VOL. 18, NO. 20, OCTOBER 2023 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

A BIBLIOMETRIC ANALYSIS ON CONDITION MONITORING OF MACHINERY USING IR THERMOGRAPHY

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ABSTRACT

In order to extend the life of machinery, condition monitoring of equipment has become crucial in every industry or power plant. IR Thermography is a strong tool for condition monitoring since it can detect flaws earlier than other techniques. The most important technique for condition monitoring is infrared thermography. Machine condition monitoring has evolved along with machine maintenance, from manual maintenance through approaches involving the use of sensors to the now under discussion methods and techniques centered on shared automation, data processing, and exchange. The purpose of this paper is to give a brief summary of the academic work that has been done on using IR thermography to monitor the status of machinery. In order to present an up-to-date, content-based analysis that includes bibliometric performance analysis and systematic literature evaluation, this paper evaluates the body of current literature. The writers may concentrate on identifying the most important researchers, journals, and publications, as well as the most significant and influential researchers, thanks to the mix of literature review methodologies used. These conclusions have prompted the authors to outline research trends pertinent to the studied domain and, in addition, to identify potential future research goals from engineering viewpoints.

Keywords: bibliometric analysis, condition monitoring, fault diagnosis, infrared thermography, scientometric analysis.

Manuscript Received 22 August 2023; Revised 27 November 2023; Published 30 December 2023

1. INTRODUCTION

Production machine maintenance [1-7] has a bright future thanks to the growing interdependence of machines in industrial production and the advancements in the storage, retrieval, and analysis of massive volumes of data. Predictive maintenance has recently received more and more attention in relation to equipment maintenance systems. Predictive maintenance [8], in contrast to other methods, is based on machine behavior models, which have various benefits. There is a dearth of a literature review of pertinent study disciplines and realization approaches in this highly interdisciplinary field. Large data sets of pertinent literature must be taken into account in order to get a thorough picture of the state of the art, and in the best case scenario, they should be automatically divided into pertinent research categories. The bibliometric analysis method is an appropriate methodology for obtaining such an overview. In the work that is being given, the authors used bibliometric analysis [9] to examine the subject of equipment maintenance systems. In order to be more specific, the authors examined groups of the identified literature in an effort to have a better understanding of the associated study areas. Additionally, an analysis of the temporal cluster formation reveals the history of research themes, while cluster metrics highlight the significance of a particular work. The authors presented a new measure in this context to compare data from various time periods in an appropriate manner. This, in turn, among other things, makes it easier to analyze issues with several subtopics. Overall, the results particularly offer a thorough overview of current approaches and new developments in equipment maintenance systems.

By doing adequate maintenance, Authors may extend the life of the machinery. Condition Monitoring [10] is utilized to locate flaws in machine parts. Prior fault detection can help us prevent catastrophic failures. By combining machine sensor data that monitors vibration and other characteristics (in real-time) with cutting-edge machine monitoring software, condition monitoring (CM), one sort of maintenance strategy, predicts the health and safety of the machine. This page explains the idea of condition monitoring (CM) using IR thermography [11] and describes the work of several authors who have conducted research in the same field. It also provides information on papers that have been published by various organizations in the same field. It also provides information on the various nations [12] involved in this field of study.

2. METHODOLOGY

2.1 Methods

The condition monitoring across thermography literature was evaluated and identified using the scientometric [13] analysis technique. Research articles, conference papers, and other scholarly document publishing trends are examined using scientometric, a quantitative and statistical tool. A thorough search was conducted on September 25th 2022 using Scopus databases

VOL. 18, NO. 20, OCTOBER 2023 ISSN 1819-6608
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(www.scopus.com). The search was undertaken on a single day to reduce the potential for bias resulting from daily database changes. In this retrospective analysis, researchers selected Scopus-indexed articles published between 2000 and 2022.

Additionally, many researchers choose Scopus (instead of other databases like Web of Science, Dimensions, and so forth) for scientometric or bibliometric investigations because of its extensive data supply [14-15]. Scopus has established a solid reputation. A large member of researchers have begun tapping into it as a bibliometric data source [16]. In this study, the author attempted to provide a scientific panorama of researchers, and nations. Institution and collaborations, co-occurrence network, conceptual structures map, three factor analysis of countries, authors, and Keywords, and thematic evolution of the acquired data were also presented.

2.2 Search String

To retrieve the scientometric data on condition monitor across thermography, the Scopus database search field was used to input the following search term:
("condition monitor*" OR "fault diagnos*") AND (("IR thermography") OR ("Infrared thermography") OR ("thermal imager"))
TITLE-ABS-KEY (("condition monitor*" OR "fault diagnos*") AND (("IR thermography") OR ("Infrared thermography") OR ("thermal imager"))) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2007) OR LIMIT-TO (PUBYEAR , 2006) OR LIMIT-TO (PUBYEAR , 2005) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000))

3. ANALYSIS

3.1 Publication Trend

Figure-1 displays the frequency of publications by year and citations of wave propagation through porous media literature from 2000 to 2022. The number of publications and citations has significantly increased over the years. The most successful publication year was 2022, in which the highest (29) number of articles were published.

