Scientometrics (2014) 98:119–136
DOI 10.1007/s11192-013-1047-z

China's research in chemical engineering journals in Science Citation Index Expanded: a bibliometric analysis

Hui-Zhen Fu · Xiao Long · Yuh-Shan Ho

Received: 4 December 2012 / Published online: 21 May 2013

Abstract This study was designed to evaluate China's scientific output of chemical engineering in Science Citation Index Expanded in the Web of Science from 1992 to 2011. The document type, language, trend and collaboration patterns were analyzed, as well as the output of different journals. Distributions of article titles and abstracts, author keywords, *KeyWords Plus* of different periods, and the most cited articles were studied to figure out the research focuses and trends. *Chinese Journal of Catalysis*, *Industrial & Engineering Chemistry Research*, and *Chinese Journal of Chemical Engineering* published most of Chinese articles in the area of chemical engineering. The Chemical Engineering Department of Tsinghua University, Zhejiang University, Tianjin University, and East China University of Science and Technology were the top four institutions that published most articles in China. This study showed that adsorption, photocatalysis and synthesis have been the hot points of research in the past two decades, while ionic liquid tends to be the new area of special interest in future. Pseudo-second order model for sorption processes is getting more and more popular with great influence since its publication. In addition, the ratio of institutional independent articles: nationally collaborative articles: internationally collaborative articles has been developed to compare different institutions' publication characteristics.

Keywords Bibliometric · Web of science · Highly cited · Publication characteristics · Science Citation Index Expanded

H.-Z. Fu · Y.-S. Ho
Department of Environmental Sciences, Peking University, Beijing 100871, People's Republic of China

H.-Z. Fu · Y.-S. Ho (✉)
Trend Research Centre, Asia University, No. 500, Lioufeng Road, Wufeng, Taichung 41354, Taiwan
e-mail: ysho@asia.edu.tw

X. Long
Division of Plastic and Reconstructive Surgery, Peking Union Medical College Hospital, Beijing, People's Republic of China

Introduction

The historical origin of academic chemical engineering could be dated back to George E. Davis, whose lectures lately titled as "A handbook of chemical engineering" in 1887 (Kim 2002). Chemical engineering courses first appeared in the departments of chemistry in colleges in 1880s (Cohen 1996). Similarly, the Institution of Chemical Engineers (IChemE) and the American Institute of Chemical Engineers (AIChE) grew out of chemical instead of engineering societies (Cohen 1996). Nowadays, chemical engineering studies tend to be involved in different interdisciplinary research areas such as biology. To be specific, many U.S. chemical engineering departments have been renamed as chemical and biochemical, chemical and biomolecular, or chemical and biological engineering. For example, the Massachusetts Institute of Technology (MIT) published more papers related to tissue engineering and drug delivery, and the California Institute of Technology (Caltech) mainly focused in the field of biology (Zhu et al. 2011). There are several important events stimulating the evolution of chemical engineering, for example the biotechnology and biomedical infusion in 1985; the invention of personal computer, microelectronics and sensors in 1992; and the nanotechnology revolution in 2000 (Chen 2007). These waves have been cumulative driving chemical engineering from macroscopic towards microscopic, to nano-scale, and eventually to molecular dimensions (Chen 2007). Research trends of chemical engineering also showed more collaboration with biology and molecular science in recent years (Armstrong 2007).

China's share of scientific journal literatures is increasing rapidly recently (Arunachalam et al. 1993). Since 2006, China has become the No. 2 country in scientific publication, only behind the USA (Leydesdorff and Wagner 2009). Recently in the area of chemistry (Zhou and Leydesdorff 2009) and nanotechnology (Kostoff 2012), China has been the No. 1 output country. Bibliometric analysis has been widely applied as an approach to study the scientific production and research trends. Numerous bibliometric analyses of Chinese research have been performed in various fields, such as ophthalmology, optometry and visual science (Zou et al. 2009), semiconductor (Guan and Ma 2007), orthopaedics (Cheng 2012), water pollution and treatment (Yuan et al. 2010). Bibliometric analysis of chemical engineering publications have been investigated by publications, references and citations (Modak and Madras 2008; Schubert 1998), as well as top cited articles (Ho 2012). The development of chemical engineering in China has also been discussed according to its past, present, and future (Jin and Cheng 2011). However, the characteristics of Chinese research in chemical engineering are still uninvestigated.

In the field of chemical engineering, "co-author analysis" and "co-word analysis" were used as institutional and author's identification to analyze their gradual change in research topics (Peters and van Raan 1991, 1993) and bibliometric characteristics (Peters and van Raan 1994). Citation analysis has also been applied to assess the information of geographical origins, journals, research fronts and interdisciplinary relationships (Milman and Gavrilova 1993; Shama et al. 2000). For example, Southeast Asian chemical engineering research activities of top journal articles and keywords have been studied (Yin 2009). However, the change of citations or publication counts cannot offer enough evidence for the estimation of research trend. More detailed information of the publications including words in the title and abstract, author keywords, and *KeyWords Plus* could also be separated into different periods to analyze the variations of research trends more thoroughly and precisely (Xie et al. 2008; Zhang et al. 2010). What's more, the *KeyWords Plus* in the SCI-Expanded database could provide additional search terms extracted from article's title cited by authors in their bibliographies and footnotes (Garfield 1990). And the citation life cycles of most cited papers with significant influence could be used to get more citation information (Aksnes 2003).

This study aimed to use a comprehensive method of bibliometric analysis to provide a thoroughly graph of China's chemical engineering research from 1992 to 2011. Different bibliometric indicators were employed to analyze publication patterns of document types, languages, annual production, journals and collaborations. Time distributions of words in title, abstracts, author keywords, *KeyWords Plus* and the citation life of classic articles were also analyzed to investigate the research trends. In particular, the ratio of institutional independent articles: nationally collaborative articles: internationally collaborative articles has been developed in analyzing the characteristic of inter-institutional collaboration.

Data sources and methodology

Documents reported in this study were derived from the online version of Science Citation Index Expanded (SCI-Expanded), Thomson Reuters Web of Science database. According to Journal Citation Reports (JCR) of 2011, it indexes 8,281 journals with citation references across 176 scientific disciplines. There were 133 journals listed in the Web of Science category of chemical engineering. All documents from 1992 to 2011 with "Peoples R China", "Hong Kong", and "Macao" in the address field in the Web of Science category of chemical engineering (updated on 11 July 2012) were collected. The searched publications were checked to make sure that they were published by China; for example, the publication with "Macao" in address as "SSM, Saude Publ Lab, Macao, Portugal" was excluded. The records were downloaded using Microsoft Excel software, and additional coding was manually performed. In total, 12 document types were categorized for the 29,028 publications during 1992–2011.

Impact factors were taken from the Journal Citation Report (JCR) published in 2011. Contributions of different institutions and collaborated countries were estimated by the affiliation of at least one author to the article. Articles originating from England, Scotland, Northern Ireland, and Wales were reclassified as from the United Kingdom (UK). Collaboration type was determined by the addresses of the authors, where the term "China independent article" was assigned if the researchers' addresses were all from China (Chiu and Ho 2005). The term "institutional independent" was assigned if the researchers' addresses were from the same institution in China (Li and Ho 2008). The term "national collaboration" was assigned if authors were from different institutions in China. The term "international collaboration" was designated to those articles that were coauthored by researchers from other countries (Chiu and Ho 2005). The following discussion included two sections to determine the scientific performances and research trends. The first section dealt with publication characteristics of document types, languages, journals, institutions and collaborated countries distributions. The other section focused on the research emphases and trends by analyzing the words distributions and most cited articles.

