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A Bibliometric Analysis of Variable Displacement Pump for Optimal Control of Operating Parameters

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ABSTRACT

A centralized lubrication system or automatic lubrication system (ALS) is a system that delivers controlled amounts of lubricant to multiple locations on a machine while the machine is operating as per machine requirement. Lubrication occurs while the machinery is in operation, causing the lubricant to be equally distributed within the bearing and increasing the machine's availability. Proper lubrication of critical components ensures the safe operation of the machinery. Less wear on the elements results in extension of component life, lower breakdowns, reduced downtime, reduced replacement costs, and reduced maintenance costs. If we can measure lubrication amounts, we can control the wasted lubricant supplied in excess to machine components, resulting in lowering energy consumption. The advantages of this new technology are transparent, although the heart of the automated lubrication system is the variable displacement pump. It is observed that a total of 1554 articles are published in different forms by past researchers. Following the trend of publications in the concerned area, the last seven years are the point of significant contribution, and in the year 2020, a maximum of 109 articles are published worldwide. The detailed survey revealed that a maximum of journal articles is published compared to the other relevant sources. China is the leading country in the concerned research area publications, followed by the United States and Italy.

Keywords- Variable Displacement Pump, Precision Control Variable Displacement Pump, Radial Piston Pump, Variable Displacement Linkage.

1.INTRODUCTION

The 2% power consumption in the US is consumed by a hydraulic system which Oak Ridge studied in 2012. He also found the efficiency of industrial power systems is 50% & 21 % for mobile hydraulic power systems [1], which results in 120 to 171 million metric tons CO2 discharge in the atmosphere at the cost of $16B to $28B annually. All losses are happening because of metering flow control when flowrate and pressure are controlled by throttle opening. There is a clear requirement of eco-friendly and cost-effective flow control methods.

There are three common methods for controlling hydraulic flow: metering valves, speed control of an electric motor with a variable frequency drive, and variable displacement hydraulic pumps. Each of these is having advantages and disadvantages over each other. When the flow from a fixed displacement pump is controlled using a variable orifice valve to throttle is termed Metering valve control. This method is commonly used in both mobile and industrial applications. This method is more popular because it is cost-effective, easy to maintain, and fast response method. But this method is the most inefficient solution because a large amount of energy is dropped while Metering valve control.In Variable frequency drives (VFDs), a fixed displacement hydraulic pump is directly controlled by varying shaft speed attached with an electric drive motor. The low power density of electric motors required more space, which is the limitation of this method. While being the most efficient solution, VFDs are limited by the high cost associated with increased power drives and the reduced motor life [2] Variable displacement pumps are the pump in which the revolution of the input shaft can control discharge volume. Variable displacement pumps are a more efficient method as compare with the metering valves method [3]. A variable displacement pump can deliver the power required by the system instead of throttling, which leads to unnecessary power across a valve, thus consuming less energy to complete the same task. Positive displacement hydraulic pumps and motors are of several types: piston machines, gear, screws, and lobe. The parts that directly control variable displacement are the axial piston, bent axis, and vane. Much work is done to enhance the efficiency pump by improving the axial piston, bent axis, and vane machines [4-8]. All this work enhances the pump's efficiency but not giving the same performance at low volumetric displacement. Because of its compact size and robust design, the axial piston pump is the most suitable and accepted solution for variable displacement [9]. The main component of the axial piston pump is a non-rotating swashplate placed at an angle to the rotational axis of a cylinder block. When the cylinder block rotates piston slides along the swashplate on a hydrostatic bearing, the piston reciprocates due to relative angle. The swashplate angle decides the displacement of the piston, which is directly associated discharge of the pump.

