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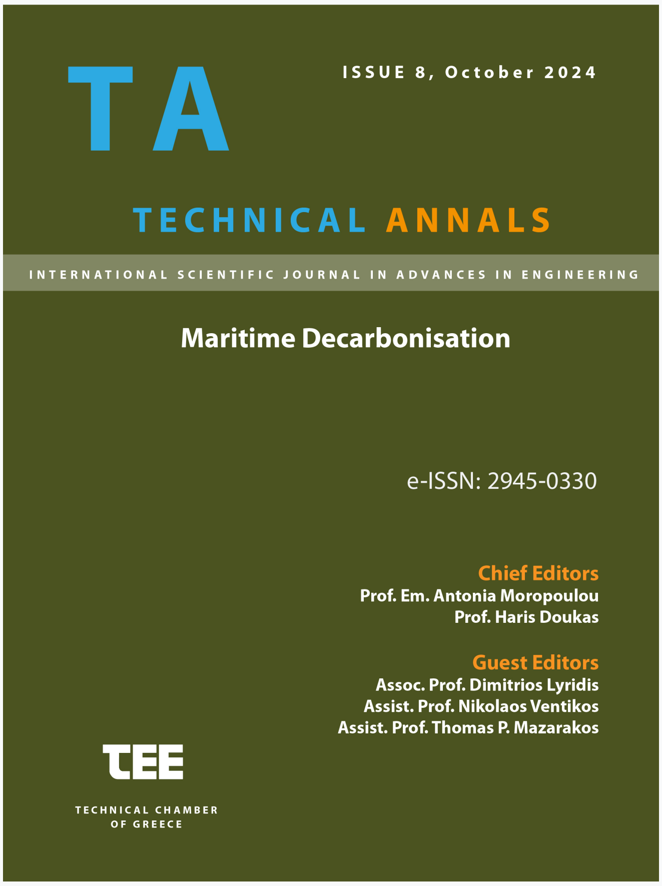

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Tracing Greek traditional shipbuilding evolution, characteristic features and typologies in order to preserve naval architecture & traditional shipbuilding

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Tracing Greek traditional shipbuilding evolution, characteristic features and typologies in order to preserve naval architecture & traditional shipbuilding

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Abstract. The Greek shipbuilding and related naval architecture and techniques present a unique and uninterrupted journey and experience from the antiquity till today. Characteristic shipbuilding typologies, materials and techniques are classified in three characteristic periods. In antiquity, types of vessels from the Minoan and Cycladic Era mainly represented by the ancient "Triremes". In Byzantine years, the war vessel "Dromon" as an evolution of the ancient Triremes. In following years, up to 19th century, wooden ships prevail in Mediterranean and in the New Continents as war, exploration and commercial transport ships arising from "Karavoskaro" and "Scuna". A decisive turning point in shipbuilding during the Industrial Age is still exploring the Greek shipbuilding art, providing evidence for the preservation of traditional shipbuilding and naval architecture.

Keywords: Shipbuilding Evolution, Traditional Shipbuilding, Naval Heritage

1 Introduction

Traditional shipbuilding (or Wooden Shipbuilding) is the handicraft construction of a vessel from natural wood (conception, design, construction, equipment, decoration). It is an important living traditional art, one of the leading expressions of technical culture in maritime societies, framed by diverse cultural practices and perceptions. The Craft of wooden shipbuilding was developed in all the Greek seas and all historical periods and is deeply rooted in the traditions of our people - especially the islanders and the inhabitants of the coastal mainland area. Its importance over time is great in the development of trade, the economy of our country, and the development of Greek shipping. Correspondingly, its importance for History and the flourishing of Greek Culture. The Craft of traditional shipbuilding has been included in the National Inventory of Intangible Cultural Heritage of the Ministry of Culture since 2013 [1-3].

2 Shipbuilding and navigation in the prehistoric Aegean

Sea voyages in Greece and probably in the whole world started from the Aegean, in prehistoric times. The transport of products presupposes some form of shipbuilding and navigation since the Mesolithic era. Tools and weapons of that period, dated around the year 8000 BC., consisting of an obsidian stone from the island of Milos, were discovered in the Fraghthi cave in Argolis (eastern coast of the Peloponnese) and the cave of Cyclops (Jura island in the Northern Sporades). These archaeological findings – evidence, prove the maritime movement of people as early as the ninth millennium BC. Therefore, it would not be an exaggeration to claim that the first inhabitants, first began to explore the sea and the island system of the Aegean, while they later they engaged in the cultivation of the land and animal husbandry [4].

Wood, which still maintains an inseparable connection with shipping, was the first shipbuilding material used. Its density is lesser than water, and therefore the buoyancy force received by a wooden body exceeds its weight, allowing even very early shipbuilding constructions the ability to sail. Trade and maritime activities on the sea routes of the Mediterranean united the peoples of the Bronze Age (3000-1100 BC), contributing decisively to the rise of the most important ancient Civilizations (Cycladic, Minoan, Mycenaean), which determined the process of world history [5].

Excavation finds prove the high technical level of shipbuilding, at least since the 14th and 13th century BC [5].

During the Archaic and Classical eras and later Roman and Byzantine times, shipbuilding continued to be a supreme expression of technology, whether for peaceful (merchant ships) or war purposes [5].

2.1 Basic construction methods

Until the first Byzantine centuries (4th-9th), shipbuilding was practiced with a different technique than today's wooden shipbuilding, while the production line was also different. Ancient shipbuilding included the construction of the shell as the first stage of shipbuilding (shell first construction), with multiple connections on the shell, and then the introduction of internal reinforcements, which however did not form a single support frame. Testimonies of the transition to medieval shipbuilding, gradually dominating the entire Mediterranean, appear in shipwrecks from the 9th to the 11th century.

