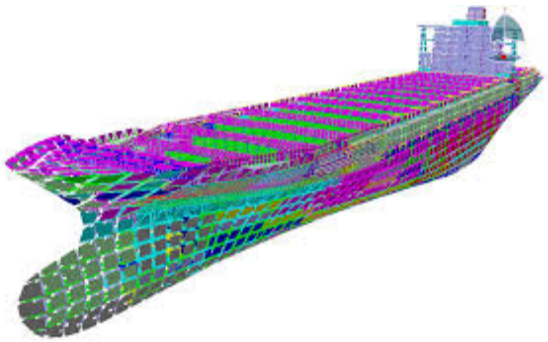
Technology Surveillance Report



Shipbuilding Materials

Fundación para o Fomento da Calidade Industrial e o Desenvolvemento Tecnolóxico de Galicia

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ATLANTIC AREA
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Executive Summary

This Technology Surveillance Report has been conducted by **FOUNDATION FOR THE PROMOTION OF INDUSTRIAL AND TECHNOLOGICAL DEVELOPMENT QUALITY OF GALICIA (FFTG)** under the proyect **AUXNAVALIA PLUS** to be constantly ahead of published developments in the field of new shipbuilding materials.

The aim of this report is to analyze the state of the art of development and identify future trends and applications of the technology in Europe. With this information we will have to measure the sector of the technology and make a preliminary analysis of how the technology has developed throughout time and its maturity level, what are the patents having greatest impact, what are the main research lines and most original developments and how the analyzed technological is positioned.

Furthermore, it will be an information tool in order to promote, disseminate and update the specific knowledge in the area, bringing to the auxiliary sector of the Naval Atlantic area the latest developments about the technology of interest.

Based on the analysis of the information gathered, it appears that most of the developments have been led by Asian companies. There is not a single leader with a dominant position in the development of technology, but some companies in metallurgical and naval sectors as **YOUR NIPPON STEEL & METAL SUMITOMO**, **KAWASAKI STEEL CORP**, **HYUNDAI HEAVY IND CO LTD** and **SAMSUNG HEAVY IND CO LTD** are the key owners of the technology according to their amount of protected innovations.

China, **Japan** and the **Republic of Korea** are geographical leaders in new developments of shipbuilding materials, bearing in mind both the perspective of generation and the market interest.

1. Introduction

Throughout its history, the shipbuilding industry has been undergoing a constant development in navigation and in the techniques and materials used in construction.

In mid-nineteenth century, iron hulls displaced the wood due to the large development of the steel industry emerging as a result of important technological achievements. In turn, by the 1880s the iron was replaced by steel. The steel has the advantages of having a low cost, ductility, mechanical strength, appropriate dimensions, ease of work and good conditions for attaching by riveting or welding, etc.

In the beginning, its main disadvantage was its low corrosion resistance, so it is no accident that several major paint manufacturers specialize in anticorrosive and antifouling products as a solution to problems in ferrous vessels.

Thereafter other construction materials have been developed, but nowadays the steel has the most widely variety of applications in both ships and large structures. Steel has dominated over the last century as the only important material for construction of cruise ships, being wood used for small boats such as fishing ones and aluminum alloys for high-speed vessels, in which the hull weight reduction is a key factor in the power/weight ratio.

Moreover, other materials have been developed for the construction of hulls, such as the reinforced fibers, composites, and sandwich structures which employs polymeric components. Among its applications are anti-mines ships, in which their non-magnetic properties are important, yachts and/or pleasure boats.

The diversity of materials used in shipbuilding is conditioned by diversity of requirements to operating characteristics of mechanisms and structural components of the vessel. All these materials are classified as follows:

- Hull metallic and non-metallic materials for shipbuilding
  - Standard, high-strength and firm ship steel
  - Titanium and aluminum alloys
  - Metal- and polymer-based composite materials
  - Protective coatings
- Materials for ship and general machine-building
  - High-alloy steel
  - Titanium alloys
  - Aluminum alloys
  - Copper alloys
  - Non-metallic materials
- Materials for fabrication of nuclear and heat engines
  - Hull radiation-resistant plates
  - Corrosion resistant steels and alloys
  - High-nickel alloys
  - Titanium alloys
  - Polymers and composite materials
- Functional or intelligent materials, etc.

On the other hand, the development of these new materials is directly related to the study and development of new assembly techniques in order to improve the joinning between traditional materials (eg steel and aluminum alloys) and new materials (eg composites). In this sense, adhesive bonding techniques and mechanical joining are positioned as an alternative to consider in future innovations.

Similarly, a continuous improvement in new techniques such as laser and hybrid welding, already on the market and used in the pre-assembly, allow the entry in shipbuilng of new materials based on composites and sandwich structures, previously used in the automotive sector, providing advantages such as high strength, stiffness, improved fire safety, thermal insulation, modular design and easy assembly.

Bellow some indicators are shown to assess trends in the area, countries and regions generators of innovation, as well as major markets and the leading entities in the area, speeding up the reading of the patent and scientific documents.

2. Analysis or Patent Documents

The search was conducted on more than a hundred of patent databases including United States Patent and Trademark Office (USPTO), European Patent Office (EPO), World Intellectual Property Office, Spanish (OEPM), Japanese (JPO), Chinese and South Korean Patent Offices, to obtain sets of results relevant to the chosen subject of study.

