Maritime Technology and Research

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Review Article

Shipbuilding materials: A bibliometric analysis of research trends

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Article information
Received: June 26, 2025
Revision: November 3, 2025
Accepted: November 6, 2025

Keywords
Shipbuilding materials;
Naval architecture;
Marine vessel materials;
Bibliometric analysis;
Research trends

Abstract

This study examines global research trends in shipbuilding materials using bibliometric matching and addresses the gap in the literature stemming from the lack of a comprehensive bibliometric study directly focusing on shipbuilding materials. The Scopus database was searched for studies published between 1970 and 2024; the starting year was chosen because it corresponds to the period when research on modern shipbuilding materials accelerated with advances in welding/joining processes, corrosion protection, and material testing standards. The search used the keywords "ship hull materials," "naval architecture materials," and "marine vehicle construction materials." The latter two terms were defined to encompass structural and construction elements directly related to shipbuilding. Bibliometric matching identified leading countries, institutions, journals, frequently cited studies, and thematic clusters. The thematic framework is organized according to four main material groups: wood, steel, aluminum, and composites. The findings indicate a growing emphasis on composite materials, and ongoing research on improving corrosion resistance, strength, and sustainability in steel and aluminum. The results obtained provide a comprehensive overview of the subject and produce insights that can contribute to the shaping of future research agendas in marine engineering and naval architecture.

1. Introduction

When studies on ships are examined in the literature, it can be seen that the majority of studies focus on topics examining the hydrodynamic behavior of ships, such as stability, motion, and resistance (Huang, 2025; Ravenna, 2022; Kim, 2023). Furthermore, studies on ships' main engines, auxiliary engines, and welded joints are also frequently seen in the literature (Dugan & Utne, 2025; Karatuğ et al., 2023; Liu, 2024; Shang, 2024; Wang, 2021).

On the other hand, it can be seen that studies focusing on the materials used as construction materials in ships are relatively limited. The choice of materials used in ships is primarily determined by the design's strength and performance requirements; the chosen material influences the achievable performance, weight, and lifecycle characteristics (Ashby, 2011). Since variations in materials used directly affect a ship's weight, the materials used are critical to the ship's economic return (Garbatov et al., 2023). When the hull materials used in ships are examined, it is seen that wood, steel, aluminum,

and composite materials come to the fore, as seen in the photographs taken by the authors in **Figure 1**.

Figure 1 Authors' photographs of various shipbuilding materials: a) wood, b) steel, c) aluminum, and d) composite materials.

Before the widespread use of iron and steel in the mid-late 19th century, wood dominated ship hull construction in many regions, though practices varied by region and vessel type. It was reliable with proper design and maintenance, but had limitations, including susceptibility to marine borers (e.g., shipworm). Large structural members were historically formed through scarfing/joinery, and in modern practice, laminations. Regular inspection and upkeep are standard across all hull materials, not unique to wood. Historical literature details this role: Reicher (2024) analyzes Caribbean hardwoods, considered among the best and most widely used in 18th-century naval construction; Wing (2012) provides an explanatory context for timber procurement in shipbuilding by discussing the relationship between forest resources and state power. Alfredo Bueno Jiménez documented one of the earliest shipbuilding/repair sites in the Americas in The Bay of La Isabela, Dominican Republic: The First Enclave for the Shelter, Reception, Construction, and Maintenance of Ships in the New World, 1494 - 1498. He summarized the industry's organization, material supply, and financial structures in Introduction: The Shipbuilding Industry in the Spanish Caribbean, 1400s - 1700s: Construction, Maintenance, Supply of Materials, and Financing (Jiménez, 2024a; 2024b). Historically, species such as oak, spruce, pine, teak, and mahogany were preferred; oak in Europe for hulls, due to its high density and strength (Hocker, 2024); teak, especially in India, for hulls and deck planking, which resist water and rot due to its natural oil content (Sérougne, 2020); and spruce and

pine for masts and spars, due to their light weight. Despite wood's advantages, such as workability, flexibility, buoyancy, and aesthetics, it can be protected against risks such as moisture, saltwater, marine organisms, decay, insects, and fire through traditional (tar and pitch coatings, lubrication (e.g., linseed oil, salt baths) and modern (impregnation, chemical preservatives, resin/epoxy coatings) methods. While wood has largely been replaced by metal and composites as the primary structural material since the late 19th - early 20th century, it continues to be used for aesthetic or traditional purposes in private yachts and historical restorations. Recent studies emphasize that the carvel technique holds potential for sustainable shipbuilding with a low carbon footprint, but regulatory shortcomings (e.g., the lack of standardized structural design rules for wooden hulls in modern classification society codes) limit its widespread adoption (Souppez et al., 2023), and that moisture, temperature, and UV exposure significantly reduce wood's mechanical properties under different atmospheric conditions (Wahidi et al., 2022).

With the transition from wood to metallic materials, the primary material in shipbuilding initially became steel (late 19th - early 20th century), followed by aluminum (mid-20th century onward) in certain applications (e.g., high-speed ferries, coastguard/patrol craft, superyachts, and warship superstructures). Steel has been the primary material for hulls, superstructures, and decks since the early 20th century, preferred for its high strength, formability, weldability, and cost-effectiveness. Ship hull and structural components are produced in accordance with classification society material standards, with standardized strength grades for primary structures, and alloys offering higher strength or improved corrosion resistance selected when required by specific operating conditions. In recent years, research on shipbuilding steels has increasingly focused on modeling temperature-dependent material properties (Norkett et al., 2024), digital twin based approaches for welding process control (Shang et al., 2024), evaluation of weldment mechanical performance and defect detection (Liu et al., 2022), deformation and heat treatment routes such as cold deformation and post-ECAP annealing (Nguyen et al., 2024; Demirtaş & Sekban, 2021), and finite element and artificial neural network methods in friction stir welded steels (Sekban et al., 2025). At the fleet scale, stock and flow dynamics of steel used in commercial ships and its recycling potential have also been discussed (Kong et al., 2021). In addition, because corrosion is a major life-cycle driver for steel hulls and topside structures, fiber-reinforced polymer barrier systems (e.g., glass-flake reinforced epoxies and GFRP laminate overlays) have been evaluated for extended coating life and reduced maintenance under seawater exposure (Hassan et al., 2024). Steel predominates in cargo carriers (tankers, bulk carriers, container ships) and many naval/offshore structures; aluminum, on the other hand, is preferred in ferries, coast guard boats, superyachts, and patrol platforms, where high speed/agility and fuel economy (critical across all vessel types) are critical, due to its density of approximately one-third of steel, its corrosion resistance from its natural passive layer, and its workability, mostly in the 5xxx (5083, 5454, 5052) and 6xxx (6061) series. Susceptibility to fire (lower melting point), the risk of galvanic corrosion when combined with steel, and the more complex welding processes, compared to steel, are the main engineering limitations. Current studies focus on fatigue performance related to post-weld strain/residual stresses, corrosion-fatigue interaction, parameter optimization of methods such as FSW/laser, and inspection sensitivity (Xu et al., 2022; Chen et al., 2024; Hendroprasetyo & Andrian, 2022).