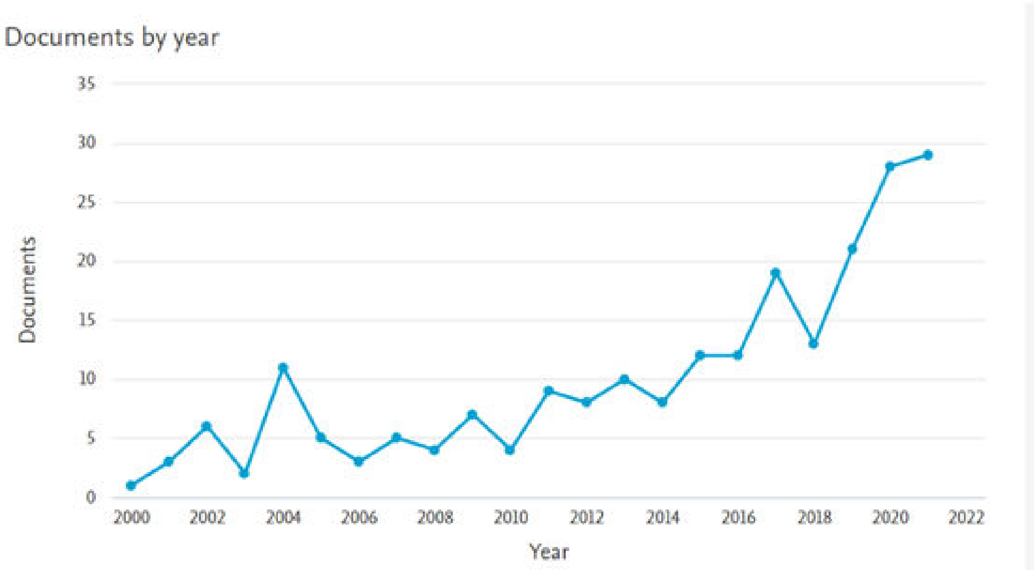

Figure-1. Scopus Publications trend of condition monitoring.

3.2 Prolific Researchers

Figure-2 displays the prolific researchers in condition monitoring. The author Antonino-Daviu, j. produced a maximum of 9 publications affiliated with the Organization Research Institute, Morales-Hernandez produced 6 documents, Botsaris, Nandhitha, N.M., Osornio-Rios, R.A. and Tsanakas. J.A produced 5 publications each. The other four authors among the top ten produced 4 publications each. According to the findings of the prolific authors as a whole, this is a growing field that has potential for significant research in the near and far future.

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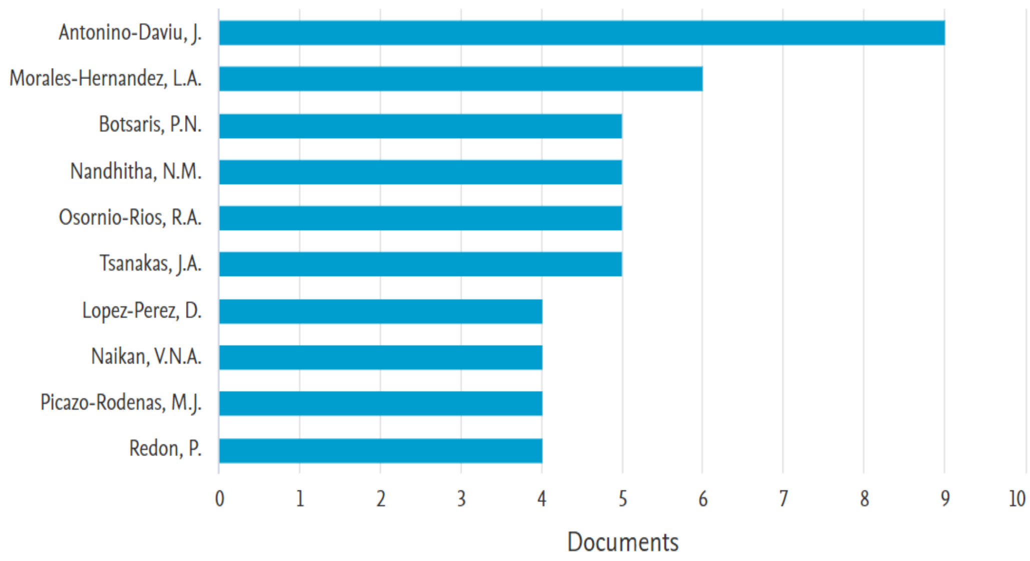

Figure-2. Most productive authors in condition monitor and thermography.

