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An Overview of Electron Beam Melting research with Bibliometric Indicators

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Abstract

Bibliometric research is one of important technique that deals with statistical analysis of publications in a specific research field. The method has the ability to classify the information with various variables such as journals, countries and authors. This study reviews a general overview of the research that has been reported in the field of electron beam melting (EBM) by using the bibliometric indicators. The indicators provide a general picture and identifying the most influential research in this field. The study divided into key analysis sections which focused on relevant journals, research papers, influential authors and countries. The main objective of the study is to be informative regarding electron beam melting research and the used indicators sum up the most essential research in this area by using the web of science (WOS) database. However, some limitation could be expected with the presented results due to the fact that some researches will be excluded from the analysis if they are not presented in the Web of Science database, which is the main source utilized for carrying out this research.

Keywords*:* Electron beam melting, bibliometric research, influential authors, influential journals, influential countries

1. Introduction

Manufacturing Engineering is a growing field that continues to evolve to suit the rapid changes of the recent era. Moreover, Manufacturing fields are constantly improving upon current designs and methods to make life simple and easier. When referring to technology, simple and easy can be directly related to fast and accurate. One of the important technologies is additive manufacturing (3D printing), which has obtained considerable importance over the last decade. This is regarding to the beneficial ability that it offers over other manufacturing processes to make 3D parts directly from CAD software (Shen and Chou, 2012).

Electron Beam Melting (EBM), is one of the recent advances in 3D printing technologies which has obtained rising attention for rapid manufacturing and repair. Electron beam melting has the ability to make a full density metallic components directly from CAD software. The Parts can be produced on a layer by layer basis by melting wire or powder metal using a laser or an electron beam. ARCAM (Sweden) has developed and commercialized electron beam meting machines, in which the powder can be melted by quick moving of electron beam, therefore it cooled and solidified rapidly. The electron beam melting technology can deal with high power density and energy efficiency (Gaytan et al., 2009). EBM has shown the ability to produce metallic parts which can be applied in medical and aerospace with multi-layers, thin walls and complex internal structures which could not be produced by traditional manufacturing technique.

The current paper focusses on the bibliometric indicators analysis of the research published in the field of EBM. Bibliometric

analysis is a technique that analyze the published articles, citations and their sources of information. The advantages of using bibliometric indicators analysis is to measure the impact and size of the reported publications based on a number of scientific papers published and its received citations. Bibliometric indicators are markedly significant tool to evaluate authors, universities, organizations and countries to make a decision according to their influence in the electron beam melting field. However, a lot of discussions and definitions have been reported on bibliometric in previous studies (Bar-Ilan, 2008),(Hood and Wilson). Researchers have presented bibliometric analysis in some fields to highlight the most influential authors, publications and institutions working in the corresponding research areas. Some of these research areas worth to be mentioned include econometrics (Baltagi, 2007), ant colony optimization (Deng and Lin, 2012), innovation (Fagerberg et al., 2012), probability and statistics (Genest and Guay, 2002), environmental and ecological economics (Hoepner et al., 2012), operations management (Holsapple and Lee-Post, 2010), productivity in production (Hsieh, 2010), entrepreneurship (Landström et al., 2012), profiling analysis of pricing research (Leone et al., 2012), data envelopment analysis (Liu et al., 2013), management (Podsakoff et al., 2008), marketing (Seggie and Griffith, 2009), health (Wagstaff and Culyer, 2012), grey system (Yin, 2013) and fuzzy systems (Merigó et al., 2015). However, no bibliometric review has been reported on the research conducted in electron beam melting.

The aim of this research study is to provide a general picture of electron beam melting research from the beginning of this field since 1960 using bibliometric techniques. Based on the information collected from the web of science website (WOS), the study will present an overview of the most productive and influential research in the concerning research area. This research is organized as follows: section 2 describes the methodology utilized in this research followed by section 3 which presented the most influential journals in electron beam melting, section 4 shows the top 20 research articles in the electron beam melting area with the highest number of citations received, section 5 reported the most productive and influential authors. Section 6 provides the most productive countries in the electron beam melting research. Last section summarize the main results.