Following wood and metallic materials, composites have rapidly become widespread in commercial and military applications in recent years. They offer high specific strength and rigidity, corrosion resistance, and design flexibility. Glass fiber reinforced polymer (GFRP), carbon fiber reinforced polymer (CFRP), and aramid fiber reinforced polymer (AFRP) are most commonly used in practice: GFRP in small boats, yachts, and superstructures; CFRP in high-performance speedboats and structures requiring ballistics; and Kevlar-based systems are prominent in minesweepers and critical areas (Material Trends for FRP Boats, 2003). Their resistance to saltwater and UV, as well as their resistance to galvanic corrosion, are significant advantages. Single-piece/double-curved surfaces and integrated components are possible in production. Major limitations include low impact

resistance, complex and lengthy repair processes, poor fire performance, and the risk of toxic gas emissions in a fire. For sustainability reasons, thermoset-based parts are difficult to recycle; therefore, research is ongoing on thermoformable thermoplastics and biodegradable fiber reinforcements (Elen et al., 2024). The recent literature emphasizes improving the structural performance of composite ship components while also addressing the efficiency and environmental impact of manufacturing processes. In this context, production practices in European shipyards have been reviewed with a focus on automation, computational design, and the use of more sustainable materials (Dolz et al., 2023). Comparisons of different solvers have been made for more accurate modeling of thermal-mechanical deformations during production (Bolf et al., 2021). Saravanan and Kumar investigated the part-level potential of advanced composites in marine (Saravanan & Kumar, 2021). The relationship between innovation capacity and governance and culture in small composite boat manufacturers has been demonstrated (Šugar & Zanze, 2021). The influence of resin and interlayer on the impact behavior of GFRP panels has also been demonstrated, with a Coremat interlayer increasing energy absorption against low-velocity impacts (Cristea et al., 2023). The potential of "green composites" as a sustainable alternative for the sea has been evaluated (Crupi et al., 2023). The weight, cost and energy advantages of carbon fiber sandwiches on a 100 m concept ship were analyzed (Lowde et al., 2022). The effect of fiber placement was studied, and the Woven Roving array gave good results in flexural/stiffness and impact resistance (Gunarti et al., 2024). Fiber-reinforced polymer (FRP) production technologies in shipyards were compared with life-cycle assessment (LCA) it was found that the environmental impact was very dependent on the material, and the loading of carbon fiber was the highest (Ziemińska-Stolarska et al., 2024). It was shown that hemp fiber-reinforced composites offer better impact performance and energy recovery than GFRP under certain conditions and can be a sustainable alternative for marine components (Scheibe et al., 2025). Raffia fiber-reinforced epoxies were suggested as candidates for boat hulls with their low density, high stiffness, and thermal insulation properties (Djoumessi et al., 2025). General voids include durability under long-term combined loads, cost-effective scalable production for large panels, and the design of ship-specific optimized hybrid solutions. These gaps frame the motivation for the present bibliometric analysis and brief materials review, clarifying where current work concentrates, and where further research is needed.

Although information about the general historical development of the materials used in ships is available, it is very important to reveal the status of the studies conducted on ship materials in recent years, and to see what kind of topics the researchers are focusing on, in order to reveal the current situation and to guide future studies. On the other hand, when the literature is examined, the absence of a bibliometric study compiling the studies conducted on the materials used in ships is seen as a significant deficiency in this field. In this context, the research trends in shipbuilding materials from 1970 to 2024 were examined using Scopus data, and a bibliometric analysis was performed. The starting year of 1970 was chosen because it marks a period when modern shipbuilding materials research began to expand significantly in both scope and diversity, supported by advancements in welding technologies, corrosion protection methods, and material testing standards. This study adopts a global perspective, analyzing publications from all countries indexed in the Scopus database during the study period. To capture relevant studies, while maintaining focus on ship construction materials, the search was conducted using the keywords "ship hull materials," "naval architecture materials," and "marine vehicle construction materials." While "naval architecture materials" can encompass a wide range of ship-related components, in this study it was used specifically to include structural and construction materials directly relevant to shipbuilding. In addition to the bibliometric assessment, a brief review of commonly used shipbuilding materials (wood, steel, aluminum, and composites) was also included within the Introduction to provide context and highlight ongoing developments in material technologies. The data obtained as a result of the study were discussed in detail at the scales of general study information, keywords in the studies, countries and universities where the studies were conducted, journals where the studies were published intensively, studies that were cited

intensively, and thematic maps of the studies. In this way, it was aimed to determine the current trends in the literature on shipbuilding materials and to present a road map that will guide future studies. To achieve this, the study was designed to integrate quantitative and qualitative perspectives within a single framework. The bibliometric mapping quantitatively reveals dominant research themes, collaboration networks, and publication dynamics, while the literature review qualitatively explores the properties, applications, and recent developments of the most widely used materials. Accordingly, the Results section reports the bibliometric analysis of research on shipbuilding materials, while the Introduction provides the brief materials overview (wood, steel, aluminum, and composites). The study aims to identify the dominant themes in shipbuilding-materials research during 1970 - 2024 and to assess how these themes differ across wood, steel, aluminum, and composites.

2. Methodology

The bibliometric analysis was conducted using data from the Scopus database. The dataset was created by applying a targeted search query designed to capture publications directly relevant to shipbuilding materials, yielding 493 documents from 249 journals. Bibliographic information, including titles, abstracts, keywords, authorship, citations, and journal sources, was extracted for subsequent analysis to identify research themes, collaboration patterns, and leading contributors in the field.

The analysis was conducted using R software with the Bibliometrix package and its Biblioshiny interface, which provided an interactive platform for advanced bibliometric analysis and visualization. Descriptive metrics, such as annual publication trends, citation counts, and journal productivity, were calculated. Co-occurrence analysis of keywords was used to uncover prominent research themes and emerging trends, while collaboration networks were mapped to identify global research partnerships. Single Country Publications (SCP) and Multiple Country Publications (MCP) were analyzed to understand the extent of international collaboration. Visualization outputs included thematic maps, collaboration networks, and citation analysis, offering insights into the research landscape and future directions in shipbuilding materials.

The analysis query code used in the study is as follows: title-abs-key ((“shipbuilding materials” or “ship hull materials” or “ship materials” or “naval architecture materials” or “ship-building materials” or “marine vessel building materials”)) and pubyear > 1969 and pubyear < 2025 and (limit-to (subjarea , “engi”) or limit-to (subjarea , “mate”) or limit-to (subjarea , “chem”) or limit-to (subjarea , “ceng”) or limit-to (subjarea , “envi”)) and (limit-to (doctype , “ar”) or limit-to (doctype , “cp”)) and (limit-to (language , “english”)).

Figure 2 Main information about data.

