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COMPREHENSIVE BIBLIOMETRIC ANALYSIS OF GLOBAL RESEARCH TRENDS IN HULL GIRDER FATIGUE STRENGTH IN NAVAL AND MARINE STRUCTURES

SVEOBUHVATNA BIBLIOMETRIJSKA ANALIZA TRENDOVA GLOBALNIH ISTRAŽIVANJA TRAJNE DINAMIČKE ČVRSTOĆE NOSAČA TRUPA MORNARIČKIH I MARINSKIH KONSTRUKCIJA

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Keywords
- bibliometric analysis
- research trends
- marine structures
- ship design
- scientometrics

Ključne reči
- bibliometrijska analiza
- trendovi istraživanja
- mornaričke konstrukcije
- projektovanje broda
- scijentometrika

Abstract

This study aims to identify the range of research trends by analysing bibliometric data in ship design and ship structure from 1990 to 2022 using the Scopus database. The findings are exported the same day to minimise differences between daily database updates. Only 'article' and 'review' are allowed as publication search types. Based on the sub-keywords: ship design, ship structures, and stiffened panels, a total of 1,279 publications (208 open access) written by 159 different authors are included in the analysis. Regarding the sub-keywords: ship reliability, hull girder, ultimate strength, and ship fatigue strength, 159 distinct authors have produced 1,774 publications (329 open access). To give a broad picture of the current state of peer-reviewed journals, this study's search of the Scopus database yielded 3.105 publications.

Izvod

Cilj ovog rada je identifikacija raspona trendova istraživanja analizom bibliometrijskih podataka projektovanja brodova i brodskih konstrukcija od 1990 do 2022, upotrebom baze Scopus. Rezultati su svedeni istog dana kako bi se umanjile razlike među dnevnim ažuriranjem baze podataka. Kao ključne reči za pretraživanja vrste publikacija, upotrebljene su 'članak' i 'pregledni'. Na osnovu pod-ključnih reči: projektovanje broda, brodske konstrukcije, i ukrućene ploče, analizom je obuhvaćeno ukupno 1279 publikacija (208 u otvorenom pristupu) od 159 autora. Razmatranjem pod-ključnih reči: pouzdanost broda, nosač trupa, zatezna čvrstoća, i dinamička čvrstoća broda, oko 159 autora ima 1774 radova (329 u otvorenom pristupu). Pretragom baze Scopus dolazi se do 3105 radova, kako bi se stekla šira slika trenutnog stanja recenziranih časopisa.

INTRODUCTION

A ship is a transportation vehicle that carries passengers and goods across oceans and other waterways, such as rivers and lakes. In addition to carrying cargo or passengers, ships can be used for special missions, such as defence, research, fishing, and trade. Ship transportation is responsible for the most significant portion of world trade.

For a ship to float, its weight must be less than the water displaced by the hull. Designing a boat includes various technical aspects, one of which is the strength of the structure and design of the ship itself /1/. Ship construction is an arrangement of stiffened panels that form the ship's space and protect the cargo or personnel from the surrounding environment. These technical aspects significantly influence a ship's reliability, which is its ability to operate safely and effectively over time without unexpected damage or failure.

Ship reliability and design are closely intertwined. A well-designed hull, for instance, can reduce the risk of damage, enhance fuel efficiency, and optimise the propulsion system. A well-designed ship is more reliable, ensuring safe and efficient operation over an extended period /2/. In other words, a well-designed ship increases reliability, allowing it to operate safely and efficiently over a long period. The reference that ensures the strength of the ship's structure is that the stress experienced by the structure under critical conditions must be smaller than the allowed stress of the material used.

Various parameters can be used to analyse the stress experienced by the ship, such as Hull Grider Ultimate Strength

(HGUS) and fatigue strength. HGUS is the maximum ability that the ship can withstand when subjected to longitudinal bending moment /3/. Fatigue strength is the ability of a ship to withstand loading for a certain number of cycles without failing. From this technical aspect, it can be concluded that research and bibliometric analysis of these supporting keywords are needed to obtain maximal results in ship design. This bibliometric analysis is also helpful for predicting further developments regarding ship design research in the period 2021-2030.

This review aims to conduct a bibliometric analysis and provides an overview of the current research landscape relating to the safety of ship structures, ship design, and various analytical parameters used to determine a ship's operability. Bibliometric analysis helps construe and map the evolutionary intricacies and scientific information that has accumulated in a particular domain by carefully organising large volumes of unstructured databases /4/. This review aims to summarise and provide a descriptive summary of the growth and distribution of literature on the topic.

METHODOLOGY

Six keywords are selected for this bibliometric analysis review: ship design and stiffened panels, ship structures, ship reliability, hull girder ultimate strength, and ship fatigue strength. A comprehensive bibliometric analysis is conducted using the six keywords to determine a descriptive summary of the growth and distribution of literature on the topic from 1990-2022. Then, from the six keywords, filtering is carried out according to the correlation between keywords; from filtering results, two strong keyword correlations are obtained, namely: ship design, ship structures and stiffened panels, and ship reliability, hull girder ultimate strength, and ship fatigue strength.

The results of filtering the two sub-keywords are then subjected to bibliometric analysis again to determine the development and distribution of literature on these keywords. Keyword data retrieval is carried out on the Scopus website on January 27, 2023 using the filter: '(KEY ('SHIP DESIGN' AND 'SHIP STRUCTURES' AND 'STIFFENED PANEL' ('EXCLUDE' (PUBYEAR, 1989) OR ('EXCLUDE' (PUBYEAR, 1987) OR ('EXCLUDE' (PUBYEAR, 1986) OR ('EXCLUDE' (PUBYEAR, 1985) OR ('EXCLUDE' (PUBYEAR, 1984) OR ('EXCLUDE' (PUBYEAR, 1983) OR ('EXCLUDE' (PUBYEAR, 1982) OR ('EXCLUDE' (PUBYEAR, 1981) OR ('EXCLUDE' (PUBYEAR, 1980) OR . . . . . OR ('LIMIT-TO' (PUBYEAR, 2008) OR ('LIMIT-TO' (PUB¬YEAR, 2007) OR ('LIMIT-TO' (PUBYEAR, 2006) OR ('LIMIT-TO' (PUBYEAR, 2005) OR ('LIMIT-TO' (PUB¬YEAR, 2004) OR ('LIMIT-TO' (PUBYEAR, 2003) OR ('LIMIT-TO' (PUBYEAR, 2002) OR ('LIMIT-TO' (PUB¬YEAR, 2001) OR ('LIMIT-TO' (PUBYEAR, 2000) OR ('LIMIT-TO' (PUBYEAR, 1999) OR ('LIMIT-TO' (PUB¬YEAR, 1998) OR ('LIMIT-TO' (PUBYEAR, 1997) OR ('LIMIT-TO' (PUBYEAR, 1996) OR ('LIMIT-TO' (PUB¬YEAR, 1995) OR ('LIMIT-TO' (PUBYEAR, 1994) OR ('LIMIT-TO' (PUBYEAR, 1993) OR ('LIMIT-TO' (PUB¬YEAR, 1992) OR ('LIMIT-TO' (PUBYEAR, 1991) OR ('LIMIT-TO' (PUBYEAR, 1990).