3.3 Leading Organizations

Leading 10 institutions in condition monitoring are concerned; The Polytechnic University of Valencia is leading with 13 articles followed by the Technological Institute of Energy with 9 publications. Autonomous University of Queretaro with 7 publications. MEISA, University Sains Malaysia, Northwestern Polytechnic University, Sathyabama Institute of Science and Technology, Democritus University of Thrace with 5 articles each. IIT Kharagpur and Nottingham Trent University with 4 documents each.

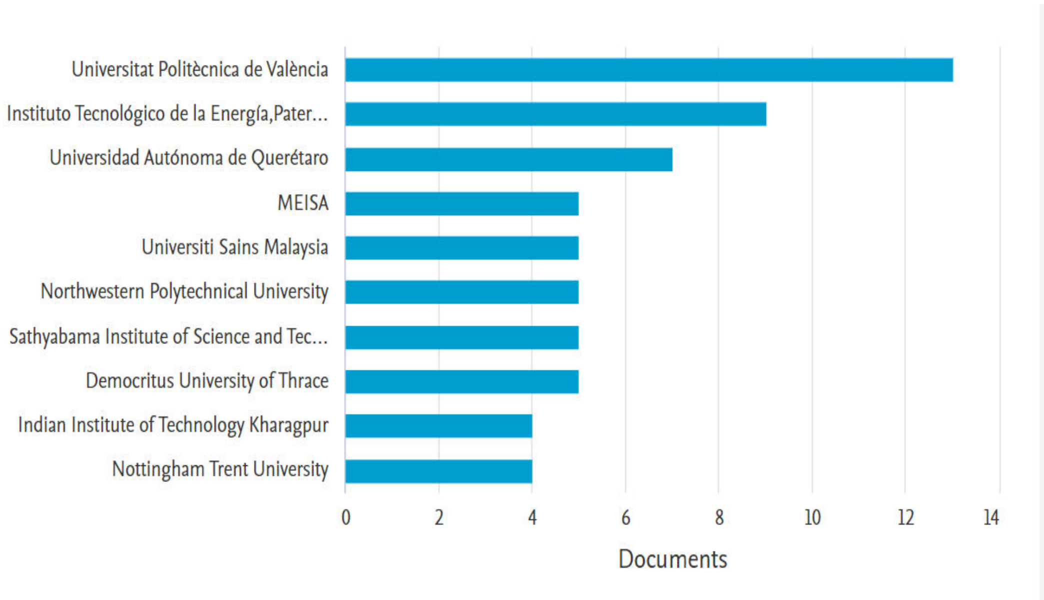

Figure-3. Documents published on leading organizations in condition monitoring.

3.4 Classification Of Publications

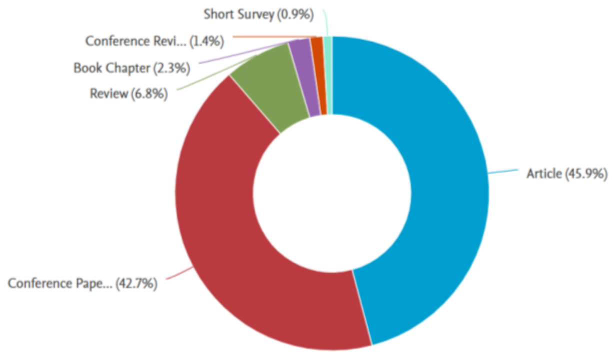

Figure-4. Classification of publications during 2000-2022.

According to the types of papers, publications are categorized in Figure-4. In the initial search, academic papers were located. These include: Journal articles made up 45.9% of the total, conference papers made up 42.7%, and review articles made up 6.8%. Book chapters made up 2.3% of the sample, and "other" made up 0.9%. The top 10 field-contributing nations, papers that were close to journal publications, and proceedings of conference publication types such as database contain no condition monitoring research publications after it has been refined. In this study, massive datasets and relationships are shown using the open-source network analytical tool VOS viewer [17-18].To comprehend contributions and relationships among them, research articles, keywords, nations, and authors researchers are represented as nodes in a network. Utilizing bibliographic data, the VOS viewer generates maps and analyses co-authorship, keyword, citation, coupling of bibliographies, or co-citations of text obtained from databases like Web of Science, Scopus, PubMed, etc.

3.5 High Productivity

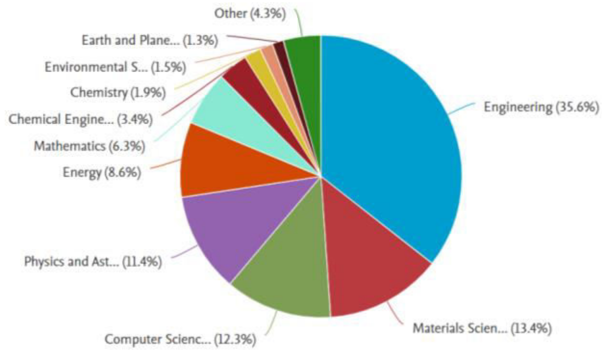

Figure-5. High productivity subject area in the field of Condition Monitoring.