3. Results and discussions

3.1 Bibliometric analysis

3.1.1 General information

The main information about the data subjected to bibliographic analysis is given in **Figure 2**. In the study, 493 different studies on materials used in shipbuilding between 1970 and 2024 were analyzed. After the analysis, it was determined that these studies were included in 249 different sources (journals, book chapters, etc.) and that 1,213 different authors were included in these studies. It was also determined that 703 different keywords were used in these studies, and that the average number of citations to the studies was 6.88.

3.1.2 Keywords, country and universities correlation

The correlation between keywords, countries where articles were made, and universities in the scanned articles is shown in **Figure 3**. This triad explicitly links geography and institutions to specific material classes and performance attributes, allowing a material oriented reading of the bibliometric landscape. As can be seen, the most frequently used keyword in the examined articles is shipbuilding, while the country with the most studies was China, and the university with the most articles was Tongji University. When the keywords are examined, it is seen that the studies conducted in China are mostly focused on the keywords shipbuilding, fracture toughness, and aluminum. Here, "fracture toughness" and "aluminum" anchor the discussion in metallic materials, notably aluminum alloys used for hulls and superstructures, directly tying China's research activity to material selection and safety critical properties (e.g., fracture toughness, ultimate strength, and welded joint fatigue life). These emphases support domestic production of lightweight aluminum fast craft and improve damage tolerance and inspection practices for large series built vessels. On the other hand, in Korea, where the most academic studies have been conducted after China, it is seen that a keyword such as ultimate strength, which is used intensively in finite element based design and analysis studies, comes to the fore in parallel with the intensive ship design activities carried out in this country. "Ultimate strength" is a material and structural property central to steel and aluminum hull girder capacity, indicating that Korea's emphasis is materially grounded in the strength performance of metallic ship structures. This aligns with Korea's high volume construction of large steel merchant ships and offshore units, where hull girder capacity and structural optimization drive class approval and cost competitiveness. Again, when the keywords are examined, it is clearly seen that many different keywords related to composite materials, the use of which has been rapidly increasing in the shipbuilding industry in recent years, are included in the list, and these keywords are the subject of studies conducted in many different countries. The dispersion of composite related terms, for example fiber types, resin systems, and sandwich panels, across multiple countries maps directly to the composite materials category, reflecting material substitution trends for lightweighting, corrosion resistance, and fatigue performance. This pattern suggests that the countries that dominate in shipbuilding are closely linking their academic research issues with industry interests. The recurrence of composite related phrases across many countries indicates a global trend toward lightweight, durable, and corrosion resistant materials, indicating both technological advancement and the growing significance of sustainability. In practice, these trends translate into weight savings for small and medium craft, lower corrosion maintenance burdens for topside structures, and emerging export niches in composite patrol and workboats. In sum, the country, university, and keyword correlation functions in this study as a material centered bibliometric indicator. It traces which material families, for example steel, aluminum, and composites, and which material properties, for example fracture toughness, ultimate strength, and durability, are prioritized by each geography, thereby directly informing the manuscript's material based analysis. In turn, this mapping clarifies how national research portfolios feed into product performance, certification pathways, and yard level productivity.

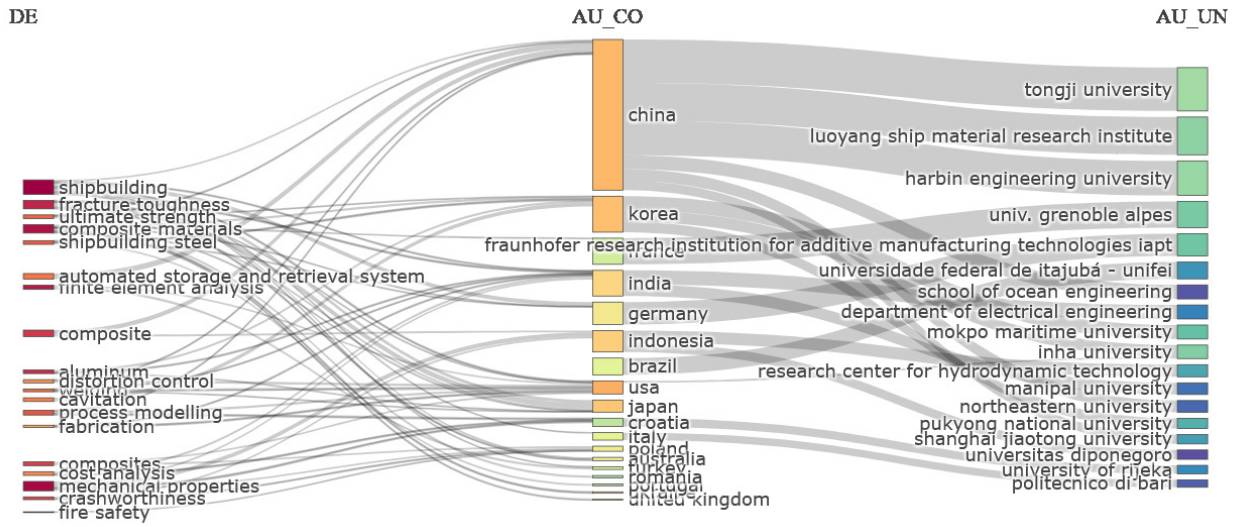

Figure 3 Keyword, country, and university correlation.

3.1.3 Annual scientific production

Figure 4 shows the distribution of materials used in shipbuilding by year. When the number of publications is examined by year, it is seen that there was a significant rise in the number of publications from the beginning to the middle of the 1980s, and that the peak was reached around 1984. This rise corresponds to a period in which steel and aluminum based hull technologies were being optimized, placing material selection and mechanical performance at the center of shipbuilding research. The main reason for the increase in this period is the rapid progress in material technologies in industry and shipbuilding, particularly the intensive research on metal based materials such as advanced high strength steels, aluminum alloys, and composites. After this year, there was a significant decrease in the number of publications. The reason for this is probably that the fundamental problems in terms of materials were overcome at that time, and the research focus shifted to different topics such as hydrodynamic optimization and CFD, propulsion and propeller design, structural reliability beyond material selection, machinery efficiency and emissions control, and classification and regulatory compliance. An increase was observed in the number of publications, although fluctuating, from the beginning of the 2000s onwards. The reason for this situation can be shown as the popularization of composite materials, advanced welding methods, and digital design tools. During this stage, composite materials began to be studied not only as structural alternatives, but as key solutions to corrosion resistance, weight reduction, and fatigue performance, directly linking publication volume to material innovation. Again, with the increasing importance of sustainability and environmental effects, academic interest in the search for new materials in shipbuilding has increased and, as a result, the number of publications has increased, albeit slightly, in recent years. This indicates that publication trends are shaped by the emergence and industrial adoption of specific material families and performance priorities. This fluctuation in publication volume highlights how material research in shipbuilding has responded to broader technological and industrial shifts. This period based assessment provides a clearer chronological framework for interpreting changes in research activity. Periods of increased activity often coincide with the emergence of new material technologies or manufacturing methods, while declines may reflect phases in which research priorities shifted to other areas. A period based analysis of the published data reveals three distinct eras. From 1970 to 1990, research was primarily focused on steel materials, welding processes, and corrosion control. From 1990 to 2010, research on aluminum alloys, surface coating methods, and mechanical property advancements gained prominence. After 2010, there was a noticeable trend toward more current and innovative issues, such as composite materials,

sophisticated joining techniques, numerical modeling, and sustainable material use. When interpreted in a material centered framework, these eras reflect shifts from strength and durability concerns in steel, to lightweight and corrosion resistant aluminum, to high performance composite solutions and sustainability driven material strategies. When examined with the bibliometric mapping, this temporal development shows how academic research priorities have changed in response to technological advancements and rising industrial needs.

