# From Safe-Life to Damage-Tolerant Design: A Scientometric Mapping of Fatigue and Fracture Mechanics Research (2015–2025)

P. Sammaiah[1], K. Poongodi[2], Shirisha Balle[3*]

[1]Department of Mechanical Engineering, SR University, Warangal-506371, Telangana, India
[2]Department of Civil Engineering, SR University, Warangal-506371, Telangana, India
[3*]Center for Informetrics and statistics, SR University, Warangal-506371, Telangana, India

1pullasammaiah@sru.edu.in; 2k.poongodi@sru.edu.in;
3*shirishaballe10@gmail.com

**Abstract.** The idea of fatigue and fracturing mechanics has always been primary in the safety and reliability of structural and mechanical systems, and over the past few years, there has been a paradigm shift between the conventional safe-life design and the damage-tolerant design. This paper intends to review and map the research area of fa-tigue and fracture mechanics between 2015 and 2025 with an aim of providing an insight into the emerging trends, global inputs and trend development. Scien-tometric analysis of 257 documents was done, retrieved out of 118 sources (journals, books and conference proceedings). The data sample indicated that the yearly increase rate was 15.15, and the 1,671 authors contributed to it in more than 25 countries, and this data reflects a high level of international cooperation (25.29%). China was the top publisher (31.3%), then United States (16.6% and United Kingdom (10.3%). Others of these leading institu-tions, including the University of Strathclyde and Universidade do Porto, each provided 28 publications, and key thematic clusters were around fracture mechanics, fatigue damage, crack propagation and finite element methods. The co-citation analysis, as well as network analysis of keywords, was used to identify the form of inter-linkages between experimental testing and computational modeling, which reinforced the shift towards a predictive and performance-based design. In general, the results contribute to the profound understanding of the state of research advancement, essential contributors, and intellectual frameworks with an emphasis on the worldwide impetus in forming strong damage-tolerant strategies in the engineering field of use.
**Keywords:** Fatigue Analysis, Fracture Mechanics, Safe-Life Design, Damage-Tolerant Design, Structural Integrity, Scientometric Analysis.

## 1 Introduction

The significance of the mechanics of fatigue and fracturing in structural and material design is unquestionable. Fatigue failure is one of the main degradation phenomena in any in-dustries like shipbuilding, construction, automotive, and aerospace,


R. Vasanth Kumar Mehta et al. (eds.), *Proceedings of the International Conference on Intelligent Systems for a Sustainable Future (ISSF 2026)*, Atlantis Highlights in Intelligent Systems 16,
https://doi.org/10.2991/978-94-6239-693-7_80

where struc-tures are subject to cyclic loads and adverse environmental conditions. These effects have the capacity to cause disastrous failures despite the fact that the largest stresses are less than the material yield strength, and thus they are very important in promoting safety and reliability [1]. Fatigue and fracture studies are fundamental in the optimization of the maintenance of wind turbine support structures and avoidance of financial losses [2]. The conventional method of assessing fatigue with stress-life and strain-life hypothesis is not always sufficient in forecasting the complicated geometries and advanced materials [3]. Components Critical elements have historically been controlled to be put out of service before damage can be identified, through conservative lifetime design based on empirical fatigue tests. Although such a solution is safe, it has drawbacks, such as inefficiency, lack of flexibility, and premature disposal of equipment [2].

The safe-life and damage-tolerant approaches can provide the best illustration of the evolution of design philosophy. Unlike the safe-life approach, which involves adopting a conservative approach to removing components until any damage is observed, the damage-tolerant approach acknowledges the presence of small defects and proceeds to detect, monitor, and manage them throughout the service life [4]. The primary differences between the two philosophies are summarized in Table 1, which involves the relocation of hard time-based replacement strategies to soft inspection-based maintenance strategies. This not only enhances safety and reliability but also economic efficiency; therefore, it is a starting point in the investigation of fatigue and fracture mechanics to date.