Due to the total number of document results not exceeding 2000 publications, the document results are then exported in a single batch, and all publications are downloaded on the same day to avoid daily differences/changes in the database. Data/document searches are only conducted in Scopus, as the Scopus website is the most prominent database/literature that can be accessed easily. In comparison, the Web of Science contains fewer input publications, while the OVID database has the limitation of not having a feature to determine the number of publication citations /5/.

Regarding publication type, only 'article' and 'review' are included in the search, and no additional search restrictions are applied. The bibliometric data collected are as follows: number of publications (total and per year), open access status, publications per journal, journal name and SNIP 2021, publication language, document type, country of publication, author affiliation, sponsored funding, most published author and most cited publication. Trends associated with this subset of publications are identified and presented. Bibliometric data is visualised using VOSviewer® software (version 1.6.19) /6/.

RESULTS AND DISCUSSION

This bibliometric analysis starts from 1990 to January 27, 2023. Based on sub-keywords: ship design, ship structures, and stiffened panels, 1,279 publications (208 open access) are published by 159 unique authors. As for the sub keywords: ship reliability, hull girder ultimate strength, and ship fatigue strength, there are 1,774 publications (329 open access) published by 159 unique authors. These publications trended upward from 2000 to 2010 but decreased in 2011 and reached the highest publication peak in 2015, after which these publications decreased in 2019 and increased again in 2022. Figure 1 displays the number of publications (total keywords) published from 1990 to 2022. The three journals with the highest number of publications in sub keywords: ship design and stiffened panels, ship structures are *Thin Wall Structures* (n = 84), *Marine Structures* (n = 71), and *Ocean Engineering* (n = 61). Meanwhile, the three journals with the highest number of publications for sub-keywords: ship reliability, hull girder ultimate strength, and ship fatigue strength are *Ocean Engineering* (n = 68), *Marine Structures* (n = 41), *Ships, and Offshore Structures* (n = 23). The 2021 SNIP of journals in the sub-keywords: ship design and stiffened panels, ship structures, ranged from 0.448 to 2.406, while the 2021 SNIP of journals in sub-keywords: ship reliability, hull girder ultimate strength, and ship fatigue strength ranged from 0.031 to 2.406.

Table 1 provides a full breakdown of journals analysed, including full journal title, 2021 SNIP, number of papers published, and 2021 Cite score. The subject areas with the highest publication volume for sub-keywords: ship design and stiffened panels, ship structures, are *Engineering* (n = 1,214), *Materials Science* (n = 361), and *Environmental Science* (n = 113). By far, the most widely used publication language is English (n = 1,246), followed by Chinese (76) and Italian (2). Meanwhile, Table 2 provides a full breakdown of the analysed journals, including full journal title, 2021 SNIP, number of publications published, and 2021 Cite

score. Subject areas with the highest publication volume for sub-keywords: ship reliability, hull girder ultimate strength, and ship fatigue strength are *Engineering* (n = 1,540), *Materials Science* (n = 441), *Energy* (n = 224). The most widely used languages are English (1,667), Chinese (102), Croatian, German, Russian (3).

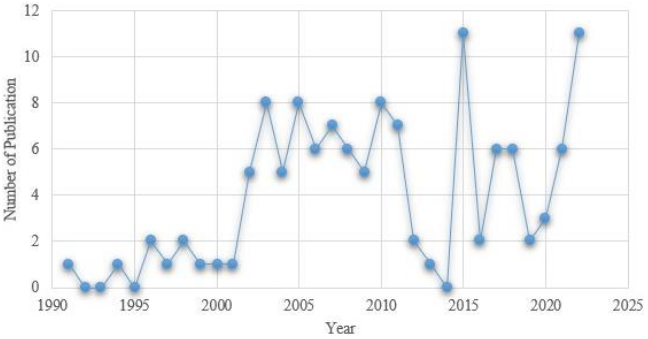

Figure 1. Number of publications (total keywords) published from 1990 to 2022.

Table 3 lists top three authors in categories of ship design, ship structures, and stiffened panels based on findings of a bibliometric study conducted using the Scopus database. C. Guedes Soares is ranked first with 88 publications. Meanwhile, Table 4 lists three most productive authors across ship reliability, ship ultimate strength, and ship fatigue strength, based on findings of a bibliometric study conducted using Scopus database. C. Guedes Soares is ranked first with 152 papers.

Based on the results of bibliometric analysis using the Scopus database, Table 5 shows the three highest cited in fields of ship design, ship structures, and stiffened panels, with *Liquid sloshing dynamics* by R.A. Ibrahim (in 2005). It ranks first with a total of 872 citations received. Meanwhile, Table 6 displays the ten most referenced works in the fields of ship ultimate strength and ship fatigue strength according to the findings of bibliometric study conducted using the Scopus database, with *Guide to Stability Design Criteria for Metal Structures*, 6th Ed. by R.D. Ziemian (in 2010). It is placed first, with 599 citations received overall.

Figures 2-4 illustrate bibliometric series compiled and visualised through VOSviewer. Figure 2 illustrates the co-authorship analysis of ten most productive countries. In the co-authorship analysis, the attachment relationship between articles is based on the number of co-authored publications.

Figure 3 describes the co-occurrence analysis of all publications' 100 most frequently used author keywords. In the co-occurrence analysis, the association between articles is based on the number of papers published together. Figure 4 explains the citation analysis of 100 most cited authors. In citation analysis, the association between articles is based on how often they cite each other. As a result, the present study will be the first of its kind, and it will use both quantitative and qualitative analyses to assess the recent trends in ship structures and design and conclude future expansion.

Table 1. Characteristics of 3 journals having published the highest number of papers on ship design, ship structures, and stiffened panel.

Journal name	Number of papers	SNIP 2021	Name of the publisher	Subject area (Scopus)	CiteScore 2021
Thin Wall Structures	84	1.979	Elsevier	Engineering: Civil and Structural Engineering; Engineering: Mechanical Engineering; Engineering: Building and Construction	7.7
Marine Structures	71	2.302	Elsevier	Engineering: Ocean Engineering; Engineering: Mechanical Engineering; Engineering: Mechanics of Materials; Materials Science: General Materials Science	6.7
Ocean Engineering	61	2.095	Elsevier	Engineering: Ocean Engineering; Environmental Science: Environmental Engineering	6.5

Table 2. Characteristics of 10 journals having published the highest number of papers on ship reliability, hull girder ultimate strength, and ship fatigue strength.

Journal name	Number of papers	SNIP 2021	Name of publisher	Subject area (Scopus)	CiteScore 2021
Ocean Engineering	68	2.095	Elsevier	Engineering: Ocean Engineering; Environmental Science: Environmental Engineering	6.5
Marine Structures	41	2.302	Elsevier	Engineering: Ocean Engineering; Engineering: Mechanical Engineering; Engineering: Mechanics of Materials; Materials Science: General Materials Science	6.7
Ships and Offshore Structures	23	1.324	Taylor & Francis	Engineering: Mechanical Engineering; Engineering: Ocean Engineering	3.8

Table 3. Three most productive authors across ship design, ship structure, and stiffened panel publications.

Author name	Number of papers	Number of articles published	Number of citations received	Institution	Country
Guedes Soares, C.	88	60	42.142	Instituto Superior Técnico	Portugal
Paik, J.K.	33	27	8.257	University College London	United Kingdom
Garbatov, Y.	25	15	5.511	Universidade de Lisboa	Portugal

Table 4. Three most productive authors across of ship reliability, ship ultimate strength, and ship fatigue strength.

