Design of SMART Ships for the IoT

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ABSTRACT

Ships vessels are like small or not so small, cities or industries. These kind of artifacts can take advantage of the developments on IoT to deliver smart vessels to improve operation, usability and profitability for shipowners, users and workers. To introduce the different possibilities of IoT in vessels it is needed to start from the initial concept and the initial design. This paper presents some ideas on how to make a ship conceptual design from the very beginning by taking into account the necessities of the different components of a ship in order to be connected in the world of the IoT. For making this design it is necessary to use advanced tools capable of incorporating the latest achievements in the IoT and to manage all this complexity.

CCS Concepts

•Applied computing → Computer-aided design;

Keywords

IoT; CAD; Lifecycle Management; Databases; Ship Design; Smart Ships

1. INTRODUCTION

In May,2013 McKinsey and company published a report in which, twelve technologies were identifed as disruptive technologies that could change our lives [3]. Among all of them, one was the internet of things. This technology can be related with big data and smart devices. If we consider the Internet of Things as it was commonly agreed as *Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization*, the question that immediately arises is *What is the objective of all that data?* or *How to manage all that information?*. It is impossible to give a detailed answer to those questions or it might be *It depends*. From our point of view it is needed to start concentrating the target into small areas of definition and to give an answer to those.

According to [5] "Internet of Things (IoT) is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach common goals". Following the authors of the aforementioned book, the most clear applications of IoT are:

- Smart cities.
- Smart Energy and the Smart Grid.
- Smart Trasnportation and Mobility.
- Smart Home, Smart Buildings and Infraestructure
- Smart Factory and Smart Manufacturing.
- Smart Health
- Food and Water Tracking and Security.
- Participatory sensing.
- Social Networks and IoT.

Ships are small pieces of humanity in the sea. They can be up to as medium sized cities, medium industries, leisure places or whatever anyone can imagine. All the necessities that a society can have shall be necessities in the ship. If the society progresses in some knowledge or technological area, sooner or later the vessels will have to lead to that progress. IoT is one of the most important challenges for the current society. All the areas in which men and woman will live will face this advance, and the ship vessels is one of them.

In a greater or lesser extent, all the applications above mentioned already exist in ships. Moreover, the controlled and limited environment, is a characteristic that makes ships ideal to be a first area of application. All the benefits related with IoT can be applied in the existing objects in a ship and all the responses can be monitored, analyzed and improved. However, vessels are humanity cells subject to hard environmental conditions. This particularity makes that any

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technological advance to be applied inside a ship have to be taken into account from the very beginning.

Currently all the designs in modern society are made by information tools and computer aided designs, supported by the adequate databases and with lifecycle management of the information. To address the challenge of the IOT for ships, it is necessary to have CAD-CAM-PLM tools adapted in different ways. We consider that there are three elements of evolution:

- CAD systems have to be adapted to the IoT
- CAD systems have to be adapted to engage the designs with the IoT
- CAD systems have to be adapted in order to have the manufactured products prepared for the IoT.

We are trying to put our stone into the wall of the Internet of Things in the scope of the shipbuilding industry. And even more, we focus on the preliminary stage of the shipbuilding which is the design of the ship. In this paper we explain our firsts steps in the path towards the bringing the IoT to the ship design tools and how we address that challenge.

1.1 Organization of the work

This paper takes a look over the shipbuilding industry as it is one of the main actors in the future development of the Internet Of Things. It is explained how we believe the Shipbuilding CAD systems have to evolve in the next future to keep upgraded.

We will explore the future of the CAD systems oriented to shipbuilding and we will analyze how the improvements in that systems are related with the, let's say, the IoT.

Then we will study what elements have to be taken into account in the tools if we want to provide the designs with features that prepare them to be connected through internet with sensors or databases.

Finally we will review what have been done in one of the most relevant CAD systems which is the FORAN System to prepare the manufactured products to be connected in the IoT. FORAN system is a shipbuilding cad system developed by the spanish company SENER Ingeniería y Sistemas, S.A. http://www.marine.sener/en/foran

2. THE FUTURE OF THE SHIPBUILDING *CAD* SYSTEMS

There are many advantages of using CAD in shipbuilding: ease of design, speed of construction, use and reuse of information, etc. It is expected that in the future CAD tools will advance further and allow greater information management and virtual access through smart devices. In general, CAD systems provide tangible benefits while the process is optimized, reducing design time and production, and therefore costs.