2. Methodology

The information for electron beam melting research overview is collected from the Web of Science (WOS) which combines a several databases. WOS include research from most of the well-known scientific resources including more than fifteen thousand journals and fifty five million articles. Bibliometric information for any research area can also be collected from other databases such as Google Scholar and Scopus. However, in this study WOS is only used for data collection.

To search the articles reported on electron beam melting, the keywords of "electron beam melting" or "electron-beam melting" or "electron-beam-melting" are used in the "topic" tab of the web of science website. The "cited reference search" is used to avoid any omission of the key research in EBM field. The search process has been done manually to carefully delete the articles or reviews that are not related to EBM.

The current search is carried out at the end of December 2016 and more than 600 publications were reported by using the selected keywords in the search tab. fifteen different types of articles were found including journals, books reviews, proceedings, notes, comments and editorial material. However, the current study only concentrated on the reviews and journal articles which decrease the total numbers of publications from more than 600 to 552 only as shown in Table 1.

3. Most Influential journals in electron beam melting

Approximately 70% of articles among the remaining 552 are from the last decade. Research in Electron beam melting has been increased over the past two decades as evident in Figure 1. Specifically, there is a prominent consistent increase in the number of reported publications on EBM particularly in the recent 10 years. According to the web of science data collection, the average number of papers published per year in the electron beam melting field are more than 9 with the highest number of yearly publications recorded in 2015 and 2016 as 77 and 101 publications respectively. This shows that the research in EBM is getting more and more importance.