Author name	Number of papers	Number of articles published	Number of citations received	Institution	Country
Guedes Soares, C.	152	85	42.142	Instituto Superior Técnico	Portugal
Garbatov, Y	83	45	5.511	Universidade de Lisboa	Portugal
Parunov, J.	42	21	1.468	University of Zagreb	Croatia

Table 5. Three highest cited ship design, ship structure, and stiffener panel publications.

Title	Author(s)	Year	Source title	Number of citations received	Reference
Liquid sloshing dynamics	Ibrahim, R.A.	2005	Liquid Sloshing Dynamics 9780521838856, pp.1-948	872	/7/
Computational models for Sandwich panels and shells	Noor, A.K., Burton, W.S., Bert, C.W.	1996	Applied Mechanics Reviews 49(3), pp.155-199	707	/8/
Fatigue assessment of welded joints by local approaches: 2nd Ed.	Radaj, D., Sonsino, C.M., Fricke, W.	2006	Fatigue Assessment of Welded Joints by Local Approaches: 2nd Ed., pp.1-639	670	/9/

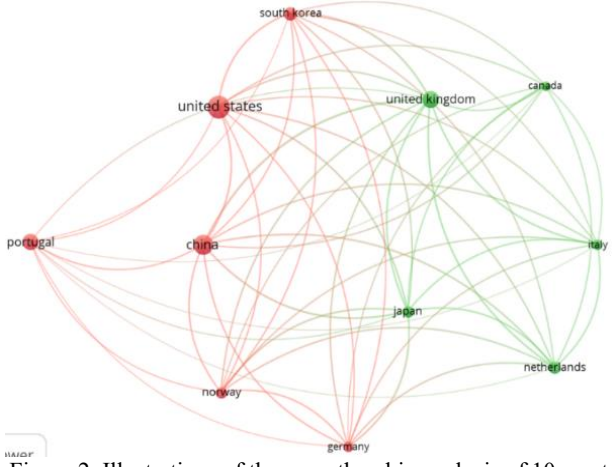

Figure 2. Illustrations of the co-authorship analysis of 10 most productive countries.

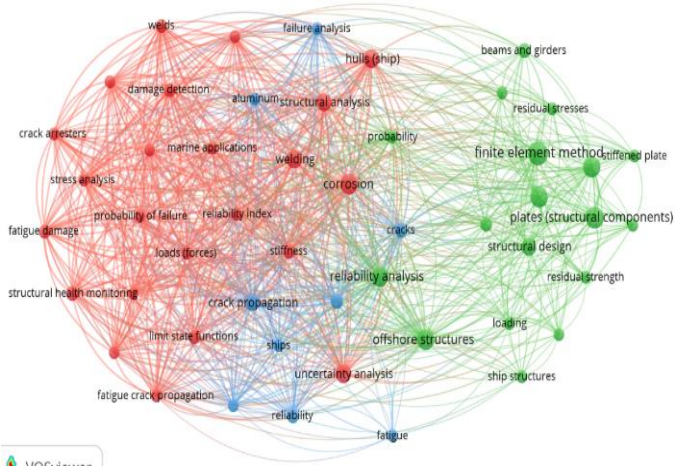

Figure 3. Descriptions of co-occurrence analysis of 100 most frequently used author keywords in all publications.

Table 6. Three highest cited of ship ultimate strength, and ship fatigue strength publications.

Title	Author(s)	Year	Source title	Number of citations received	Reference
Guide to Stability Design Criteria for Metal Structures: 6th Ed.	Ziemian, R.D.	2010	Guide to Stability Design Criteria for Metal Structures: 6th Ed.	599	/10/
Life-cycle performance, management, and optimisation of structural systems under uncertainty: Accomplishments and challenges	Frangopol, D.M.	2011	Structure and Infrastructure Engineering 7(6), pp. 389-413	436	/11/
Strengthening of steel structures with fibre-reinforced polymer composites	Teng, J.G., Yu, T., Fernando, D.	2012	Journal of Constructional Steel Research 78, pp. 131-143	433	/12/

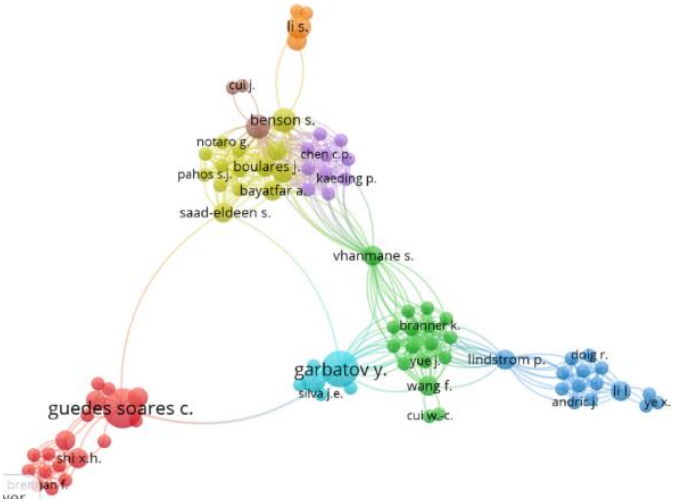

Figure 4. Illustrations of citation analysis of 100 most cited authors.

Figures 5 to 9 show the co-authorship analyses of the 30 most productive countries/regions on each keyword. Figure 5 shows the co-authorship analysis of the 30 most productive countries on ship design and stiffened panel. Figure 6 shows the co-authorship analysis of the 30 most productive countries on ship ultimate strength. Figure 7 shows the co-authorship analysis of the 30 most productive countries on ship reliability. Figure 8 shows the co-authorship analysis of the 30 most productive countries on ship fatigue strength. Figure 9 shows the co-authorship analysis of the 30 most productive countries on ship structures.

Figures 10 to 14 illustrate the bibliometric series compiled and visualised through VOSviewer software. Figure 10 shows the co-occurrence analysis of the 100 most frequent author keywords on ship design and stiffened panel. Figure 11 shows the co-occurrence analysis of the 100 most frequent author keywords on ship ultimate strength. Figure 12 shows the co-occurrence analysis of the 100 most frequent author keywords in ship reliability. Figure 13 shows the co-occurrence analysis of the 100 most frequent author keywords in ship fatigue strength. Figure 14 shows the co-occurrence analysis of the 30 most productive countries on ship structures.

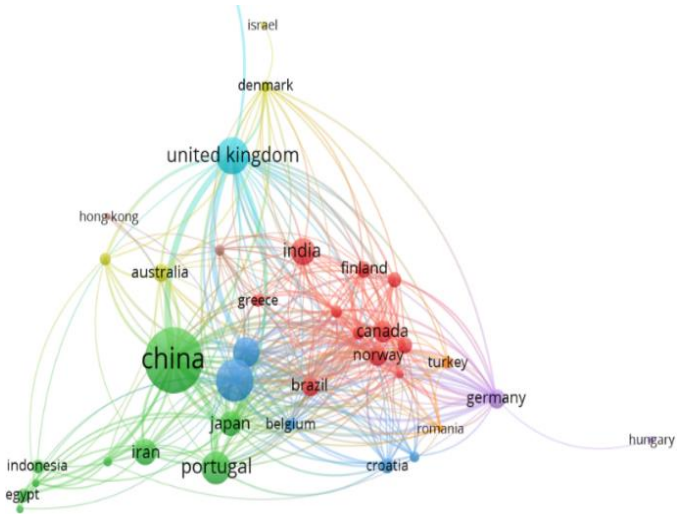

Figure 5. Co-authorship analysis of 30 most productive countries on ship design and stiffened panel.

