ADOPTING INDUSTRY 4.0 TECHNOLOGIES IN SHIPBUILDING THROUGH CAD SYSTEMS

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SUMMARY

Technologies are evolving faster than our capability to develop applications that bring us the value we can get from them. The potential is clear and the opportunity will be for those who identify the right application for each technology. One of the foundations of the fourth industrial revolution is the ability to handle huge amounts of data that is everywhere and available to anyone, thanks to the evolution in communication technologies. However, data is not information; it is necessary to have the capability to analyse, then extract conclusions and to learn from both. Technologies, such as Big Data (BD), Machine Learning (ML) and Artificial Intelligence (AI), give the capability to do this, but what really matters is how it is applied. Those who are able to recognise the value of analysing data correctly, to transform it into information and apply it to the improvement of the design, manufacturing, operation and maintenance processes will be successful in the industrial transformation that is taking place. This skill requires practitioners to make the best decisions and ultimately optimise the life cycle of the industrial products. Some of the fields of application of these technologies are already evident. It is possible to imagine how these technologies can enable ship design by applying rules, which will facilitate the design significantly. Equally, by integrating the validation of the structural models by the Classification Societies and much of the design through cloud based applications. The adoption proposed in this article is based on the evolution of CAD applications towards a central data model and with the aim of achieving a true Digital Twin. With a real and effective synchronization between what is designed, manufactured and what is operated, making it possible to cover the complete life cycle of the product. In this process, it is also very important to consider peoples experiences. It is necessary to understand how the new generations are immersed in a technological world, which is in a constant and rapid evolution. This interaction with this ecosystem will determine how the new rules should be defined for the CAD/CAM/CIM Systems. This paper examines some practical use cases in the design phase of shipbuilding as an example of what new technologies could provide ship design and shipbuilding in the near future.

NOMENCLATURE

AI	Artificial Intelligence
AR	Augmented Reality
BD	Big Data
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
DT	Digital Twin
GPS	Global Positioning System
IoT	Internet of Things
ML	Machine Learning
RFID	Radio-Frequency Identification
RPA	Robotic Process Automation
VR	Virtual Reality

1. INTRODUCTION

Industry 4.0 has favoured the expansion of many technologies whose application boundaries are very diffused. Although each technology can have very specific applications, when it is applied to Computer Aided Design, Manufacturing & Engineering (CAD/CAM/CAE) System (from now on referred to as CAD), they have to be implemented as a whole.

CAD tool is utilised in the beginning of the design to populate data that must be taken forward for further stages of the lifecycle for product. Modern CAD tools create a Data Centric Model that includes attributes and metadata that will allow effective use of Virtual Reality (VR), Augmented Reality (AR) for the creation of the Digital Twin (DT). Therefore, these technologies must handle the Big Data, generated by CAD tools and all surrounding solutions, which applies some cloud/edge/fog computing to these data in a merged technology between finite state machines and Artificial Intelligence (AI) cognitive processes (Muñoz & Perez, 2017).

To perform all these integrations a network which support different ways of connecting specific devices, i.e. Internet of Things (IoT) is required. This can access the data, creating and modifying them, in a different layer which affects the basic information layer created by the CAD System in the shipyard.

This network must be secured but at the same time open to allow distributed work, which must be tracked in such a way that records any modification of every working step. This will be done in an open, transparent, trusted and non-modifiable working method for all stakeholders involved in processes like shipyard, engineering offices, classification societies and ship owners.

Results of the design should be easily integrated with future fabrication methods like 3D printing and generating printing orders directly from the CAD. Additionally 3D printing can greatly facilitate the preparation of models for use in experimental basins.

Shipbuilding phases involve design and manufacturing, but an integrated Industry 4.0 CAD System should also be involved in operation and maintenance phases, i.e. it must cover the vessel lifecycle end to end, from design to decommission.

