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A Bibliometric Analysis of Minimum Quantity Lubrication as A Sustainable Approach

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ABSTRACT

Environment-friendly machining methods are being focused widely across the research areas concerning the consequences and challenges of the traditional methods. Flood lubrication technique which is aggressively being implemented, targeting better machining attributes of the end product. However, the devastating effects of the flood lubrication technique are causing harmful consequences to the environment majorly and the machining operator therein. Minimum quantity lubrication (MQL) which is also called Near-dry machining (NDM) is the most attributed cooling and lubrication approach which justify the sustainable requirements of the development; as it implies only 50-150 ml/hr cutting fluid under consideration. The present article presents the past researcher's contribution to the area of MQL and its allied development by a bibliometric analysis in detail. The analysis is done by using the Scopus database and tools like VOSviewer, and Imap builder. Referring to the Scopus database, it is observed that a total of 1436 articles are published in different forms by past researchers. Observing the trend of publications in the concerned area; the last 7 years are the point of major contribution and in the year 2020; a maximum of 213 articles are published worldwide. The detailed survey revealed that a maximum of journal articles are published as compared to the other relevant sources. India is the leading country in the concerned research area publications followed by China and the United States. MQL has shown promising attributes for sustainable machining practices, but it has a long way to achieve the complete elimination of environment unfriendly practices and research concentration is required in the prospective domain of MQL allied coolants and lubricants.

Keywords: Minimum Quantity Lubrication, Environment Friendly, Sustainable, Bibliometric Analysis

1.INTRODUCTION

Cutting fluid plays a vital role during machining operations to eliminate the adverse effects of the machining parameters. Cooling and lubrication is the major aim of cutting fluid application and other effects such as surface finish, chip breaking, etc. are the subsequent roles of the cutting fluid. The industrial approach of achieving superior quality of end product gives a lot of thrust on heavy usage of the cutting fluid which helps in lowering the cutting temperature of the machining zone and avoid subsequent adverse effects of the same. However, the flood lubrication technique offers the major challenge to the sustainable approach due to the overrated usage of the cutting fluid under the consideration. Elimination of cutting fluids compensating with the help of coating of the cutting tool is a succeeded attempt for lower cutting speed, but eventually, at the higher cutting speeds, the performance of the coatings is questionable as the higher temperature is the adhering part of the high-speed machining. So, dry machining has its limitations, majorly at the higher cutting speed.

Minimum quantity lubrication (MQL) which is also known as “Near-dry machining” and “Micro lubrication” is a sustainable approach that justifies the purpose of cutting fluid application along with no question of recycling or disposal of the used cutting fluid. MQL is the environment-friendly approach which uses 50-150 ml/hr of cutting fluid works on the application of compressed air and cutting fluid combination through the nozzle causing a proper penetration at the machining zone and serving the purpose of cooling and lubrication concerning the compressed air and cutting fluid mixture respectively. Sustainability is the approach that widely addresses the major issues of environment protection, safe working conditions, energy utilization, resource utilization, production cost, quality of the product, labor welfare, and overall benefits to the society as a major goal, etc. (Fratila & Caizar, 2011; Eker et. al., 2014; Rahim et. al., 2015; Gajrani & Sankar, 2018; Gajrani et. al., 2019).

Past researchers have noticed the superior performance of the MQL environment as compared to the flood lubrication and dry machining environment. The comparative study shows a significant reduction in cutting temperature, forces, and machining cost alongside improved tool life, surface finish, and overall machining performance. While attempting the performance evaluation of MQL during the machining of hard to cut materials such titanium alloy, nickel alloy, hardened steel, etc. (Gill et. al., 2011; Thakur et. al., 2013; Elshwain et. al., 2013; Sharma et. al., 2016; Park et. al., 2017).

MQL is a versatile method as it is compatible for application with all the material types and a variety of cutting fluids. The recent trend of the last 7 years is prone to evaluate the application of vegetable-based cutting fluids which is also known as “Biolubricants” which is compatible under the MQL method. Researchers have noted the compatible application of a variety of biolubricants such as coconut, sunflower, soybean, canola, castor, peanut, alove-vera, etc. under the application of MQL. Biolubricants offers better lubrication and environment-friendly solution attributed to their biodegradability up to 95%. This adds to the sustainable approach of MQL along with the usage of biolubricants addressing the major issues of environment, health, and cost (Lawal et. al., 2013; Pande & Patil, 2014; Agrawal & Patil, 2018). The performance of the MQL method is evaluated for varied machining processes such as turning and grinding and better results are noted over the flood and dry machining approach (Wang et. al., 2016;). Past researchers have noted the minimum chip thickness under the application of MQL and biolubricants leading to lower energy consumption during machining under consideration (Gunjal & Patil, 2018; Gunjal et. al., 2020).