Publication patterns

Document type and language of publication

The distribution of document types at the Web of Science was analyzed. Journal article was the most frequently used document type with 26,202 articles, accounting for 90 % of the total productions, followed by proceedings paper articles (2,118; 7.3 %) and reviews (303; 1.0 %). The others were less significant, such as editorial materials (203), corrections (73), letters (65), notes (51), biographical-items (5), news items (4), meeting abstracts (2), addition correction (1) and book chapter review (1). Altogether 26,202 journal articles were extracted from the 29,028 documents for further analyses. Ninety-three percent of all these journal articles were published in English (24,342), followed by Chinese (1,832; 7.0 %), German (20), Rumanian (2), Japanese (2), Norwegian (1), Russian (1), and Romanian (1).

Trend of production

The research of chemical industry in China was started in 1980s (Jin and Cheng 2011). The earliest four China's publications could be found in the year after Chinese Culture's Revolution. These four articles were entitled "Two phase flow in a climbing-film evaporator" (Tang 1980) in *Canadian Journal of Chemical Engineering*, "Determination of the overall distribution constant of deuterium in the GS process for heavy water production" (Chang and Huang 1980) in *Separation Science and Technology*, "Tectonic evolution of Chinese petroleum basins" (Zhu and Chen 1980) and "Geothermal resources in China" (An and Huang 1980) in *Revue de l Institut Francais du Petrole*. The cumulative numbers of articles during the past 20 years are presented in Fig. 1. An increasing trend was observed from 120 in 1992 to 4,521 in 2011. It is notable that a significant correlation was found between the yearly cumulative number of articles and the number of years from 1992. The number of years since 1992 was labeled as *Y*, for example, the year of 1992 corresponding to the number of one, the year of 1995 corresponding to four. *P* represented the cumulative number of articles; for example, the cumulative number of articles in 1995

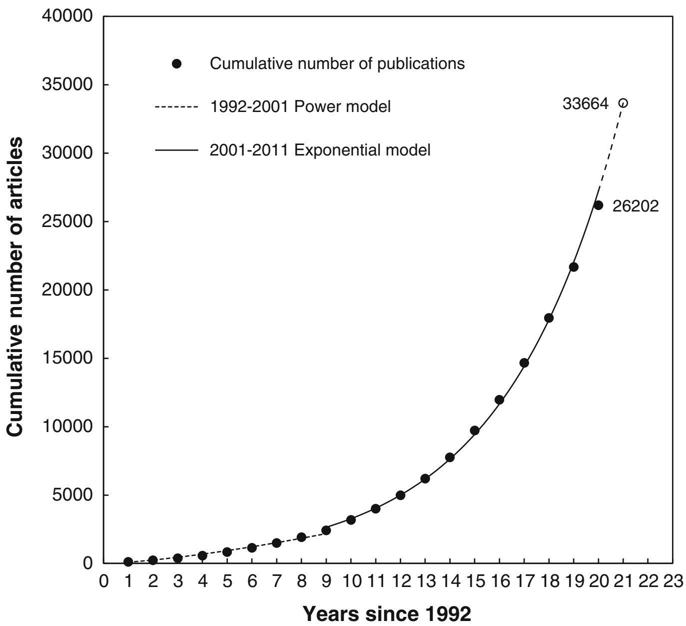

Fig. 1 Cumulative number of articles by year during 1992–2011

was the sum of the annual productions during 1992–1995. The relationship between P and Y from 1992 to 2011 was found to be: $P = 93.56Y^{1.433}$ ($r^2 = 0.979$) during 1992–2001 and $P = 393.0\exp(0.2119Y)$ ($r^2 = 0.999$) for 2001–2011. Based on the exponential model during 2001–2011, it could be estimated that the cumulative number of articles published by authors in Chinese institutions in chemical engineering will probably be 62,803 in 2015, which indicate 12,133 articles would be published by China in 2015. This performance represents a high growth rate for annual China's chemical engineering articles, which could explain the phenomenon that China's number of chemical engineering publications has surpassed USA in the last decade (Modak and Madras 2008).

Outputs of journals

Top most productive journals (TA >400) and their impact factors in 2011, impact factor ranks, and numbers of articles being published by China are shown in Table 1. In total, 16,895 (64 %) articles were published in the 20 journals. *Chinese Journal of Catalysis* published the most articles (2,100) comprising 8.0 % of total, followed by *Industrial & Engineering Chemistry Research* (6.3 %) and *Chinese Journal of Chemical Engineering* (6.2 %). China has made great progress in chemical engineering research, but the growth of China's articles are partially due to the increasing number of China-based journals recorded by the international databases recently (Chen et al. 2006). Among the 20 journals, seven journals are from USA, five from Netherlands, four from the UK, two from China

Table 1 Top 20 journals in the Web of Science category of chemical engineering during 1992–2011

Journal	TA (%)	Rank (IF2011)	Journal country
Chinese Journal of Catalysis	2,100 (8.0)	61 (1.171)	China
Industrial & Engineering Chemistry Research	1,655 (6.3)	30 (2.237)	USA
Chinese Journal of Chemical Engineering	1,637 (6.2)	78 (0.826)	China
Journal of Chemical and Engineering Data	1,294 (4.9)	46 (1.693)	USA
Journal of Membrane Science	1,189 (4.5)	8 (3.850)	Netherlands
Energy & Fuels	999 (3.8)	18 (2.721)	USA
Chemical Engineering Journal	951 (3.6)	11 (3.461)	Switzerland
Process Biochemistry	646 (2.5)	21 (2.627)	UK
Separation and Purification Technology	639 (2.4)	16 (2.921)	Netherlands
Powder Technology	609 (2.3)	36 (2.080)	Switzerland
Dyes and Pigments	584 (2.2)	14 (3.126)	UK
Chemical Engineering Science	575 (2.2)	26 (2.431)	USA
Fuel	565 (2.2)	13 (3.248)	UK
Petroleum Science and Technology	545 (2.1)	112 (0.335)	USA
Desalination	538 (2.1)	23 (2.590)	Netherlands
Applied Catalysis B-Environmental	512 (2.0)	6 (5.625)	Netherlands
Fluid Phase Equilibria	507 (1.9)	33 (2.139)	Netherlands
Polymer Engineering and Science	480 (1.8)	60 (1.302)	USA
Journal of Catalysis	452 (1.7)	5 (6.002)	USA
Applied Energy	418 (1.6)	7 (5.106)	UK

TA (%) total number and percentage of articles, *IF2011* impact factor in 2011, *Rank* rank in descending order of impact factor and Switzerland. It is noticed that these two journals in China contributed a notable percentage of China's chemical engineering articles (14 %).

Collaborations

The contributions of Chinese institutions were identified as the participation of at least one author. Of all the 26,202 articles with author addresses in Web of Science, 21,700 (83 %) articles were China independent articles and 4,502 (17 %) articles were internationally collaborative articles. Only about 47 % of China's articles in Essential Science Indicators (ESI) were internationally collaborative (Fu et al. 2011). These results demonstrated China's strong independent research ability in chemical engineering. Table 2 lists the top ten internationally collaborative countries, their number of articles cooperated with China, and the quantity and ranks of first author articles and corresponding author articles. USA dominated the collaborative countries, followed by Japan and Canada. This is not surprising since these three countries were also the top three countries by top-cited articles in chemical engineering (Ho 2012).