The search strategy includes different methodologies. The main one consists in using keywords and concepts provided by the **Auxnavalia Plus** project partners, and others learned during the documentation process before designing the search strategy. In this search the keywords were directed to focus the existing materials in shipbuilding. Therefore, the keywords were:

- *Steels;*
- *High-strength clad corrosion-resistant steel;*
- *High-strength non-magnetic steels;*
- *Aluminum 1575;*
- *Aluminum 1561;*
- *Panels of aluminum alloys;*
- *Steel-aluminum bimetal with asymmetrical layer arrangement;*
- *Styrene-free polyether structural glass plastic;*
- *Three-layer polyether structural glass plastic;*
- *Titanium alloys;*
- *Composite materials;*
- *Polymeric foam;*
- *PVC based polymeric foam;*
- *Nanoparticles modified with a phosphorous Flame Retardant;*
- *Nanocomposites;*
- *Thermoplastic polymers;*
- *Hybrid Nanocomposite Material;*
- *Sandwich structures;*
- *Carbon nanotubes;*
- *Aluminum alloys;*
- *Polyesther;*
- *Brass or bronze;*
- *Copper alloys, Copper-Nickel;*
- *Nickel-Aluminium-Bronze;*
- *Aluminium-Silicon-Bronze;*
- *Nickel Alloys;*
- *FRP-Sandwich (composite materials);*
- *Carbon fibre;*
- *Fe-Cr-W-V basic composition;*
- *Polymer-based composites;*
- *Epoxy resins;*
- *Sandwich metal-&-polymer damping material, etc.*

Besides the keywords, the International Patent Classification (IPC) has been used[1]. Specifically, the subclasses taken into account are related to *ships or other waterborne vessels* (**B63B**) and *alloys* (**C22C**), which describe, among others, the technology of interest.

Finally, after the combination of the aforesaid search it has been collected a total **of 3,800 families of patents and utility models** (5,917 documents) in the last 10 years (2003-2013). Regarding scientific literature about **1,000 publications** in the area of interest were collected[2].

In order to identify the specific weight of the different materials in the context of the intellec-

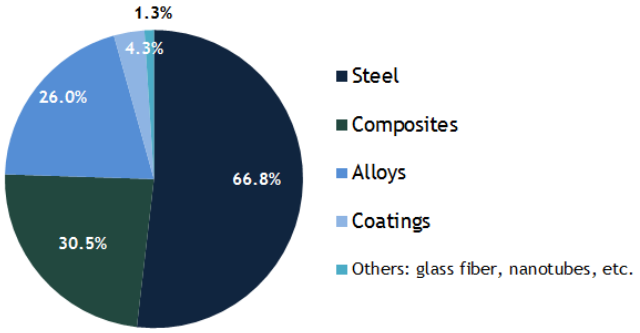
[1] This classification is a hierarchical system where the technology field is divided into a number of sections, classes, subclasses and subgroups. This system is essential to retrieve patent documents in the search in a specific field of technology. The is-burning classification contains approximately over 74,000 entries.

[2] The complete list of the patents families and scientific publications are compiled in Annexes I and II, respectively (Excel).

tual property, a preliminary of the representative sample of the technology analysis has been made, compairing these technological solutions.

In this regard, it is important to emphasize that within the universe recovered two-thirds of the total innovations regards to new steels with improved characteristics, followed by composites (including sandwich structures and polymeric systems). Thirdly, the developments related to new alloys comprise more than a quarter of the total, including the aluminum ones with different proportions of manganese, titanium and nickel alloys.

It is important to notice that coatings are mainly paints comprising anti-corrosion compositions and fire retardants.



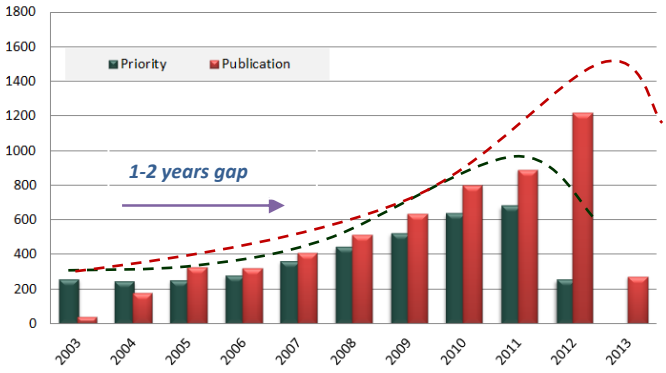
Source: Own generation based on patent databases

Figure 1. Percentage per material

2.1. Technological Development

The initial analysis of the last ten year patent data reveals how the technology is growing and the interest of the market on it. The Figure 2 shows the innovative level of the patents by analysing the evolution of the yearly number of patents at a worldwide level. The chart was made using two variables: the earliest priority year and number of patents per year.

The area of shipbuilding materials has caused a continuous interest in the last ten years, due to the progressive development of new inventions. On the other hand, it should be mentioned that the figures of years 2012 and 2013 should be considered with reservations, due to the period of time from the application to the publication takes between 18 months and two years.



Source: Own generation based on patent databases

Figure 2. Patents per priority year)

Looking at the development of patent applications is inferred that despite being a technology that has more than a century, the continuous improvements in the development of new materials has motivated a new growth stage in the area.

2.2. Research Lines and Emerging Technologies

Then based on the initial analysis of the evolution of the technological area, it delves into the analysis by studying the codes of the International Patent Classification (IPC).

The procedure consists in analyzing these classifications in those hierarchical levels of classification more representative of the whole patent information gathered through the quantification of subclasses and the subgroups with the highest number of occurrences in quantity, allowing infer the technological field covering and new potential research or application areas.

Main subclasses

By analyzing the main subclass provides an overview of trends in R & D and general applications presented in Table 1. The subclass that has a higher number of applications is the **B63B** concerning ships or other waterborne vessels, that along with subclasses **B63C** and **B63H** comprise all the innovations related to boats.

Moreover, the following sub-classes in the table concern to the materials used in the ship construction as well as to the assembly techniques adapted to those new materials. Thus, subclasses **A22C**, **A21D** and **A22F** and classify those innovations related to alloys (19%); the code **B32B** defines layered products and could be identified with the sandwich structures (9%); and all those ones under class **C08** refer to macromolecular compounds, namely polymers or composites (8%).

On the other hand, the subclass **B23K** refers to weldings, that is methods of assembly metallic materials such as steel, aluminum or alloys thereof, while for plastics or polymeric new techniques adhesive bonding or mechanical joining are used. These techniques will be classified in classes **B29** and **B21**, which represents a 6% and 8% respectively.

Interestingly, all subclasses listed in Table 1 have a high participation rate over 30% in the last three years; which means that they all belong to research lines currently under development.

Similarly, Figure 3 shows the relationship between the main IPC codes used in the technology under study. Thus, the subclass **B63B** referred to *equipment for shipping* includes about a third part of the inventions in the area. It is worth to highlight the relationship between the methods and techniques of assembly with the new materials compiled in this work. In this regard, the aluminum and steel alloy gain importance when welding methods are referred, while composites and plastic materials require new assembly methods.