The current bibliometric analysis is a summarized study to present the past researcher's contributions from the year 1993 to 2020. The present study gives a detailed analysis of worldwide research in terms of different segments like subject area, source, country, funding sponsor, etc. The presented analysis will provide the path for the researchers working in a similar area with the necessary insights for review and future work.

2. PRIMARY DATA COLLECTION

Scopus is the most popular source of scientific database. For the current study, the Scopus database is used for analysis. The master and primary keywords used are summarized in table 1.

Table 1: Keywords used in Scopus Database.

Master keyword	“Minimum Quantity Lubrication”
Primary keyword	“Minimum Quantity Lubrication” AND “Lubrication” AND “Cutting Fluids” AND “Cooling” AND “Coolants” AND “Floods” AND “Experimental Investigations” AND “Sustainable Development” AND “Lubricants” AND “Dry

“Minimum Quantity Lubrication” is used as a primary source of keyword for database search which shows 1436 publications in the Scopus database, while the search concerning the specific keywords for the analysis gives 1280 publications in the Scopus database (Data accessed till Dec. 12th, 2020). Figure 1 indicates the word cloud of secondary keywords. The cluster analysis of overall keywords is done using “VOS viewer” software. Figure 2 shows the cluster of overall keywords as below. One can easily emphasize the impacting keywords for the research area under consideration using the cluster analysis.

3 ANALYSIS AND INTERPRETATION OF DATA

Referring to the literature available in the Scopus database concerning the access type, publication year, document type, subject area, source title, etc. following analysis is presented.

3.1 Analysis by Affiliation, Author, and Language of Publication

Based on the resource data; the top 10 affiliations are taken into consideration. A maximum of 35 affiliations are observed for the Ministry of Education China and observed to be the top in the table.

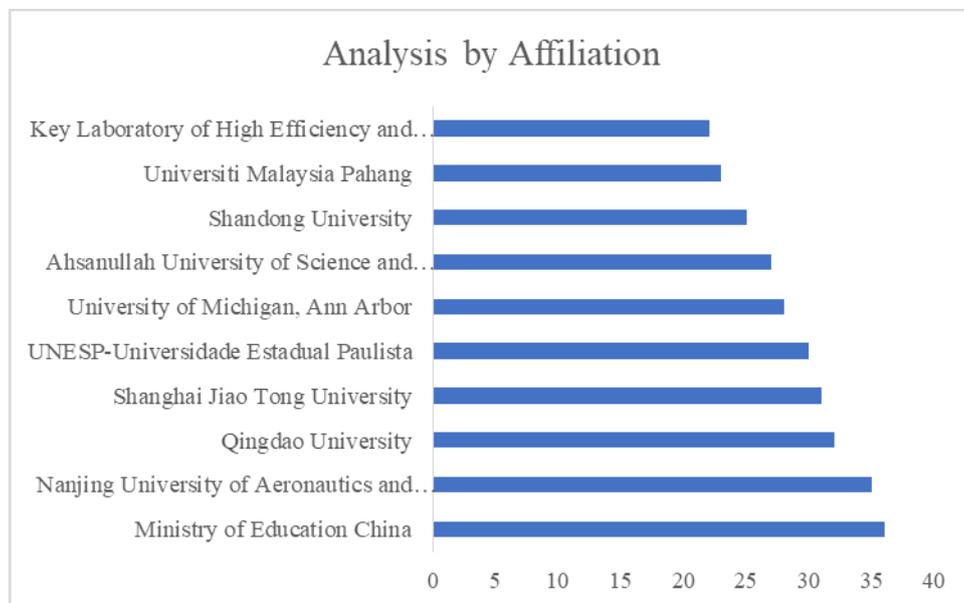


Figure 3: Analysis by Affiliation (Data access till Dec. 12th, 2020).

A total of 289 publications are noted for the top 10 affiliations in the current study of bibliometric analysis. Referring to the data available for authors; analysis shows that a total

of 339 papers are published by the top 10 authors worldwide. Considering the analysis of publication language; a maximum of 1235 publications contributing to 96% of a total count is written in the English language by the researchers to date worldwide. Other languages like Chinese is used in 26 publications and remaining like German, Japanese, Portuguese, Korean, and Spanish are used in single digit.

