Development trend analysis of variable oxygen concentration combustion research based on bibliometrics

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Abstract. Based on CiteSpace, 955 journal literature related to variable oxygen concentration combustion research collected in the web of Science (WOS) core database were analyzed visually. The results show that: 1 Literature publication trends. According to the total number of published literature, it can be divided into three stages: initial development, steady development, and rapid development. 2. Analysis of the author's co-occurrence map. The author's cooperation network in this field is obvious, but the overall cooperation network presents a "core-edge" structure, and the cooperation of academic teams is scattered. 3. Research hotspots, the related research mainly focused on the combustion characteristics of polymer synthetic materials, and chemical cycle combustion related to the field of energy and power engineering. 4. Research on the frontier trend. At present, "mechanical property" and "Nanoparticles" are the keywords representing the latest frontier trend in this field.

Keywords: Variable oxygen concentration, Visual analysis, Bibliometrics, Citespace.

1. Introduction
In theory, the oxygen content in the combustion reaction process of the material in the air is sufficient and can be continuously supplemented, that is, in the combustion process of the material, the oxygen concentration in the combustion atmosphere is maintained at 21%. But this may not be the case in a real fire. When the combustion proceeds, the oxygen concentration near the material changes all the time, and the amount of oxygen content will affect the degree of complete combustion of the material, and then affect the heat release rate, smoke release rate, and toxic gas production of the material. Based on this, academic research and practical application must study the influence of oxygen concentration, especially the changing oxygen concentration, on the combustion and pyrolysis characteristics of materials.

At present, experts and scholars in related fields mainly carry out small-scale experiments to study the influence of oxygen concentration on the combustion characteristics of experimental materials. The main research can be divided into quantitative research and qualitative research. Up to now, there is little systematic analysis of variable oxygen concentration combustion by using visualization method of knowledge map. Therefore, this paper is based on the literature on Material Combustion Behavior including changes in oxygen concentration recorded in the WOS (Web of Science) core database from 1991 to 2020. By using CiteSpace visualization software to analyze the literature data, this paper attempts to grasp the development context, current research hotspots, and future development trends of
variable oxygen concentration combustion research. Hope to provide some methods and ideas for related research.

2. Materials and methods

2.1. Data Sources
Based on the web of science (WOS) core database, the retrieval time is set from 1990 to 2020, set the Boolean expression to TS = material combination behavior And TS = variable oxygen concentration. A total of 1326 articles were retrieved. In order to ensure the credibility of the research results, through manual verification, we excluded the literature with weak topic relevance and excluded the statements, the first part of the volume, and other nonacademic papers. Finally, 955 valid pieces of literature were obtained as the sample literature of this study.

2.2. Research Methods
The literature research method adopted in this paper is the bibliometric analysis based on information visualization. The traditional bibliometric analysis takes the literature system and bibliometric characteristics as the research object and uses statistical methods to analyze the distribution structure, quantitative relationship, and change law of scientific literature information [1]. Through information visualization method mining and analyzing the potential value of related industry literature data, practitioners in this field can understand the research hotspot and development trend in this field, and provide directional guidance for their research. CiteSpace is an information visualization software developed by Chen Chaomei's team for measuring and analyzing scientific literature data. The software can quantitatively and visually analyze the literature, assist in analyzing the basic knowledge, research hotspots, and development frontiers of the literature in this field, and predict the research characteristics and evolution trend of this field [2] [3]. In this paper, sample literature is used as the data source, and CiteSpace software is used to present the time distribution of research on variable oxygen concentration combustion of materials, and the development vein and research frontier of oxygen concentration on material combustion characteristics in the past 30 years are analyzed in detail.

3. Result analysis

3.1. Statistics of published literature
The diachronic change of literature publication quantity is an important index to measure the development trend of specific scientific research fields.[4] From 1990 to 2020, the number and percentage of literature published in variable oxygen concentration combustion research are shown in Figure 1. On the whole, the total amount of literature published in this field shows an increasing trend year by year, and the change process can be divided into three stages. The first stage is the initial stage of research from 1991 to 1997. Due to the single research materials at this stage and the influence of laboratory technology, the total amount of literature published at this stage is less, and the growth is relatively slow. The period of this stage accounts for 23.3% of the total time, and the number of published papers only accounts for 0.7% of the total number of pieces of literature. The second stage is the stage of steady development, starting from 1998 to 2011. The demand for coal, wood, and other natural resources has increased. Therefore, relevant experts carried out variable oxygen concentration combustion experiments for coal, wood, and other materials, and clarified the smoldering mechanism of coal and wood, which provides a guarantee for the safety of coal and wood processing and transportation in the future. Compared with the previous stage, the level of laboratory research technology and material processing in various countries in this stage has been significantly improved, and the number of literatures published has increased steadily year by year. The period of this stage accounts for 26.7% of the total time, and the number of literatures published accounts for 26.7% of the total literature. The third stage is the rapid growth stage, starting from 2011 to 2020. During this period, the technology of material synthesis has developed rapidly. Experts in the field of material combustion
turn their main research objects from the single materials of natural resources to the diversified materials of artificial synthesis. Due to the increase of material types and the improvement of scientific research technology in related fields, the number of literatures on variable oxygen concentration combustion has increased significantly. The third stage accounted for 26.7% of the total period, and the number of literatures published accounted for 70.8% of the total. In general, in the past 30 years, the research on the effect of oxygen concentration on the combustion characteristics of materials has experienced three stages: initial, development, and rapid growth, and the number of relevant literatures in authoritative journals has increased significantly.

