Research Output and Citation Analysis of Leading Global Engineering Research Countries during 2002-16

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ABSTRACT *:*

In the present study, output and citation analysis of research activities in engineering in the world are mapped during 2002-2016.The study aims to promote the awareness of the global research output in engineering. With this aim, Scimago Journal & Country Rank data (Scopus® database of Elsevier) has been accessed for obtaining the required scholarly publication data. An attempt for evaluation on different qualitative and quantitative parameters like number of publications, citation analysis, research output, and h-index has been done. With these indicators in the research, analysis and assessment of total 7252275 publications from engineering field were done. The results show that out of the total research output, China stands first with 22.22% share of the research and is followed by United States (17.78%) and Japan (6.04%). Outstanding countries in engineering research have significant impact and 68.93% of the total global engineering research has been done in 10 leading countries. During the period of study, the research output of engineering has improved considerably with an average annual growth of 6.88%.

Keywords: Research Output, Citation Analysis, Engineering Research, Global Research.

1. Introduction :

Research in engineering plays a very important and vital role and indicators like number of articles, author, citations and impact factor etc are being used for measuring the research of the organization. The organization uses these indicators in various recruitment and promotion activities. Scopus, through its Journal Citations Report (JCR) indexes the specialist journals which helps the researchers in locating the required information of an interested subject. The diffusion of articles published in journals indexed in JCR is increased and the articles get more citations, in turn, increasing the impact factor and international recognition. The impact and quality of the research can be quantified by the tools which are provided by The SJR and are very useful in understanding and applying the concept for the researchers. The researchers can easily find out data for their researches, which are the leading countries and the analysis can be done with different angles. But in spite of the fact that a very valuable analysis can be done which can be of very help, no study has been done to analyze the global engineering research data.

The study is done with the aim of uncovering the status of engineering research in the world. The results of the study are focused on global engineering research and different valuable information can be extricated.

Valuable analysis can be done to reveal the status of research in engineering. The bibliometric indicators from the SCImago Journal & Country Rank database can be used as per the website statement. According to the website"The SCImago Journal & Country Rank is a publicly available portal that includes the journals and country scientific indicators developed from the information contained in the Scopus® database (Elsevier B.V.)." (SJR, 2017)

2. Review of Literature :

The present study tries to explore the research output and citations analysis within the field of engineering. For this, the analysis of literature review is done by the authors.

The recent study on analysis of mechanical engineering research showed that in the field of mechanical engineering Japan has more achievements as compared South Korea and India. (Pattanshetti, D M and Harinarayana, N S, 2017)

It is clear through quantitative analysis for 25 years of faculty publications of the physics department, SP Pune university that the growth in the research output is steady although the faculty members are very active in research (Nagarkar, S., & Kengar, M., 2017) Most of the studies related to emergy shows the availability of academic collaborations between the most dominant contributors like China, Italy and USA. (Chen, W., Liu, W., Geng, Y., Brown, M. T., Gao, C., & Wu, R., 2017). (Patra, S. K., & Muchie, M., 2017) mapped the scientific productivity of engineering research in African Union member countries. The used Scopus® database to map engineering publications data and analyzed that in spite of a tremendous growth in publications in the recent period, the engineering is not favorite area of research. They established that South Africa has more global and African collaborator countries in research in comparison Africa.

(Hussain, A., & Swain, D. K., 2011) inferred that, in the pinnacle of the research in Computer Science, major part is the collaborative research. Akyildiz, I. F (USA) is the most sought after author. Likewise, European Journal of Operational Research is the most sought after journal and Wireless sensor networks: a survey by Akyldiz; Su; Sankarasubramaniam; and Cayirci is the top paper with a record 3879 citations. USA is the top productive country and has the momentous impact in Computer Science field.

(Cañas-Guerrero, I., Mazarrón, F. R., Pou-Merina, A., Calleja-Perucho, C., & Suárez-Tejero, M. F., 2013) studied that structuration and complexity in research is increasing. 87% of the research is done in 30 countries and USA (2013) produces 27% of the total research followed by China, Germany, India, South Korea, Turkey, Spain, and Iran. They also established that 96.2% of the total publications is carried out in English language and is distantly followed by the German language (2.2%). The journals having higher IF have wide boundaries in terms of diffusion and internationalization of publications.