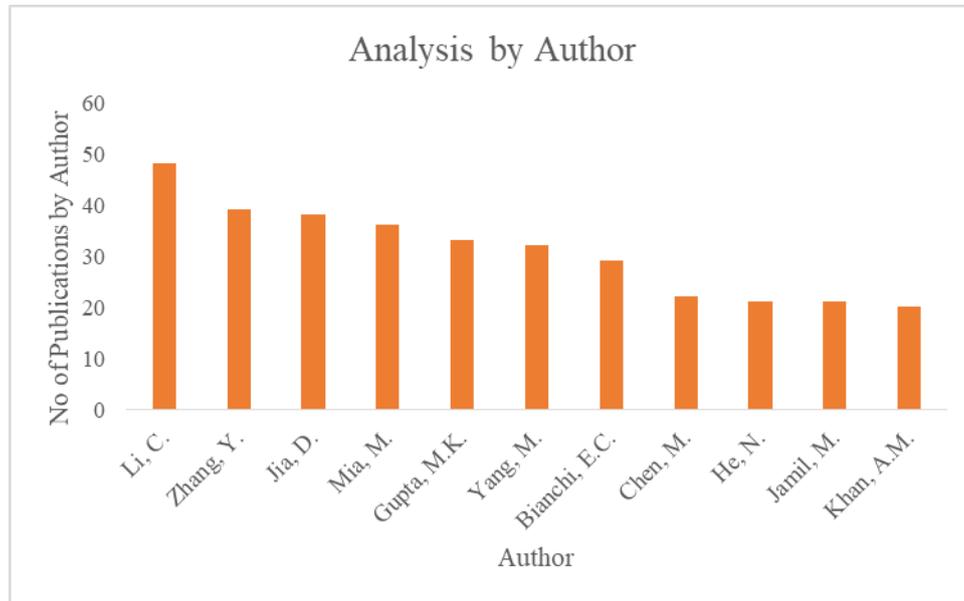


Figure 4: Analysis by Author (Data access till Dec. 12th, 2020).

Figure 3 and 4 indicates the summary of analysis for top 10- affiliations and authors respectively in the current study. Table 2 shows a summary of data concerning the publication language.

Sr. No.	Publication Language	No. of Publications in Scopus
1	English	1235
2	Chinese	26
3	German	8
4	Japanese	6
5	Portuguese	3
6	Korean	1
7	Spanish	1

3.2 Analysis by Access and Document Type

In this type of analysis, one can find the analysis of the current study by access and document type. Referring to the available data in the Scopus database; there are 227 publications as an open-access and the rest are 1053. Figure 4 as shown below shows the representation of the analysis by access.

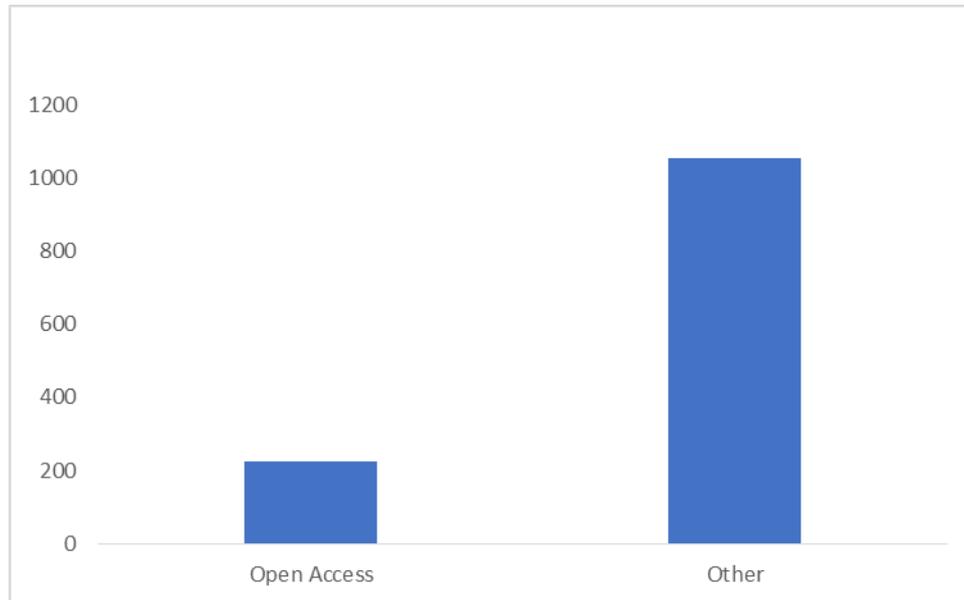


Figure 5: Analysis by Access (Data access till Dec. 12th, 2020).