The first written shipbuilding manuals, originating from Venice and dating back to the first half of the 15th century, refer exclusively to medieval shipbuilding, known as skeleton-first construction. Traditional woodworking practiced today includes several elements from this medieval technique [5].

2.2 Wooden shipbuilding in Ancient Greece

The main types of shipbuilding timber in ancient Greece were sky-high trees, such as the fir, the pitis vlothri (tall straight pine), the cedar, the cypress, the oak, and the sycamore. The fir, due to its lightness, was mainly used for masts but also for warships where speed and maneuverability were required, such as, for example, triremes. The pine was used in commercial ships because it ensured the necessary strength and durability of the construction over time. Another very important advantage of pines is the resin (the well-known tree resin), which is still used in traditional shipbuilding for waterproofing. The oak was mainly used in the helm, which surrounded the outside of the rudder (pseudo-rudder). The hull had to be made of strong wood to act as a shield in the event of a collision and also to protect against corrosion. Theophrastus explains "*The wood of the oak, if cut at the proper season, does not rot, is largely immune from worms, and its texture is dense and hard as horn*". On the ship of Kyrenia, there is an oak hull [6].

3 Types of ships by historical period

It is conjectured, as there are no historical sources that can substantiate it, that the first floating constructions were single logs from tree trunks, rafts, and ships from reeds.

The Cycladic ships were the first official and historically attested form of shipbuilding craft. They were long narrow structures, with about 15 oars on each side. One end was low and ended in a ledge, while the other end was elevated and adorned with a fish-shaped device, which was either a talisman of the ship and crew, or some early form of wind vane-compass (Fig. 1). However, even today we cannot know with absolute certainty which was the bow and which was the stern. As they reopened to deeper, more remote waters, the Cyclades began to build their ships with pointed rather than flat bottoms. In other words, they invented the oar for safer and more stable sailing in waves and winds [4].

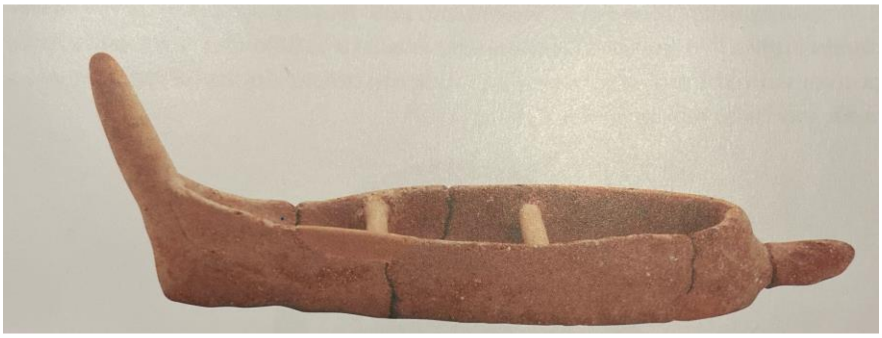

Fig. 1. Clay model of a Cycladic ship, dated 2400-2200 BC. [4, pp. 21]

In the Bronze Age, in the 3rd millennium BC, due to these ships, the Cycladic Civilization developed in the area. This is a period without written sources, which makes it difficult to document how the people lived, which Gods they believed in, and how they organized their society. Keros and Daskalio, two very small islands of the Cyclades, at a very long distance by the standards of that era from the continental area, and forgotten in time until today, are an excellent example of a prehistoric enigma, with countless finds, surprising and exciting cases. In Daskalio, a large settlement of about 13 acres was discovered, which due to the steep terrain was developed on a hill, based on an excellent urban plan, with streets, houses, squares, meeting places, and stairs. This is an example of early urbanization, unprecedented for the time. The main building material was marble, not from Keros, as it was considered of poor quality, but from Naxos, six nautical miles away. Tons of marble were transported by rowboats, through an arduous, monumental undertaking that required resources, strategy, and manpower. The most special finds of Daskalio include the -countless- pebbles that were found in a 15-meter-long building. At the same time that traces of an organized settlement emerge in Daskalio, Keros reveals its strange treasures. In Kavos, opposite the entrance of Daskalio, two depositories were identified, the northern and the southern, in which large quantities of broken figurines and ceramics were found. Through analysis of the construction material, it was revealed that the objects did not come from Keros, but from neighboring islands: Naxos-Ios-Amorgos (the so-called "trigon of Keros"), Milos, Thira, Tinos, and others. The prevailing theory today states that the prehistoric Cyclades broke the figurines in various Cycladic islands, put them in wooden - probably – baskets, and transported them to the Keros depositors. This is because there was a pan-cycladic sanctuary on the island, perhaps the first island sanctuary in the world. According to another theory, which nowadays has been put aside, the broken figurines of Keros were placed there due to the existence of a cemetery. Some of the most interesting finds identified during the excavations were the bellows and the dies of metallurgical objects. Prehistoric Keros is considered a center of metallurgy, a very important fact, since during the Bronze Age metallurgy was extremely important for the flourishing of Civilization. Keros and Daskalio had no ores, meaning that the metals were imported from other islands such as Kythnos and Serifos, and processed here. The Cycladic ships therefore allowed Keros and Daskalio, joined by an isthmus in the Bronze Age, to be a pan-Cycladic religious, cultural, craft, and commercial center of that time [7-10].

The Cycladic civilization (Fig. 2) was gradually succeeded by the maritime empire of the Minoans. In Minoan ships (Fig. 3), which were originally built like the Cycladic ones, both ends were raised and a center sail was placed to harness the propulsion power of the oars and the power of the wind [4].