Figure-5 demonstrates a topic with high productivity in which Condition Monitoring research was carried out. It is found that the Engineering Stream has the highest contribution with 35.6% followed by Material Science as the next leading category with 13.4%, Computer Science area with 12.3% articles which majorly include articles of Physics and Astronomy with 11.4%, Energy, Mathematics, Earth and Planetary Sciences and Environmental Science, etc.

3.6 Leading Countries

Figure-6 shows leading countries during the period 2000-2022, 40 research articles were published by more than 10 countries in the field of Condition Monitoring across thermography leading nations in Condition Monitoring are concerned. India is in first place with 43 articles then by China with 35 documents respectively. United Kingdom with 22 documents followed by Spain and United States with 15 documents each. Germany, Malaysia, Greece, Mexico, South Korea, and Mexico each contributed five to ten documents.

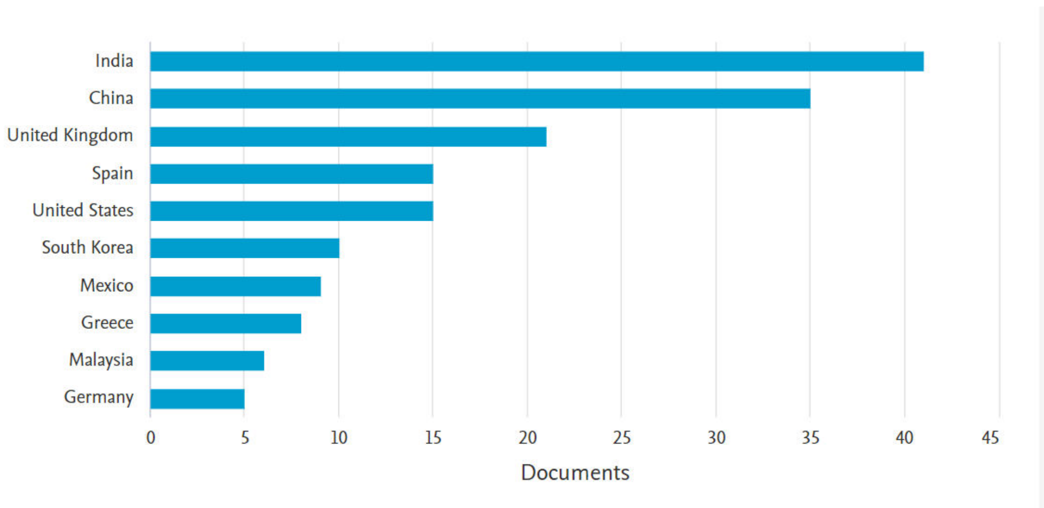

Figure-6. Leading countries in Condition Monitoring and Thermography research.

3.7 Cite score

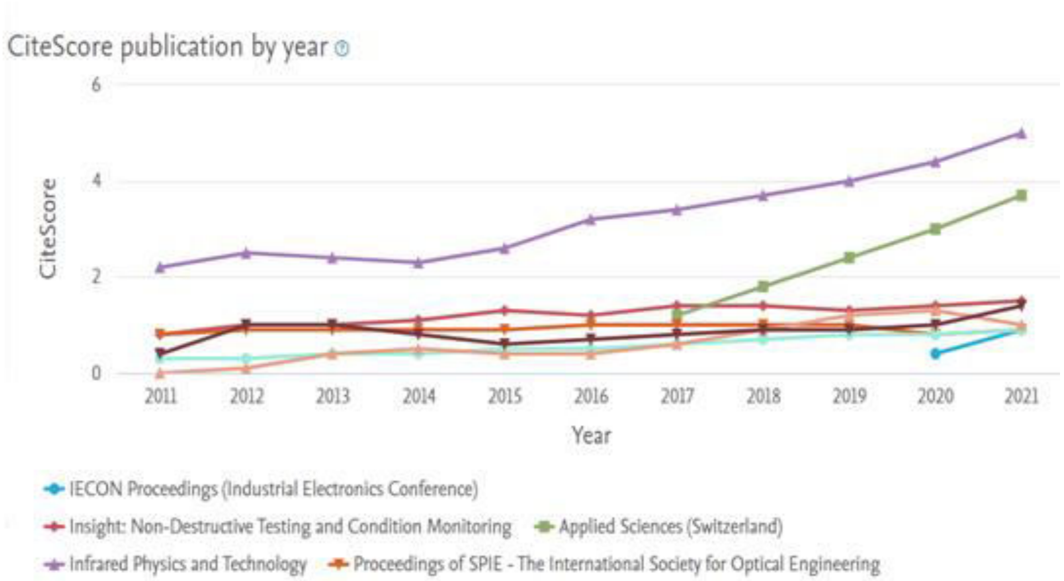

Figure-7. Cite score published in condition monitor during 2011-2021.