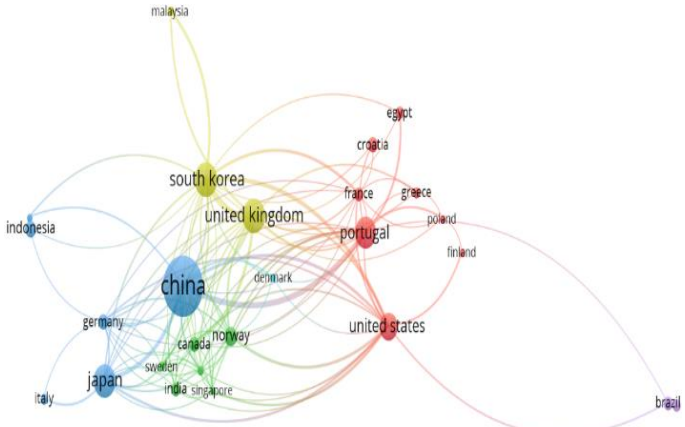

Figure 6. Co-authorship analysis of 30 most productive countries on ship ultimate strength.

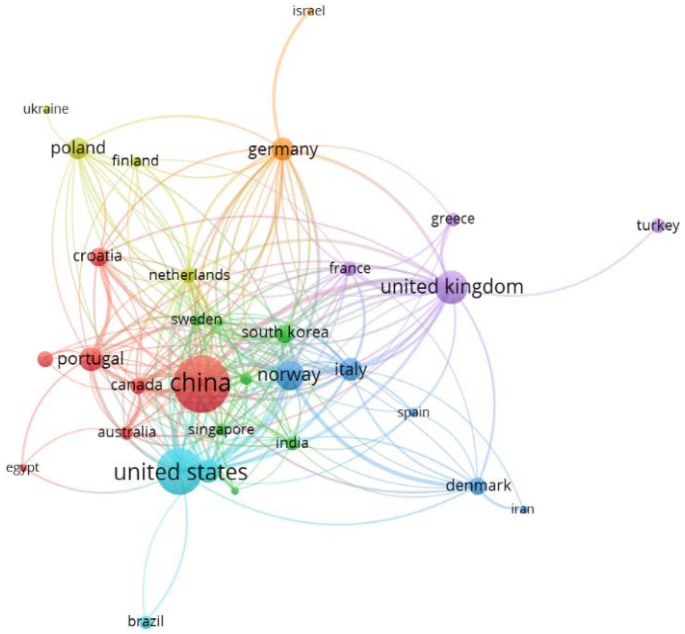

Figure 7. Co-authorship analysis of 30 most productive countries on ship reliability.

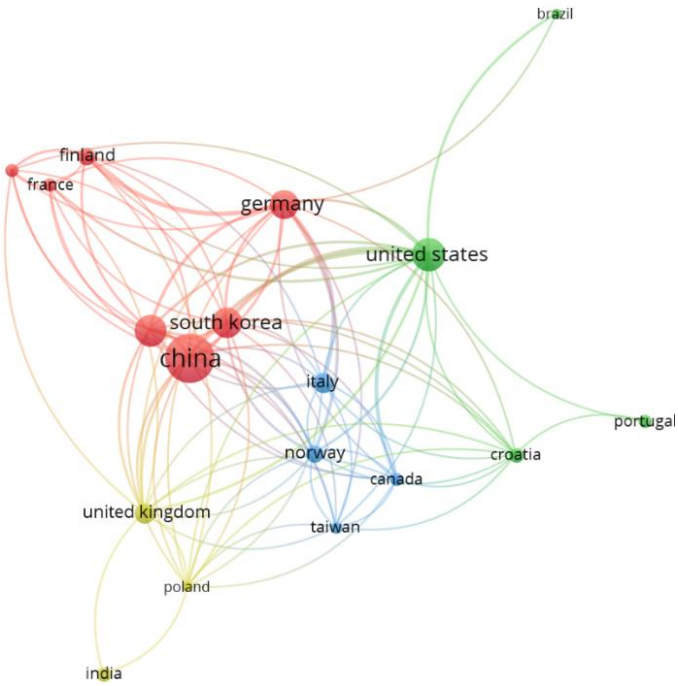

Figure 8. Co-authorship analysis of 30 most productive countries on ship fatigue strength.

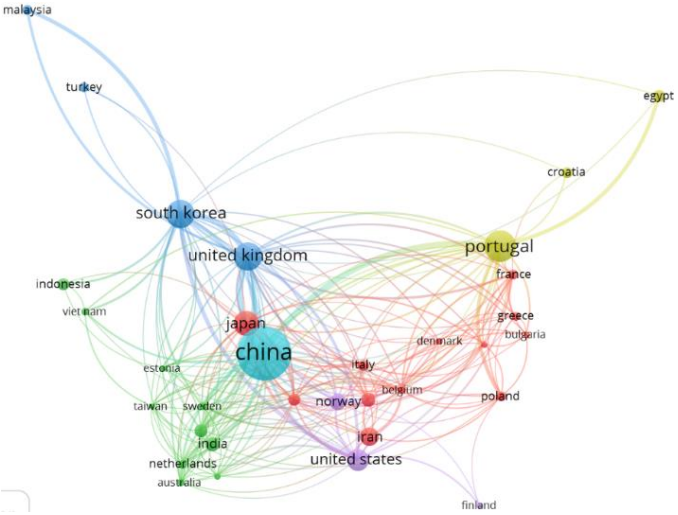

Figure 9. Co-authorship analysis of 30 most productive countries on ship structures.

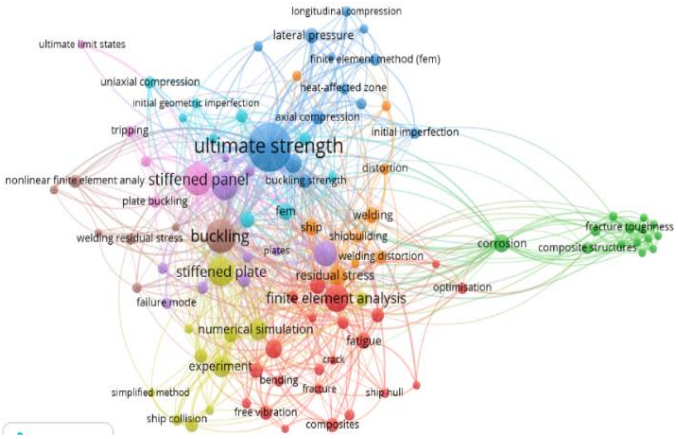

Figure 10. Co-authorship analysis of 30 most productive countries on ship structures.

