KETmaritime Case Study 1 - Advanced Manufacturing Shipbuilding Applications

A pioneering scientific centre in northern Portugal has led a major two-year project studying advanced manufacturing technologies with the potential to revolutionise the Atlantic maritime sector. The International Iberian Nanotechnology Laboratory (INL) located in Braga is the lead partner in the €1million 'KETmaritime' project backed by the European Regional Development Fund. Project coordinator Ana Vila said the INL is now releasing details of the first case study focusing on 'advanced manufacturing for shipbuilding applications'. She said the pan-European project identifies ways in which pioneering technology including 3D-scanning, 3D-printing, Robotics, Virtual and Augmented Reality can shape the future shipbuilding process.

Key findings from the KETmaritime project are now being revealed following two years of intensive international work involving a world-class consortium of partners across Spain, Portugal, France, Ireland and the UK. Its mission has been focused on identifying KET (Key Enabling Technologies) to meet the future needs and demands of the Atlantic maritime industry.

Project partners include French multidisciplinary research laboratory CIMAP (CEA group), Portuguese maritime economy association Fórum Oceano and Spanish technology centre IDONIAL. Ireland's national centre for marine and renewable energy MaREI and UK marine cluster organisation Marine South East have also provided major input. The consortium was completed by Spanish technology centre AIMEN.

A total of five detailed case studies have been produced under the €1million initiative based around 'Advanced Manufacturing Shipbuilding Applications', 'Nanotechnology Marine Applications', 'Marine Industrial Biotechnology', 'Photonic Marine Applications' and 'MEMS (Micro Electro Mechanical Systems) Marine Applications'.

Advanced manufacturing – a timeless concept

The first case study led by Spanish technology centre IDONIAL focuses on 'Advanced Manufacturing Shipbuilding Applications' (access http://ketmaritime.eu/media/ to view the full report). The detailed study clearly illustrates how 'new-age' technology is already having a major impact on the global shipbuilding sector. The production of shipbuilding patents rising sharply, even tripling between 2010 and 2018, highlighting the rapid pace of innovation and technological change. This is being met with an increase in 'industrial protection activity' particularly across the Far East, with China and Korea accumulating more than 80pc of the production patents over the last decade. Operators across USA, Japan and Europe continue to rely heavily on traditional technology, further influencing the balance between world shipbuilding superpowers.

However, advanced manufacturing need not be exclusive to any nation or limited to a specific technology. More accurately, it incorporates of a range of innovative technologies within the manufacturing process, with the purpose of making an entire operation more agile, flexible and efficient. In this sense, advanced manufacturing is not so much a concept of our time, as a timeless concept, that in each moment embraces current innovative technologies.

Today, advanced manufacturing is strongly influenced by intense technological development experienced in recent years on several fronts. This has occurred largely in the fields of digital manufacturing, ICT (Information and Communications Technology) and automation. All of these advances have converged, giving rise to concepts such as industry 4.0 - marking a turning point on the path to complete digitalisation.

Technology to transform future shipbuilding

There are several forms of technology which will greatly influence the future shipbuilding process. These include digital manufacturing technologies, involving tools for design, simulation, engineering, manufacturing, 3D scanning and 3D printing. In addition, ICT infrastructures, technologies and services are of high importance including wireless networks, mobile devices, cloud computing, low cost development hardware, cross-platform programming languages and wearables. Furthermore, automation will be a key driver including 'intelligent' robotics, artificial vision and autonomous vehicles. Finally, simulation and immersion technologies are set to have a major impact involving virtual and augmented reality.

A critical factor is that all of this technology is approaching a point of maturity and affordability essentially making it more commercially viable. In addition, it is all becoming highly compatible, lending itself to scalable implementation. This is why advanced manufacturing is now of greater relevance and importance than ever before. Key findings below from the KETmaritime case study on 'Advanced Manufacturing for Shipbuilding Applications' highlight why successful implementation of new and advanced technology is of paramount importance to the competitiveness of the Atlantic shipbuilding trade.

3D Design – improving project agility and reducing design errors

Tools for 3D design and engineering have existed for more than three decades. However, a large portion of the shipbuilding design processes still take place in 2D, especially during initial design phases. This is largely due to an historic 'effort-cost' relationship. While 3D-design from the initial stages offers a series of advantages shipbuilders still find 2D design tools an agile way to make estimates and quickly launch projects.