Table 1. Main subclasses

Subclass	Nº Families	%Total[1]	%10-12[2]
***B63B**: Ships or other waterborne vessels; equipment for shipping*	940	24,7	46%
***C22C**: Alloys*	612	16,1	34%
***C21D: M**odifying the physical structure of ferrous metals; general devices for heat treatment of ferrous or non-ferrous metals or alloys; making metal malleable by decarburisation, tempering, or other treatments*	389	10,2	33%
***B23K**: Soldering or unsoldering; welding; cladding or plating by soldering or welding; cutting by applying heat locally, e.g. flame cutting; working by laser beam*	386	10,2	34%
***B32B**: Layered products, i.e. products built-up of strata of flat or non-flat, e.g. cellular or honeycomb, form*	280	7,4	33%
***B63H**: marine propulsion or steering*	179	4,7	47%
***B29C**: Shaping or joining of plastics; shaping of substances in a plastic state, in general; after- treatment of the shaped products, e.g. repairing*	162	4,3	32%
***C08L**: Compositions of macromolecular compounds*	159	4,2	41%
***B21B**: Rolling of metal*	156	4,1	33%
***C08J**: Working-up; general processes of compounding*	139	3,7	42%
***B63C:** Launching, hauling-out, or dry-docking of vessels; life-saving in water; equipment for dwelling or working under water; means for salvaging or searching for underwater objects*	127	3,3	57%
***C08K**: Use of inorganic or non-macromolecular organic substances as compounding ingredients*	95	2,5	39%
***B21D**: Working or processing of sheet metal or metal tubes, rods or profiles without essentially removing material; punching*	79	2,1	32%
***C08G**: Macromolecular compounds obtained otherwise than by reactions only involving carbon-to-carbon unsaturated bonds*	74	1,9	43%
***C22F**: Changing the physical structure of non-ferrous metals or non-ferrous alloys*	67	1,8	57%
Total	**3.844 ***	**101,2%**	

Source: Own generation based on patent databases

[1] *Each patent can be classified by more than one code, therefore the sum of the percentages could exceed 100%. This was repeated for all patent classification codes in the number of patents by applicants and priority countries due to co-occurrence.*

[2] *Percentage for the period 2010-2012.*

Source: Own generation based on patent databases

Figure 3. Relationship between IPC codes

2.3. Most Innovative Technologies

From the previous state of the art, a small number of those patents are the ones leading current investigation. By studying the impact of those documents on later documents and R&D projects, it can detect those developments having a higher repercussion, thus facilitating a comparative study between the Technological Offer and the most consolidated technological developments.

The grade of innovation (i) is calculated by combining the analysis of three different variables:
- Priority year, showing how novel the patent is
- How many cites the patent has, measuring how close is the patent to the general state of the art and the degree of innovation it represents
- How many times has the patent been cited, showing the relevance of the patent.

A ranking has been made where the top patent is the one that has the bigger positive value of the defined innovation indicator (i). In general, a 12% of the innovations has been cited.

Table 2 shows the largest patent innovation index ("*i*" greater than or equal to 1) relative to the universe of patents on new materials of construction in the shipbuilding industry, from highest to lowest in terms of this innovation indicator "*i* ".

First, it is important to highlight that about a 90% of the innovations compiled in the table does not cite previous papers, so that could be regarded as new researchs which involved a break with the state of the art existing at the time of those innovations were published[3].

[3] The innovations presented in Table 2 are the most innovative at the present, notwithstanding that recent patents

First, the application **US20050084407A1** has been cited an average of 6 times a year since its publication on 2005. It regards to methods and compositions relating to powder metallurgy in which an amorphous-titanium-based metal glass alloy is compressed above its glass transition temperature Tg with a titanium alloy powder which is a solid at the compression temperature, to produce a compact with a relative density of at least 98%. It is useful in aerospace, industrial, marine, military, and commercial applications.

The following application, **US20060029537A1**, has been cited 21 times since its publication in 2006. It describes a conductive carbon nanotube film having high tensile strength and initial tensile modulus comprises primarily oxidized small-diameter carbon nanotubes wherein the diameter of the small-diameter carbon nanotubes are at most about 3 nm. A heat-treated small-diameter carbon nanotube film can have a tensile strength of over 70 MPa and an initial tensile modulus of about 5 GPa. It is useful in composites e.g. in structural reinforcement for sports equipment, buildings, vehicles, ship hulls, aircraft, and artillery vehicle and personal body armor; in the construction of laminates for composite components of aircraft, automobiles and other structures.

Among the most recet innovation of the table, it is worth mentioning the development of the **US DEPT OF THE ARMY** in collaboration with the **Universidad de Virginia** and the company **CMI CELLULAR MATERIALS INT INC**. The innovation regards to structures based upon periodic cellular materials that provide a potential for defeating combinations of both air blast loading and ballistic attack either sequentially or simultaneously, or combination of both. The cellular structures may also be configured to meet the stiffness and strength support requirements of particular vehicle or other applications, systems or structures.

Finally, it is of interest that some of the most innovative developments own to lider companies in the área of interest (see Table 5):

- **KAWASAKI STEEL CORP**. The application **JP2005097694A** provides a non-heat-treated high-strength thick steel plate having a high tensile strength of 700 MPa or higher together with a superior brittle crack arrestability.
- **KOBE STEEL LTD**. Its application describes a thick steel plate having excellent welded joint toughness at a low temperature in a level of -40^{0}C even in the case high heat input welding is performed, and also satisfying the requirement for strength necessary as the one for welded structures such as vessels, marine structures, bridges and building structures.
- **POSCO** protects a tandem electro gas arc welding apparatus used in shipbuilding industry, has front side electrode and unelectroded wires which are fused together by supplying electricity to wires through arc heat welding process.
- **TORAY IND INC**. Its Japanese application describes a prepreg providing a carbon fiber-reinforced composite material exhibiting high-degree mechanical strength not only in a room-temperature dried condition but also in a wet heat condition; and to provide a carbon fiber-reinforced composite material obtained therefrom.

with less cites will accumulate more, and in the following years may result in patents with a higher innovative indicator.