Figure-7 displays the Journal of Infrared Physics and Technology which consistently maintains the top Cite Score in comparison with other articles from 2011 and has the highest Cite Score of 5 in 2021, whereas ARPN Journal of Engineering & Applied Sciences has the lowest Cite Score of 0.7 in 2021.

3.8 Co-Authorship of Authors

Figure-8 displays a visualization of a network. In the image, the separation between the two writers shows how closely related the authors are based on co-citations. In general, the stronger the relationship between two authors is the closer their locations are to one another. Lines are used to depict the co-authorship of writers who have the strongest co-citation ties. Figure-8 depicts the map-based bibliographic Scopus data base files that were utilized to construct co-authorship of authors with a minimum of 10 out of 539 writers meeting the 58 standards for each of the 17 authors and a maximum of 10 authors per document.

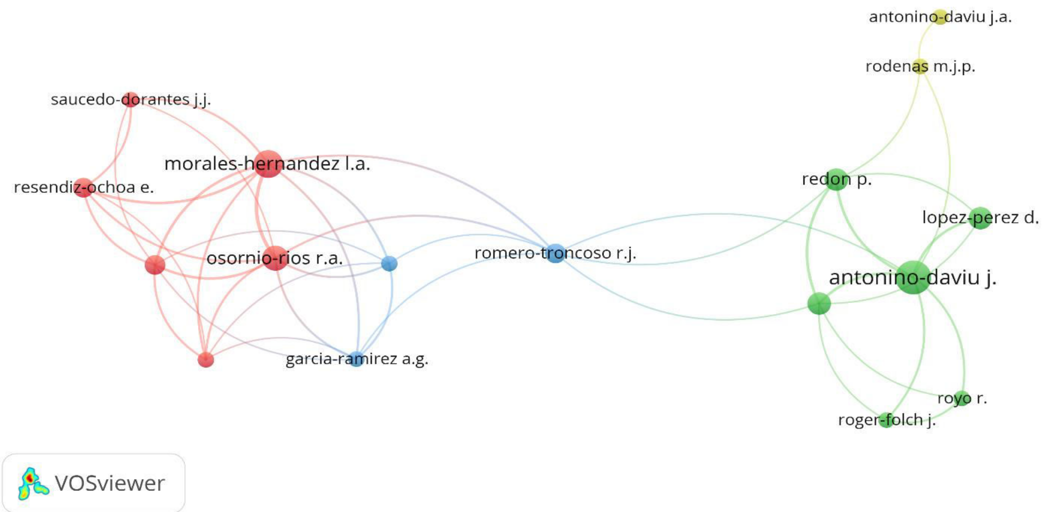

Figure-8. Co-authorship of authors.

3.9 Co-Authorship of Countries

Figure-9 shows, that the generation of Network visualization on co-authorship in 45 countries meets the 24 thresholds with each of 14 items connected using VOS viewer, the highest number of publications shows the yellow in colour it indicates India followed by China, United Kingdom, etc.

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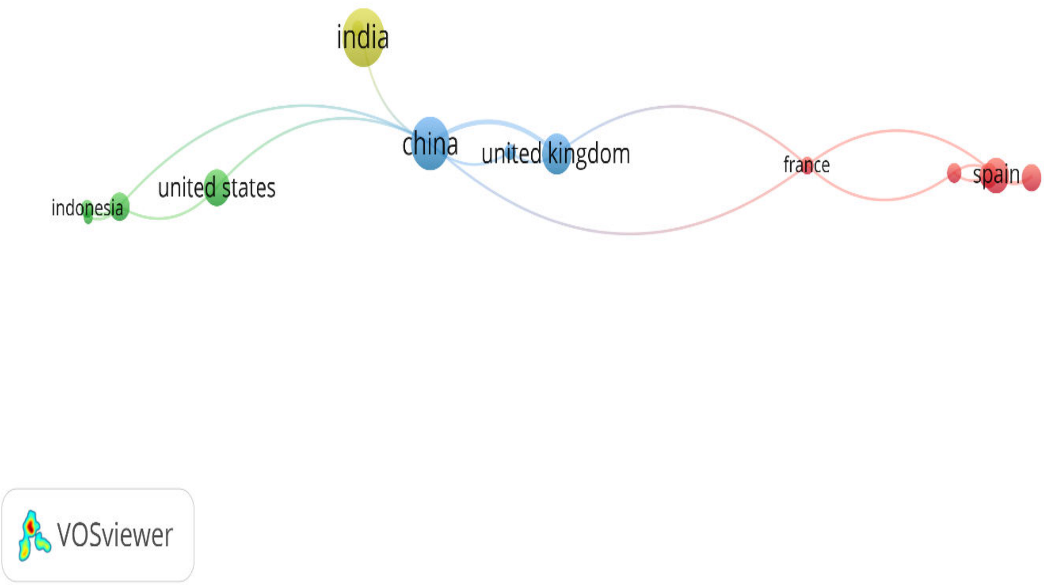

Figure-9. Co-Authorship of countries.

