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Tribology Research Output in BRIC Countries : A Scientometric Dimension

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Abstract

The tribology research output in BRIC countries for a period of five years from 2006 to 2010 was analysed. SCOPUS database has been used to retrieve the bibliographic records for the study period. The authors analyzed the document type, authorship and publication pattern of tribology research output among the BRIC countries. Statistical methods and scientometric tools such as, growth rate, collaboration co-efficient, co-authorship index and transformative activity index are used for the study. The quality and impact of tribology research output among the BRIC countries have been analyzed with citations per paper and relative citation impact. Further highly productive journals have been mapped and ranked based on h-index.

INTRODUCTION

Tribology is multidisciplinary in nature and includes mechanical engineering, materials science, surface technology and the chemistry of lubricants and additives [1]. British Lubrication Engineering Working Group (1966) defined tribology as the science and technology of interacting surfaces in relative motion and the practices related thereto. The word Tribology was first coined by Jost (1966) in a report and it was derived from the Greek word tribos [2].

Over the years, the subject of Tribology came to be recognized as a very important aspect in all industrial operations. The application of correct tribological practices protect and enhance the life of plants and machinery, improves efficiency of operations, reduce energy consumption and prevent expensive breakdowns [3]. Tribology is receiving increasing attention, as it has become evident that the waste of resources resulting from high friction and wear is very great. Correspondingly, the potential savings offered by improved tribological knowledge are also great [4].

An acronym, BRIC (refers to Brazil, Russia, India and China) was coined by Jim O'Neil in a paper entitled "Building Better Global Economies BRICs" and it is estimated that BRIC economies will overtake G7 economies by 2027. As early as 2003, Goldman Sachs forecasted that china and India would become the first and third largest economies by 2050 with Brazil and Russia capturing the fifth and sixth spots. BRIC nations account for much of the increase in science research investments and scientific publications. From 2002 to 2007, the current spending on science research will be doubled by China, India and Brazil. By 2020, China plans to invest 2.5% of GDP in science research [5].

A very few studies on scientific output of BRIC countries have been carried out in the past. Norbert Walz (2010) [6] analyzed the scientific output of BRIC countries and outreach countries during 1999 – 2007 in the field of limnology. Alex and Preedip Balaji (2010) [7] compared the scientific output of BRIC countries during 2004 – 2009 in the field of climate change research. Rons (2011) [8] compared the research performance between BRIC countries and N-11 countries. Kumar and Asheulova (2011) [9] analyzed the scientific output of BRIC countries. More recently, Yu, Wang, Xu and Ho (2012) [10] compared the growth trends of BRIC countries in the field of photosynthesis during 1992 – 2010. A conclusion has been made from the above studies that there was study on tribology research output in BRIC countries has been reported. The purpose of the present study is to investigate the tribology research output in BRIC countries reflected in the SCOPUS database during 2006- 2010. The focus of the present study are to compare the growth of literature using compound annual growth rate, pattern of co-authorship using Co-Authorship Index, changing pattern of research activity among BRIC countries using Transformative Activity Index and compare the performance of BRIC countries using citation per paper and relative citation impact.

LITERATURE REVIEW

Some of the earlier studies have been reviewed related to the objectives of the present study and presented below.

Sridhar (2007) [11] measured the growth rate of mobile subscribers across regions of India using Compound Annual Growth Rate (CAGR).

Elango and Rajendran(2012) [12] analyzed the authorship pattern using Collaboration Co-efficient in the research field of Marine Sciences published in the Indian Journal of

Marine Sciences during the period 2001 – 2010 which revealed that the average collaboration rate was better among the authors.
Rajendran, Jeyshankar and Elango(2011) [13] used Co-Authorship Index (CAI) to analyze the pattern of co-authorship among the papers published in the Journal of Scientific and Industrial Research during 2005 – 2009. The study revealed that the average Co-Authorship Index for all the authors reflects the world average in the journal and improving trend of coauthored papers.

Sinha and Joshi (2012) [14] studied the changing pattern in thrust of research in different solar photo voltaic materials using Transformative Activity Index (TAI) in India's solar photo voltaic research output during 2000 – 2009.
The relative indicators Citations Per Paper (CPP) and Relative Citation Index (RCI) have been used by Lalitha Kumari(2009) [15] in Synthetic Organic Chemistry and Joshi, Avinash and Carg (2010) [16] in global forest fungal research to evaluate the scientific impact of a publication.
Moussa and Touzani (2010) [17] ranked marketing journals using h-type indices like *h*-index, g-index and hg-index.