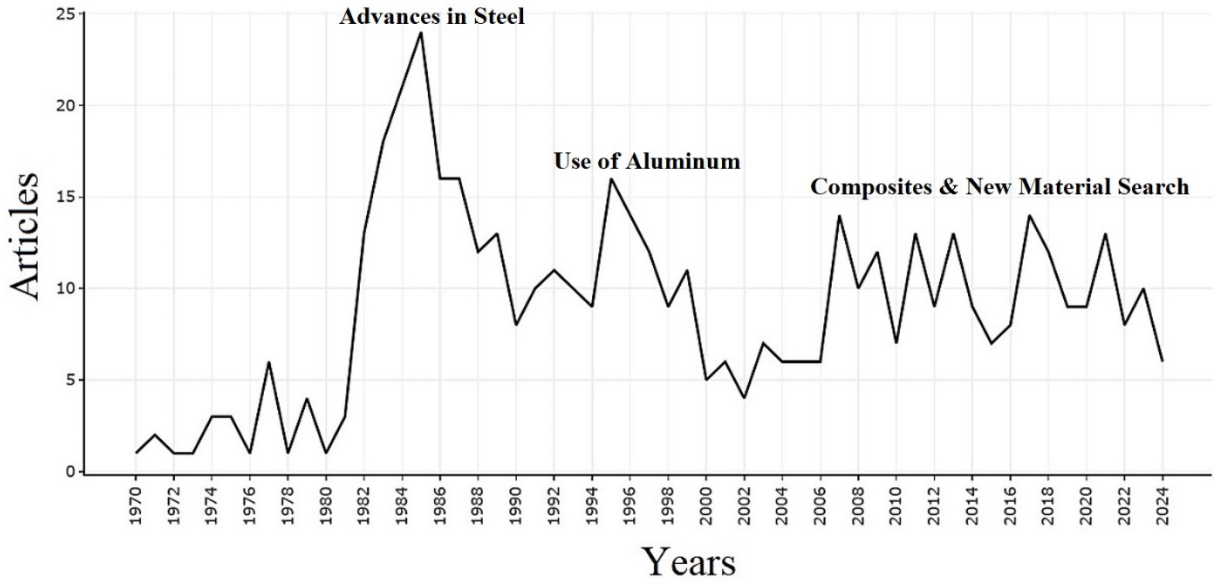

Figure 4 Annual scientific production.

3.1.4 Most relevant sources

The most published sources of publications on materials used in shipbuilding are shown in **Table 1**. When the journals in the list are examined, it is seen that the first 3 of the list are UK and USA based journals. Several of the remaining high output titles, however, are comparatively recent launches. On the other hand, it can be clearly seen that these 3 journals are the academic publications of large maritime societies: the Royal Institution of Naval Architects, ASNE, the American Society of Naval Engineering, and SNAME, the Society of Naval Architects and Marine Engineering. Accordingly, the rankings reflect productivity within the study window, rather than historical longevity, and society journals are interpreted as long standing venues, versus newer titles that have scaled output more recently. This concentration indicates that societies central to ship design also serve as primary channels for disseminating material focused research, including studies on strength, corrosion, fatigue, and manufacturability that directly affect hull and superstructure performance. Additionally, when the list is examined, it is seen that there are frequent publications on shipbuilding materials in the International Offshore and Polar Engineering Conference Proceeding book, organized every year by ISOPE, the International Society of Offshore and Polar Engineers, one of the major organizations of the shipbuilding sector. These proceedings typically feature results on material selection under extreme environments such as low temperature and wave loading, linking source prominence to material performance requirements in offshore and polar applications. Inferring from this information, it is possible to say that large societies that are of great importance for shipbuilding frequently include research on materials used in shipbuilding in their own academic publications. In parallel, the presence of general materials science journals among the top sources shows cross domain validation of shipbuilding material research, where testing protocols, microstructural analyses, and processing routes inform practical choices between steel, aluminum, and composite systems. On the

other hand, when **Table 1** is examined, it can be seen that there are frequent publications on shipbuilding materials in academic journals with general material science themes. Taken together, the source pattern ties the bibliometric signal directly to materials by emphasizing venues that evaluate and compare material families and properties relevant to ship structures. Therefore, the start years of the principal titles were verified and the output counts were interpreted in light of their time in print.

Table 1 Most relevant sources.

Journals	Articles
THENAVAL ARCHITECT	26
NAVAL ENGINEERS JOURNAL	23
JOURNAL OF SHIP PRODUCTION AND DESIGN	18
ADVANCED MATERIALS RESEARCH	13
PROCEEDINGS OF THE INTERNATIONAL OFFSHORE AND POLAR ENGINEERING CONFERENCE	8
APPLIED MECHANICS AND MATERIALS	7
IOP CONFERENCE SERIES: MATERIALS SCIENCE AND ENGINEERING	6
OCEAN ENGINEERING	6
IOP CONFERENCE SERIES: EARTH AND ENVIRONMENTAL SCIENCE	5

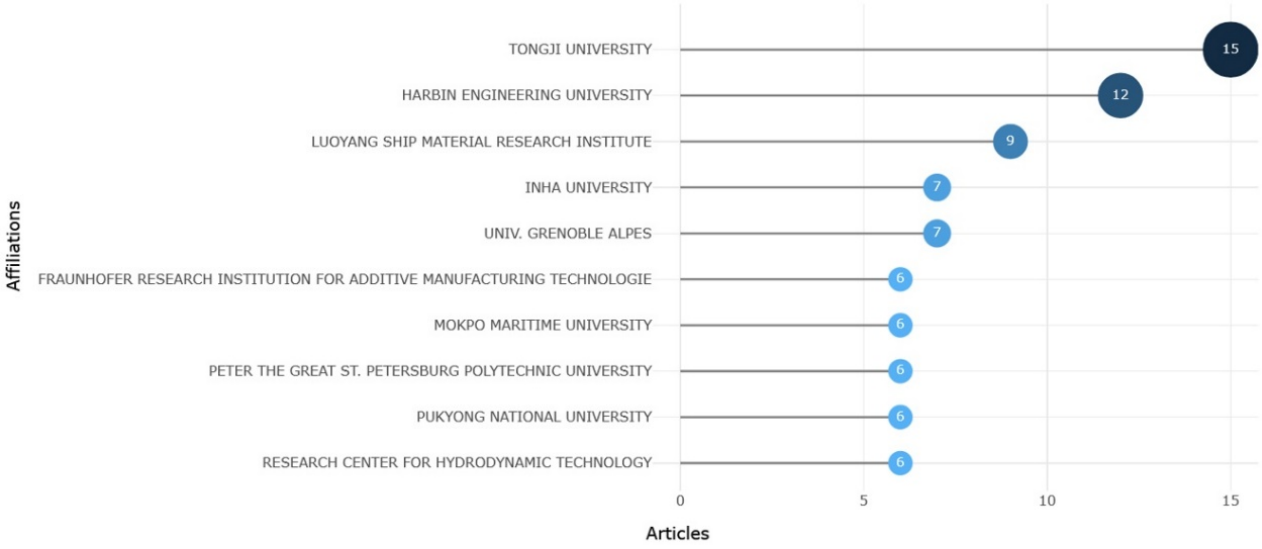

Figure 5 Most relevant affiliations.

