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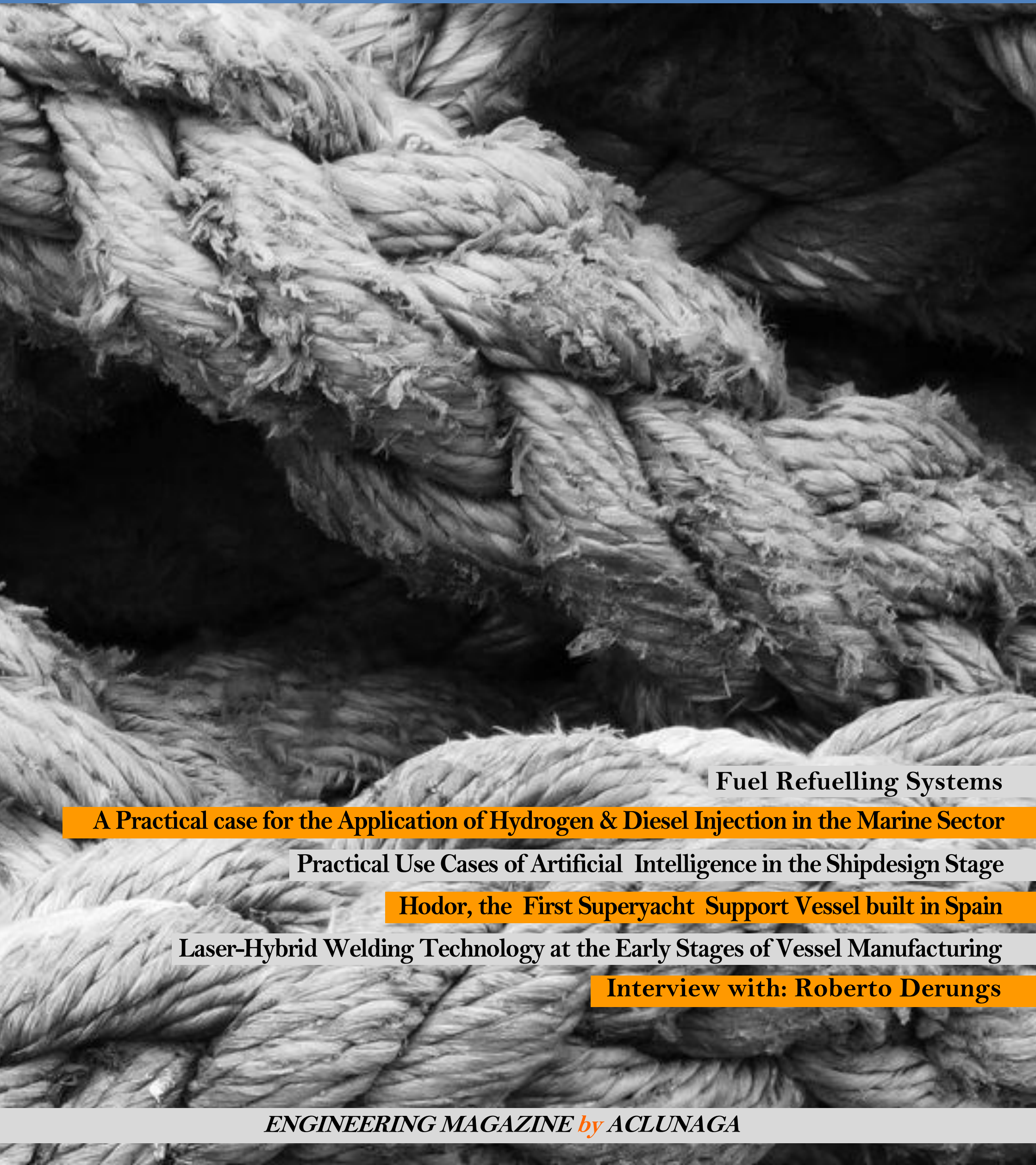
GMT *by* ACLUNAGA



Fuel Refuelling Systems

A Practical case for the Application of Hydrogen & Diesel Injection in the Marine Sector

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ENGINEERING MAGAZINE by ACLUNAGA

Editorial

By the time this new issue of the magazine comes out, the situation will have changed considerably for the Galician shipbuilding and repair sector. We still do not know to what extent, but we do know how the group has reacted to past unfavourable contexts: planning, research, flexibility, know-how, development, specialisation, technology, quality and a lot of effort; are some of the characteristics that define us and that will serve as a solid base for the so-called recovery, for the continuation.

The spirit of the Cluster is based on the union of the sector, the promotion of collaboration and the development of the entire ecosystem of companies that integrate it. These, some of which are called tractors, have already proved to have the muscle enough when the occasion arises. The international shipbuilding landscape, which is where we move, has never been easily predictable. Perhaps it does have an even more marked component of uncertainty, but this factor has always been there in other situations, so it is not alien to us. However, our certainty, the reality that has not changed, nor will it, is the capacity to overcome and adapt of each of the members who are dedicated to making the most sophisticated and advanced products on the market from Galicia.

Since the beginning of this century, shipbuilding in the Autonomous Community of Galicia has supplied vessels to more than 32 countries, with a clear predominance of those that provide great added value, this is, those that require technological specialisation on a par with the best world builders. Being an absolute reference in fishing vessels, modern floating factories, with all that this implies at present. It is not a coincidence either that leading states trust our sector to manufacture the most sophisticated prototypes, such as oceanographic or training ships, to give a representative example. Of course the context will hit and affect the order book and workload, we don't know yet to what levels, but we have always known where to look, where to lead. And we certainly dominate construction sectors which are also necessary.

We therefore propose in this line, and as will be reflected below, the powerful and continuous collaboration between research companies and technology centres. Joint contributions to face the situation with strength and optimism, with facts, for the time being with a view to the near future, but which are and will undoubtedly be our foundations; our basis.

ACLUNAGA Editorial Team

"...planning, research, flexibility, know-how, development, specialisation, technology, quality and a lot of effort…"

FUEL REFUELLING SYSTEMS

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WHAT IS THE PURPOSE?

Refuelling systems, either for helicopters, zodiacs, or land vehicles, are the solution for the supply of the different types of fuels, both in offshore platforms (Jack-up, semi-submersible, etc), and in FPSOs, FSOs, yachts, military ships, or in any other type.

The purpose of the equipment is to receive and store fuel on board, to supply it safely, in optimal conditions and at the required time.

MAIN COMPONENTS

The Systems usually consist of four modules. The first one corresponds to the fuel storage tank, which can be static or aero transportable.

Aero transportable tanks over a Laydown skid

Static Tank

Second, is the pumps unit, whose basic components are the motor-pump groups.

Pumps Unit

Thirdly, the Dispensing unit, where the fuel filtering takes place and from where the supply is made through the unit's nozzle, which can be over wing or underwing.

Dispensing without cabin or with cabin

Finally, the main control panel of the system, which will be installed in a safe area.

¿HOW DOES IT WORK?

The basic operation of the equipment is as follows :

The solenoid valve that operates on the pneumatic discharge valve of the tank is activated, and the fuel is sucked in by one of the pumps installed in the pumps module. This unit is protected against vacuum operation and it is usually attached to the fuel tanks.

