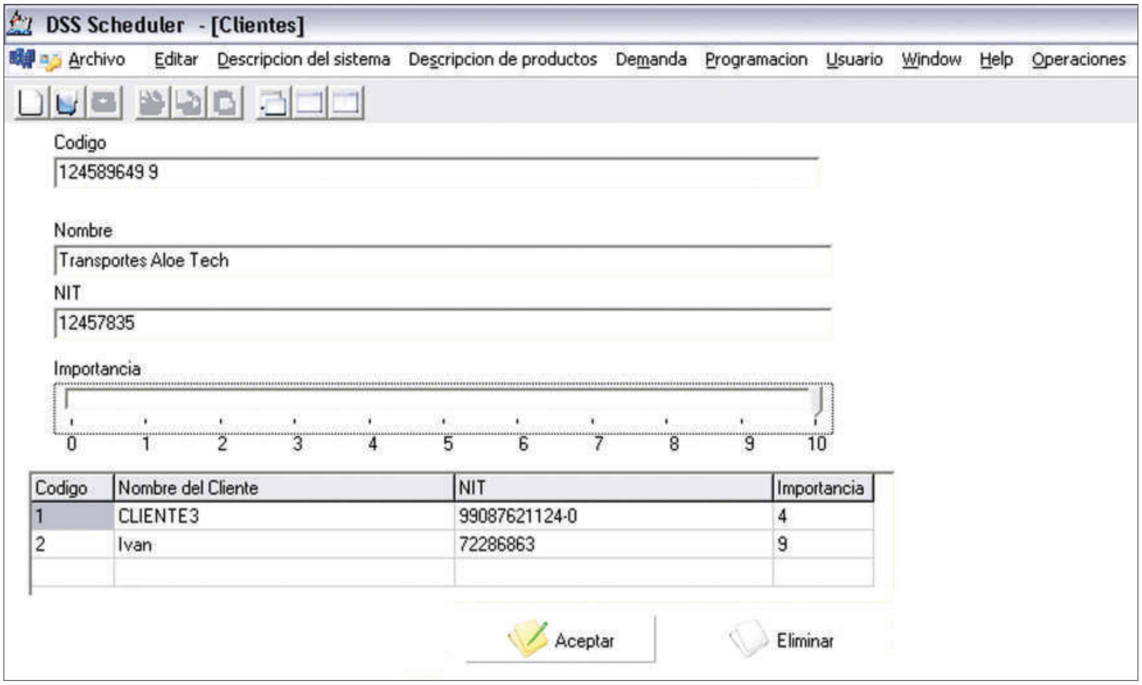
Results and implementations

As can be seen in Fig. 11 the DSS return a set of no dominated solutions. Each solution optimizes the overall cost and time of the production. In this test we build a unique ship. The solutions generated by the DSS always try to use equitative the resources for the scheduling step. Due to this, the resources are available for future works. Besides, the DSS uses the resources and take into account the cost. Consequently, the overall cost is minimized.

As can be seen in Fig. 12 b. The set of solutions are independent.