The application of a variable displacement pump and a low-speed high torque (LSHT) motor is seen in off-highway vehicles [10]. The radial piston motors are displacement dense but are not continuously variable, whereas the axial piston motors are continuously variable. Experimentation is performed to find the efficiency model for a low-power single-cylinder pump; results Shown that this architecture can achieve greater than 90% efficiency across the majority of the operating region [11]. Dr. James D. Van et al. [12] This paper outlines various applications and methods of implementing variable displacement pumps. Which is having High Efficiency – Wide Range, Reaches True Zero Displacement, Water Compatible. Zachary Wagner [13] An pressure is regulated in a hydro-mechanical control system by controlling inlet and outlet pressure difference by the flow control valve. With a constant margin pressure, predictable flow control and improved efficiency are achieved by controlling the orifice area of the flow control valve. Longke Wang [14] aims to develop the program and hydraulic circuit for a valve-less solution that will give pump displacement controlled actuators from controls background. Experimental results are presented to validated for valve-less control performance. In this paper, two approaches are stated to resolve the noise problem in axial piston pumps. Viral Mehta [15] focuses on motivation in the first approach, which is the driving force to reduce the pump noise from the current level. In the second approach, the focus is given to understand the problem and the mechanisms involved. Ing. M. Deeken [16] This paper focuses on developing the specific computation algorithms required to solve the differential equations is being prevented by the use of existing software tools. The kinematics of the pump or motor can be modeled in a mechanical simulation program, while the hydraulic section is modeled using a hydraulic design tool. Mr. Kekare H.T [17] The economical solution to vary the discharge is a bent axis piston pump. Variable displacement linkage will give stroke variation; which controls release manually in the two-cylinder radial piston pump. This variable displacement piston pump has an advantage over the power to weight ratio, making the pump most suitable for control of high power levels.

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	"Variable Displacement Pump"
Primary keyword	"Precision Control Variable Displacement Pump" AND "Floating Eccentric Mechanism" AND "Bent Axis Piston Pump" AND "Radial Piston Pump" AND "Variable Displacement Linkage"

Figure 1: Word Cloud of Keywords

"Variable Displacement Pump" is used as a primary source of keyword for database search. In this search, we found that 1664 publisher published their data in the Scopus database, while the search concerning the specific keywords for the analysis gives 2025 publications in the Scopus database (Data accessed till May. 14th, 2021). Figure.1 indicates the word cloud of secondary keywords. One can easily emphasize the impacting keywords for the research area under consideration using the cluster analysis.

3 ANALYSIS AND INTERPRETATION OF DATA

The details of database from literature available in the Scopus database, which contains access type, publication year, document type, subject area, source title, etc. the predictions are made as follows.

3.1 Analysis by Affiliation, Author, and Language of Publication

According to the Scopus resource data, after comparing the top 10 affiliations worldwide it is observed that National Natural Science Foundation of China is having 95 affiliations which is maximum amount of affiliations worldwide.

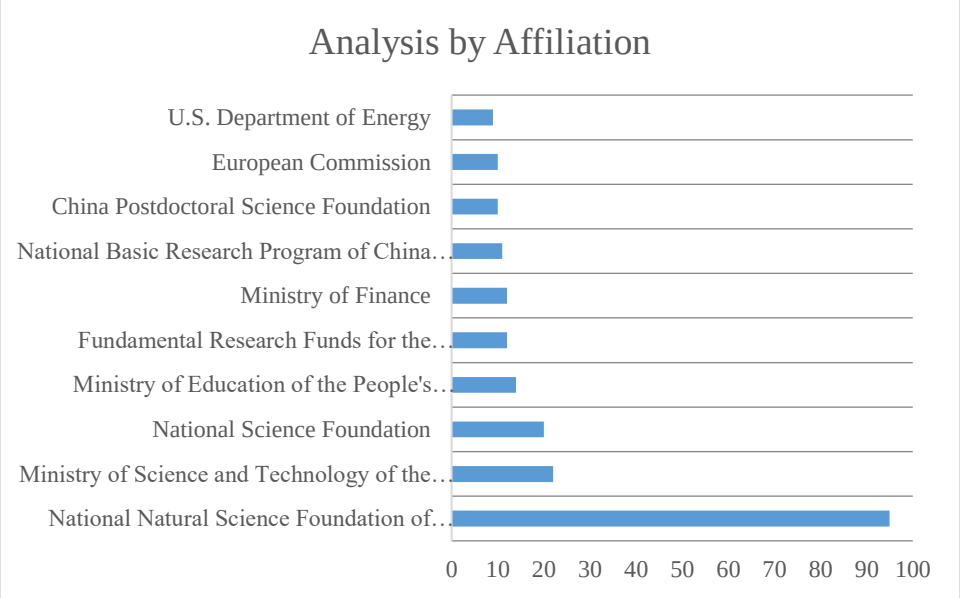

Figure 2: Analysis by Affiliation (Data access till May. 14th, 2021)

A total of 215 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 229 papers are published by the top 15 authors all over the globe. Considering the analysis of publication language; a maximum of 1786 publications contributing to 82% of a total count is written in the English language by the researchers to date worldwide. Other languages like Chinese is used in 8% publications and German is used 7%, remaining like Italian, French and Japanese is below 5%.