Fig. 2. Convoy frescoes of 1550 BC [4, pp. 27]

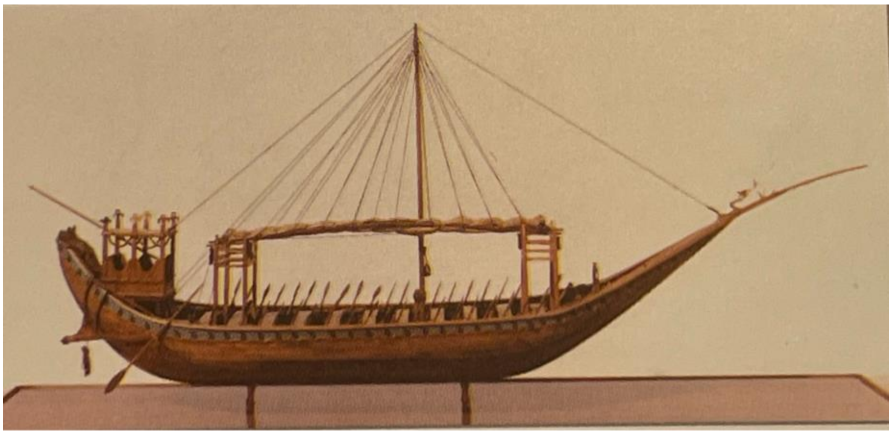

Fig. 3. Model of a typical Minoan ship [4, pp.27]

With these ships the Minoans traveled throughout the eastern Mediterranean but also in the west, reaching the Iberian Peninsula, establishing colonies and trading posts. Maritime trade mainly with Egypt, Cyprus, and Syria brought great wealth to Crete, with which splendid palaces, aqueducts, and port facilities were built. Because of their significant contribution to the prosperity and well-being of the island, shipowners held prominent positions in Minoan society [4]. Shipping had such an important place in the life of Minoan Crete (see Fig. 4) that their ships ended up being works of art [4].

Fig. 4. Ship of Thera during the heyday of the Minoan Civilization [11, pp. 61]

About the year 1500 BC, the Minoan world was shaken by devastating earthquakes and tidal waves that followed the terrible eruption of the volcano of Thera, which is only 65 nautical miles from the coast of Crete. The Achaeans, who had been deeply influenced by the Minoan Civilization, benefiting from the weakening of the Minoans, succeeded them as a naval power in the eastern Mediterranean. In the years of the early geometric period, a new type of ship was introduced, the pentacontor (Fig. 5), so named because it had 50 oars [4], [6], [11].

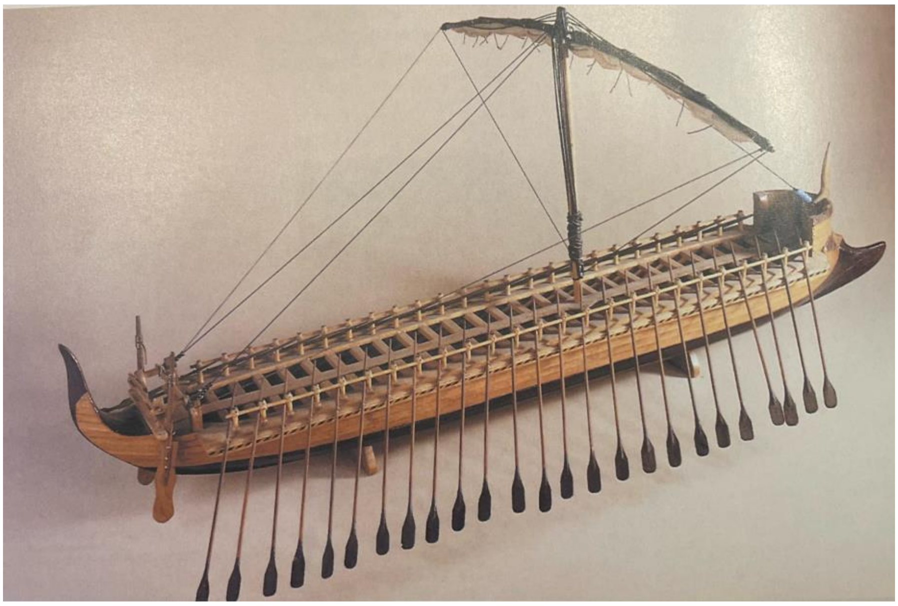

Fig. 5. Pentacontor [4, pp. 28]

This impressive schooner was the main ship of the Trojan War, as mentioned in the Homeric epics. Pentacontorus was also the ship of the Argonautic Campaign (Fig. 6), which according to the legend was made of pines of Pelion and was so light that Jason and his companions could carry it on their shoulders whenever they needed to cross land [4].

Fig. 6. Argo [4, pp. 30]

In the 7th century BC, the masterpiece of ancient Greek shipbuilding, the Athenian trireme (Fig. 7), appears in the foreground. A long, narrow, low-rise warship was 35 meters long and 5 meters wide, so named because her 170 oars were in 3 tiers. On the lowest level rowed 54 thalamites, on the middle 54 zygites, and the highest 62 thranites.

The ship also had two auxiliary rectangular sails, one small and one large, which were used when the ship was traveling and not during battle. In the bow they had a piston, first of brass and then of iron, which allowed them to pierce the hull of enemy ships, causing them to sink [4], [6].

