Bibliometric Analysis of Oil and Gas Pipeline Safety

Shengli Liu, Ye Zhang, Huibin Liu, Xinyi Liu, Jiaming Wang, and Qingru Meng

Abstract The safety issue of oil and gas pipelines has attracted more attention. In this research, the bibliometric method has been applied to analyze the research hotspots and trends of oil and gas pipeline. Base on the Web of Science (WoS) Core collection database, a total of 2164 papers on pipeline safety published from 2004 to 2022 were collected. The distribution of research forces and the hotspots of pipeline safety study have been analyzed. The obviously increasing number of annual publications from 2004 to 2021 also indicates that the safety issues of pipeline transportation have attracted more and more attentions. Although China has obvious advantages in the total number of publications, total citations and h-index, the average number of citations per article published in China is less than most of rest in the top 12 most productive countries. In this study, the network visualization and cluster density visualization have been used to explore the research status and trends based on the database of Web of Science. Obviously, the main contents of pipeline safety research are divided into four clusters. In addition, the co-authorship of the collected papers has been studied to track the research dynamics of related institutions. The result shows that the international cooperation in the study related to pipeline safety is widespread from the perspective of the co-authorship of the paper.

Keywords Bibliometric analysis · Oil and gas pipeline · Safety

1 Introduction

As we all know, oil and gas play important roles in the global energy market with the development of economy. Hence, the safety of oil and gas pipeline, which is main facility for oil and gas supply, has attracted more and more concerns. A lot

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S. Li (ed.), *Computational and Experimental Simulations in Engineering*, Mechanisms and Machine Science 146, https://doi.org/10.1007/978-3-031-44947-5_90

of researches related to the safety management of oil and gas pipeline have been carried out by domestic and foreign scholars since twenty-first century. These studies associated with oil and gas pipeline accidents focus on the consequence analysis [1-7], failure probability analysis [8–13] and the leakage detect analysis [14]. Due to the huge literature data information, it is difficult to systematically summarize these results with traditional methods. Fortunately, with the advent of Citespace, HistCite and VOS viewer [15], the visual analysis of massive literature materials has become a reality. The bibliometric analysis can visually display complex data information and solve the problem that the required information cannot be obtained quickly and accurately due to the large amount of data. As suggested by the previous researchers, these software have been used to analyze the safety of LNG supply chain [16], the supply chain analytical techniques [17], hydrogen storage [18], and the development of safety science [19]. In this research, the massive relevant literatures on oil and gas pipeline safety have been analyzed to explore research hotspots and trends with the help of the visualization of similarity (VOS) viewer.

2 Materials and Methods

In this study, the Web of Science (WoS) Core collection database has been used to analyze the safety issues of oil and gas pipelines. The keyword used to collect the related research papers is "pipeline safety" AND "oil or gas or hydrogen or CO_2". The document types included are articles, proceeding papers and review. The used database is updated on January 10, 2022. A total of 2164 papers on pipeline safety published from 2004 to 2022 were collected from the database of WoS. To be more concise, the most influential documents and the most productive authors have been analyzed by the visualization of similarity (VOS) viewer.

3 Results and Discussion

3.1 Overview of Publications on Pipeline Safety

As shown in Fig. 1, the most productive year is the year 2021, which witnesses 1515 authors and 405 articles. In addition, the obviously increasing number of annual publications from 2004 to 2021 also indicates that the safety issues of pipeline transportation have attracted more and more attentions. There were relatively few published researches focused on pipeline safety before 2011. In this period, only 70 research institutions related to this issue annually and no more than 40 articles were published each year. It indicates that the study concentrated on pipeline safety in the energy delivery industry has just begun and not gain enough attention from researchers. From 2012 to 2021, the number of authors has grown rapidly, and its growth rate is