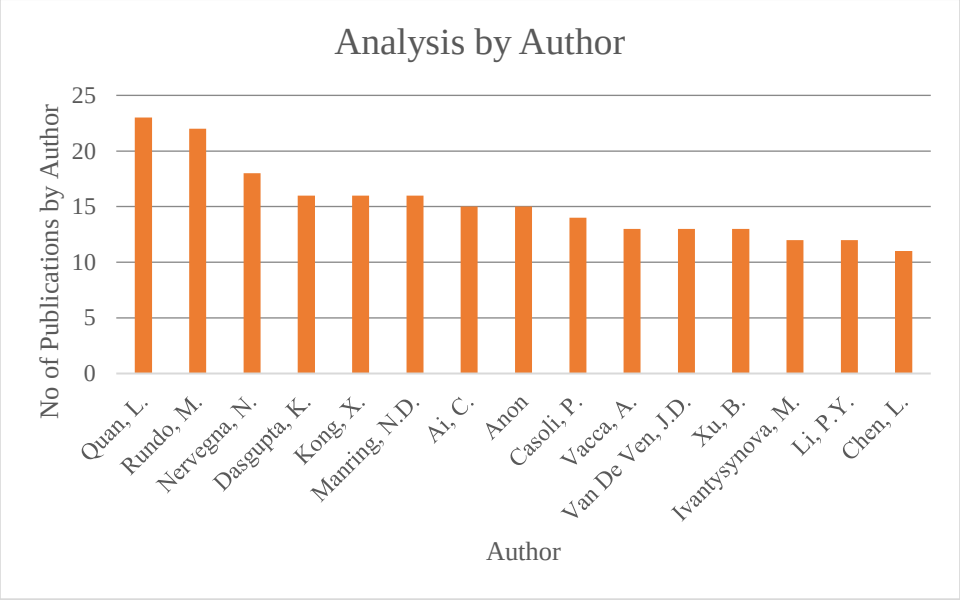

Figure 3: Analysis by Author (Data access till May. 14th, 2021).

Figure.2 and Figure.3 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.

Table.2 Summary of data concerning the publication language (Data access till May. 14th, 2021)

Sr. No.	Publication Language	No. of Publications in Scopus
1	English	1786
2	Chinese	170
3	German	156
4	Italian	47
5	French	38
6	Japanese	14

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 230 publications as an open-access and the rest are 177. Figure.4 shows the representation of the analysis by access.

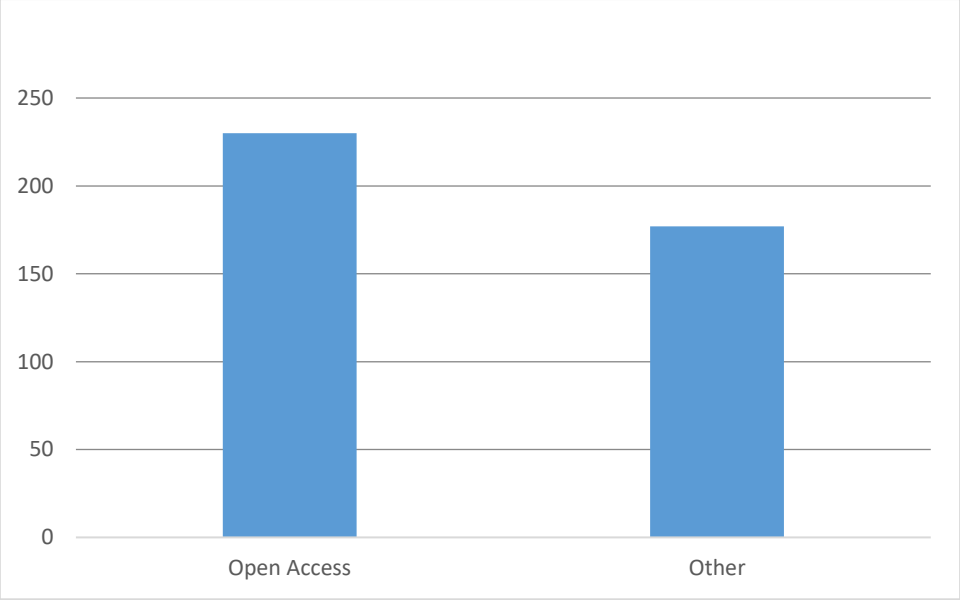

Figure 4: Analysis by Access (Data access till May. 14th, 2021).