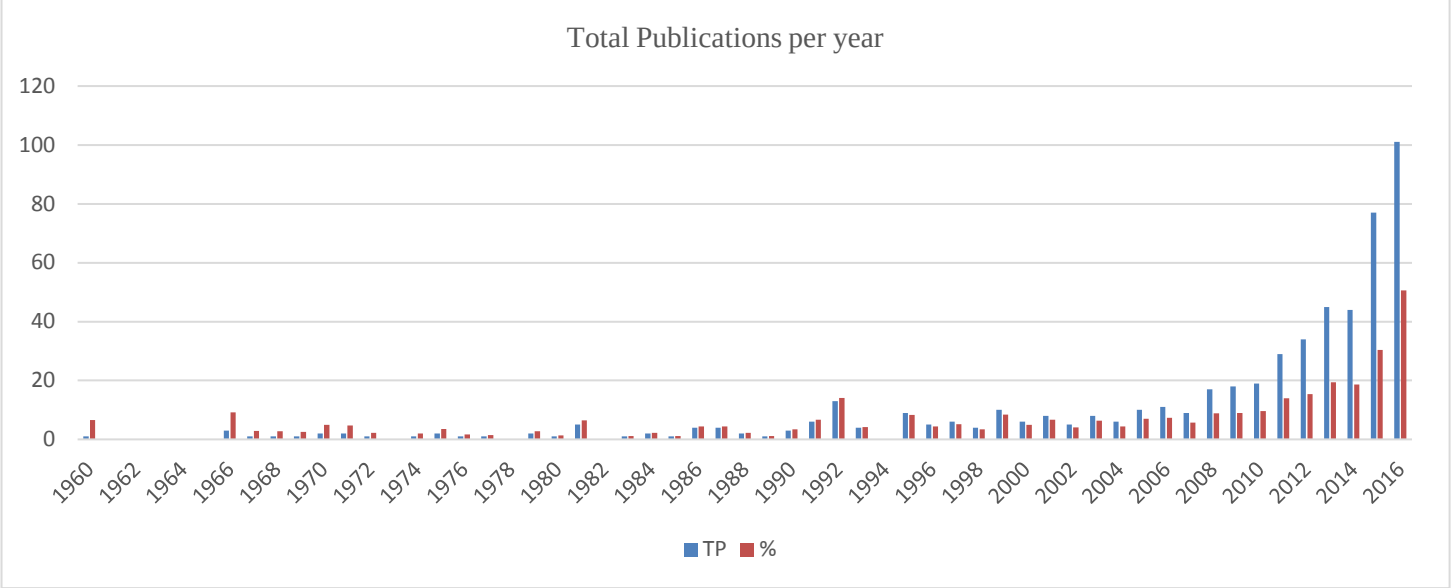

Figure 1. Number of publications per year in EBM research (reviews & articles) from 1960 to 2016. The bars with blue color indicate the total number of EBM articles published each year in the web of science and the orange one indicate the ratio (N-EBM-P/TNP) × 1,000,000 where N-EBM-P is the number of EBM papers in year X and TNP is the total number of papers published in the WOS in year X.

Table 1. General citation structure in electron beam melting research from WOS.

Number of citations	Number of papers	% Papers
>=100 citations	8	1.45
>=50citations	14	2.54
>=20citations	62	11.23
>=10citations	81	14.67
<10citations	387	70.11
Total	552 papers	

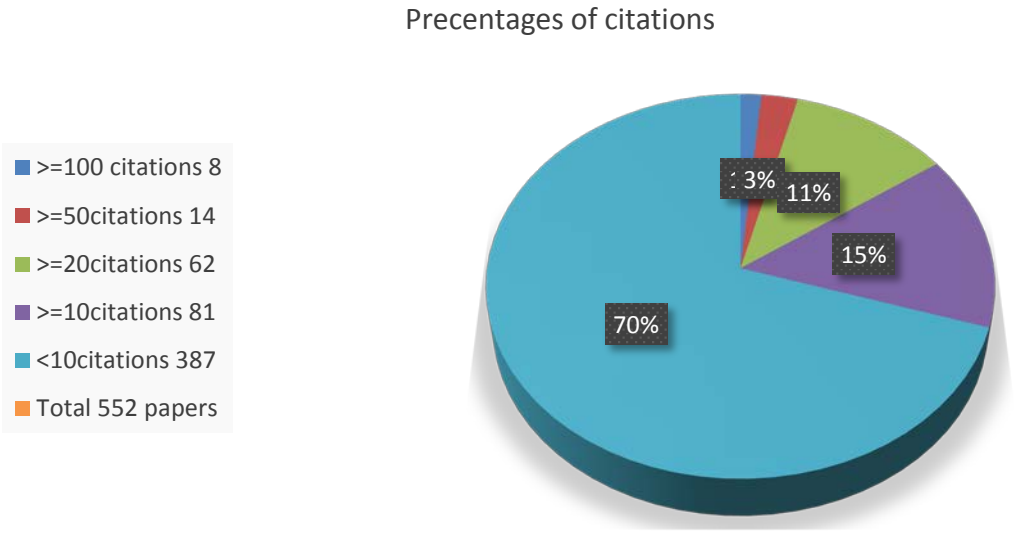

Figure 2. The percentages of citations

Table 1 shows the citation structure in electron beam melting research. It can be seen that only 1% (8) articles have got more than or equal to 100 citations, 3% (14) papers received more than or equal 50 citations, 11% (62) papers received more than or equal 20 citations, 15% (81) papers received more than or equal 10 citations while the remaining papers received less than 10 citations. The H-index is also known as H-classics (Martínez et al., 2014) which is one of the interesting action to analyze any published research. It can be utilized to measure the significance of published articles (Alonso et al., 2009). For example, if some articles have an H-index of 40, then 40 of the articles included in these articles should have received at least 40 or more citation for each. For the whole information of collected articles in electron beam melting, the H-index is 39. Therefore, 39 articles have been got at least 39 citations. However the H-index has been presented by some authors (Chapman et al., 2015).