However, over the last 30-years 3D design tools have reached considerable maturity creating key advantages over 2D design. This includes 'visualization and assemblies' making it possible to detect conflicts in the fit of elements, otherwise invisible in

2D processes. This has a direct impact on the cost of design, which is greatly reduced through the 3D design process, since the corrections are made directly on the affected elements. In general, 3D design software is much more agile, especially when the product as a whole is highly adapted to the client's specifications. In addition, 3D design can be integrated with other technologies that also start from a 3D file, such as technologies for structural simulation or 3D printing technologies.

Essentially, 3D design offers clear benefits in terms of error reduction, streamlining of change and reuse of information. These tools are fast evolving and close attention should be paid to determine at which point of a project to migrate to the 'total' 3D concept, as this allow designers to respond at all the stages of a project in an agile and effective way.

Simulation Technologies – search and testing for design optimisation

Existing simulation technologies cover many aspects of shipbuilding activity. Some tools simulate stresses and deformations, informing the design, dimension and optimisation of structures and elements. Other tools simulate productive processes, which facilitate the design and reconfiguration of plants and the optimisation of internal flows. Westerns shipbuilders are now having to adapt and maximise the efficiency of their processes to maintain competitiveness, due to pressure from emerging markets, especially in Asia.

Simulation software (such as Quest, Flexim, Promodel, Area) is capable of modelling the productive processes of an entire organization, implementing a virtual environment, for the search and testing of optimisations. Although these tools are not considered 'packaged solutions' for a specific sector or activity, they include all the necessary functionalities to characterize and model any type of productive activity. Once the core of an activity is modelled, it is possible to define and simulate different situations, introduce modifications, or "put to the test" the system.

There are numerous ways in which to apply these tools to shipbuilding. Key areas include applying digital manufacturing technology to ship production and the maritime environment. Research has been carried out on a simulation-based ship production support system for middle-sized shipbuilding companies – creating a framework for the standardisation of information necessary to manage production and to adapt planning. In addition, simulation software has been used in the application of shipbuilding with the production of three "sister" LNG carriers. This project concluded that simulation models led to more efficient manufacturing strategies. More recently, major Spanish shipbuilder Navantia concluded a study of the industry 4.0 concept to shipbuilding, which served to develop a simulation model. This model showed its usefulness, serving as a means to detect bottlenecks and optimise time and resource planning, in turn driving productivity.

Simulation technologies have great potential. However, the development of models is complex, since simulations start from the initial modelling process demanding a general definition of processes, data collection, standardisation of information and establishment of the specific objectives of the simulation.

3D Scanning – rapid capture of dimensional information

The fusion of laser scanning technology and 3D modelling tools enable rapid capture of dimensional information.
There are a broad number of applications for this technology. This includes 'dimensional verification during manufacturing'. The main capacity of this technology involves the extraction of a 'cloud of points' capable of characterizing a 3D element, and the possibility of making measurements 'as you go' or processing at a later stage. This is highly valuable not only to verify adjustment to tolerances of independent elements, but also to make adjustments in the manufacturing and assembly processes. For example, an item could be received which is not 100pc in line with original specifications. By performing a 3D scan it would be possible to create a 3D model to review and modify the component in order to achieve a faster adaptation. The technology can be further used for 'documenting'. The number of elements integrated in a single ship is such that the documentation and configuration can only be done with the support of technologies capable of quickly characterizing them. This is possible with 3D scanning technologies, which open the door to documentation of various sections of a ship, and subsequent monitoring, maintenance and verification.

Further uses include 'maintenance and verification'. 3D scanning technologies can be of great use for verification and scheduled maintenance of ships, helping make quick verifications with which to make updates. For example, it is possible to carry out a scan and analysis of a ship's hull to detect dimensional variations that should be repaired or compensated. In the same way, these same tools can be used to inspect piping and any aspect of the internal configuration of the ship's systems, especially if these areas are previously documented in 3D based on previous scans. Lastly, 3D models can be integrated in virtual reality and augmented reality applications. The generation of 3D models is an essential requirement in development of VR and AR technology in the field of shipbuilding. The speed in which 3D models can be captured by a 3D scanner is unparalleled, compared with the time needed to make those models based on conventional design tools.

The last decade has seen a proliferation in 3D scanning systems, with important capacities and certain accessibility from an economic point of view. This has been accompanied by a similar evolution of the 3D data processing software. This means that access to these technologies does not currently encounter significant obstacles. This is the reason why many organizations offer services in this field. The incorporation of this technology by leading shipbuilding companies is becoming increasing visible, including Denmark's OSK-Shiptech, Spain's TYM Ganain and Lithuania's Western Baltic Engineering. However, the greatest difficulty in implementing these technologies does not perhaps come from the technologies themselves, but from the need to be implemented through ship-survey projects developed in an efficient and effective time and form.