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 May. 14th, 2021).

Sr. No.	Document Type	No. of Publications in Scopus
1	Research Article	1554
2	Conference Paper	696
3	Review Paper	35
4	Conference Review	29
5	Book Chapter	13

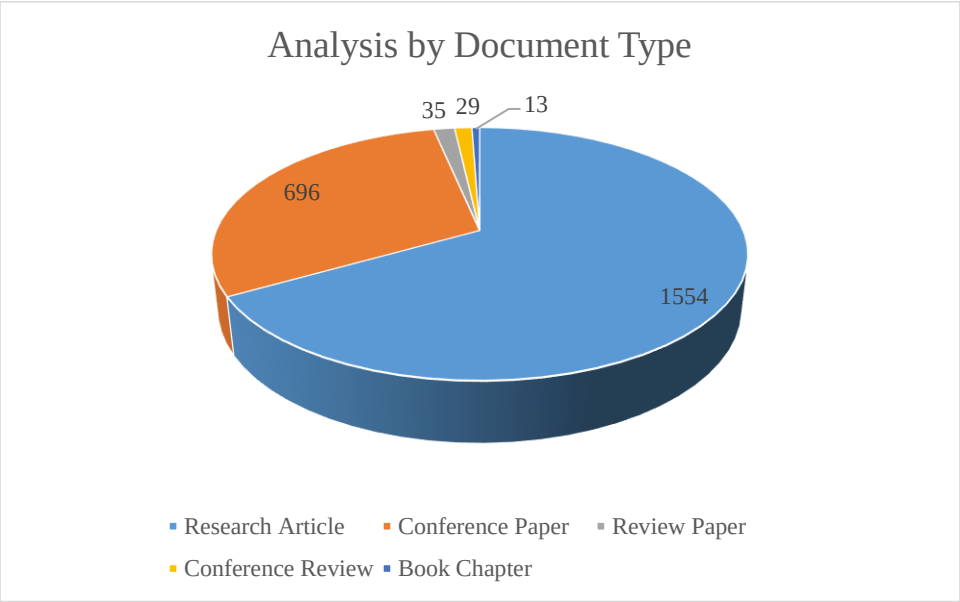

Figure 5: Analysis by Document Type (Data access till May. 14th, 2021).

Observing the analysis based on document type; maximum publications are observed as 1554 research articles, whereas; the conference papers are 696, review papers are 61, and book chapter contribution is 13 as shown in figure 5. 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 51 years; 1969 to 2021 are analyzed for the current study.

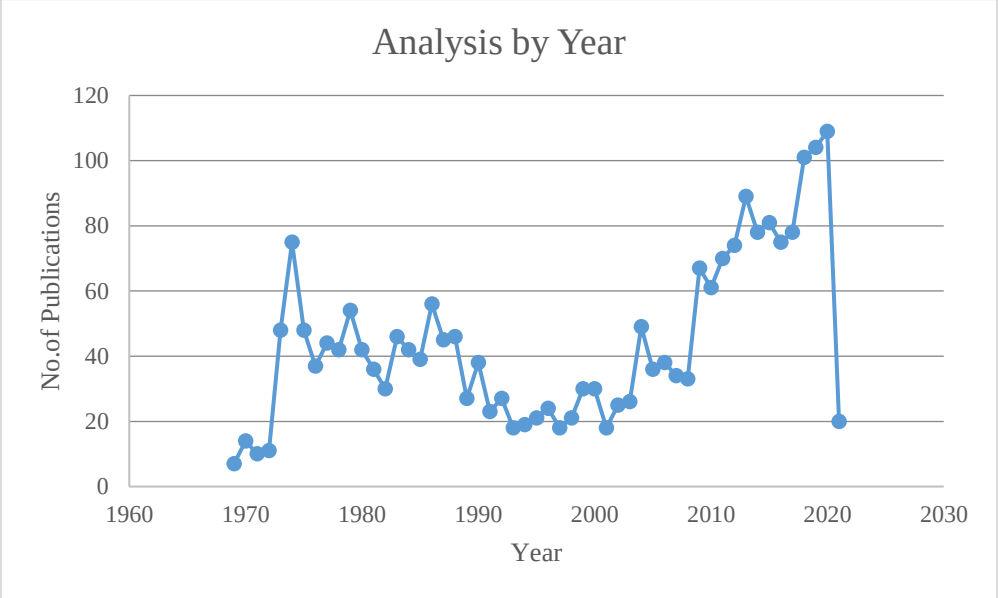

Figure 6: Analysis by Year (Data access till May. 14th, 2021).