OBJECTIVES

- To identify the pattern of tribology research output in BRIC countries during 2006 – 2010.
- To examine the quality and impact of tribology research output of BRIC countries
- To study the collaboration pattern of authors and activity profile of tribology research.
- To map the highly productive journals and its ranking

METERIALS AND METHODS

SCOPUS abstract and citation database has been used for the present study and searched for the keyword 'TRIBOLOGY'. For downloading the bibliographic records for the period 2006 – 2010, the following search strategy has been used.

TITLE-ABS-KEY(**tribology**) AND PUBYEAR >**2005** AND PUBYEAR <**2011** AND (LIMIT-TO(AFFILCOUNTRY, "**China**") OR LIMIT-TO(AFFILCOUNTRY, "**India**") OR LIMIT-TO(AFFILCOUNTRY, "**Russian Federation**") OR LIMIT-TO(AFFILCOUNTRY, "**Brazil**")) AND (LIMIT-TO(DOCTYPE, "**ar**") OR LIMIT-TO(DOCTYPE, "**cp**") OR LIMIT-TO(DOCTYPE, "**re**"))

Information relating to title, authors, affiliations, document type and number of citations, source title and keywords for each publication are exported to MS-Excel then analyzed with the IBM SPSS Statistics 19. In some records, there is no information available for corresponding author. For our analysis, the first author approach where only the first author of a paper is taken into account (straight count) [18] has been applied and finally a total of 4405 papers have been taken into account for further analysis. Scientometric tools such as, growth rate, collaboration co-efficient, co-authorship index, transformative activity index, citation per paper and relative citation impact have been employed.

LIMITATIONS

The present study is limited to a period of five years from 2006 to 2010 based on the records as reflected in the SCOPUS database and document types are restricted to articles, conference papers and reviews.

ANALYSIS AND DISCUSSION

Country wise Growth Rate

Growth Rate is being measured with Compound Annual Growth Rate (CAGR). The mathematical formula of CAGR [19] is given below.

$$CAGR = \left(\frac{Ending\ Value}{Beginning\ Value}\right)^{\frac{1}{n-1}} - 1$$

The growth of publications in each BRIC countries is calculated with the above formula and presented in the table 1. Out of total publications, China topped with 3536 (80.27%) papers, followed by India 537 (12.19%), Russia 202 (4.59%) and finally Brazil 130 (2.95%). Among the BRIC countries, Russia recorded the higher growth rate of 63.81% followed by India with 51.91%.

Table 1 - Year wise output and growth rate

Country	Year					Total	%	Growth in %
	2006	2007	2008	2009	2010			
China	326	252	577	1118	1263	3536	80.27	40.30
India	40	49	74	161	213	537	12.19	51.91
Russia	10	14	25	81	72	202	4.59	63.81
Brazil	15	13	19	38	45	130	2.95	31.61
Total	391	328	695	1398	1593	4405	100	

Collaboration Rate

Collaboration Co-efficient suggested by Ajiferuke (1988) [20] has been used to assess the strength of collaboration and the mathematical formula is given below.

$$CC = 1 - \frac{\sum_{j=1}^{j=k}\left(\frac{1}{j}\right)F_j}{N}$$

Where, Fj = the number of j authored research publications
N = total number of research publications and
k = the greatest number of authors per publication.

Collaboration Coefficient is a number between 0 and 1. The more it is bigger than 0.5 the better is the collaboration rate among authors. When it is near 0, it means that authors have a weak collaboration.

Table 2 – Collaboration Rate

Country	# Authors					Total	CC
	1	2	3	4	5+		

Brazil	3	22	28	34	43	130	0.689
China	93	480	923	1042	998	3536	0.689
India	27	154	190	110	56	537	0.616
Russia	29	40	45	21	67	202	0.591
Total	152	696	1186	1207	1164	4405	

It is observed from table 2 that among the BRIC countries, Brazil and China have been recorded higher collaboration rate of 0.689 followed by India with 0.616 and Russia with 0.591. According to Ajiferuke, the range of CC (0.591 – 0.689) for all BRIC countries seems to better collaboration among the authors.

Co-authorship Pattern

Co-Authorship Index (CAI) is obtained by calculating proportionately the publications by single, double, multi and mega multi authored papers. CAI is calculated with the following formula suggested by Garg&Padhi (2001) [21].

$$CAI = \frac{N_{ij}/N_{io}}{N_{oj}/N_{oo}} X\ 100$$

Here,
N_{ij} = Number of publications for the particular authorship pattern for a particular country
N_{io} = Total output for the particular authorship pattern
N_{oj} = Total output of the particular country
N_{oo} = Total output of all BRIC countries

CAI = 100 reflects that the number of publications corresponds to the world average, CAI > 100 reflects higher than the world average and CAI < 100 reflects lower than the world average within a co-authorship pattern.

