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Research Trend of Metal Matrix Composites reinforced with silica extracted by green route: A Bibliometric Analysis

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Abstract

Metal Matrix Composites have acquired an important place in the engineering applications due to their distinctive characteristics such as high specific strength, lower specific gravity, improved material stiffness, better durability, enhanced creep and fatigue strength etc. Worldwide scientists are working on the improvement of mechanical properties of composite materials. The present work attempts to summarise all the research carried out on metal matrix composites reinforced with silica extracted by green route and provides up-to-date research material for researchers who are interested in the field of composites with metal matrices. Scopus databases and software such as Gephi Vos Viewer and Table2Net are included in the bibliometric analysis. The study can be seen as a manual reflecting the gradual exploration of the Metal Matrix Composite reinforced with silica extracted by the green route.

Keywords: Metal Matrix Composite, Bibliometric analysis, Silica, Green Route, Rice Husk

1.Introduction

Metal matrix composites represent a new generation of engineering materials incorporating the metallic characteristics of matrix alloys with the reinforcement characteristics desirable today for the industry [1]. Metal matrix composites are favoured over traditional materials owing to their outstanding properties in aerospace, automotive, electronics, defense, and marine applications [2].

Crystalline silica is one of the most abundant minerals on the Earth's crust [3]. It can also be extracted from natural raw material i.e., rice husk ash [4]. It displays many special

characteristics, such as crystalline nature, porosity, light-weight, [5], high strength, withstands high temperature, and chemically non-reactive behavior [6].

Metal matrix composites (MMCs) are emerging materials that have superior properties in terms of hardness, specific strength than metals, lower specific gravity, improved material stiffness, maintained composite weight even at high temperatures, improved strength, better creep, and fatigue strength [7]. Different methods are available for the extraction of silica from natural raw material rice husk, and for manufacturing metal matrix composites. Also, different silica sources are available, which can be further used for the development of silica-reinforced metal matrix composite. This paper only discusses the significance of silica extraction from rice husk ash and its reinforcement in synthesizing metal matrix composites [8].

2. Approach to use Silica as a reinforcement of the Metal Matrix Composites

There are various reinforcement materials like SiO_2 , SiC , Al_2O_3 , B_4C , SiC , TiC , AlN , Fly ash, etc, which are used in synthesizing metal matrix composites. Silica (SiO_2) can be extracted from natural, low-cost, agricultural waste called rice husk. The reinforcement of silica particles extracted from rice husk ash not only reduces the cost of the composites, but also enhances the composite properties. The results of the previous researchers' findings in this proposed survey were classified and briefly summarised. A research study has reported the properties of various organic reinforcements such as neem leaf ash, rice husk ash, coconut shell ash, breadfruit seed hull ash, bamboo leaf ash, bagasse ash with various matrices [9]. Among different powder metallurgy casting techniques, stir casting along with squeeze casting shows better properties and also gives the consistency of composites. In the manufacture of composites in factories, rice husk ash is widely used as reinforcement material and helps in converting industrial waste into industrial wealth [10]. The properties of the resulting composites depend not only on the individual properties of the constituent materials but also on various other parameters, such as the shape of the reinforcement material, load fraction of the filler material, modification of the surfaces, etc. Owing to the low wettability of these particles with the metal matrix and the disparity in density between the particles and the matrix, the product is much more expensive. Researchers have begun using agro-waste materials as reinforcement, which has the potential to meet the requirements of advanced engineering applications. Reinforcement materials such as silica derived from rice husk ash are used to optimize the mechanical properties of the metal matrix composite [11]. The metal matrix composite reinforced with the silica particles not only enhanced the properties of the matrix metal but also make it cost effective. Composite output

depends on the proper combination and composition of the matrix material with the reinforcement material. Silica as the agrowaste is the cheapest reinforcement available in large amounts.