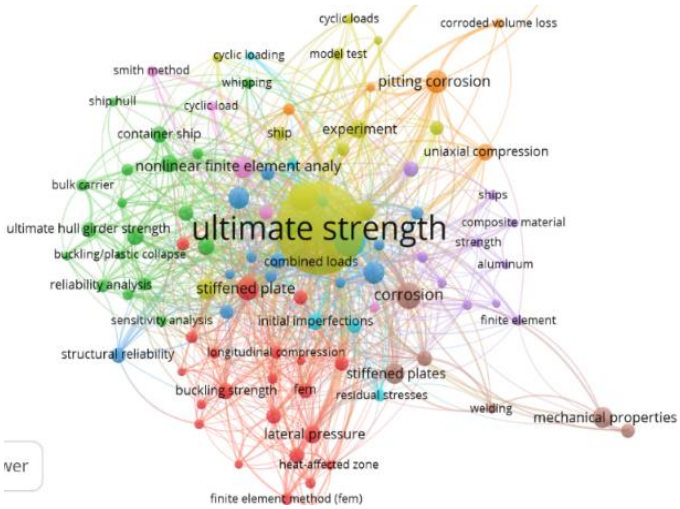

Figure 11. Co-occurrence analysis of 100 most frequent author keywords ship on ultimate strength.

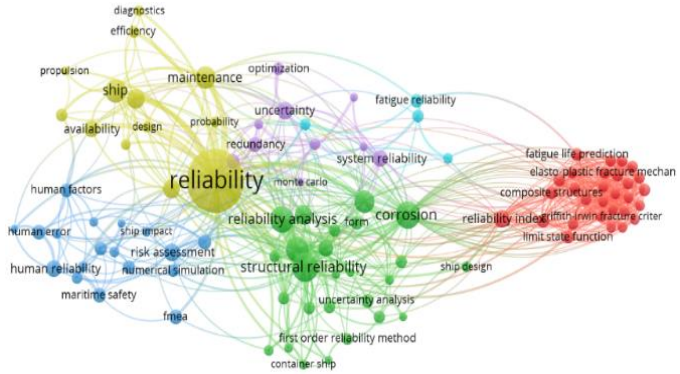

Figure 12. Co-occurrence analysis of 100 most frequent author keywords on ship reliability.

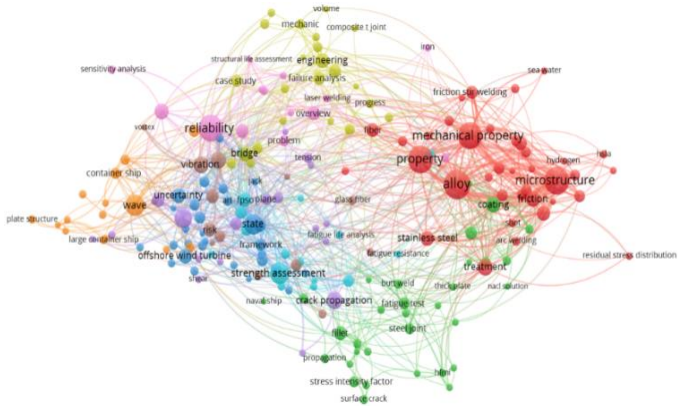

Figure 13. Co-occurrence analysis of 100 most frequent author keywords on ship fatigue strength.

Figures 15-19 illustrate the bibliometric series compiled and visualised through VOSviewer software on citation analysis of the 50 most cited authors. Figure 15 shows the citation analysis of the 50 most cited authors in ship design and stiffened panel. Figure 16 shows the citation analysis of the 50 most cited authors in ship ultimate strength.

Figure 17 shows the citation analysis of the 50 most cited authors in ship reliability. Figure 18 shows the citation analysis of the 50 most cited authors in ship fatigue strength. Figure 19 shows the citation analysis of the 50 most cited authors in ship structures.

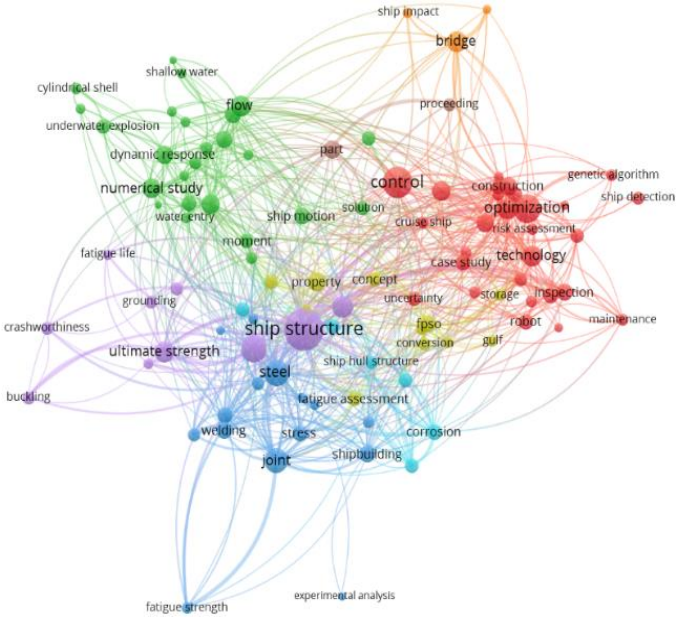

Figure 14. Co-occurrence analysis of 100 most frequent author keywords on ship structures.

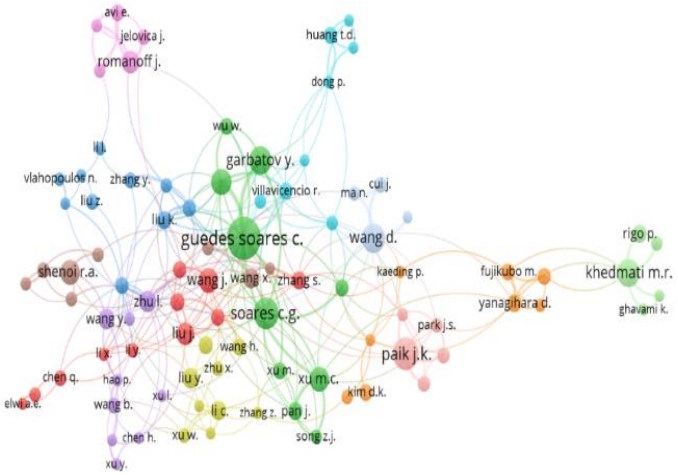

Figure 15. Citation analysis of 50 most cited authors on ship design and stiffened panel.

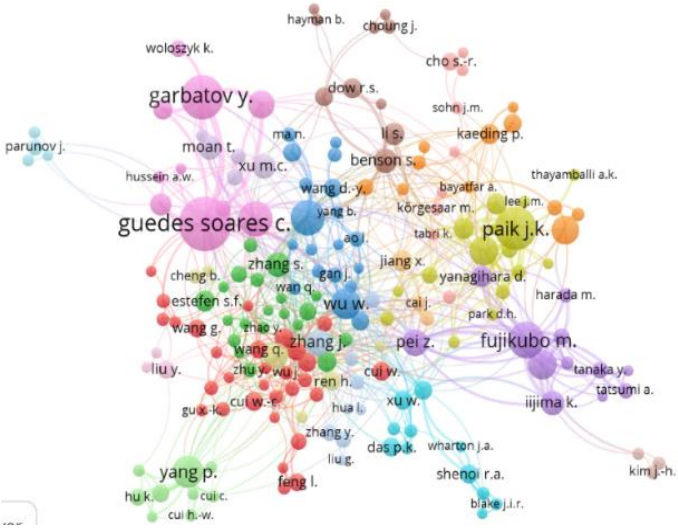

Figure 16. Citation analysis of 50 most cited authors on ship ultimate strength.