3.10 Co-Occurrence of Keywords

The top 20 search terms with roughly 20 or more appearances in the articles are displayed in Table-1 and Figure-10 created by the VOS viewer [19-20], Figure-10. Figure-10 displays the top 20 keywords with the strongest overall co-occurrence relationships with other terms. From the color coding, it can be seen that "Condition Monitoring" has the greatest co-occurrence score, then by "Thermography" & "Infrared Thermography." These words frequently occur in conjunction with other top keywords. It shows that the majority of researchers are motivated to investigate different methods of thermography condition monitoring. Additionally, a lot of scholars were drawn to research "fault detection" and "fault diagnosis" in conjunction with other terms displayed in the network. The most popular keywords should always be included because popular keywords indicate that many researchers are interested in reading. The weight of each keyword is represented based on the nodes in the map. The strength of their association is indicated by the proximity of keywords and lines.

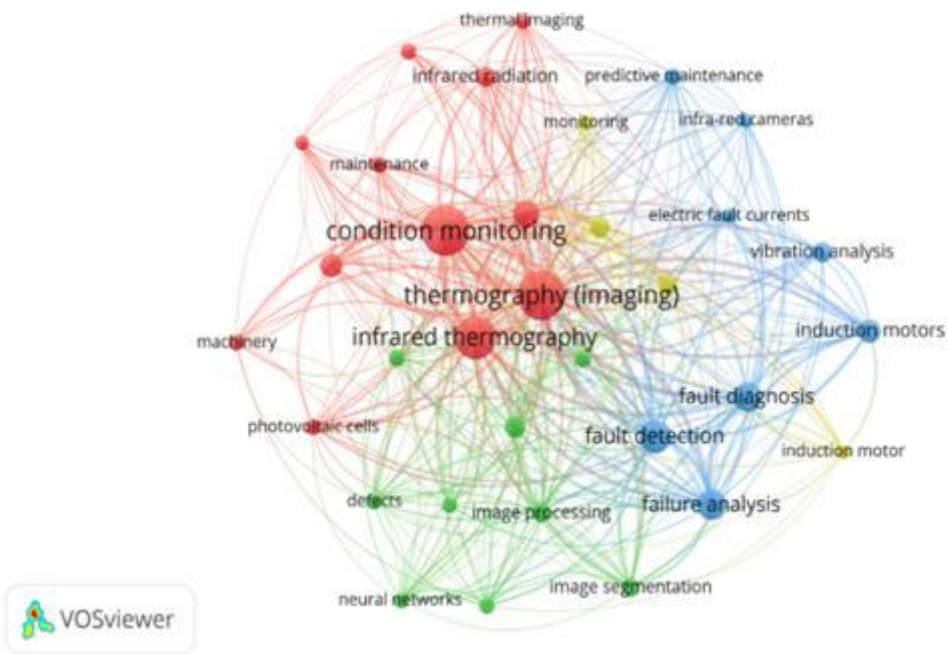

Figure-10. Network visualization of co-occurrence of keywords.

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Table-1. Key word search results of top 20 with frequencies.

Create Map

Verify selected keywords

Selected	Keyword	Occurrences	Total link strength
✓	thermography (imaging)	121	555
✓	condition monitoring	125	427
✓	infrared thermography	92	367
✓	fault detection	53	307
✓	failure analysis	45	272
✓	fault diagnosis	43	228
✓	infrared imaging	36	193
✓	induction motors	27	155
✓	electrical equipment	23	112
✓	nondestructive examination	27	104
✓	image segmentation	18	99
✓	thermography (temperature measurement)	20	91
✓	image processing	17	90
✓	thermography	22	87
✓	photovoltaic cells	14	79
✓	vibration analysis	21	78
✓	infrared radiation	20	75
✓	predictive maintenance	13	74
✓	defects	12	73
✓	[illegible]	[illegible]	[illegible]

< Back Next > Finish Cancel

Table-2. Search results of selected Cited Sources.

