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SYSTEMATIC REVIEW ARTICLE

Worldwide Research Trend on Steel Casting: A Visualization and Future Research Directions

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Abstract: ***Aims*:** In this study, we conducted a bibliometric study about steel casting between the year 2000-2023. We carried out a bibliometric analysis of sand casting, investment casting, die casting, and squeeze casting in which optimization and simulation models are available and have been thoroughly developed to enhance the quality of the casting product, according to the keyword co-occurrence network and word cloud generated by the bibliometric analysis and text mining of the publications.

***Methods*:** By delving further into the optimisation and simulation models, this study finds multiple casting procedures with various process parameters that have a major effect on the process results. Defects of the mechanical kind are the most prevalent, and factors taken into consideration are emissions, yield, dimensional tolerances, and qualities.

***Results*:** The necessity for data-driven modelling in new casting environments has been identified in this study, which will allow for a dynamic casting process and fine-tuning and aid in attaining desirable results in today's competitive markets. In order to illustrate the future prospects of this sector, this research focuses on potential technical interventions in steel casting processes that could enhance the efficiency of the process and the quality of the products produced by steel casting.

***Conclusion*:** This study examines the body of literature on various researchers' contributions to the production of excellent casting components and performs a bibliometric examination of the publications. However, the literature study examines research publications from high-quality essential sources to determine the essential criteria influencing steel casting quality.

Keywords: Casting, simulation, bibliometric analysis, foundry, scopus, VOS viewer.

1. INTRODUCTION

In the casting process, the liquid steel cools and solidifies before being removed for cleaning. To get the necessary characteristics, heat treatment may be required [1]. The design of the casting process is an essential part of the entire casting production process as a result of the application and advancement of computer technology in the casting industry [2-4]. Casting is the oldest and most cost-effective method of producing metal parts, and it has been employed since 4000 BC [5]. Various casting methods were scientifically recognised in the twentieth century, and various rules were developed to ensure faultless castings [6-8]. According to the World Foundry Organization (WFO), global foundry production reached 112.7 million metric tons in 2019, with China, India, and the United States accounting for

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this percentage. Across industries and applications, casting parts are used in over 90% of all locally finished goods [8]. Industries, such as automotive, aircraft, oil and gas, mining, electrical equipment, and medicine, all depend on castings [9-11]. The greater demand for these casting items with minimal cycle time, high dimensional precision, flawless surface polish, good mechanical qualities, zero defect, and complicated designs have made the casting process challenging, and old casting technologies are no longer used, which have been found to perform poorly [12-14].

Meanwhile, 90% of foundries are MSMEs (Micro, Small, and Medium Enterprises). Thus, there must be a movement in thinking before capacity [15]. Even though scholars have published bibliometric publications on casting, we could find no bibliometric articles that used steel casting [16, 17].

1.1. Objectives

This article aimed to provide relevant statistics for analysing global publication patterns in steel casting. This research aimed to look at the bibliographic characteristics and trends of publications. From 2000 through 2021, experts from all across the world published on steel casting in Scopus-indexed publications, and they conducted a keyword co-occurrence analysis using VOSviewer [17-20].

2. METHODS

This descriptive study was based on a literature database. The research focused on translating research questions into search strings utilising keywords and determining the association of keywords utilising the Boolean operator, including (AND, OR, and NOT), (steel casting AND process parameter) OR (steel casting AND optimisation modeling) OR (steel casting AND simulation). Further, Scopus databases were used to retrieve journal articles published from 2000 to 2021.

2.1. Method of Analysis

We used the methods described in earlier research on social network analysis to search the scientific literature on metal casting because we could not find a bibliometric study employing steel casting with casting-related themes [16, 21]. On February 2, 2022, we browsed the Scopus database in the first phase. We used the phrase (steel casting AND process parameter) OR (steel casting AND optimisation modeling) OR (steel casting AND simulation) to search for all publications published in the Scopus database and then sorted the data in the search tab according to the title, abstract, and keyword. We also restricted the search to publications published within the last 21 years (2000-2021). We also restricted our hunt for articles and selected "all" as the sort of access. We discovered 948 publications during this step. The results were then adjusted by employing an inclusion technique to reduce the number of articles by utilising three subject areas (engineering, material science, and computer science). We also limited the search by applying filters to other factors, such as "final" articles for the publication stage, "journal" for the source type, and only English-language articles. We found 515 publications during this level of inclusion, as shown by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram Fig. (**1**). We retrieved the Scopus articles and examined the 948 publications categorised by relevance.