Table 2. Patents with higher innovation grade

Publication number	Title	Applicant	Pub. Year	Priority Country	Count Cited Patents	Count Citing Patents	*i*
US20050084407A1	Titanium group powder metallurgy	MYRICK J J	2005	USA	0	45	5
US20060029537A1	High tensile strength carbon nanotube film and process for making the same	KUMAR S | LIU T VEEDU S T | ZHANG X	2006	USA	0	21	2,6
US20070079775A1	Welding Forged Steel Single Piece Piston and Its Manufacturing Methods	BOHAI PISTON CO LTD	2007	China	0	16	2,3
JP2005097694A	Method for manufacturing non-heat-treated high-strength thick steel plate superior in brittle crack arrestability	KAWASAKI STEEL CORP	2005	Japan	0	16	1,8
US20070072776A1	Polyols for breaking of fracturing fluid	BAKER HUGHES INC	2007	USA	0	12	1,7
JP2006002198A	Steel sheet with little welding distortion	NIPPON STEEL CORP	2006	Japan	0	10	13
JP2005232515A	Thick steel plate having excellent high heat input welded join toughness	KOBE STEEL LTD	2005	Japan	0	11	1,2
US20070199481A1	Synthetic Organoclay Materials	ENGELHARD CORP	2007	Netherlands	0	8	1,1
JP2005298877A	Steel plate with excellent fatigue crack propagation characteristic, and its manufacturing method	NIPPON STEEL CORP	2005	Japan	0	10	1,1
US20130022824A1	High-Strength Film Laminates Having Layers Of Plasticizer-Containing Polyvinyl (N)Acetal and Plasticizer-Containing Polyvinyl (Iso)Acetal	KURARAY EURO GMBH	2013	EPO	0	1	1
US20110283873A1	Hybrid Periodic Cellular Material Structures, Systems, and Methods For Blast and Ballistic Protection	UNIV VIRGINIA PATENT FOUND US DEPT OF THE ARMY CMI CELLULAR MATERIALS INT INC	2011	USA	0	3	1
KR2010072822A	Tandem electro gas arc welding apparatus | tandem electro gas arc welding apparatus utilizing the heat of welding arc and the heat of molten metal	POSCO	2010	Rep. Korea	2	6	1
US7799710B1	Ballistic/impact resistant foamed composites and method for their manufacture	TAN S	2010	USA	1	5	1
US20080241455A1	Encapsulated Members, and Processes and Apparatuses for Forming Same	GLOBAL TECH INT INC POINTER R L	2008	USA	0	6	1
US20060179733A1	Durable wood-plastic composite flooring for trailers	HAVCO WOOD PROD LLC	2006	USA	0	8	1
JP2006233188A	Prepreg for composite material and composite material	TORAY IND INC	2006	Japón	0	8	1

Source: Own generation based on patent databases

2.4. Geo-strategical Position

The analysis of the geographical extension of patents belonging to a specific technical area allows analyzing both the impact of technology and its market potential. This is accomplished by a double geographical analysis, ranging from an approach to generating regions of innovations to the regions of publication of those patents, explaining the flow of technology. The following tables and figures summarize the activity of generating and publishing the offices and countries with more activity.

Table 3 highlights in the first instance the lidership of the Asiatic region wherein China, Japan and Republic of Korea have generated the 80% of the total patents in the technological area of interest. This region is followed by Europe and North America that sums the 8% and 6.7%, respectively.

In turn, Figure 3 shows the evolution of applications in the top ten priority countries or offices which adds a temporal nuance that allows for the continuity of research and development in the area.

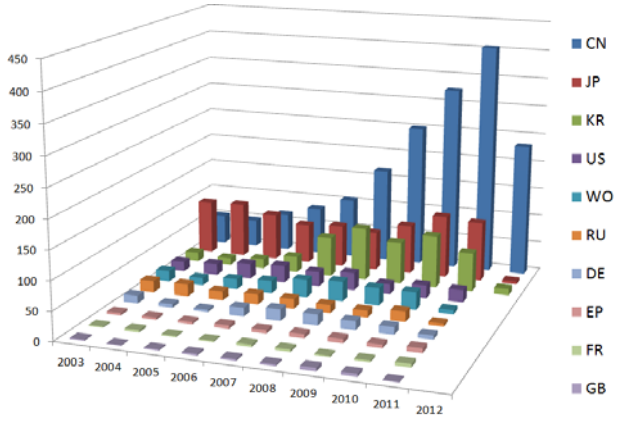
It emphasizes the exponential activity in China with a growth over the 50% in the past three years. By contrast, Japan has stagnated in its upward trend and the Republic of Korea shows an increase in the generation of new inventions since 2007, concentrating a third of its developments since 2009.

Table 3. Number of patentes by major countries or offices of Priority Application

Application Country/Office	Applications	% Total
China (CN)	1739	45,8%
Japan (JP)	816	21,5%
Korea Rep (KR)	483	12,7%
USA (US)	246	6,5%
WIPO (WO)	241	6,3%
Russia (RU)	142	3,7%
Germany (DE)	127	3,3%
EPO (EP)	58	1,5%
France (FR)	29	0,8%
Great Britain (GB)	28	0,7%
The Netherlands	13	0,3%
Australia	9	0,2%
Spain	9	0,2%
Ukranie	7	0,2%
Italy	7	0,2%
Brazil	7	0,2%
Finland	6	0,2%
Canada	6	0,2%
Sweden	6	0,2%
Taiwan	6	0,2%
Denmark	3	0,1%
Bulgary	3	0,1%
Austria	3	0,1%
Greece	3	0,1%
TOTAL	**3997***	

Source: Own generation based on patent databases

Note (*). While the number of patent families recovered was 3800, the priority claim of these may involve several countries, and therefore the number of applications per country exceeds the number of families recovered.



Source: Own generation based on patent databases

Figure 3. Evolution of the distribution of patents by priority country

Regarding publication, Table 4 shows the distribution of patents (5,917) by country or office where its extension has been managed.