(Pandita, R., Singh, S., & Gaur, R. C., 2016) have noticed a steady growth (annual 58.90%) in medical sciences research publications in the country, with maximum research contribution from AIIMS.

(Pandita, R., & Singh, S., 2014) studied that research is disproportionate in oncology field in the world They also suggested that support efforts like creation of infrastructure for biomedical research and sustainability programmes should be provided to all the under-developed nations by the leading countries in oncology research like the United States, Japan, the United Kingdom, France, Germany, China, etc., which in turn will help in promotion of research in the field.

(Ravichandra Rao, I., & Suma, M., 1999) found in their analysis that of the Indian engineering literature only a few journals and some selected institutions were involved in research in engineering in India. However, research output in bioengineering, applied physics, information science and light and optics are increasing in India and at global level. (Kaur, H., & Gupta, B. M., 2009) in their study of microbiology and immunology publications during 1999-2008 analyzed the performance of India. They analyzed the publications on different parameters like annual average country growth rate, global rank and share of publications, international collabo-rative partners and their profiles, communication patterns journals both at national and international level and some common characteristics the most productive authors had. (Jesiek, B. K., Borrego, M., Beddoes,

K., Hurtado, M., Rajendran, P., & Sangam, D., 2011) analyzed the major global trends in engineering education and suggested for collaborations at cross-national levels also. They also suggested some steps though which global capacities can be built in engineering education. (Panat, R., 2014) found in his study that China in ahead in research output as compared to India. (Banshal, S K, Singh V K, Basu A & Muhuri, P K, 2017) found that top 5 engineering disciplines attract most of the decision makers in fund allocation and policy making and most of funds are allocated to these. The research output of the India's most prestigious engineering and technology institutions like IITs with international institutes like MIT-USA and NTU-Sin-gapore was compared in the study.

(Barrot, 2017), (Zou Y., & Laubichler, M. D., 2017), (Nobre, G. C., & Tavares, E., 2017) (Singh, V. K., Banshal, S. K., Singhal, K., & Uddin, A., 2015), (Hadagali, G. S., & Anandhalli, G., 2015), (Elango, B., Rajendran, P., & Bornmann, L., 2016), (Bhattacharya, S., Shilpa, & Bhati, M., 2012) (Gupta, B. M., Kshitij, A., & Verma, C., 2010) and (Sangam, S. L., & Keshava & Agadi, K. B., 2009) are of the studies done to access the growth of scientific research output .

3. Problem Statement :

The obsolesce of literature depends mainly on two facts. The first is if the research is being done at a very fast rate and at large scale, then the immediate past literature becomes obsolete. Also if the research is not done as per the future requirements, then also there are more chances of the literature obsolesce. In the modern era of information explosion, the first reason seems to be major cause of literature obsolesce because the research is being done at a very fast rate and the literature in engineering research is increasing day by day. Thereby, it is very difficult to know the growth rate of research output in engineering at global level.

4. Objectives of the Study :

After discussion over the literature survey and analytical framework, the study strives at following key research objectives:

- To measure the growth rate and overall status of research in engineering at global level.
- To know the most outstanding countries in the field of engineering reasech.
- To study the research output in engineering in 10 outstanding countries .
- To analyze the status of citations and self citations using different parameters at world level
- To know the status of citations per document in the field at world level

5. Methodology :

Keeping in mind the objectives of the study, the required data to measure the research output was retrieved from the website of SJR -SCImago Journal and Country Ranking" at the below link: http://www.scimagojr.com/countryrank.php

(The list of countries is given in Appendix A). To measure the output of research in engineering, the Scopus® database which is largest database for indexing and abstracting covering more than 28606 scholarly journals from various subject areas. The year wise data was revealed by entering subject area as engineering with all subject categories and all regions. The data for the period of 2002-2016 was exported in raw csv comma delimited MsExcel®.