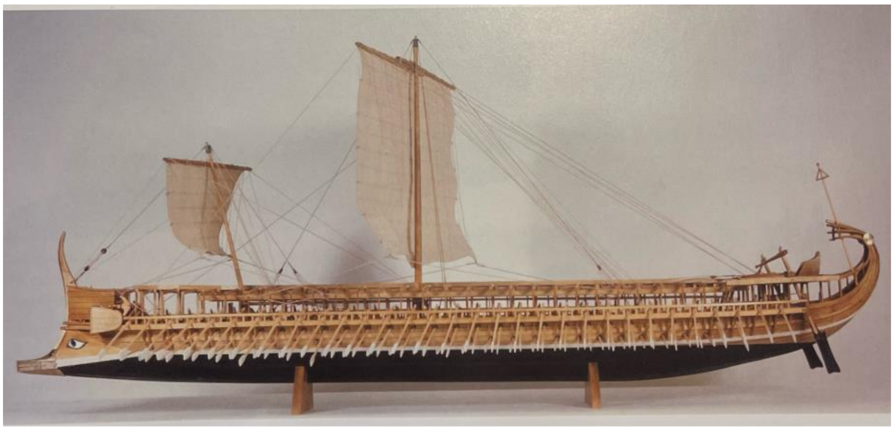

Fig. 7. The Athenian Trireme [4, pp. 53]

The speed, seaworthiness, and exceptional maneuvering ability of these ships led the Greek fleet to the great victory over the Persian Empire, in the Naval Battle of Salamis. The triremes made Athens a symbol of naval power with an invincible fleet. Athens was filled with wealth, arts and culture flourished, leading to the Golden Age: The century of Pericles, founder of the Athenian Republic [4].

During the years of Alexander the Great, in addition to the triremes that led the war conflicts, we have the appearance, for the first time in history, of a ship with sheer [5].

The ship of Kyrenia (Fig. 8), with a shape optimized for Mediterranean conditions, was seaworthy and capable of carrying goods, was 14.3 meters long, 4.5 meters wide and is a forerunner of today's boats. It is confirmed by archaeologists that the Kyrene ship, which was found off the coast of Northern Cyprus in 1967, traveled for about 80 years before it was sunk by pirates. From this fact, and with the utilization of today's knowledge and technology, the lifespan that a wooden boat can have can be concluded [6].

Fig. 8. The ship of Kyrenia [4, pp.68]

In the Hellenistic era larger and larger ships began to be built, four-remes, five-remes, and even four hundred-remes, able to feed the ambitions of the rulers in volume and imposingness. These ships were called super galleys and were flagships of the fleet [4].

Over the years, we pass from Roman rule to Byzantium. Maintaining order and securing the borders of the vast Empire required Byzantium to develop into a maritime power. The Byzantine dromon (Fig. 9), the core of the Imperial fleet, decorated with representations of fish and painted in the characteristic purple color, was equipped with crossbows, catapults, and a secret weapon, “liquid fire” [4].

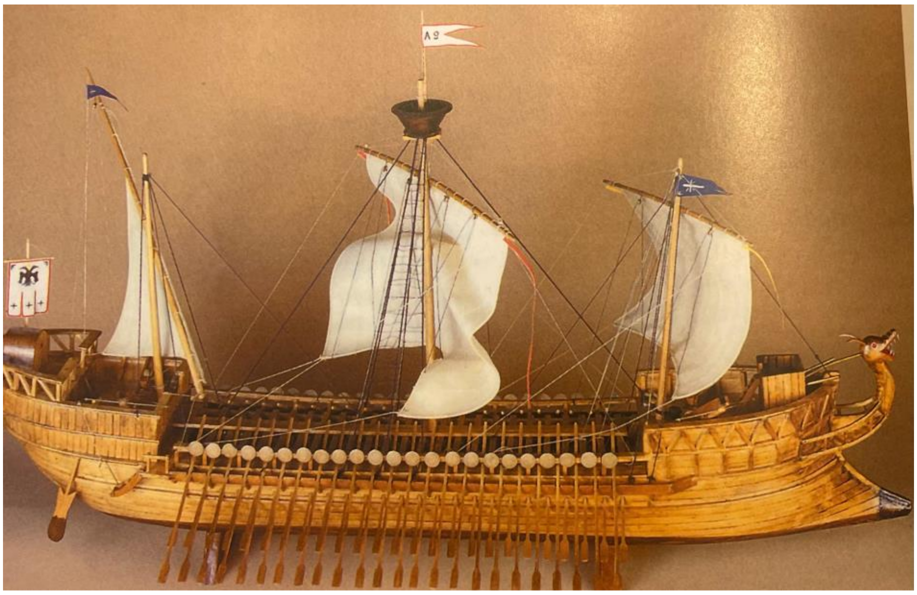

Fig. 9. Byzantium Dromonas [4, pp. 90]

During the period of Ottoman rule, the Greeks pioneered the sea, both in trade and in shipbuilding. About 3000 caulkers and shipwrights, unrivaled in their craft, worked in the shipyards in Constantinople. Despite slavery, Greek sailors never stopped building magnificent wooden ships and resisting Ottoman rule. Treadmills, boats for trade and fishing, galleys for the pirates, corvettes, and frigates for the corsairs, pollacks, brigs, barques, barquettes, liberties, corvettes, schooners [4].

The schooner (Fig. 10) is so far the most advanced design type of dikaart and above, wooden sailing ship, which combines seaworthiness with the comfort of the passengers and at the same time sailing speed, even in the most turbulent wave and wind conditions. Schooners consist of two or more masts. Characteristic of their sailing, is the lack of crucifixion, while in addition to the jibs, each mast carries a boom sail or otherwise an epidromous (trapezoidal type of sail). Hence the original name of these ships was "*epidromeis"* [11].

