



The Related Study Tendencies in the Field of Gasification: A Bibliometric Approach

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Highlights

- The coal gasification related to both bibliometric and historical analyses have investigated.
- The number of coal gasification publications have especially increased after 2005.
- In total, 3413 publication have been found in the subject of coal gasification.

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Abstract

Undoubtedly, energy plays a vital role in every sphere of life. Fossil energy sources such as coal and natural gas are generally used for energy production. People are looking for more efficient use of the source in recent years due to the rapid depletion in the fossil fuel resources. Gasification of coal is a useful method for produce clean and efficient energy. This study was carried out to find out the various trends in scientific studies that provide literature for the field of coal gasification on world. All data used in this study have been reached from Web of Science database. In this study, the coal gasification related to both bibliometric and historical analyses were investigated. The Web of Science database was scanned for the articles about coal gasification between the years of 1989 and 2020. The considered parameters in the bibliometric analysis are the number of citations and documents, authorships and ownerships, patterns of international collaborations and addresses.

1. INTRODUCTION

Nowadays, the world population is increasing rapidly and consequently industrialization is increasing in a significant way. As a result, there is an increase in energy consumption. More than half of the world's energy production is provided by using fossil sources [1,2]. Considering the harmful effects of the fossil fuels and the possibility of exhaustion, it is very important to be able to use those resources more efficiently [3–7].

Coal is the oldest known fossil fuel all around the world. It is an important source of energy because of its low costs at an acceptable level. Moreover, coal is abundant and omnipresent [8–13]. Generally, coal is burned to produce energy at thermal plants. Therefore, the use of coal causes greenhouse effect such as SO_x , NO_x , CO_x gases [14–18]. One of the ways of using coal more efficiently is to convert the coal into gas [19–22]. Gasification technology was widely used in European countries in the 1940s when oil was insufficient. Then, the coal gasification plants were developed and coal gasification systems have reached today. Gasification is a chemical transformation that solid fuel is converted to gas by using high temperature, high pressure and oxygen [23–28]. The coal gasification reaction is endothermic and the working temperature is higher than 700 C°. Gasification process also generates less greenhouse effect [29–31]. Therefore, the gasification technology is promising for future [32,33]. The composition and the amount of syngas depend on the coal type, oxidant type, gasifier temperature, residence time and the gasification methods [34]. Syngas contains various gases, such as CO, CO₂, H₂, CH₄.. etc.[35]. Electricity, heat, hydrogen and various synthetic fuels can be produced thanks to the syngas [36–38].

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The integrated gasification combined cycle (IGCC) system is more effective than general combustion systems [39]. The IGCC produces power from coal. The coal is converted into syngas in the gasifier. The syngas which is produced after the gasification of coal is sent to the combined power systems that are called gas turbine and steam turbine systems. As a result, the electricity is produced [40–43]. Hydrogen can also be produced with integrated systems that are applied to coal gasification systems [44–50]. Additionally, synthetic fuels can be produced [51–57].

The literature of coal gasification has grown substantially thanks to the advancement of the gasification technology. Coal gasification systems have drawn the attention of researchers because of their advantages. It is very important to analyze the studies in any discipline according to the periods. This investigation indicates the position of the subject in the science. One of the most important ways of achieving that is the bibliometric analysis. The application of mathematical and statistical methods to books and other communication is called bibliometry [58,59]. Bibliometric analyses may describe illustrative (such as the number of articles published in a given year) or evaluative (such as citation analysis) [60] aspects of the literature. Statistical investigation of data such as author, subject, cited author, and cited sources is possible thanks to the bibliometric analysis [61].