A maximum of 109 publications is observed in the year 2020 which is the highest of the last 51 years. Figure.6 shows the analysis of the literature by year based on Scopus data. Variable Displacement Pump was the untouched area before 1980 but from 2009 to 2015 when precise volume discharge is need of hour from that time we can find the increasing trend in publication on Variable Displacement Pump. In the last 6 years; from 2015 to 2021 the contribution is significant and is maximum 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 after 2015 year as attributed in years analysis as well.

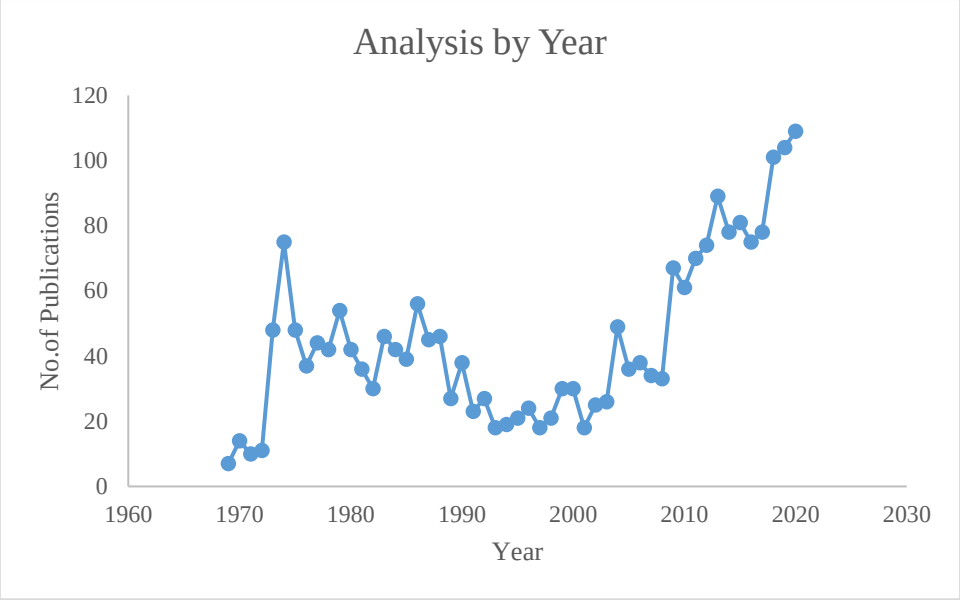

Figure 7: The Trend of Citations Year wise (Data access till May. 14th, 2021).

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 1981 publications are noted under the Engineering subject area followed by 251 publications in the area of Computer Science. Figure 9 shows the analysis by subject area based on the Scopus database.

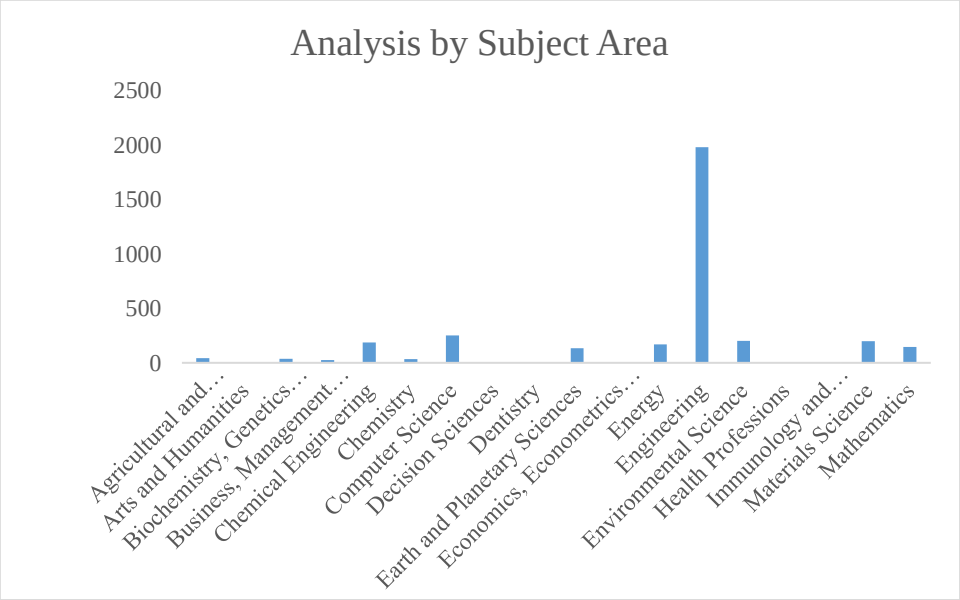

Figure 8: Analysis by Subject Area (Data access till May. 14th, 2021).