3.1.5 Most relevant affiliations

Figure 5 shows the institutions of researchers who have published on materials used in shipbuilding. When the list is examined, it is seen that the universities to which the researchers in the first 3 places on the list are affiliated are located in China. As it is known, China is the clear leader in terms of new shipbuilding orders in the world. It is possible to associate the abundance of studies on materials used in shipbuilding in universities in this country with the developed shipyard sector in

this country. In material terms, leading Chinese affiliations frequently publish on steel grades, aluminum alloys, welding and joining, corrosion and protective systems, and fatigue performance, indicating a direct link between industrial demand and material property optimization. On the other hand, it is seen that there are 3 different universities from South Korea, which has the highest new shipbuilding production after China. Korean affiliations are similarly prominent in topics such as ultimate strength of metallic hull structures, high strength steels for large container ships and LNG carriers, aluminum superstructures, and composite applications for lightweighting, showing that institutional output tracks material selection for national fleet profiles. In this context, it is possible to say that academic studies on shipbuilding in these countries are concentrated as a reason and/or result of the developed shipbuilding industry. Additionally, it was determined that the rest of the list includes Universities and Research Institutes in countries such as Germany, Russia, and France, which are active in the shipbuilding sector in Europe. These European institutions often contribute on ice class and low temperature steels, hybrid composite and steel solutions, advanced coatings, and numerical modeling of material behavior, which together anchor the affiliation pattern to distinct material families and performance requirements. Overall, the affiliation distribution functions as a material oriented indicator by revealing where expertise, testing infrastructure, and industry collaboration converge to shape research on steel, aluminum, and composite systems used in ship structures.

3.1.6 Countries' article production over time

The number of studies conducted in different countries over the years is shown in **Figure 6**. As can be seen, the United States (purple line) came to the forefront in publication output and research influence early on, and maintained its leadership for a long time, largely due to its technological superiority and strong research infrastructure in shipbuilding. In material terms, early United States leadership is closely associated with studies on steel and aluminum for hull structures, development of testing standards for fracture and fatigue, and foundational work on corrosion control and protective systems. In contrast, China (red line) has shown a remarkable rise in recent years, driven by the rapid expansion of its shipbuilding industry and substantial investments in research and development (R and D). This growth has accelerated academic activity in the field, leading to a significant increase in publications. The recent surge in China aligns with a portfolio centered on high strength steels, large plate fabrication, aluminum superstructures, modern welding and joining techniques, and expanded work on coatings and corrosion mitigation that directly supports industrial production. Japan (green line) and Korea (blue line) have demonstrated steady growth since the 1990s and now hold an important share of total publications. Their trajectories reflect sustained research on ultimate strength and fatigue of metallic hull girders, cryogenic and low temperature materials for LNG and polar service, and increasing evaluation of composite solutions for lightweighting. Indonesia has also recorded a notable increase in recent years, likely reflecting its emphasis on R and D and academic studies to strengthen its shipbuilding industry, boost domestic production, and enhance its role in regional maritime trade. In this case, the publication rise corresponds to practical material themes, such as aluminum for fast ferries and composite applications for small craft and coastal vessels. The rapid rise of China underscores the strong link between national industrial capacity and academic output, suggesting that future research leadership in shipbuilding materials may increasingly shift toward emerging economies with expanding shipyard infrastructure. Overall, the time based country pattern operates as a material oriented indicator, showing how national publication curves track the adoption and optimization of specific material families and properties relevant to ship structures. It is acknowledged that publication volume can be influenced by national research funding policies. However, in this study, publication counts are interpreted as indicators of research activity, rather than direct measures of research quality.

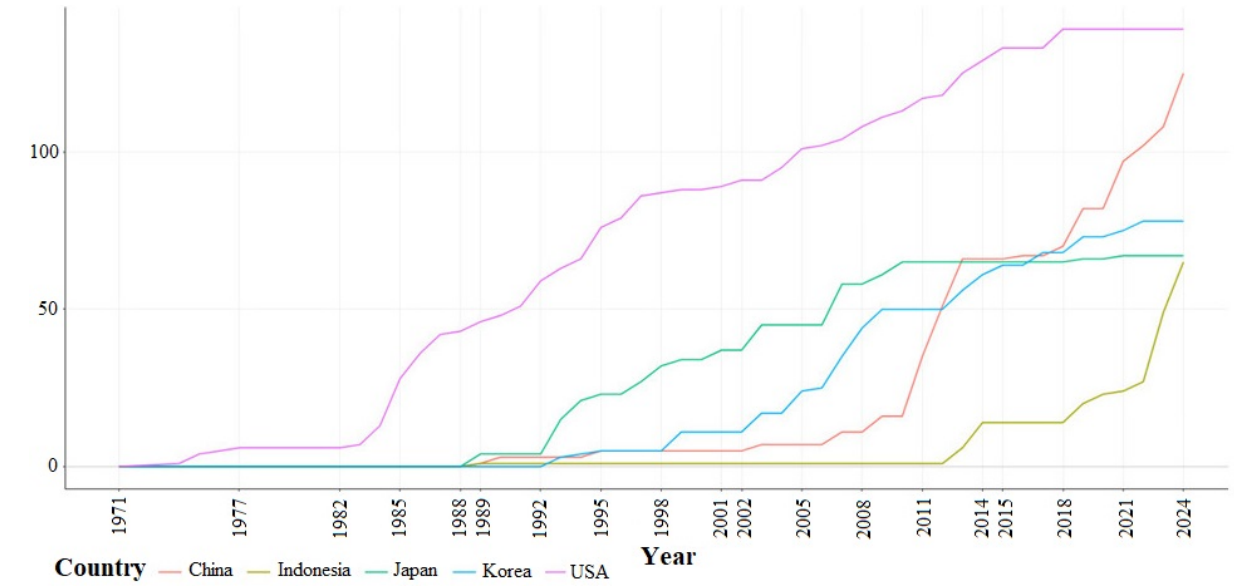

Figure 6 Countries' article production over time.