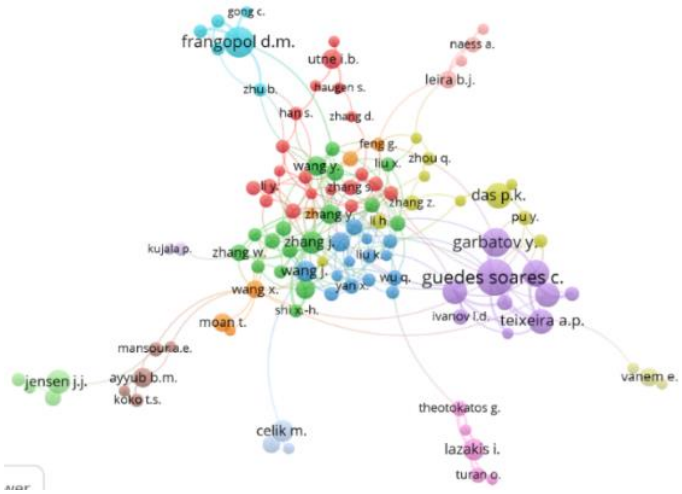

Figure 17. Citation analysis of 50 most cited authors on ship reliability.

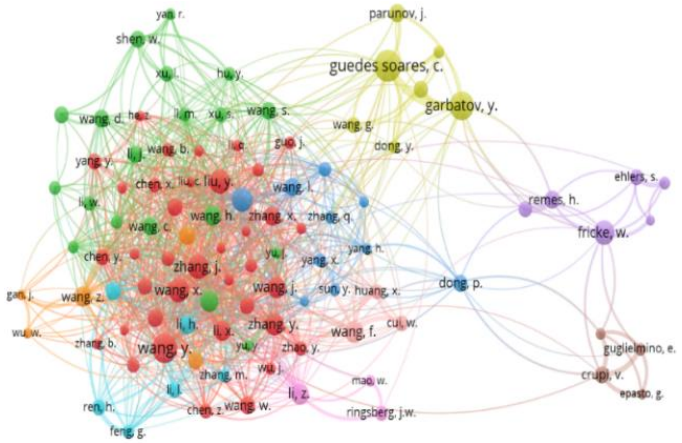

Figure 18. Citation analysis of 50 most cited authors on ship fatigue strength.

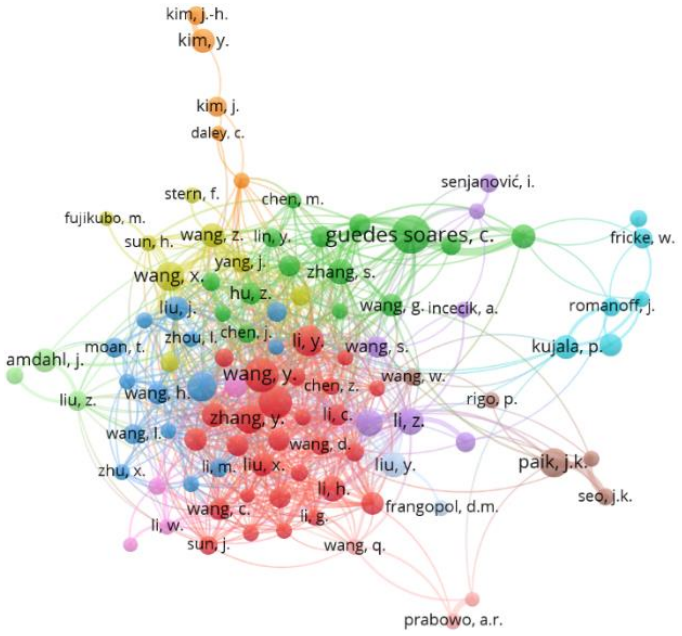

Figure 19. Citation analysis of 50 most cited authors on ship structures.

DISCUSSIONS

This study aims to perform a bibliometric analysis that provides an overview of the current landscape of peer-reviewed publications in ship structures and design research. The Scopus database search retrieved 3,105 (total keyword) publications. The present analysis of ship design and stiffened panels, ship structures, determined that 410 publications originated from China, making it the country with the highest publication count in this sub-keyword, followed by the United States and the United Kingdom with 187 and 137 publications, respectively. Thus, the present analysis for the keywords ship reliability, hull girder ultimate strength, and ship fatigue strength determined that 565 publications originated from China, making it the country with the highest publication count in the field of this sub-keyword, followed by the United States and the United Kingdom with 242 and 197 publications, respectively.

On the other hand, most publications are written in English, and Chinese is the second most common language. Among the top 9 affiliated institutions that are involved in the publication of this research, the top three institutional affiliations of sub-keyword ship design, ship structures, and stiffened panel, are Universidade de Lisboa (100), Instituto Superior Técnico (96), Shanghai Jiao Tong University (69), and thus the top three institutional affiliation of sub keyword ship reliability, hull girder ultimate strength, and ship fatigue strength are Instituto Superior Técnico (177), Universidade de Lisboa (173), Shanghai Jiao Tong University (77). As a quantitative research methodology, bibliometric analysis uses statistical methods to identify the characteristics of scientific publications and determine the correlation or relationship between existing keywords.

PRESSURE DISTRIBUTION

In comparative literature, it's important to highlight some bibliometric studies focused on different subjects linked to the keywords. The research explores how research trends on ships at the end of their life have evolved over the past thirty years. This investigation collected data on different approaches to breaking and recycling ships and essential laws that assist in managing end-of-life (EOL) vessels /13/. The keyword ‘ship recycling’ reduces the number of documents to 72. Thus, for bibliometric analysis, 71 documents are considered for shipbreaking, and 72 are considered for ship recycling. In conclusion, this study also assessed EOL ship research trends from 1991 to 2021 through a systematic review with bibliometric analysis with the Scopus database. For the systematic review, the topmost relevant publications are evaluated, and the key findings are compiled to determine the overall status of their contributions to shipbreaking and ship recycling research. Based on the comparative study of existing literature, there is a difference between the topics discussed: end-of-life ship research, which refers to ship recycling, and ship breaking. At the same time, this review raises the topic of ship design and ship structures which refers to six total keywords, namely: ship design /14-17/, stiffened panels /18-21/, ship structures /22-25/, ship reliability /26-29/, hull girder ultimate strength /30-33/, and ship fatigue strength /34-37/. A bibliometric analysis is conducted from the six keywords to determine a descriptive summary of the growth and distribution of literature on the topic from 1990-2022. The purpose of this study is to conduct a bibliometric analysis that provides an overview of the publication landscape

that has been reviewed from the last three decades in the field of ship structure and design research, as well as identifying and finding correlation relationships between keywords, making this journal the first in finding research gaps in the field of ship structure and design research. Future research directions that might serve as a roadmap for further research development on this topic are discovered.

STRENGTH AND LIMITATIONS

This bibliometric study has several important strengths. First, the characteristics of 3,105 publications are collected. Second, the review has six keywords analysed using bibliometric methods, making it possible to search for research gaps and find correlations between keywords in ship structure and design over the last three decades. Compared to other well-known academic databases, such as the Web of Science, Scopus is chosen due to its more extensive publication coverage /38-51/. However, despite its advantages, this database may fail to capture all the existing literature that could have been found had we expanded our search to include other databases. Attempts to reduce this limitation will incur additional complexity that hinders the ability to analyse search results efficiently, such as deduplicating many publications. Another potential limitation stems from the lack of manual filtering for search results, mitigated by the chosen search strategy.