Shipbuilding CAD Systems have specific characteristics that make them different from other mechanical CADS. Ships are big objects with a lot of other objects inside. In order to take advance not only in the design, but also in the production and the rest of the product lifecycle, it is required to manage all that data from a single core. This core was known some time ago as the product data model. However this concept has evolved and now it is decisive to concentrate in new tools, distributed to all stakeholders but accessible from different sites to all related agents. Currently this approach is the PLM (Product Lifecycle Management) system. If we think how to extend the capabilities to the IoT, our conclusion is to provide the CAD software with the significant characteristics for having those capacities. However this extension must maintain the principal objective of a CAD system, which is the objects design. To define those characteristics it is basic to identify the IoT and the CAD system(real or expected) characteristics.

The Internet of Things (IoT) is the network of physical objects that contains embedded technology to communicate and sense or interact with their internal states or the external environment. However, this concept can also be extended to the logical objects. The software is one of these objects and in this meaning, it is both the way and the actor in the connection to the IoT. CAD systems are one of the most valuable software for companies, due to they are the tool for creating new manufactured products and these products are the actors in the real IoT.

There are several fields where shipbuilding CAD systems could improve in the near future. Here the focus is on functionalities that are related with the IoT. The first relevant feature of CAD systems related with the IoT is the ability of self-diagnose its functionality. We all have seen that when an application blocks, a message usually pops up to request permissions to inform the sellers about the issue. This is one of the most common features currently available. However is this really useful?. The problem in CAD systems is that many of the bugs or crashes are induced by the content that CAD is managing and this information is not usually shared as it might be confidential. This is a clear limitation of the possibilities of the IoT for the CAD's. So, the path for improvement must be a different one. It is clear that tools need to be improve by themselves and also their functionalities, so E.g. in hull forms fairing, the global shape modelling or the advance continuity and capping could transform complex surfaces with excellent results, less interaction, high accuracy, and full control. These techniques shorten dramatically the design time, from days to minutes while obtaining excellent results. Another area of improvement concerns one of the most time-consuming tasks in outfitting design, the routing of pipes, HVAC ducts and cable trays. Automatic routing options minimize this time without reducing the robustness of the design. There are several algorithms for Automatic routing which provide simple solutions, with optimization of material. But the matter is not only to consider existing elements for future routings; it is also vital to assign priorities, and eventually handle automatic modifications of existing elements as a consequence of new ones. In practice, the complexity of the problem explains that there is not yet fully satisfactory solution for the automatic routing. Current solutions provided by CAD systems solve partial problems, offering already significant support. The results of the designs are one of the most valuable assets for the companies, so it is not imaginable that the companies share their designs. Possibly, the companies might have their repository of information that can be managed by the applications. Also, the applications are able to evaluate the designs reaching by internet those repositories of legacy information that could improve the designs. Or even more, the CAD's vendor could offer by Internet, in an autonomous way, the CAD system to be connected with the vendor designs repository to give a figure of merit.

Figure 1: Marine design future, information in each stage of the ship in electronic devices.