Based on document type; most of the publications are observed as an article category. Table 3 shows a summary of data based on the Scopus database.

Table 3: Summary of Data based on Document Type (Data access till Dec. 12th, 2020).

Sr. No.	Document Type	No. of Publications in Scopus
1	Research Article	888
2	Conference Paper	336
3	Review Paper	37
4	Book Chapter	18
5	Book	1

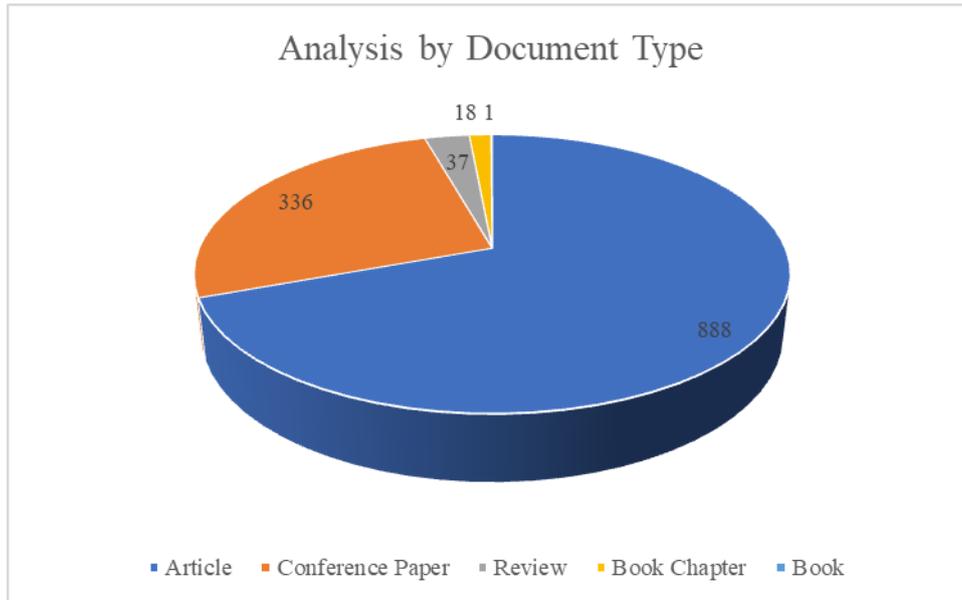


Figure 6: Analysis by Document Type (Data access till Dec. 12th, 2020).

Observing the analysis based on document type; maximum publications are observed as research articles, whereas; the conference papers are 336, review papers are 37, and book chapter contribution is 18 as shown in figure 6. This shows the quality contribution of past researchers in various aspects.

3.3 Analysis by Year

The comprehensive summary of the year-wise publication is presented under this section. The publications in the last 25 years; 1993 to 2020 are analyzed for the current study.

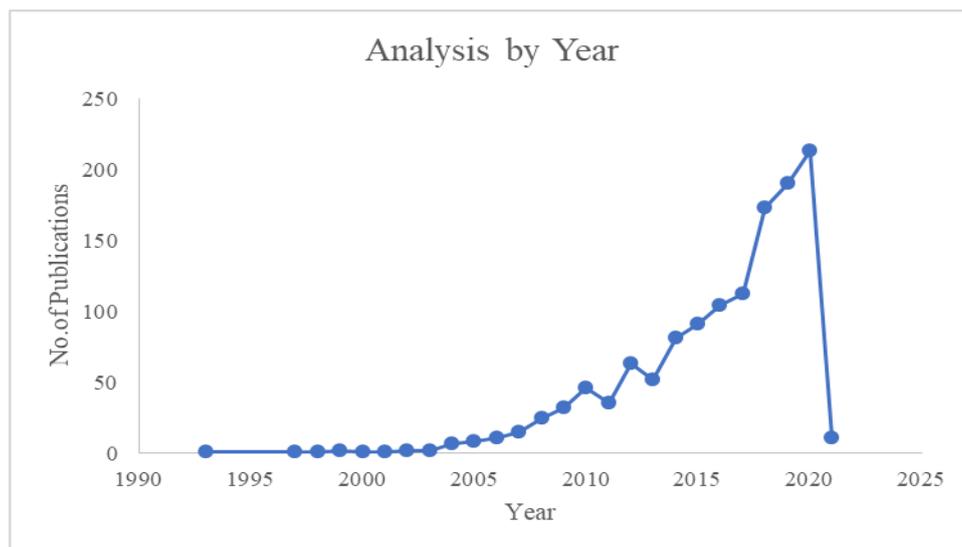


Figure 7: Analysis by Year (Data access till Dec. 12th, 2020).