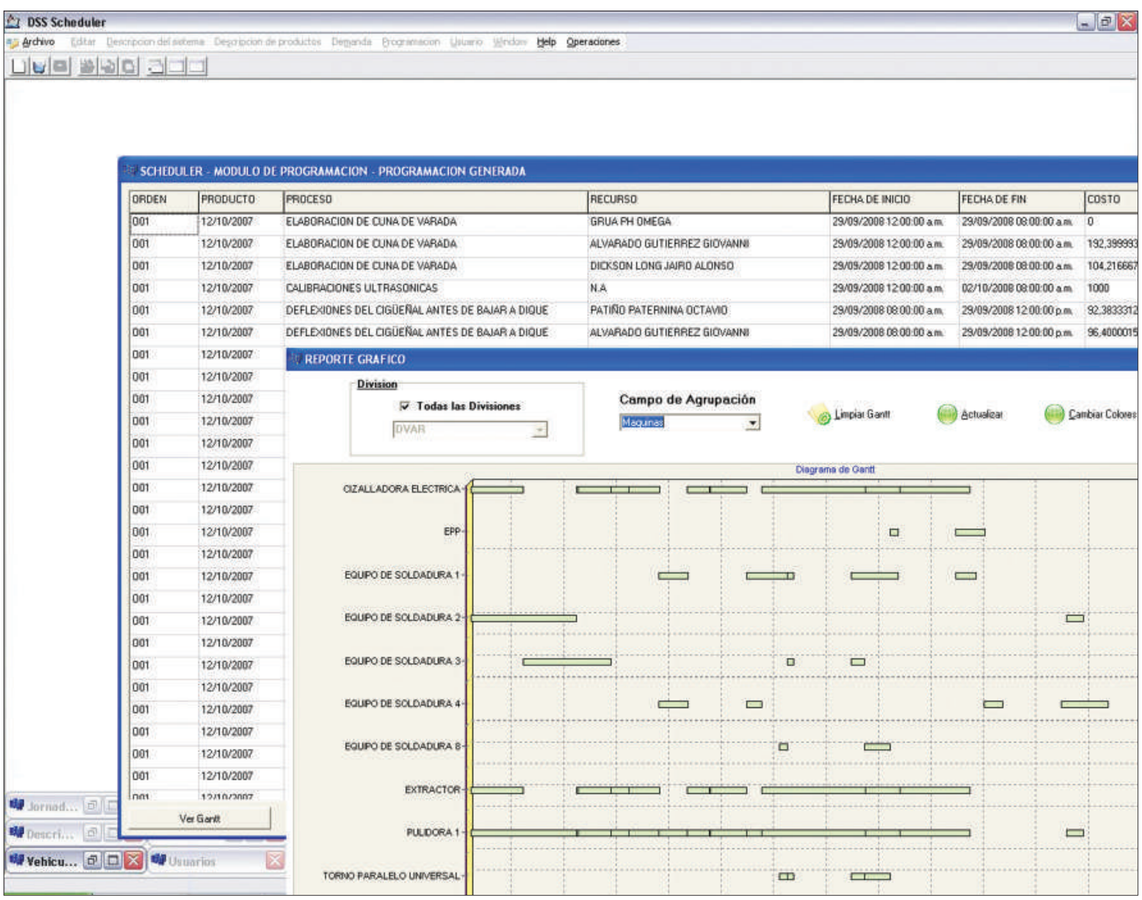
Fig. 9. Demand.