Research in electron beam melting have been published in various journals, the number of journals are increasing from one year to another. The 20 most influential journals in electron beam melting are shown in Table 2. According to H-index received for the papers published regarding EBM (H-EBM),the two most influential journals from amongst the top 20 journals list are identified as Materials Science and Engineering a Structural Materials Properties Microstructure and Processing (MSESMPMP) and ACTA Materialia (ACTAM). Moreover, other journals consider as the top influential journals such as Rapid Prototyping Journal, Vacuum, and Metallurgical and Materials Transactions a Physical Metallurgy and Materials Science. The quality of the papers published in these journals can be accessed by the impact factor (IF) that is presented in Table 3.

Table 2. Most influential and productive journals in electron beam melting research

Rank	Name	H-EBM	TP-EBM	TC-EBM	>=20	>=10	TP	TC	IF	H
1	MSESMPMP	11	25	395	8	5	28273	527285	2.647	168
2	ACTAM	10	21	338	5	5	12311	430986	5.058	202
3	RPJ	9	17	272	4	5	915	10683	1.352	47
4	VAC	8	15	145	2	3	12023	78475	1.558	67
5	MMTPMMS	7	13	238	4	1	9226	145187	1.749	110
6	JMPT	8	13	245	5	2	13660	204042	2.359	103
7	ISIJI	6	13	118	2	2	6767	79665	0.96	83
8	RMME	3	12	16	0	0	12374	16620	0.236	20
9	JAC	6	11	90	1	2	39262	470978	3.014	128
10	IJAMT	3	11	34	0	1	10805	82687	1.568	63
11	SCT	5	9	129	3	1	19235	329887	2.139	130
12	RM	1	9	6	0	0	7209	2882	0.007	12
13	MD	4	9	131	3	0	9352	109338	3.997	79
14	JOM	3	9	57	1	1	2888	17124	1.798	49
15	ML	4	8	110	1	1	21825	262449	2.437	100
16	JMBBM	7	8	532	6	0	2013	18057	2.876	44
17	ASS	4	8	37	0	1	34752	431804	3.15	136
18	THJISIJ	3	7	49	1	1	10786	18188	0.26	32
19	MSECMBA	2	7	25	0	1	4354	31804	3.42	49
20	MAT	3	7	59	1	0	2979	20163	2.728	55

Abbreviations: R, rank; H-PC, H-index with electron beam melting only; TC_PC and TP_PC, total citations and papers only with red; %P-EBM, percentage of electron beam melting papers in the journal; ≥20, ≥10, number of papers with more than or equal 20, 10 citations; TP and TC, total papers and citations; IF, impact factor 2015; H, H-index; MSESMPMP, Materials Science and Engineering a Structural Materials Properties Microstructure and Processing; ACTAM, ACTA MATERIALIA; RPJ, Rapid Prototyping Journal; VAC, Vacuum; MMTPMMS, Metallurgical and Materials Transactions a Physical Metallurgy and Materials Science; JMPT, Journal of Materials Processing Technology; ISIJI, ISIJ International; RMME, Rare Metal Materials and Engineering; JAC, Journal of Alloys and Compounds; IJAMT, International Journal of Advanced Manufacturing Technology; SCT, Surface Coatings Technology; RM, Russian Metallurgy; MD, Materials Design; JOM, JOM; ML, Materials Letters; JMBBM, Journal of the Mechanical Behavior of Biomedical Materials; ASS, Applied Surface Science; THJISIJ, Tetsu to Hagane Journal Of The Iron and Steel Institute Of Japan; MSECMBA, Materials Science Engineering C Materials for Biological Applications; MAT, Materials.

Table 3. The Impact factor in electron beam melting research

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
TP	8	6	10	11	9	17	18	19	29	34	45	44	77	101
TC	111	129	212	140	184	541	507	676	586	522	720	261	332	108
TC2	8	11	8	13	20	22	18	67	79	112	156	229	314	450
TP2	13	13	14	16	21	20	26	35	37	48	63	79	89	121
IF	0.62	0.85	0.571	0.813	0.952	1.1	0.692	1.914	2.135	2.333	2.476	2.899	3.528	3.719

Abbreviations: TP, total published papers per year n; TC, total citations received from articles published in year n; TC2, all citations received in year n – 1 and n − 2 from year n; TP2, total published papers per year n − 1 and n − 2; IF, impact factor of year n.