Fuel will pass through the pipe that connects the pump module with the Dispensing, which is installed as close to the heliport as possible. In this last module previous to the supply to the helicopter tank, the fuel (JET A-1, JP-5, etc) passes through the separator filter, where solid particles and free water present in the fuel are removed. Subsequently, the flow meter indicates the litres that have been supplied. The quality of the fuel that arrives at the helicopter is guaranteed by the sampling points, upstream and downstream of the separator filter, which allows us to check the possible presence of water in fuel by means of the detection capsules.

Finally, the fuel enters the helicopter tank through the nozzle installed in the hose.

DESIGN AND TEST

The helicopter supply systems (Helicopter Refuelling Units), currently the most in demand, have been designed by Detegasa according to the recommendations of the Standard CAP 437_"Standards for offshore helicopter landing areas". The main goal in the development of this equipment is to ensure that the refuelling process will be carried out safely and that the fuel supplied to the helicopter is optimum quality.

Taking into account that the equipment will work with fuel, electrical components with ATEX/IECEX certification are essential, suitable for the specific area in which each of these components will be installed.

3D Model of a Dispensing Unit

The design is tailored to the different requirements of the client, both civil and military, to the temperature conditions, which in some cases are extreme, and to the different classification societies.

Dispensing with dosage of anti-icing

The possibilities that may arise are wide and are not only given by the type of system to be refuelled. The type of fuel and the needs of each customer will lead to a custom design in each of the projects. In this way, it is possible to request that the system makes defuelling, as well as refuelling. This also allows greater flexibility in the supply so that refuelling inflight operations (HIFR), can be carried out, including the supply of a spill tank to the drains of the trays are leaded, etc.

Spill tank

For safety reasons, the equipment could have a leak detection system, both for gases and liquids.

Finally, the relevant internal tests are carried out in Detegasa. Then, the Factory Acceptance Test is performed in the presence of a surveyor of the Classification Society of the ship.

A PRACTICAL CASE FOR THE APPLICATION OF HYDROGEN & DIESEL INJECTION IN THE MARINE SECTOR

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INTRODUCTION

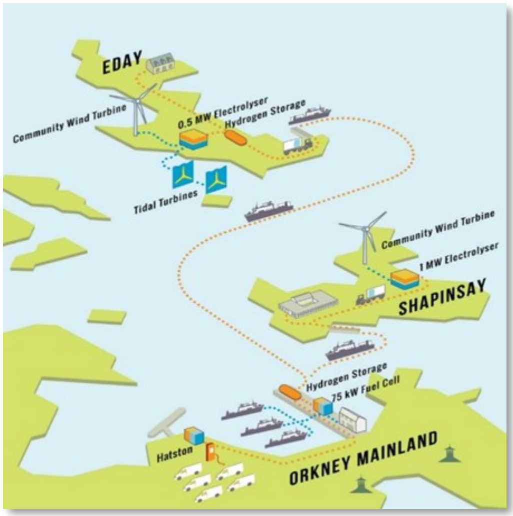
Hydrogen injection is a technology proven to reduce emissions within the automotive industry. This is achieved by injecting hydrogen into the ICE (internal combustion engine) and displacing the total amount of diesel required. The HyDIME (Hydrogen & Diesel Injection in Marine Environment) project is concerned with proving this technology in the marine industry, on board the MV Shapinsay ferry in Orkney.

The HyDIME system will utilise carbon free hydrogen produced using curtailed energy from wind and tidal turbines as onboard fuel for the hydrogen injection system.

The HyDIME project is tackling the following key issues:

- **The marine sector** is responsible for 3.3% of global Co2 production, with figures from the EEA suggesting that this will rise significantly if the marine industry does nothing to reduce their environmental impact.

- **The Orkney Isles** currently experience a community problem with renewable energy curtailment – where over 100% of the demand is being produced by renewable assets and some must be turned off, wasting this clean energy.



Simulation modelling was used to create a representation of the hydrogen-diesel ferry operating with different diesel displacement percentages and as part of the larger hydrogen infrastructure. This method allowed for the impact of the system to be quantified and also highlighted bottlenecks and threats within the system. It also facilitated scaled-up versions of the system to be modelled in order to assess the potential impact of future developments in this space.

ENVIRONMENTAL IMPACT

The environmental impact of the system was quantified in terms of diesel fuel and GHG emissions displaced and the use of simulation allowed for parameters of influence such as ferry timetables, and hydrogen transport logistics to be accounted for.

There were three main emission factors to consider :

- **Emissions saved** by displacing diesel on the hydrogen fuelled ferry .

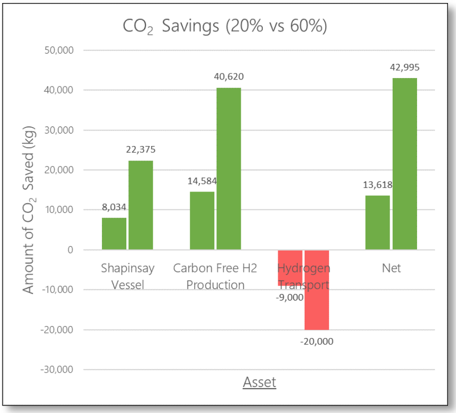
- **Emissions displaced** by utilising carbon-free electricity to produce the hydrogen in use .

- **Emissions produced** by the transportation of the hydrogen from the point of production to utilisation .

The model allowed for all of these factors to be considered and was simulated for 20% and 60% hydrogen-diesel displacement levels. The following results were obtained :

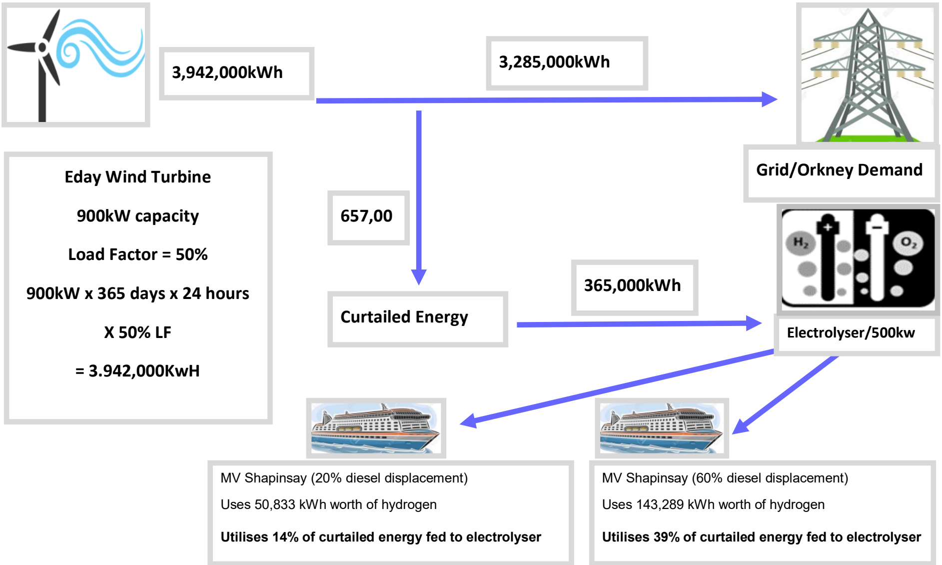
Parameter	Value	
Displacement Percentage	20%	60%
Total Diesel Displaced (L)	2,998	8,349
Total CO_2 Displaced from Diesel Displacement (kg)	8,034	22,375
Total H_2 Consumed by MV Shapinsay (kg)	937	2,609
Electricity Required to Produce H_2 Used by MV Shapinsay (kwh)	51,522	143,49
Total CO_2 Displaced from Carbon Free H_2 Production (kg)	14,584	40,620
Total CO_2 Displaced (kg)	22,618	62,995
CO_2 Emissions Associated with Transporting Hydrogen for HyDIME Use (kg)	9,000	20,000
Net CO_2 Displaced (kg)	13,618	42,995