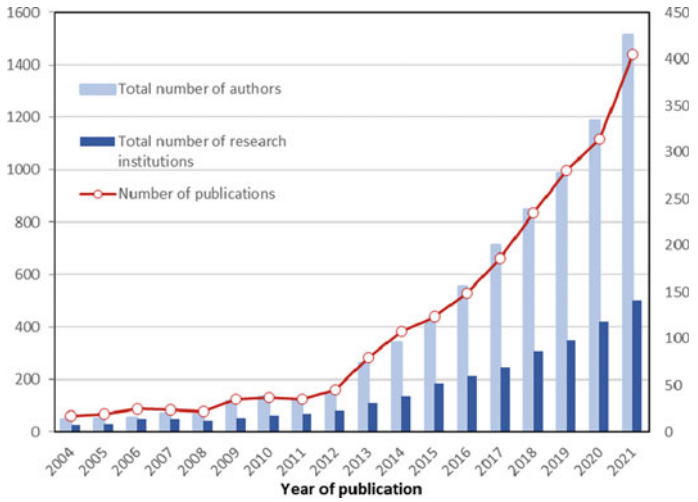


Fig. 1 Histogram of the number of authors, research institutions and publications related to pipeline safety

close to exponential. To be concrete, the annual growth rate of authors in 2014(341) to 2015 (421) was as high as 23.5%. In addition, the number of researchers studied pipeline safety exceeded 1000 and reached 1515 in 2021. During this period, the number of annual citations was 2047, and the total number of research institutions related to pipeline safety increased to 500. The reason for this rapid growth is the promulgation and implementation of pipeline safety regulations in different countries around the world. For example, in the United States, 2012 Pipeline Safety Act has requested the pipeline managers to take relative measures to improve the integrity of the total transmission pipeline systems. Obviously, the research results are very important in the pipeline safety study. More and more papers have been published due to the fact that this issue has attracted increasing attentions in the worldwide in the recent years.

3.2 Distributions of Research Forces

As we can see in the Table 1, the total number of articles published by China, USA, Canada, England, Australia, Italy, Japan and so on has been listed respectively. Figure 2 shows the top 12 countries where articles focused on pipeline safety are published. Obviously, P. R. China is the most productive research country in the term of quantity. As suggested by the previous researchers, the quality of research papers, which is always represented by h-index and citations, is another important index to measure the research forces. The result indicates that although China has obvious advantages in the total number of publications, total citations and h-index,

the average number of citations per article published in China is less than most of rest in the top 12 most productive countries.

In order to get more details, the annual number of research papers in the top 12 most productive countries from 2004 to 2021 has been analyzed. Figure 3 shows that there was a marked increase in the number of articles published in China since 2012, indicating that the research on pipeline safety in China has attracted more attention. In 2014, China's number of publications even exceeded that of all the rest in the top 12 most productive countries. Similar to China, the number of research paper published by Japan in the recent years has also increased significantly.

Figure 4 is the citation-based and time-based analysis of country productivity, and the color represents the average citations per research papers. The circle's size indicates the quantity of citations. Notably, although Chinese researchers have published

Table 1 Top 12 most productive countries where focused on pipeline safety are published

Number	Country	Total number of publications	Total citations	h-index	Average number of citations per article
1	P.R. China	1368	12,997	43	9.5
2	USA	266	4300	32	16.17
3	Canada	118	1546	23	12.99
4	England	105	1826	24	17.39
5	Australia	92	1475	22	16.03
6	Italy	71	1019	20	14.35
7	Japan	66	610	14	9.24
8	South Korea	59	718	15	12.17
9	France	54	1309	19	24.24
10	Brazil	43	516	12	12
11	Germany	41	683	15	16.66
12	Iran	40	761	15	19.03