Table 1. *Bibliometric studies in the field of Engineering and Energy*

Authors	Database	Descriptions	Timeframe
Ma et al. [62]	WoS	Understanding for a potential direction of microalga-derived biodiesel	1993-2016
Zhang et al. [63]	WoS	Tendencies of the global biodiesel	1991-2015
Li et al. [64]	WoS	The research trends in Solid waste reuse and recycling	1992-2016
Tian et al. [65]	WoS	The characteristics of carbon emissions research in the transportation sector	1997-2016
Park and Nagy [66]	WoS	Investigate the interaction between thermal comfort and building control research.	1970-2016
Imran et al. [67]	Scopus	The research in the field of the organic Rankine cycle	2000-2016
Chen et al. [68]	WoS	A comprehensive analysis of emergy related literatures	1999-2014
Wang and Li [69]	WoS	The development trends in shale gas research.	1990-2014
Zhang et al. [70]	WoS	The research in the field of Water Footprint	2006-2015
Wang et al. [71]	Scopus	investigated the characteristics of the low carbon	1995-2014
Geng et al. [72]	Scopus	Investigated residential energy and greenhouse gas emission related researches	1996-2016
Feng et al. [73]	Scopus	The research in the field of corporate social responsibility in supply chain management	1997-2017
Zeng and Chini [74]	WoS	The research on the embodied energy of buildings.	1996-2015
Grando et al. [75]	WoS	The research on biogas production	1990-2015
Jiang et al. [76]	WoS	Bibliometric exploration of hydropower research	1994-2013
Chen et al. [77]	WoS	The examine Chinese energy and fuels research	1993-2012
Zhang and Liang [78]	WoS	The research in the field of emission reduction	1992-2019
Li et al. [79]	WoS	The research on the carbon footprint of higher education	2010-2019
Kasavan et al. [80]	WoS	Tendencies of the plastic pollution in the water ecosystem	2000-2020

The aim of the bibliometric analysis is to measure science globally. The bibliometric analysis involves different disciplines such as social, physical and health science. Therefore, it is important to choose any discipline for the analysis. There are three laws such as Zipf, Bradford and Lotka on basis of bibliometric analysis [81–84]. The Zipf's law is related the frequency distributions of the words. Bradford's law is used to determine the number of main journals in a known area. Lotka's law evaluates the performance of the authors in a known area. Bibliometric analysis has two main steps such as performance analysis and mapping. Firstly, the data is collected and then it is classified according to author names, affiliation, years, document type, country, citations and institutions. Secondly, maps are made of using classified data thanks to the different ways such as co-citation and co-word analysis [85,86]. There are widely used sources for bibliometric analysis such as Web of Science, Google Scholar and Scopus [87]. The data received from the sources is arranged and mapped by using different softwares such as bibexcel, vosviewer, pajek, Excel,

SSPS and Gephi [65,88,89]. Although the bibliometric analysis is generally used in the social sciences, it has also been used in the engineering sciences recently. Table 1 presents the bibliometric study in the field of engineering in the last decade.

The main objective of this study is to inspect the research activities within the coal gasification at the global level in the period between 1989 and 2020. There is no article that uses bibliometric analysis and mapping to summarize scientific developments on this topic in the existing literature. Therefore, in this study, we propose a bibliometric approach for the review of coal gasification at the literature. This paper has four sections. Section 2 presents bibliometric methods, scientific approach and the data where and how it is taken. The results and discussions are given in section 3 and finally, section 4 presents the conclusion remarks.

2. BIBLIOMETRIC ANALYSIS

This study was carried out to ascertain the assorted trends in studies in the field of coal gasification. All data used in this study was taken from Web of Science database. This study answers some questions such as “What is the number of publications on coal gasification?”, “Who are the most productive authors?”, “What are the most productive countries?”, “How is the distribution of document type of studies?”, “What are the most popular journals about coal gasification?”, “What are the leading keywords?” etc.

The researchers should know some limitations about bibliometric analysis. One of them, the bibliometric analysis may not show that a publication is always a good quality publication, which means the number of citation of a publication does not mean that a paper is at a high quality. The other one, all research areas and all publications may not be included in the bibliometric databases. For that reason, time is required for a comprehensive citation analysis [90].

Bibexcel software which was developed by Persson is used to carry out the bibliometric analysis [91]. Bibexcel is commonly used as a tool for helping the bibliometric analysis. That software arranges the data taken from Web of Science or Scopus. Afterwards, the data is used for mapping.

The data to be used in this study was taken from Web of Science database according to “coal gasification” keyword, considering the period 1989-2020. Web of Science is the most widely accepted and frequently used database for the analysis of scientific publications [92–95]. There are several sub databases in Web of Science. For instance, Science Citation Index Expanded (SCI-E), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), Emerging Sources Citation Index (ESCI), Conference Proceedings Citation Index- Science (CPCI-S) and Conference Proceedings Citation Index Social Science & Humanities (CPCI-SSH). SCI-E, SSCI, CPCI-S and CPCI-SSH indexes are preferred in this study.