Another area where the CAD companies are active is Virtual Reality. The objective is to create a user-friendly environment in order to review, audit, obtain metrics such as the progress of a project, etc. This type of review process of the model does not need to use tools for designing, just a simplified tool allowing easy access ("viewer"). In Figure 1, a 3D visualization model is reviewed in a tablet, where the authorized designers/engineers could have all the project information. These navigators allow access for reading 3D information in order to load the component tree of any customer project for obtaining information about any item. Other basic tools available in these programs have different modes, allowing navigation commands to take action such as measuring distances or angles, creating sections to access internal components, etc. The interface with the program is via a mouse, but Virtual Reality opens windows of opportunities, with globes, glasses or helmets. Advanced browsers allow incorporating human models in order to study ergonomic aspects, creating highlights and textures for advanced renders, movements of components to perform simulations, etc. Browsers can connect to the database of a project in order to access information in real time. Sometimes there is a need to take information from an on-line database and if there is an Ethernet network by means of the shipyard, it is possible to implement a shared computer with a viewer that allows connecting to a project. If there is not an accessible database, viewers should be able to read files with the project information required for 3D modelling of the product and component data with optimal performance. So far it was prevalent to implement viewers on laptops, because laptops are usually equipped with processor and graphics cards that allow navigating through the entire project. In recent years there has been a breakthrough in mobile devices like tablets or smartphones. This hardware progressively incorporates new processors that enable enhanced graphics. On the software side, operating systems have been developed specially adapted for such devices (such as Android or IOS) allowing interfacing naturally by touch gestures. The widespread use of these devices nowadays has precipitated its use by software companies. Software developers have taken their time preparing oriented solutions and among those, the ones that allow us to have project plans or 3D models on tablets and other electronic displays. In modern projects, there is the need, for technicians, to carry these devices to work better, with a quickly access to the 3D model of the project, with all parts of information and construction drawings needed. A wi-fi connection would allow connecting to an information server to update the information needed, mainly in files, as for example: 3D models, classification or production drawings, among others. Another advantage of mobile devices is that the user interface might interact with the project model or parts using gestures just as everybody does on daily basis with smartphones. One develop line for navigator's evolution would incorporate augmented reality technology. It would be helpful for production technicians to scroll through the project and pointing the camera of their mobile device to a particular component to obtain information from it and have the actual image of the same 3D design model displayed. This is possible through the use of markers that help the device to position itself within the project and also for the use of QR codes. CAD systems must handle the information needed for creating a collision-free design and for generating all production and assembly information, but not only this. The 3D model information is, at the same time, necessary for other activities and other departments involved in the construction of the ship, as planning, purchasing, subcontracting, accounting, etc. It is usual that several design agents collaborate in the same project; so it is necessary that 3D model information should be shared between them to serve as reference. The paradigm of this problem appears when two or more design agents collaborate in the same project, using different CAD tools. In this case, the CAD systems must provide data exchange between them, leading to different degrees of integration, like visualization, spatial integration and cross manufacturing, depending on the characteristics and size of 3D model information transferred. At least, it should be geometry and key attributes. A worldwide format for data transfer has not been found yet. Despite recognized international standards, in most cases we see dedicated formats or special adaptations from standard ones. Transfer of 3D model information could produce loss of performance due to different geometrical approaches to represent elements in CAD systems. In this case, special solutions must be adopted in order to minimize this impact.

Robotics is probably the technological area where the connection of devices with the design has he most clear link. There are many specific characteristics of the shipbuilding that makes robotics the natural growing path. However there are some challenges that must be addressed. The material used in shipbuilding along with the size of the parts make it important assure that robots make what is desired. So, it is necessary an intermediate step with the human validation. But this is just one more key among all of the challenges that IoT has to deal with.

Another recent milestone is the integration between different CAD systems and Product Lifecycle Management (PLM) tools, e.g. the FORAN Product Lifecycle Management (FPLM) tool with a neutral architecture. In this case, all the information generated in FORAN may be transferred to a PLM and may be subject to all processes: control, configuration and releases lifecycle and process management. FPLM consists of a series of tools and features that enable bidirectional integration between different modules of FORAN and PLM tools. The solution is based on standards such as XML, Web Services and Common Object Request Broker Architecture (CORBA) as it is described in [4]. Figure 2 shows an example of tool integration. The colors highlight parts or elements that are or are not to be transferred to PLM.

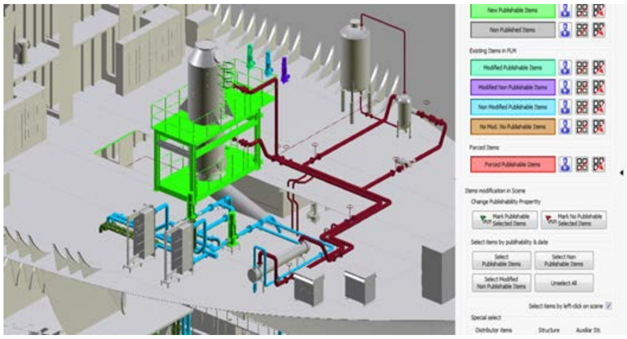

Figure 2: Integration between FORAN and a Project Lifecycle Management tool.