Among the 26,202 articles, 2,895 Chinese affiliations collaborated with 1,591 overseas affiliations. Totally 15,106 (58 %) were institutional independent articles, 6,594 (25 %) were national collaborations, and 4,502 (17 %) were international collaborations. A potential bias in analysis of institutions might occur when authors use different spelling of affiliations for the same institution and some institutions merged to be a university in China. The Chinese Academy of Sciences with over 100 branches in different cities published 3,662 articles (14 % of total). Except 25 (5.4 % of 467) single author articles, the Chinese Academy of Sciences ranked top one in many indicators, including 1,785 institutional independent articles (12 % of 15,106), 1,361 (25 % of 6,594) nationally collaborative articles, 516 (11 % of 4,502) internationally collaborative articles, 2,680 (10 % of 26,202) first author articles, and 2,636 (10 % of 25,789) corresponding author articles. The top 20 institutions were ranked by the following factors: total number of articles (including the institutional independent articles, nationally collaborative articles, internationally collaborative articles), single author articles, first author articles, and corresponding author articles (Table 3). Two universities located in Hong Kong ranked in the top 20. There were four universities: Tsinghua University (1,913), Zhejiang University (1,675), Tianjin University (1,543), and East China University of Science and Technology (1,290) with more than 1,000 articles. It could be partially interpreted by the phenomenon

Table 2 Top ten most internationally collaborative countries/territories during 1992–2011

Country/territory	TA	TAR (%)	FAR (%)	RAR (%)
USA	1140	1 (4.4)	1 (1.7)	1 (1.6)
Japan	635	2 (2.4)	2 (1.0)	2 (0.91)
Canada	444	3 (1.7)	3 (0.76)	3 (0.71)
UK	409	4 (1.6)	4 (0.68)	4 (0.65)
Australia	347	5 (1.3)	5 (0.46)	5 (0.46)
Germany	311	6 (1.2)	5 (0.46)	6 (0.44)
Singapore	278	7 (1.1)	7 (0.41)	7 (0.41)
South Korea	214	8 (0.82)	8 (0.40)	7 (0.41)
France	206	9 (0.79)	10 (0.30)	10 (0.30)
Taiwan	180	10 (0.69)	8 (0.40)	9 (0.39)

TA total number of collaborative articles with China, *TAR (%)*, *FAR (%)*, *RAR (%)* rank and percentage of total articles, first author articles, corresponding author articles in total articles that the Chinese State Key Laboratory of Chemical Engineering has only four branches, which are located in these four universities respectively. Tsinghua University published not only the most articles but also dominated single author articles, first author articles, and corresponding author articles. Tsinghua University and Zhejiang University have been ranked in the top Asian 50 universities based on the Times Higher Education World University Rankings (http://www.timeshighereducation.co.uk/world-university-rankings/). The Chemical Engineering Department of Zhejiang University also publishes two journals, including *Journal of Chemical Engineering of Chinese University* and *Chemical Reaction Engineering and Technology* (http://che.zju.edu.cn/english/redir.php?catalog_id=36760). Although Tianjin University and East China University of Science and Technology were not as famous as Tsinghua University and Zhejiang University in China, they performed well in the field of chemical engineering due to China's national discipline of college restructuring in 1952. According to the discipline, the Department of Chemical Engineering at Tianjin University was created by combing several chemical engineering departments from the most respected universities in North China, including Beiyang University, Nankai University, Yanjing University, Furen University, Peking University, Tsinghua University, Hebei Technology College, and Tangshan Railroad College in 1952 (http://chemeng.tju.edu.cn/en/NavContent.aspx?HCID=100039). East China University of Science and Technology, originally named East China Institute of Chemical Technology, was also founded in 1952 and consolidated by the chemistry departments of National Chiaotung University, Université d'Aurora, Utopia University, Soochow University, and Yangtze University (http://www.scut.edu.cn/).

A ratio of institutional independent (single institution) articles: nationally collaborative articles: internationally collaborative articles (S:N:I) might be used to describe institutions or authors publication characteristics. China's ratio of S:N:I is 58:25:17 in the Web of Science category of chemical engineering. It indicated that China's research in chemical engineering field had more national teamwork or collaboration among different institutions than international collaborations among different countries. The Tsinghua University's ratio of S:N:I is 59:23:18, which is different from the Chinese Academy of Sciences as 49:37:14. Thirteen universities in Table 3 had at least 50 % institutional independent articles of their total publications. The Tianjin University was more inclined or able to conduct research independently with S:N:I = 64:27:9.4. The Hong Kong University Science and Technology was the only one that had more international than national collaborations with S:N:I = 51:22:27. This ratio could show three important rates related with college collaboration, which was more comprehensively and visually than just one traditional collaboration rate at a time for measurement and comparison.

Research emphases and trends

Article titles and abstracts

Usually the main subjects of articles were expressed in the titles (Baskerville 1904). The title has important functions such as clarifying the matter to be discussed in the text, drawing the readers' attention, motivating further reading, etc. (Imbelloni 2012). It was noticed that features of article titles could help to predict the number of article's citation counts (Paiva et al. 2012). Recently, distribution of words in article titles of different periods was applied in mapping research trends in aerosols (Xie et al. 2008) and volatile organic compounds (Zhang et al. 2010). In this study, all single words within the title of

Table 3 Top 20 most productive universities during 1992–2011

University	TA (%)	IA (%)	NCA (%)	ICA (%)	SAR (SP)	FAR (%)	RAR (%)
Tsinghua University	1,913 (4.4)	1,125 (59)	442 (23)	346 (18)	1 (25)	1 (2.3)	1 (2.3)
Zhejiang University	1,675 (6.4)	1,013 (60)	447 (27)	215 (13)	3 (15)	2 (5.5)	2 (5.5)
Tianjin University	1,543 (5.9)	981 (64)	417 (27)	145 (9.4)	5 (12)	3 (5.2)	3 (5.2)
East China University of Science and Technology	1,290 (4.9)	750 (58)	347 (27)	193 (15)	12 (7.0)	4 (4.1)	4 (4.1)
Dalian University of Technology	922 (3.5)	480 (52)	311 (34)	131 (14)	17 (5.0)	5 (2.9)	5 (2.9)
Beijing University of Chemical Technology	848 (3.2)	507 (60)	230 (27)	111 (13)	40 (2.0)	6 (2.8)	6 (2.8)
Shanghai Jiao Tong University	680 (2.6)	373 (55)	229 (34)	78 (11)	40 (2.0)	7 (2.2)	7 (2.2)
South China University of Technology	558 (2.1)	239 (43)	199 (36)	120 (22)	4 (14)	10 (1.5)	9 (1.5)
China University of Petroleum	523 (2.0)	251 (48)	191 (37)	81 (15)	19 (4.0)	8 (1.6)	8 (1.6)
Hong Kong University Science and Technology	521 (2.0)	268 (51)	113 (22)	140 (27)	8 (10)	9 (1.5)	10 (1.5)
Sichuan University	465 (1.8)	278 (60)	140 (30)	47 (10)	76 (1.0)	11 (1.5)	11 (1.5)
University of Science and Technology of China	444 (1.7)	217 (49)	154 (35)	73 (16)	19 (4.0)	12 (1.3)	12 (1.3)
Harbin Institute of Technology	423 (1.6)	145 (34)	178 (42)	100 (24)	26 (3.0)	13 (1.2)	13 (1.2)
Nanjing University of Technology	363 (1.4)	222 (61)	93 (26)	48 (13)	26 (3.0)	14 (1.2)	14 (1.2)
Huazhong University of Science and Technology	320 (1.2)	144 (45)	90 (28)	86 (27)	N/A	18 (0.85)	17 (0.87)
Nanjing University	312 (1.2)	125 (40)	165 (53)	22 (7.1)	76 (1)	16 (0.87)	18 (0.86)
Xiamen University	294 (1.1)	150 (51)	94 (32)	50 (17)	76 (1.0)	19 (0.85)	19 (0.86)
Hong Kong Polytechnic University	288 (1.1)	143 (50)	101 (35)	44 (15)	8 (10)	17 (0.87)	16 (0.88)
Southeast University	277 (1.1)	164 (59)	88 (32)	25 (9.0)	76 (1.0)	15 (0.92)	15 (0.93)
Fudan University	265 (1.0)	106 (40)	107 (40)	52 (20)	76 (1.0)	22 (0.75)	22 (0.73)

TA total number of articles, *IA* institutional independent articles, *NCA* nationally collaborative articles, *ICA* internationally collaborative articles, *SA* single author articles, *SAR* single author article rank, *FAR* first author article rank, *RAR* corresponding author article rank, *N/A* not available articles were statistically analyzed. Some prepositions and common words such as "using", "of", "the", and "during" were discarded, as they were meaningless for further analysis. The 25 most frequently used substantives in titles were grouped into ten two-year periods (Table 4). "Synthesis" ranked first which was found in 1,983 article titles. Words related to catalysis including "catalytic" and "catalysts" were also frequently used. "Acid", "carbon", "oxidation", "aqueous", "production", "novel", and "removal" showed a notable increasing trend in titles, while the terms "model" showed a decreasing trend.