3. RESULTS AND DISCUSSION

The data used in this study was obtained from Web of Science database by using keyword “coal gasification”. The research area was limited to thermodynamics, engineering, energy fuels and chemistry. The publications were downloaded in the bibliographic style that is called plain text of Web of Science with information in title, authors, country, keywords etc. Then, “Plain Text” was imported to BibExcel software. BibExcel was used for the general statistical information of publications. As a result, the number of publications is determined as “3413” at the Web of Science between the years of 1989 and 2020. The data was extracted in August 2021. The timeline of the coal gasification publications from 1989 to 2020 is shown in Figure 1. In addition, Figure 2 shows the number of published document type according to published years.

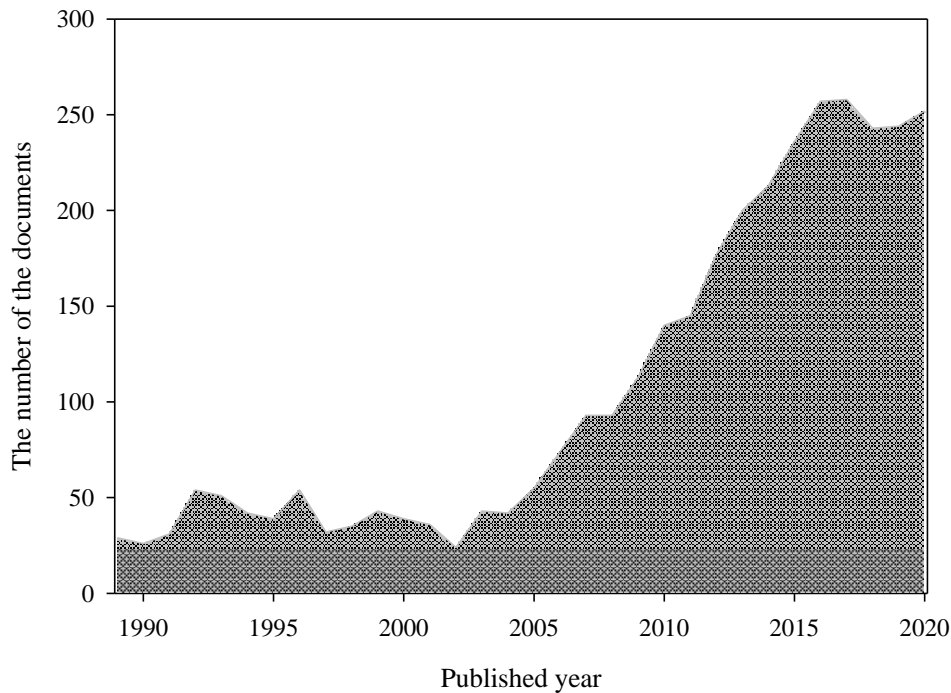


Figure 1. Trends in Coal Gasification publications (1989-2020)