3. Bibliometric Analysis

With the extensive research being carried out worldwide on composite materials, huge research data are produced and it continues to grow with each passing year. To avoid any duplication of the study, it is important to have the profound awareness, understanding, and current status of ongoing research in the field of metal matrix composites. Webometrics, bibliometrics, scientometric, and H-index are some of the methods used to evaluate patterns in different fields of study. These studies also form the basis for a researcher to contribute to novelty during research work. In all these methods, bibliometric analysis is a definitive and summative study of quantitative and qualitative research work. It is a common analysis tool for the study of trends in research work [12]. Types of articles, subjects, secondary data analyses, annual patterns in printing, geographical region of publications, and citations are part of the present review. Bibliometric analysis is conducted using the Scopus database. The keywords, titles of publications, authors, affiliations, publishing year, publishing sources, citations, etc are used to build various networks for analysis.

4.1 Significant Keywords

Keywords were divided into three blocks for scopus search; master, primary and secondary keywords. The proposed strategic keywords used for this research are explained in Table 1.

Table 1: The Proposed keywords strategy for Scopus database search.

Master Keyword (AND)	“Metal Matrix Composite”
Primary Keyword (AND)	“Silica”
Secondary Keyword (AND)	“Green Route”

4.2 Initial Search Result

The present work focuses on the findings obtained through keywords from the Scopus database scan. A total of 119 publications resulted in a preliminary search of the keywords (2015 to 2020). The subsequent search was then limited to English language publications only. This search results in 89 English publications and 1 Japanese publication (Table 2). For the trend

study, all published or unpublished research work was considered. Journal papers on the subject “Metal Matrix Composite reinforced with silica extracted through the green route” were found to be the highest in the number of publications. Very few published studies were identified in the form of conference papers, books, and reports.

Table 2: Language developments in the Metal Matrix Composites reinforced with green route extracted from silica

Sr. No	Language	Publication
1	English	89
2	Japanese	1

The large-scale research carried out in this area is mainly published in English.

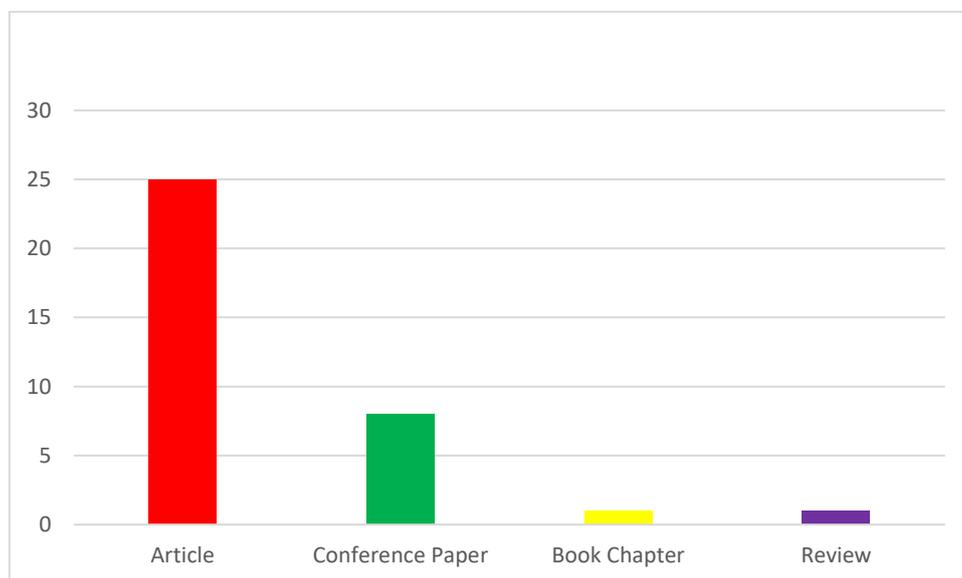


Figure 1: Types of Document published in five years span

Table 3: Publication Sources of “Metal Matrix Composites reinforced with silica extracted by green route”

Sr. No	Source Title	No of Publication	Publication (%)
1	Journal of Alloys and Compounds	2	14.29%
2	Materials	2	14.29%
3	Materials Science Forum	2	14.29%
4	Materials Today Proceedings	2	14.29%
5	Advanced Composite Materials	1	7.14%
6	Applied Surface Science	1	7.14%

7	Materials and Manufacturing Processes	1	7.14%
8	Materials Research Express	1	7.14%
9	Materials Science and Engineering A	1	7.14%
10	Tribology Materials Surfaces and Interfaces	1	7.14%

4.3 Preliminary data highlights

The related documents were journal papers, conference articles, books, research studies, etc over 5 years, i.e., from 2015 to 2020. The annual trends in Metal matrix composite reinforced with silica publication are shown in figure 2. The trend shows a continuous increase in research exploration.