To figure out China's most prolific centers according to different topics, the top four institutions for each of these 25 most frequently used words in titles are presented in Table 5. The ranks of top four institutions changed when cataloged by different words. As expected, CAS dominated all these words except "model". CAS contributed the most to "catalysts" with a percentage of 26. The No. 1 institution THU by the total articles in Table 3 ranked 2nd for five words including "model", "oxidation", "gas", "removal", and "flow". No. 2 ZJU had one word of "model" in the 1st position and four words including "process", "water", "aqueous", and "system" in the 2nd position. TJU with the third position in Table 3 was active in many hot issues, ranking 2nd for nine words including "membranes", "catalyst", "catalytic", "catalysts", "preparation", "acid", "surface", "adsorption", and "method". The No. 4 institution ECUST, which ranked 2nd for "synthesis", "properties", and "production". Different institutions might have their different research focuses.

Distribution of words in article abstracts of different periods could also be the information of research trend analysis (Zhang et al. 2010). In our study, results from analysis of words in article abstracts showed that "temperature", "method", "process", "model", "reaction", "surface", "conditions", "concentration", "rate", "degrees", "time", "activity", "system", "water", "solution", "catalyst", "properties", "acid", "ratio", "structure", "phase", "pressure", "gas", "chemical", "paper", and "catalytic" appeared in at least 3,000 article abstracts.

Author keywords

Authors gave author keywords in articles. The author keywords of an article usually include the information authors would most likely to express to their readers. Using author keywords analysis as the information to find research focus has been recently developed (Chiu and Ho 2007). Distribution of author keywords in different periods was further applied to analyze research trends (Xie et al. 2008). Altogether 39,794 author keywords were used in 20,171 articles. Table 6 shows the 26 most frequently used author keywords with their rankings and percentages. The top seven author keywords in 1992–1993 were "theory", "liquid liquid equilibria", "immobilization", "solvent extraction", "turbulence", "vapor pressure", and "systems engineering", while in the latest sub-period of 2009–2011, "adsorption", "kinetics", "photocatalysis", "optimization", "synthesis", "simulation", and "biodiesel" ranked in the top seven author keywords. Hot issues changed a lot during the study period. "Photocatalysis" and "ionic liquid" might be new hot topics in the future in China since both of them did not appear in 1992–1999, but ranked 3rd and 11th in 2009–2011 respectively. The two most frequently used keywords were "adsorption" and "kinetics", which are also the most important topics in water resources research (Wang et al. 2011).

China's four most prolific centers by top 26 author keywords are revealed in Table 7. CAS kept its superiority by leading in 22 author keywords except "optimization",

Table 4 Top 25 most frequently used substantives in article titles during 1992–2011 and ten two-year periods

Words in title	TA	1992–2011 *R* (%)	1992–1993 *R* (%)	1994–1995 *R* (%)	1996–1997 *R* (%)	1998–1999 *R* (%)	2000–2001 *R* (%)	2002–2003 *R* (%)	2004–2005 *R* (%)	2006–2007 *R* (%)	2008–2009 *R* (%)	2010–2011 *R* (%)
Synthesis	1,983	1 (7.6)	9 (3.8)	1 (6.6)	16 (3.3)	2 (5.8)	1 (6.8)	2 (8.0)	2 (7.9)	1 (8.3)	1 (8.1)	1 (7.4)
Catalyst	1,524	2 (5.8)	3 (5.5)	20 (2.4)	36 (2.6)	45 (2.1)	2 (6.4)	1 (9.3)	1 (7.9)	3 (6.1)	4 (5.8)	6 (4.9)
Properties	1,484	3 (5.7)	6 (4.6)	1 (6.6)	2 (6.0)	3 (5.3)	5 (4.6)	5 (5.1)	6 (4.8)	5 (5.6)	3 (5.9)	2 (6.1)
Preparation	1,455	4 (5.6)	12 (3.4)	39 (1.8)	50 (2.1)	22 (2.7)	13 (3.5)	4 (5.7)	4 (5.4)	2 (6.5)	2 (6.0)	3 (5.8)
Catalytic	1,440	5 (5.5)	17 (3.0)	6 (4.2)	45 (2.3)	13 (3.4)	9 (4.0)	3 (7.5)	3 (6.6)	4 (5.6)	5 (5.5)	5 (5.4)
Acid	1,319	6 (5.0)	136 (0.84)	31 (2.1)	9 (3.9)	11 (3.9)	6 (4.5)	5 (5.1)	5 (5.1)	7 (4.7)	6 (5.4)	4 (5.4)
Membrane	1,175	7 (4.5)	23 (2.5)	8 (3.9)	6 (4.2)	12 (3.7)	7 (4.1)	10 (3.6)	9 (4.0)	6 (5.2)	7 (5.1)	12 (4.2)
Catalysts	1,091	8 (4.2)	1 (8.9)	14 (3.0)	12 (3.7)	15 (3.2)	4 (5.0)	8 (4.0)	13 (3.7)	12 (3.9)	8 (4.5)	13 (4.1)
Process	1,050	9 (4.0)	36 (2.1)	16 (2.7)	45 (2.3)	15 (3.2)	20 (2.9)	11 (3.5)	7 (4.3)	9 (4.2)	12 (4.0)	10 (4.4)
Water	1,048	10 (4.0)	N/A	54 (1.5)	6 (4.2)	13 (3.4)	23 (2.7)	11 (3.5)	8 (4.2)	10 (4.1)	10 (4.1)	11 (4.3)
Carbon	1,046	11 (4.0)	48 (1.7)	111 (0.9)	12 (3.7)	45 (2.1)	18 (2.9)	14 (3.4)	10 (4.0)	13 (3.9)	11 (4.1)	8 (4.6)
Characterization	983	12 (3.8)	23 (2.5)	39 (1.8)	54 (1.9)	22 (2.7)	20 (2.9)	19 (3.0)	15 (3.5)	13 (3.9)	9 (4.3)	15 (3.9)
Adsorption	969	13 (3.7)	5 (5.1)	39 (1.8)	29 (2.8)	29 (2.6)	12 (3.7)	17 (3.3)	12 (3.8)	18 (3.1)	20 (3.2)	7 (4.6)
Oxidation	965	14 (3.7)	36 (2.1)	111 (0.9)	107 (1.2)	31 (2.4)	10 (3.8)	7 (4.5)	11 (4.0)	11 (4.1)	15 (3.5)	16 (3.7)
System	885	15 (3.4)	84 (1.3)	14 (3.0)	19 (3.2)	9 (4.0)	15 (3.2)	11 (3.5)	14 (3.6)	15 (3.5)	18 (3.2)	20 (3.4)
Membranes	873	16 (3.3)	23 (2.5)	54 (1.5)	29 (2.8)	22 (2.7)	34 (2.3)	27 (2.6)	27 (2.6)	8 (4.3)	14 (3.7)	21 (3.3)
Model	870	17 (3.3)	3 (5.5)	3 (5.4)	1 (6.7)	1 (5.9)	3 (5.8)	9 (3.9)	17 (3.3)	16 (3.3)	23 (2.9)	35 (2.5)
Aqueous	862	18 (3.3)	N/A	39 (1.8)	29 (2.8)	6 (4.3)	28 (2.5)	39 (2.1)	25 (2.7)	27 (2.6)	21 (3.1)	9 (4.5)
Production	842	19 (3.2)	N/A	39 (1.8)	189 (0.7)	6 (4.3)	48 (1.9)	27 (2.6)	20 (3.1)	19 (3.1)	13 (3.8)	19 (3.4)
Novel	812	20 (3.1)	N/A	111 (0.9)	61 (1.8)	70 (1.5)	34 (2.3)	44 (2.0)	20 (3.1)	17 (3.2)	16 (3.4)	18 (3.6)
Gas	805	21 (3.1)	136 (0.84)	39 (1.8)	19 (3.2)	9 (4.0)	24 (2.6)	18 (3.2)	16 (3.4)	22 (2.9)	23 (2.9)	22 (3.3)
Removal	772	22 (2.9)	84 (1.3)	111 (0.9)	125 (1.1)	70 (1.5)	66 (1.6)	54 (1.8)	26 (2.7)	29 (2.4)	18 (3.2)	14 (4.0)
Method	758	23 (2.9)	2 (5.9)	11 (3.6)	19 (3.2)	53 (1.9)	38 (2.2)	36 (2.2)	28 (2.5)	20 (3.1)	17 (3.4)	26 (2.8)
Flow	751	24 (2.9)	23 (2.5)	5 (4.8)	3 (5.1)	8 (4.1)	8 (4.1)	14 (3.4)	17 (3.3)	34 (2.3)	25 (2.8)	37 (2.4)
Surface	731	25 (2.8)	23 (2.5)	20 (2.4)	16 (3.3)	63 (1.7)	32 (2.5)	20 (2.9)	24 (2.7)	22 (2.9)	22 (2.9)	25 (2.8)