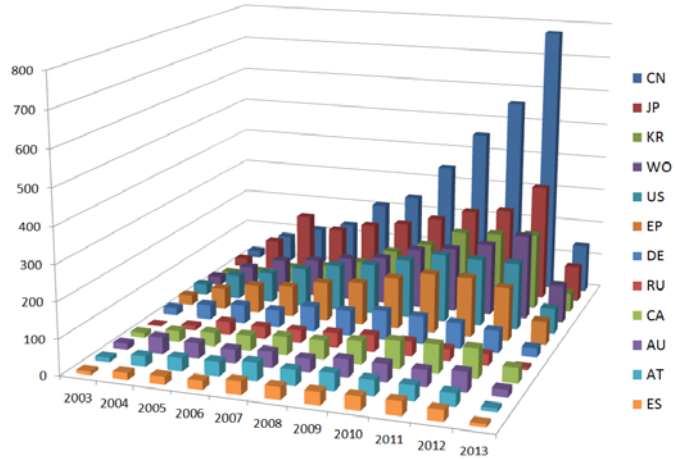
China, Japan and Republic of Korea concentrate a 60% of the publication above mentioned, so the Asiatic region continue to stand out, not only for having the leading countries in the generation of innovations but also as a market of interest.

Asiatic continent is followed by the North American area with around a 10%, and wherein the United States remains as the head country of the region.

At European level it is worth mentioning the strong presence of Germany and Sapin. Finally, in Latin America, only Brazil and Mexico appear to have interest at market level.

There is also a discrete interest in extending the protection of inventions through International Office (WIPO) and European (EPO), with a 13.5% of the publications, due in part to the policies in Asian countries, wherein the protections are nationaly conducted

In addition, Figure 4 shows the evolution of patents published in the top twelve countries or offices, which adds a temporary shade to assess the market interest. Specifically China continues to stand as the main market of interest over the years.



Source: Own generation based on patent databases

Figure 4. Evolution of the distribution of patents by publication country/office

Table 4. Number of patents by major countries or offices

Publication Country/Office	Publications	% Total	Major Companies
China (CN)	2002	33,8%	DALIAN SHIPBUILDING IND CO LTD [36]; KOBE STEEL LTD [30]; NIPPON STEEL CORP [23]
Japan (JP)	924	15,6%	KAWASAKI STEEL CORP [164]; NIPPON STEEL CORP [144]; KOBE STEEL LTD [81]
Rep. Korea (KR)	583	9,9%	HYUNDAI HEAVY IND CO LTD [51]; POSCO [51]; SAMSUNG HEAVY IND CO LTD [34]
WIPO (WO)	484	8,2%	NIPPON STEEL CORP [34]; JFE STEEL CORP [17]; BASF SE [15]; THE BOEING COMPANY [15]; EVONIK DEGUSSA GMBH [15]; MITSUBISHI HEAVY IND CO LTD [15]
USA (US)	425	7,2%	THE BOEING COMPANY [35]; NIPPON STEEL CORP [14]; BASF SE [11]
EPO (EP)	315	5,3%	BASF SE [15]; THE BOEING COMPANY [14]; NIPPON STEEL CORP [13]
Germany (DE)	191	3,2%	BASF SE [15]; EVONIK DEGUSSA GMBH [14]; HYUNDAI HEAVY IND CO LTD [4]
Russia (RU)	173	2,9%	AVIATION MATERIALS RES INST [22]; POSCO [4]
Canada (CA)	138	2,3%	EVONIK DEGUSSA GMBH [12]; THE BOEING COMPANY [8]; NIPPON STEEL CORP [4]
Australia (AU)	107	1,8%	EVONIK DEGUSSA GMBH [8]; NIPPON STEEL CORP [6]; POSCO [4]
Austria (AT)	73	1,2%	BASF SE [8]
Taiwan	66	1,1%	EVONIK DEGUSSA GMBH [8]; NIPPON STEEL CORP [7]; JFE STEEL CORP [4]; KAWASAKI STEEL CORP [4]
Spain (ES)	61	1,0%	BASF SE [5]; NIPPON STEEL CORP [2]
Brazil	49	0,8%	None
Great Britain	42	0,7%	THE BOEING COMPANY [5]
Mexico	39	0,7%	None
France	32	0,5%	STX OFFSHORE&SHIPBUILDING CO LTD [2]
Denmark	23	0,4%	None
Norway	20	0,3%	None
Portugal	15	0,3%	None
South Africa	14	0,2%	POSCO [3]
TOTAL	**5.776**	**97,62%**	

Source: Own generation based on patent databases

2.5. Competitive Landscape

Regarding the type of applicants, it is possible to have an idea about who is developing the technology, its distribution and how close is its commercialization.

In this sense, the companies own a 53% of the innovation, a 10% comes from universities and/or research institutes, and the resting 37% is owned by individual inventors. It is therefore an area introduced in the market, with a direct application in shipbuilding, and pushed by the research and developments in new, easier to work with and lighter materials, wich reduce construction and maintenance costs in this industry.

On the other hand, based on the search results of the State of the Art, a first a competitive intelligence landscape analysis was conducted to identify key owners behind the innovations in the field of shipbuilding materials.

These key players are identified based on the number of patents they have. Players owning patents and published applications in the last ten years could be important players in the research and development of this technology. The initial analysis of the patent data reveals the following key players active in the area of interest, which could be seen in Table 5.

This table comprises mainly Asian companies in the metallurgical, naval and/or aerospace industries, but also highlights the presence of chemical multinationals such as **BASF SE**. This group only represents a 1% of the total applicants but accounts a 15% of all innovations in the area.

The Japanese companies **NIPPON STEEL & SUMITOMO METAL** and **KAWASAKI STEEL CORP** highlight as the technological leaderships, which together with **KOBE STEEL LTD**, also Japanese, represent about a 12% of total publications.