3D-Printing – simplifying the manufacturing concept

This technology is based on the principle of "layer by layer" manufacture. Starting with a 3D file/model and dividing it into "slices", this technology is able to shape an entire element through the progressive manufacture of each one of the layers that form its geometry. Far from being a unique technology, 3D printing is above all a manufacturing concept. Today this is reflected in various technologies that vary considerably in characteristics and capabilities, depending on the basic technology used to achieve the layer-by-layer conformation of an element.

Many designers in the maritime field are already implementing 3D printing technologies. For example, German hydrodynamics research organization Hamburg Ship Model Basin incorporated an Object Eden350V 3D Machine from Stratasys which reduced the company's lead production times by 70pc and global development costs by 30pc. However, it is necessary to bear in mind that the part size is currently a key limitation for most existing 3D printing technologies. Currently, this technology is not especially suited for the manufacture of large-sized parts (> 1m), with the exception of Direct Energy Deposition technologies (for metals), or some applications for Fused Deposition Modelling technologies (for plastics and fibres).

Direct Energy Deposition technologies are undoubtedly the strongest candidates to transfer the capacity of 3D printing to the field of manufacture and repair of large structural parts in the maritime field. This technology results from the union of the material deposition concept with a traditional metallic welding, in such a way that these processes are characterized by having a nozzle capable of depositing and melting metallic material following the 'layer by layer' principle.

This principle of operation is key to the application of 3D printing in large parts because by its relative simplicity. It can be implemented through any system with the ability to provide the nozzle with the required mobility, from a robotic arm capable of operating on multiple axes, up to a large Cartesian system. While these systems are not as precise as technologies working with thin-layer thicknesses, it may not be a disadvantage in the field of large parts - where the tolerances are significantly greater. This technology is in fact being strongly explored in a special way in the field of repair of parts.

Fused Deposition Modelling technologies are undoubtedly the most accessible form of 'Additive Manufacturing' technology available today, with a wide variety of materials and dimensions, and important scalability, given the relative simplicity of the manufacturing concept. This technology is starting to give birth to commercial machines with interesting capabilities in the scope of large parts, illustrated by Dutch company CEAD. The Netherlands-based additive manufacturing company is creating an industrial-scale 3D printer specifically engineered to help produce parts for ships and other maritime vessels. The Continuous Fibre Additive Manufacturing (CFAM) machine will be able to print engineering plastics and continuous carbon fibre composites, offering a build volume of 4 x 2 x 1.5 meters; equipped with a high-temperature granule extruder. This machine is capable of printing around 25kg of material per hour.

There are many other examples illustrating how the shipbuilding industry is effectively adopting additive manufacturing into its design and build process. Newport News Shipbuilding partnered with 3D Systems to develop metal additive manufacturing technologies. The goal of the joint effort is to revolutionize how the next generation of warships is assembled. As part of the joint development agreement, 3D Systems installed a ProX DMP 320 high-performance metal additive manufacturing system at Newport News Shipbuilding. The state-of-the-art machine is capable of making three-dimensional, marine-based alloy parts for castings or other fabricated parts, such as valves, housings and brackets.

Meanwhile, the new Marine Additive Manufacturing Centre of Excellence at the University of New Brunswick in Fredericton is the first of its kind in Canada to combine research, commercialization and workforce development and training. The centre will be the first in Canada to use 3D metal printing as a method for manufacturing certified, custom parts for the marine sector. Its mission is to ensure the adoption of this leading-edge technology in the marine sector in Canada by developing new methods, procedures, and effective training programs.

Additive manufacturing has also been incorporated by Sembcorp Marine to focus on the fabrication of large-scale structures for new vessels and component repair, using SIMTech's Laser Aided Additive Manufacturing (LAAM) process. Furthermore, Damen has partnered with the RAMLAB, a field lab for Wire Arc Additive Manufacturing (WAAM) in Rotterdam, Netherlands. Together with a number of other partners Damen worked on the development of a 3D printed propeller.

Further afield, Hyundai Heavy Industries joined the South Korean government's creative economy initiative by opening the nation's 15th creative 'economy innovation center in Ulsan. The Ulsan Center consists of two branch locations including one inside of the University of Ulsan and another in the city's start-up assistance center building. Both centers help foster South Korean start-ups with a focus on 3D printing and automated medical services industries. A significant focus will also be placed on boosting the efficiency of the shipbuilding industry through the use of additive manufacturing.