**Table 1.** Comparison of Safe-Life and Damage-Tolerant Design Approaches

| Aspect | Safe-Life Design | Damage-Tolerant Design |
|---|---|---|
| Philosophy | Preventing failure by retiring components early | Accept flaws but ensure safe operation throughout life |
| Focus | Conservative life estimation from fatigue tests | Crack detection, monitoring, and growth management |
| Safety Margin | High, but often wasteful and inflexible | Optimized through inspections and maintenance intervals |
| Design Practice | Assumes no detectable damage during service | Assumes small cracks/defects exist and manages them |
| Applications | Traditional aerospace, automotive, defense structures | Modern aerospace, civil infrastructure, offshore wind |

In the past few decades, the design philosophy has changed towards a damage-tolerant approach, essentially acknowledging that in real-world operations, some flaws and damage are unavoidable. Damage-tolerant design combines flaw detection, monitoring, and continuous structural integrity evaluation. The idea here is not only to avoid the onset of the cracking process but also to identify, track, and control cracking and other destruction during the lifecycle of a particular structure. The main aspect of this philosophy is the adoption of improved nondestructive evaluation (NDE) techniques and the relationship between the inspection times and the kinetics of crack propagation [5]. This paradigm shift is particularly significant in high-reliability systems, such as aerospace systems, where the structure must be designed to survive the appearance of even minor flaws [5]. Another application of the technique in the field of civil engineering is revolutionary, with technologies of continuous health monitoring and rapid damage detection making bridges and buildings safer and cheaper to maintain. In the automotive and offshore wind sectors, the accumulation/tolerance of damage may be explained and utilized to innovate lightweight schemes and new substances, offering an apparent and favorable cost- and security-benefit [6](Igwemezie et al., 2018).

In recent years, fatigue and fracture mechanics research has witnessed extensive growth. Machine learning algorithms are increasingly used to predict fatigue life, automatically identify patterns from large operational datasets, and support the move towards automated, real-time integrity management [1]. New methods of computation, including digital twins, reduced-order modeling, and multi-scale finite element simulations can be used to quickly and precisely simulate crack propagation and damage development in complicated structures [7]. There has also been an improvement in materials science with new materials including high-strength steel, new composites and additively manufactured alloys, which have greater ability to withstand damage and possess distinctive fracture properties. Phase-field and cohesive zone models are new modelling techniques that are more predictive of crack propagation in a variety of loading and environmental conditions [8]. International collaborations have increased significantly as well, with infrastructure being international in nature and the multi-disciplinary capabilities needed to tackle contemporary engineering issues [9].

Despite this, there are still plenty of scientific issues and gaps in the research. The current fatigue and fracture models are constrained by the lack of perfect understanding of the microstructural effect on crack genesis and progression [10]. The influence of the grain boundaries, phases, and interactions of defects under cyclic loading need to be further characterized in order to increase the predictive fidelity. Complex loading conditions, for example, variable amplitude and multi-axial fatigue: There is a limit to current models owing to complex loading conditions, and superior models need to be developed to capture realistic service conditions [11]. Moreover, multi-material system fatigue information, especially the information produced by additive manufacturing, is lacking and fails to enable the free practice of design. There is also the challenge of extrapolating laboratory results into operational realities because inaccessibility and controlled data collection during the validation of in-service models make this challenging [12]. There is also a continuing discrepancy between academic developments in the methodology of damage-tolerant systems and their broad-scale application in the industry. The problem of standardizing inspection intervals and criteria according to damage tolerance persists, as it is not always possible to define component criticality and the circumstances of the operation. The level of adoption across industries differs greatly, as it is determined by the acceptance of regulations, cost, and organizational culture [13]. Moreover, scaling lab-tested procedures to full-scale in-service components is logistically problematic and difficult to incorporate.