When a ship comes for a reparation, especially if the ship is old, the 3D model is not available to be used for making the design of the transformation. Modelling an existing entire engine room or any other local from scanned model into the CAD System, could be a nightmare. AI could be used for processing the resulted cloud of points and to create similar geometries that could be used as references in the CAD. This could create equivalent models, which can be converted with a minor user intervention, and lesser as the AI learns, in a CAD integrated and full modifiable design (Muñoz *et al.*, 2018). This process needs to populate the AI tools with a large number of images corresponding to similar models, and later on with a human intervention allowing the AI to map those clouds of scanned points with real 3D models.

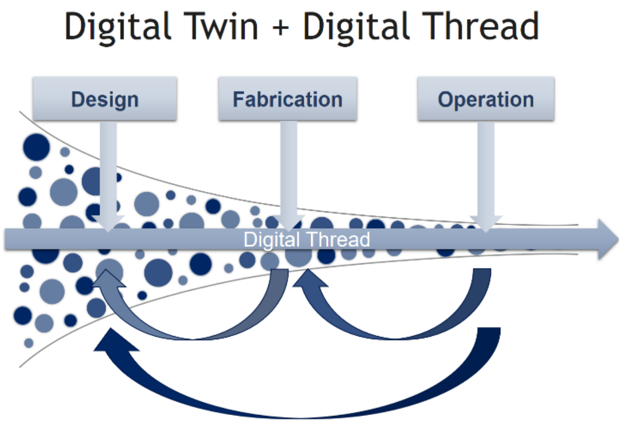

Figure 1: Digital Twin - Tractor for Digital Transformation

Although DT is hardly starting to become a reality, it is an engine for the digitalization of the shipbuilding industry, as it was explained by Alok Aggarwal (Aggarwal, 2018) in the 5th Day of the Cycle on Digital Transformation in the Marine Sector. Figure 1 represents the expected workflow of a DT in the different stages of the lifecycle of products. Having a DT, the results of performance and simulations will provide feed to improve the previous stage. DT shall be different in stages and they will be focused in the most beneficial functionalities. A DT of the operational product must be useful to improve the operation but also to improve future designs. Companies developing DT's of their products will move irremediably towards a digital transformation of their own business.

2. WHAT IS THE INDUSTRY 4.0

To be able to understand how Industry 4.0 became today's buzzword, a look at its predecessors might give us a perspective on how this revolution in particular is different.

- **First Industrial Revolution**. The industrial revolution in Britain came in to introduce machines into production by the end of the 18th century (1760-1840). This included going from manual production to the use of steam-powered engines and water as a source of power. This helped agriculture greatly and the term factory became a little popular. One of the industries that benefited a lot from such changes is the textile industry, and was the first to adopt such methods. It also constituted a huge part of the British economy at the time.
- **Second Industrial Revolution** dates between 1870 and 1914 (although some of its characteristics date back to the 1850) and introduced pre-existing systems such as telegraphs and railroads into industries. Perhaps the defining characteristic of that period was the introduction of mass production as a primary means to production in general. The electrification of factories contributed hugely to production rates. The mass production of steel helped introduce railways into the system, which consequently contributed to mass production. Innovations in chemistry, such as the invention of the synthetic dye, also mark such period as chemistry was in a rather primitive state then. However, such revolutionary approaches to industry were put to an end with the start of World War I. Mass production, of course, was not put to an end, but only developments within the same context were made and none of which can be called industrial revolutions.
- **Third Industrial Revolution** is much more familiar to us than the rest as most people living today are familiar with industries leaning on digital technologies in production. However, the third industrial revolution is dated between 1950 and 1970. It is often referred to as the Digital Revolution, and came about the change from analogical and mechanical systems to digital ones. Others call it the Information Age too. The third revolution was, and still is, a direct result of the huge development in computers and information and communication technology.
- **Fourth Industrial Revolution** takes the automation of manufacturing processes to a new level by introducing customized and flexible mass production technologies. This means that machines will operate independently, or cooperate with humans in creating a customer-oriented production field that constantly works on maintaining itself. The machine rather becomes an independent entity that is able to collect data, analyse it, and advise upon it. This becomes possible by introducing self-optimization, self-cognition, and self-customization into the industry. Manufacturers and operators will communicate with computers rather than operate them. Digitalization is

extended to all the aspects of the businesses and processes. Connectivity is applied to share information, data and results.