Automation – the rise of 'intelligent' robotics

Automation has a major role to play in shipbuilding as a 'heavy industry'. Key benefits can be offered by robotization - driving greater efficiencies across an entire production process, and greatly enhancing repetitive processes. However, the application of this technology becomes more complicated in areas requiring greater flexibility. In recent years, the introduction of large-scale robotics within production processes has been prolific, with some of the largest shipbuilders in the world successfully incorporating the technology, such as Hyundai Heavy Industries. In this specific case, the latest advances are confined to welding and painting, through 'intelligent' robots capable of working flexibly, adapting to specific work environments. Development of 'intelligence' within robotic systems is where special attention should be paid.

A project delivered by KETmaritime partner Fundación Prodintec involving the application of technologies with artificial vision for the welding of flat pieces with large dimensions illustrated why robots have not always been economically viable for operations requiring flexibility. This is largely due to possible improvements in quality being offset by the cost of the investment and operating costs of programming the robots. However, in recent years great strides have been taken incorporating new concepts in the field of robotics, in particular with sensors and 'artificial vision'. This is allowing robotic technology to evolve towards a concept of intelligent, collaborative and flexible automation.

Applied to the industrial environment, 'artificial vision' would involve the process of automatically acquiring images followed by subsequent analysis, with the purpose of characterising an object, element, operation, process, activity, etc.. Robots can then extract the necessary information to perform specific tasks in relation to the process. Artificial vision has many applications, such as the measurement of parts without contact, quality control in real time, the recognition of people and scanning of objects.

This technology can be used to develop many different systems to inform the shipbuilding practice. For example, prior to carrying out welding work, robots could be programmed to recognise parts and surfaces, scanning them to define an accurate 3D model of the elements to be welded. Using algorithms developed for this purpose, robots could compare the extracted 3D image with its nominal values (2D planes - original 3D models) and establish and adjust the points that determine the welding trajectory. An operator could review and make adjustments later, but this would essentially slash down on time required to determine spatial coordinates of different points of the weld.

A wide range of cameras and vision sensors are currently available with different capacities and accuracies, as well as software and hardware tools capable of developing these types of applications. Today's robots have a greater ability to adapt to different environments and situations than ever before. The recent development of 'intelligent' robotics with a collaborative capacity will not only help large-scale shipbuilders but also smaller organisations. In the near future we can expect to see a rise in the use of intelligent and versatile robotic technology fully integrated into larger systems.

Immersion technologies – working in virtual reality

Two key forms of simulation and immersion technology include 'virtual' and 'augmented' reality. Virtual reality helps create of a complete virtual environment where a user can operate. Meanwhile, augmented reality is created through the superposition of information and complementary images on the user's field of vision. Both forms of technology are generated in a similar way through specific software, helmets, glasses and other accessories. However, they have unique potential applications.

Within shipbuilding the focus for virtual reality lies in its potential application for training. The existence of a totally virtual environment makes it possible to replicate a real environment and simulate real-life activity. This is particularly useful where actions are demanded in the absence of the real environment, as well as training purposes. Augmented reality meanwhile complements information already visible by the human eye - with additional real-time information. This can be used to optimise or facilitate an operation. Verification and maintenance activities are key examples where this technology can enhance operations through a simple overlay of information over the real image. This can be achieved with AR glasses as well as mobile device equipped with cameras and software of sufficient capacity.

These technologies are beginning to find specific applications in the field of shipbuilding. Organisations such as Navantia, BAE Systems, IndexAR and Newport News Shipbuilding are developing and testing solutions based on these technologies, although its use cannot yet be considered widespread.

Further examples of use include Danish ship design firm Knud E Hansen (KEH) which has developed a VR tool called ShipSpace, offering a 3D rendering engine which allows engineers, designers and owners to walk on board their new vessels from preliminary design stages all the way through construction. Meanwhile, German Cruise shipbuilder Meyer Werft has created a VR room for engineers to analyse structural elements, including complete steel models, pipelines, shafts and cables, during the planning phase before manufacturing.

Military contractor BAE systems uses virtual reality to analyse and improve 3D CAD ship designs. This enables it to make modifications to the general design, scale, detail, etc. BAE can further evaluate aspects such as security challenges involved with specific environments. Dutch operation Damen Shipyards is further testing VR and AR technologies. In the latter case, they are experimenting with applications in the maintenance field, testing augmented vision systems and applications to inform an operator if a component is close to the end of its planned lifespan, while further informing about the availability of a replacement part. A similar use of AR has been tested by Newport News Shipbuilding one of the US Navy's main ship providers. The shipbuilder is using AR for seven applications (work instruction, cable routing, inspection, workflow management, training and operations), using tablets loaded with a specific AR software providing on screen information helping operators performing and repairing cable installations.

Finally, Navantia in Spain is involved in AR activity under the framework of its Shipyard 4.0 initiative. This involves the development of a low-latency system for the exchange of information on AR environments tested on different applications, as remote guiding for maintenance operators or 3D images projection.