3. THE INTERNET OF SHIPS

In November, 2015 Gartner estimated that the number of devices connected to internet would be around 6,4 billion and it is estimated that in 2020, this number will reach the number of 25 billion [2]. This revolution that began a few years ago has aroused enormous interest in all industries, and in some of them, already works with apparent normality. Nowadays, it is possible to order directly from our refrigerator as soon as it detects that we need our regular products. We also have smart lamps that light up alone when needed lighting. The world goes on steadily toward what will be undoubtedly, one of the most important revolutions in the history of humanity. We could define the Internet of Things as a consolidation through the network of networks, a "network" that keeps a multitude of objects or devices, this means, it connects all things of this world to a network, such as vehicles, appliances, mechanical devices, or simply objects such as shoes, furniture, luggage, measuring devices, biosensors, or anything that we can imagine. At its core, IoT is simple: it's about connecting devices over the internet, letting them talk to us, and applications, one with each other. But IoT is more than smart homes and connected appliances. It scales up to include smart cities - think of connected traffic signals that monitor utility use, or smart bins that signal when they need to be emptied - and industry, with connected sensors for everything, from tracking parts to monitoring crops.

In this context the question is if the naval sector is ready for this revolution. Is it possible that this traditional and conservative sector moves into this technology? There is already evidence that the shipbuilding industry is no stranger to these developments and it is already connecting to the Internet some components of the ships, as it is shown on Figure 3. But this is not the only field of application of the IoT for shipbuilding. The different systems integrated in a ship shall be connected between them in order to share the significant information. E.g. the equilibrium system of the ship will take measurements of inclination of the ship and will order to the ballast system in order to get the upright position of the ship. This means that the ballast system, composed of the ballast pumps must be connected to the centralized control of the ship in order to receive the orders. In the initial design stage, it must be taken into account what systems and what components of the ship will be, let's say smart components and what other not. The life in a ship has a component of risk and danger and not all devices have to take part of the IoT of a ship.

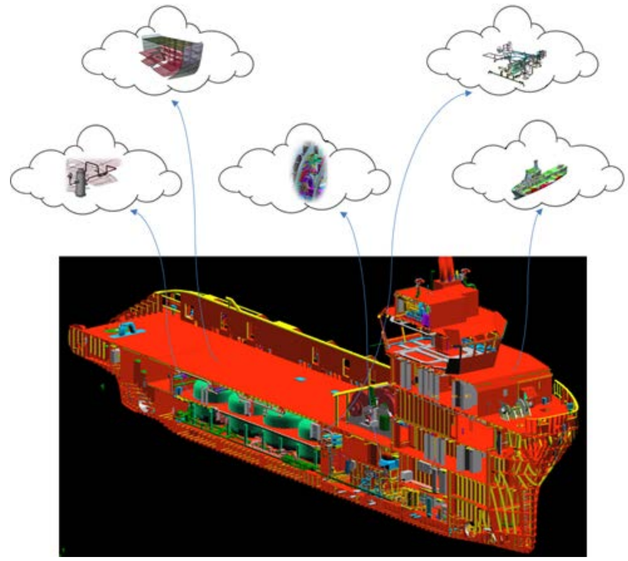

Figure 3: Ideal representation of a 3D model with access to the different ship design disciplines.

As there are smart homes or smartphones, there will be new smart ships that will be equipped with a network of sensors that capture a range of voyage information, including:

- Location.
- Weather.
- Ocean current.
- Status of on-board equipment.
- Status of cargo.

Ship owners can monitor the vessel's status in real time and apply analytics to current and historical data to make decisions that enable them to run more efficiently, saving time and fuel. Sensors and IT technologies are facilitating the introduction of new applications at sea, like energy distribution, water control and treatment, equipment monitoring in real timeĚ The aim is to take this technological revolution by acting in the design and production phases in order to build efficient, safe and sustainable vessels. In a decentralized sector, like naval, where the engineering and production are often in different locations and where critical decisions cannot wait, we can speak about the internet of ships or the connection through the network of critical components in the design/shipbuilding. This concept starts to glimpse as something that the sector cannot obviate. The idea is to monitor all those parts in which early detection of events allows us to make the right decisions. In this sense, the available sensors during the early stages of construction of the ship, allow us to identify if the construction of the boat is completely according to the design we have created with CAD. If we can reduce materials or use another material, if we must change anything according with naval architecture calculations. The continuous monitoring integrated with a naval CAD design as FORAN will reduce costs and avoid mistakes and will allow to make decisions in real time from the shipyard, the design offices or remote locations. Nowadays solutions CAD like FORAN can be used in a pocket tools, which turns them to be the indispensable ally in this new technological revolution (see Figure 4).