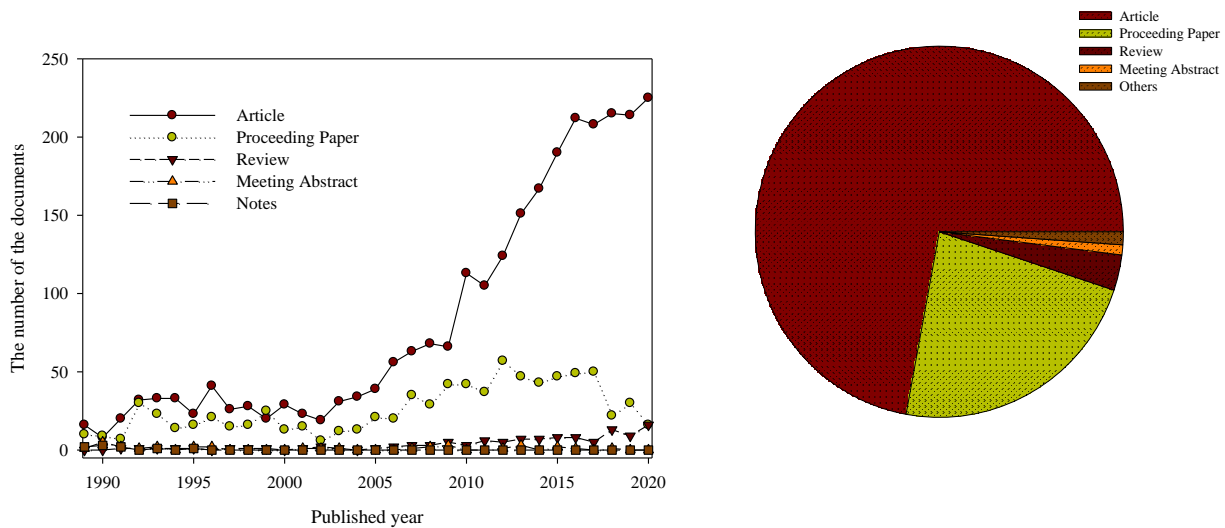


Figure 2. Number of published document types on coal gasification between 1989 and 2020

Figure 1 depicts the change of the number of publications with respect to the published year. The number of coal gasification publications increased from only 29 in 1989 to 252 in 2020. Especially, the publication rates have considerably increased since 2005. The results show that the topic presents a rising trend. This result can be explained by increasing energy requirement, decreasing greenhouse effect and increasing need of using coal more effectively. There are 12 document types in the database. Articles are the dominant document comprising 2632 of the total. The remaining publications are conference proceeding papers (832), reviews (112), meeting abstract (33), news item (17), editorial materials (15), note (9), letter (7), correction (2) and retracted publications (2). Figure 2 shows the number of published document type with respect to the published year and the distribution of the document type. In addition, the dominant language for publications in coal gasification is English (96.52 %) which is followed by Polish (1.137 %), Japanese (0.891 %), German (0.769 %) and Chinese (0.154 %).

Table 2. Top 5 productive journals in the coal gasification field from 1989 to 2020

Journal	Amount	Percentage	h-index	Avr. citation per item	IF (2020)
Fuel	331	9.69 %	56	33.12	5.578
Energy & Fuels	199	5.82 %	41	25.22	3.421
Int. J. of Hydrogen Energy	191	5.59 %	40	31.79	4.939
Fuel Processing Tech.	122	3.57 %	30	26.56	4.982
Energy	117	3.42 %	32	27.68	6.082

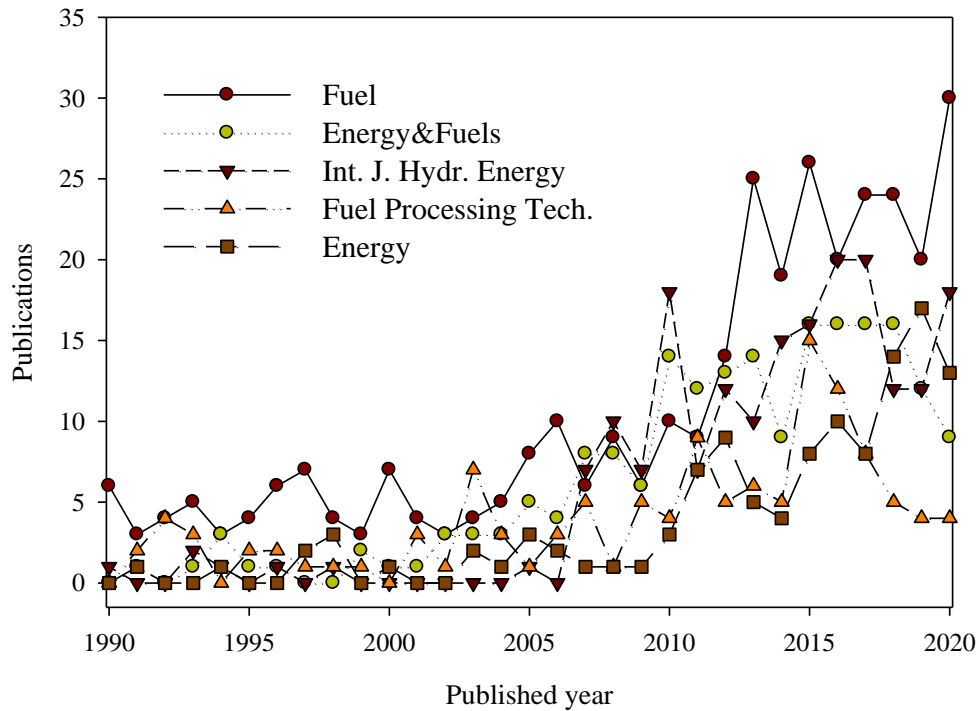
**Figure 3.** Timeline of coal gasification publications of the most productive journals between 1989 and 2020