2.2. Visualisation

To evaluate the data, the collected articles were analysed in the third step, VOSviewer 1.6.15 (https://www.vosviewer.com/). Co-occurrence was the subject of the first VOSviewer study, which was used to discover themes in steel casting. We chose "all keywords" to guarantee that all of the keywords in the papers were retrieved. We then displayed trends in steel casting publications before conducting a co-occurrence analysis for sources and countries using VOSviewer and bibliographic coupling. Based on this phase, we offered the top ten journals and publications with the most affiliations.

3. RESULTS

Amount of steel casting research conducted between 2000 and 2021.

Globally, steel casting publications have increased during the last 21 years Fig. (**2**). However, the annual number of publications connected to steel casting in the Scopus database has fluctuated. Materials science was the most widely published subject related to steel casting, with 515 publications, followed by engineering with 333, business and management with 201, and computer science

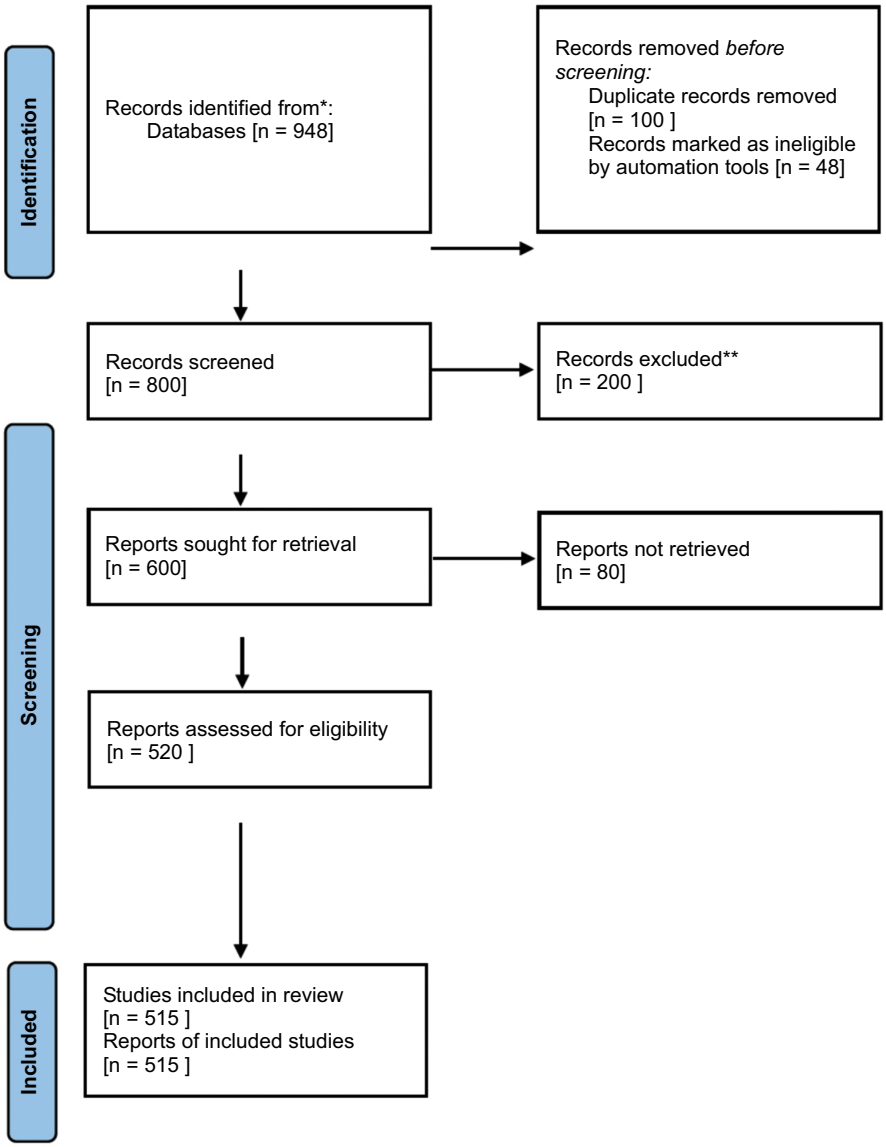

Fig. (1). Publication data exclusion according to PRISMA diagram. Source: PRISMA website. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

with 47 articles. There are some other journals identified as 'others', such as IOP conference proceedings. Nonetheless, there are a number of publications connected to steel casting in the agricultural and biological sciences subject area, with only one article published before 2016.