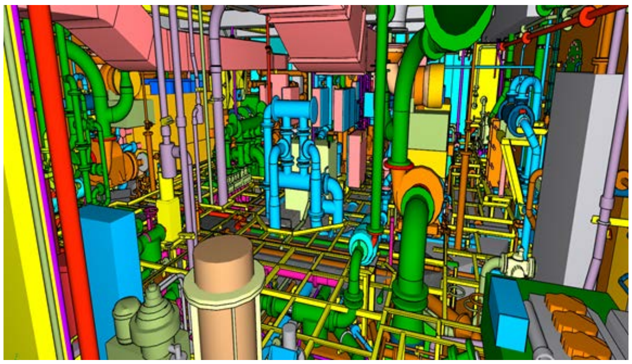

Figure 4: 3D model on a virtual portable solution like tablets or smartphones.

Shipbuilding process, generates a lot of information and data, which a priori makes it seem unlikely to have all this data in real time, but the new processors, simpler and smaller, with a good connection to the Internet, make it possible. The data management is, however, only one side of the coin of the IoS. Energy efficiency is also a fundamental aspect in new devices that connect to the network. But IoS not only covers the stages of design or production of the boat. Once the sensors are in the components whose information want to monitor, anyone will be able to obtain information along the whole life of the ship. Internet of ships is presented as a solution capable of detecting when a component on a ship is close to failure and must be replace, when we take the boat to repair, when we have to paint again, when corrosion has reached a certain limit ... and we can manage all this with our pocket tool, and early enough to avoid late or unforeseen performances. IoS reaches this sector to ensure profitable production, or safe, efficient and sustainable process for all types of fishing vessels, tugboats, tankers, charges, ferries, dredgers and oceanographic ...

4. THE IOS IN A CAD SHIPBUILDING ENVIRONMENT

Shipbuilding process, generates a lot of information and data. This reality connects directly with the concepts of big data. The concept of Big Data is one of the mos intrinsically related with the IoT, but not exclusively. The four dimensions that characterise big data are: Volume, Velocity, Variety, Veracity miss. Another one more important is View. View means, the purpose, the objective of collecting the information. The view must be the leader of the existance of big data. Our vision is that the view must be establisehd in the very early design for managing the information that must be collected by identifying the properties during the design stage. So, the engineers must decide the properties that will match the information that have to be shared with the the rest, and this must be guided by the view, or the purpose. As it is concluded by the Lloyd's Register Foundation [1] one of the expected impacts of big data in the marine is the dynamic non-linear processes for predictive and preventative maintenance. I.e. , a pump must be reviewed after 1000 working hours. The object pump, in the CAD database must have the property of working time. The database will have a working time field associated to each one of the pumps. The working time is monitored and sent to the middle tier connected to the PLM. The maintenance program will check the value against the limit and will decide when it is necessary to enter in the maintenance program. Even more, it can decide to stop the pump and to replace by the backup pump.

Together with this future development there are implications in the concept of the ship that have to be taken into account. The most obvious one is the necesity of having connected data infrastructures. In practice, in a vessel we can imagine two different networks:

- Internal network where the vessel's systems are connected.
- External network where the vessel is connected.

These two networks are the representation of the IoT, but for different purposes. We can accept that many of the internal connected systems are already working. The step forward is to allow the systems and the parts in the system to connect ourtside and to allow them to interact in a more or less autonomous manner.

One single vessel can contain millions of objects. From a design perspective, all of these objects must be completely designed by the CAD software and managed for having control from the lifecycle point of view. This management covers a wide range of common and user specific properties. The CAD allows to assign these properties to the objects. The methodology of assignment assures a unique id within the entire project. The project itself will be controlled by the PLM system, so it is possible to address one of the challenges of the IoT: to assure trusted identifications to the objects. Of course this method forces to access the object through the PLM, that acts as a middleware between the objects and the outer stakeholders. In the case the objects communicate each other inside the object it is not necessary to use the PLM properties. All the information is stored in the unique database for each project. This is the method used by the FORAN System.