6. Data Analysis and Discussion

Percentage has been drawn up to two decimal points and has not been rounded off. So at places, it may reflect a slight variation while computing data for 100% figure.

Table 1: Ranking of the outstanding 10 countries during the period of study (2002-2016)

Country	Rank	No. of Publications	Global Share %	CG%
China	1	1611732	22.22%	16.67
United States	2	1290001	17.78	2.22
Japan	3	438084	6.04	1.22
Germany	4	332909	4.59	4.61
United States	5	295116	04.06	4.63
South Korea	6	239246	3.29	7.82
India	7	233298	3.21	14.67
France	8	173554	2.39	4.60
Italy	9	192946	2.66	6.43
Russian Federation	10	130935	1.80	5.91

Table 2: Year wise growth of engineering research in leading 10 countries

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	(Share %)
China	21427	24817	42105	63792	71398	84430	100694	105791	123035	156788	162935	176286	186668	143258	148308	1611732 (22.22%)
CG%		15.821	69.662	51.507	11.923	18.253	19.263	5.0619	16.3	27.434	3.9206	8.1941	5.8893	-23.255	3.5251	16.67%
United State	65443	72273	88137	100210	89862	83212	83253	84980	89619	88539	87391	89919	92508	89521	85134	1290001 (17.78%)
CG%		10.437	21.95	13.698	-10.326	-7.4002	0.0493	2.0744	5.4589	-1.2051	-1.2966	2.8927	2.8793	-3.2289	-4.9005	2.22%
Japan	22907	25948	27506	35533	34728	30925	29989	30406	30914	30122	29587	29246	28774	25900	25599	438084 (06.04%)
CG%		13.275	6.0043	29.183	-2.2655	-10.951	-3.0267	1.3905	1.6707	-2.5619	-1.7761	-1.1525	-1.6139	-9.9882	-1.1622	1.22%
Germany	14224	16150	18954	22334	21358	21776	22065	22378	22745	23879	24627	24019	26769	25723	25908	332909 (4.59%)
CG%		13.54	17.362	17.833	-4.37	1.9571	1.3271	1.4185	1.64	4.9857	3.1325	-2.4688	11.449	-3.9075	0.7192	4.61%
United King	12855	14039	17126	20165	19328	19628	19902	19961	20258	20623	20428	20847	23523	23007	23426	295116 (04.06%)
CG%		9.2104	21.989	17.745	-4.1508	1.5522	1.396	0.2965	1.4879	1.8018	-0.9455	2.0511	12.836	-2.1936	1.8212	4.63%
India	4826	5282	6352	7492	9084	9975	11668	12517	13939	17447	19783	21612	28811	33024	31486	233298 (3.21%)
CG%		9.4488	20.257	17.947	21.249	9.8085	16.972	7.2763	11.361	25.167	13.389	9.2453	33.31	14.623	-4.6572	14.67%
South Kore	7337	9044	10663	13049	14954	16198	15613	15410	17366	18416	19052	19777	21190	21059	20118	239246 (3.29%)
CG%		23.27	17.9	22.38	14.6	8.319	-3.612	-1.3	12.69	6.046	3.454	3.805	7.145	-0.618	-4.468	7.82%
France	9675	10127	12416	14241	15092	14934	16278	16533	16567	17494	17798	18155	19419	18767	17609	173554 (2.39%)
CG%		4.6718	22.603	14.699	5.9757	-1.0469	8.9996	1.5665	0.2056	5.5955	1.7377	2.0058	6.9623	-3.3575	-6.1704	4.60%
Italy	7384	8046	9601	10883	11274	11956	12287	12665	13233	13491	14270	15157	17597	17784	17318	192946 (2.66%)
CG%		8.9653	19.326	13.353	3.5928	6.0493	2.7685	3.0764	4.4848	1.9497	5.7742	6.2158	16.098	1.0627	-2.6203	6.43%
Russian Fe	8453	7762	8182	8163	6388	6827	6604	6551	6747	7534	7496	8160	11736	13727	16605	130935 (180%)
CG%		-8.1746	5.411	-0.2322	-21.744	6.8723	-3.2664	-0.8025	2.9919	11.664	-0.5044	8.8581	43.824	16.965	20.966	5.91%

* CG % = Corresponding Growth Percentage, the formula for determining CG is:

Present year figures -previous year figures / previous year figures * 100.