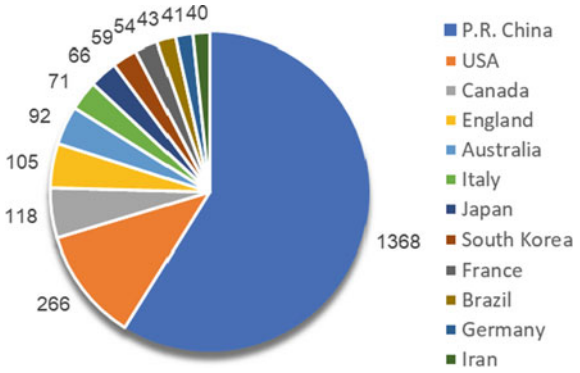
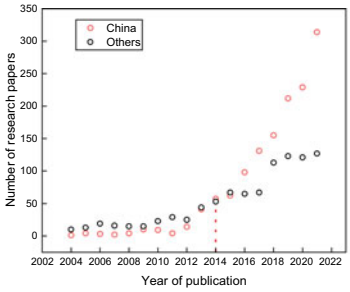
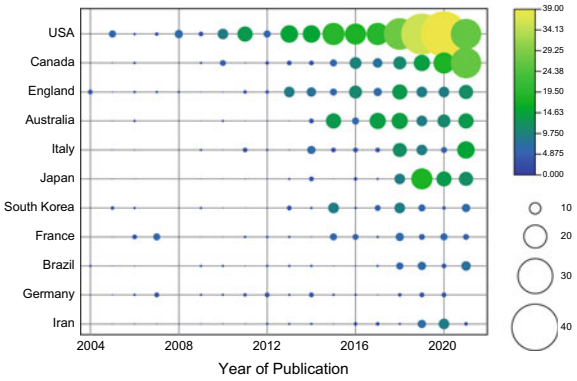


Fig. 2 Country distribution of publications



(a) The annual number of publications in China and the rest 11 most productive countries

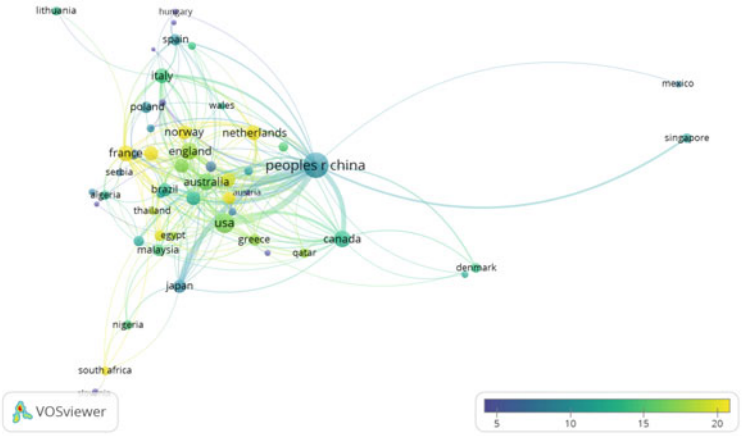


(b) The annual number of publications in the rest 11 most productive countries

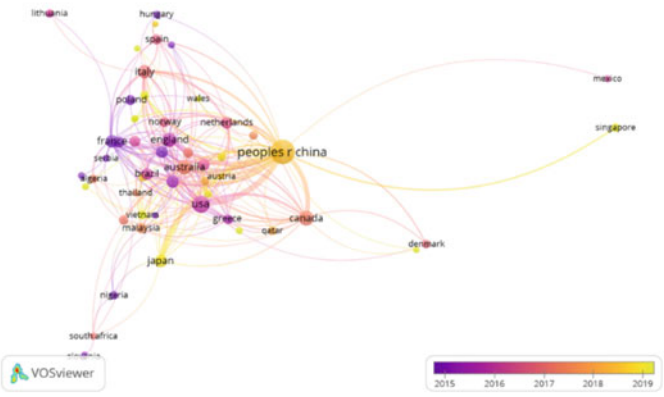
Fig. 3 Annual number of publications in the 12 most productive countries

a large number of papers related to the topic of pipeline safety, the average number of citations of these articles is relatively small compared with other countries such as USA, Canada, France, indicating that China's research level of pipeline safety needs to be improved. As shown in Fig. 4a, there is a clear gap between China and other countries in the term of the average citations per research papers. This is due to the fact that the research on pipeline safety in China started relatively late as shown in Fig. 4b, which is the time-based analysis of country productivity. In this figure, the color is used to indicate the average published year of different countries. Note that lighter the color, the closer the time.