Create Map

Verify selected sources

Selected	Source	Citations	Total link strength
✓	renew. sustain. energy rev.	43	988
✓	ieee trans. ind. electron.	61	936
✓	infrared phys. technol.	78	785
✓	renew. energy	23	535
✓	infrared physics & technology	93	495
✓	sol. energy mater. sol. cells	20	485
✓	sol. energy	24	371
✓	ieee access	28	368
✓	measurement	44	310
✓	ieee trans. ind. appl.	33	309
✓	energies	30	284
✓	sensors	46	234
✓	ndt&e international	20	226
✓	mechanical systems and signal processing	38	185
✓	energy and buildings	21	124
✓	ieee transactions on industry applications	32	112
✓	mech. syst. signal process	20	60
✓	infrared phys technol	21	43

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3.11 Bibliographic Coupling

If two journals quote the same third publication they are said to be bibliographically connected. Bibliographic coupling is a metric used to determine how related a subject is across many publications [21] Figure 11 displays the bibliographic connections between a few selected documents. Various levels of connectivity and group o coupling in the bibliography are represented by the circle`s size and color accordingly. Journals were deemed relevant if they had at least 10 publications and 56 citations. The criteria are met by 68 of the 220 papers. Clusters are collections of journals with closely related content, and links between them can be characterized by quantitative network metrics.

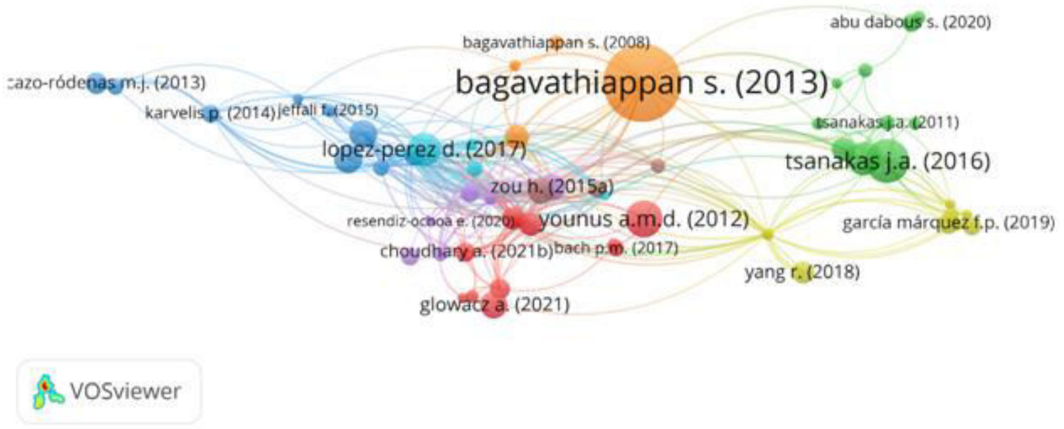

Figure-11. Bibliographic coupling of documents in condition monitor.

3.12 Co-Citation Study of Citations Displayed as a Network

Using the VOS viewer, Figure-12 illustrates 50 Condition Monitoring articles from 2000 to 2022 that are taken into account by citations for referenced references. A reference is deemed to have four citations or more when there are less than four 110 of the 4936 mentioned sources satisfy the criteria for each of the 110 cited references, the overall strength of the co- citation links the other 110 references is calculated mentioned references with strongest overall connections are chosen. Table-1 shows the top 20 cited references.

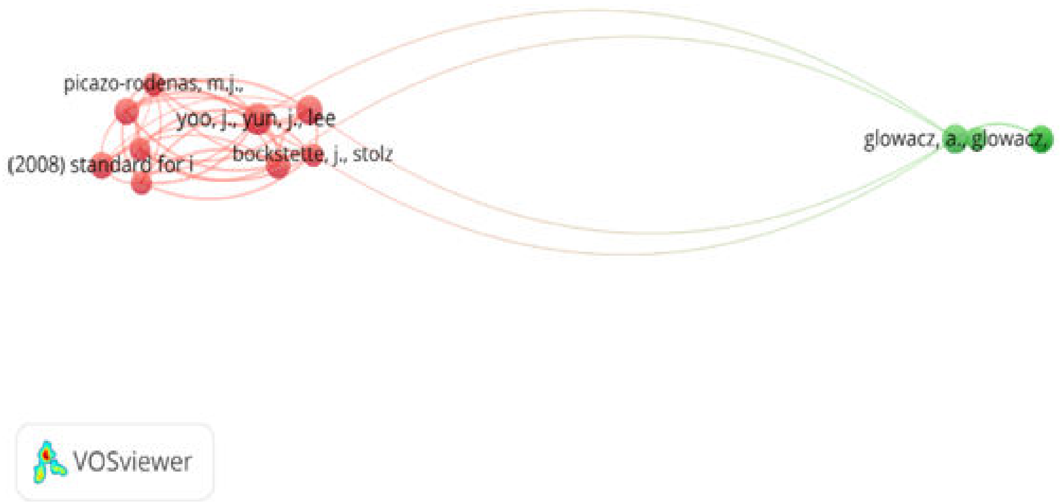

Figure-12. Co-citation study of Citations displayed as a network.