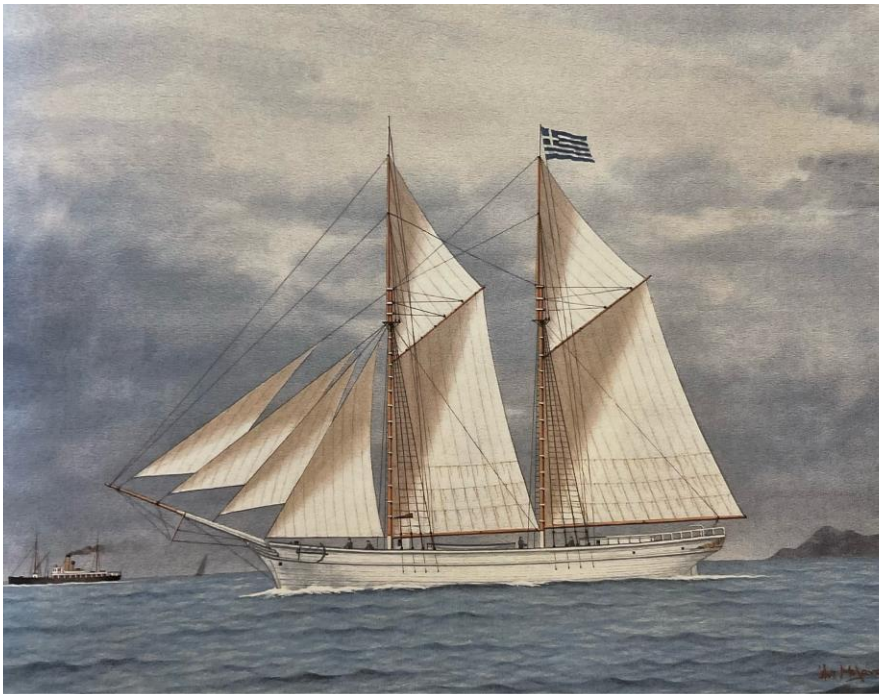

Fig. 10. Greek schooner engraving [11, pp. 89]

Until the middle of the 18th century, Greek shipbuilders built small mainly private boats due to economic and political constraints. This situation began to change in the second half of the 18th century, due to the development of commercial shipping which gave an impressive boost to shipbuilding. First in the Ionian and subsequently in the Aegean, shipbuilding centers developed and local fleets of merchant ships were formed, initially active in the Eastern Mediterranean and the Black Sea, then expanding their routes to wider maritime trade routes [1], [5], [6].

In the last quarter of the 18th century a series of changes in the regime of trade in the Eastern Mediterranean provided the possibility for the development of Greek merchant shipping under foreign flags (mainly Russian). Until the end of this century, shipbuilding was one of the most important technical activities of the enslaved islanders. These developments, combined with the local lifting of the restrictive measures for the construction of large ships, provided a boost to the shipbuilding activity and contributed to its modernization with the introduction of new methods which are still applied today [6].

The most important of these innovations was the introduction of the lofting floor (sala), on which the shipbuilder drew the profiles of the main pieces of a vessel's frame. Based on these profiles, tracks were cut, which were used as guides on the wood, from which the corresponding pieces of the frame would emerge. The sala method eventually replaced the older moulding methods (especially monochnaro) in various Aegean and Ionian shipyards. This development made it possible to build larger ships with better symmetry in their shape, while the typology of commercial ships was also enriched with new designs. Even today, the use of the sala method is considered the most advanced design method in traditional Greek wood yards. However, the older moulding methods were not abandoned and are still applied in the construction of small boats [5].

In the 19th century, shipbuilding was one of the main technical productive activities of the new Greek state. During this period there are shipyards on several islands and coastal areas. Syros was the largest shipbuilding center, followed by Galaxidi, Spetses, Hydra, Piraeus, Skiathos, Skopelos, and other smaller islands and coastal areas. Numerous sailing ships of the Aegean were then anchored in the tarsanades of the Archipelago. Dozens of ships were built each year, some of them large, with three masts, such as ships, barges, and barcombes, and other smaller ones with two masts, such as brigs, schooners, and bobbers. They were built with ease, in almost every place, by the experienced shipbuilders of the Aegean and Ionian [5], [12].

The kerestes, the shipbuilding timber, came from the forests of Greece or was imported from other Balkan countries. It was transported first by animals to the nearest sea or rivers and from there by ships in the skera (the lumberyards) of islands and coastal areas. Nails, maps, rigging, and other hardware were made in the “gyftaria” (the smithies), which were always present next to the tarsanas. A series from other professions, caulkers, ropemakers, sailmakers, riggers, and others, worked side by side to complete the building and rigging of a sailing ship. The money for the orders usually came from merchants and pirates who reinvested in shipping, an activity they knew well, was lucrative and mainly relied on the supply of skilled islanders in the professions of the sea. At that time shipbuilding is going through a period of great prosperity. It was perhaps the most important construction industry in the coastal Greek regions, liberated or not [1], [2], [5], [12].

So, during the years of the Revolution, the Greeks have a significant number of merchant ships. Several of their ships take part in the struggle for liberation and with rudimentary conversions they become armed, and they form the revolutionary fleet. They clashed with the Ottoman and Egyptian ships with significant losses but also great successes, contributing decisively to the cause of liberation and the creation of the new Greek state. The majority of merchant ships converted into warships during this period were brigs or barges. They were fast sailing ships with two masts and many sails. These ships played a catalytic role in the Revolution of 1821 and in the success of the national liberation struggle [5], [12].

Towards the end of the 19th and the beginning of the 20th century, the building of large wooden ships declines, mainly due to the appearance of steamships and iron ships. Throughout the 20th century, fishing boats remain the main products of the timber yards. The adaptation of production to the demands of fishing was reversed at the end of the 1980s, after the implementation of the Regulation of the European Community for the reduction of the fishing fleet. Also, in the framework of the Community fisheries policies, unique examples of the Greek shipbuilding tradition were destroyed, without regard for their cultural value, causing a serious blow to the stock of maritime cultural heritage [1], [2], [5], [12].