Industry 4.0 can be considered as a set of technologies that applied to industry in general will allow for the connection of machines, products and services to share and analyse data. This will enable flexible, faster and efficient processes to produce cheaper and higher quality products and services. The most relevant technologies considered in this scope are Internet of Things (IoT), digital platform, cloud computing, cybersecurity, augmented & virtual reality (AR & VR), additive manufacturing, autonomous robots, simulation, Artificial Intelligence (AI), and blockchain. The key is to identify which technologies should be used by companies to adopt the Industry 4.0 paradigm and how it is to be used. To determine the correct strategy for the change and to get success, by minimizing the risks. In the following chapters, we will review some of the technologies that could be adopted by the shipbuilding industry through the capabilities offered by dedicated Computer Aided Design (CAD) applications or by adding new ones. Our statement is that CAD systems with specific functionalities can be the base for the marine industry to adapt business and processes to Industry 4.0 in a faster and lower risk manner. Let's see how some of these technologies can be included or adopted by CAD systems and the benefit that can be obtained with them.

Furthermore, green design is one of the aspects pushing the industrial transformation and therefore it is an engine of Industry 4.0 in terms of the use of new technologies for concepts such as energy savings, environmental conservation, new materials and new processes.

3. DIGITAL PLATFORM

Under the concept of a digital platform there are several related technologies to propose this concept. These concepts are total connectivity and Internet of things. To understand the ideology it is necessary to explain the concepts in detail.

The shipbuilding industry has been able to adapt to the evolution of design through the use and adaptation of CAD applications. However, the different software manufacturers have been incorporating other applications in addition to the CAD systems into their portfolios, thus creating a system of systems that cover the entire end-to-end product life cycle. The different systems had their own ecosystem and their unification was done through interfaces, which led to a heterogeneity of data and products, with a significantly high cost and very low efficiency.

3.1. CONNECTIVITY

One of the pillars of Industry 4.0 is the connectivity of the systems. Therefore the natural evolution of the systems used in shipbuilding must be towards a single and completely integrated platform, that we can call a digital platform. For this platform to be efficient, it must be supported by the 3D model and product data. Therefore, the core of the platform must be the system that is capable of giving birth, evolving and developing the model, as long as it is in a single location. CAD systems, such as FORAN, AVEVA, Catia, etc. are powerful enough for this purpose. Capable of integrating into a single database, geometric design and product attributes that can be at the core of digital platforms, which will enable the marine industry to enter the 4.0 revolution.

As Stuart Taylor declared in (Taylor, 2016): "The platform is the key to success. The "things" will get increasingly inexpensive, applications will multiply, and connectivity will cost pennies. The real value will be created in the horizontal platform that ties it all together, i.e. the new OS."

In an article published in the Harvard Business Review, Michel E. Porter and James E. Heppelmann in (Porter & Heppelmann, 2015), described the new technology stack: "Smart, connected products require companies to build and support an entirely new technology infrastructure. This "technology stack" is made up of multiple layers, including new product hardware, embedded software, connectivity, a product cloud consisting of software running on remote servers, a suite of security tools, a gateway for external information sources, and integration with enterprise business systems". If a company wants to enter into this business, they must have products that connect with the products of other companies. Therefore, the necessity of having an opened product is increasing.

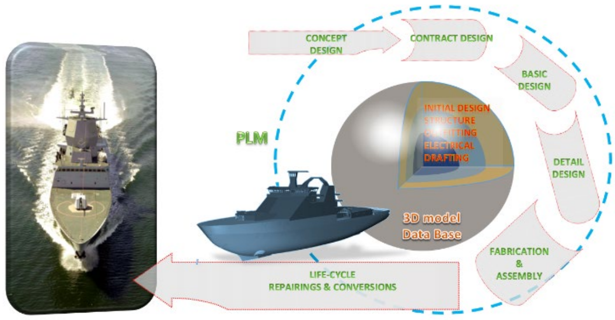

Figure 2: Integration through platform

From our point of view, the mentioned platform is not exactly an OS, but a set of interconnected applications, which share the same data about the product. Data that have been appearing since the early design phases and populates a unique database, not only with the design attributes but also with the desirable values for optimal performance. Applications around this database will control the life cycle of the components and the sensors that collect the information of operation or operational life of the same objects and devices. Figure 2 represents the different applications around the unique database supporting the functionality of an entire digital platform. Applications connect through the database. Currently, Project Lifecycle Management (PLM) systems have been raised as a digital platform for the generic industry and specifically for aeronautic and others. However, there are also alternatives by linking CAD with the PLM trough the plugins.