TA total number of articles, *R (%)* rank and percentage of substantives in titles in total articles, *N/A* not available

Table 5 Top four institutions for the 25 most frequently used words in title during 1992–2011

Words in title	Rank 1 (%)	Rank 2 (%)	Rank 3 (%)	Rank 4 (%)
Synthesis	CAS (20)	ECUST (6.1)	DLUT (6.0)	TJU (4.7)
Catalyst	CAS (24)	TJU (8.0)	ECUST (4.9)	ZJU (3.5)
Properties	CAS (14)	ECUST (5.1)	ZJU (5.0)	DLUT (4.7)
Preparation	CAS (12)	TJU (6.5)	ZJU (5.2)	DLUT (4.3)
Catalytic	CAS (20)	TJU (5.3)	ECUST (5.3)	ZJU (4.8)
Acid	CAS (14)	TJU (7.1)	ZJU (6.9)	ECUST (6.3)
Membrane	CAS (13)	DLUT (7.2)	TJU (6.6)	ZJU (5.4)
Catalysts	CAS (26)	TJU (6.3)	DLUT (4.4)	NJU (3.9)
Process	CAS (11)	ZJU (10)	TJU (6.4)	THU (5.8)
Water	CAS (11)	ZJU (10)	THU (6.6)	TJU (6.1)
Carbon	CAS (16)	ECUST (7.0)	THU (6.3)	TJU (5.8)
Characterization	CAS (16)	DLUT (5.2)	TJU (4.6)	ZJU (4.5)
Adsorption	CAS (13)	TJU (7.4)	ZJU (5.9)	NJU (5.4)
Oxidation	CAS (20)	THU (6.7)	TJU (5.9)	ZJU (5.7)
System	CAS (15)	ZJU (8.8)	TJU (5.8)	ECUST (5.0)
Membranes	CAS (14)	TJU (13)	ZJU (9.4)	NJU (7.1)
Model	ZJU (10)	THU (10)	CAS (9.2)	ECUST (7.7)
Aqueous	CAS (13)	ZJU (8.1)	THU (5.3)	ECUST (4.6)
Production	CAS (17)	ECUST (7.1)	ZJU (6.2)	TJU (5.1)
Novel	CAS (13)	DLUT (6.9)	ECUST (6.2)	ZJU (5.7)
Gas	CAS (16)	THU (10)	CUP (7.0)	ZJU (5.8)
Removal	CAS (13)	THU (6.9)	ECUST (5.6)	HBIT (4.7)
Method	CAS (10)	TJU (9.5)	ZJU (8.6)	ECUST (4.7)
Flow	CAS (15)	THU (10)	TJU (9.2)	ZJU (6.0)
Surface	CAS (14)	TJU (7.1)	THU (6.7)	ZJU (5.1)

% percentage for the number of articles by one institution to total articles for each words in title, *CAS* Chinese Academy of Sciences, *THU* Tsinghua University, *TJU* Tianjin University, *ZJU* Zhejiang University, *ECUST* East China University of Science and Technology, *DLUT* Dalian University of Technology, *NJU* Nanjing University, *CUP* China University of Petroleum, *HBIT* Harbin Institute of Technology

"pervaporation", "modeling", and "mass transfer". It is noticeable that ZJU surpassed CAS and took the lead for "optimization", and "modeling". THU contributed the most to "mass transfer", and contributed the second to "separation", "numerical simulation", "oxidation", "optimization", and "methane". TJU ranked second in 17 author keywords including "separation" "numerical simulation", "oxidation", "optimization", "methane", "palladium", "methanol", "simulation", "modeling", "silica", "carbon dioxide", "adsorption", "phenol", "nickel", "titania", "mechanism", and "supported catalyst". The No. 4 institution ECUST ranked No. 2 in three words including "synthesis", "photocatalysis" and "kinetics". In particular, some institutions did not have high positions in total publications in Table 3, while ranked No. 1 by certain author keywords such as FDU led "hydrogenation", and HKUST dominated "activated carbon". It is interesting that SINOPEC (also called China Petroleum & Chemical Corporation), a Chinese oil and gas company based in Beijing, contributed a lot to chemical engineering research related to alumina and nickel.

Table 6 Top 26 most frequently used author keywords used during 1992–2011 and ten two-year periods