There are also problems in the analysis of bibliometric authors. Namely, two different naming sources exist for Guedes Soares C. and C. Guedes Soares. Therefore, in the bibliometric study, authors are combined into one naming, which is C. Guedes Soares. Publications about keywords, for example, ship reliability is likely to include one of the following search sources containing the term 'ship' or 'reliability' and these same search strings rarely refer to non-ship reliability publication. Observations from initial searches have shown that it is rare for authors using these terms to incorporate these words into the titles of their articles.

CONCLUSIONS

The study identifies characteristics of 3.105 publications and represents the first bibliometric analysis published on ship structure and ship design research. Countries with the highest number of publications are China, United States, and United Kingdom. This study recognises the progressive paradigm of ship design and structure, develops a network, and plots the accumulative research data. The research has set foundations for valuable future research and development of meaningful conduct as it enables researchers to obtain the status of the research area and identify gaps in available literature. Therefore, the study provides a collection of results, areas where further research is needed, and potential pathways for future research which can provide a valuable overview for improving research.

REFERENCES

1. Lindstad, E., Stokke, T., Alteskjær, A., et al. (2022), *Ship of the future - A slender dry-bulker with wind assisted propulsion*, Marit. Transp. Res. 3: 100055. doi: 10.1016/j.martra.2022.100055
2. Tran, T.G., Kim, H.C. (2024), *New approaches to assess and improve ship operating performance*, Int. J Nav. Archit. Ocean Eng. 16: 100607. doi: 10.1016/j.ijnaoe.2024.100607
3. Qi, Z., Hongqi, Y., Huan, Z., et al. (2022), *Ultimate strength assessment of hull structural plates with general corrosion based on fractal theory*, Ocean Eng. 245: 110417. doi: 10.1016/j.oceaneng.2021.110417
4. Ng, J.Y., Chiong, J.D., Liu, M.Y.M., Pang, K.K.Y. (2023), *Characteristics of the Echinacea Spp. research literature: A bibliometric analysis*, Eur. J Integr. Med. 57: 102216. doi: 10.1016/j.eujim.2022.102216
5. Campos-Asensio, C. (2018), *How to develop a bibliographic search strategy*, Enferm. Intensiva, 29(4): 182-186. doi: 10.1016/j.enfi.2018.09.001
6. Du, Q., Zhao, R., Wan, Q., et al. (2024), *Protocol for conducting bibliometric analysis in biomedicine and related research using CiteSpace and VOSviewer software*, STAR Protoc. 5(3): 103269. doi: 10.1016/j.xpro.2024.103269
7. Ibrahim, R.A., Liquid Sloshing Dynamics: Theory and Applications, Cambridge University Press, 2009. doi: 10.1017/CBO9780511536656
8. Noor, A.K., Burton, W.S., Bert, C.W. (1996), *Computational models for sandwich panels and shells*, Appl. Mech. Rev. 49(3): 155-199. doi: 10.1115/1.3101923
9. Radaj, D., Sonsino, C.M., Fricke, W., Fatigue Assessment of Welded Joints by Local Approaches, 2nd Ed., Woodhead Publishing, 2006. ISBN 978-1-85573-948-2
10. Ziemian, R.D. (Ed.), Guide to Stability Design Criteria for Metal Structures, John Wiley & Sons, Inc., 2010. doi: 10.1002/9780470549087
11. Frangopol, D.M. (2011), *Life-cycle performance, management, and optimisation of structural systems under uncertainty: accomplishments and challenges*, Struct. Infrastruct. Eng. 7(6): 389-413. doi: 10.1080/15732471003594427
12. Teng, J.G., Yu, T., Fernando, D. (2012), *Strengthening of steel structures with fiber-reinforced polymer composites*, J Constr. Steel Res. 78: 131-143. doi: 10.1016/j.jcsr.2012.06.011
13. Mannan, B., Rizvi, M.J., Dai, Y.M. (2023), *Does end-of-life ships research trends change in last three decades? A review for the future roadmap*, J Int. Marit. Safety, Environ. Aff. Shipp. 7(1): 2187603. doi: 10.1080/25725084.2023.2187603
14. Bram, S., Burgén, J., Dederichs, A.S., Hedvall, P.O. (2025), *No one left behind: A universal design analysis of ship evacuation*, Appl. Ergonom. 123: 104406. doi: 10.1016/j.apergo.2024.104406
15. Rinauro, B., Begovic, E., Mauro, F., Rosano, G. (2024), *Regression analysis for container ships in the early design stage*, Ocean Eng. 292: 116499. doi: 10.1016/j.oceaneng.2023.116499
16. Rahmaji, T., Prabowo, A.R., Tuswan, T., et al. (2022), *Design of fast patrol boat for improving resistance, stability, and seakeeping performance*, Designs, 6(6): 105. doi: 10.3390/designs6060105
17. Bahatmaka, A., Fitriyana, D.F., Anis, S., et al. (2024), *Analytical review of numerical analysis in hydrodynamic performance of the ship: Effect to hull-form modifications*, Mek. Maj. Ilm. Mek. 23(1): 54-63. doi: 10.20961/mekanika.v23i1.83635
18. Prabowo, A.R., Ridwan, R., Muttaqie, T. (2022), *On the resistance to buckling loads of idealized hull structures: FE analysis on designed-stiffened plates*, Designs, 6(3): 46. doi: 10.3390/designs6030046
19. Psihoyos, H., Fotopoulos, K., Lampeas, G., et al. (2024), *Development of a numerical methodology for the analysis of the post-buckling and failure behavior of butt-joint stiffened thermoplastic composite panels*, Eng. Fail. Anal. 160: 108193. doi: 10.1016/j.engfailanal.2024.108193
20. Mancini, F., Remes, H., Romanoff, J. (2024), *On the modelling of distorted thin-walled stiffened panels via a scale reduction*