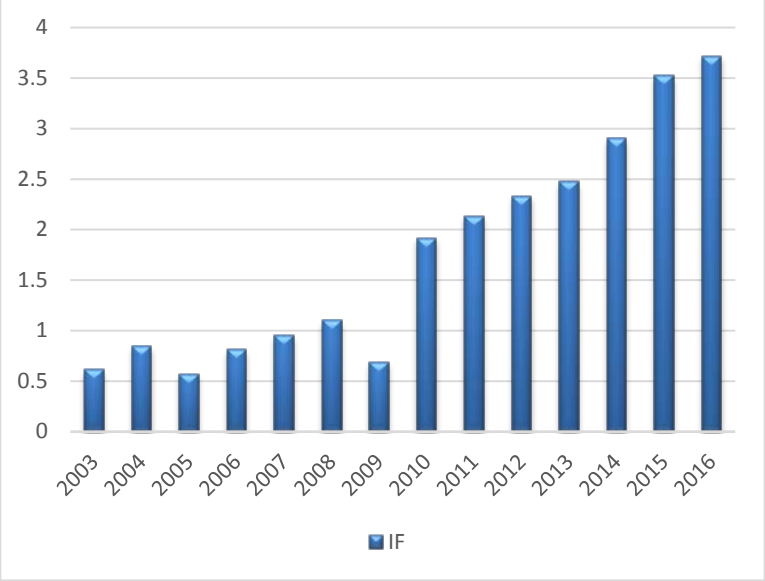

Figure 3. Impact factor for electron beam melting (articles + reviews) since 2003.

The impact factor is an indicator that has the ability to present the publication's value which can be calculated by dividing the citations number received in the last two years (i.e. n − 1 and n – 2) from year n by the total number of papers published in the last two years (n − 1 and n – 2). The impact factor for all articles reported on electron beam melting are shown in Table 3. It can be seen that the impact factor is increasing from one year to another except in 2005 and 2009. In general, the electron beam melting revived more attentions in the last 6 years as evident from Figure 3 which shows an increasing impact factor from 2010 to 2016. A few critics are arguing with impact factor calculations due to the manipulation and general result when they are using the self-citations (Stonebraker et al., 2012),(Garfield, 2014). However, another study (Hood and Wilson)has also reported new technique to deal with impact factor calculations whereby the quality of the journals plays an important role to decide the impact factor due to the value of journals and field of study.

4. Most Influential articles in electron beam melting

The most influential articles in electron beam melting has been classified according to the highest cited articles. The articles with more citation is considered more important which could be due to reasons such as new or useful ideas being presented. Table 4 presented the top 10 most cited papers in electron beam melting research. Murr, et al. in 2009 has been identified as the most cited article with average of over 28 citations per year (C/Y).

Table 4: The top 10 cited papers in EBM research of all time.

Journal	***TC***	***Author/s***	***Year***	***C/Y***
JMBBM	200	Murr, L. E.; Quinones, S. A.; Gaytan, S. M.; et al.	2009	28.57
ACTAB	186	Heinl, Peter; Mueller, Lenka; Koerner, Carolin; et al.	2008	23.25
JMST	144	Murr, Lawrence E.; Gaytan, Sara M.; Ramirez, Diana A.; et al.	2012	36.00
JMBBM	136	Parthasarathy, Jayanthi; Starly, Binil; Raman, Shivakumar; et al.	2010	22.67
MSEBSS	104	Harrysson, Ola L. A.; CansiZoglu, Omer; Marcellin-Little, Denis J.; et al.	2008	13.00
JPS	102	Bi, Zhonghe; Paranthaman, M. Parans; Menchhofer, Paul A.; et al.	2013	34.00
MMTPMMS	100	Al-Bermani, S. S.; Blackmore, M. L.; Zhang, W.; et al.	2010	16.67
AEM	100	Heinl, Peter; Rottmair, Andreas; Koerner, Carolin; et al.	2007	11.11
PTRSMPES	95	Murr, L. E.; Gaytan, S. M.; Medina, F.; et al.	2010	15.83
ACTAM	78	Murr, L. E.; Gaytan, S. M.; Ceylan, A.; et al.	2010	13.00