Author keywords	TP	1992–2011 *R* (%)	1992–1993 *R* (%)	1994–1995 *R* (%)	1996–1997 *R* (%)	1998–1999 *R* (%)	2000–2001 *R* (%)	2002–2003 *R* (%)	2004–2005 *R* (%)	2006–2007 *R* (%)	2008–2009 *R* (%)	2010–2011 *R* (%)
Adsorption	663	1 (3.3)	N/A	35 (1.1)	4 (1.8)	27 (0.75)	1 (2.6)	2 (2.9)	1 (3.4)	1 (2.5)	1 (2.9)	1 (4.5)
Kinetics	400	2 (2.0)	N/A	104 (0.55)	15 (1.2)	6 (1.9)	6 (1.8)	5 (2.1)	4 (2.1)	3 (1.7)	2 (1.7)	2 (2.4)
Supported catalyst	320	3 (1.6)	N/A	N/A	N/A	N/A	1 (2.6)	1 (4.7)	2 (3.3)	2 (2.1)	13 (0.88)	28 (0.65)
Synthesis	271	4 (1.3)	N/A	N/A	15 (1.2)	2 (2.4)	8 (1.5)	10 (1.5)	7 (1.6)	5 (1.4)	3 (1.4)	5 (1.1)
Methane	254	5 (1.3)	8 (2.0)	N/A	165 (0.30)	27 (0.75)	5 (1.9)	3 (2.7)	5 (2.0)	9 (1.2)	6 (1.2)	14 (0.81)
Alumina	242	6 (1.2)	N/A	N/A	N/A	282 (0.19)	4 (2.1)	4 (2.5)	3 (2.7)	7 (1.2)	17 (0.82)	18 (0.70)
Photocatalysis	228	7 (1.1)	N/A	N/A	N/A	N/A	24 (0.94)	47 (0.75)	18 (1.1)	7 (1.2)	11 (0.92)	3 (1.5)
Simulation	212	8 (1.1)	N/A	35 (1.1)	165 (0.30)	19 (0.94)	24 (0.94)	26 (1.0)	16 (1.2)	12 (1.1)	8 (1.0)	6 (1.1)
Optimization	211	9 (1.0)	N/A	104 (0.55)	165 (0.3)	103 (0.38)	77 (0.52)	38 (0.89)	14 (1.3)	14 (1.1)	7 (1.1)	4 (1.2)
Pervaporation	208	10 (1.0)	N/A	N/A	4 (1.8)	13 (1.1)	10 (1.4)	41 (0.82)	32 (0.79)	6 (1.3)	4 (1.2)	11 (0.84)
Titania	205	11 (1.0)	N/A	N/A	N/A	282 (0.19)	3 (2.2)	8 (1.6)	6 (1.8)	4 (1.4)	36 (0.67)	35 (0.62)
Numerical simulation	203	12 (1.0)	8 (2.0)	N/A	3 (2.1)	47 (0.56)	53 (0.63)	20 (1.2)	8 (1.5)	26 (0.91)	8 (1.0)	9 (0.89)
Carbon dioxide	198	13 (1.0)	N/A	104 (0.55)	23 (0.90)	103 (0.38)	8 (1.5)	14 (1.4)	17 (1.2)	9 (1.2)	23 (0.73)	8 (0.90)
Hydrogenation	189	14 (0.94)	8 (2.0)	104 (0.55)	N/A	282 (0.19)	24 (0.94)	7 (1.6)	14 (1.3)	14 (1.1)	10 (0.95)	18 (0.70)
Oxidation	186	15 (0.92)	N/A	N/A	N/A	9 (1.5)	13 (1.1)	13 (1.4)	20 (1.1)	22 (0.94)	12 (0.9)	16 (0.76)
Modeling	183	16 (0.91)	8 (2.0)	18 (1.7)	54 (0.6)	1 (2.8)	24 (0.94)	23 (1.2)	23 (0.93)	17 (1.0)	17 (0.82)	25 (0.66)
Mass transfer	180	17 (0.89)	N/A	18 (1.7)	4 (1.8)	13 (1.1)	18 (1.0)	55 (0.68)	13 (1.3)	29 (0.79)	13 (0.88)	17 (0.74)
Palladium	176	18 (0.87)	8 (2.0)	104 (0.55)	54 (0.6)	282 (0.19)	18 (1.0)	16 (1.3)	9 (1.4)	27 (0.88)	16 (0.84)	28 (0.65)
Separation	168	19 (0.83)	N/A	11 (2.2)	8 (1.5)	47 (0.56)	18 (1.0)	26 (1.0)	32 (0.79)	12 (1.1)	32 (0.69)	21 (0.68)
Methanol	167	20 (0.83)	N/A	104 (0.55)	165 (0.30)	282 (0.19)	32 (0.84)	10 (1.5)	18 (1.1)	20 (1.0)	23 (0.73)	25 (0.66)
Ionic liquid	167	20 (0.83)	N/A	N/A	N/A	N/A	578 (0.10)	280 (0.21)	48 (0.66)	11 (1.1)	4 (1.2)	11 (0.84)
Nickel	162	22 (0.80)	N/A	N/A	165 (0.3)	282 (0.19)	12 (1.3)	8 (1.6)	28 (0.84)	20 (1.0)	27 (0.71)	33 (0.63)
Silica	154	23 (0.76)	N/A	104 (0.55)	N/A	N/A	32 (0.84)	5 (2.1)	10 (1.4)	17 (1.0)	79 (0.43)	64 (0.44)

Table 6 continued

Author keywords	TP	1992–2011 *R* (%)	1992–1993 *R* (%)	1994–1995 *R* (%)	1996–1997 *R* (%)	1998–1999 *R* (%)	2000–2001 *R* (%)	2002–2003 *R* (%)	2004–2005 *R* (%)	2006–2007 *R* (%)	2008–2009 *R* (%)	2010–2011 *R* (%)
Phenol	153	24 (0.76)	N/A	N/A	165 (0.3)	282 (0.19)	41 (0.73)	16 (1.3)	28 (0.84)	14 (1.1)	45 (0.58)	21 (0.68)
Activated carbon	150	25 (0.74)	N/A	N/A	N/A	282 (0.19)	53 (0.63)	47 (0.75)	21 (1.0)	36 (0.70)	19 (0.80)	15 (0.77)
Mechanism	150	25 (0.74)	N/A	35 (1.1)	54 (0.60)	N/A	32 (0.84)	33 (1.0)	70 (0.53)	33 (0.73)	21 (0.75)	13 (0.82)

TA total number of articles, *R (%)* rank and percentage of author keywords in total articles, *N/A* not available

Table 7 Top four institutions for the 25 most frequently used author keywords during 1992–2011

Author keywords	Rank 1 (%)	Rank 2 (%)	Rank 3 (%)	Rank 4 (%)
Adsorption	CAS (14)	TJU (5.3)	HKUST (5.0)	ZJU (4.1)
Kinetics	CAS (13)	ECUST (9.0)	ZJU (8.5)	TJU (6.5)
Supported catalyst	CAS (26)	TJU (9.4)	ZJUT (5.6)	ECUST (4.4)
Synthesis	CAS (11)	ECUST (11)	DLUT (10)	ZJU (5.2)
Methane	CAS (30)	THU (9.4)	TJU (8.7)	BJUCT (5.9)
Alumina	CAS (27)	SINOPEC (8.3)	SCU (8.3)	TJU (5.4)
Photocatalysis	CAS (15)	ECUST (4.8)	TJU (4.8)	FZU (4.4)
Simulation	CAS (15)	TJU (11)	ZJU (10)	THU (8.5)
Optimization	ZJU (11)	THU (7.6)	ECUST (5.7)	CAS (5.2)
Pervaporation	TJU (18)	CAS (16)	ZJU (12)	THU (12)
Titania	CAS (18)	TJU (9.3)	ECUST (5.4)	FZU (3.9)
Numerical simulation	CAS (21)	THU (13)	ZJU (11)	HBIT (9.4)
Carbon dioxide	CAS (17)	TJU (15)	THU (11)	BJUCT (6.6)
Hydrogenation	CAS (20)	FDU (12)	TJU (10)	SHNU (7.4)
Oxidation	CAS (21)	THU (5.9)	TJU (5.9)	ECUST (5.4)
Modeling	ZJU (12)	TJU (12)	THU (11)	CAS (9.3)
Mass transfer	THU (18)	CAS (18)	TJU (17)	BJUCT (8.3)
Palladium	CAS (27)	TJU (10)	SCU (6.8)	ZJU (5.7)
Separation	CAS (13)	THU (11)	ZJU (7.1)	TJU (7.1)
Methanol	CAS (23)	TJU (10)	THU (7.8)	ECUST (7.2)
Ionic liquid	CAS (27)	ECNU (6.6)	BJUCT (6.6)	ZJU (5.4)
Nickel	CAS (17)	TJU (8.0)	SCU (7.4)	SINOPEC (5.6)
Silica	CAS (27)	TJU (13)	XMU (8.4)	DLUT (7.1)
Phenol	CAS (14)	TJU (7.2)	DLUT (6.5)	NJUT (5.2)
Activated carbon	CAS (13)	HKUST (10)	ZJUT(6.0)	ECUST (6.0)
Mechanism	CAS (15)	TJU (9.3)	ZJU (7.3)	THU (7.3)

% percentage for the number of articles by one institution to total articles for each author keywords, *CAS* Chinese Academy of Sciences, *THU* Tsinghua University, *TJU* Tianjin University, *ZJU* Zhejiang University, *ECUST* East China University of Science and Technology, *DLUT* Dalian University of Technology, *NJU* Nanjing University, *HBIT* Harbin Institute of Technology, *HKUST* Hong Kong University of Science & Technology, *ZJUT* Zhejiang University of Technology, *FZU* Fuzhou University, *NJUT* Nanjing University of Technology, *XMU* Xiamen University, *ECNU* East China Normal University, *BJUCT* Beijing University of Chemical Technology, *FDU* Fudan University, *SHNU* Shanghai Normal University, *SINOPEC* China Petroleum & Chemical Corporation