The development of composites and hybrid materials adds complications to the fatigue behaviour, such as anisotropic damage accretion and non-uniformity in crack propagation [14]. Defects during manufacturing, including voids and delaminations, and the remnants of stresses during manufacturing, are extremely important factors that affect fatigue life and are poorly understood. Other extrinsic environmental conditions, such as changes in temperature, corrosion, and moisture ingress, also alter fatigue performance, and these require multifactorial research strategies [15]. There is an immediate need to undertake extensive research to resolve these uncertainties and provide a foundation for the concept of damage-tolerant design of new materials.

## 2 Methodology

With the increasing rapidity, variety, and multi-disciplinarity of recent scholarship, a systematic scientometric (bibliometric) analysis is required. This type of analysis can objectively map the structure and dynamics of a research field, showing trends in publications over time, new subfields, and contributors to the field. Scientometric mapping is uniquely positioned to reveal collaboration networks, contrast institution- and country-level effects, and highlight key papers and research clusters. This is the evidence base that can inform policymakers, funding agencies, and researchers on effective investment and collaboration strategies.

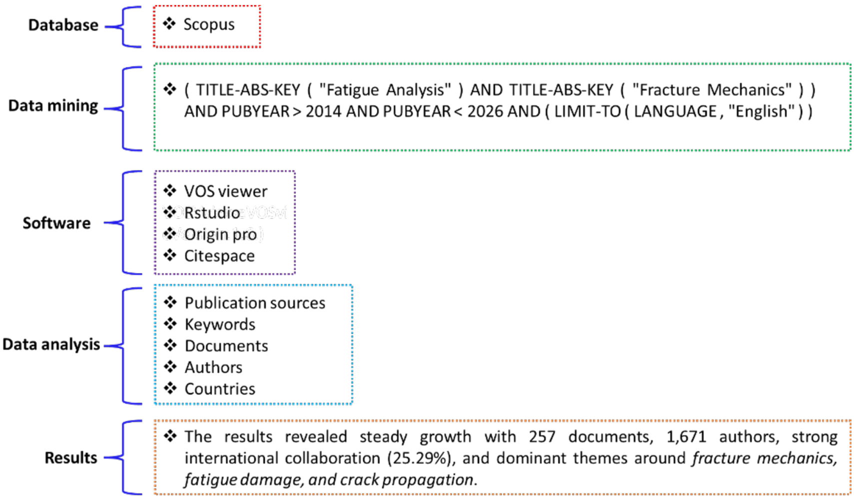


**Fig. 1.** Methodological Framework and Results of Scientometric Analysis on Fatigue and Fracture Mechanics (2015–2025)

The main tasks of the presented research are to examine the trends of fatigue and fracture mechanics research publications of 2015-2025 in terms of time, determine the main re-search clusters and new areas of research using network and co-citation analysis, visualize the patterns of collaboration among authors, institutions, and countries globally, assess the contribution of the contributions of the most significant papers, authors, and research topics, identify new tools, methods, and materials in the face of safe-life to damage-tolerant design, and give practical recommendations about future research, education, and industry practices.

### 2.1 Research Questions

1. What are the publication trends and growth patterns in fatigue and fracture mechanics research between 2015 and 2025?
2. Which countries, institutions, and authors have made the most significant contributions, and how do they collaborate internationally?
3. What are the most influential journals, sources, and document types that shape knowledge dissemination in this field?
4. Which thematic clusters and keywords dominate the research landscape, and how have they evolved over the past decade?
5. How does the shift from safe life to damage-tolerant design manifest in recent scientific outputs and intellectual structures?

## 3 Results and Discussion

The findings and discussion indicate the dynamic development of fatigue and fracture mechanics literature in 2015–2025, manifested by the establishment of a growing international and multidisciplinary contribution. China, United States and the United Kingdom are on the list of the top contributors, and such institutions like the Universidade do Porto and the University of Strathclyde are central figures. The keyword analysis showed that the focus on fracture mechanics, fatigue damage, and propagation of cracks was high, with the assistance of both numerical and experimental investigations. Networks of sources and authors also refer to the connectedness of knowledge base, and influential journals and scholars are going to make progress. Taking altogether, these results promote the tendency towards damage-tolerant design solutions in the global context.