Results produced after altering the refuelling logistics of the model (20% and 60% displacement levels; results are per year)



CO2 savings achieved after changing refuelling logistics for 20% and 60% displacement levels

The HyDIME project is tackling another energy problem – the curtailment of renewable energy that is experienced in Orkney when the full energy demand is met. During times of curtailment, the energy is used to produce green hydrogen which currently only has one use – as a fuel for a port side fuel cell. The HyDIME project provides another use of this hydrogen allowing more curtailed energy utilisation. The simulation modelling work estimated that the retrofitted vessel could utilise between 1 and 2.5 tonnes of hydrogen yearly which equates to between 52 and 140 MWh worth of electricity. The diagram below gives an approximated indication as to how HyDIME provides a solution to the curtailment issue experienced by the Eday wind turbine .



Overview of how the HyDIME system utilizes curtailed energy from the Eday wind turbine

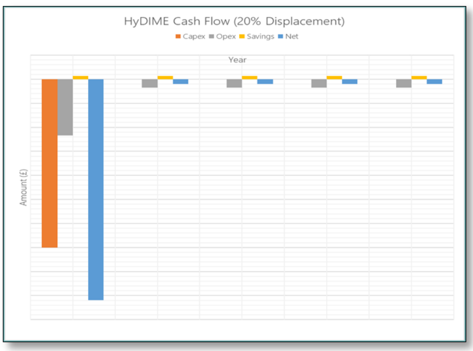
ECONOMIC IMPACT

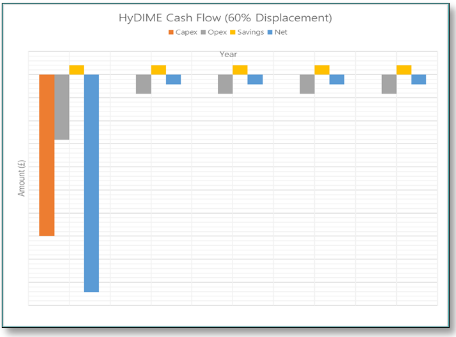
The economic impact of the HyDIME system was also addressed. The cost of hydrogen as a fuel is often regarded as the major pitfall to fully incorporating it as an alternative fuel for transport applications. This is especially true for the marine industry where the cost of marine diesel is so low.

Using the model, it was possible to evaluate some key economic outcomes such as the cost associated with the hydrogen being utilised on the ferry, as well as the cost savings associated with reducing diesel consumption.

Utilising other key information about the system and its operation along with data figures the capex, it was possible to estimate a high level economic assessment of the system. Full cost details cannot be provided due to confidentiality agreements.

As can be seen in the next graphs, the major challenge with the majority of hydrogen systems – the cost – is evident in the HyDIME system, where the cost of hydrogen as a fuel results in a yearly economic loss.





Cost balance graph of the system operating at 20% and 60% diesel displacement

It is worth noting that these results have been estimated under the assumption that the cost of producing hydrogen and the cost of marine diesel does not change. In reality, it is likely that the cost of hydrogen will decrease as technology and efficiencies improve, and with the potential of support from government subsidies. Furthermore, the cost of marine diesel will increase due to tightening legislation around emissions.

It is likely that a carbon tax or other similar incentives will be implemented in the near future which will significantly increase the cost of diesel and provide a further incentive to move away from marine diesel and towards utilising green fuels. Once hydrogen becomes more competitively priced, a positive net cash balance can be expected.

Furthermore, the hydrogen injection system in question is a proof of concept and so is installed on the auxiliary engine of the vessel. This is a relatively small unit compared to the propulsion engine and therefore, it was expected that the fuel savings would be small. The HyDIME system also provides a further benefit to the community in that it offers a use for the curtailed renewable energy.

One of the main messages of the HyDIME project was to demonstrate the significant emission savings that could be achieved with the technology as well as the further benefits the project brings to the community. It was expected that until there is a scaled-up version of the system in operation, and hydrogen is more competitively priced, it would not result in significant economic savings.

MODELLING FUTURE SCENARIOS

The model was used to represent potential scaled up scenarios of the HyDIME system. The model was altered to represent a centralised production site, eliminating the issues associated with transporting hydrogen to and from different islands within Orkney. Furthermore, a scaled-up version of the MV Shapinsay hydrogen injection system was also created by altering the model parameters to represent the injection system operating at 60% diesel displacement on the propulsion engine. To facilitate for increased hydrogen consumption, the onboard storage was increased to 100kg.

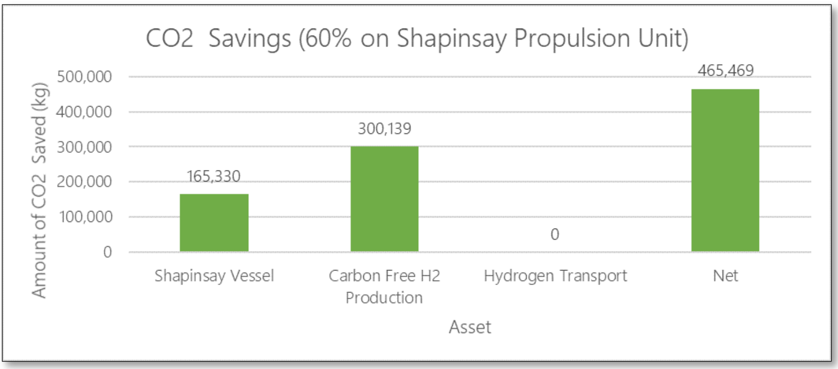
Operating the system with the propulsion unit has a significantly greater environmental impact with a net saving of almost 500 tonnes of CO_2 being displaced.

Not only is there a greater amount of diesel being displaced, but the CO_2 emissions associated with transporting the hydrogen have been eliminated. It can be argued that there are no negative emissions associated with the HyDIME system in this configuration.

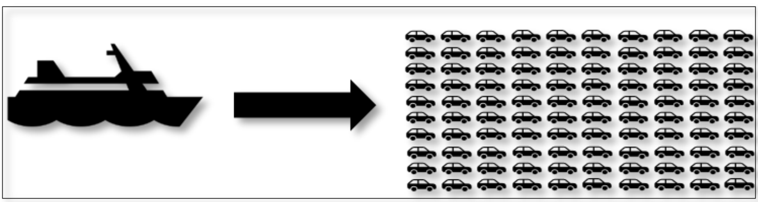
The net CO_2 savings of the system at 60% displacement on the propulsion unit are equivalent to removing 100 passenger vehicles from the road per year.