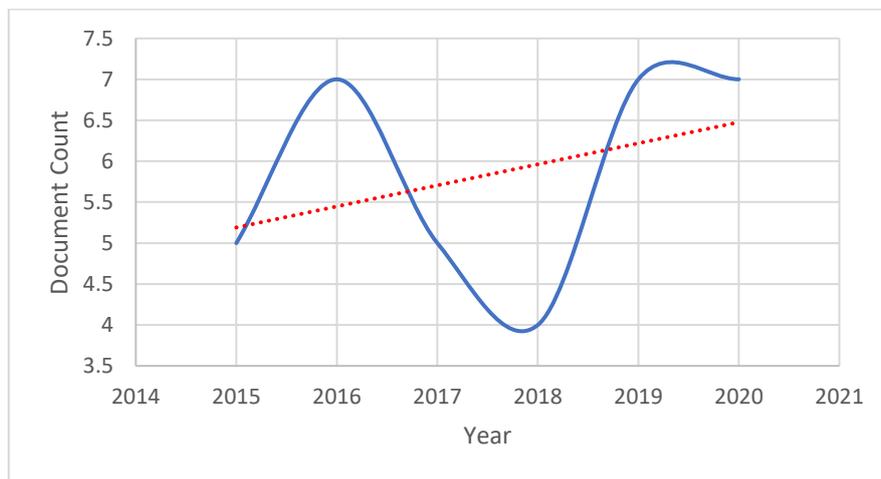


Figure 2. Number of Publications on topic Metal Matrix Composite reinforced with silica extracted by green route

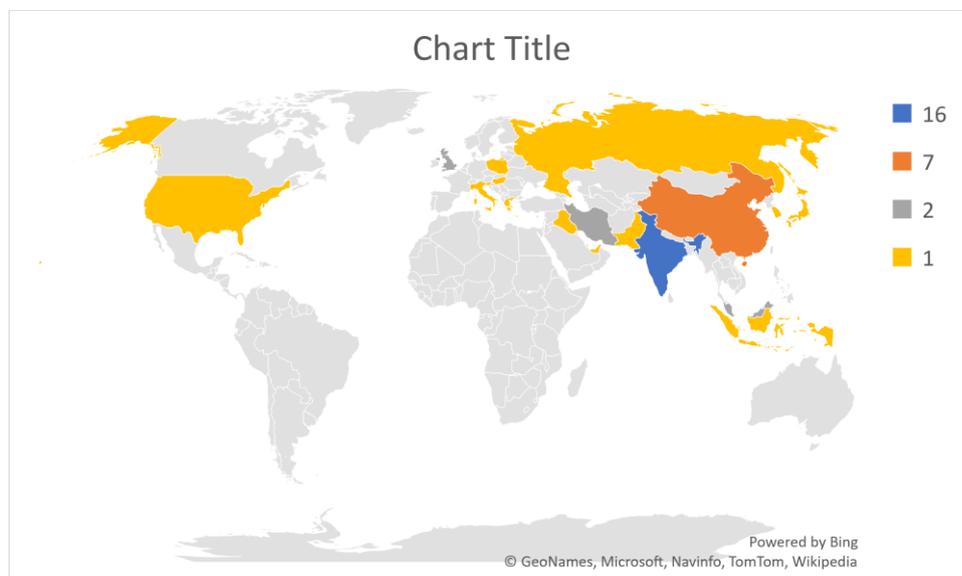


Figure 3. The geographical location of the study carried out for Metal Matrix Composites reinforced with silica

Figure 3 shows the geographical locations of the study carried out on the metal matrix composites reinforced with silica extracted from the green route. It is evident that India is the leading country in this area.

4.4.1 Keyword Statistics

Table 4 lists the first 20 keywords from publications on “Metal Matrix Composites reinforced with silica extracted by Green Route”. Keywords indicate interest and the field of research. The right combination of keywords helps to search for the most relevant information.