A maximum of 213 publications is observed in the year 2020 which is the highest of the last 25 years. Figure 7 shows the analysis of the literature by year based on Scopus data. The trend of research contribution to the minimum quantity lubrication area is increasing concerning the environment-friendly approach and sustainable attributes of it. In the last 7 years; from 2014 to 2020 the contribution is significant and is exponential in the year 2020. Observing the trend based on the year's analysis; one can notice the increasing citations in the last 10 years and significant improvement in the year 2020 as attributed in years analysis as well.

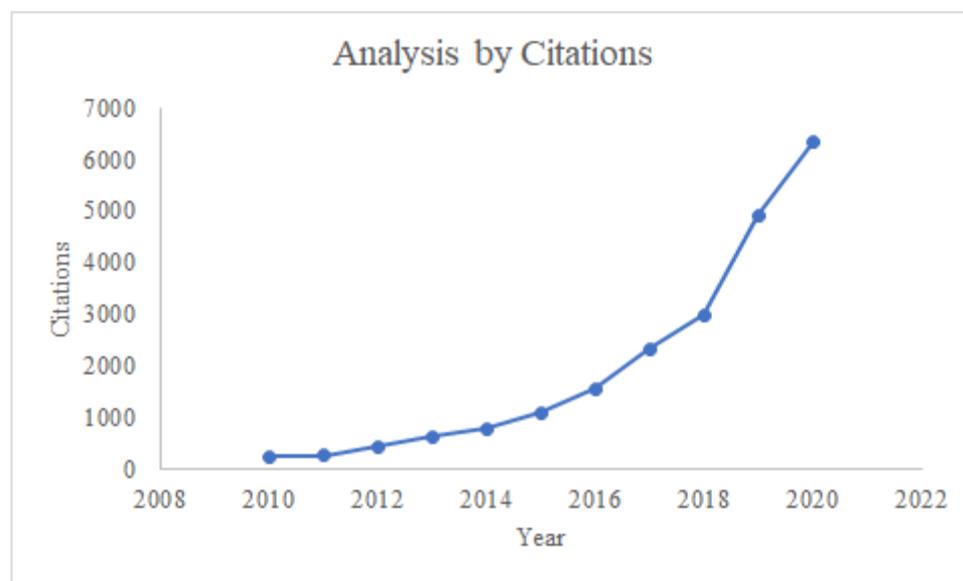


Figure 8: The Trend of Citations Yearwise (Data access till Dec. 12th, 2020).

3.4 Analysis by Subject Area

The analysis by subject area helps in identifying the key areas of concentration for the current study. A total of 1136 publications are noted under the Engineering subject area followed by 396 publications in the area of material science. Figure 9 shows the analysis by subject area based on the Scopus database.