To get more details, the research institutions focused on the pipeline safety have been analyzed. As shown in the Table 2, among the top 20 most productive research institutions, 16 institutions are in China, Japan, England, Canada and China are each represented by one institution. The top one is China University of Petroleum, which published 682 research papers. Its h-index (36) ranked first, indicating that it plays a very important role in the field of pipeline safety. Note that the influence of the research institutions in the other countries should not be neglected. To be concrete,



(a) The citation-based analysis of country productivity



(b) The time-based analysis of country productivity

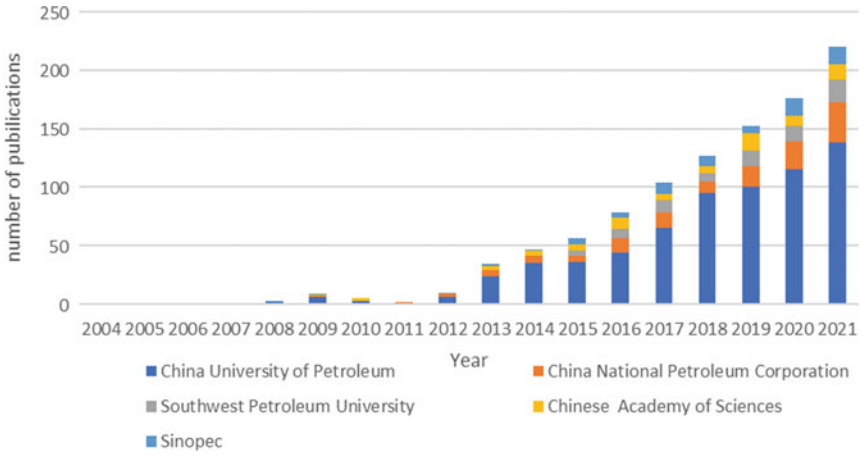
Fig. 4 The citation-based and time-based analysis of country productivity

although the total number of articles published by University of London is less than 40, its h-index (17) ranked third and average number of citations pre article (19.94) ranked first.

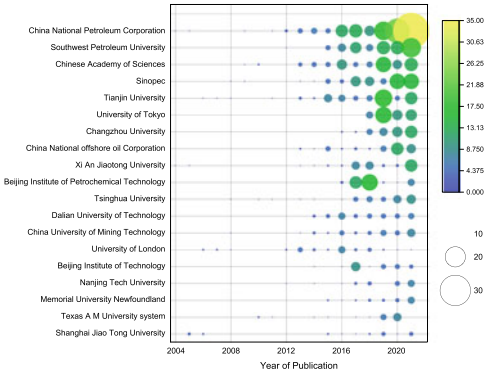
Figure 5 shows that there were less than six articles issued annually by various institutions before 2012. In 2013, the number of articles published by China University of Petroleum annually exceeded 10 for the first time in the field of pipeline safety. From then on, China University of Petroleum has been ranked first in the terms of the number of publications. Since 2016, the number of articles published by China National Petroleum Corporation has also increased significantly, which indicates that Chinese pipeline managers also have paid more attention to pipeline safety.

Table 2 Top 20 most productive research institutions related to pipeline safety

Number	Institution	TNP	TC	h-index	ANC	Country
1.	China University of Petroleum	682	6647	36	9.75	China
2.	China National Petroleum Corporation	137	1356	21	9.9	China
3.	Southwest Petroleum University	78	542	14	6.95	China
4.	Chinese Academy of Sciences	76	1255	21	16.51	China
5.	Sinopec	70	595	13	8.5	China
6.	Tianjin University	69	596	14	8.64	China
7.	University of Tokyo	46	449	14	9.76	Japan
8.	Changzhou University	42	301	10	7.17	China
9.	China National offshore oil Corporation	42	381	11	9.07	China
10.	Xi An Jiao Tong University	42	359	11	8.55	China
11.	Beijing Institute of Petrochemical Technology	41	335	12	8.17	China
12.	Tsinghua University	40	535	12	13.38	China
13.	Dalian University of Technology	39	528	12	13.54	China
14.	China University of Mining Technology	38	491	13	12.92	China
15.	University of London	36	718	17	19.94	England
16.	Beijing Institute of Technology	26	250	11	9.62	China
17.	Nanjing Tech University	23	149	6	6.49	China
18.	Memorial University Newfoundland	22	337	10	15.32	Canada
19.	Texas A M University system	21	172	7	8.19	USA
20.	Shanghai Jiao Tong University	20	165	7	8.25	China