approach for a simplified structural stress analysis, Thin-Wall. Struct. 197: 111637. doi: 10.1016/j.tws.2024.111637
21. Ridwan, R., Sudarno, S., Nubli, H., et al. (2023), *Numerical analysis of openings in stiffeners under impact loading: Investigating structural response and failure behavior*, Mek. Maj. Ilm. Mek. 22(2): 115-125. doi: 10.20961/mekanika.v22i2.76774
22. Mahmood, S.L., Haddara, M.R., Seshadri, R. (2010), *Lower bound limit loads of ship structure components using the m_α-tangent method based on single linear elastic analysis*, Ocean Eng. 37(13): 1139-1148. doi: 10.1016/j.oceaneng.2010.05.003
23. Prabowo, A.R., Ridwan, R., Braun, M., et al. (2023), *Comparative study of shell element formulations as NLFE parameters to forecast structural crashworthiness*, Curv. Layer. Struct. 10 (1): 20220217. doi: 10.1515/cls-2022-0217
24. Valtonen, V., Bond, J., Hindley, R. (2020), *Improved method for non-linear FE analysis of polar class ship primary structures*, Mar. Struct. 74: 102825. doi: 10.1016/j.marstruc.2020.102825
25. Fuadi, A.P., Muttaqie, T., Nugroho, A.C.P.T., et al. (2024), *Patrol boat strengthening against a collision with COLL notation based on class rules and regulation in Indonesia - An overview*, Mek. Maj. Ilm. Mek. 23(1): 1-11. doi: 10.20961/mekanika.v23i1.74967
26. Dong, Y., Garbatov, Y., Soares, C.G. (2021), *Strain-based fatigue reliability assessment of welded joints in ship structures*, Mar. Struct. 75: 102878. doi: 10.1016/j.marstruc.2020.102878
27. Omidali, M., Khedmati, M.R. (2018), *Reliability-based design of stiffened plates in ship structures subject to wheel patch loading*, Thin-Walled Struct. 127: 416-424. doi: 10.1016/j.tws.2018.02.022
28. Liu, Y., Frangopol, D.M. (2018), *Time-dependent reliability assessment of ship structures under progressive and shock deteriorations*, Reliab. Eng. Syst. Safety, 173: 116-128. doi: 10.1016/j.ress.2018.01.009
29. Moan, T., Ayala-Uraga, E. (2008), *Reliability-based assessment of deteriorating ship structures operating in multiple sea loading climates*, Reliab. Eng. Syst. Safety, 93(3): 433-446. doi: 10.1016/j.ress.2006.12.008
30. Faqih, I., Adiputra, R., Prabowo, A.R., et al. (2023), *Hull girder ultimate strength of bulk carrier (HGUS-BC) evaluation: Structural performances subjected to true inclination conditions of stiffened panel members*, Results Eng. 18: 101076. doi: 10.1016/j.rineng.2023.101076
31. Aydin, M. (2023), *An analysis of human error and reliability in the operation of fixed CO_2 systems on cargo ships using HEART Dempster-Shafer evidence theory approach*, Ocean Eng. 286 (Part 2): 115686. doi: 10.1016/j.oceaneng.2023.115686
32. Kovač, M., Tadić, S., Krstić, M., et al. (2023), *Stochastic financial evaluation: The case of an intermodal terminal*, Sust. Fut. 5: 100104. doi: 10.1016/j.sftr.2022.100104
33. Akyuz, E., Celik, M. (2015), *A methodological extension to human reliability analysis for cargo tank cleaning operation on board chemical tanker ships*, Safety Sci. 75: 146-155. doi: 10.1016/j.ssci.2015.02.008
34. Fajri, A., Prabowo, A.R., Muhayat, N. (2022), *Assessment of ship structure under fatigue loading: FE benchmarking and extended performance analysis*, Curv. Layer. Struct. 9(1): 163-186. doi: 10.1515/cls-2022-0014
35. Tasdemir, A., Nohut, S. (2012), *Fatigue analysis of ship structures with hinged deck design by finite element method. A case study: Fatigue analysis of the primary supporting members of 4900 PCTC*, Mar. Struct. 25(1): 1-12. doi: 10.1016/j.marstruc.2011.09.001
36. Chulahwat, A., Mahmoud, H. (2023), *Entropy-based framework for optimal life-cycle management of multiple fatigue cracks in ship structures*, Struct. Safety, 105: 102379. doi: 10.1016/j.strusafe.2023.102379
37. Magoga, T., Ojeda, R., Cannon, S., Thomas, G. (2019), *Interdependencies between variables in fatigue analysis of a weight-optimised naval ship*, Proc. Struct. Integr. 22: 267-274. doi: 10.1016/j.prostr.2020.01.034
38. Wilke, D., Grewe, C., Thavathilakarjah, D., et al. (2023), *Method engineering - a systematic literature review on Scopus base*, Proc. CIRP, 120: 1636-1641. doi: 10.1016/j.procir.2024.06.001
39. Meyers, S.D., Azevedo, L., Luther, M.E. (2021), *A Scopus-based bibliometric study of maritime research involving the Automatic Identification System*, Transp. Res. Interdisc. Persp. 10: 100387. doi: 10.1016/j.trip.2021.100387
40. Zavadskas, E.K., Skibniewski, M.J., Antucheviciene, J. (2014), *Performance analysis of Civil Engineering Journals based on the Web of Science® database*, Arch. Civ. Mech. Eng. 14(4): 519-527. doi: 10.1016/j.acme.2014.05.008
41. Faizatama, A.M., Firdaus, N., Adiputra, R., et al. (2025), *Mooring stress analysis of OC3-Hywind floating platform with variation anchor placement*, Struct. Integr. Life, 25(2): 193-202. doi: 10.69644/ivk-2025-02-0193
42. Utama, A.M.A., Adiputra, R., Prabowo, A.R., et al. (2025), *Toward ultimate bending moment of marine-based structures: mesh convergence study using the MST-3 box girder*, Struct. Integr. Life 25(2): 203-212. doi: 10.69644/ivk-2025-02-0203
43. Prabowo, A.R., Yusuf, T.F., Adie, P.W., et al. (2025), *Engineered novel-mechanical design and performance assessment of stiffened plates against ballistic loading*, Struct. Integ. Life 25(1): 89-98. doi: 10.69644/ivk-2025-01-0089
44. Firdaus, M.I., Adiputra, R., Prabowo, A.R. (2025), *Empirical formulation for assessing the ultimate strength of ship hull plates under geometrical imperfection*, Struct. Integr. Life 25 (1): 79-88. doi: 10.69644/ivk-2025-01-0079
45. Anastasovska, E., Doncheva, E., Zdraveski, F. (2024), *A review study on hydrogen embrittlement of steel*, Struct. Integr. Life 24(3): 277-281. doi: 10.69644/ivk-2024-03-0277
46. Leshchinskii, L., Ivanov, V., Lavrova, E., et al. (2024), *Fracture resistance of the deposited metal under dynamic and cyclic loading*, Struct. Integr. Life 24(2): 187-192. doi: 10.69644/ivk-2024-02-0187
47. Krausz, T., Popa, C.F., Galațanu, S.V., Marșavina, L. (2023), *Numerical and experimental study for polycarbonate composites under static and dynamic tests*, Struct. Integr. Life 24(3): 251-256.
48. Prabowo, A.R., Bae, D.M., Sohn, J.M., et al. (2017), *Effects of the rebounding of a striking ship on structural crashworthiness during ship-ship collision*, Thin-Wall. Struct. 115: 225-239. doi: 10.1016/j.tws.2017.02.022
49. Prabowo, A.R., Ridwan, R., Tuswan, T., et al. (2022), *Forecasting the effects of failure criteria in assessing ship structural damage modes*, Civil Eng. J. 8(10): 2053-2068. doi: 10.28991/CEJ-2022-08-10-03
50. Hanif, M.I., Adiputra, R., Prabowo, A.R., et al. (2023), *Assessment of the ultimate strength of stiffened panels of ships considering uncertainties in geometrical aspects: Finite element approach and simplified formula*, Ocean Eng. 286(Part 1): 115522. doi: 10.1016/j.oceaneng.2023.115522
51. Lutfi, Y.M., Adiputra, R., Prabowo, A.R., et al. (2023), *Assessment of the stiffened panel performance in the OTEC seawater tank design: Parametric study and sensitivity analysis*. Theor. Appl. Mech. Lett. 13(4): 100452. doi: 10.1016/j.taml.2023.100452