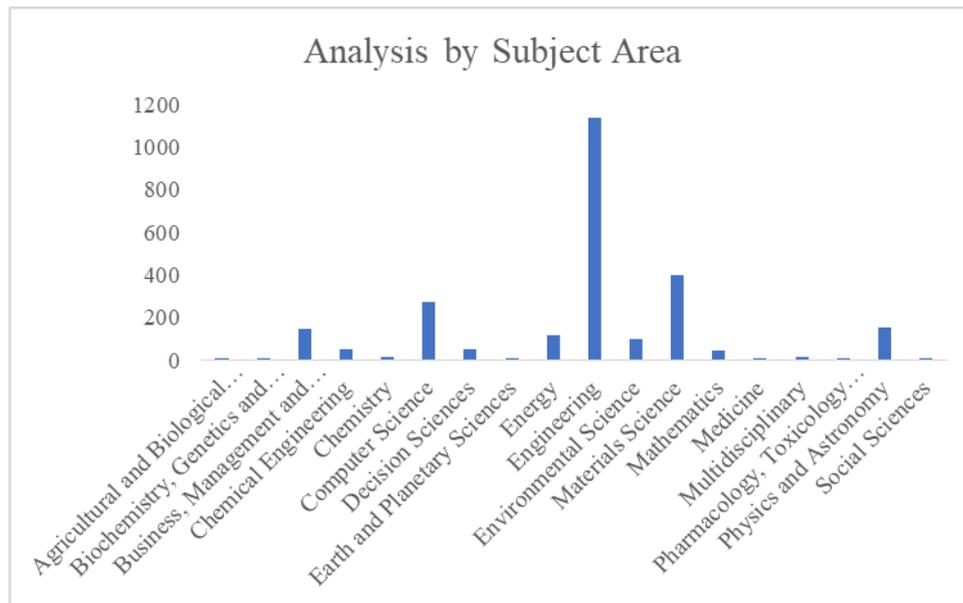


Figure 9: Analysis by Subject Area (Data access till Dec. 12th, 2020).

The maximum contribution in the area of engineering and material science is attributed to the core applications of minimum quantity lubrication in machining and material characterization aspects. Various cutting fluids under the application of minimum quantity lubrication are evaluated for the range of materials by the past researchers and the compatibility of the MQL as a machining environment is well justified without affecting the quality of the end product. Other areas apart from engineering and material science are noted as chemical engineering, energy, environmental science, physics, etc.

3.5 Analysis by Source

This section describes the summary of data concerning the various sources based on the Scopus database. A maximum of 158 publications is noted from the International Journal of Advanced Manufacturing Technology followed by 75 in the Journal of Cleaner Production. Table 4 shows the summary of data concerning the analysis for the top 10 sources.

Table 4: Summary of Data based on Source (Data access till Dec. 12th, 2020).

Sr. No.	Source Title	No. of Publications in Scopus
1	International Journal Of Advanced Manufacturing Technology	158
2	Journal Of Cleaner Production	75
3	Procedia CIRP	41
4	Journal Of Manufacturing Processes	40

5	Materials Today Proceedings	36
6	Proceedings Of The Institution Of Mechanical Engineering Part B Journal of Engineering Manufacture	33
7	International Journal Of Machine Tools And Manufacture	31
8	Materials And Manufacturing Processes	29
9	Tribology International	27
10	Advanced Materials Research	23