Journal abbreviations are available in Table 2 except for**:** JMBBM, Journal of the Mechanical Behavior of Biomedical Materials; ACTAB, ACTA Biomaterialia ; JMST, Journal Of Materials Science & Technology; MSEBSS, Materials Science & Engineering C-Biomimetic And Supramolecular Systems; JPS, Journal Of Power Sources; AEM, Advanced Engineering Materials; PTRSMPES, Philosophical Transactions Of The Royal Society A-Mathematical Physical And Engineering Sciences.

5. An Overview of the Most Productive and Influential Authors

So many contributions have been reported by authors in electron beam melting research. Table 5 shows the top 20 authors with highest number of publications in electron beam melting. The number of publications are an indicative only because so many factors could be consider such as, co-authorship, paper size, and journal quality. According to the number of publications, Korner C is the highest author who has published in electron beam melting with 43 papers, next is Murr Le (28 papers), Wicker Rb (23 papers), Medina F (21 papers), Singer Rf (20papers), and so on for the rest authors as shown in Table 5. The table also shows the most influential authors in electron beam melting according to the total citations, Murr Le is the most influential author in electron beam melting with more than 1100 citations, followed by Wicker Rb who is also received more than 1000 citations in this field.

Table 5: The most influential authors in electron beam melting research

Rank	Author Name	Country	TP-EBM	TC-EBM	H-EBM	**TP10**	**TC10**	TP	TC	H
1	Korner C	Switzerland	43	839	16	43	839	617	24646	81
2	Murr Le	USA.	28	1110	16	28	1110	458	9631	48
3	Wicker Rb	USA	23	1010	14	23	1010	73	1772	22
4	Medina F	Spain	21	855	13	21	855	802	15037	56
5	Singer Rf	Germany	20	685	13	20	685	181	2776	30
6	Gaytan Sm	USA	19	924	12	19	924	37	1292	17
7	Jiang Dc	China	18	138	8	18	138	146	1300	18
8	Tan Y	USA	18	138	8	18	138	3201	30181	63
9	Tang Hp	China	17	66	5	17	66	336	2175	22
10	Martinez E	USA	16	941	13	16	941	3383	47779	85

11	Shi S	China	16	100	6	16	100	1785	28902	74
12	Li Sj	China	14	258	8	14	258	4847	47403	83
13	Dong W	China	12	135	8	12	135	2245	25070	67
14	Dehoff Rr	USA	11	174	5	11	174	20	272	7
15	Hao Yl	USA	11	175	7	11	175	659	11624	40
16	Todd I	England	11	192	5	11	192	289	5919	35
17	Vutova K	Bulgaria	11	60	5	5	19	71	631	14
18	Heinl P	Germany	10	553	9	10	553	32	744	13
19	Schwerdtfeger J	Germany	10	227	9	10	227	26	518	14
20	Yang R	China	10	157	6	10	157	4462	60283	96

Abbreviations: TP10, the total number of publications in the last ten years; TC10, the total citations in the last ten years (2007-2016).

6. Analysis by Country

Research is an important variable to determine the countries growth in terms of education. The main focus of this section is to analyze the electron beam melting research distribution across different countries. It doesn't matter if researchers moved from one country to another. Consequently, an author in this case may have publications from more than one country. USA and China received the highest number of authors because they have attracted a lot of researchers from all over the world due to good infrastructure for research.