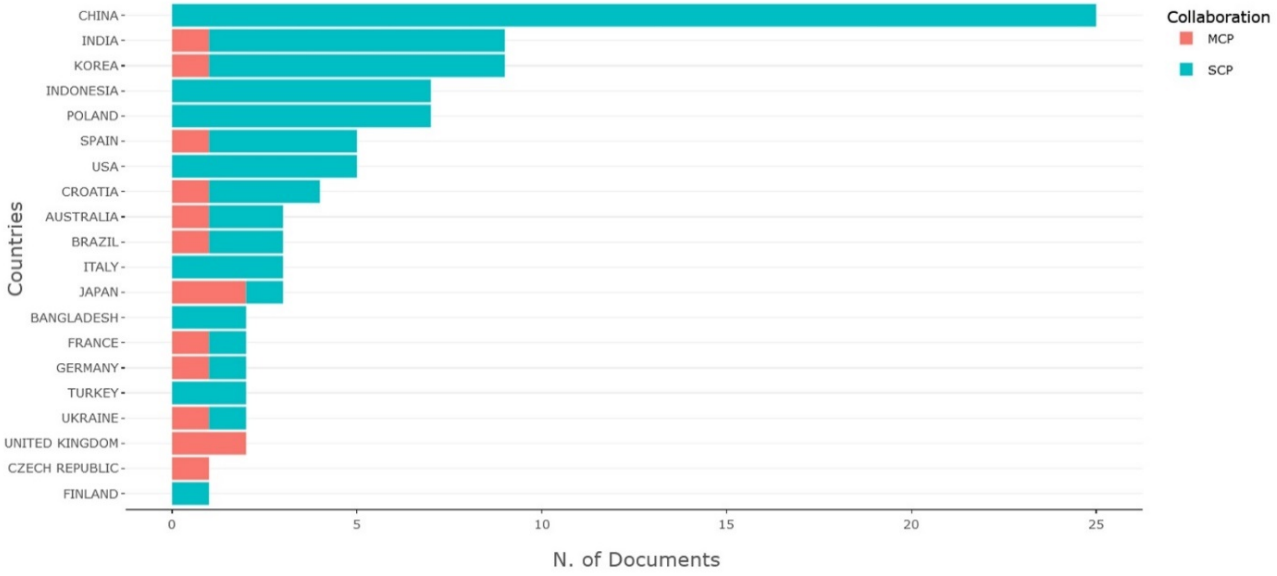

Figure 7 Corresponding author's countries.

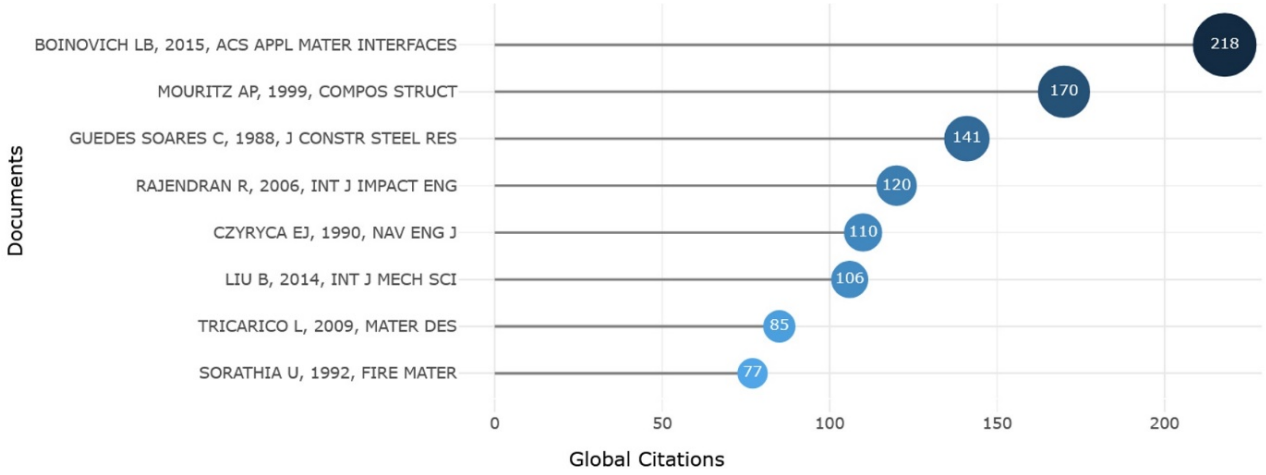

Figure 8 Most global cited documents.

3.1.7 Corresponding author's countries

The countries of the corresponding authors in the publications on materials used in shipbuilding are shown in **Figure 7**. As can be seen, academic studies on materials used in shipbuilding are generally from countries such as China, Korea, Indonesia, and the USA, which are advanced in the shipbuilding industry. On the other hand, it can be seen that authors from many countries in Europe are also conducting studies on this subject. It is clear that India, which is ranked 2nd on the list, is not one of the leading countries in terms of shipbuilding industry. However, it is possible to think that India gives importance to academic research on materials used in shipbuilding, both in terms of its pioneering research in materials science and the advanced metal production in this country. In material terms, India's position aligns with strong capacities in steelmaking, aluminum processing, welding and joining research, and corrosion science, which translate into publications relevant to hull materials, even if domestic shipbuilding volumes are lower. **Figure 7** also shows whether the publications are made by single national authors (SCP) or multinational authors (MCP). It is seen that multinational authors are more involved in the publications made, especially in Japan, Korea, India and European countries. It is thought that the reason for this situation is that the habit of international cooperation is more common in academic and industrial studies in these countries. From a material perspective, higher MCP shares often indicate access to complementary testing infrastructure and supply chains, for example, plate mills for high strength steels, foundries and extruders for aluminum, and labs for composite manufacturing and characterization, which together support comparative studies across material families. Accordingly, the distribution of corresponding author's countries functions as a material oriented bibliometric signal by revealing where expertise, facilities, and collaborations converge for steel, aluminum, and composite systems used in ship structures.

3.1.8 Most global cited documents

The most cited publications among the publications on materials used in shipbuilding are shown in **Figure 8**. The most cited study among these studies investigated the method of creating superhydrophobic coatings on stainless steel surfaces by micro and nano level patterning with infrared laser and its effects on wear and cavitation resistance on surfaces by utilizing its water repellent properties (Boinovich et al. (2015)). This topic directly addresses material performance in marine environments because hydrophobic surface engineering on stainless steels can mitigate corrosion, fouling, and cavitation erosion relevant to hull appendages and fluid exposed components. The second most cited study in the research on materials used in shipbuilding examined the mechanical properties of different marine composites after fire (Mouritz and Mathys (1999)). Fire performance of composites is a core material criterion for ship structures and interiors, linking resin systems and fiber architectures to post fire residual strength and safety compliance. The third most cited study addressed the design equations in plates subjected to compressive loads (Guedes et al. (1998)). These plate formulations underpin buckling and ultimate strength assessments for steel and aluminum plating in hull girders, which are material dependent through thickness, yield strength, and stiffening layouts. When the most cited studies in the list are examined, it can be seen that studies on many different subjects fall into this category. Despite covering varied topics, each highly cited work contributes foundational insights into material families and properties critical to ship structures, for example surface engineered stainless steels, fire resistant composites, and compressive strength of metallic plates. On the other hand, it is possible to say that the number of citations increases when the studies are conducted in areas that are not specifically related to shipbuilding, but which also address shipbuilding, and can be used in different areas. Accordingly, high citation counts often reflect cross domain applicability of material methods and models, which amplifies their impact within shipbuilding while extending to adjacent marine and engineering fields. High citation counts also indicate that these research areas have remained active over time, suggesting sustained scientific interest and continued development in the corresponding material technologies.