(a) The total number of publications in the top 5 most productive research institutions



(b) The total number of publications in the top 20 most productive research institutions (except China University of Petroleum)

Fig. 5 The total number of publications in the top 20 most productive research institutions

Note that inter-agency cooperation occurs frequently among research institutions in China, such as China University of Petroleum, China national petroleum corporation, Chinese Academy of Sciences, Tsinghua University, and Beijing institution of Petroleum Technology. This is due to the fact that Chinese researchers have paid more attention to the pipeline safety issues. This result is shown in Fig. 6.

Based on the data collected from WoS core database, the researchers with the largest number of papers published in the field of pipeline safety have been analyzed. As shown in Table 3, the top 5 most productive researchers related to pipeline safety

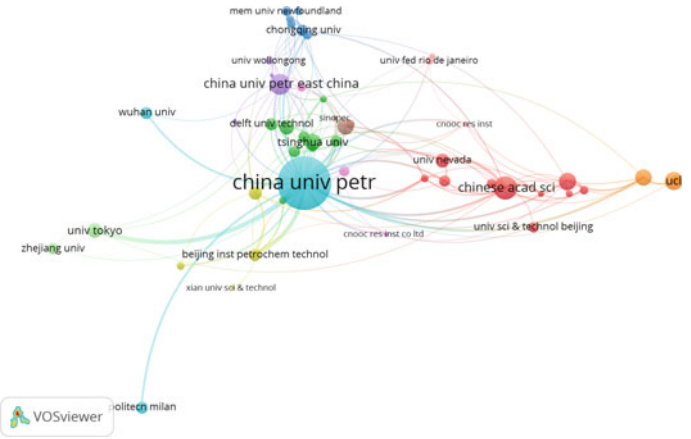


Fig. 6 Visualization of papers in the top 50 research institutions where co-authored papers on pipeline safety are published

are from China. To be more specifical, they are also from the same research institution, China University of Petroleum. Similar to the previous, this result suggests that China University of Petroleum is in the leading position related to pipeline safety.

In this research, various types of co-occurrence relationships have been analyzed through VOS viewer. First of all, the co-authorship network has been analyzed in Fig. 7. As shown in Fig. 7, the research teams engaged in pipeline safety study can be screened. The different colors represent different research teams. To be more concrete, the team Jing Gong and Bohui Shi are engaged in the flow assurance study, and most of the published research papers are related to the hydrate formation, plugging mechanism, gas–liquid flow pattern and molecular dynamics simulation. The application of artificial intelligence technology in the research of pipeline safety also has attracted many researchers' attentions. Notably, the team of Jinjun Zhang and Changchun Wu has applied the deep learning technology to improve the energy supply reliability of integrated energy systems. In addition, Yuxing Li and Fasial Khan have used the Bayesian approach to calculate the accidental probability of subsea pipelines and improve the quantitative risk assessment of gas pipelines. In

Table 3 Top 5 most productive researchers related to pipeline safety

Number	Author's name	Total number of publications	Total citations	h-index	Average number of citations per article
1	Gong Jing	96	1015	21	10.57
2	Liang YongTu	76	696	16	9.16
3	Yu Bo	66	516	14	7.82
4	Zhang JinJun	61	879	18	14.41
5	Zhang Hong	53	489	13	9.23

order to improve the energy supply reliability and enhance the energy delivery efficiency, more and more pipelines have been connected with each other. This leads to the flourishing development of energy pipeline networks. The team leaded by Yongtu Liang has proposed many novel methods to fulfill the optimal operation control of large-scale multi-product oil pipelines. In addition, the study of bubble nucleation has also become a research hotspot. This is due to the fact that more and more researchers have paid attentions on the flow mechanism of waxy crude oil, which is the basic core problem of crude oil pipeline transportation in China. Note that the results is coincident with the above conclusions that China is ranked first in the study of pipeline safety.