3.1. Content Analysis of Steel Casting Publications

About 515 papers were categorised by relevancy and subjected to content analysis. We then used VOSviewer to run a co-occurrence analysis, employing the "all keyword" and the "full counting" approach. We restricted the frequency of keyword usage occurrence to two times, and VOS- viewer detected 1048 keywords that met the criteria out of 4,086 keywords.

3.2. Bibliographic Coupling of Sources on Steel Casting

Zhuzao/Foundry Journal (China) published the most publications with "steel casting" in their titles, keywords, and abstracts over the last two decades, with 51 articles. The Archives of Metallurgy and Materials was placed second (Poland). Table **1** lists the top ten journals that published steel casting-related articles. There were three journals from the United States, three from the United

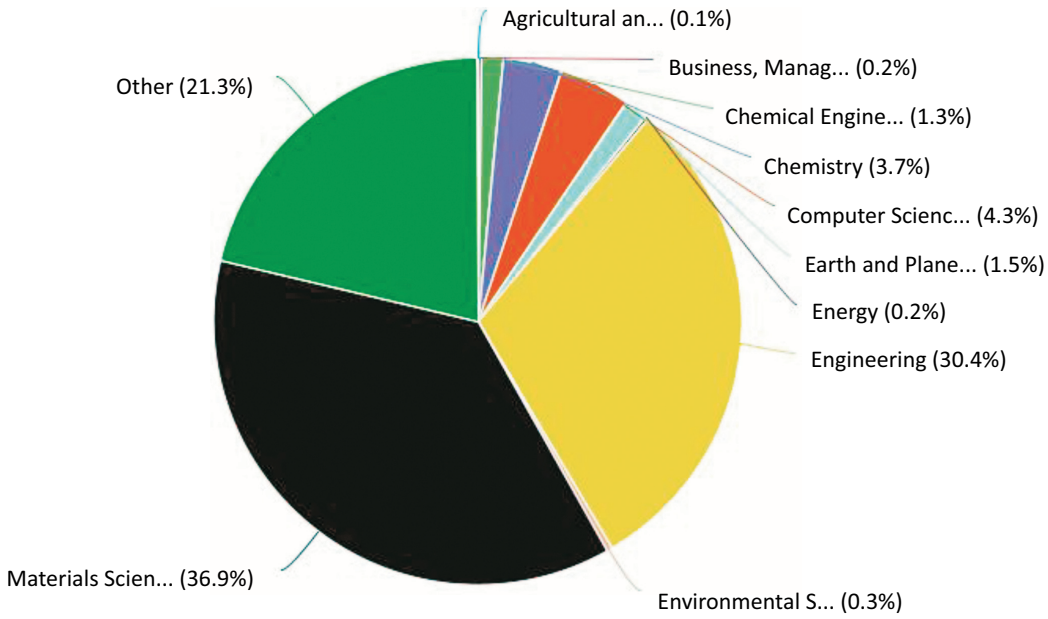

Fig. (2). Publication data about steel casting in the Scopus database from 2000 to 2021. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

Table 1. Top 10 journals on steel casting.