Different smart devices, components and systems will share their state, or their needs for a better operation. But, another connection must be done to the external world. This external connection will provide the interconnection of the whole ship as a smart ship with the centralized intelligence of the ship-owner. This connection will share information needed for the better operation of the ship, or will allow to receive the orders for a better operation according yo the information received from other ships. Also the necessary information to get the replacement or revisions of the components will be transmitted from the components itself. To make possible this approach it is necessary that the CAD tools may manage the amount of data generated and that the relationship between the components and target of the information they share.

It is significant to clearly define which of all the objects existing in a ship must be involved in the IoT universe. The

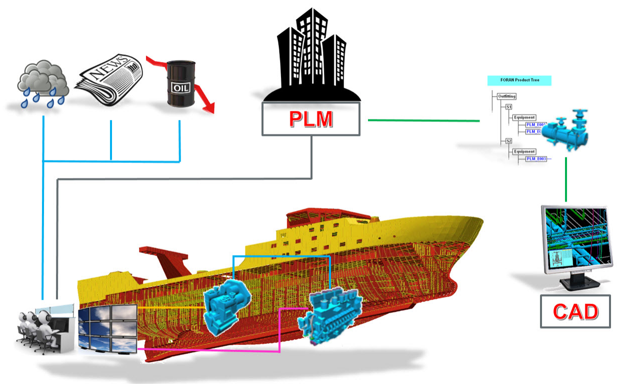

Figure 5: Ideal representation of the smartship connected to IoT.

scope of different types of objects in a vessel is so wide that it is vital to define and, mostly, to reduce the possibilities of connecting those that can have added value. But not allways this is possible and probably it is necessary to wait for technology to be mature enough. To illustrate this idea the case of weldings is explained.

The weldings are one of the most important objects in a ship, as anyone can imagine. Currently the CAD is able to identify the welding, to know what elements are joined by a welding, the length of the welding, the type, the weight, etc. But one of the new concepts to manage would be the state of the welding. The state should be the situation of the welding that allows to accomply with its purpose of joining elements without permeability. It would be necessary to monitor the permeability of the welding, what could be done by measuring. This monitor could be a kind of device that must be developed in some way. The advantage of this monitoring is that the owner will have adequate information of the state of the ship and when the ship needs maintenance or repairing, etc..

The information can also be analyzed from the point of view of the security. This monitorization gives relevant information to have safer ships. What to do whith this information is something that needs to be deeply studied. It might be used to prepare the ship for inspection and even controlling if the ship could be operative or not.

The connection with the IoT must not stop here but it also must be fed by the experience of other cases. If the results of monitoring pumps reveal that the time for a pump review must be reduced, this information must be used from the PLM system to update the maintenance program of such a pump.

5. CONCLUSIONS

Here the concept of IoT is extended not to just to physical objects but to the designs and to the software that it is the vehicle that allows to go from the initial concept (design) to the product (the object). This paper opens several lines of work for preparing software used in ship design to work in the openned world of the IoT.

Adapting shipbuilding to the concept of IoT can be done from different approaches. The future ship design tools must be opened to take advantage of the information that smart devices and smart ships already adapted to IoT will supply information such as the performance of its operations, consumption, trips, etc. They will allow an early evaluation of naval projects and better designs. The information shared in the scope of the IoT must be managed 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. Many of those characteristics are not yet available and the software developers must prepare them. It is mandatory to design CAD software able to receive information of ships in operation and to evaluate the performance of the designs with real data. The product data model must have the ability of incorporating relations between internal and external components.

FORAN link to PLM has the necessary tools to provide the information for connecting the objects to the world of the IoT. It has solved the problem of connection of the objects identifiers , by designing the intermmediate tier between the PLM and the CAD. This middleware is intended to be the core of the connection between the objects and the rest of the IoT.

6. FUTURE WORK

One of the considered as more relevants is to connect the design calculation software to databases that allow to optimize the designs. Here we can mention some of them:

- Connection with classification societes to evaluate compliment of steel structure.
- Evaluation of hydrodinamics of the designs comparing with results of existing designs.

Other field of improvement will be directly related with the physical integration of measurement devices inserted in the welding and pipe joints to monitor states of those elements that can warn about their situation in the ship's structure or pipelines.

The connection of the external objects, companies, etc. with the internal network of the ship must be done through a middle tier that needs to be specified with very detail. The definition of the specifications of that midle tier must take into account to all the stakeholders involved in the entire lifecycle of the ship.

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