The top 20 most productive journals related to pipeline safety are listed in Table 4. In the terms of publication volume, the Journal of Loss Prevention in the Process Industries ranked first. Figures 8 and 9 show the visualization of the corresponding results with distinct colored marks.

Figure 8 is the citation-based analysis of journal productivity, and the legend represents the average citations per research papers. The circle's size indicates the quantity of citations. Notably, although the International Journal of Greenhouse Gas Control, International Journal of Hydrogen Energy, and Applied energy have a lower acceptance of articles on this topic, the average number of citations of the articles from these journals exceeded 24 times, that is, 24.13, 26.43 and 29.46 with impact factors of 3.738, 5.816 and 9.746, respectively, indicating that they have great influence in the study of pipeline safety. It can be observed that the number of annual publications in the top 20 most productive journals is continuously increasing in the recent years. Obviously, more and more researchers have been paying attention on the study of pipeline safety Since 2012, which is reflected in the publication volume of different journals. As shown in Fig. 8, the traditional industrial safety journals including journal of Journal of Loss Prevention in the Process Industries, Process Safety and

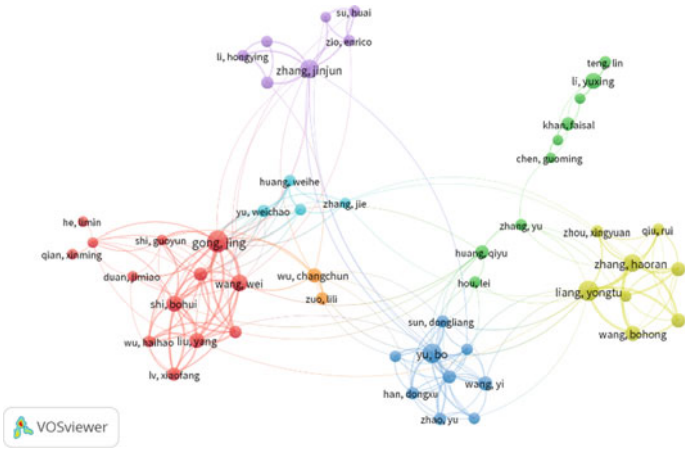


Fig. 7 The co-authorship network of most productive researchers

Table 4 Top 20 most productive research journals related to pipeline safety

No.	Journal	TP	TC	h-index	ANC	IF (2021)	SI-JCR	Country
1	Journal of loss prevention in the process industries	133	2061	24	15.5	3.66	Q2	England
2	Process safety and environmental protection	105	1204	20	11.15	6.158	Q1	England
3	Journal of natural gas science and engineering	66	912	19	13.82	4.965	Q1	England
4	Reliability engineering and system safety	58	1068	19	18.41	6.188	Q1	England
5	Journal of petroleum science and engineering	54	434	13	8.04	4.346	Q1	Netherlands
6	Engineering failure analysis	49	543	14	11.08	3.114	Q1	England
7	Energy fuels	47	743	17	15.81	3.605	Q1	United States
8	International journal of greenhouse gas control	40	965	15	24.13	3.738	Q1	England
9	International journal of hydrogen energy	40	1057	18	26.43	5.816	Q1	England
10	Energies	39	292	9	7.49	3.004	Q1	Switzerland
11	International journal of pressure vessels and piping	37	499	15	13.49	2.028	Q2	England
12	Energy	36	673	13	18.69	7.147	Q1	England
13	Journal of pressure vessel technology-transactions of the ASME	34	176	8	5.18	1.051	Q2	United States
14	Journal of pipeline systems engineering and practice	28	81	5	2.89	1.952	Q2	United States
15	Advances in mechanical engineering	27	62	4	2.3	1.316	Q2	United States
16	Applied energy	26	766	17	29.46	9.746	Q1	England
17	Journal of cleaner production	26	303	12	11.65	9.297	Q1	United States
18	Ocean engineering	26	441	13	16.96	3.795	Q1	England
19	Fuel	25	418	14	16.72	6.609	Q1	England
20	Process safety progress	24	143	6	5.96	1.344	Q3	United States