Table 3 – Co-authorship Pattern

Country	Single	Two	Multi	Mega	Total
China	93 (76)	480 (86)	1965 (102)	998 (107)	3536
India	27 (146)	154 (182)	300 (103)	56 (39)	537
Russia	29 (416)	40 (125)	66 (60)	67 (126)	202
Brazil	3 (67)	22 (107)	62 (88)	43 (125)	130
Total	152	696	2393	1164	4405
( ) indicates CAI					

Here the publications have been divided into four categories according to the number of authors, i.e. single authored, two authored, multi authored (comprising three and four authors) and mega multi authored (comprising five or more authors). The results of CAI have been presented in the table 3. The values of CAI for China for multi and mega authored publications are higher than the average and it seems that they were more preferred to work in small and big teams. With regard to India, the same for single, two and multi authored publications are higher than the average and it seems that Indian scientists more preferred to work in small teams. For Russia, it is higher than the average for single, two and mega authored publications and single authored publications have received the highest value (416) for CAI which seems to Russian scientists were more preferred to work by oneself. However, Brazil scientists were more preferred to work with co-authored as well as big teams.

Relative Research Effort

To study the development of tribology research activities among the BRIC countries during 2006 – 2010, Transformative Activity Index (TAI) suggested by Guan and Ma (2004) [22] has been employed. The mathematical form of TAI is given below.

$$TAI = \frac{C_i/C_o}{W_i/W_o} \; X \; 100$$

Here,
C_i = Number of publications for a particular country in a particular year
C_o = Total output for a particular country during the study period
W_i = Number of publications for all countries in a particular year
W_o = Total output for all countries during the study period

For this study, the publications for all BRIC countries in the year 2006 and 2010 have been taken into consideration. It is noticed from Table 4 that the tribology research activity has been increased for India and Russia while it is decreased for China and Brazil from 2006 to 2010. Higher increase of TAI was observed for Russia with 43 and decrease for Brazil with 34. Even though, there was decrease in TAI for China and Brazil but the value is relatively equal to the average in 2010. The value of TAI is relatively equal to the average for all BRIC countries in the year 2010 have been observed.

Table 4 – Transformative Activity Index of BRIC countries

Country	2006	2010	Change in TAI	Total
China	326 (104)	1263 (99)	-5	3536
India	40 (84)	213 (110)	+26	537
Russia	10 (56)	72 (99)	+43	202
Brazil	15 (130)	45 (96)	-34	130
Total	391	1593		4405

( ) indicates TAI

Citation profile of tribology output of BRIC countries

Of the total 4405 papers, 2129 (48%) papers did not receive any citation and remaining 52% of papers received one or more citations from their date of publication up to 15.04.2012. Out of total papers, 2276 papers received 11303 citations during 2005 – 2012 (up to 15.04.2012) with an average rate of citation as ~ 5 (Table 5). Average citation rate is 2.6 for all publications and both Brazilian and Indian papers received the citations more than average. A total of 586 papers received more than 5 citations each and it has accounted to 13% of total publications. 25% of Indian publications received more than 5 citations and only one Indian paper received the highest number of citations of 407 which was published in 2007.

Table 5 – Citation profile of BRIC countries

Citations Range	# Papers				Total
	Brazil	Russia	India	China	
0	59	132	175	1763	2129
1	14	33	76	605	728
2	14	16	51	321	402
3	10	5	43	202	260
4	4	3	33	134	174
5	7	1	24	94	126
6 – 10	17	8	70	231	326
11 – 20	2	3	50	143	198
21 – 50	3	1	14	38	56
51 – 80	0	0	0	5	5
>80	0	0	1	0	1
Total	130	202	537	3536	4405
Total Citations	376	217	2589	8121	11303
Avg Citation	2.9	1.1	4.8	2.3	2.6
More than 5	22 (17%)	12 (6%)	135 (25%)	417 (12%)	586 (13%)

Performance of Tribology Research output of BRIC countries

Quality and impact of scientific publications are being measured with two relative indicators, namely Citations Per Publication (CPP) and Relative Citation Impact (RCI). CPP was used by Zhi Lei and Yuh-Shan Ho (2008) [23] to assess the impact of a publication of years, countries, institutes and authors. It is computed as the average

number of citations per publication. RCI is more robust than other indicators in the sense that it measures both the influence as well as visibility of research activity, irrespective of the level of evaluation either country or institute or author [24]. It is calculated with the following formula.

$$RCI = \frac{A\ country's\ \ share\ of\ total\ citations}{A\ country's\ share\ of\ total\ publications}$$

RCI = 1 indicates that the country's citation rate is equal to average citation rate, RCI > 1 indicates that the country's citation rate is higher than the average citation rate and also implies high impact of research in that country & RCI < 1 indicates that the country's citation rate is lower than the average citation rate and also implies that the research efforts are higher than its impact.