It is evident from the above tables 1 & 2 that during 2002-2016, total 4999372 articles were published by 10 leading engineering research countries. Out of these, the China has the highest publications share at global level with 32.23% (1611732 articles) share and is followed by United States (1290001, 25.80%) and Japan (438084, 8.76%) respectively. 332909 articles (6.65%) were published in Germany. Likewise, UK has a share of 5.90% with 295116 articles and India has 4.66% share with 233298 articles. South Korea has published 239246 articles

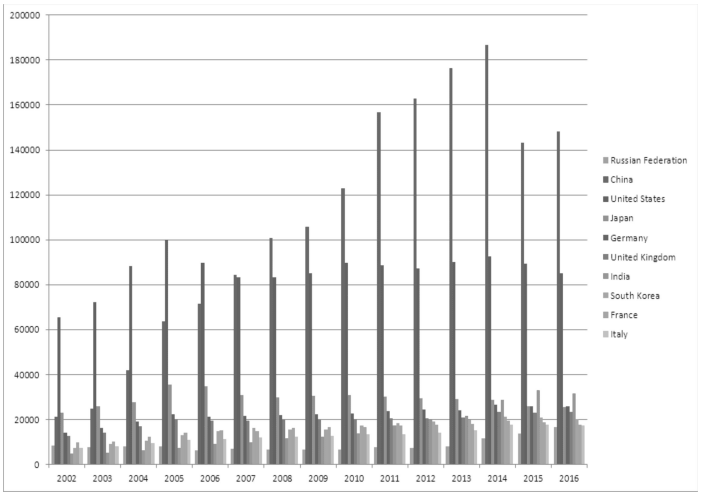
(4.78%), France 173554 (3.47%), Italy 192946 (3.85%) and Russian Federation has published 130935 articles (2.61%) during the period of study.

During the data analysis, it was revealed that the leading countries have a contribution of 68.93% (4999372) in the total publications during the study and the contribution of the rest of the world is (2252903, 31.07%). China has the highest Corresponding Growth Percentage (16.67%) and Japan has the least (1.22%) during the period of study.

During the study period the publications of the leading countries grew with an annual growth of 6.87%.. China has the highest growth and leading with 16.67% growth. India follows China with 14.67% and in turn is followed by South Korea 7.82% ,Italy 6.72% and Russian Federation with 5.91% annual growth. United Kingdom has 4.63% growth and is followed by Germany (4.61%) and France (4.60%). The average annual growth of USA is mere 2.22% and Japan has the least growth with only 1.22%.

6.1 No. of Citable Documents:

By citable documents we mean those research publications appeared in peer-reviewed or refereed journals. The nature of journals can be either open access or commercial. There is no denial of the fact that in today's technological era, the researchers can publish their researches in many forms like web portals, own blogs, websites and many more. However, articles in only peer reviewed and referred journals are considered more authentic, credible and are considered most for citations.



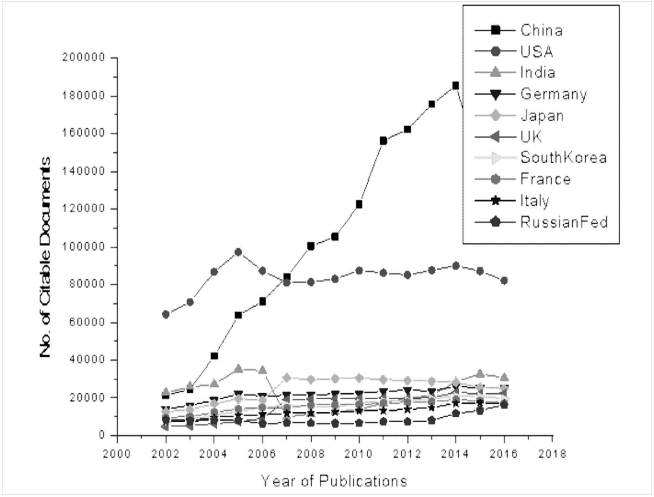
Graph 1: Shows that China has the highest growth rate.