Parameter	Value
Displacement Percentage	60%
Total Diesel Displaced (L)	63,192
Total CO_2 Displaced from Diesel Displacement (kg)	169,361
Total H_2 Consumed by MV Shapinsay (kg)	19,748
Electricity Required to Produce H_2 Used by MV Shapinsay (kwh)	1,086,155
Total CO_2 Displaced from Carbon Free H2Production (kg)	307,458
Total CO_2 Displaced (kg)	476,819
CO_2 Emissions Associated with Transporting Hydrogen for HyDIME Use (kg)	0
Net CO_2 Displaced (kg)	**476,819**
Cost Reductions Through Fuel Savings (£)	30,333

Results produced for 60% diesel displacement on vessel propulsion engine (one year of operation)



CO_2 savings achieved from 60% diesel displacement on propulsion engine



Infographic representing the CO_2 savings achieved from 60% diesel displacement on vessel propulsion engine

REPLICATION OPPORTUNITIES

A major challenge associated with innovative technology and fuels in marine is that there is a lack of application opportunities. However, the interest in hydrogen as a fuel is growing. The graphic on the following page details identified opportunities where a system similar to the HyDIME system could be implemented.

CONCLUSION

The HyDIME project focussed on addressing the issues of the emissions associated with the industry through fossil fuel usage, as well as the community renewable energy curtailment issue experienced in Orkney.

The project was able to address these challenges by demonstrating that a hydrogen dual fuel system on a public ferry has the potential to significantly reduce GHG emissions as well as utilise a significant portion of curtailed energy which would otherwise be lost.

There is an increasing appetite for the use of hydrogen as a fuel in the marine industry and there are growing opportunities within the UK and Europe where this can be realised.

The main barrier and challenge as addressed in this article is that of the cost of hydrogen. Until it is cost partitive with marine diesel, it will be difficult to fully penetrate this technology within the marine industry. However, this will hopefully soon be the case as the price of hydrogen is only going to decrease, while diesel prices will increase.

Western Isles

- **Excellent** renewable potential
- **Rely on** interisland ferry crossings
- **Potential savings** of 13,000 tonnes of CO_2 with 60% diesel displacement on Stornoway – Ullapool ferry

Lancaster Hydrogen Hub

- **Looking to** develop hydrogen hubs across various industries including the regions port activities
- **Using low** carbon hydrogen from nuclear power plants
- **Passenger ferries** and large shipping vessels leave and enter the nearby port
- **Aiming to** have a dedicated research hub to assess hydrogen fuelling and transport logistics

Isle of Wight

- **Currently** operating solar plant generating 4.68 GWh of green electricity
- **Experience** energy curtailment - a good opportunity to produce hydrogen
- **Rely on** passenger ferries to transport residents to and from mainland (over 200 daily ferry crossings)
- **Have ambitions** to be self-sustaining island
- **Ferry companies** have expressed interest in hydrogen as a fuel

UK map showing recommended locations that could benefit from a system similar to that of the HyDIME project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PRACTICAL USE CASES OF ARTIFICIAL INTELLIGENCE IN THE SHIPDESIGN STAGE

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INTRODUCTION

Artificial Intelligence (AI) has become a fashion expression. In every field of activity AI is present. It does not matter if we speak about retail, agriculture, urban planning, transport,… AI seems the incantation or magical word that would change the destiny of all of us.

However, in the marine sector, it is observed certain delay and a significant less penetration of AI compared with other sectors. Both in design, fabrication and operation phases of ships, it is made a reduced use of the possibilities that AI offers. It becomes therefore an opportunity to improve and to transform shipbuilding and shipping industries in modern and leading ones.

LEVELS IN AI

It is commonly accepted that there are four key points that machine must fulfil in order to be considered as intelligent one:

- **To act** as humans do
- **To reason** as humans do
- **to reason** rationally
- **To act** rationally

AI, as any other technology, is not something monolithic, to be implemented as a whole. There exist different levels of AI (maturity) that define the capacity of the machines to reproduce behaviour patterns, or to create new ones.

- **Basic AI.** Covers everything that allows computers to behave like humans: automatic learning, natural language comprehension, language synthesis, computer image recognition, robotics, signalling and results analysis, optimization and simulation, etc…

- **Machine Learning (ML)** is the subset of AI which deals with the extraction of patterns from data sets: deep learning, support vector machines, decision trees, learning Bayes, clustering k- means, learning of association rules, regression algorithms, etc.

- **Deep Learning** is a specific class of ML algorithms that use complex neural networks. In a sense, it is a group of related techniques comparable to a group of 'decision trees' or 'support vector machines': artificial neural networks, convolution neural networks, recursive neural networks, long, short-term memory networks deepest beliefs and many more.

AI IN CONTEXT

AI is neither a stand-alone technology, but on the contrary, is only one of the technologies available in order to successfully achieve the term Industry 4.0. AI should interact with the rest of the technologies, as all of them are involved in the digital transformation of the industry. Among the most relevant ones we can specify the following:

- **IoT.**
- **Cloud computing**
- **Blockchain**
- **Additive Manufacturing**
- **Big Data & Analytics**
- **Virtual Reality**
- **Augmented Reality**
- **Robotics**
- **Cybersecurity**
- **Autonomous vehicles**

All these technologies become the catalysts that allow to develop the concept of Industry 4.0, and therefore we can call them as the enabling technologies.

¿WHY AI IN SHIPBUILDING?

Most of the reasons that recommend the appliance of AI in marine projects are common to other industries. Nevertheless, there are some reason more specific of shipbuilding industry, and whose impact is significant.

- **More complex projects.** Ships, and therefore marine projects, are becoming more complex, with more demanding technical specifications, more strict national and international regulations, and with tighter budgets,

- **Shorter delivery times.** At the same time projects are more complex, the competitiveness obliges to shorten delivery times, and this means that all phases are compressed, but without producing any reduction in the quality of the final product;

- **Non-expert workers.** This fact, common to all industries, is sharper in the marine sector, as shipyards and technical offices are obliged to involve into the development of projects new staff, young or with no previous experience in shipdesign and shipbuilding;

- **More complex tools.** Tools used in design, construction and operation of ships are increasingly complex trying to provide solutions to the objective of shorten delivery times at reduced cost. The use of such a tools require knowledge that is difficult and takes time to get; time that does not exist according to project timing;

- **Loss of know-how.** Cyclic evolution of shipbuilding industry forced shipyards and technical offices to dispense with significant staff. These leaves rely mainly in elderly people that have the most relevant experience and expertise.

All these reasons, among others, mean important risks in marine projects, that can be minimised with the use of AI techniques.

WHAT DOES AI CONTRIBUTE TO THE PROCESS?

Taking into account that the widely used tool for the design is nowadays the CAD/CAM/CAE 3D system, the integration must rely in adding AI capabilities to it. And what does AI add to CAD/CAM/CAE system (in our case to FORAN System)?.

- **Efficiency.** Efficient handling of design options is achieved by consulting use manuals, design guidelines, calculation norms,… that the designer can have, with the help of AI technology, in an interactive mode.