KeyWords plus

KeyWords Plus provides search terms extracted from the titles of articles cited by authors in their bibliographies and footnotes in the ISI database, and substantially augments title-word and author-keyword indexing (Garfield 1990). Distribution of *KeyWords Plus* in different periods has been used to provide further information for research trends (Xie et al. 2008). The analysis of *KeyWords Plus* shows that 29,017 *KeyWords Plus* were used in 23,239 articles. Similar to the results of author keyword analysis, “adsorption”, “kinetics”, “oxidation”, “separation”, and “mechanism” were also hot spots in *KeyWords Plus* analysis. The top ten most frequently used *KeyWords Plus* were “water” (1,326 articles), “performance” (1,120), "adsorption" (940), "kinetics" (908), "oxidation" (898), "removal" (887), "model" (833), "separation" (825), "behavior" (791), and "systems" (718). Some new research focuses could also be found. "Nanoparticles" was never used in 1992–1999, while ranked 10th in 2009–2011. China's nanotechnology publication activity has grown exponentially at an annual increasing rate of nearly 20 % from 2000 to 2009 (Ye et al. 2012). The publication output has already surpassed the USA since 2009 (Kostoff 2012). "Degradation" and "wastewater" did not appear in 1992–1995, while ranked 12th and 16th in 2009–2011. Furthermore, there was no article with "acid" in *KeyWords Plus* in 1992–1993, while it ranked 19th in 2009–2011. The 60th position "removal", "temperature", "oxidation", and "model" in 1992–1993 raised to 3rd, 7th, 6th, and 11th during 2007–2011.

Most cited articles

The most frequently cited articles are proved to be the pioneers of research for the publication of these papers worked as the watershed of research history and created lots of follow-on papers (Schwartz et al. 2005). Article history has been investigated by the percentage of cited papers (Chiu and Ho 2005) and the citations of per article versus time (Li and Ho 2008). The number of citations versus time was also presented for article life (Chiu and Ho 2007). The top seven most frequently cited articles were cited for more than 300 times from Web of Science updated on 25 July 2012. The citation histories of these seven articles are shown in Fig. 2. Six were China's independent articles and only one was collaborated with Germany. Two top-cited articles were published in *Journal of Catalysis*. Most articles had overall increasing citations after their publications. The most frequently

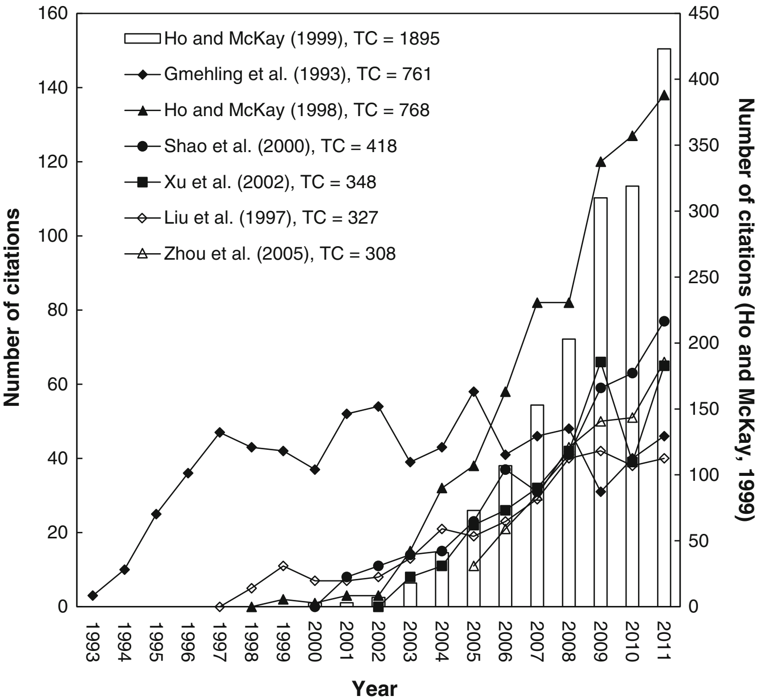

Fig. 2 Citation history of the most frequently cited articles (TC >300) during 1992–2011

cited China's research article with 1,895 citations was "Pseudo-second order model for sorption processes" published in *Process Biochemistry* by Ho and McKay from the Hong Kong University Science and Technology in 1999. The citations of the most frequently cited article (Ho and McKay 1999) continued sharply increasing recently and reached 423 times in 2011. This article also ranked NO. 1 in the annual citations from 2008 to 2011, and ranked 9th in the chemical engineering field all around the world (Ho 2012). It is still in a leading position to influence current research in chemical engineering. The pseudo-second order model has been widely accepted and applied in adsorption studies (Ho 2005). The second most cited article "Sorption of dye from aqueous solution by peat" (Ho and McKay 1998) with 768 citations was published in *Chemical Engineering Journal* by the same authors from Hong Kong University Science and Technology. These two articles focused on "adsorption" and "kinetics", which is consistent with the results of author keywords and previous research (Zhu et al. 2011). Another article with more than 500 citations, "A modified UNIFAC model. 2 present parameter matrix and results for different thermodynamic properties" (Gmehling et al. 1993), was contributed by Gmehling and Schiller of Universität Oldenburg and Li of Tsinghua University which was published in *Industrial & Engineering Chemistry Research*. Three classic articles were related with catalysts, which ranked No. 2 in the analysis of title words, included the article published by Gmehling et al. (1993) with 761 citations; "the preparation, characterization, and their photocatalytic activities of rare-earth-doped TiO_2 nanoparticles" with 348 citations in *Journal of Catalysis* (Xu et al. 2002); and "enhanced catalytic activity of ceria nanorods from well-defined reactive crystal planes" with 308 citations in *Journal of Catalysis* (Zhou et al. 2005). In particular, two articles by Xu et al. (2002) and Zhou et al. (2005) about nanoparticles appeared to be the emerging research focus by *KeyWords Plus* analysis.

Conclusions

Significant points on worldwide research performance from 1992 to 2011 were revealed, based on the publications of the authors with their affiliations in China in the Web of Science category of chemical engineering. The effort provided a systematic structural graph and clues to the impact of Chinese research on chemical engineering. China showed a rapidly ascending trend in the number of articles during the last 20 years. China's strong independent research ability was observed with the original ratio of single institution articles: nationally collaborative articles: internationally collaborative articles (S:N:I), equals 58:25:17. Except the Chinese Academy of Sciences, Tsinghua University, Zhejiang Unverisity, Tianjin University, East China University of Science and Technology hold well-performed chemical engineering departments, which were just the four branches of Chinese State Key Laboratory of Chemical Engineering. Results from distributions of article titles and abstracts, author keywords, and *KeyWords Plus* of different periods showed that adsorption, synthesis and catalyst were highly concerned by authors in China, especially adsorption. Pseudo-second order model for sorption processing and a modified UNIFAC model have been frequently cited since its publication and still has a strong influence.

References

Aksnes, D. W. (2003). Characteristics of highly cited papers. *Research Evaluation, 12*(3), 159–170.

An, K. S., & Huang, S. Y. (1980). Geothermal resources in China. *Revue de l Institut Francais du Petrole, 35*(3), 449–460.

Armstrong, R. C. (2007). The chemical engineering evolution: What comes next? *Chemical Engineering Progress, 103*(1), 33.

Arunachalam, S., Singh, U. N., & Sinha, R. (1993). The sleeping dragon wakes up: A scientometric analysis of the growth of science and the usage of journals in China. *Current Science, 65*(11), 809–822.

Baskerville, C. (1904). The titles of papers. *Science, 19*, 702.

Chang, T. L., & Huang, H. T. (1980). Determination of the overall distribution constant of deuterium in the GS process for heavy water production. *Separation Science and Technology, 15*(3), 397–403.

Chen, J. C. (2007). As we dig our heels into the 21st century. Where is the chemical engineering industry headed? *Chemical Engineering Progress, 103*(1), 26–29.

Chen, T. J., Chen, Y. C., Hwang, S. J., & Chou, L. F. (2006). The rise of China in gastroenterology? A bibliometric analysis of ISI and MEDLINE databases. *Scientometrics, 69*(3), 539–549.