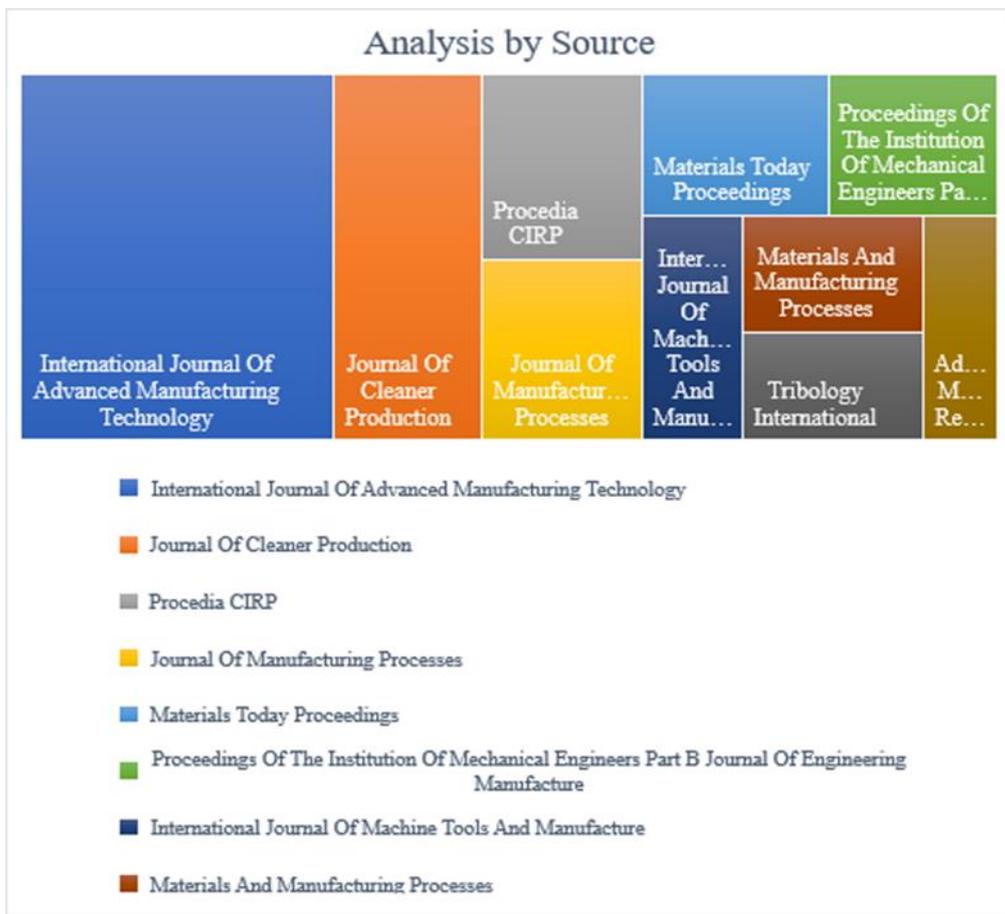


Figure 10: Analysis by Source (Data access till Dec. 12th, 2020).

3.6 Analysis by Country

Analysis of country is presented to understand the concentrations in the concerned research area. Based on the Scopus database; it has been observed that a maximum of 354 publications is contributed from India followed by 250 in China, and 174 in the United States as the top three countries worldwide. The top 10 countries are taken into consideration to present the analysis. Figure 11 shows the analysis by country based on the Scopus database under consideration.

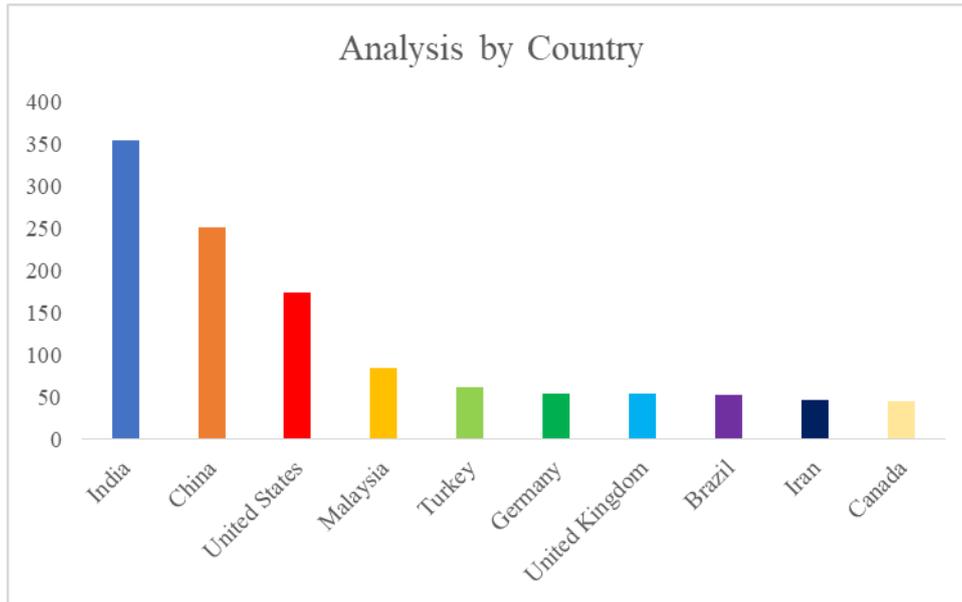


Figure 11: Analysis by Country (Data access till Dec. 12th, 2020).

In addition to the above; the topographical locations of the country having publications in the Scopus database is located and presented using Imap builder software.



Figure 12: Topographical Locations of the Country (Data access till Dec. 12th, 2020).

3.7 Analysis by Funding Sponsor

Funding for the research work promotes the researchers for motivation and acts as a catalyst in the entire process of the research. This section emphasizes the analysis by the funding sponsor. Figure 13 shows the representation of the analysis for the top 10 funding sponsors worldwide.