Table 4: First twenty keywords related to “Metal Matrix Composites reinforced with silica extracted by Green Route”

Keyword	No. of Publications	Keyword	No. of Publications
Metallic Matrix Composites	28	Mechanical Properties	7
Silica	22	Metal Matrix Composite	7
Aluminium	13	Metals	7
Metal Matrix Composites	10	Silicon Carbide	6
Aluminum Alloys	9	Ceramic Material	5
Reinforcement	9	Sintering	5
Hardness	8	Powder Metal	5

4.4.2 Network analysis

Network analysis can be used to present the relationship between various statistical parameters. The open-source program Gephi is used to perform network research. Gephi allows network data to be filtered, navigated, manipulated, and clustered. Different authors have displayed using nodes and edges. Keywords, citations obtained, affiliations, title, and year are shown. Fruchterman Reingold was used in this layout with different manual adjustments. Figures 4,5 and 6 display networks with various parametric combinations “Metal Matrix Composite reinforced with silica extracted by green route” derived from Scopus search results. In figure 4 there are 192 nodes and 142 edges which describe the network of author keywords and source titles. Figure 5, defines the publication title cluster and the year of publication. The node size indicates that most of the work was published between 2015 to 2020. There are 157 nodes and 150 edges in the network. The size of the cluster directly depends on the number of research

publications. Figure 5 shows that maximum research documents were published in the year 2019.

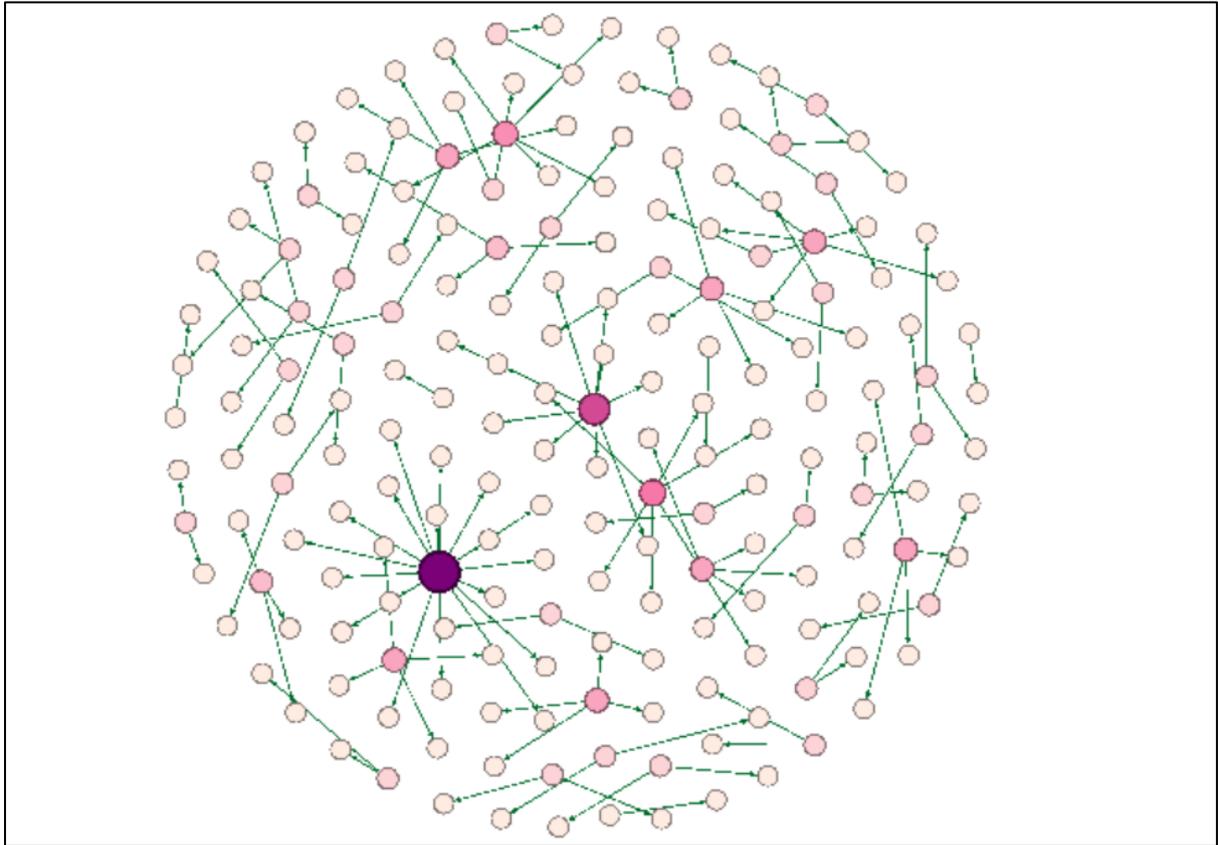


Figure 4: Cluster of keywords used by author keywords and source title (journals)