**Table 2.** Descriptive Summary of Fatigue and Fracture Mechanics Research Dataset (2015–2025)

| Description | Results |
|---|---|
| **MAIN INFORMATION ABOUT DATA** | |
| Timespan | 2015:2025 |
| Sources (Journals, Books, etc) | 118 |
| Documents | 257 |
| Annual Growth Rate % | 15.15 |
| Document Average Age | 3.91 |
| Average citations per doc | 7.798 |
| References | 2144 |
| **DOCUMENT CONTENTS** | |
| Keywords Plus (ID) | 2243 |
| Author's Keywords (DE) | 2620 |
| **AUTHORS** | |
| Authors | 1671 |

| | |
|---|---|
| Authors of single-authored docs | 0 |
| **AUTHORS COLLABORATION** | |
| Single-authored docs | 0 |
| Co-Authors per Doc | 11.6 |
| International co-authorships % | 25.29 |
| **DOCUMENT TYPES** | |
| article | 151 |
| book | 3 |
| book chapter | 3 |
| conference paper | 95 |
| conference review | 2 |
| review | 3 |

Table 2 gives a full overview of the bibliometric dataset of fa-tigue and fracture mechanics studies published between 2015 and 2025. The 257 documents obtained because of the search of 118 journals, books and proceedings have an annual growth rate of 15.15, which clearly shows that there is a consistent increase in the field. All papers contain 7.8 on average citations and an average age of 3.91 years, which are proved by over 2,144 references. The data set was increased with 2, 243 Keywords Plus (ID) and 2, 620 author keywords (DE) which signified thematic diversities. The authors are over 1,671, and there are no single author works, which underlines the high levels of collaboration in the present research. The average paper has 11.6 co-authors with 25.29 percent of the publications having international collaboration. When it comes to the type of publication, it was articles (151) followed by conference papers (95), and reviews and books occupied a lesser yet worthwhile part. This profile depicts the multidisciplinary and globally coupled nature of the field of research.


**Fig. 2.** Cluster View of Country Collaboration in Fatigue and Fracture Mechanics Research (CiteSpace, 2015–2025)

The cluster viewer created by CiteSpace depicts the collaboration trends between countries worldwide in the study of fatigue and fracture mechanics between the years 2015 and 2025. The larger the size of the node, like the ones of the United States, the United Kingdom, China, Germany, and India, the greater the impact in terms of research output and power. The links are a mirror of international co-authorship networks where the interlinking is heavy and implies active international collaboration. North America and Europe are the dominant ones, and well connected with Asian nations, including China, Japan, and India. The research is becoming increasingly varied in the emerging contributors, such as Brazil, Norway, Portugal, and Saudi Arabia. The color coding indicates a chronological sequence of activity with red and orange nodes (20222025) indicating recent growing sources of activity, especially China, India and Brazil. The international and interdisciplinary character of the fatigue and fractured mechanics research is emphasized by this clustering, and the collaborative networks generate innovations and contribute to the development of the principles of designs that are damage-tolerant.