Table 2 presents the top five most productive journals based on publications including the number of papers, h-index, average citation per items and impact factor (IF). Fuel journal that has an impact factor of 5.578 and an h-index of 56 is the most preferred journal and accounts for 9.69 % of the total coal gasification publications from 1989 to 2020. Fuel journal ranking the first place by the number of articles among all related journals has the second highest impact factor and its h-index is also first highest among those five journals. It results that the Fuel journal is a journal with a large influence on the coal gasification research. The average number of articles on the subject of coal gasification that are published in Fuel journal is 10.6 papers per year. This is followed by Energy&Fuels (6.41 papers per year) and International Journal of Hydrogen Energy (6.16 papers per year). The top five journals account for 28.09% of the coal gasification publications. Fuel, Energy&Fuels, International Journal of Hydrogen Energy, Fuel Processing Technology and Energy journals have more than 100 publications and impact factor of higher than 3. Figure 3 presents the timeline of the publications in the Top 5 journals based on published years.

Table 3. Top 10 productive countries in the coal gasification field from 1989 to 2020

Country	Total Publication	Citation	Ave citations per item	Citations per year	Per. of publications of a country	h-index
China	1166	19981	17.14	644.5	28.76 %	60
USA	478	12397	25.94	399.9	18.69 %	58
Japan	268	4883	18.22	157.5	7.03 %	35
Canada	177	5340	30.17	172.2	7.68 %	39
Poland	168	2045	12.17	65.9	2.94 %	23
South Korea	144	2404	16.69	77.5	3.46 %	26
Germany	142	3891	27.4	125.5	5.60 %	29
India	140	2343	16.74	75.5	3.37 %	25
Australia	138	4766	34.54	153.7	6.86 %	41
England	120	3273	27.28	105.5	4.71 %	33

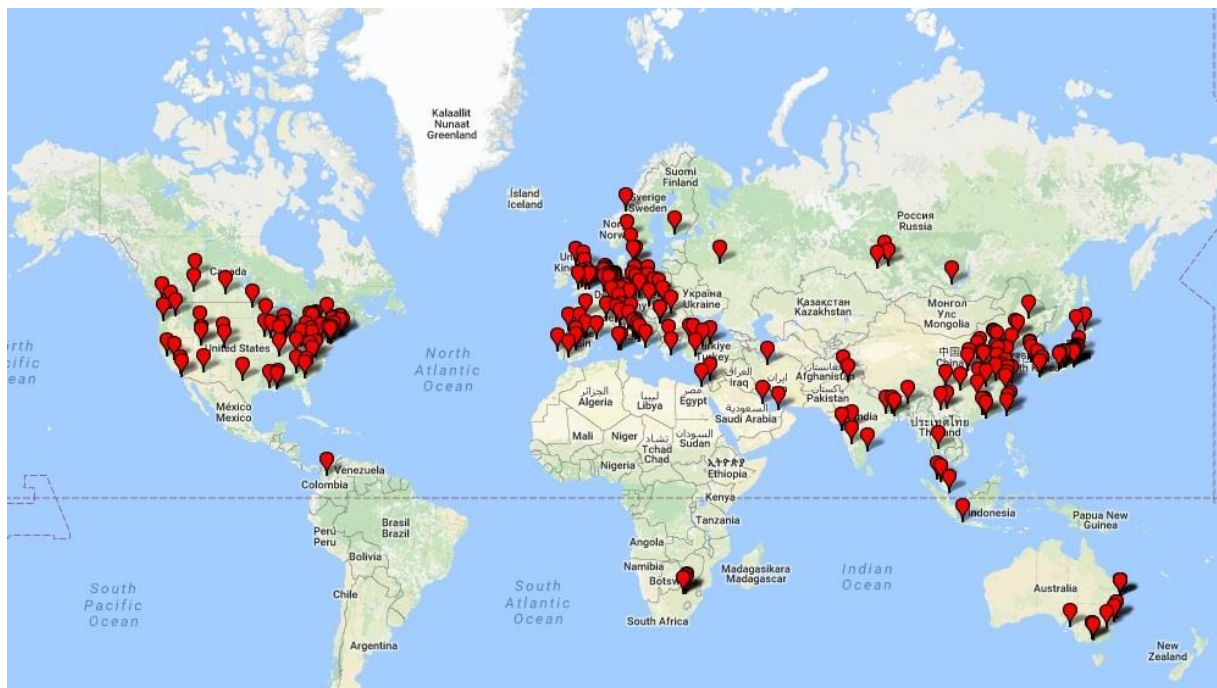
**Figure 4.** The global distribution of coal gasification publications