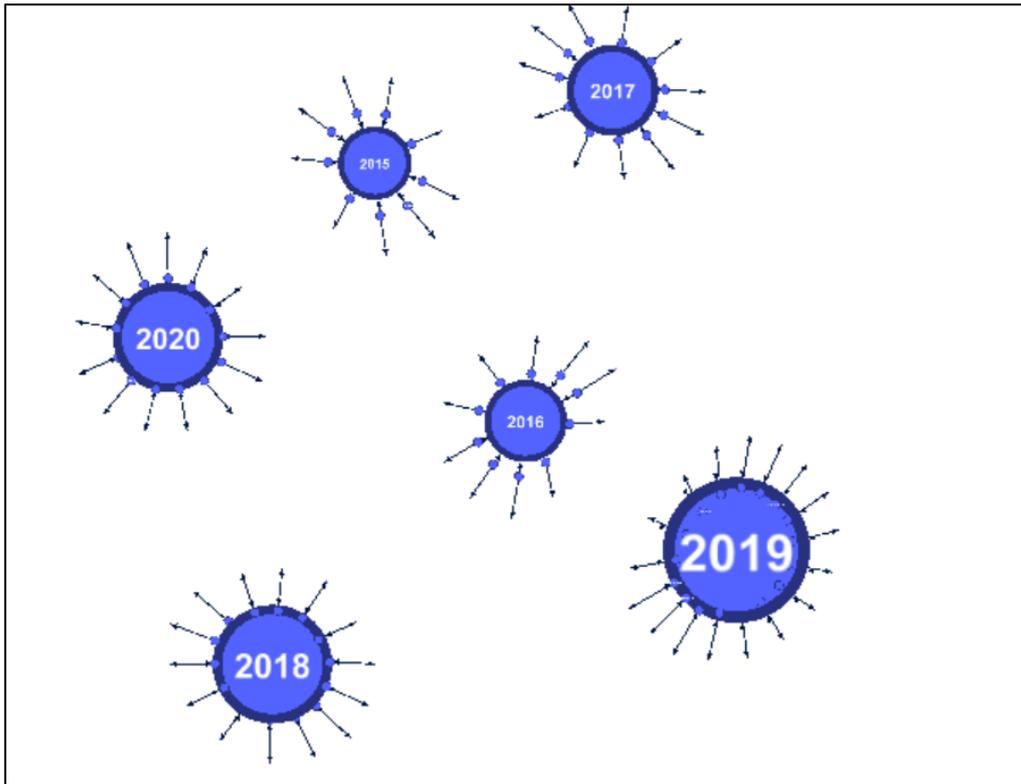


Figure 5: Cluster of publication title and year of publication

The Co-appearance of authors and their keywords among similar papers shown in Figure 6. It was observed that the relevant and significant keywords in the search were “metal matrix composites”, “mechanical properties”, “stir casting”, “wear”, “hardness”, and “microstructure which were found to be used extensively in the search of “Metal Matrix Composite reinforced with silica extracted by green route”.