During the first decade of the 21st century, the downsizing and subsidized destruction of fishing vessels continued. The art of wooden boat building in Greece faces the risk of extinction for the first time as new problems are added. New materials such as steel, aluminum, and composites give new properties for high-performance boats in terms of speed and the transport of large loads, with lower delivery times due to industrialized processes.

However, it is worth emphasizing at this point that wooden boats, built and maintained according to the specifications, have a lifespan of at least 100 years, twice the 50 years of an iron one. In addition, wood is an ecological, recyclable, sustainable material. Lovers of the sea, for whom the journey is important, choose wooden boats and not only for their beauty. The connection of the wood with the sea offers unrivaled sailing even in the most difficult conditions.

4 Shipbuilding timber - Types, Properties, Characteristics

The shapes and properties that shipbuilding timber must have, the method and time of cutting the timber, its treatment after cutting, and the preparation of the timber before construction, constitute knowledge derived from earlier times. Shipbuilders know from their tradition and experience the static and dynamic stresses that the boat they are building will endure, as well as the life cycle of the wood they use, and they adjust the construction's cross-sections and connections accordingly.

More specifically, the art of ship carpentry involves the search for suitable trees for the construction of the ship. The shipwright and lumberjack know the characteristics and different qualities of shipbuilding lumber species (pine, oak, cypress, elm, mulberry, eucalyptus, holly), as well as the differences that characterize hybrids of the same tree (e.g., the differences between trachea, halepium, and other pine hybrids). Suitable wood is found in the forest before logging. Mechanical interventions have even been recorded on the trees (mainly by hanging weights or exerting traction forces through ropes) several years before they were cut, to obtain the natural curves necessary for shipbuilding. The ship carpenter also knows that in dense forests the trees, tending to find the light, grow in height and consequently give trunks without branches, of great length, straight and without rosettes. The strongest wood is that which has no rosettes and is smooth. He also gives great importance to the resin content of the wood and the smooth configuration of the wood fibers. He also knows how much abiotic factors influence the conditions in which trees grow, such as orientation, sunlight, humidity, and even geological conditions. North-facing trees are usually more suitable. We notice in the same tree, the wood of the northern side that it is denser and more robust. In general, wood from wet, sheltered, and deeply shaded areas is inferior for both woodworking and burning. This extraordinary coincidence (which is scientifically explained because the stronger-dense-robust-dry wood is also thermodynamically superior for the combustion reaction) explains the fact that while we had selective logging by the ship carpenters, the terrible fires were also absent from our forests. Without controlled selective logging, the forest is more vulnerable to fires. Also, apart from the size of a tree, its age plays a role as it must be at its prime. Very young trees provide very watery wood, while very earthy and very old trees. In addition, the season of logging is of great importance, both for the reproduction of the forest and for the required result. When cutting the wood, the appropriate shapes must be ensured that correspond to specific structural elements of a boat's frame [1], [2], [5].

This is followed by proper drying after cutting, proper processing to cut the lumber, and dealing with the rot problem. To become invulnerable, the logs must be immersed in salt water and tilted. Their required exposure time varies, depending on the type of tree they come from.

In recent years there has been talk of plasticizing wooden boats. But this poses risks for the wood, as in cases of trapped moisture or some minor failure it will not be able to dry and will rot. Wood is noble and alive, it must breathe and cool, become one with water and cooperate with it.

In addition to wood, shipbuilders use and process other natural materials, such as metals (iron, copper, galvanized iron), derivatives of plant materials (tar, resin, ropes, hemp, linen cloth), and animal materials (animal fat).

The boats and the techniques they use for their construction are in direct relation to the environment in which they will travel. Boats for the sea have great differences (typology, shape and construction) from boats for lakes, rivers or lagoons. These differences come largely from the knowledge of local conditions (environment, raw materials, local differences in use).

5 Vessel typology

The wooden boats manufactured in the Greek shipyards have special typological and morphological characteristics. There are several names from types or from kinds of boats that are separate constructions. We distinguish two basic typologies, in terms of the shape of the hull and in terms of the type of rigging. The most famous and characteristic hull types that have been saved in vessels of the Greek seas are: the trechantiri, the gajao, the botis, the cherniki, the perama, the trata (rower), the varkalas, the hydraikos varkalas, the Chanio pike, the caravoskaro and the liberty. Some of these types are now extremely rare and are no longer manufactured, such as the gajao, cherniki, perama and trata. Other types that are still manufactured today are based on their older form, such as the trechantiri and the liberty. Others are also still being manufactured but with variations on their older form, such as the botis, the barkalas, the Hydraic barkalas and the Chanio gaita. There were even older types of hulls that were built in certain regions or islands for specific uses. An eloquent example is the Symi boat, a sponge boat that was mainly built in Symi. Another example, less known, is the chiliotissa, a type of fishing boat built in Nea Chili (Alexandroupoli area) by the refugees from Chili of the Black Sea [1], [2], [4], [5], [11], [12].

For sailing ships, there was also typological differentiation based on sailing structure. Except for of small boats, on all other vessels, the sails involved a set of sails in a particular combination, which usually characterized the type of sail. For example, in the 19th century brigs and schooners were types of sailing that, although carrying the same types of sails, differed in both the different number of sails and their combination. The types of individual sails were distinguished, in terms of their shape, into basic ones, such as the Latin, the jib, the mat, the boom (rada) and the square sail (cross), and into auxiliary ones, which were usually triangular (various types of jibs and staysails) or square. Sailboats, now studied mainly from old photographs and oral accounts, had a wide variety with frequent local variations.