The maximum contribution in the area of engineering and Computer Science is attributed to the core applications of minimum quantity lubrication in machining aspects. Other areas apart

from engineering computer Science and Environmental science having contribution in said area.

3.5 Analysis by Source

This section describes the summary of data concerning the various sources based on the Scopus database. A maximum of 120 publications is noted from the SAE Technical papers followed by 40 in the Applied Mechanics and Materials. 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 May. 14th, 2021).

Sr. No.	Source Title	No. of Publications in Scopus
1	SAE Technical Papers	120
2	Applied Mechanics And Materials	40
3	Hydraulics And Pneumatics	31
4	Olhydraulik Und Pneumatik	31
5	Oelhydraul Pneum	30
6	Journal Of Dynamic Systems Measurement And Control Transactions Of The ASME	29
7	Advanced Materials Research	24
8	Oleodin Pneum	22
9	Jixie Gongcheng Xuebao Journal Of Mechanical Engineering	21
10	International Journal Of Fluid Power	19

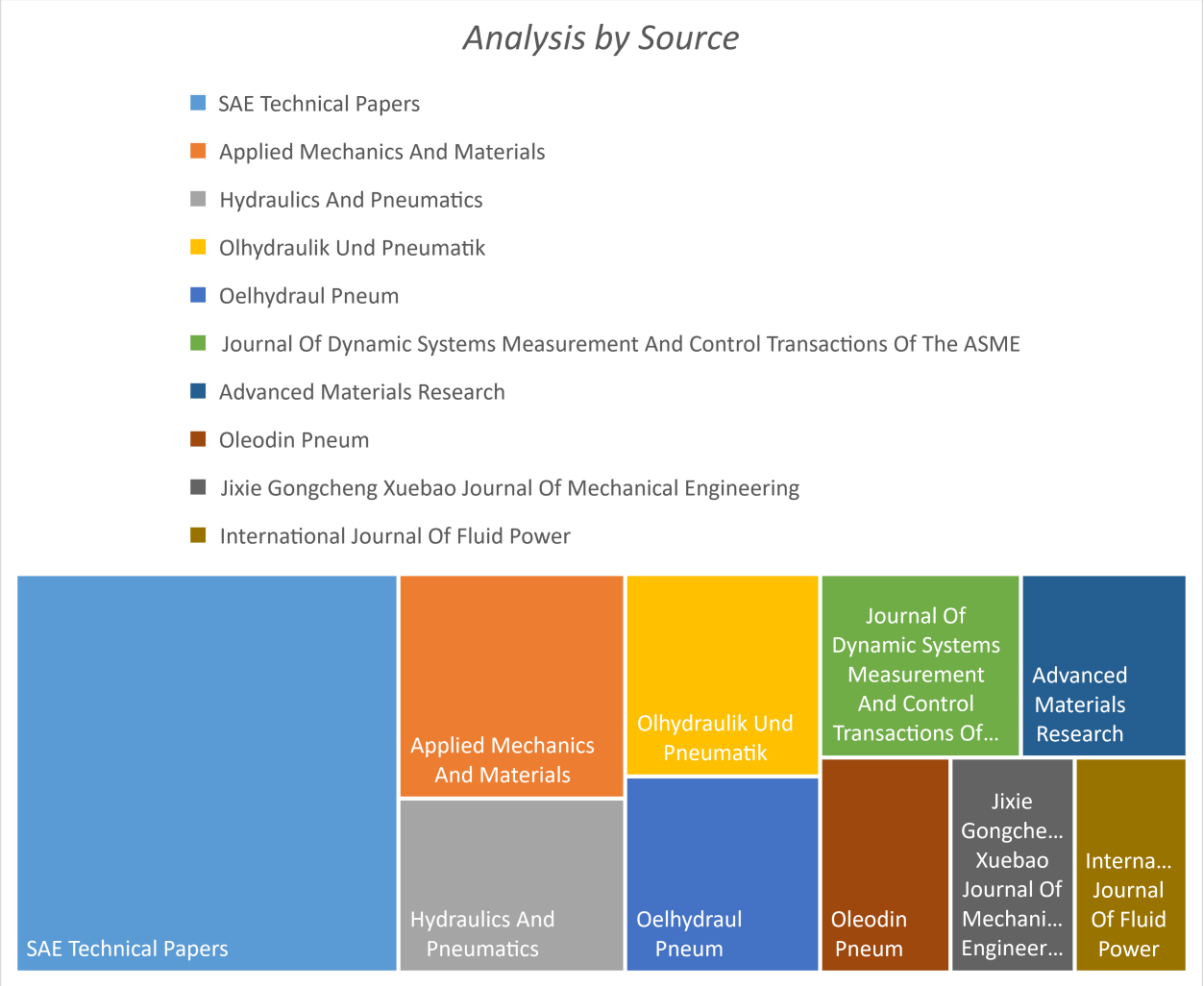

Figure 9: Analysis by Source (Data access till May. 14th, 2021).

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 474 publications is contributed from China followed by 359 in United States, and 101 in the Italy as the top three countries worldwide. The top 10 countries are taken into consideration to present the analysis. Figure.10 shows the analysis by country based on the Scopus database under consideration.

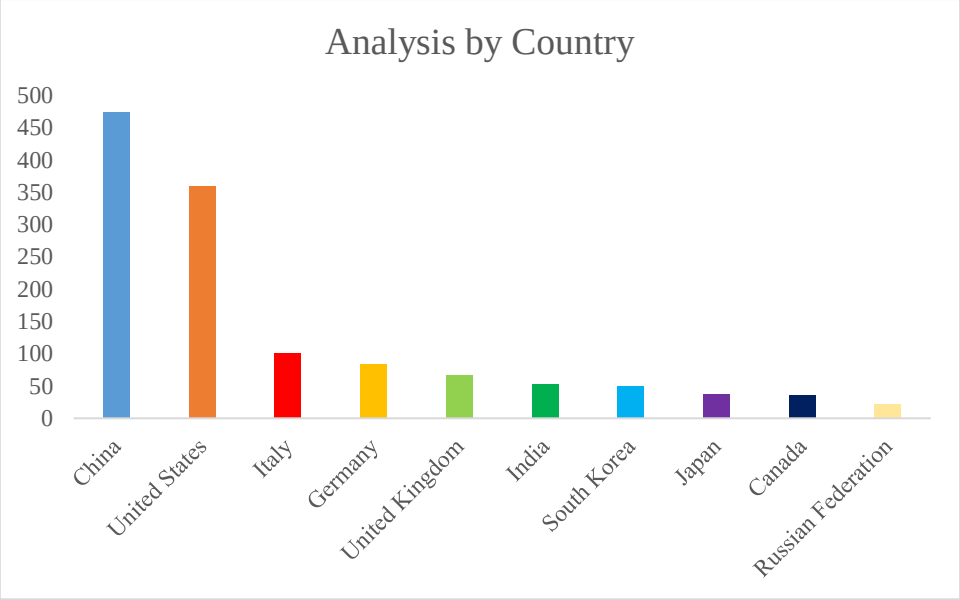

Figure 10: Analysis by Country (Data access till May. 14th, 2021).

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 11: Topographical Locations of the Country (Data access till May. 14th, 2021).

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.12 shows the representation of the analysis for the top 10 funding sponsors worldwide.