- **Reliability.** AI can incorporate algorithms that verify the fulfilment of certain KPI´s and making the tasks of designers more reliable, and the project more consistent.

- **Experience.** AI can help in providing designers with comparative and historic data, information from previous projects, or learned lessons, everything with the objective of helping in facilitating prototyping of new ships and in looking for the best alternatives among existing ones.

- **Optimization.** By means of AI, engineers can receive online recommendations and data for adopting best practises and for automating certain design tasks.

Additionally to all of this, AI technology integrated in design systems would enrich itself with data coming from current project, making it a real live project with self-learning capacity.

¿HOW AI WORKS INSIDE FORAN SYSTEMS?

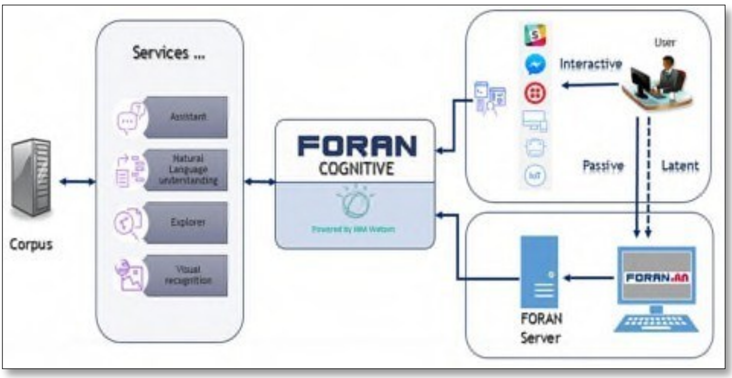
FORAN modules are linked with AI services (Assistant, Natural Language Understanding, Explorer, Visual Recognition) by means of a new application called FORAN Cognitive that is invoked from the FORAN modules.

When working with FORAN against database, user can launch FORAN Cognitive for getting AI assistance about the subject desired. In that moment, the AI engine makes the correspondent operations and gives the user the proper answer. This answer is based in the type of query made, the historic data, the profile of the user, and in the Corpus created for the FORAN Cognitive.

The mode of operation of the FORAN Cognitive application can be:

- **Interactive:** FORAN Cognitive works on demand, once the user launches it requesting to solve a particular need.

- **Passive:** FORAN Cognitive is running in the “background”, and every time the user executes a command.



FORAN Cognitive on work

- **Latent:** FORAN Cognitive entries into Passive mode only in the case some circumstances, previously specified by the user, are matched.

In any of the working modes, FORAN Cognitive checks the action launched with the command (the required one for the interactive mode and every command for the passive mode), with the Corpus available, getting the user the information, suggestions, warnings, or misalignments from expected results.

¿WHAT DOES CORPUS MEANS?

The Corpus of information is composed by any data considered valuable for the purposes of design and construction. FORAN Cognitive deals with the matter of comparing the level of affinity and importance that the different data of the Corpus have in relation with the action executed, selected only those data actually relevant.

The data included in the Corpus come from different origins:

- **Common:** General data of general application for each project, as a standard for the designs (i.e. Regulations from Class Societies, or equipment information from suppliers).

- **Restricted:** Related mainly to data belonging to the know-how of each company, that is different (in many cases even contradictory) to the same data of other company (i.e. design guidelines or fabrication procedures).

The way of creating the Corpus also depends on its type. The part considered as "Common" can be fed with data coming from third party companies (suppliers, standardization bodies, class societies,…), while the part considered as "Restricted" should be created by the company user of the FORAN Cognitive, avoiding to disclose this information to other users.

Among others, types of data composing the typical Corpus (Common and Restricted) include:

- **Design and fabrication requirements;**
- **Design rules**
- **Class Societies and National Authorities regulations**
- **Best practises**
- **Technical specifications**
- **Information from suppliers**
- **Legacy data**
- **Users manuals**
- **Learned lessons**
- **Operational data**

Companies can decide the location of the Corpus: inside the network of the company with no access from outside the company, or "public", accessible not only by a particular company, but by any other interested in having data to feed their AI. Even more, it is not difficult to imagine that the typical configuration should be a mixed one, in which the part of the Corpus considered as "Common" is in a kind of public space, and in which the core "Restricted" data remains without interaction from third parties.

Corpus does not mean fixed data. Is dynamic data that can be refed and enriched during the execution of the project. And moreover, it is self-learning, automatically creating new data based in previous experiences, in actual results on similar processes, in optimization processes, and others. It means: the more the Corpus is used, the more it is enhanced and will give more valuable information.

PRACTICAL CASE: AUTOMATIC ROUTING OF PIPES

One of the most complex aspects of the outfitting design, as well as one of the most designer time consuming tasks is the routing of distributors (pipes, ventilation ducts, cable trays) on board.

Due to this, routing of pipes is one of the paradigmatic cases in which the application of AI to the design can help designers and make the design itself more robust, consistent, and efficient.

For it, the Corpus to be used by the AI algorithms should consider all documentation relevant to the design: material specifications, requirements from the shipowner, fabrications constraints from the shipyard, applicable regulations, information from equipment suppliers and electrical connections, guidelines, experience from existing projects, available P&ID´s or preliminary flow diagrams, structural consistency…

All these documents, once structured, would allow the user to ask for help (or to get this help without interaction in case of Passive working mode) for any task in execution.

The application of AI techniques would assist the designer in taking decisions and adopting routings that optimize the design and minimise the design time. Among others, the following aspects are considered as suitable for optimization and automation:

- **To prioritize** systems;
- **To select** main routing areas (reservation of space);
- **To select** technological attributes of elements;
- **To optimize** the routing geometrically and operationally;
- **To improve** results from previous projects;
- **To consider** the impact in production;
- **To feed-back** new designs with data coming from actual operations of the ship.

The result of the application of AI techniques in routing tasks would lead to the automatic routing, avoiding more than 70% of the hours currently spent in this part of the design. Even more, the design is more robust as the designer and the workers know exactly the restrictions or incompatibilities of any design.

PRACTICAL CASE: MOUNTING SEQUENCE OF BLOCKS

In the idyllic working method, structural blocks are assembled once there are finished and completely preoutfitted (or to the level the shipyard considers acceptable). But in some cases, due to several reasons blocks are not finished but the overall schedule of the ship recommends to assembly without any delay.

In order to detect these cases, and with the objective of reducing as much as possible the construction time, the application of AI can help the production manager to decide to immediate assembly the block and to mount missing elements (mainly from outfitting) in a further stage. Among others, the following aspects are considered as suitable for optimization and automation:

- **Mounting** sequence;
- **Production** planning;
- **Preoutfitting** of blocks;
- **Blocks** standby area;
- **General** impact of any decision in the cost/delivery time of the project;
- **Optimization** of material;
- **Production** flow.

PRACTICAL CASE: OPERATION & MAINTENANCE

AI can also serve to optimize the third phase of the shipping process, considering available information and comparing it with parameters coming from other sources, making suggestions and taking decisions based in the best performance of the ship.