Typology in boats, both in terms of hulls and sails, constitutes a complex classification that sometimes has unexpected overlaps or even local differences. A particular example is the name of the knapsack, which in the past sometimes indicated the shape of a specific sail and sometimes the type of sailing vessel (a combination of a main knapsack sail and other auxiliary sails). In addition, the name sakoleva is used to refer to a special type of hull, at least in Chios, Samos and Plomari. Finally, a similar type of hull in the Cyclades, mainly in Mykonos, was called a belou.

Morphological variations existed even between the same type of hull, depending on the local shipbuilding tradition from which it came or the use for which it was intended. For example, the Plomaritic peramas had some morphological features different from the Syriac or Sami ones. Also, fishing trawlers had different geometrical characteristics compared to commercial or sponge trawlers, which were called achtarmades and were built mainly in Kalymnos, Hydra in Piraeus and Symi [1], [2], [5], [12].

6 Parametric design of traditional boats

The emerge and rapid evolution of computing engineering favored the development of parametric design. An object geometry design through a mathematical process which combines a series of initial parameters is often called parametric design. Usually the term "parametric" refers to an activity that is well defined while the term "design" refers to an activity that is unclear or unpredictable. The latter leads to many contradictory problems considering the amphibological state the phrase sets itself [13]. However, when it comes to the engineering design, constructive rules and limitations concerning the sufficient structural strength, the geometry complexity, the structural cost, etc., are usually entered in the initial steps of parametric design with the purpose of eliminating the number of alternative designs and reducing the production and evaluation time.

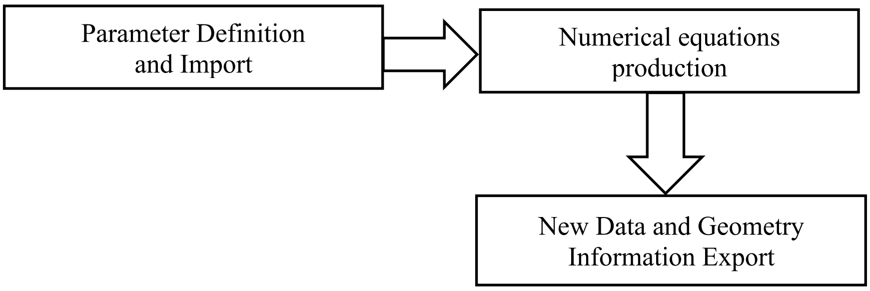

Fig. 11. Parametric design procedure organization

Main steps of parametric design are presented in the above figure (Fig. 11). It seems that one of the crucial steps of parametric design that affects the whole design procedure is the definition of the appropriate parameters. Parameters are divided into two main categories: the “known” and the “unknown” parameters. The “known” parameters related to design requirements and limitations while the “unknown” parameters related to the interest of a designer in investigating new folds of a particular design problem. It is a common use, the “unknown” parameters to be turned to “known”, with the aim of an appropriate algorithmic function, only on the condition that one specific parameter is unknown in each design problem. In that case, two additional subcategories are occurred: the “driver” and the “driven” parameters. The “driver” parameter constitute the main parameters by which the other unknown parameters are defined while the “driven” parameters are defined as a logical continuity of the algorithmic function of other unknown parameters.

Parametric design can be occurred through algorithmic functions and digital programs. The main algorithm consists of logical relations and organized processes and leads to different possible designs using different parameters as imported data. Therefore, using different processes and associations the designer can be led to a significant number of possible alternative final forms.

Numerical and logical relations between the parameters define the parametric space which consists of infinity, independent and interactive geometries. The instable parametric relations give entity to the parametric design and the changes between them affect the information environment. The information environment is managed by algorithmic functions, which produce complex structures and forms from mutable possible geometries of a repeatable totality. The production and shape of geometric objects are entirely based on the parameters, while the designer only defines the appropriate algebraic relations and rules, between the parameters and the corresponding geometries that they designate. The range of parametric values and the algorithms used in the design, create a hierarchy of numerical and geometrical relations, thus allowing the production of a particular design, as well as the investigation for alternative designs, based on the range of parametric values.

In 1978, R. Hyllard [14] presented a method that determines the geometric constraints between the coordinates, in a manner consistent with the limitation of possible alternative forms to a range defined by certain tolerances. Based on Hyllard work, Gossard and Light [15] presented their own method which concludes new geometric design techniques and new computational tools, leads to the generalization of a parameterization model. Through the years many researchers have been involved with the parametric design science [16-24]. In the literature [25], two main parametric technique categories are spotted: parametric techniques based on internal model representations and parametric techniques that allow the modification of the model dimensions and the design limitations after the model production.

The extended use of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) programs favored the development of the parametric design according to features. The term “feature” corresponds to an entity that transcends the limits of geometry. More specifically, in the literature, an object feature is defined as a form with specific function and frame. The features of a parametric model are divided into categories, which are imported into the model as sub-features of a main feature, which is included in a corresponding feature library. These features are organized according to type or object. In first case, model representation is occurred with the aim of features such as geometric properties of the main feature (length, width, radius), tolerances, relations with other features etc. In second case, model representation is based on processes that elaborate the main properties of features.

The feature import in parametric model must be determined by well-defined appropriate parameters. In CAD programs, some features have natural limitations (for example the end of an engineering gear that should fit into a gear interior). Therefore, the parametric system should be able to sustain and manage an appropriate complex system of relationships involved in the parametric model.