The key is that all devices, sensors, components are not connected directly to the IoT, but connected to a management core that controls the data to interchange the IoT for those devices allowed to enter in that network. This makes it possible to take advantage of the fact that all the existing components in the ship have its respective model created, incorporated, and defined from the CAD system. We could say that CAD is the birthplace of the elements of the ship. Therefore, it is the CAD system that tracks elements and from where they can be assigned a mission and the level of participation in that world of the IoT.

Future smart ships must be connected to the IoT or they will not be smart. The connection of smart devices within a smart ship must be human controlled. The control should start from the design tools because they control the shipbuilding process from the early stages of the design up to the final production. The set of design tools, product lifecycle management and device must be inter connected among them, and will be the platform for the smart ships connected to the IoT. The information shared in the scope of the IoT must be managed by human interaction, following along the whole lifecycle of the ship, starting from the beginning of the initial design. This need requires the CAD tools to be prepared with specific characteristics to handle that information. This new ecosystem, now opened, incorporating the new trend of technology but adapted to the specific environment of shipbuilding will be the Internet of Ships.

3.2. DIGITAL TWIN AND SERVICES RELATED

Other concepts integrated within the digital platform concept are the following:

- Digital services. The digital services include the generation of a DT of the ship, with all the relevant information. This mock-up is going to be of high value, not only for the Classification Societies, but also for the shipyards during the phase of construction, and for the ship-owners along the exploitation phase.
- Customer Experience. Is about improving the Customer experience by means of the digital certification and with a specific set of applications. These will facilitate the tasks of inspection and maintenance according to the Classification Society Rules.
- Operations. In this case, the enhancement shall be focused on the improvement of the effectiveness and efficiency of the interventions on board the ships, and on the internal procedures of the Classification Societies.
- Intelligent surveillance for predictive maintenance. This includes the monitoring of several aspects of the ship, such as structure and welding, that can be integrated in the digital twin through IoT thereby avoiding possible failures or reaching ultimate limit states or service, through fatigue or fracture, as well as vibrations and noise.
- Cybersecurity. The expected automation of the ships are day by day more dependant of the communications, together with the new technologies based on software (dynamic positioning, consumption optimization, electronic systems, gas emission reducers, etc.). All these characteristics are making our hardware/software systems potentially one of the weakest points for international navigation, therefore it must be enhanced and secured. Both the DT and its fundamental digital services, are forced to revaluate aspects such as cybersecurity, piracy control, accidents prevention, performance of the software or systems, etc. Inside the concept of cybersecurity, the Classification Societies are defining a new classification notations, such is the SYS-COM from the Bureau Veritas (Pancorbo, 2017). That concept is assigned to those ships that will have the incremented reliability thanks to the communication services between themselves and the land base. This will allow for the monitoring analysis as well as the resolution of issues remotely. This augmented the reliability of the ship and their operations while using these automation systems, for support and maintenance, as it is presented in Figure 3.