Assuming that FORAN data base already includes all information relevant to design and construction of the ship, among others, the following aspects are considered as suitable for applying AI:

- **Data** sensorization ;
- **Performance** monitoring;
- **Meteorological** conditions;
- **Harbor** situation;
- **Consideration** of cargo and consumables;
- **Management** of stocks;
- **Management** of permissions and certificates.

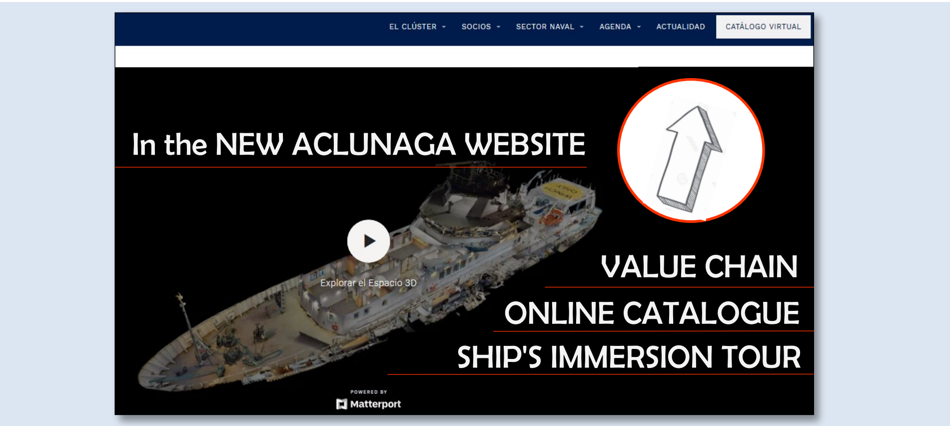
CONCLUSIONS

AI is not a matter for science fiction; is a technology that has a tremendous impact in the shipdesign, shipbuilding and shipping industry, helping to build and operate ships better, faster and cheaper.

However, the technology is not completely developed, being the responsibility of CAD/CAM/CAE system to adopt it in order to improve its functionality.

As a conclusion, we remark the following ideas:

- **AI** is one of the enabling technologies that is going to most change the current shipdesign, having a direct impact in the development of the concept of Shipyard 4.0.
- **AI** in shipbuilding is currently in development process with huge potentiality in all aspects of the production chain.
- **AI** can be adopted in every phase: design, construction and operation (lifecycle).
- **As** AI learns from previous cases (designs), it is essential to have reliable and correct data, allowing to learn and refine its application.
- **The experience** acquired in the implementation of AI in other industries is essential for its application in the marine sector, thus reducing the current technological gap.



HODOR, THE FIRST SUPERYACHT SUPPORT BOAT BUILT IN SPAIN

Juan A. Oliveira/ **"Va de Barcos.net"**

Naval Architect/ vadebarcos@gmail.com

There are multimillionaires who have a superyacht. Then there are multimillionaires who have a support vessel for their superyacht. And finally there is the American multimillionaire Lorenzo Fertitta, a freak of Game of Thrones who has named his superyacht support vessel as Hodor.

Built in 2019 by Astilleros Armón in Burela following the design of the Australian firm Incat Crowther, the Hodor is an aluminium catamaran that will support the Lonian superyacht, increasing the possibilities of fun for its passengers, transporting different boats (from a submarine to jet skis), having a decompression chamber for divers or a heliport.

Although they appeared during the 1990s, it has only been in recent years that the use of shadow yachts (support yachts) has become popular.

More than twenty boats serve as support for their owners' superyachts, transporting support boats, jet skis, underwater or land vehicles, or any other toy for the enjoyment of the yacht owners and their guests. In addition, they carry fuel, food or spare parts for the main yacht. Although most superyacht support vessels are not designed to carry guests, some have cabins to increase the number of guests.

The reasons for their use are varied: increasing the size of the mother ship (the main yacht) to accommodate all those toys and supplies on board would limit your access to certain ports, reducing the places you can go; sometimes the cost of this increase in size is greater than the cost of a new support vessel; in addition, increasing the capacity of supplies carried allows to move to more distant locations; and the owners may simply not want to be on board with the toys and other equipment until they need them.

The Hodor is the first shadow yacht to be built in Spain, and the first in the world with a catamaran hull. The Armón Shipyard, located in Burela (Galicia), delivered the ship in March this year after 16 months of construction, based on a design by the Australian Incat Crowther.

Its task will be to support the 87-metre-long superyacht Lonian, built by the Dutch Feadship in 2018. Incat Crowther engineers worked hand in hand with Lorenzo Fertitta, owner of the Lonian and the Hodor, to give him the solution best suited to his needs.

And who is Lorenzo Fertitta? According to the portal Superyacht Fan Lorenzo is the owner of the capital fund Fertitta Capital. Lorenzo and his brother Frank inherited a 5,000-square-meters casino in Las Vegas from their father, and with its sale they financed the purchase of the rights to the Ultimate Fighting Championship in 2001 for about $2 million. Its sale in 2016, fifteen years later, brought each brother two billion euros.

The Hodor is a catamaran 66 meters length by 14 meters beam, built in aluminum and divided vertically into three decks. Capable of reaching 22.5 knots of maximum speed, the Hodor includes a heliport, a mini-submarine, a hyperbaric decompression chamber for divers, a 17-meter-long dinghy and several small boats, such as outboard boats and jet skis. Its design is based on the 70m Fast Crew Boat model from Incat Crowther, widely tested in the offshore world.

Inside, it has storage areas for fresh and refrigerated food, as well as spare parts for the mother ship and cabins to accommodate its 20 crew members. Its interiors, designed and manufactured by the Basque company Oliver Design, have two cabins for the officers plus another seven doubles, as well as a kitchen, dining room and salon, laundry, medical spaces and workshops.

Two MTU engines totalling 5660 kW enable it to reach a maximum speed of 22.5 knots. At a cruising speed of 13.2 knots, its range reaches 5,500 nautical miles. An IMO Tier 3 and EPA Tier 4 compliant exhaust gas treatment system reduces the vessel's greenhouse gas emissions.

Having left Spain this summer for the USA where it met her mother ship, the Hodor is now sailing to Athens, as is the Lonian, as she fulfils her role in the shadow.

MAIN FEATURES

Length 66,2 meters
Beam: 14 meters
Crew: 17 people
Installed power: 5.660 kW
Speed: 13,2 knots (cruising);
22,5 knots (maximum)

LASER-HYBRID WELDING TECHNOLOGY AT THE EARLY STAGES OF VESSEL MANUFACTURING

Daniel Gesto / Coordinator of the Mixed Research Unit "NAUTILUS" at AIMEN

Eva Vaamonde / Responsible of the laser-hybrid welding line at the Mixed Research Unit "NAUTILUS" at AIMEN

Javier Caamaño / Responsible of the laser-hybrid welding line at the "NAUTILUS" Joint Research Unit at NAVANTIA Ferrol

Laser-hybrid welding technology has been used for two decades for panel but welding and fillet welding of longitudinal stiffeners in deck panels manufacturing. This is a technology that offers significant advantages over conventional arc welding techniques, but also requires a high degree of investment and automation, which not all shipyards can assume. In this article, some examples where the technology has been implemented by European Shipbuilding industry, as well as its main advantages and limitations, are briefly reviewed. Finally, the introduction of this technology at the NAVANTIA Shipyard in Ferrol, in its new panel line within the new sub-block workshop for the construction of the F-110 Frigates from 2022 is also briefly discussed.