Parametric design enhances the automatic design and production. One of its advantages is to find the optimum solution from a series of possible alternative solutions in much less time than other traditional methods. During model production, high-level controls were taking place while at the same time working hours were reducing, thus contributing to the increase of profit. Parametric design also enables the designer to use one specific parametric approach in other possible alternatives designs and geometric models, while it is able to introduce various limitations in each design, thus avoiding possible mistakes in subsequent designs. Finally, parametric design optimizes the design process, with an appropriate organization and export a number of possible alternative solutions for a specific design problem.

In naval architecture, the concept of parametric design emerged in early 1950s, when first ship parametric designs are observed. Murphy [26] and Mandel [27] were the first one who attempted to investigate the use of parametric design in naval architecture field. Their work is marked as the first application of ship parametric design and as an attempting to determine optimal solution searching techniques. In his thesis, Chryssostomidis [28] presented an analytical process of parametric design in a container ship design optimization concept. In 1982, Lyon [29], being taken advantage of the time-being technology and avoiding the use of computing programs, due to the amount of energy they consumed, presented a preliminary study procedure with the aim of a TI-59 calculator programming. In 1989, Papanikolaou et al. [30] presented the first application of parametric design in a Ro-Ro passenger ship design optimization concept. The computing power of the era allowed not only the geometry representation of the ship hull through its description from a set of suitable curves, but also the calculations evolved in the evaluation of a proposed design solution (hydrostatics, stability, etc.)

Parametric design is mainly used in ship preliminary design and usually includes the process of the generation of the ship hull and the corresponding calculations, related to the evaluation of the ship hydrodynamic behavior. When it comes to a more detailed ship hull representation (internal subdivision, general arrangement, superstructures, etc.) ship designer may deal with a series of additional design problems related to the ship hull representation precise, the number and value range of design parameters and the elements of evaluation procedure.

7 Conclusions

7.1 Transmission process of the craft

Carriers of the craft of wooden shipbuilding are almost exclusively the craftsmen themselves, who pass on centuries-old knowledge and tradition to the younger ones with the system of practical apprenticeship. In the past, the craft was largely passed down from father to son. In recent decades, after the crisis brought about mainly by the use of new materials for the construction of small boats, anyone interested could be apprenticed to a craftsman to learn the work. Today, unfortunately, few young people are interested and thus there is a problem with its preservation.

The complexity of the craft, the cumulative introduction of new materials and technologies, the low financial rewards, are some of the reasons why other forms of its transmission have not been developed, beyond the practical apprenticeship to a craftsman.

7.2 Utilization of the wooden shipbuilding heritage

A primary goal today for the enhancement of wooden shipbuilding heritage is training young people in the craft, young people who will be interested and believe in the value of its preservation. To do this, however, more comprehensive efforts should be undertaken to restore the economic and social recognition of shipbuilding. There must also be permanent and institutional structures of apprenticeship or extended training with good professional prospects.

An additional significant goal is the promotion of wooden ship construction products and the creation of structures or institutions for their quality control and evaluation as regards the technical and aesthetic subjects. Moreover, the shipbuilding market should be expanded to other countries and even new products (e.g. pleasure crafts and yachts) should be developed. Tourism is one of the sectors that should be connected as a matter of priority, including visiting the traditional shipyards.

In the context of technical support, the optimal uses of modern materials and techniques can be explored that will be fully harmonized with the morphology and typology of traditional Greek boats.

7.3 Protection and promotion measures

The law N.3028/2002 “On the Protection of Antiquities and Cultural Heritage in general”, constitutes the legal framework for the protection and promotion of intangible cultural assets, including the craft of wooden shipbuilding. The Ministry of Culture has declared many boats as well as karnayas as preserved and traditional. The Ministry of Shipping and Insular Policy has designated a special category of traditional boats to facilitate their rescue.

Nevertheless, the risks in conserving the craft are many. That is why various institutions, public and non-public, have expressed their intention, in recent years, to contribute to the creation of a unified system for the protection, restoration and promotion of the monuments of the shipbuilding cultural heritage. In particular, the support of the craft must be based on cross-sectoral policies (culture, tourism, shipping, local development). In this regard, it is crucial to acknowledge the pivotal role that private charitable foundations and educational institutions play in fostering awareness within the maritime community. Their contributions are poised to make a substantial impact in this endeavor.

In recent years it seems that something is gradually changing. Publications and studies on traditional shipbuilding are increasing. Associations for the protection of boats are becoming more visible. Efforts to teach the craft to the new generations are intensifying. Archives and stories of shipwrights are being digitized and made accessible via the internet. The Museum of Shipbuilding and Maritime Crafts of the Aegean has revived hopes for their preservation and promotion. They are encouraging initiatives that we all, and especially those involved in maritime professions, owe to us to support. Traditional Shipbuilding, a craft linked to the History and Culture of our maritime homeland, is an important heritage that should be preserved and dynamically developed into a source of wealth for today's Greece.

7.4 Parametric design and wooden shipbuilding

The concept of parametric design in combination with computing programs ushered in a new era in ship design by allowing the production and evaluation of multiple alternative design solutions with high precision, quality and effective computing speed. However, parametric design is not able to totally replace the traditional drawing because it lacks crucial elements like the traditional designer know-how and experience, the low-cost equipment and the intuitive workflow.

It is a strong belief that parametric design could be used at the stage of evaluation and optimization of traditional ship lines plans. The valuable data of traditional ship drawings and technical information can be represented in a 3D view and evaluated in real time, where new modifications and geometry limitations may have occurred based on the design expectations, the kind and shape particularities of available timber and the model operation. Based on parameter values and ranges, new possible alternative drawings for specific design concepts will be generated and consist a new traditional ship library, which will be able to be accessed to the traditional designers. Therefore, the time consuming in the lines plan drawing procedure will be limited and the main interest will be swift to the stage of construction.

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