Table 6 shows that USA is the most productive country in electron beam melting research. In the top 20 countries list, USA has received more than 120 papers in EBM with more than 2500 citations. China comes in the second position with 105 articles with more than 800 citations but with lower H-index (16) when it compared with Germany occupying the third position with 71 total paper with 18 H-index. Moreover, Japan also appeared too close to Germany in terms of number of publications but it got fewer H-index and the rest of countries has been presented in the Table 6. Furthermore, it can be seen that some of the developing countries like Pakistan and Saudi Arabia have also secured positions in the list of top 20 influential countries.

Table 6: The most influential countries in electron beam research.

Rank	Name	TP-EBM	TC-EBM	H-EBM	>=50	**>=20**	**>=10**	TP-EBM10	TC-EBM10
1	USA	120	2561	29	14	26	16	95	2118
2	CHINA	105	833	16	3	7	15	98	735
3	GERMANY	71	1135	18	4	13	13	60	971
4	JAPAN	60	398	11	0	6	8	21	84
5	ENGLAND	37	430	10	2	2	8	31	335
6	SWEDEN	25	311	10	1	4	5	25	311
7	UKRAINE	21	174	6	0	6	0	11	38
8	BRAZIL	20	296	11	1	3	9	4	58
9	FRANCE	20	226	7	1	2	4	13	75
10	AUSTRALIA	18	133	7	0	2	4	18	133
11	ITALY	18	254	8	2	3	1	17	254
12	RUSSIA	18	172	6	0	4	1	8	12
13	SOUTH KOREA	17	70	6	0	0	1	14	62
14	INDIA	14	87	6	0	1	1	12	76
15	BULGARIA	13	67	5	0	0	2	5	7
16	PAKISTAN	13	60	4	0	0	2	6	32
17	CANADA	11	78	6	0	0	2	5	23
18	SINGAPORE	10	103	5	0	2	2	10	103
19	SAUDI ARABIA	9	6	1	0	0	0	9	6
20	NETHERLANDS	8	111	4	1	0	2	1	0

7. Conclusions

This study has presented a bibliometric overview of electron beam melting research. The results shows that the EBM research is receiving a progressive attention particularly over the last decade. EBM has become one of the influential topic because of its increasing application in manufacturing field. Analyzing the bibliometric results show that, USA is the most influence country in electron beam melting field research followed by China in the second place and Germany in the third. Murr Le is found to be the most influential author in electron beam melting with more than 1100 citations with total 28 papers, followed by Wicker Rb who is also received more than 1000 citations in this field. USA has the highest number of the influential authors and also it received the highest number of publications and citations among all countries. China comes in the second position according to the number of publication in electron beam melting but with low citation when it compared with USA. However, Korner C has been received the most number of publications among all in electron beam melting papers. Korner C has been received more than 850 citations. Results reveal that many developing countries are becoming more influential, because of their significant researches in this area, and some of them including Ukraine, Pakistan and Saudi Arabia are already obtaining remarkable results. The current study showed a general bibliometric overview of EBM research, however, there could be some limitations in the reported results. This is due to the fact that only web of science has been used as the source of bibliometric indicators and studies that have been reported in the journals not encompassed by WOS would have been neglected. However, the main objective of this study is that the reader can be informative about the electron beam melting research in terms of its impact and influence.

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BIOGRAPHY

Dr. Saqib Anwar is an assistant professor of Industrial Engineering at King Saud University since 2014. He received PhD degree in 2013, and MSc degree in 2009 with distinction from the University of Nottingham, UK in manufacturing engineering. He did his bachelor in industrial and manufacturing engineering (2007) from the University of Engineering and Technology, Lahore, Pakistan and received a golden medal. He started his research and academic activities since 2009 at the University of Nottingham, UK where he worked as a teaching assistant and researcher. His research interests are related to the application of finite element method to investigate manufacturing processes, new implant designs and machinability assessment of difficult to cut material.

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