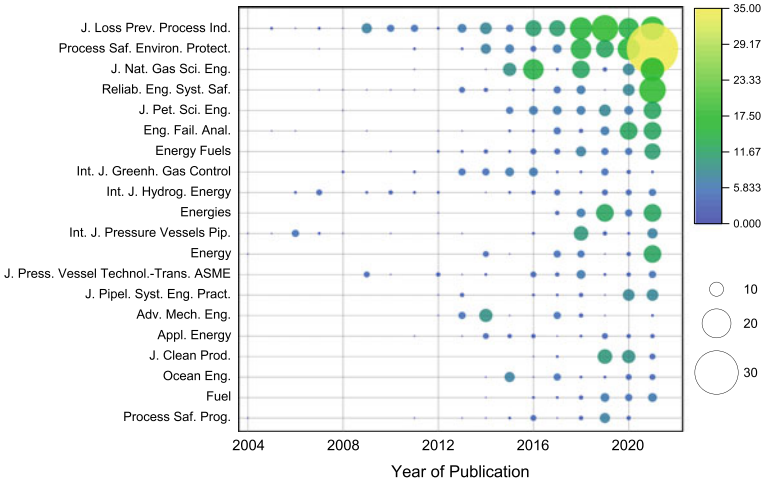


Fig. 8 The citation-based analysis of the top 20 most productive journals

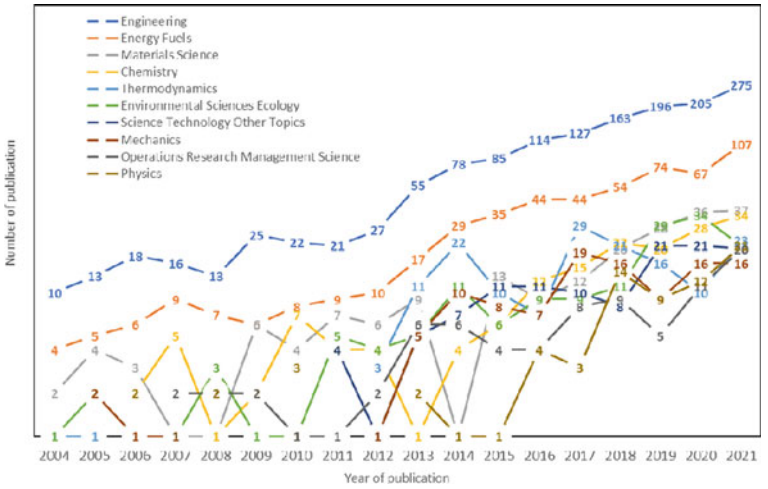


Fig. 9 The number of publications in the top 20 most productive research areas

Environmental Protection, Reliability Engineering and System Safety and so on, have paid more concerns on the oil or gas pipeline safety research in the recent years.

In order to get more details on the research trends, the field and category of the research content related to pipeline safety can been shown with the term of research areas as suggested by the previous researchers. In the following sections, the category module in the WoS has been used to analyze the research areas. Figure 9 shows the annual number of publications in the top 10 most productive research areas. Note that the annual number of publications in various disciplines was less than 50 before

2012. To be more specific, as we can see in Fig. 9, the number of publications in these two research areas including engineering and energy fuels has grown exponentially since 2012. This result also indicates that researchers have paid more attention on pipeline safety issues, which is consistent with the above.