Cheng, T. (2012). Research in orthopaedics from China has thrived over the last decade: A bibliometric analysis of publication activity. *Orthopaedics & Traumatology: Surgery & Research, 98*(3), 253–258.

Chiu, W. T., & Ho, Y. S. (2005). Bibliometric analysis of homeopathy research during the period of 1991 to 2003. *Scientometrics, 63*(1), 3–23.

Chiu, W. T., & Ho, Y. S. (2007). Bibliometric analysis of tsunami research. *Scientometrics, 73*(1), 3–17.

Cohen, C. (1996). The early history of chemical engineering: A reassessment. *British Journal for the History of Science, 29*(101), 171–194.

Fu, H. Z., Chuang, K. Y., Wang, M. H., & Ho, Y. S. (2011). Characteristics of research in China assessed with essential science indicators. *Scientometrics, 88*(3), 841–862.

Garfield, E. (1990). *KeyWords Plus*: ISI's breakthrough retrieval method. Part 1. Expanding your searching power on *Current Contents on Diskette*. *Current Contents, 32*, 5–9.

Gmehling, J., Li, J. D., & Schiller, M. (1993). A modified UNIFAC model. 2. Present parameter matrix and results for different thermodynamic properties. *Industrial and Engineering Chemistry Research, 32*(1), 178–193.

Guan, J. C., & Ma, N. (2007). A bibliometric study of China's semiconductor literature compared with other major Asian countries. *Scientometrics, 70*(1), 107–124.

Ho, Y. S. (2005). Comment on "Adsorption of naphthalene on zeolite from aqueous solution" by C. F. Chang, C. Y. Chang, K. H. Chen, W. T. Tsai, J. L. Shie, Y. H. Chen. *Journal of Colloid and Interface Science, 283*(1), 274–277.

Ho, Y. S. (2012). Top-cited articles in chemical engineering in Science Citation Index Expanded: A bibliometric analysis. *Chinese Journal of Chemical Engineering, 20*(3), 478–488.

Ho, Y. S., & McKay, G. (1998). Sorption of dye from aqueous solution by peat. *Chemical Engineering Journal, 70*(2), 115–124.

Ho, Y. S., & McKay, G. (1999). Pseudo-second order model for sorption processes. *Process Biochemistry, 34*(5), 451–465.

Imbelloni, L. E. (2012). Scientific articles' titles: Thanks for the information contained in your title. *Revista Brasileira de Anestesiologia, 62*(2), 140.

Jin, Y., & Cheng, Y. (2011). Chemical engineering in China: Past, present and future. *AIChE Journal, 57*(3), 552–560.

Kim, I. (2002). Chemical engineering: A rich and diverse history. *Chemical Engineering Progress, 98*(1), 2S–9S.

Kostoff, R. N. (2012). China/USA nanotechnology research output comparison—2011 update. *Technological Forecasting and Social Change, 79*(5), 986–990.

Leydesdorff, L., & Wagner, C. (2009). Is the United States losing ground in science? A global perspective on the world science system. *Scientometrics, 78*(1), 23–36.

Li, Z., & Ho, Y. S. (2008). Use of citation per publication as an indicator to evaluate contingent valuation research. *Scientometrics, 75*(1), 97–110.

Liu, T. X., Mo, Z. S., Wang, S. G., & Zhang, H. F. (1997). Nonisothermal melt and cold crystallization kinetics of poly (aryl ether ether ketone ketone). *Polymer Engineering & Science, 37*(3), 568–575.

Milman, B. L., & Gavrilova, Y. A. (1993). Analysis of citation and co-citation in chemical engineering. *Scientometrics, 27*(1), 53–74.

Modak, J. M., & Madras, G. (2008). Scientometric analysis of chemical engineering publications. *Current Science, 94*(10), 1265–1272.

Paiva, C. E., Lima, J. P. D. N., & Paiva, B. S. R. (2012). Articles with short titles describing the results are cited more often. *Clinics, 67*(5), 509–513.

Peters, H. P. F., & Van Raan, A. F. J. (1991). Structuring scientific activities by co-author analysis: An exercise on a university faculty level. *Scientometrics, 20*(1), 235–255.

Peters, H. P. F., & van Raan, A. F. J. (1993). Co-word-based science maps of chemical engineering. Part I: Representations by direct multidimensional scaling. *Research Policy, 22*(1), 23–45.

Peters, H. P. F., & van Raan, A. F. J. (1994). A bibliometric profile of top-scientists: A case study in chemical engineering. *Scientometrics, 29*(1), 115–136.

Schubert, A. (1998). The profile of the chemical engineering journal and biochemical engineering journal as reflected in its publications, references and citations, 1983–1996. *Chemical Engineering Journal, 69*(3), 151–156.

Schwartz, F. W., Fang, Y. C., & Parthasarathy, S. (2005). Patterns of evolution of research strands in the hydrologic sciences. *Hydrogeology Journal, 13*(1), 25–36.

Shama, G., Klaus, K., & Oppenheim, C. (2000). Citation footprint analysis Part I: UK and US chemical engineering academics. *Scientometrics, 49*(2), 289–305.

Shao, Z. P., Yang, W. S., Cong, Y., Dong, H., Tong, J. H., & Xiong, G. X. (2000). Investigation of the permeation behavior and stability of a $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ oxygen membrane. *Journal of Membrane Science, 172*(1–2), 177–188.

Tang, C. L. (1980). Two phase flow in a climbing-film evaporator. *Canadian Journal of Chemical Engineering, 58*(4), 425–430.

Wang, M. H., Li, J. F., & Ho, Y. S. (2011). Research articles published in water resources journals: A bibliometric analysis. *Desalination and Water Treatment, 28*(1–3), 353–365.

Xie, S. D., Zhang, J., & Ho, Y. S. (2008). Assessment of world aerosol research trends by bibliometric analysis. *Scientometrics, 77*(1), 113–130.

Xu, A. W., Gao, Y., & Liu, H. Q. (2002). The preparation, characterization, and their photocatalytic activities of rare-earth-doped TiO_2 nanoparticles. *Journal of Catalysis, 207*(2), 151–157.

Ye, X. T., Liu, Y., & Porter, A. L. (2012). International collaborative patterns in China's nanotechnology publications. *International Journal of Technology Management, 59*(3–4), 255–272.

Yin, C. Y. (2009). Bibliometric analysis of journal articles published by Southeast Asian chemical engineering researchers. *Malaysian Journal of Library & Information Science, 14*(3), 1–13.

Yuan, J. P., Yue, W. P., Su, C., Wu, Z., Ma, Z., Pan, Y. T., et al. (2010). Patent activity on water pollution and treatment in China: A scientometric perspective. *Scientometrics, 83*(3), 639–651.

Zhang, G. F., Xie, S. D., & Ho, Y. S. (2010). A bibliometric analysis of world volatile organic compounds research trends. *Scientometrics, 83*(2), 477–492.

Zhou, P., & Leydesdorff, L. (2009). Chemistry in China—a bibliometric view. *Chimica Oggi, 27*(6), 19–22.

Zhou, K. B., Wang, X., Sun, X. M., Peng, Q., & Li, Y. D. (2005). Enhanced catalytic activity of ceria nanorods from well-defined reactive crystal planes. *Journal of Catalysis, 229*(1), 206–212.

Zhu, X., & Chen, H. J. (1980). Tectonic evolution of Chinese petroleum basins. *Revue de l Institut Francais du Petrole, 35*(2), 223–230.

Zhu, Y. Q., Wang, M. H., & Ho, Y. S. (2011). An analysis of research activity in department of chemical engineering in USA. *Archives of Environmental Science, 5*, 62–70.

Zou, F., Wu, M. X., & Wu, K. L. (2009). Outcomes associated with ophthalmology, optometry and visual science literature in the Science Citation Index from mainland China, 2000–2007. *Scientometrics, 81*(3), 671–682.