Table 3 – Citable documents in leading countries

Out of the total 7255275 published articles during the study period, 98.43% (7141707) articles over the globe were citable. Once again, China leads the chart with 23.67% global share. US follows with 18.52%

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total	(Share
China	21368	24733	42017	63670	71244	84270	100461	105361	122657	156348	162327	175635	185586	142182	145738	1603597	23.67%
CG%		15.748	69.882	51.534	11.896	18.284	19.213	4.8775	16.416	27.468	3.8242	8.1983	5.6657	-23.39	2.501	16.57%	
United States	64214	70742	86839	97366	87351	81074	81334	83112	87462	86295	85167	87700	90110	87250	82232	1258248	18.52%
CG%		10.166	22.755	12.122	-10.29	-7.186	0.3207	2.186	5.2339	-1.334	-1.307	2.9742	2.748	-3.174	-5.751	2.10%	
India	22716	25781	27232	35177	34415	9860	11552	12387	13796	17265	19636	21382	28441	32679	30703	343022	5.06%
CG%		13.493	5.6282	29.175	-2.166	-71.35	17.16	7.2282	11.375	25.145	13.733	8.8918	33.014	14.901	-6.047	7.15%	
Germany	14075	15984	18769	21990	20973	21376	21703	22020	22333	23434	24111	23526	26197	25160	25196	326847	4.82%
CG%		13.563	17.424	17.161	-4.625	1.9215	1.5298	1.4606	1.4214	4.9299	2.889	-2.426	11.353	-3.958	0.1431	4.48%	
Japan	12618	13738	16854	19547	18800	30657	29681	30061	30547	29705	29156	28798	28234	25409	24963	368768	5.44%
CG%		8.8762	22.682	15.978	-3.822	63.069	-3.184	1.2803	1.6167	-2.756	-1.848	-1.228	-1.958	-10.01	-1.755	6.21%	
United Kingd	4751	5201	6288	7398	8968	19048	19359	19427	19675	19991	19777	20220	22828	22249	22453	237633	3.50%
CG%		9.4717	20.9	17.653	21.222	112.4	1.6327	0.3513	1.2766	1.6061	-1.07	2.24	12.898	-2.536	0.9169	14.21%	
South Korea	7211	8895	10592	12976	14862	16115	15496	15246	17216	18281	18808	19501	20831	20666	19588	236284	3.48%
CG%		23.353	19.078	22.508	14.535	8.4309	-3.841	-1.613	12.921	6.1861	2.8828	3.6846	6.8202	-0.792	-5.216	7.78%	
France	9589	10050	12328	14089	14910	14769	16082	16314	16322	17241	17500	17901	19056	18352	17144	231647	3.41%
CG%		4.8076	22.667	14.285	5.8272	-0.946	8.8902	1.4426	0.049	5.6304	1.5022	2.2914	6.4522	-3.694	-6.582	4.47%	
Italy	7306	7938	9503	10709	11083	11762	12061	12444	12986	13235	13960	14812	17217	17386	16730	189132	2.79%
CG%		8.6504	19.715	12.691	3.4924	6.1265	2.5421	3.1755	4.3555	1.9174	5.4779	6.1032	16.237	0.9816	-3.773	6.26%	
Russian Fede	8428	7738	8157	8139	6359	6800	6586	6510	6660	7382	7226	8092	11649	13504	16162	129392	1.90%
CG%		-8.187	5.4148	-0.221	-21.87	6.9351	-3.147	-1.154	2.3041	10.841	-2.113	11.985	43.957	15.924	19.683	5.7394	

and is followed by Japan (5.44%), India (5.06%) and Germany (4.82%). UK shares 3.5%, France 3.41%, Italy 2.79% and Russian Federation has 1.9% share at global level.