3.1.9 Trend topics

Figure 9 depicts the most frequently used phrases in shipbuilding material investigations, as well as their distribution by year. Mechanical qualities emerge as the most commonly used phrase, which is understandable given that enhancing such properties is a primary goal of material based research. In a material centered reading, mechanical properties here refer to strength, toughness, fatigue and fracture behavior, stiffness, and corrosion resistance, directly guiding selection among steel, aluminum, and composite systems for hull and superstructure applications. Composite materials also stand out, demonstrating advances in composite boat manufacturing techniques that have allowed for the building of larger vessels and greater market share. This prominence reflects the pursuit of lightweighting, improved durability in marine exposure, and reduced maintenance, compared with traditional metallic solutions, which ties composite adoption to both performance and sustainability objectives. This technological progress has been mirrored by a growing body of academic research on composites in shipbuilding. Terms such as finite element analysis and modelling are also prominent, indicating the widespread use of advanced simulation tools that can deliver fast and reliable results comparable to experimental testing (Sekban et al., 2024; Sekban, 2025; Yaylacı et al., 2025). In material terms, these tools enable property driven design by linking constitutive models and failure criteria to plate and stiffener response in steel and aluminum, and to laminate stacking, core shear, and delamination behavior in composites. Additionally, welding, one of the most critical joining methods for ships and fire safety, appears frequently, underlining its ongoing importance in ship design and construction. Welding trends track material usage by focusing on high strength steels, aluminum alloy joinability, heat affected zone performance, and dissimilar joints in hybrid metal composite concepts, while fire safety research addresses resin systems, surface treatments, and protective solutions essential for composite structures and interiors. Overall, the sustained prominence of mechanical properties, coupled with the rising focus on composites, suggests a shift towards materials that combine high performance with reduced environmental impact. Taken together, the trend topics align the bibliometric signal with material families and properties, showing how research emphasis migrates as shipbuilding adopts and optimizes steel, aluminum, and composite solutions.

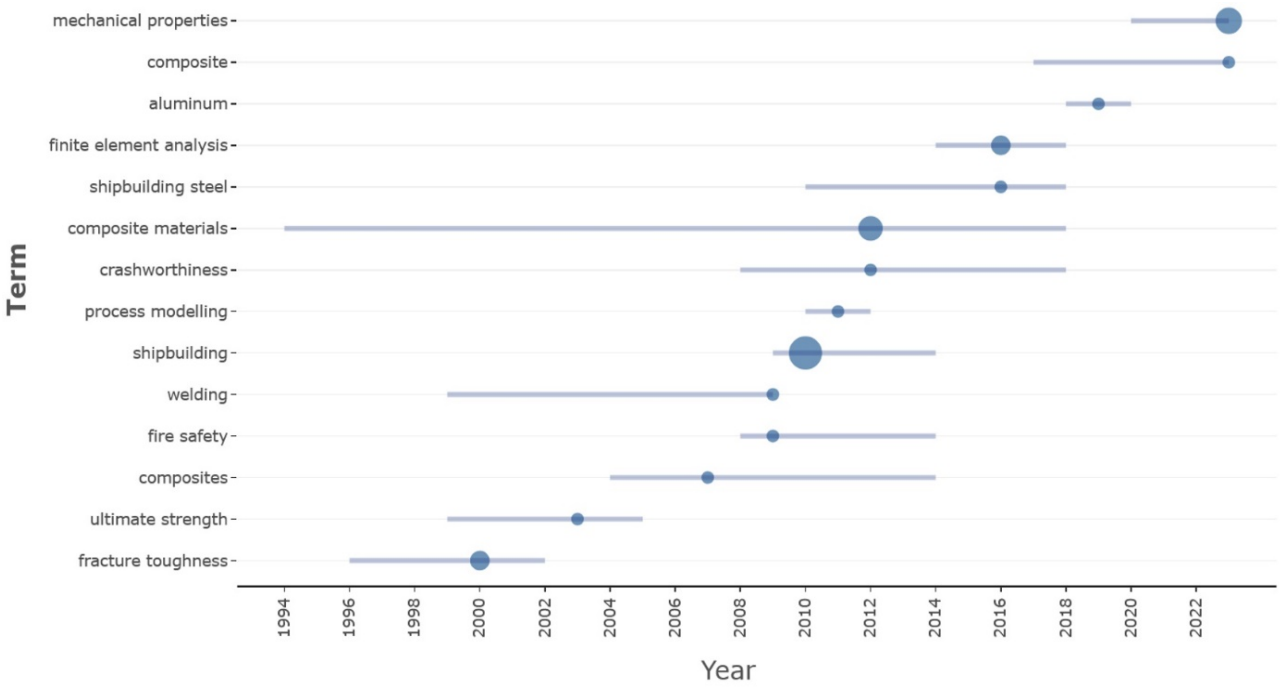

Figure 9 Most frequently used terms and their distribution by year.