3.3 Distribution of Research Papers

As for the network visualization, the frames and labels are used to represent the analyzed items by default. The size of the label or frame is determined by the weight of the item. Figure 10 shows the network visualization of keyword from 2004 to 2021 based on VOS viewer. Note that the labels of some items have not been displayed in order to avoid overlapping labels. In addition, the distance between two frames represents the relatedness of these two items in term of co-citation links. For instance, the frames of "optimization" and "numerical simulation" are large, indicating that they are research hotpots, and the distance between these two items is also large, which represents that their relatedness is weak and the probability of these keywords appearing in the same research article is low. Obviously, the main contents of pipeline safety research are divided into four clusters. The main research content of red clusters is the quantitative risk assessment of oil pipelines, including corrosion, accidental consequence analysis, and the reliability of pipelines. The study on blue clusters is the failure of pipeline bodies including corrosion and the pipeline steel strength analysis. The green cluster mainly focus on the numerical simulation of oil or gas pipelines, such as the waxy deposition in the crude oil pipelines, the formation mechanism of methane in the gas distribution pipelines, and the flow assurance of oil and gas pipelines, including the parameter analysis such as temperature, viscosity and so on. The research on yellow clusters is the safety transportation of gas pipelines, including the design and operation of CO_2 pipelines, the carbon capture and storage, and the release of gas pipelines.

4 Conclusion

The obviously increasing number of annual publications from 2004 to 2022 indicates that the safety issues of pipeline transportation have attracted more and more attentions. Although China has obvious advantages in the total number of publications, total citations and h-index, the average number of citations per article published in China is less than most of rest in the top 12 most productive countries. The most productive research institution is China University of Petroleum, which published 682 research papers. Its h-index(36) ranked first, indicating that it plays a very important role in the field of pipeline safety. Note that the influence of the research institutions in the other countries should not be neglected. In the terms of publication volume, the Journal of Loss Prevention in the Process Industries ranked first. In

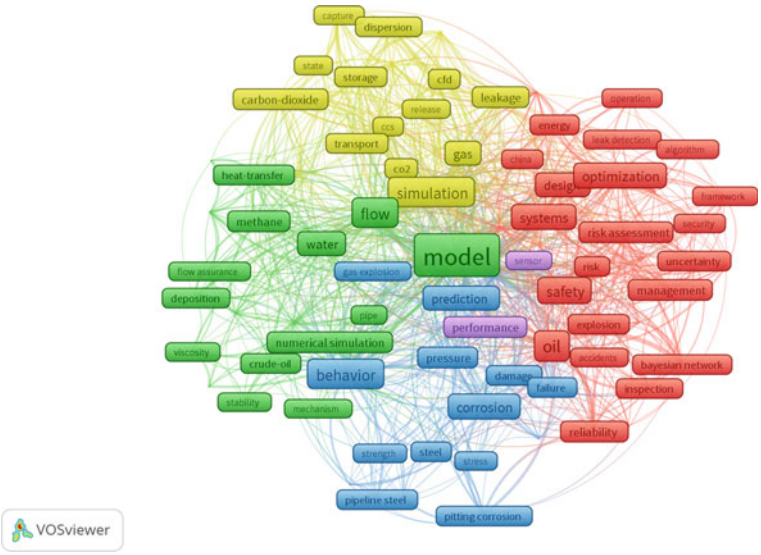


Fig. 10 Network visualization of keyword from 2004 to 2022 based on VOS viewer

addition, the number of annual publications in the top 5 most productive journals is continuously increasing in the recent years. Obviously, more and more researchers have been paid attention on the study of pipeline safety since 2012. At the same time, with the construction of hydrogenation pipeline, more and more studies have been made on the properties and flow mechanism of the fluid in the pipeline. This maybe the reason for the increase of annual number of publications in the discipline of Chemistry, thermodynamics, mechanics and physics.

Acknowledgements This paper is funded by Science and Technology Project of Hebei Education Department (QN2022172). Thanks are also given to anonymous reviewers for their valuable comments to improve the paper.

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