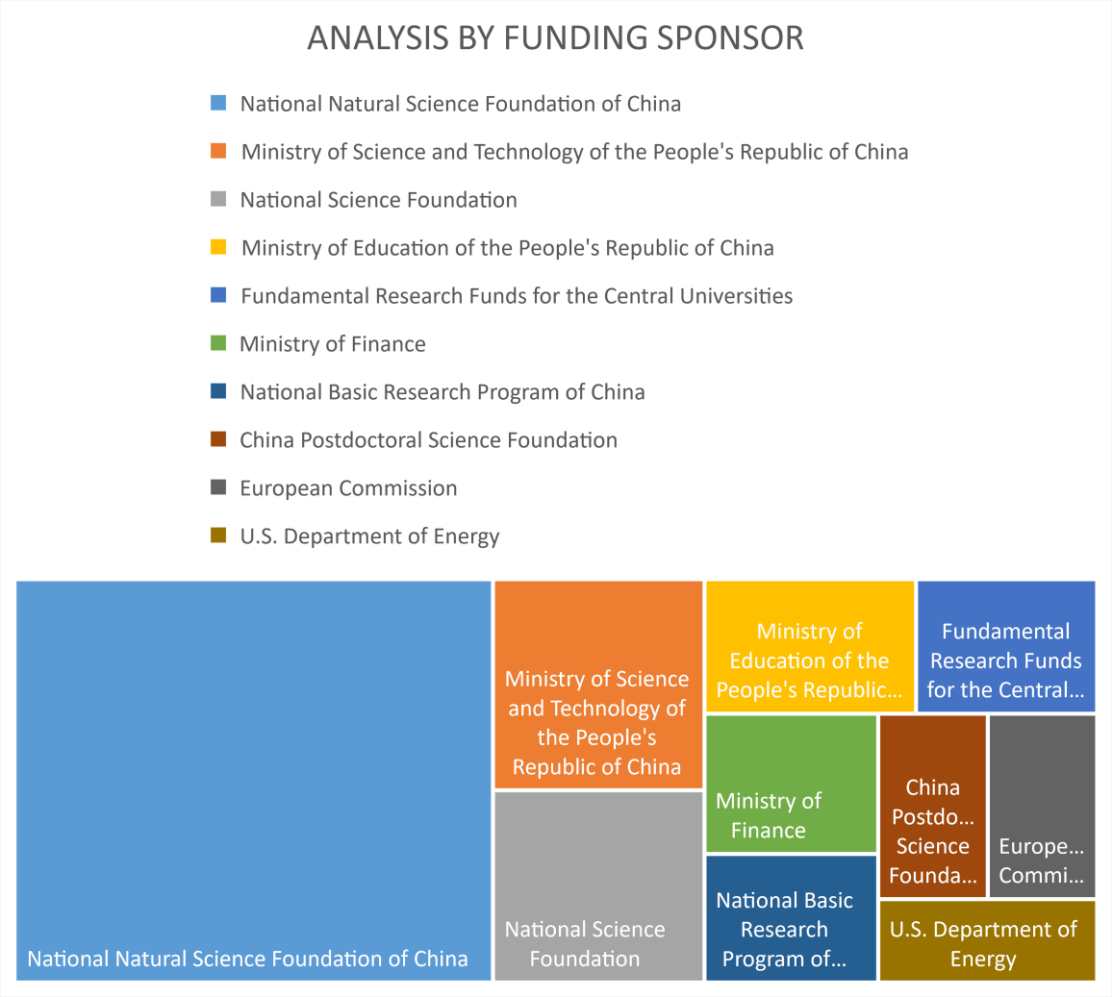

Figure 12: Analysis by Funding Sponsor (Data access till May. 14th, 2021).

Based on the analysis; one can note that the National Natural Science Foundation of China is the top most funding source in the world accounting for a maximum of 95 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 May. 14th, 2021).

Sr. No.	Source Title	No. of Publications in Scopus
1	National Natural Science Foundation of China	95
2	Ministry of Science and Technology of the People's Republic of China	22
3	National Science Foundation	20
4	Ministry of Education of the People's Republic of China	14
5	Fundamental Research Funds for the Central Universities	12
6	Ministry of Finance	12
7	National Basic Research Program of China	11

8	China Postdoctoral Science Foundation	10
9	European Commission	10
10	U.S. Department of Energy	9

4. CONCLUSIONS

A centralized lubrication system or automatic lubrication system (ALS) supply of the optimized volume of coolant is a very costly affair if we use the bent pump. The radial piston pump with a floating fulcrum mechanism is a cost-effective solution to control the precise volume of coolant discharge from zero to maximum volume. The radial piston pump is cost-effective and increases the efficiency of the system by giving control discharged. The review has touched on many aspects of cost-effective solutions to archive precise volume discharge.

The comprehensive study is presented in the current bibliometric analysis emphasize the Scopus-based data of the last 51 years, 1969 to 2021. The significant contribution in the year 2010 is observed in the concerning research area, and it is well attributed to the exponential rise in the last six years. It justifies the attention of the researchers to address and promote sustainable practices for the time to come. The presented bibliometric analysis's future scope would be the comprehensive study of a different efficient mechanism for controlled volume discharge. It will enable researchers to study and refer to the complete sustainability cycle and productivity for a better tomorrow.

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