Table 5. Top Applicants

Applicants	Nº Families	% Total	Priority Country
NIPPON STEEL & SUMITOMO METAL	188	5,0%	Japón; OMPI; Rep. Corea
KAWASAKI STEEL CORP	167	4,4%	Japón; OMPI; EE. UU.
KOBE STEEL LTD	89	2,3%	Japón; OMPI; Rep. Corea
HYUNDAI HEAVY IND CO LTD	64	1,7%	Rep. Corea
POSCO	56	1,5%	Rep. Corea; Estados Unidos
TORAY IND INC	43	1,1%	Japón; OMPI
SAMSUNG HEAVY IND CO LTD	40	1,1%	Rep. Corea
DALIAN SHIPBUILDING IND CO LTD	36	0,9%	China
MITSUBISHI HEAVY IND CO LTD	36	0,9%	Japón; OMPI
THE BOEING COMPANY	35	0,9%	Estados Unidos
DAEWOO SHIPBUILDING&MARINE ENG CO LTD	32	0,8%	Rep. Corea
STX OFFSHORE&SHIPBUILDING CO LTD	32	0,8%	Rep. Corea; Francia; China
NITTETSU JUKIN YOSETSU KOGYO KK	26	0,7%	Japón
BASF SE	25	0,7%	OMPI; Alemania; OEP
CHENGXI SHIPYARD CO LTD	22	0,6%	China
AVIATION MATERIALS RES INST	22	0,6%	Rusia
JFE STEEL CORP	21	0,6%	Japón; OMPI
UNIV ZHEJIANG OCEAN	21	0,6%	China
HUDONG ZHONGHUA SHIPBUILDING GROUP CO LT	20	0,5%	China
NANJING IRON&STEEL CO LTD	19	0,5%	China
SUNBIRD YACHT MFR CO LTD	18	0,5%	China
TOTAL	**566***	**15%**	

Source: Own generation based on patent databases

Note (*) Some of these companies can perform their innovations with other companies. Thus one can belong to several patent applicants.

The table also indicates that the protection strategy is eminently national, that means that

the main applicants protect their inventions through their national patent and trademark offices.

It is interesting to note that while Japanese companies are also interested in extending their inventions internationally to markets like the American one, Korean companies like **HYUNDAI HEAVY IND CO LTD**, **SAMSUNG HEAVY IND CO LTD** or **DAEWOO SHIPBUILDING & MARINE ENG CO LTD** or the Chinese **DALIAN SHIPBUILDING IND CO LTD** and **CHENGXI SHIPYARD CO LTD**, protected only with a view focused on their local market.

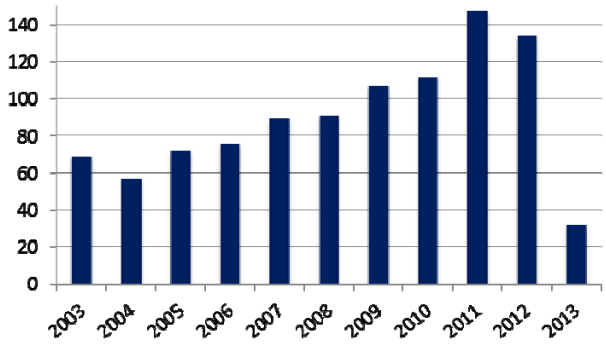
Beetween the main competitors of the top companies are **POSCO**, **MITSUBISHI HEAVY INDUSTRIES**, **KOBE STEEL** and **JFE STEEL CORP**.

3. Analysis of Scientific Publications

Regarding to the literature, It has been used a search strategy similar to that employed with patents in order to identify those scientific papers published since 2003 and related with new construction materials in the naval industry.

Some simple conclusions could be recoverd from the 988 scientific publications, such as the evolution of publications. In this case the following figure shows a continuous and constant growing trend throughout the past decade, with an average of 100 science publications.

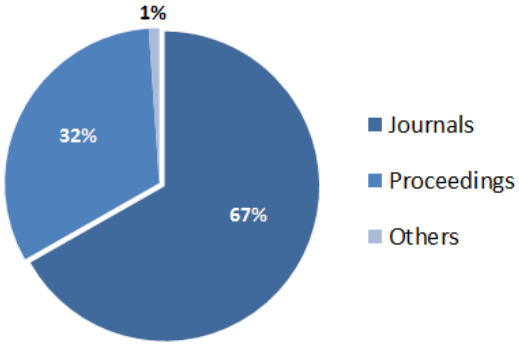
The trend is similar to the innovations protected by patents (see section 2.1. *Technological Evolution*), which reinforces the idea that the technology under study is in a development stage and It is also introduced in the market with a substantial business sector that protects its innovations by intellectual property mechanisms, and also a research core focused on basic research of new materials, which reports its result in spezialized scientific journals.



Source: Own generation based on scientific publications databases

Figure 5. Evolution of scitntific publications

In this sense, regarding the distribution of scientific publications by document type, Figure 6 shows that journal articles are the first source of broadcasting the studies in the area, representing two-thirds of the total scientific documents published. As a second type appear articles the congresses and conferences representing a 32%, while the remaining 1% corresponds to books and news.



Source: Own generation based on scientific publications databases

Figure 6. Publications type

Table 6 shows the main sources of information (those in which they have presented more than 8 scientific publications, which represents a 27% of all publications), ie journals, congresses, con-

ferences, yearbooks or symposia which have been published from 2003 to the present.

Table 6. Main Sources

Source	Total
COMPOSITE STRUCTURES	32
ADVANCED MATERIALS RESEARCH	27
KEY ENGINEERING MATERIALS	26
INTERNATIONAL OFFSHORE AND POLAR ENGINEERING CONFERENCE PROCEEDINGS	19
MATERIALS SCIENCE FORUM	19
APPLIED MECHANICS AND MATERIALS	16
COMPOSITES PART A APPLIED SCIENCE AND MANUFACTURING	14
MATERIALS DESIGN	13
CORROSION	12
COMPOSITES SCIENCE AND TECHNOLOGY	11
BIOFOULING	9
COMPOSITES PART B ENGINEERING	9
JOURNAL OF REINFORCED PLASTICS AND COMPOSITES	9
MATERIALS SCIENCE AND ENGINEERING A STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING	9
POLISH MARITIME RESEARCH	9
ACTA METALLURGICA SINICA	8
APPLIED COMPOSITE MATERIALS	8
MARINE STRUCTURES	8
PROCEEDINGS OF THE SOCIETY OF PHOTO OPTICAL INSTRUMENTATION ENGINEERS SPIE	8
Total	**266**

Source: Own generation based on scientific publications databases

More than half of the scientific articles are retrieved in the environment of science and engineering of materials, particularly in the area of composites and polymeric compounds, metallurgy and chemical. Thus, the journals with more publications in the area are **COMPOSITE STRUCTURES**, **ADVANCED MATERIALS RESEARCH** and **KEY ENGINEERING MATERIALS**, which account a 9% of total scientific publications.