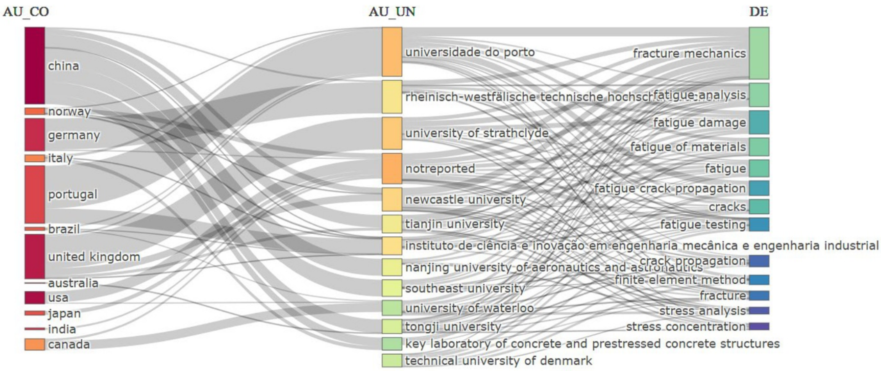


**Fig. 3.** Three-Field Plot of Countries, Institutions, and Keywords in Fatigue and Fracture Mechanics Research (2015–2025)

The three-field plot displays the interdependence between fatigue and fracture mechanics research in 2015-2025 that yield to countries (AU), institutions (AU), and research themes that prevail (DE). Countries like China, Germany, Portugal, and the United Kingdom are the most prominent contributors to the right, and they are closely associated with such institutions as the Universidade do Por-to, University of Strathclyde, and Tianjin University. The keywords that are related to these universities are fracture mechanics, fatigue analysis, crack propagation, and stress concentration. Visualization is also focused not necessarily on the distribution of research activity all over the world but on the ways the collaborative network between countries and institutions influences thematic orientations. This demonstrates the superiority of European and Asian institutions, and studies are now focusing on key do-mains of damage-tolerant design, fatigue crack growth and stress modeling, thus supporting the change in safe-life to performance-based design policies in engineering materials.


**Fig. 4.** Bibliographic Coupling Network of Source Journals

The network is a visual representation of the bibliographic connection between source journals in fa-tigue, fracture and structural mechanics. A journal can be characterized by each node; the size of the node corresponds to the volume of publication/impact in the dataset, and the thickness of the edge represents the strength of the coupling between the two nodes taking into consideration the number of shared references. Key, well connected, journals are International Journal of Fatigue, Engineering Fracture Mechanics, Journal of Constructional Steel Research, Ocean Engineering and Journal of Offshore Mechanics and Arctic Engineering (OMAE) which serve as intermediaries between offshore/structural and materials-oriented venues. The connection between the Engineering Structures, Marine Structures, Materials, Applied Sciences (Switzerland), Procedia Engineering, and the conference proceedings (e.g., ISOPE/OMAE) can also be seen as a strong tie between academia and industries, indicating that the citation base is united. All that can be said is that, with such a high level of connectivity, literature is well-developed and cross-Disciplinary: As innovations in fatigue assessment, crack propagation, and boundary/finite element analysis are being developed and spread out across journals at a disconcerting rate.

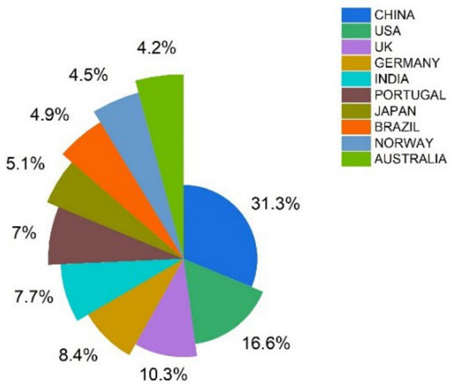


**Fig. 5.** Distribution of Articles by Country in Fatigue and Fracture Mechanics Research (2015–2025)

The pie diagram shows the contribution of the research articles in the fatigue and fracture mechanics country-wisely in the year 2015-2025. China leads with 31.3% of the entire publications, which indicates its significant research potential and constant attention to the structural safety and damage-tolerant design. The US comes next at 16.6 indicating that it leads in advanced materials and aerospace. The UK (10.3%), Germany (8.4%) also contributed significantly to supporting the role of Europe in the research of fracture mechanics. Others who contribute significantly are India (7.7%), Portugal (7%), and Japan (5.1%), and new entrants such as Brazil, Norway and Australia (4.2-4.9%). The distribution indicates a wide research network across the globe, with Asia and Europe leading, and North and South America contributing their regular yet small roles to the development of the fatigue and fracture of mechanics knowledge.