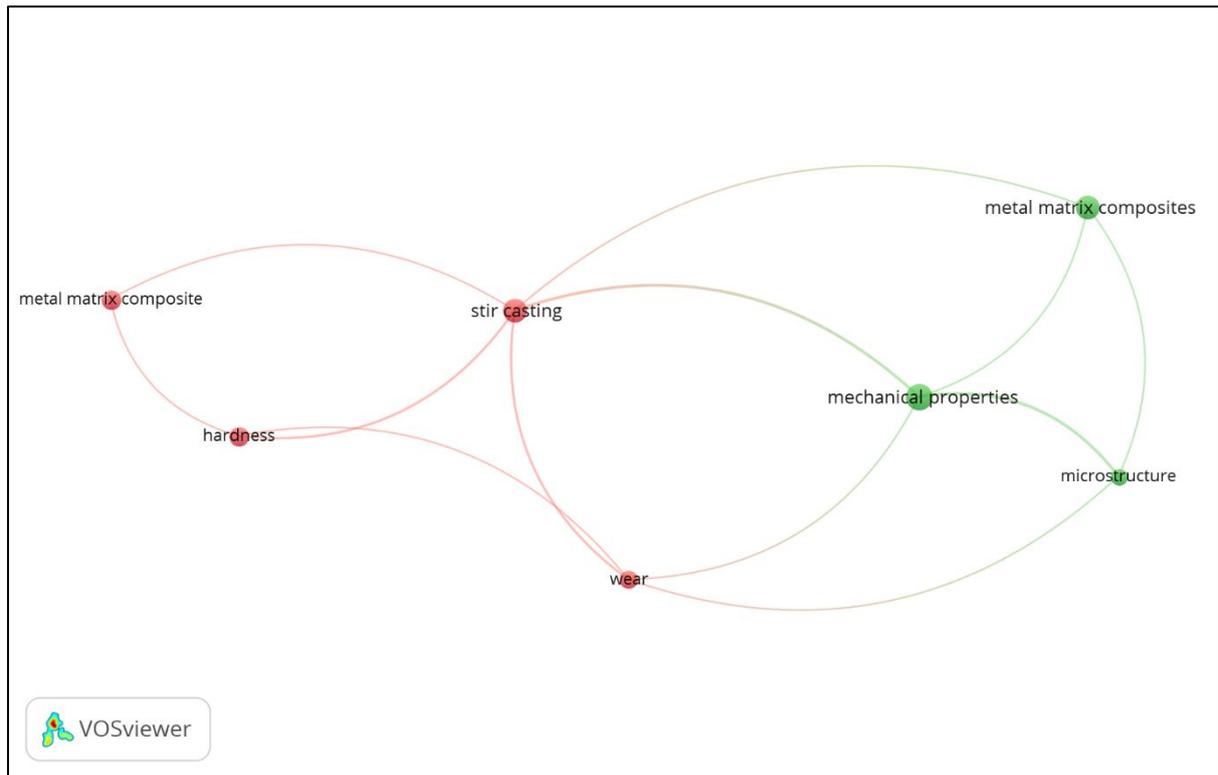


Figure 6: Co-appearance of the author and their keywords among similar papers

4.4.3 Statistics of Affiliation

The top ten contributing universities or organizational affiliations are shown in figure 7. The present work indicates that “Metal Matrix Composite reinforced with silica extracted by green route” is of great research interest among the Defense Research Development Organization, India, National Institute for Interdisciplinary Research, Jadavpur University, Universiti Tun Hussein Onn Malaysia, etc.