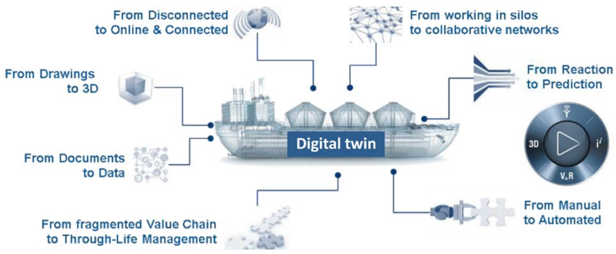

Figure 3: Applying the digital transformation into the Asset Integrity Management (Pancorbo, 2017)

Other tools that had already been in use are those oriented to help with the customer experience of the ship-owner:

- Mobile applications. Specific applications developed for ship-owners that can perform the tracking of the ship, handling its certificates, as well as classification services, etc.
- Specific cargo tools. Are those where it is possible to verify that the ship is ready to transport a particular cargo. Responding to specific needs from the shipping Company to verify, in the short term, the viability to transport a particular cargo that is not in the originally approved cargo list.
- E-Commerce. The e-commerce started as a web tool where the ship-owner can request the certification of the Ship drawings, while obtaining an on-line price for it and having the possibility to pay by credit card. It is specially oriented to improve ship-owners experience, above all by taking into account the financial advantages of reducing the time to get the already mentioned Class Certification.

4. ARTIFICIAL INTELLIGENCE

As it has been stated above, AI is probably the most disruptive technology that will transform our entire lives. So, let's try to understand what is AI actually? It can be said that there is no single origin of the concept known as AI and therefore there is no consensus to define that concept. To be able to understand any of the definitions that apply, it is convenient to know at least briefly the most relevant facts and some of the milestones in its history.

It can be considered that AI was born as a philosophical study on human intelligence, based on the concern of man to imitate the behaviour of other beings. Beings with capabilities beyond the reach of human beings (such as flying or diving), reaching the point of trying to imitate itself. In this sense, it can be said that AI is the search to imitate human intelligence. It is clear that it has not yet been completely achieved, but it is also increasingly true that we are closer.

The first man who became aware of his own existence and was able to think, surely wondered how his thought would work and would conclude the idea of superior creator. An intelligent being capable of creating another one. In this sense, the idea of a virtual design for intelligence is as old as human thought.

In 1920, the Czech writer Karel Capek published a science fiction stage play called Rossum's Universal Robots. The play is about a company that builds artificial organic humans in order to lighten the workload of other people. Although in the play these artificial men are called robots, they have more to do with the modern concept of androids or clones. They are creatures that can be passed as humans and have the gift of being able to think.

The English mathematician Turing publishes an article entitled Computing Machinery and Intelligence that opens the doors to AI (Turing, 1950). The article itself began with the simple question: Can machines think?

Later Turing proposed a method to evaluate if the machines can think, which got known as the Turing test. The test, or Imitation game, as it was called in the document, was presented as a simple test to judge if machines could think.

1956 Dartmouth conference convened by McCarthy and where the term AI was coined. The conference was attended by researchers from Carnegie Mellon University and IBM, including: Minsky, Newell and Simon. In this conference extremely optimistic forecasts for the next ten years were made that were never fulfilled. This caused the almost total abandonment of the investigations during fifteen years, known today as AI winter (Aggarwal, 2018).

The concept of the IoT was born at MIT's research centre Auto ID in 1999, where research for realizing the object identification using radio frequency (RFID) was the main idea of Kevin Ashton. The idea of the research was to identify all the objects and all the people in some way, permitting some of the objects to exchange data with others through the internet. The object identification was the prerequisite of the IoT.

The reasons that recommend the appliance of AI in marine projects, are mostly common to other industries, but there are some more specific reasons which impacts significantly within the shipbuilding industry.

- More complex projects. Ships, and therefore marine projects, are becoming more complex, with more demanding technical specifications, stricter national and international regulations, and with tighter budgets.
- Shorter delivery times. Projects are more complex, competitive and with shorten delivery times, yet demanding the same quality, thus compressing the building phases.
- Non-expert workers. This fact, common to all industries, is sharper in the marine sector, as shipyards and technical offices are obliged to be involved in the development of projects and new staff. New staff are young or with no previous experience in ship design and shipbuilding. This implies the adoption of non-optimized solutions, or of solutions out of common marine practise. This impacts negatively with consequences not only in the construction, but also in the operation of the ships.
- 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 tools require knowledge that is difficult and takes time to get; time that does not exist according to project timing. Therefore, the use of a virtual assistants that would guide the users and allow them not only to learn quickly, but also to solve problems without wasting time would be very convenient.
- Loss of know-how. Cyclic evolution of shipbuilding industry forced shipyards and technical offices to dispense with significant staff. Leaving mainly elderly people that have the most relevant experience and expertise. The problem is not only in the loss of experience, but also the lack of transmitting the know-how to younger generations.