Figure 4 presents the global distributions of coal gasification publication from 1989 to 2020. The Top 10 productive countries are ranked with respect to the number of publications in Table 3. The table also shows the citation rate, average citations per items rate, citations per year rate, the percentage of publications of a country rate and h-index. The Top 10 countries which published about 86.17% of the publications are four Asia countries, two North America countries, three Europa countries and one Oceania country. China which has 1166 publications is the most productive country and accounts for 34.16 % of the total coal gasification publications from 1989 to 2020. China is developing rapidly and has increasing need for the energy. In addition, the main energy source of China is coal [96,97]. Therefore, the result can be expected. The second most productive country is USA (478 publications) which is followed by Japan (268 publications), Canada (177 publications) and Poland (168 publications) respectively. Australia has the highest average citations per items among other countries.



Figure 5. *The cooperation network of the top 10 productive countries*

Figure 5 shows the cooperative relationships among the top ten productive countries in the field of coal gasification research by using social network analysis. The size of the circles is related to the number of the publications while the thickness of the lines between circles shows the frequency of cooperation between two countries. China and USA are most productive countries and those countries are also the most cooperating countries in the network, followed by Japan-China and China-England respectively. China, USA and Australia are in the cooperation with all top 10 productive countries. Those are followed by England and Germany. In addition, India is the least cooperative country among all top productive countries.