![Figure 1](image1.png)

**Figure 1.** The number and proportion of papers published in the research fields of variable oxygen concentration combustion from 1991 to 2020

3.2. Authors co-present atlas analysis

Researchers and their social network relationships are central elements of a field of research[5]. In the CiteSpace software, the time range was set as 1991-2020, the time slice was set as 1 year, the node type was set as the author, and other default parameters were kept unchanged. The authors with more than 2 published kinds of literature were selected for visual analysis, and the co-occurrence map of authors was obtained. The results were shown in Figure 2.

![Figure 2](image2.png)

**Figure 2.** Co-author atlas of variable oxygen concentration combustion studies
Each cluster in the diagram represents a research team, and each node represents an author. In the figure, the number of nodes $N=698$, the number of connections $E=659$, and the network Density are 0.0027, indicating that 698 authors can be included. As can be seen from Fig. 2, the whole co-generated graph network presents a core-edge structure, and the cooperation is relatively scattered. According to the metrological method, the top 10 scholars in terms of their publications were counted and sorted according to their publications. The results are shown in Table 1. Table 1 shows that Abad Alberto and Adanez Juan represent the top scientific research in the field of variable oxygen concentration combustion. As can be seen from Figure 2 and Table 1, the research results of each research team are outstanding, but each group is relatively scattered and isolated. In future research, all teams need to strengthen cooperation and technology sharing.

Table 1. Top 10 authors in the literature published in the field of variable oxygen concentration

| Ranking | Author                        | publications |
|---------|-------------------------------|--------------|
| 1       | Abad Alberto                  | 22           |
| 2       | Adanez Juan                   | 22           |
| 3       | Gayan Pilar                   | 20           |
| 4       | Garcia-Labiano Francisco      | 19           |
| 5       | Hu Yuan                       | 19           |

3.3. Analysis of Research Priorities

Keywords are natural language words that express the thematic concepts of literature. Key words for a large number of academic achievements in an area of academic research over a long period, can reveal the overall content and characteristics of the research results in this field, the internal relations among the research contents, the development vein, and direction of academic research, etc. In CiteSpace, select the node type as Keywords, and the time slice is one year. The keyword co-occurrence map is obtained by analyzing the keyword frequency and co-word network. The result is shown in Figure 3. The larger the keyword nodes in the second Figure are the more attention this research direction receives in the field of variable oxygen concentration combustion. The line between the keywords reflects the co-occurrence relationship between the node and the research direction. From the perspective of the occurrence of keywords, the keywords with higher occurrence frequency are closely related. The emergence of the two keywords composite and coal proves that the research object in the field of variable oxygen concentration combustion has shifted from the single natural resource material to the synthetic composite material. The appearance of Chemical looping combustion and catalyst indicates the wide application of variable oxygen concentration combustion in the energy field.

Figure 3. Keyword’s co-occurrence network in variable oxygen concentration combustion field
3.4. Analysis of the latest research areas
Research frontier trend refers to the frontier hot spots that can best represent the future development direction of a certain field [6]. Mutation rate detection can be used to understand relevant kinds of literature active in a certain period and track the future trend of this research according to the changing trend of literature. With other parameters unchanged in the CiteSpace software, the built-in "Citation/Frequency Burst History" function was used to generate the keyword view of the variable oxygen concentration combustion field mutation in the WOS core database from 1991 to 2020, and the result is shown in Figure 4.

![Top 19 Keywords with the Strongest Citation Bursts](image)

**Figure 4.** Keywords of mutagenicity in the field of variable oxygen concentration combustion

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4. Conclusions
According to the visual literature analysis map drawn by CiteSpace software after data analysis, the development context of variable oxygen concentration combustion was summarized, and its research hotspots and development trends were analyzed, and the following conclusions were drawn:
1. The data of literature about variable oxygen concentration combustion from the WOS core database were collected and imported into CiteSpace software for analysis. The research field of variable oxygen concentration combustion is highly related to the development level of science and technology in society. From 1990 to 2000, the development of variable oxygen concentration combustion field was relatively slow due to the limited level of scientific and technological development at that time. Since the 21st century, with the rapid improvement of the level of scientific and technological development, the field of variable oxygen concentration combustion has achieved rapid development.

2. The development of variable oxygen concentration combustion is lagging compared with the field of material synthesis. In the 21st century, with the improvement of material synthesis technology, a lot of new materials have emerged in people's life. Faced with the fire risk brought by new materials, researchers shifted their main research objects from natural resources to synthetic materials.

3. The researchers of variable oxygen concentration combustion cooperate with the research institutions more dispersed. To make a more thorough study, it is necessary for all teams to strengthen cooperation and technology sharing, and jointly promote the milestone development in the field of variable oxygen concentration combustion.

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