Quality and impact of scientific publications of BRIC countries are being measured for the two categories namely, document type and country wise scientific outputs. A total of 8121 citations have been received by contributions from China with 72% and Indian contributions received 23% of total citations received by the publications contributed by BRIC countries. It is noticed from table 6 that among the BRIC countries, Brazil and India have received higher citation rate and citation impact than average while China and Russia received lower rates than average. India topped with high citation rate of 4.82 and high citation impact of 1.88.

Table 6 – Country wise output & their impact

Country	TP	TC	CPP	RCI
China	3536	8121	2.30	0.90
India	537	2589	4.82	1.88
Russia	202	217	1.07	0.42
Brazil	130	376	2.89	1.13
Total	4405	11303	2.57	

For calculating CPP and RCI for various document types, the country has been replaced by document type in the above said formula. It is observed from table 7 that out of 4405 publications, articles comprised of 79% followed by conference paper 20% and review 0.7%. Citation impact explored that the articles and reviews have received higher CPP and RCI rates while conference paper received lower rates than average.

Table 7 – Document types & their impact

Document Type	TP	% P	TC	% C	CPP	RCI
Article	3482	79.0	10383	91.86	2.98	1.16
Conference Paper	891	20.2	325	2.88	0.36	0.14
Review	32	0.7	595	5.26	18.59	7.51
Total	4405	100.0	11303	100	2.57	

Impact of highly productive journals& their rank

Quality and Impact of journals have been measured with h-index and the mathematical formula is given below.

$$h = cP^{\frac{1}{3}}(CPP)^{\frac{2}{3}}$$

Where, c is constant (0.9 for journals), P is number of papers and CPP is citation per publication.

Among the various methods to calculate the h-index, Fred Y Ye (2009) [25] found that Glanzel-Schubert model of h-index was better to estimate the h-index of countries and other information sources.

Table 8 – Impact of highly productive journals

Name of Journal	Papers (R)	Total Citations	*h*-index	Rank by *h*
MocaxueXuebao/Tribology	254 (1)	347	7	7
Wear	195 (2)	1483	20	1
Advanced Materials Research	130 (3)	49	2	9
Surface and Coatings Technology	120 (4)	895	17	2
Tribology International	96 (5)	732	16	3
Run Hua Yu MiFeng/Lubrication Engineering	93 (6)	40	2	9
Tribology Letters	90 (7)	423	11	6
Key Engineering Materials	67 (8)	46	3	8
Applied Surface Science	61 (9)	492	14	4
Journal of Friction and Wear	60 (10)	27	2	9
Materials and Design	60 (10)	406	13	5

Impact of journals of contributions with more than 60 by each BRIC country published during 2006 – 2010 has been analyzed and provided in the table 8. A total of 1226 papers contributed by authors from BRIC countries have been published in the top eleven journals during 2006 – 2010 and these account to 28% of total papers. A total of 4940 citations have been received by 1226 papers published in the top 11 journals since their publication and these citations account to around 44% of total citations. Out of top 11 journals, only 2 journals are published in the BRIC countries (China) while remaining 9 journals are publishing from rest of the world. Out of 202 total contributions by Russia, 77 papers published in the top 11 journals with 38% of its total contributions and other BRIC countries managed to 28%. The journals *Tribology*, *Wear* and *Advanced Materials Research* ranked first, second and third respectively in terms of number of publications while they ranked seventh, first and ninth respectively in terms of *h*-index. *Materials and*

Design ranked 10th in terms of number of publications while it is ranked 5th in terms of *h*-index.

CONCLUSION

The present study examined the tribology research output in BRIC countries as reflected in the SCOPUS database for the period from 2006 to 2010 using scientometric tools. The study reveals that China leads in terms of number of publications with 80% of total output and Russia recorded the higher growth rate among the BRIC countries with 63%. According to Ajiferuke, the collaboration rate for all BRIC countries is better collaboration among the authors. India outperformed other BRIC countries by higher citation rate and citation impact. Review papers received higher citation rate and citation impact than average while conference paper received lower than average. Among the BRIC countries, China was a leader in terms of number of publications in the field of tribology during the study period and this result acknowledged the analysis conducted by Kumar and Asheulova (2011) [26].The journal *Tribology* gets top rank in terms of number of publications and *Wear* gets top rank in terms of h-index.

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