In addition, the list also collected journals directly applied to shipbuilding such as **POLISH MARITIME RESEARCH** or **MARINE STRUCTURES**.

Regarding publishing entities, universities and research centers concentrate the 90% of the publications, followed by companies with the remaining 10%.

Among the companies that have disclosed their research activity through scientific publications are: **POSCO** (8 publications) and **SAMSUNG HEAVY IND** (6 posts), which are also on the list of top patent applicants (Table 5).

Finally, the following table lists the main entities that have published in specialized journals in the technological area of interest, i. e. **Indian Inst Technol**, **Pusan Natl Univ**, **Univ Newcastle**, and **Mokpo Maritime Univ**.

Tabla 7. Top Entities

Entities	Total
INDIAN INST TECHNOL	19
PUSAN NATL UNIV	17
UNIV NEWCASTLE	16
MOKPO MARITIME UNIV	15
HARBIN ENGN UNIV	14
UNIV SOUTHAMPTON	12
RMIT UNIV	11
IFREMER	10
KOREA ADV INST SCI TECHNOL	10
LEHIGH UNIV	9
NATL TECH UNIV ATHENS	9
UNIV BIRMINGHAM	9
DEF SCI TECHNOL ORG	8
NORTHWESTERN UNIV	8
POSCO	8
UNIV TECN LISBOA	8
total	**183**

Source: Own generation based on scientific publications databases

4. Bibliographic References

To complement the results of the searches, additional information is provided concerning the top companies in the area. In this section we attach a brief summary of the company and relevant data that may be of interest.

4.1. NIPPON STEEL & SUMITOMO METAL

Nippon Steel Corporation
Marunouchi Park Building
6-1 Marunouchi 2-chome
Chiyoda ku
Tokyo 100 8071
JPN
T: 81 3 6867 4111
www.nssmc.com

NIPPON STEEL is one of the largest steel makers in the world. The company is engaged in steel making and fabrication, engineering and construction, chemicals, new materials, system solutions, and urban development businesses. Nippon Steel operates in Japan. It is headquartered in Tokyo, Japan and employed 59,183 people as of March 2011.

The company recorded revenues of JPY4,109,774 million ($48,084.4 million) in the financial year ended March 2011 (FY2011), an increase of 17.8% over FY2010. The operating profit of the company was JPY165,605 million ($1,937.6 million) in FY2011, compared with an operating profit of JPY32,005 million ($374.5 million) in FY2010. The net profit was JPY93,199 million ($1,090.4 million) in FY2011, compared with a net loss of JPY11,529 million ($134.9 million) in FY2010.

On October 1, 2012, Nippon Steel formally merged with Sumitomo Metal Industries at a ratio of 0.735 Nippon Steel shares per Sumitomo Metal share. The merged stock is listed (under number 5401, the old Nippon Steel number) as Nippon Steel & Sumitomo Metal Corp. The logistics branches of both companies are announced to be merged on April 1, 2013, under the name "Nippon Steel & Sumikin Logistics Co., Ltd.", wholly owned by Nippon Steel & Sumitomo Metal Corporation. The merged company plans to publish a common fact book in summer of 2013.

4.2. KAWASAKI HEAVY IND LTD

1-14-5, Kaigan
Minato-ku
Tokyo 105-8315
JPN
T: 81 3 3435 2111
www.khi.co.jp

Kawasaki Heavy Industries, Ltd. (KHI or "the group") is a manufacturer of transportation equipment and industrial goods. The group is engaged in the production of ships, rolling stock, aircraft and jet engines, gas turbine power generators, environmental and industrial plants, as well as consumer products and a range of manufacturing equipment and systems. It primarily operates in Japan, the US and other parts of Asia. The group is headquartered in Tokyo, Japan and employed about 33,267 people as on March 31, 2012.

The group recorded revenues of JPY1,303,778 million ($16,558 million) during the financial year ended March 2012 (FY2012), an increase of 6.3% over FY2011. The operating profit of the group was JPY57,484 million ($730 million) during FY2012, an increase of 34.9% over FY2011. The net profit was JPY23,323 million ($296.2 million) in FY2012, a decrease of 10.2% as compared to FY2011.

4.3. KOBE STEEL CORP

Shinko Building
10-26 Wakinohamacho 2 chome
Chuo ku
Kobe
Hyogo 651 8585
JPN
T: 81 78 261 5111
www.kobelco.co.jp

Kobe Steel, Ltd. is a manufacturer of steel, as well as a supplier of aluminum and copper products. It is also engaged in wholesale power supply, machinery, construction machinery, real estate, and electronic materials and other businesses. The company operates in Japan, the Americas, Asia, and Europe. It is headquartered in Hyogo, Japan and employed 35,496 people as on March 31, 2012.

The company recorded revenues of JPY1,864,691 million ($23,625.6 million) during the financial year ended March 2012 (FY2012), an increase of 0.3% over FY2011. The operating profit was JPY60,555 million ($767.2 million) during FY2012, a decrease of 51.4% compared to FY2011. The net loss was JPY14,248 million ($180.5 million) in FY2012, compared to a net profit of JPY52,940 million ($670.7 million) in FY2011.

4.4. HYUNDAI HEAVY IND CO LTD

Suite 1 Jeonha-dong
Dong-gu
Ulsan 682 792
KOR
T: 82 2 746 4603
www.hyundaiheavy.co

Hyundai Heavy Industries Co., Ltd. (HHI or "the company") is one of the largest heavy industries company and one of the leading shipbuilders in the world. The company is also engaged in other businesses, including oil refining, construction equipment, offshore and engineering, engine and machinery, industrial plant and engineering, electro electric systems, financial services and green energy. The company has operations in the Americas, Europe, Asia, Middle East and Africa. It is headquartered in Ulsan, South Korea and employs 24,948 people.