VR and AR technologies can work well in unison to enhance various activities across the field of shipbuilding. However, its use largely depends on the degree to which other digital technologies are being deployed by a given shipbuilder. The implementation of systems which standardise digital information will allow for a faster introduction of augmented and virtual reality applications.

ICT & Digitalisation – driving the digital revolution

A number of terms are becoming increasingly common in the industrial field - Industry 4.0, Big Data, Internet of Things, Connected Industry, are just some of them. While all unique in concept they can be placed under the same framework involving the implementation of technologies which result in digitalization of productive activity. All technology and developments framed within the ICT concept are applicable to the field of shipbuilding, and there are many examples illustrating how recent advances in ICT are supporting the industry.

One example is digital manufacturing technologies. Information and communication technologies form the basis of all systems, processes and activities in the field of digital manufacturing. They are the basis not only for the existence of systems and computer programs capable of managing the information, but enabling the creation of standards, communication protocols between applications, integration of information in intranets and in the “cloud”. The increase in the power of computing systems and the development of advanced algorithms led to the eruption of simulation technology and 3D scanning, as well as the application of algorithms for the optimisation and design of lightened structural elements, and the progressive evolution of 3D printing technologies.

Meanwhile, advances in automation and ICT are enabling the development of intelligent, collaborative and flexible robotization concepts. This was previously unimaginable in the classical paradigm of machines requiring programming in a detailed manner for each individual action. The development of complex decision systems or more commonly ‘artificial intelligence’, is a key aspect of this automation. Furthermore, simulation and immersion technologies have emerged alongside the considerable increase in power of computing systems. Advances in ICT have informed the development of visualization software and enabled standardized management of 3D files. In turn we can now work in new dimensions, recreating products and environments in virtual reality, generating new interactions during the process.

Global shipbuilding patents – measuring the impact of advanced manufacturing

In order to take a broader view of the impact of advanced manufacturing on the global shipbuilding sector, partners involved in the KETmaritime project undertook several detailed studies involving the international classification of patents. One family of patents – ‘B63B: SHIPS OR OTHER WATERBORNE VESSELS; EQUIPMENT FOR SHIPPING’ - proved particularly instructive. Many activities involved in shipbuilding are covered under the code. A key aim of the study was to assess how shipbuilding has evolved in recent years in regard to ‘protecting activity’ through patent applications. Patent results were restricted to the time period 2010 - 2018. More than 3,800 patents were obtained giving rise to a series of notable observations.

Firstly, there was a temporal evolution in the number of patents published. The production of patents in the field of shipbuilding has consistently doubled throughout the last decade, even tripling in 2018. This indicates that far from stagnating, innovations in manufacturing are increased at pace. Secondly, there are prominent patent families. The most prominent codes firmly indicate that industrial protection activity is taking place in every aspect related to the manufacture of floating structures. This includes methods of designing, building, maintaining, converting, refitting, repairing, or determining properties of vessels.

Thirdly, the study identified the most active patenting countries. Throughout the last decade China and Korea have accumulated more than 80pc of the industrial protection activity in the field of shipbuilding. The most prominent applicants were Korean shipbuilders: Daewoo, Samsung, and Hyundai. These three organizations gathered more than 15pc of the total patent production alone. This clearly indicates the prominence of specific operators in relation to commercially exploiting and protecting manufacturing innovations for shipbuilding.

The data collected further underlines the immense impact of advanced manufacturing on the global shipbuilding sector and its influence on the pace of innovation and technological change.

For more information on the KETmaritime project visit the website www.ketmaritime.eu phone +351 253 140 112 email Ana Vila on Ana.Vila@inl.int

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Project Partners:

Notes to editors:

KETmaritime is a €1million project that aims to transfer Key Enabling Technologies (KETs) to the Maritime Industries of the Atlantic Area. Focused on building a cooperative network that stimulates innovation and competitiveness, the project embraces the challenge of increasing the capabilities, skills and knowledge on KETs in an integrated and cross-national approach. The consortium brings together seven partners from five countries that, under the framework of the project, work closely with industries and businesses. The ultimate goal is to bring to market new processes, products and services. Partners in the consortium include French multidisciplinary research laboratory CIMAP (CEA group), Portuguese maritime economy cluster Fórum Oceano and Spanish industrial design centre IDONIAL. Ireland's national centre for marine and renewable energy MaREI and UK marine cluster organisation Marine South East are delivering further support, alongside Spanish non-profit research association AIMEN. KETmaritime is a project funded by the Interreg Atlantic Area Program, supported by the European Regional Development Fund.