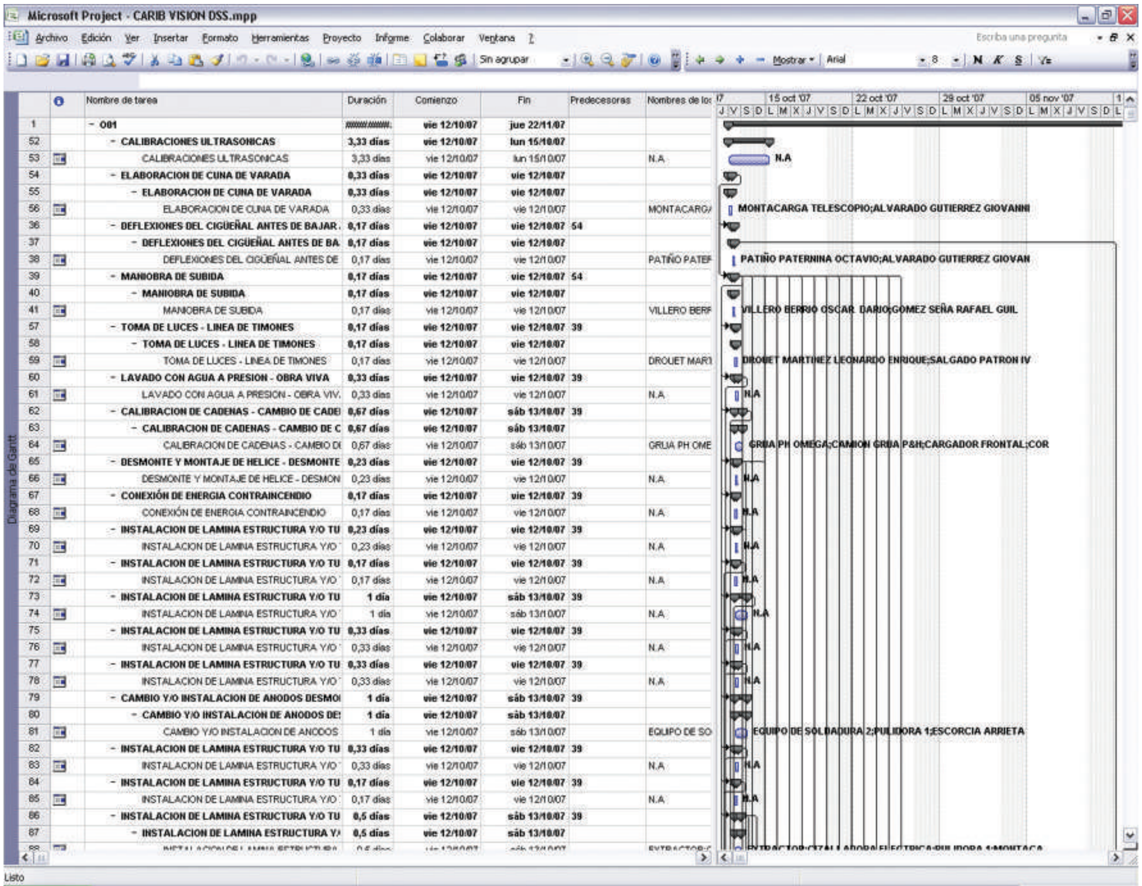




Source: DSS-SCHEDULER Modules.

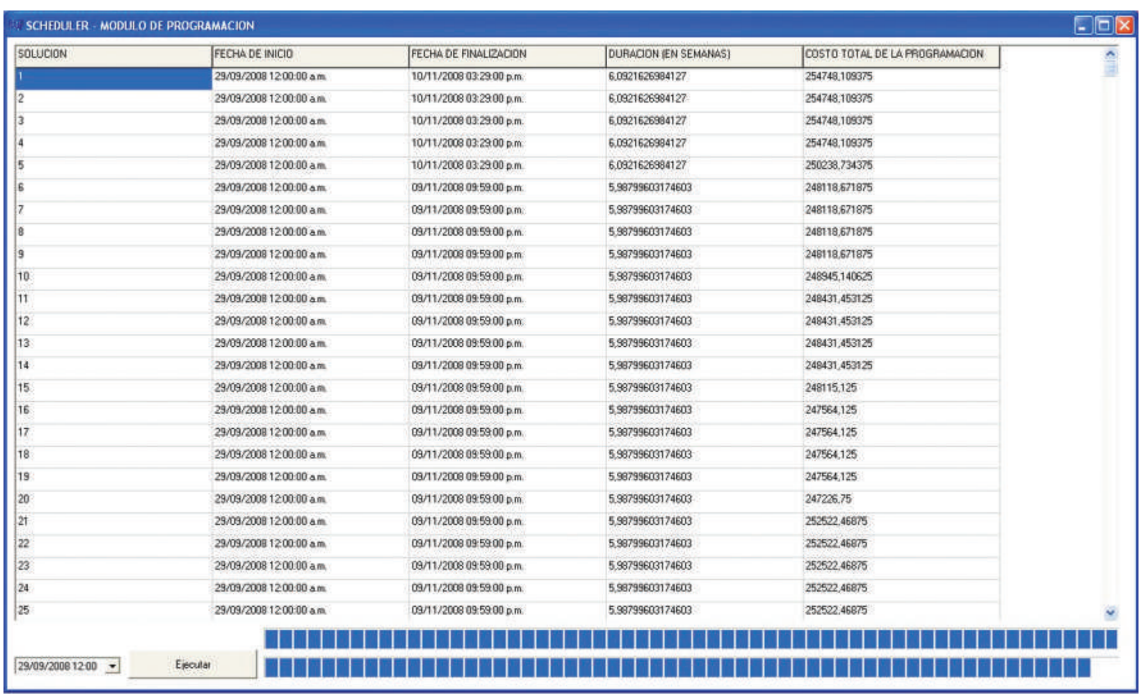
Fig. 10. Reports.