3.13 Network Representation of Source Co- Citation

Condition Monitoring journal's bibliographic couplings were divided into three groups and graphically represented in Figure-13 using the VOS viewer. The journals with the most active bibliographic coupling had a Minimum number of sources that must be cited all three of these journals were assigned to cluster I because 20 of the 2485 sources, of which 18 fulfill the top 20 source requirement, were taken into account. Table-2 lists the referenced sources that have been specifically chosen, with an average of more than 20 citations and a connection strength of 988 with renewable sustainable energy For example.

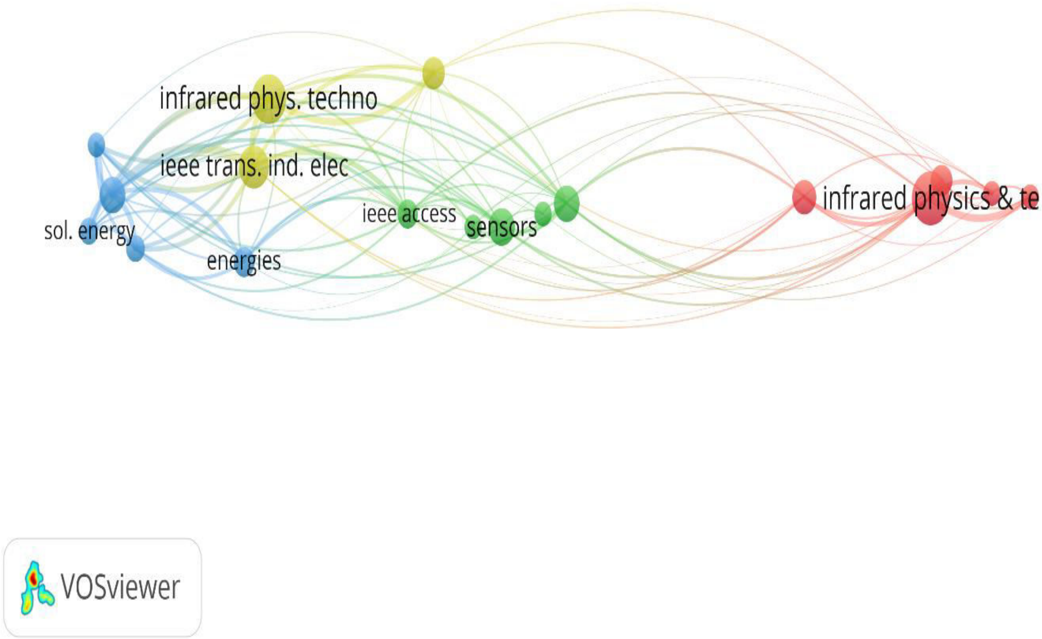

Figure-13. Network Representation of Source Co- Citation.

4. CONCLUSIONS

The authors of this work used scientometric analysis, which maps publishing trends to evaluate research output, to examine the research output of condition monitoring. In order to determine research productivity, the top nations and organizations that thrive in the field, the prolific writers, the most significant journals, the most popular keywords, citations, and citation sources, the Scientometrics concept is used in this analysis. The data were gathered in July 2022 and used for the entire analysis in the Scopus database.

This work identified significant publications and methods utilized in the field of modern equipment upkeep methods based on bibliometric analysis. It deals with questions related to chronology, geography, authorship, and method. The authors pulled groups of publications from an academic database utilizing search terms and modern maintenance methods. Present work, by offering look up tables for study topics and approaches, acts as a scheme for categorizing future research results while also giving an overview of maintenance tactics. Authors used search strings using contemporary maintenance techniques to pull collections of publications from an academic database. This work serves as a schema for classifying upcoming maintenance strategies as well as an overview of current maintenance methods. The approaches used by researchers to study equipment maintenance systems may be seen in the strategies, which were primarily found using keywords. Additionally, each study field`s most significant work is shown, and its value is obsessed with the quantity of cite score [22]. Due to different historical eras and research disciplines, the collection of lead documents obtained from various search strings is incomparable. By standardizing the paper's features and expressing the paper's importance with no dependency on clusters. This method is therefore flexible and can be used with other bibliometric analyses. It is crucial to keep up with recent research since equipment maintenance systems, which are predominantly represented by predictive maintenance, are a burgeoning study topic [23].

This work makes it possible to categorize new works and compare them to earlier works of literature. It has been shown that the subject of equipment maintenance systems spans a variety of study areas and applied methodologies. Our upcoming study will focus on applications for modular predictive maintenance. It is crucial for these applications to scale with an increase in the number of sensors in the Internet of Things environment. The authors will assess how well the new equipment maintenance system modules incorporate the disclosed methodologies. Applications for predictive maintenance are modularly constructed and will also be emphasized in future research to facilitate scalable applications and flexible processes.

DECLARATION

Author Contributions: Conceptualization by I.R; Findings, content preparation, V.R; Review and Editing, Supervision E.L; All authors have read and agreed to the published version of the manuscript.

Funding: No funding was received to assist with the preparation of this manuscript.

Conflicts of Interest: The authors say they have no competing interests.

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