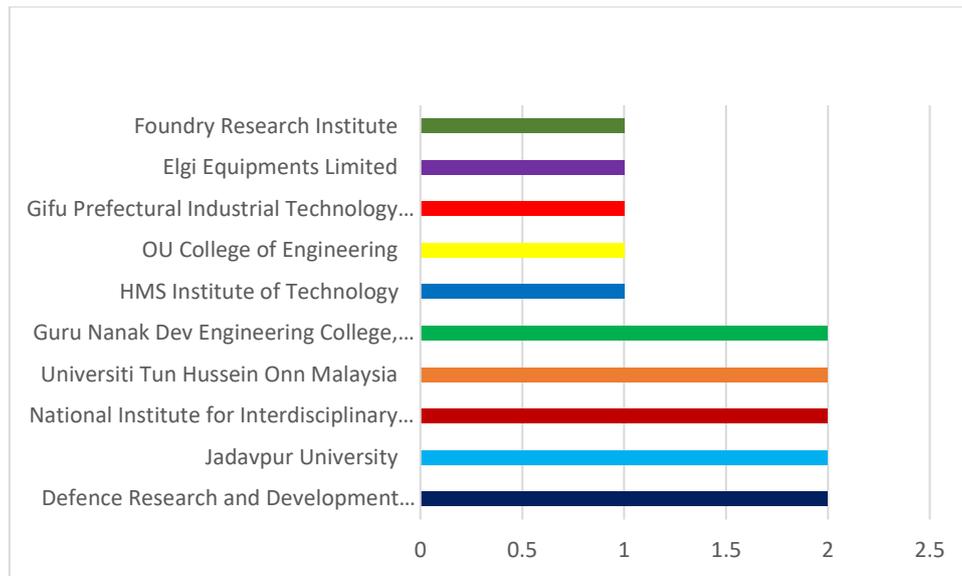


Figure. 7 Statistics of Affiliation for publications in the study of “Metal Matrix Composite reinforced with silica” in the most popular top five journals.

4.4.4 Analysis of Citations

Table 4 displays annual citations received in the field “Metal Matrix Composite reinforced with silica”. A total of 119 publications have been cited and the citation count is 409. Table 5 shows the highest cited publications in the study of “Metal Matrix Composite reinforced with silica” from 2015-2020.

Table 5: Citations analysis of highest cited publications of the “Metal Matrix Composite reinforced with silica”

Year	Number of citations
2020	11
2019	61
2018	90
2017	188
2016	47
2015	12

4.4.5 Statistics of Journal

Figure 8 describes the statistical view of journal publications in the study of “Metal Matrix Composite reinforced with silica”. The Journal of Alloys and Compound, Materials Sciences Forum, Material Today Proceedings, and Transaction of Nonferrous Metals Society have the maximum number of publications.

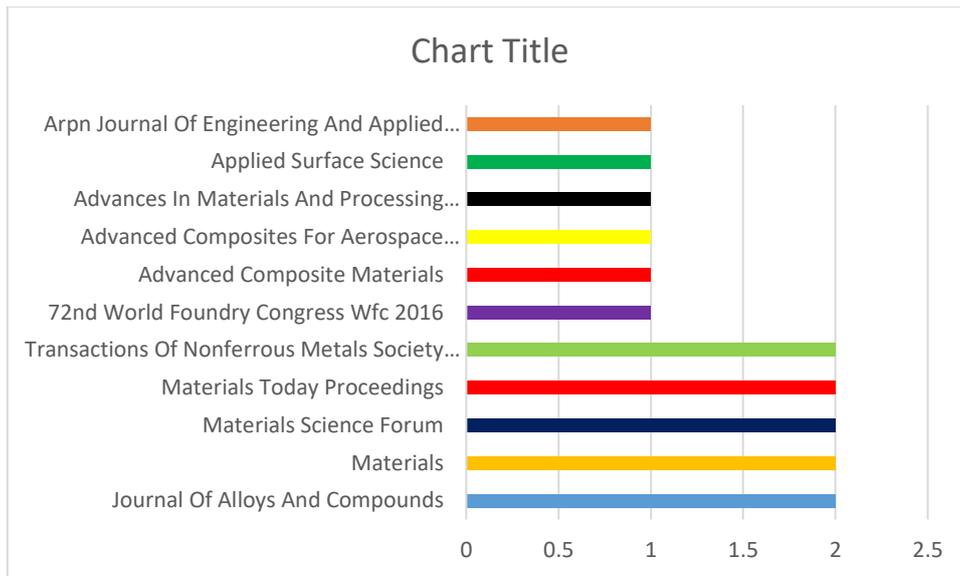


Figure. 8 Journal statistics for publication in the most common top 10 journals for studying “Metal Matrix Composite reinforced with silica”.

4.4.6 Subject Area Analysis

The subject compartmentation graphical analysis for the search for “Metal Matrix Composite reinforced with silica” is shown in figure 8. The search through the selected keywords was confined to the disciplines: Material Science, Engineering, Physics and Astronomy, Chemical Engineering, Earth and Planetary Science, Biochemistry Genetics and Molecular Biology, Chemistry.