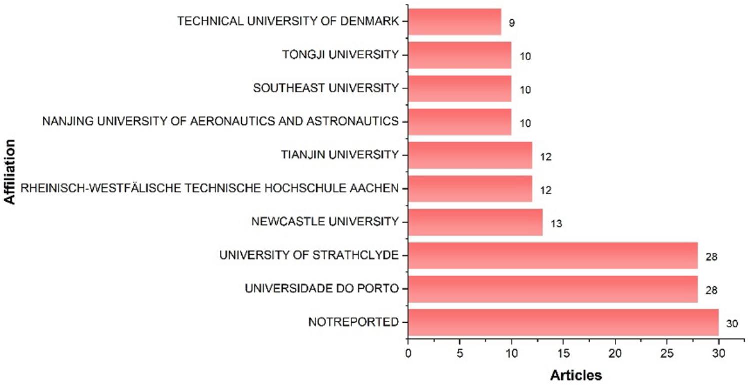


**Fig. 6.** Top Contributing Institutions in Fatigue and Fracture Mechanics Research (2015–2025)

The horizontal bar chart indicates the top institutions that are contributing to fatigue and fracture mechanics studies between the year 2015 and 2025. The most prolific institutions were Universidade do Porto and the University of Strathclyde who published 28 articles each, highlighting their key role in the research on the topic of structural durability and crack propagation. Close behind it was Newcastle University (13 articles) and universities like Rheinisch-Westfalische Technische Hochschule Aachen and Tianjin University (both 12 articles). Asian institutions such as the Nanjing University of Aeronautics and Astronautics, Southeast University and Tongji University provided a significant contribution with about 10 articles each as compared to the Technical University of Denmark which provided nine articles. It is worth noting that the category named Not Reported holds the largest portion (30 articles) based on the in-complete affiliation of metadata in bibliometric records. All in all, the spread indicates a robust institutional leadership of Europe and China with even contributions of the emerging Asia.

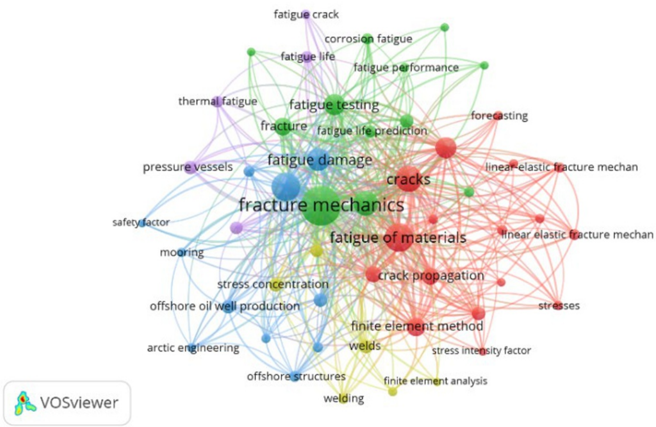


**Fig. 6.** Keyword Co-occurrence Network in Fatigue and Fracture Mechanics Research (2015–2025)

The co-occurrence network of keywords created using VOSviewer demonstrates the thematic focus of fatigue and fracture mechanics studies in the years 2015-2025. The most dominant and interrelated term became fracture mechanics, which became extensively coupled with clusters, including fatigue of materials, crack propagation, and finally with fatigue damage. The green cluster lays stress on fatigue testing, fatigue life prediction and corrosion fatigue, which are experimental and predictive procedures. The red cluster is concerned with the modeling of the concepts of linear elastic fracture mechanics, stress intensity factors and finite element analysis. The blue cluster is put under the engineering applications which include offshore structures, pressure vessels and welding and the yellow cluster underlines the industrial and safety consideration, which includes offshore oil well production and safety factors. The thick interconnections between clusters point to a very interdisciplinary field where experimental research, numerical models and industrial practices work synergistically to promote further progress of damage-tolerant design and structural reliability.