Graph 2: No. of citable documents

The citable documents have the annual growth of 7.20% at global level during the study period. Leading ten countries have produced 68.95 % of the total citable documents. The rest of the world has 31.05% share of the total citable documents in the area of engineering research.

6.2 No of Citations

Citation means the way to tell the readers that some certain material has come from another source. The necessary information regarding the material source is also provided to the readers like the author, title, link of the source etc.Table 4: Number of citations in outstanding countries

The total numbers of citations during the study period were 55322605 and the average annual growth of citations per document was 7.20%. It is evident that the maximum citations 3913312 (12.89%) were received in the year 2006. United States leads with 13814656 citations and has 27.90% share at global level. Russian Federation has the least contribution with 0.83% share only. The outstanding ten countries have the 66.48% share and rest countries of the world have 33.52% of the total citations.

Graph 3:No. of citations in leading countries

It is evident from the graph given above that average numbers of citations have decreased continuously from 2002 to 2016. China has the maximum growth between 2009-2013 but has also decreased 2013 onwards. USA has the maximum citations during 2004-05 but decreased the citations in 2016.

6.3 Self Citations

Giving reference of own article from the same journal is called self citation. It is very helpful for the researcher to increase the visibility and awareness of the research among his peers.

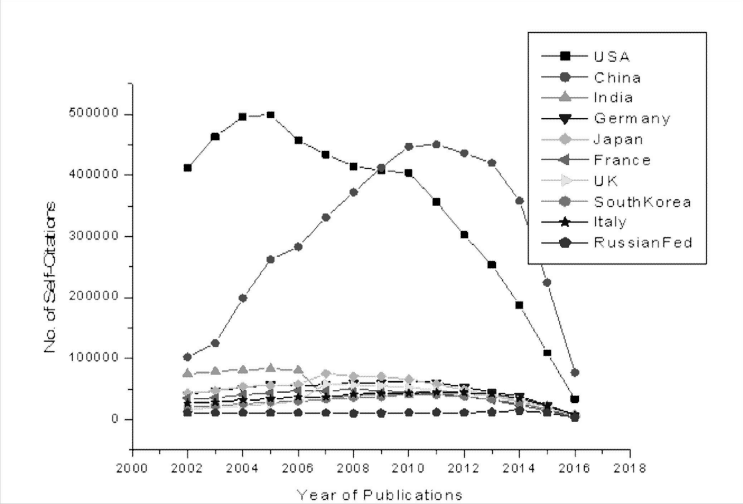
Table 5: No. of Self-Citations

The United States leads the world with (5233721, 29.02%) global self citations and is followed by China (24.97%) which is in turn, followed distantly by India (4.16%), Germany(4.02%), Japan (4.1%) and France

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total (Share%)
China	175879	219442	321941	410321	443574	519143	583469	639416	693001	687316	653023	614705	519673	320586	108734	6910223 (13.95%)
United States	1E+06	1E+06	1E+06	1E+06	1E+06	1E+06	1E+06	1E+06	1E+06	909561	751875	611735	449046	249642	71642	13814656 (27.90%)
India	240200	247592	257359	265183	255184	113233	123310	127367	120818	121288	111854	101437	81222	52259	18100	2236406 (4.51%)
Germany	188696	220669	228328	241416	227447	236295	232728	227056	232267	213635	176426	142813	117681	67479	20648	2773584(5.60%)
Japan	217711	221786	264852	272921	269155	234364	214482	211562	195633	169554	135884	104598	79250	44032	14194	2649978 (5.35%)
United Kingd	57420	68313	75084	86174	102550	294500	260852	246329	230613	206281	178533	154838	122234	71950	22993	2178664 (4.40%)
South Korea	105126	117741	132297	142854	147840	158782	156152	159995	174414	162207	148492	121658	91147	54792	16113	1889610 (3.81%)
France	144013	152495	164866	184700	188030	180493	196504	179523	169304	159680	132281	112219	78427	46084	14009	2102628(4.24%)
Italy	119559	123500	134976	146286	149644	146066	153659	152839	151516	139492	127852	111250	90557	55591	17779	1820566(3.67%)
Russian Fed	30501	35142	32331	32330	34581	32626	28714	27364	28221	25661	23257	23233	24427	18085	6394	402867(0.83%)

(3.04%).Some outstanding countries in the list are UK with 2.95%, South Korea with 2.42% Italy with 2.89% and Russian Federation with 0.92% global share of the total self citations in the area of engineering research during the period of study.