The laser-hybrid technology is an excellent solution for panel butt welding and fillet welding of longitudinal stiffeners in the manufacturing of panels in the shipbuilding sector. This process enables the realization of welded joints of excellent quality, causing a minimum degree of distortion of the components, which minimizes rework operations.

Introduction to panel butt welding and fillet welding of longitudinal stiffeners in the panel line

The manufacture of panels is one of the critical points in the construction of a vessel. With a few exceptions, in most of the shipyards and in practically all the small and medium-sized shipyards, the panel butt welding and fillet welding of longitudinal stiffeners is carried out manually or semi-automated, using conventional arc welding processes:

- **Panel** butt one-side welding by SAW (Submerged Arc).
- **Fillet welding** of stiffeners using the GMAW (MIG-MAG) process.

However, conventional electric arc processes causes important thermal effects that result in distortion of the welded structures. This implies to dedicatean important amount of man-hours in reworking processes to bring the panels within the required dimensional tolerances.

In Europe, some large shipyards with strong investment capacity have replaced the conventional panel butt welding and the fillet welding by the laser-hybrid welding technology.

Laser-hybrid welding technology

The process of laser-hybrid welding combines an electric arc (MAG, TIG or plasma) with the keyhole generated by the laser beam. Although the first studies on this process date from the 1970s [1], it was at the beginning of the 21st century, with the emergence of high-power solid state laser sources [2], when it raised great industrial interest.

The laser-arc hybrid process enables to combine the high penetration depth provided by the laser welding process with the greater tolerance in terms of joint positioning and filling capacity provided by the MIG-MAG process, which substantially increases the productivity of the process. In addition, the higher heat input with regard to the autogenous laser process, allows to increase the cooling rate and the formation of fragile structures in the heat affected zone to be minimized.

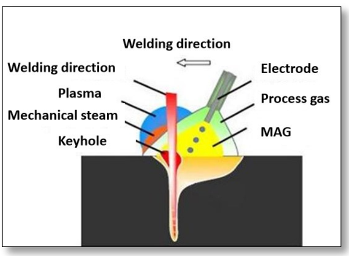


Figure 1. Diagram of the Laser-Hybrid welding process.

On the other hand, the degree of complexity in the process set up is high, due to the large number of parameters to be controlled.

The great progress experienced in recent years in the development of new high power laser sources (up to 20kW) and high beam quality (spot diameter 100µm) enables the welding of 20mm thick structural steel butt joints in a single pass.

Use of laser-hybrid welding technology in European shipyards

The first research on the application of laser welding in shipbuilding was carried out in Europe in the 1980s. Since then, several shipyards have implemented laser-hybrid welding in their production processes.

Thus, MEYER WERFT shipyard has introduced the laser welding and the laser-GMAW hybrid variant for butt and fillet welding in the panel line using a 12 kW CO2 laser source.

Other shipyards in Europe have followed MEYER WERFT and have introduced different solutions for laser and/or laser-hybrid welding in the panel line. This is the case, among others, of FINCANTIERI in Italy, AKER YARDS in Turku, Finland (formerly KVAERNER, later STX and now belonging to the MEYER group), AKER YARDS in Germany (now MV WERFTEN), BLOHM & VOSS also in Germany or ODENSE STEEL SHIPYARD (now extinct) in Denmark.

Below are some of the solutions implemented in some of the above mentioned shipyards in the last 20 years

AKER YARDS Rostock (current MV WERFTEN) installed in 2005 the laser welding of deck panels in its panel line using a 10kW fiber laser source, developed by the German firm IMG [3].

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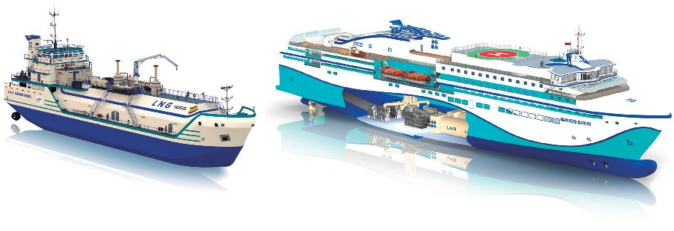

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Figure 2. First 12m panel welded on the facilities of AKER YARDS Rostock in 2005.

Figure 4. Installation developed by IMG for the laser-hybrid welding of cloths in the FINCANTIERI shipyard in Italy.

AKER YARDS Turku also upgraded, through IMG, an old installation for one-sided butt welding using SAW technology. The installation was converted into a laser welding installation using a 6kW fibre laser source in 2006 [3].

Figure 3. Cell upgraded at AKER YARDS Turku in 2006 for butt jointing through plate butt welding technology in the panel line.

FINCANTIERI Monfalcone implemented in 2008 [3] a complete welding panel line based on laser-hybrid technology. In this line developed by IMG, a 10kW fiber laser source was installed for panel butt welding up to 16x32m2.

For longitudinal stiffeners welding on the panels, a gantry system with 4 welding carriages was set up (2 with 8kW sources and another 2 with 4kW sources to take on stiffeners in different thicknesses). Already in 2013, FINCATIERI installed a new line for panel butt welding for its shipyard at Monfalcone, integrated by PEMAMEK [4].

On the other hand, MEYER WERFT shipyard in Papenburg, Germany, was the first manufacturer of large cruise ships to choose definitively the laser-hybrid technology as early as 1999 [5]. It currently has a laser centre equipped with up to 6 stations with CO_2 power sources of 12 kW each, for butt-welding and fillet welding in the panel line.

Figure 5. Laser-hybrid welding plant for reinforcements at MEYER.

STX Saint Nazaire installed in 2016 a panel welding line developed by PEMAMEK, which allows single side welding of panels up to 25mm thick by as single pass using Laser-hybrid welding technology [6].

Figure 6. Installation of STX France for the welding of panels.

More recently, PEMAMEK has installed a panel line over 300m long at MV WERFTEN Rostock, which has invested over 250M€ in its current facilities [7].

Figure 7. Current line of panels that includes laser-hybrid welding of cloths and reinforcements from MV WERFTEN, developed and installed by PEMAMEK.

Main advantages of laser-hybrid welding

In general terms, laser-hybrid welding technology makes possible to reduce by more than five times the cost of consumables such as filler material or shielding gas, and electricity, compared to conventional arc welding. In addition, the productivity in a critical construction phase in the building of a vessel is significantly increased[8]. In this sense, this technology enables the joining of panels with very low degree of distortion compared to arc welding, minimizing the rework operations with no added value, that frequently involve a significative consumption of time.

Introduction of the laser-hybrid welding technology at the NAVANTIA shipyard in Ferrol

In the next 3 years, the NAVANTIA shipyard in Ferrol will invest just over 100€ [9], which will result in an advanced manufacturing line of flat sub-blocks. A new panel line will be integrated in the shipyard, where laser-hybrid welding will have a clear leading role.

In this sense, in recent years NAVANTIA has been supported by AIMEN Technology Centre through the development of innovation projects to generate the required knowledge for the application of this technology.