All these reasons, and other ones not explicitly mentioned here, mean important risks in marine projects, including the design phase that can be minimised with the use of AI techniques.

This minimization can be addressed by incorporating all the information related with the shipbuilding processes, and designing knowledge into an AI system like IBM © Watson Cognitive solution. AI can identify the most relevant how-to's to help the users in the design. By understanding the natural language or even the specific language of designers, or by identifying scanned documents where the system can find what designers are looking for.

5. VIRTUAL REALITY AND AUGMENTED REALITY

Shipbuilding industry is affected by a global and extremely competitive environment. All processes and systems have to be adapted to this challenging scenario, making special efforts in innovation and applying the most advanced technology available in the market. From a user point of view, it is now possible to find a wide range of solutions to meet the most demanding requirements, to achieve measurable results, in terms of efficiency and costs. The 3D model now appears, not only as the set of geometries on which the components must be defined, but as the nexus to allow related designs, tasks, data, manufacturing and management of the vessel's ecosystem from an end-to-end computing platform.

3D model is not only the container to allocate objects, tasks and logical information, but it is still the reference for thousands of tasks that are absolutely based on the coherence of the model. So the geometric model can be exploited beyond just geometry and as an added value, CAD suppliers develop smart tools to use the model in realistic sceneries with multiple purposes. This representation of the model in a computer, tablet or any electronic device is known as Virtual Reality (VR). The applications that allow this kind of vision also allows the use of additional tools to take measurements, check collisions, simulate the movements of the object, etc. When this model is mixed with the real environment, it is known as Augmented Reality (AR). In many of the use cases it is used indistinctly as VR or AR. The popularization of the AR and VR is largely due to the reduction in the cost of electronic devices, together with the increase in their computing power.

5.1 VIRTUAL REALITY DURING THE SHIP DESIGN STAGES

Maybe the engineering, manufacturing departments of a shipyard is where this kind of solutions should be extended, to reduce errors and save costs. Manufacturers are not used to working with VR solutions, because it is a concept far removed from the day to day factory operations. However new generations of workers will have VR solutions among their more commons working tools. These tools allow for checking the model, to avoid errors and inconsistencies. Also to take measurements on real time with the real model, and therefore improving manufacturing tasks for safety and for the entire efficiency of the projects. The possibility of viewing the ship 3D model as realistic as possible is effective to find errors in all stages of the design. From early design stages, to manufacturing and production phases, it is possible to check all the elements. Checking for inconsistencies, to prevent interferences and collisions, to query about properties, attributes and to study different design alternatives that changes dynamically. In addition, the user and model interaction has become much more realistic with the implementation of 3D tracking devices, which give the sense of being inside the model, walking and moving on it, touching it.

Simulation is another important area of application of VR in ship design, engineering and production. It is being applied in the study of many tasks with different purposes, from the study of escape routes to the simulation of dismantling for maintenance of equipment items. Another application of the AR&VR is the help with clash detection, i.e. the analysis of mounting elements into the ship and how surrounding elements are affected.

Needless to say the use of VR for the control of the design is very useful, just to see the progress of the project. Moreover, once it is being built the comparison between the model and the real ship is necessary, and VR can help to find out errors that need to be solved as soon as possible, eliminating further unnecessary costs.

Figure 4: AR engine room integrated with Virtual Model (Muñoz & Ramirez, 2019)

On the other hand, it is very common that the ship design, engineering and also the manufacturing is divided into different blocks that are subcontracted to different design offices, i.e. subcontractors and shipyards. The shipyard receives all the information of the ship and needs to supervise that everything is correct. Having a VR tool that allows the integration of all the information in a simpler form makes it possible to have a single model, which is much more effective than having many different models. Figure 4 shows a real engine room merged with the virtual model of the same. This capability allows comparing the as built solution with the model solution, and therefore allowing to validate the building. Another approach of the same functionality is for revamping vessels needing a retrofit. Before acquiring the assets, AR allows to verify if the solution is viable or not.