Graph 4: Self-Citations status



It is clear from the graph above that USA and China are the only giant with reference to self citations during the period. Yet there is a drastic decrease in the self citations. The trend has fallen during 2014-16 drastically both in USA and China, along with the whole world.

6.4 Citations per Document

Citations per document mean average number of citations received by the journal during the period. It is calculated by dividing the total number of citations from total number of articles.

Table 6: No. of citations per document

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Avg
United States	17.44	17.89	15.48	13.53	13.7	13.99	13.33	12.54	11.67	10.27	8.6	6.8	4.85	2.79	0.84	10.45
Italy	16.19	15.35	14.06	13.44	13.27	12.22	12.51	12.07	11.45	10.34	8.96	7.34	5.15	3.13	1.03	10.02
United Kingd	11.9	12.93	11.82	11.5	11.29	15	13.11	12.34	11.38	10	8.74	7.43	5.2	3.13	0.98	9.63
France	14.89	15.06	13.28	12.97	12.46	12.09	12.07	10.86	10.22	9.13	7.43	6.18	4.04	2.46	0.8	9.21
Germany	13.27	13.66	12.05	10.81	10.65	10.85	10.55	10.15	10.21	8.95	7.16	5.95	4.4	2.62	0.8	8.48
South Korea	14.33	13.02	12.41	10.95	9.89	9.8	10	10.38	10.04	8.81	7.79	6.15	4.3	2.6	0.8	8.35
Japan	16.94	15.8	15.46	13.53	13.93	7.58	7.15	6.96	6.33	5.63	4.59	3.58	2.75	1.7	0.55	7.53
India	10.49	9.54	9.36	7.46	7.35	11.35	10.57	10.18	8.67	6.95	5.65	4.69	2.82	1.58	0.57	6.91
China	8.21	8.84	7.65	6.43	6.21	6.15	5.79	6.04	5.63	4.38	4.01	3.49	2.78	2.24	0.73	5.02
Russian Fede	3.61	4.53	3.95	3.96	5.41	4.78	4.35	4.18	4.18	3.41	3.1	2.85	2.08	1.32	0.39	3.46

It is clear from the table above that USA leads with highest with 10.45 average citations per document. Surprisingly, Italy has also emerged as the second highest with 10.02 average citations. UK has 9.63 citations and is followed by France(9.21), Germany (8.48), South Korea(8.35) and Japan(7.53). India received 6.91 average citations per document and is followed by China with 5.02 and Russian Federations with 3.61 citations per document.

Graph 5: No. of citations per document

The graph above shows the radical decrease in citations per document at the global level. The citations per documents were decreased severely during 2014-16. It happened in all the countries, including the leading ones.

7. Conclusion

It is very clear from the research undertaken that the research output is disproportionate in the field of engineering at the global level. 68.93% of the total engineering research globally has been done in 10 leading countries and the rest of the world has only 31.07% share. It shows that research is being done only in some countries and the rest of

the world by any reason, don't have proper research environment. During the period of study, the research output of engineering has improved considerably with an average annual growth of 6.88%.

The need of the hour is to create an environment at global level so that the research in engineering can be encouraged in the under-developed countries through all possible means. The help by the leading countries like technical support, funds, human resource training should be provided to the unnoticeable nations. The engineering research in the deprived and poor countries can be increased to a considerable degree by promoting the research related activities. A great help is required by the leading countries like USA, China, UK, Germany, India etc to promote engineering research at global as well as regional level. These countries should provide all the possible support for the needy nations for promotion of the research. Also the developing countries should also establish some intuitions dedicated to engineering research.

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