Since 2018, the NAUTILUS Joint Research Unit is being developed, a collaboration between NAVANTIA and AIMEN Technology Centre in which different lines of action on PROCESSES and PRODUCTS are developed. The laser-hybrid welding technology and its application in the panel line is one of these actions.

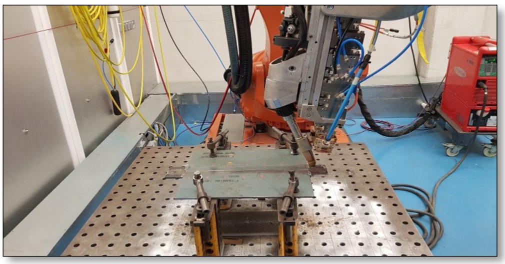

Figure 8. Laser-MAG welding process set up at AIMEN's facilities.

In this area, AIMEN is developing the set-up of the process and the parameters for different process configurations, butt joints and fillet joints with full penetration, for different combinations of thickness and steel qualities. For all the configurations, the quality of the welded joints is evaluated by carrying out both non-destructive (X-ray) and destructive tests (traction, bending, hardness, etc.). The results obtained shall be evaluated against the requirements defined by the competent classification society.

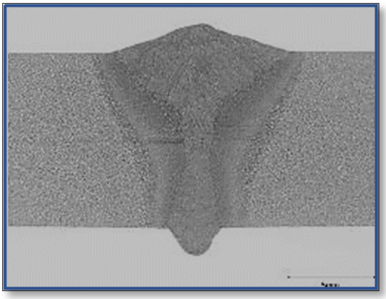

Figure 9. Butt joint section in DH36 steel in 10 mm thickness welded by laser-hybrid process.

In addition to optimal process parameters, the aim is to minimize the distortion generated by conventional welding processes in order to minimize subsequent reworking tasks. For this purpose, small demonstrators will be welded using hybrid laser technology and distortion measurements will be performed using a 3D scanner. The results will be compared with the demonstrator welded with the arc welding technology currently available at NAVANTIA shipyard in Ferrol.

Access to laser-hybrid technology by small and medium-sized shipyards

The introduction of laser-hybrid technology in small and medium-sized shipyards is a major challenge. The implementation of this technology in the production process requires a strong investment, difficult to assume by a SME, particularly in the shipbuilding sector where it is complicated to have a long-term business vision that ensures the RoI of this high investment. Another factor is the limited capacity of space and qualified personnel to engross this panel line.

A possible solution to overcome most of these limitations would be to create a common shared facility, managed by technicians, to cover the needs of small and medium sized shipyards, under pre-agreed conditions. In some regions such as Galicia, this means to break down certain historical barriers, which undoubtedly adds great complexity to this challenge.

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ROBERTO DERUNGS

Manager of TALLERES MECÁNICOS GALICIA S.L.

What is the origin of Talleres Mecánicos Galicia?

Although Talleres Mecánicos Galicia, S.L. was created in 1981, its origins date back to 1958, when my father, Manuel Derungs Baño, together with another partner, founded Taller Mecánico Galicia. At that time, the company focused its activity on the manufacture of lightweight boilermaking, casting and galvanizing for the Spanish Navy and the shipyards in the Ferrol estuary. At the end of the 1960s, the firm was left entirely in the hands of the Derungs family, after the other partner left. And it will be in 1981, with the incorporation of the second generation, when Talleres Mecánicos Galicia, S.L. is created.

Do you maintain the three original lines of activity?

No, in the 1990s the galvanizing and casting areas were closed, as they were not profitable. Currently, along with light boilermaking, our activity is focused on CNC machining and industrial maintenance, both mechanical and boilermaking.

You have been in business for over 60 years. What is the key to staying in the market for six decades?

Undoubtedly, diversify into other activities and adapt to new market demands. I would like to clarify that diversifying means not depending on a single client, but working with a varied cast of clients, and from different sectors. In Talleres Mecánicos Galicia we have taken advantage of the knowledge, which we have contributed to work for decades for the naval sector, in other activities and sectors.

Who are your main customers?

Our main activity is naval, with Navantia as our main customer. But due to our diversification we have clients in the automotive sector, industrial sector and renewable energies, mainly wind energy. With regard to its typology, due to our approvals we work with large companies, however, we are open to collaborate and, in fact, we collaborate with many SMEs in the area.

And what about your direct competitors, are they at regional, national or international level?

In our work for the naval sector, our direct competition is at a local level, but in other activities we find that we compete with regional and national companies.

Is there much competitiveness?

Yes, there is very much indeed

What does Talleres Mecánicos Galicia offer that its competitors do not have?

The capacity of response to the client, we are fast and we do a quality work. We compete better because we have boilermaking and machining, so we are able to offer a more complete service to the customer. We are the ideal company for an engineering company. And we owe all this capacity to the fact that we have excellent professionals.

Has demand in your business changed in recent years?

Yeah, it's changed a lot. We now make more sophisticated products. This has implied a lot of investment, especially to meet orders for the wind sector, in equipment and machinery, approvals and procedures.

How has the adaptation to all these changes been in the market?

It's been costly at economic levels. We have had to introduce new technologies, such as CNC machining equipment, in order to be competitive in the market. In addition, quality requirements have meant that we have had to increase the staff structure in non-productive areas, significantly raising the company's costs.

What is the key to the future of the business?

I think it's the same thing that's maintained us until now. The eagerness and commitment to do a good job, invest and adapt to market needs and new technologies. Furthermore, another point that I consider fundamental is collaboration with companies in the sector, since cooperation would make us more competitive.

Nowadays, we talk about the so-called industry 4.0. Which are the main problems that the naval sector is facing to advance in the innovation path?

In the case of the naval sector, the lack of projects to be executed. If we had more work, we'd try to be more competitive. In my opinion, the development of the 4.0 industry will materialize as soon as there are projects that require me to invest. We need continuity and stability at work in order to consider investments in innovation.

With your background, what would you say is the future of the naval sector in Galicia?

I would say that it would have to be good, but in the specific case of my company and, by extension, the whole of Ferrol's naval auxiliary industry, it is going to depend on the future of the public shipyards.

Galicia is a power in the naval sector. In your opinion, what are the weaknesses and strengths of the sector in the region?

I think I will agree with most of the businessmen that we are dedicated to this activity, that one of the main strengths of the Galician naval sector is to have highly qualified and trained professionals. In terms of weaknesses, I think one of our biggest challenges is generational change, both at management level and in the production area. We have a big problem, there are no replacements for when the current workers retire.

About this problem of generational changeWhat should be done to make the shipbuilding and repair industry more attractive to young people?

The problem that young people do not want to work in the naval sector is the lack of continuity in the work. We have periods of high demand, followed by periods of very low activity, so many companies are forced to reduce staff. The solution to this is to give stability to the sector, that is, continuous work.

Environmental protection is one of the challenges that Shipbuilding sector faces Do you think the industry has taken action on this?

Yes, at first we took environmental protection measures because we were required to do so by legislation and by our own customers, but what started out as a requirement became an awareness on the part of the company. Today it is unthinkable that a company should not take environmental protection measures.

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