No.	Journal	Total Publication	Country
1	Zhuzao/Foundry	51	China
2	Archives of Metallurgy and Materials	31	Poland
3	Metallurgical and Materials Transactions B: Process Metallurgy and Materials Processing Science	28	United States
4	Steel Research International	22	United States
5	ISIJ International	19	Japan
6	International Journal of Metalcasting	16	United States
7	Ironmaking and Steelmaking	16	United Kingdom
8	Metalurgija	12	Croatia
9	Beijing Keji Daxue Xuebao/Journal of University of Science and Technology Beijing	10	China
10	International Journal of Cast Metals Research	10	United Kingdom

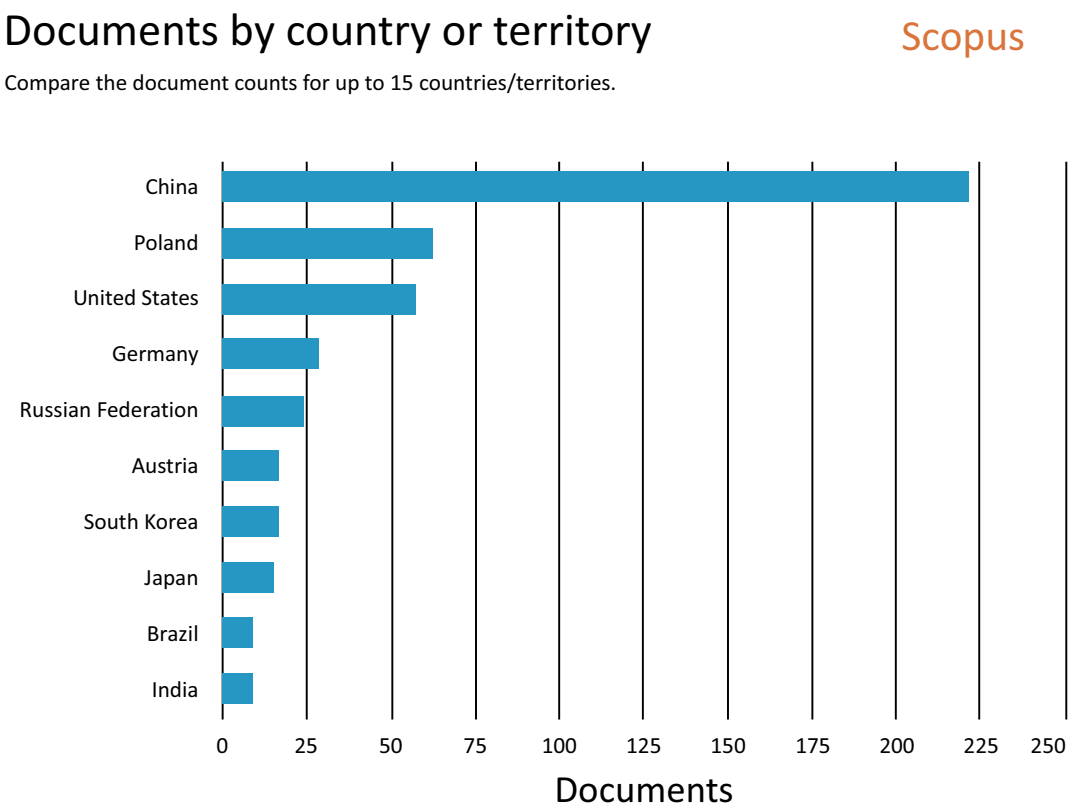

Fig. (3). Documents'data by country or territory. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

Kingdom, one journal from Japan, and one from Croatia.

Bibliographic connection of sources with at least five articles and one minimal citation resulted in 170 sources, 61 of which met the requirement. According to Table **1**, there were seven journal clusters. The top three publications were in a group of three. Cluster 1 was dominated by material science journals, whereas Cluster 2 was dominated by engineer materials journals. The third cluster included journals related to computational material science. Bibliographic connection of sources containing at least five documents and one minimum citation yielded 170 sources, 61 of which met the requirement. We found there were seven clusters of journals. The top three journals were in a group of three (red). Cluster 1 was dominated by material science journals, whereas Cluster 2 was dominated by engineer materials journals. The third cluster included journals related to computational material science.

3.3. Bibliographic Coupling of Countries for Research on Steel Casting

China had the most publications on steel casting from 2000 to 2021, with 221 articles, followed by Poland, which had 62 articles. Germany, Russia, Austria, South Korea, Japan, Brazil, and India were among the top ten countries regarding the number of steel casting publications. The top ten countries are depicted in Fig. (**3**).