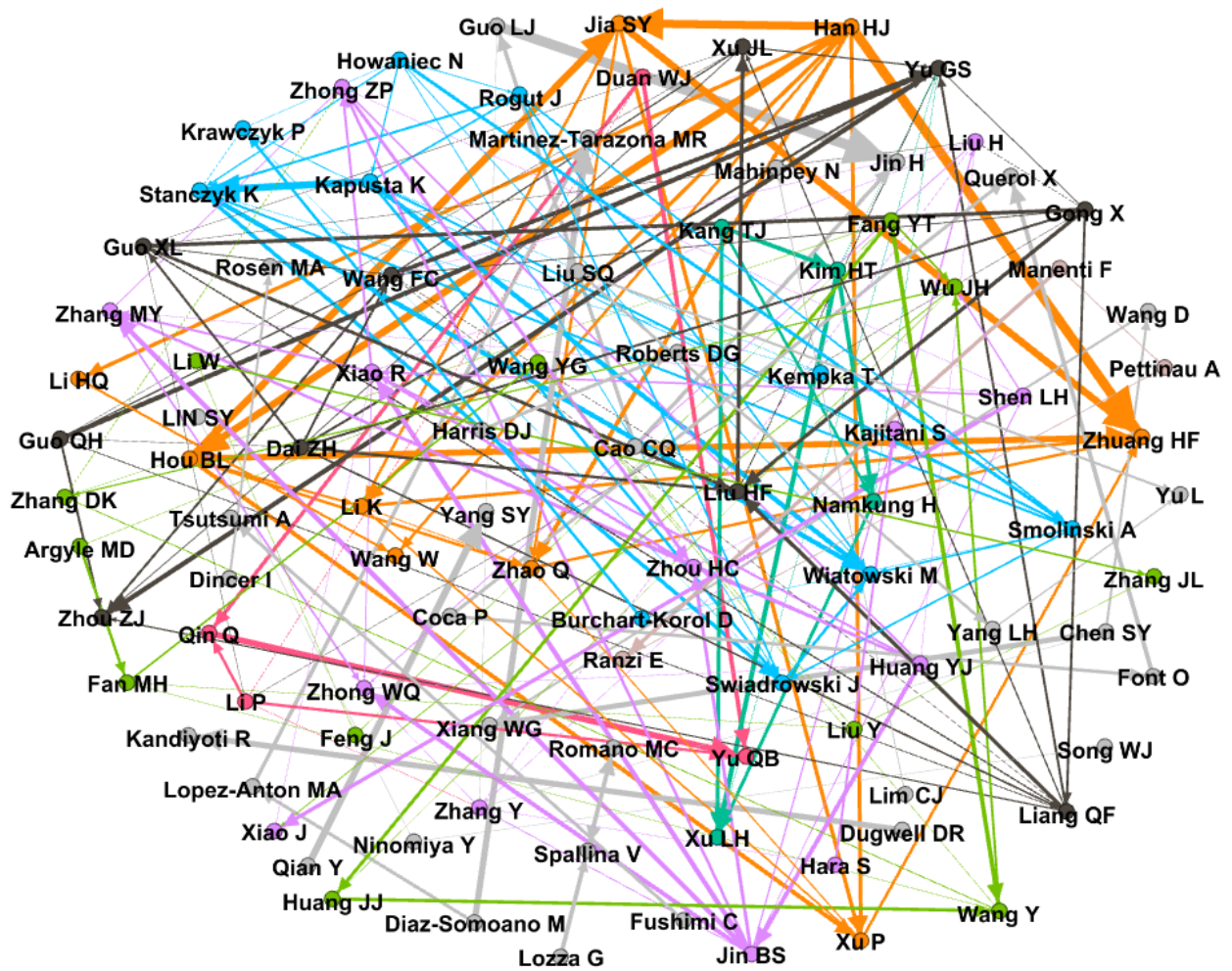


Figure 6. The cooperation network of the authors

Totally, 7067 authors have contributed to the field of coal gasification. The most productive author is Han HJ with 50 publications from China. The authors list includes more authors from China. The author cooperation is shown in Figure 6. In Figure 6, each author is presented as a circle and the size of circles is proportional to the number of the collaboration. The thickness and number of the lines between the authors show the strength of collaboration in the field. According to Figure 6, the most collaborative authors are from China, followed by authors from USA.

4. CONCLUSION

Energy demand increases day by day. Therefore, it is very important to use energy sources efficiently. Coal is one of the most used energy sources. A way of using coal efficiently is the gasification of coal. The scientific publications on coal gasification at the Web of Science database were examined in terms of bibliometric properties and relations between different structures. Then the results were visualized through social network analysis. The major results from this study are summarized as follows;

- Using a bibliometric analysis technique, the number of publications of a country, the number of publications of an institute and the quality of those publications can be determined in a scientific field.
- In total, 3413 publication have been found in the subject of coal gasification according to the selected research areas such as thermodynamics, engineering, energy fuels and chemistry between 1989 and 2020.
- The number of coal gasification publications have increased between 1989 and 2020 especially after 2005. The result shows that the topic presents a rising trend.
- Despite the fact that China is the top country in terms of productivity, the developed countries such as USA, Japan, Canada, Poland, South Korea and Germany are in the upper ranks at the most productive countries list. Turkey has a leading position among the Middle East countries.
- The most productive author is Han HJ from China. The most frequently cited article authors are Stefan Rönsch, Jens Schneider, Steffi Matthischke, Michael Schlueter, Manuel Götz, Jonathan Lefebvre, Praseeth Prabhakaran and those authors published in the journal of "Fuel" in 2016.
- "Fuel", "Energy and Fuel" and "International Journal of Hydrogen Energy" were found as the most preferred journals by the authors. "Fuel" that has an impact factor of 5.578 and an h-index of 56 accounts for 9.69 % of the total coal gasification publications between 1989 and 2020. "Fuel" is a journal with a large influence on coal gasification research. The journal has published 10.6 papers on an average per year related to the coal gasification.
- According to the publication types, the rate of the articles is 77.09 %, the rate of conference proceeding paper is 24.40 % and the rate of the review is 3.281 %.
- The most used language in publications is in English (97.01 %) followed by Polish (1.11 %), Japanese (0.76 %), German (0.73 %), and Chinese (0.11 %).
- The data of each database cannot be evaluated without any action. For that reason, serious data cleaning must be done on the database.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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