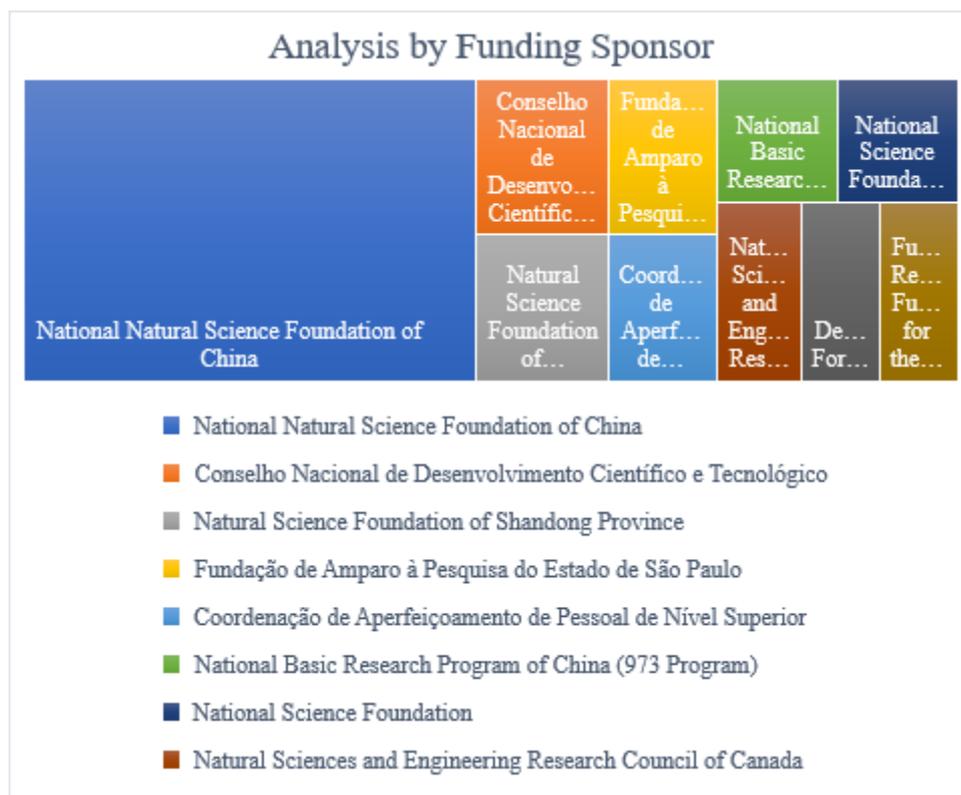


Figure 13: Analysis by Funding Sponsor (Data access till Dec. 12th, 2020).

Based on the analysis; one can note that the National Natural Science Foundation of China is the topmost funding source in the world accounting for a maximum of 128 publications. Table 5 shows the summary of data for the top 10 funding sponsors based on the Scopus database.

Table 5: Summary of Data based on Funding Sponsor (Data access till Dec. 12th, 2020).

Sr. No.	Source Title	No. of Publications in Scopus
1	National Natural Science Foundation of China	128
2	Conselho Nacional de Desenvolvimento Científico e Tecnológico	19
3	Natural Science Foundation of Shandong Province	18
4	Fundação de Amparo à Pesquisa do Estado de São Paulo	16
5	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior	15
6	National Basic Research Program of China (973 Program)	14
7	National Science Foundation	14
8	Natural Sciences and Engineering Research Council of Canada	14
9	Deutsche Forschungsgemeinschaft	13

10	Fundamental Research Funds for the Central Universities	13
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4. CONCLUSIONS

Sustainability is a broader concept and outreach to every best possible aspect of Engineering, Environment, and Society as a key attribute. The research contribution in the last 7 years is well articulated worldwide to signify the application of the Minimum Quantity Lubrication technique in the industry. Challenges associated with the flood lubrication such as cutting fluid cost, operational safety, resource utilization, environmental issues, etc. and that for dry machining; especially at the higher cutting speed, such as extreme temperature in the machining zone, abrupt tool failure, uneven surface finish, etc. are well answered and justified by the MQL method. The compatibility of the MQL system is evaluated and the performance evaluation is done by the past researchers concerning the various materials, machining conditions and applications are the sign of sustainable tomorrow. The comprehensive study is presented in the current bibliometric analysis emphasize the Scopus-based data of the last 25 years; 1993 to 2020. The significant contribution in the year 2020 is observed in the concerning research area and it is well attributed to the exponential rise in the last 7 years. This justifies the attention of the researchers to address and promote sustainable practices for the time to come.

India being the top contributor in the research area of Minimum Quantity Lubrication will hopefully continue to add further development aligning the sustainability for higher productivity. As the industrial approach is inclined to achieve superior product quality with the minimal consumption of resources; MQL would be the significant method in attributing the same. Future scope for the presented bibliometric analysis would be the comprehensive study of environment-friendly cutting fluids under Minimum quantity lubrication along-with the performance evaluation study of nanoparticles in the same. This would enable researchers to study and refer to the complete cycle of sustainability and productivity for a better tomorrow.

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