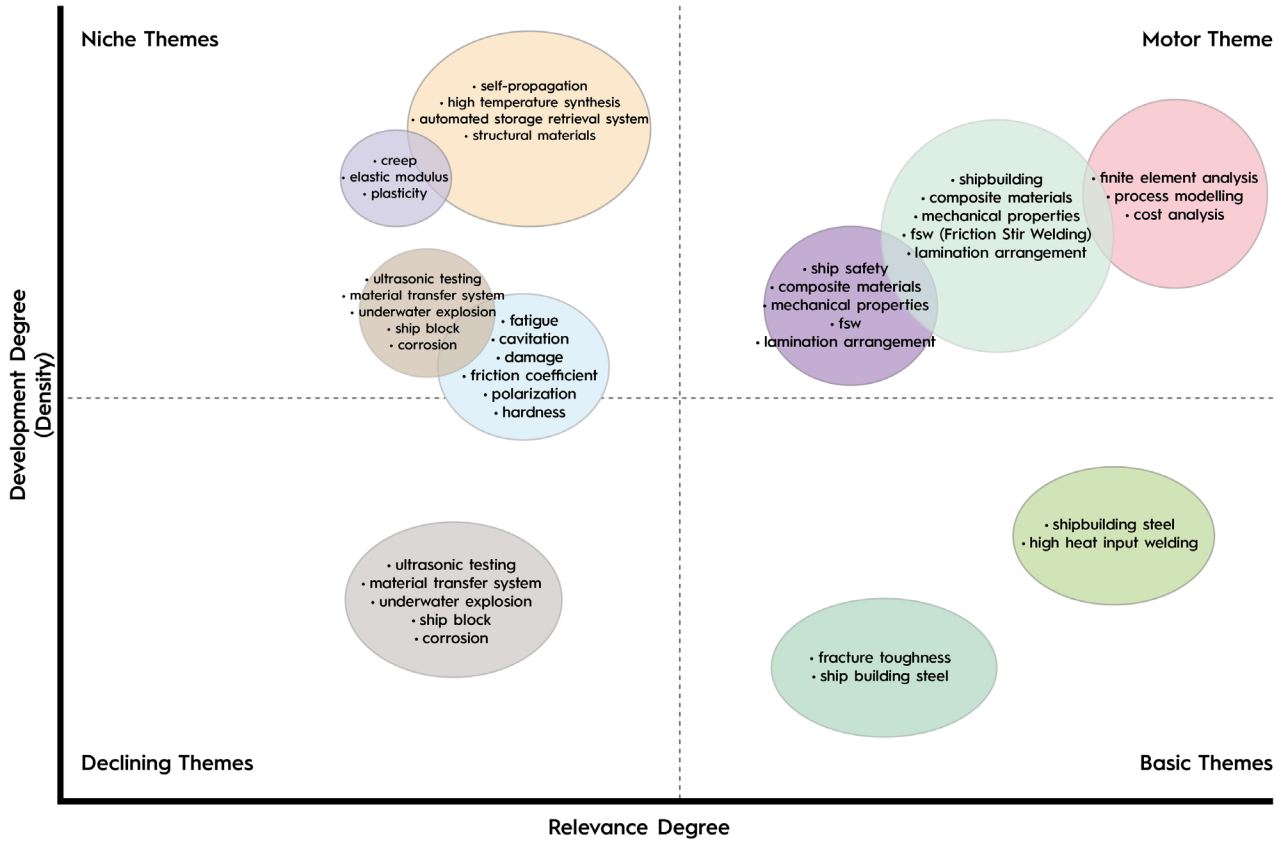

Figure 10 Thematic map of research trends in shipbuilding materials.

3.1.10 Thematic map

Figure 10 shows the thematic map obtained as a result of the bibliographic query on materials used in shipbuilding. As can be seen, basic research topics, such as composite materials, mechanical properties, welding methods and development of mechanical properties, are classified among engine and basic themes. This shows that such topics have been researched since the past, and that research continues. In material terms, these themes correspond directly to the core families used in ship structures, namely, steels, aluminum alloys and composite systems, and to their key performance attributes, such as strength, toughness, fatigue, and corrosion resistance. On the other hand, it is seen from the analyses that alternative welding methods, such as friction stir welding, finite element methods where mechanical performance can be examined as an alternative to experimental methods, and cost analyses are frequently studied, and continue to be studied. Friction stir welding is especially relevant to aluminum alloys and, increasingly, to steels and dissimilar joints, while finite element methods connect material properties to structural response, and cost analyses link material choice to lifecycle and maintenance outcomes. In the analysis, it was determined that topics such as plasticity, elasticity modulus, ultrasonic examination, and high temperature synthesis, which are specific engineering problems and are included in studies on materials used in shipbuilding, continue to be studied specifically, although relatively rarely. These topics map to material behavior and processing, for example, plasticity and modulus for metallic plates and stiffeners, ultrasonic examination for defect detection in welds and composite laminates, and high temperature synthesis for coatings and alloy development. The topics included in the declining themes category represent areas that have lost priority in the literature or have fallen behind current research trends. Ultrasonic tests, material transfer systems, underwater explosions, corrosion of ship blocks, and similar topics, which were of

critical importance in terms of shipbuilding in the past, are seen to have made significant progress in these areas today. In a material focused interpretation, the decline of some corrosion and inspection themes reflects maturity in protective systems for steels and aluminum, the wider use of corrosion resistant composites in selected applications, and the standardization of testing protocols. The reason for this is that topics such as energy efficiency, composite materials, advanced welding technologies, and digitalization, which are on the current research agenda, have shifted the literature focus to more modern and innovative areas; this has caused a decrease in the research intensity of classical or established themes. It is thought that the main reason for the decrease in the research intensity of the corrosion topic is that many basic mechanisms and prevention methods have now become well understood and applicable, thanks to the studies carried out in this field for many years. On the other hand, the widespread search for new generation materials, such as composites in shipbuilding, has reduced the interest in the corrosion end, and shifted the research focus to more innovative material technologies. Overall, the thematic map operates as a material oriented indicator by locating where steels, aluminum alloys, and composite systems are being advanced, which properties are prioritized, and which earlier topics have reached engineering maturity.

4. Conclusions and recommendations

This study analyzes publications on shipbuilding materials in the Scopus database between 1970 and 2024 using bibliometric methods and interprets the findings through a material-themed literature review presented in the Introduction. The findings indicate that material selection in shipbuilding is driven by strength, weight, corrosion resistance, sustainability, and production efficiency, and that these priorities have evolved with advances in joining technologies, protective systems, and analytical modeling.

The bibliometric results reveal four dominant research themes: improving mechanical properties, increasing the use of composite materials, developing and applying welding and joining methods, and finite element-based structural analysis. The importance of steel and composites reflects both the historical role of steel in traditional shipbuilding and the relevance of composites to current performance and sustainability goals. Between 1970 and 1990, research focused on steel, welding technologies, and corrosion control. Between 1990 and 2010, aluminum alloys, surface coatings, and mechanical enhancements came to the fore. After 2010, the literature has expanded into the areas of composites, advanced joining, computational modeling, and the use of sustainable materials. China, Korea, and India stand out in terms of publication volume and international collaborations, and their universities and research institutes have been identified as making central contributions to knowledge generation.

Future research on shipbuilding materials should align with technological advancements and environmental goals. Priority areas include advanced composite systems, additive manufacturing, digital twin approaches, and smart ship structures. For steel and aluminum, which will continue to be central to commercial fleets, more evidence is needed on weldability, fatigue strength, and corrosion resistance under service conditions representative of the marine environment. While these findings confirm the growing interest in composites, they also indicate that performance evaluations under harsh and compound conditions remain limited. Therefore, research should expand long-term durability testing under combined mechanical, thermal, and environmental loads, address fire performance and toxicity, develop scalable and cost-effective production routes for large panels, and establish recycling and circularity benchmarks. Optimized ship-specific hybrid solutions, combining steel or aluminum with composites, deserve focused research under realistic loading and maintenance regimes. The material impacts of automation and crewless ship technologies should be examined, with an emphasis on lightweight, durable, and maintainable solutions for autonomous operations. Strengthening multinational and interdisciplinary collaborations will increase scientific impact and practical applicability in diverse maritime contexts. Finally, it is fair to note that future bibliometric

studies should extend beyond the scope of Scopus to include established journals in maritime history and technology, in order to fully represent regional and specialized contributions.

CRediT author statement

Dursun Murat Sekban: Conceptualization; Methodology; Investigation; Supervision; Project administration; Writing-Original Draft; Visualization. **Muhammet Berigel**: Software; Validation; Formal analysis. **Fatih Kirma**: Resources; Data Curation; Writing-Review & Editing.

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