5.2 VIRTUAL REALITY FOR COMMERCIAL PURPOSES

Benefits of using VR for marketing and commercial purposes are evident. That is why VR tools are having a great reception in sales and marketing activities. Thanks to the wide range of possibilities available in the market, from small and portable solutions to big and on-demand solutions, the present and future applications of VR is higher than we can imagine.

From a marketing point of view, the possibility to present a ship 3D model with the higher level of detail in an immersive VR experience adds an inestimable value to the sales activity. Many shipyards are already taking advantage of this technology, not only in their facilities but also in fairs and exhibitions, thanks to the portable solutions that will be described later.

5.3 SHIPYARD MANAGEMENT

Shipyard management play the role of ensuring that the commitments made to the clients are fulfilled. The project needs to be accurate, with the highest quality level and in accordance with estimations, to ensure customer satisfaction. To achieve it, it is very important to have a clear idea about the progress of the project and also about changes that can affect further requirements, schedules and costs. Having the opportunity to check the VR model from early design stages is a great advantage and allows a friendly checking, quick evaluation of alternatives and fast decision-making. At the end, the great impact in cost reduction is possible thanks to the early error detection, which is more expensive for the modifications in manufacturing and production stages.

5.4 SHIP-OWNERS MANAGEMENT

The presentation of the progress of the ship project to ship-owners is another important use of VR, adding the value of being very easy to conceive the project in a very realistic and intuitive way. This has become a great advantage in comparison with conventional presentations. In fact, VR can substitute the old scale ship models that are expensive and with a short level of detail. The capabilities to present the information available in the VR solutions are as big as the user´s ability, because now it is possible to provide realistic finishes and all the level of detail required. Ship-owners can also check and monitor the progress of the model and also, to promote design alternatives less cost-effective than in further stages.

Maintenance of the assets is one of the main areas of improvement where

5.5 NAVAL SHIPBUILDING MANAGEMENT

The military shipbuilding industry is affected by the most demanding requirements, both in the design and production stages. It is true that these kind of naval projects, both in submarines and in surface ships, are lengthy and complex although they have more human resources. However, at the end the project needs to comply with the strictest building rules and budgets imposed by the ministries. This is not an easy task, and that is why all the help in the control and supervision of the building process is welcome. It is in this area of shipbuilding where VR solutions have been well-received a time ago. The application of the most advanced technologies usually starts in ambitious building programmes with major innovations and budgets. That is the case of application of VR in shipbuilding, because having an appropriate VR solution is costly, and that long-term military projects are those with a larger budget to afford them.

Other important use around naval shipbuilding is in that of the ship's crew and the ship owners. The use of VR is an advantage for the crew training. In submarines, this can be particularly interesting for the lack of space. Simulation is the other important activity, since there is a real difficulty to enhance some kind of operations inside a submarine and in a surface ship. The help of VR to simulate operations and dismantling and maintenance tasks is unquestionable. Here there is a great area of improvement.

5.6 AREAS OF IMPROVEMENT

From another point of view, there are still some drawbacks to mention around the use of this kind of technology in shipbuilding. The most important one is the price, because although there are cheaper devices available in the market, the truth is that hardware is expensive. It is also necessary to add the costs of the software: implementation, conditioning of the room and the training, etc.

Another important drawback is the necessity to have a good 3D model of the ships. Sometimes this is not possible, because there are multiple CAD systems applied in the same project, with the difficult of having just one model of the ship with all the information. To avoid this situation, it is much better to develop the whole project in the same CAD, or at least to have the necessary tools to integrate the information in a compatible viewer for all of them, which sometimes is a very difficult task.

Finally, the ergonomic aspect of the solution is important too. The use of 3D glasses for a long time is straining for the eyes, and the standing position looking at a screen without any light could be unpleasant if used too often. Recent studies and experiments within a real factory show that workers prefer to work with manual devices, where they can physically touch rather than trying to pick a floating handle in the air.