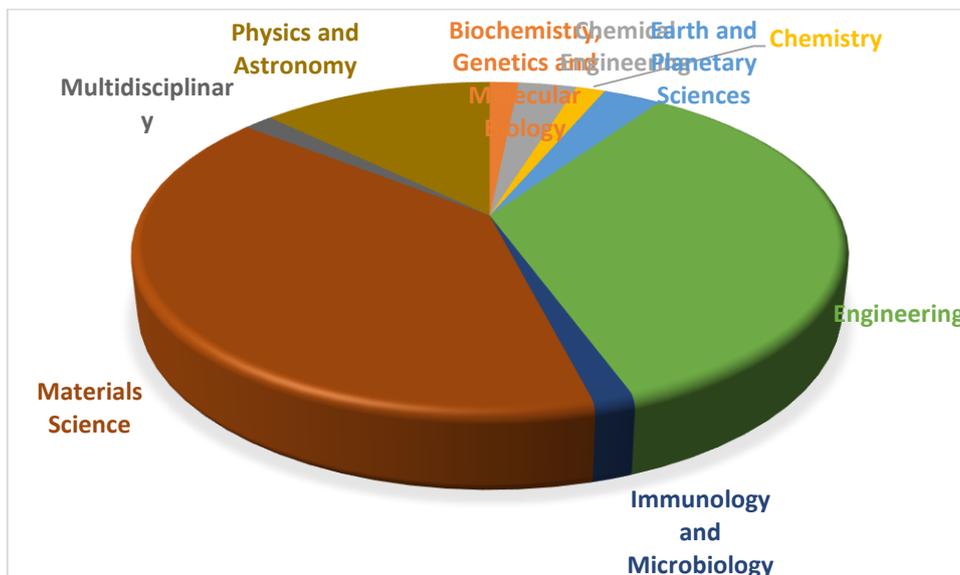


Figure. 9: Subject areas publishing article related to “Metal Matrix Composite reinforced with silica”.

Table 6 displays the top ten documents obtained with the highest citation data available till the date of the survey.

Table 6: Analysis of citations of the top ten publications in the study of “Metal Matrix Composite reinforced with silica ”.

Sr. No.	Document Title	<2016	2016	2017	2018	2019	2020	Total
1	“Direct selective laser sintering and melting of ceramics: A review”	0	0	8	24	36	46	120
2	“Investigations for dimensional accuracy of Al alloy/Al-MMC developed by combining stir casting and ABS replica-based investment casting”	0	0	2	13	13	4	32
3	“On the sintering mechanisms and microstructure of aluminum-ceramic cenospheres syntactic foams produced by powder metallurgy route”	0	0	5	7	8	6	26
4	“WEDM of Mg/CRT/BN composites: Effect of materials and machining parameters”	0	0	0	3	9	12	24
5	“Wear and mechanical properties of surface hybrid metal matrix composites on Al-Si aluminum alloys fabricated by friction stir processing”	0	0	0	0	9	7	16
6	“Wear Behaviour Analysis of Silica Carbide Based Aluminum Metal Matrix Composites”	0	0	0	0	3	12	15
7	“Mechanical Properties and Abrasive Wear Behaviour of Functionally Graded Al-Si ₁₂ Cu/Al ₂ O ₃ Metal Matrix Composite”	0	0	1	6	5	1	13
8	“Investigations on mechanical and tribological properties of Al-Si ₁₀ -Mg alloy/sugarcane bagasse ash particulate composites”	0	0	0	1	6	5	12
9	“Investigation of mechanical, microstructure, and wear behaviors of Al-12%Si/reinforced with melon shell ash particulates”	0	0	0	1	5	4	10
10	“A Comparative study on mechanical properties of Al-SiO ₂ composites fabricated using rice husk silica in crystalline and amorphous form as reinforcement”	0	0	0	1	3	5	9

5. Confines of the present study

A mixture of keywords “Metal Matrix Composite reinforced with silica” used for the search in this area is used in the Scopus database. During the data collection processing phase of this report, some major journals and periodic papers were not available in the Scopus database so those could not be included in this report. This review also restricts research papers published in English only.

6. Conclusion

In the field of Metal Matrix Composites worldwide research is being carried out. The enormous demand for reinforced material silica and its application for Industrial used with ideal functionality and centered study can be fulfilled by the novel approach of extracting silica from the agro waste rice husk ash through the green route and fabricating metal matrix composites using silica as the filler material. This method not only fulfills the industrial demands but also helps to utilize agriculture waste resulting in solving the problem of environmental pollution and the economic use of the agro waste in the growth of the economy and environmental health.

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