Source: DSS-SCHEDULER Modules.

Fig. 11. Test results promise delivery dates.



SCHEDULER - MODULO DE PROGRAMACION

SOLUCION	FECHA DE INICIO	FECHA DE FINALIZACION	DURACION (EN SEMANAS)	COSTO TOTAL DE LA PROGRAMACION
1	29/09/2008 12:00:00 a.m.	10/11/2008 03:29:00 p.m.	6,0921626984127	254748,109375
2	29/09/2008 12:00:00 a.m.	10/11/2008 03:29:00 p.m.	6,0921626984127	254748,109375
3	29/09/2008 12:00:00 a.m.	10/11/2008 03:29:00 p.m.	6,0921626984127	254748,109375
4	29/09/2008 12:00:00 a.m.	10/11/2008 03:29:00 p.m.	6,0921626984127	254748,109375
5	29/09/2008 12:00:00 a.m.	10/11/2008 03:29:00 p.m.	6,0921626984127	250238,734375
6	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	248118,671875
7	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	248118,671875
8	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	248118,671875
9	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	248118,671875
10	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	248945,140625
11	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	248431,453125
12	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	248431,453125
13	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	248431,453125
14	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	248431,453125
15	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	248115,125
16	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	247564,125
17	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	247564,125
18	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	247564,125
19	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	247564,125
20	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	247226,75
21	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	252522,46875
22	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	252522,46875
23	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	252522,46875
24	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	252522,46875
25	29/09/2008 12:00:00 a.m.	09/11/2008 09:59:00 p.m.	5,98799603174603	252522,46875

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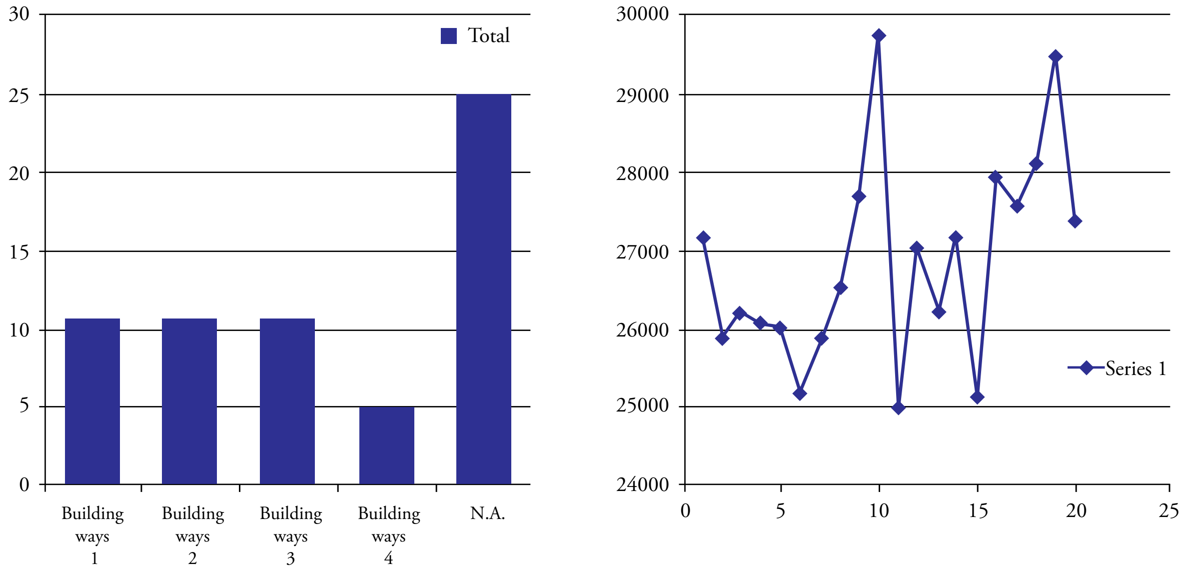
Source: DSS-SCHEDULER Modules.