6. CONCLUSIONS

After this light review of all these technologies, it is possible to have an idea of the magnitude and complexity of the changes that Industry 4.0 is demanding.

In most cases, it is an unavoidable step that must be taken to remain competitive, but with the adoption of only a part of what is exposed. It could mean a too risky and complex step that should be studied carefully before taking any decision. Some of these technologies are in early stages for industrial implementation but it is important to be aware and analyse what can be beneficial and or useful for each case.

Most of the different technologies exposed in this paper are not new and are well known, but the true potential came with the improvements in the communications infrastructures; and that is why a concept like DT is something that will be achievable.

Now with 5G, it is expected that the IoT will grow in an exponential way and its true potential will arise, which will also track from the development of the DT.

Other technologies like VR have reappeared mainly thanks to the Game Development Industry and the lower cost of technology derived from the evolution of flat screens and miniaturization among other factors. VR seems to have an important future for training and simulation purposes, but its implementation in companies has a lower interest compared with AR.

Contact lenses that works with AR, are science fiction now? DARPA is interested in a new wirelessly connected contact lens recently unveiled in France. These contact lenses provides augmented vision assistance to users by relying visual information wirelessly.

There is another important piece of the puzzle: the security, veracity and trust in the data transactions between all the different participants. Cloud + security are two pieces of the game and without them, all this ecosystem will never work. Data transactions should be guaranteed and all the steps should be tracked from the first step to the last one of the process thanks to blockchain.

This data centric model will be complemented with Big Data, Analytics and AI:

- Extracting conclusions from that big amount of data acquired from IoT devices.
- Making possible a better predictive maintenance thanks to the capability to predict failures or detect problems in early stages as well as the consequences of those problems.
- Learning from manpower that works in our Industries by analysing the activities in order to process all that information, and to be able to suggest better practices by detecting bottlenecks and possible solutions.

Repetitive tasks and dangerous activities that nowadays are carried out by labour force, can be replaced or supported by robots, which means an important change for the companies and the people that works there, but this transformation is unstoppable. New jobs will be created and new profiles will be necessary but those jobs that could be replaced totally or partially with robots will disappear. People should react to these new conditions and adapt.

The implementation of robots and autonomous vehicles in the Industry will produce new tools that will improve working conditions for current workers, but adapting to all these new technologies may not be easy. Shipbuilding is an Industry that could take advantage of this, depending on the preferences of each shipyard. This technology will be more or less easy to implement, but even if it is feasible, the decision should be taken with caution, because physical robots and autonomous vehicles need special conditions to work. A different case is the use of RPA, which could be easier to implement and very useful if the processes are clearly defined and can be automated.

New materials and 3D printing techniques will have an important role in the future of Shipbuilding, as is already being demonstrated in other industries such as aeronautics and automotive, but in shipbuilding there are interesting challenges for the use of 3D printing on board.

In the middle of this ecosystem we will find a 3D model, created mainly with CAD tools and this means that the importance of CAD will be even more capital than today. The interface between the 3D model and the rest of the Industry 4.0 is the DT; the link between the reality and the virtual world; both living concurrently during the evolution of the construction and extending this world of possibilities to the entire lifecycle of the product.

CAD tools, as an important part of this entire environment, should also evolve to be easily linked to these technologies, but also it is important to be adapted to the new generation of users. These users demand a different kind of interface and workflow which will require greater effort.

This big world is now open and Shipbuilding is starting to see the potential benefits, but is clear to remain competitive and to study how these technologies can improve the benefits by upgrading processes, resources, workflow and cooperation between stakeholders. The tools are here, now it is necessary to study and analyse our particular case. There is no global solution for all industries, not even a global solution for a particular industry, but digitalization is on hand and it is mature enough to start implementation and be part of our strategy for the future.

In this transformational journey is essential to get the commitment of all stakeholders and particularly the participation of universities. Industry 4.0 should also address the collaboration between academics and industry to facilitate the transition to Industry 4.0 for industrial partners and professionals in the maritime sector.

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