The company recorded revenues of KRW53,711,665.8 million ($48,877.6 million) during the financial year ended December 2011 (FY2011), an increase of 43.8% over FY2010. The operating profit of the company was KRW4,535,738.7 million ($4,127.5 million) in FY2011, a decrease of 18% compared to FY2010. Its net profit was KRW2,559,005.8 million ($2,328.7 million) in FY2011, a decrease of 38.4% compared to FY2010.

4.5. POSCO

1 Goedong-dong
Nam-Gu
Pohang City
Gyeongsangbuk-do
KOR
www.posco.com

POSCO is engaged in the manufacture and sale of steel products, including hot rolled and cold rolled products, plates, wire rods, silicon steel sheets, and stainless steel products. The company operates in South Korea, Japan, China, North America, and other parts of the Asia-Pacific region. It is headquartered in Seoul, South Korea and employed 34,936 people as on December 31, 2011.

The company recorded revenues of KRW68,938,725 million ($62,734.2 million) during the financial year ended December 2011 (FY2011), an increase of 44% over FY2010. The operating profit was KRW5,408,102 million ($4,921.4 million) during FY2011, a decrease of

0.5% compared to FY2010. The net profit was KRW3,648,136 million ($3,319.8 million) in FY2011, a decrease of 11.1% compared to FY2010.

4.6. TORAY IND INC

Nihonbashi Mitsui Tower
1-1 Nihonbashi Muromachi 2-chome
Chuo ku
Tokyo 103 8666
JPN
T: 81 3 3245 5111
F: 81 3 3245 5054
www.toray.com

Toray Industries is engaged in manufacturing, processing and selling chemical products worldwide. The group primarily operates in Asia, North America and Europe. It is headquartered in Tokyo, Japan, and employed 40,227 people as of March 31, 2012.

The group recorded revenues of JPY1,588,604 million ($20,175.3 million) during the financial year ended March 2012 (FY2012), an increase of 3.2% over FY2011. The operating profit of the group was JPY107,721 million ($1,368.1 million) during FY2012, an increase of 7.6% over FY2011. The net profit was JPY64,218 million ($815.6 million) in FY2012, an increase of 10.9% over FY2011.

4.7. SAMSUNG HEAVY IND CO LTD

Samsung Life Insurance Seocho Tower
1321-15
Seocho-Dong
Seocho-Gu
Seoul 137 955
KOR
T: 82 2 3458 7000
www.shi.samsung.co.kr

Samsung Heavy Industries (SHI) is a shipbuilding and offshore company. It develops ships for polar applications, Arctic ice-breaker container ships, Arctic shuttle tankers, LNG carriers, ultra-large container ships and passenger ships. SHI is also engaged in the construction of premium office buildings. The company operates in the US, Asia and Europe. It is headquartered in Seoul, South Korea, and employs around 13,185 people.

The company recorded revenues of KRW13,358,610.8 million (approximately $12,156.3 million) in the fiscal year ended December 2011, an increase of 2.2% over 2010. The company's operating profit was KRW1,101,701.9 million (approximately $1,002.5 million) in fiscal 2011, a decrease of 20% compared to 2010. Its net profit was KRW863,934.1 million (approximately $786.2 million) in fiscal 2011, a decrease of 11.5% compared to 2010.

4.8. DALIAN SHIPBUILDING IND CO LTD

Number 72 Kunminghu Nan Lu
Haidian District
Beijing 100097
CHN
T: 86 10 8859 8000
F: 86 10 8859 9000
www.csic.com.cn

Dalian Shipbuilding Industry Company located in Dalian, Liaoning, China, is the largest shipbuilding company in China. It is part **of China Shipbuilding Industry Corporation** (CSIC), one of the two state-owned shipbuilding enterprises in China.

China Shipbuilding Industry Corporation (CSIC) is a state-owned enterprise group engaged in shipbuilding and ship repairing. The group's business operations include asset management for the group and its subsidiaries; domestic and overseas investment and financing; researching, developing and producing military products such as naval ships; designing, building and repairing

merchant ships; and designing and manufacturing marine equipment and non-marine products for domestic and overseas markets. CSIC is also involved in turnkey project contracting and labour supply; manufacturing products under overseas licences and technology transfer agreements; and carrying out other businesses under the state authorization and appointment. The group primarily operates in China, where it is headquartered in Beijing and employs around 140,000 people.

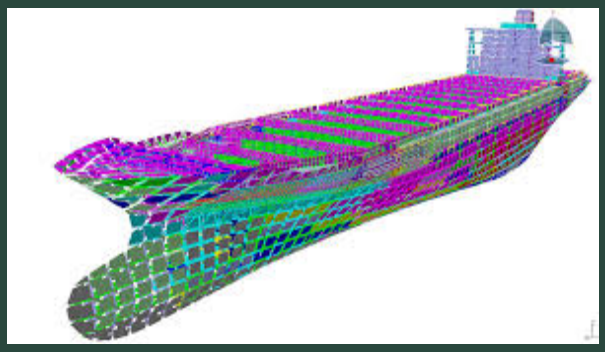
As a privately held group, China Shipbuilding Industry Corporation is not obliged to release its financials.

5. Disclaimer

International Patent Classification is made according to objective criteria. However, the interpretation of these documents always involves a degree of subjectivity, due to the fact that the classification is made by different examiners, from different technical sectors and countries of origin (and, therefore, different languages), and therefore that leaves certain limits to subjectivity and interpretation of some concepts. Therefore, it should always keep in mind that we have to accept a margin of error.

During the investigations, the only files (either patents or utility models) that can be detected are those that have already been published. In Spain (as in most countries), the utility model applications are not published until at least 6 months from the date of application, and patents to a minimum of 18 months from the date of application. Therefore, the utility model applications filed in the last 6 months and the patent of the last 18 months are not "detected" during investigations. In some countries, patent applications are not published until they are granted, so that in such cases, the period during which they are not detectable is 2-3 years or more. In other countries such as Italy (and some Latin American countries), there is an enormous delay in the Patent Office and this process could take several years. Either way, it should be noted that patent applications are not published, in most cases, even after 18 months from the filing date or priority date (if claimed).

On the other hand, it is desirable to indicate that many companies do not apply for patents and / or utility models using their name, but using other companies or individuals to make the applications.



Shipbuilding Materials

TECHNOLOGY SURVEILLANCE REPORT