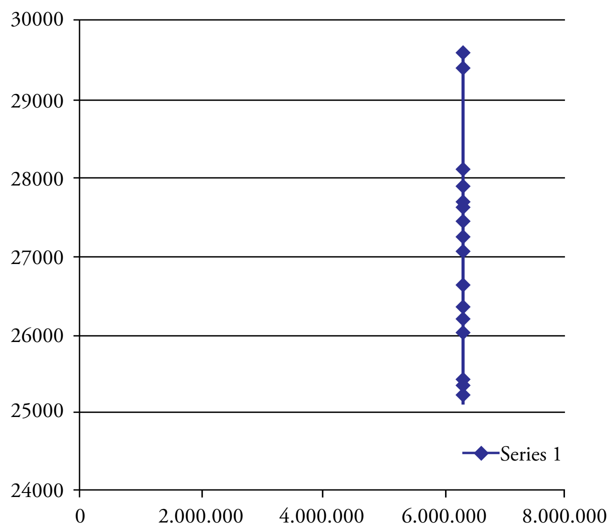
Fig. 12. Resource utilization results.



Using resources for OPV Building

Independence of the solutions generated by the optimizador, variable of study-cost

Fig. 13. Solutions generated by the DSS.



The DSS can be applied to companies of the productive sector. Due to this, each company that need a set of process for building a product can use the software for controlling and yielding of the overall production.

Conclusions

DSS is an information system used as a support to make decisions instead of an automatic decision maker. A support to make decisions is regarded as an aid for the people to work alone or in group in such a way that alternatives are generated and the most appropriate decisions can be made based on actual information. This tool has been assessed under the repair works of a ship where the results obtained by the DSS were lower in terms of times of execution as compared to the actual values for the execution of the test project. It is necessary to use the tool to promise delivery dates to the customers and to make an estimate of the costs involved in the development of the projects to be carried out since it allows for the assessment of the probabilistic scenerios requested by the company's potential clients.

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Volume 6 Information

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

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It must be concise (no more than 25 words) with appropriate words so as to give reader a slight idea of content. It must be sent in English and Spanish language.

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Author's name must be written as follows: name, initial of second name and surnames. Affiliations of author must be specified in following way and order:

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

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Text must be explanatory, clear, simple, precise and original in presenting ideas. Likewise, it must be organized in a logic sequence of parts or sections, with clear subtitles that guide reader. The first part of document is the introduction. Its objective is to present the theme, objectives and justification of why it was elected. Likewise, it must contain sources consulted and methodology used as well as a short explanation of status of 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 theme, status of its analysis, results obtained and conclusions.

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All of these elements must be numbered in order of appearance according to its type and have at the foot, that is, exactly underneath of chart, graph or picture, the source from where data was taken and who made it.

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All expressions and mathematical analysis must explain all symbols (and unit in which it is measured) that have not been previously defined in the nomenclature. If work is extremely mathematical by nature, it would be advisable to develop equations and formulas in appendixes instead of including them in body of text.

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

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