**Table 3.** Leading Authors in Fatigue and Fracture Mechanics Research (2015–2025)

| Author | h_index | Total Citations | Number of Publications |
|---|---|---|---|
| DE JESUS ABÍLIO M.P. | 7 | 213 | 8 |
| CORREIA JOSÉ ANTÓNIO FONSECA DE OLIVEIRA | 6 | 164 | 7 |
| CALÇADA RUI ARTUR BÁRTOLO | 5 | 117 | 5 |
| AHMADI HAMID | 3 | 75 | 3 |
| CHEN NIANZHONG | 3 | 95 | 8 |
| XUE XUTIAN | 3 | 95 | 8 |
| ABDOLLAHIPOUR ABOLFAZL | 2 | 43 | 2 |
| ALIZADEH REZVAN | 2 | 43 | 2 |

Table 3 features the authors with the highest contributions to the fatigue and fracture mechanics research by showing their h-index, the number of publications and total citations between 2015 and 2025. As an indicator of productivity and impact, de Jesus Abílio M.P. has the strongest h-index (7), 213 citations, and 8 publications. Close behind him are Correia Jose Antonio Fonseca de Oliveira (h-index 6, 164 citations, 7 publications) and Calcasada Rui Artur Bartolo (h-index 5, 117 citations, 5 publications). Ahmadi Hamid, Chen Nianzhong, and Xue Xutian are moderate authors who have h-index values of 3 and almost 100 citations respectively. In the meantime, new scholars like Abdollahipour Abolfazl and Alizadeh Rezvan had fewer publications, but they were still cited (43 citations and 43 citations, respectively). In general, the information serves as a reminder of the presence of both older and newer researchers, with the Portuguese writers being on the forefront of the discipline.

# 4 Conclusion

The scientometric work offers a detailed review of the study of the fatigue and fracture mechanics research published in 2015-2025 and traces the intellectual framework, international contributions, and the development of themes in the research field. The results indicate that the growth rate of it is 15.15 per year and contributions covers 257 publications, 1,671 authors, and 118 sources which itself is the image of dynamism and development of the field. China, the United States and the United Kingdom became the major contributors, whereas the European institutions, like the University of Strathclyde and Universidade do Porto, showed extremely high research output. The analysis of the keywords and network indicates that the core of the topic is fracture mechanics, fatigue damage, and crack propagation, supported by the increase in the use of finite element methods and advanced computer modeling. The mutual support of experimental and simulation-based investigations highlights a paradigm shift between safe life and damage-tolerant design to allow greater predictive accuracy and reliability of the structure. Besides, the great proportion of the international cooperation (25.29 percent) indicates the growing globalization of the given sphere of research. This study can not only benchmark the current achievements by identifying key authors, journals and institutions but also give strategic insight into the future direction of things in the future. The findings highlight the urgency of fatigue and fracture mechanical research in the development of safer, more stable and effective engineering structures globally.

## References

1. Gbagba, S., Maccioni, L., & Concli, F. (2023). Advances in machine learning techniques used in fatigue life prediction of welded structures. *Applied Sciences (Basel, Switzerland)*, *14*(1), 398. https://doi.org/10.3390/app14010398
2. Amirafshari, P., Brennan, F., & Kolios, A. (2021). A fracture mechanics framework for optimising design and inspection of offshore wind turbine support structures against fatigue failure. *Wind Energy Science*, *6*(3).
3. Chapetti, M. D., Belmonte, J., Tagawa, T., & Miyata, T. (2004). Integrated fracture mechanics approach to analyse fatigue behaviour of welded joints. *Science and Technology of Welding & Joining*, *9*(5), 430–438. https://doi.org/10.1179/136217104225021634

4. Zerbst, U., Beretta, S., Köhler, G., Lawton, A., Vormwald, M., Beier, H. T., … Klingbeil, D. (2013). Safe life and damage tolerance aspects of railway axles – A review. *Engineering Fracture Mechanics*, *98*, 214–271. doi:10.1016/j.engfracmech.2012.09.029
5. Kundu, S., Jones, R., Peng, D., Matthews, N., Alankar, A., Raman, S. R. K., & Huang, P. (2020). Review of requirements for the durability and damage tolerance certification of additively manufactured aircraft structural parts and AM repairs. *Materials*, *13*(6), 1341. https://doi.org/10.3390/ma13061341
6. Igwemezie, V., Mehmanparast, A., & Kolios, A. (2018). Materials selection for XL wind turbine support structures: A corrosion-fatigue perspective. *Marine Structures*, *61*, 381–397. https://doi.org/10.1016/j.marstruc.2018.06.008
7. Zhou, X., He, S., Dong, L., & Atluri, S. N. (2022). Real-time prediction of probabilistic crack growth with a helicopter component digital twin. *AIAA Journal*, *60*(4), 2555–2567. https://doi.org/10.2514/1.j060890
8. Aranda, M. T., García, I. G., Quintanas-Corominas, A., & Reinoso, J. (20). Crack impinging on a curved weak interface: Penetration or deflection? *Journal of the Mechanics and Physics of Solids*, *178*(105326), 105326. https://doi.org/10.1016/j.jmps.2023.105326
9. Edalati, K., Bachmaier, A., Beloshenko, V. A., Beygelzimer, Y., Blank, V. D., Botta, W. J., Bryła, K., Čížek, J., Divinski, S., Enikeev, N. A., Estrin, Y., Faraji, G., Figueiredo, R. B., Fuji, M., Furuta, T., Grosdidier, T., Gubicza, J., Hohenwarter, A., Horita, Z., … Zhu, X. (2022). Nanomaterials by severe plastic deformation: review of historical developments and recent advances. *Materials Research Letters*, *10*(4), 163–256. https://doi.org/10.1080/21663831.2022.2029779
10. Bagheri, A., Mahtabi, M. J., & Shamsaei, N. (2018). Fatigue behavior and cyclic deformation of additive manufactured NiTi. *Journal of Materials Processing Technology*, *252*, 440–453. doi:10.1016/j.jmatprotec.2017.10.006
11. Hensel, J., Nitschke-Pagel, T., Tchoffo Ngoula, D., Beier, H.-T., Tchuindjang, D., & Zerbst, U. (2018). Welding residual stresses as needed for the prediction of fatigue crack propagation and fatigue strength. *Engineering Fracture Mechanics*, *198*, 123–141. doi:10.1016/j.engfracmech.2017.10.024
12. Marques, F., Correia, J. A. F. O., de Jesus, A. M. P., Cunha, Á., Caetano, E., & Fernandes, A. A. (2018). Fatigue analysis of a railway bridge based on fracture mechanics and local modelling of riveted connections. *Engineering Failure Analysis*, *94*, 121–144. doi:10.1016/j.engfailanal.2018.07.016
13. Shittu, A. A., Kolios, A., & Mehmanparast, A. (2020). A systematic review of structural reliability methods for deformation and fatigue analysis of offshore jacket structures. *Metals*, *11*(1), 50. doi:10.3390/met11010050
14. Banothu, D., Kumar, P., Reddy, R., Dhanapalan, S., & Gobinath, R. (2025). Design, 3D printing, and fatigue analysis of bone implant lattices: a study on structural integrity and failure mechanisms. *Smart Materials & Structures*, *34*(4), 045021. doi:10.1088/1361-665x/adc9e9
15. Katakam, R., Gobinath, R., & Shyamala, G. (2025). Research trend and knowledge gap analysis on fracture energy based concrete analysis and design. *Journal of Infrastructure Preservation and Resilience*, *6*(1). doi:10.1186/s43065-025-00129-z