An examination of the bibliographic connection of countries with at least five papers and one reference yielded 45 countries, 33 of which matched the criteria. There were five clusters. China, Poland, Germany, the United Kingdom, and the Russian Federation were divided into various groups. Turkey, Denmark, Spain, Indonesia, and Romania were among the countries that collaborated with German experts, while Poland had ties to the Russian Federation and India. Surprisingly, Sweden and the United States

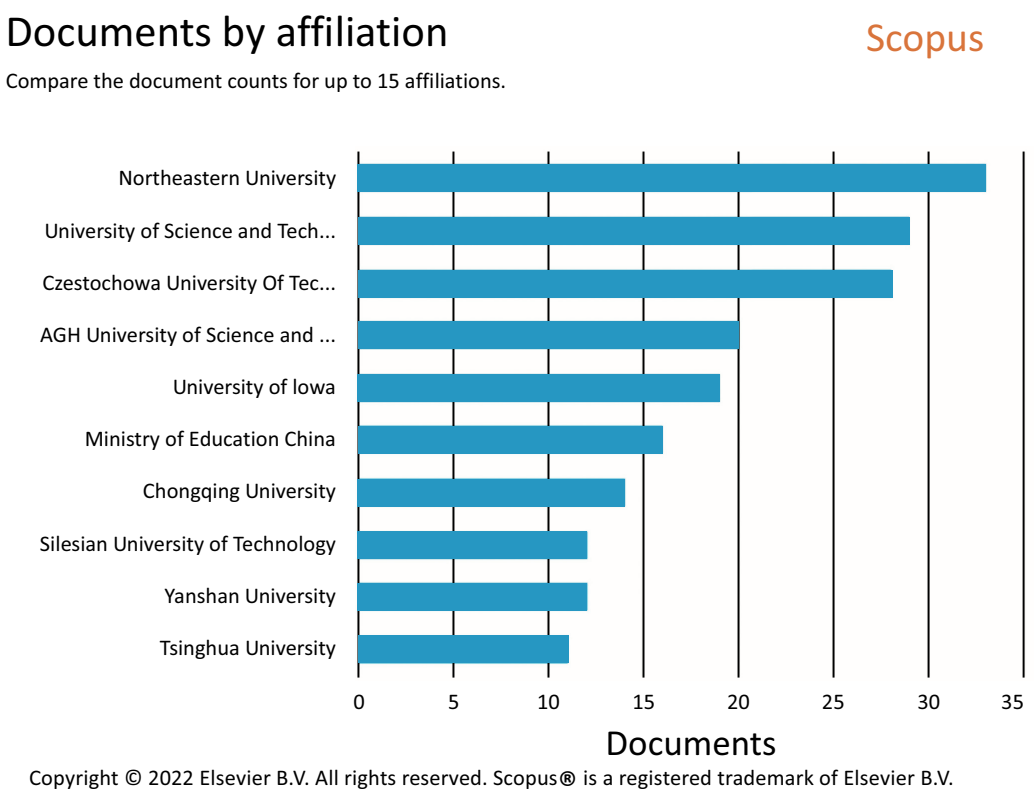

Fig. (4). Affiliations of the publications. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

were in Cluster 5, but they were close to China in Cluster 4 and Germany in Cluster 1.

3.4. Affiliations with Global Institutions

Northeastern University had the most steel casting topic publications in the last 21 years, with 33 papers, followed by the University of Science and Technology Beijing (with 29 articles) and Czestochowa University Of Technology (with 28 articles). China and the United Kingdom each had four of the top ten institutions. Among the top ten institutions that published steel casting publications, the Chinese Academy of Sciences was the sole Asian institution, as shown in Fig. (**4**).

4. DISCUSSION

The analysis revealed that China, the United States, and India are the leading countries in terms of research output, highlighting their significant contributions to the advancement of steel casting technology. The most prolific journals, institutions, and authors were also identified, providing valuable insights into the key players and sources of research in this field.

An article regarding the most recent casting was published in the United States of America Journal. The Zhuzao/Foundry Journal is a forensics industry staple. The nations that produce the most short pieces are Poland, the United States, and England. But after five years, scholars in other nations have started to investigate and write on a range of subjects. Northeastern University is the university in China that publishes the most papers, despite the fact that there are 10 other institutions that do the same.

The study also highlighted a number of new research directions and themes in the field of steel casting, such as the use of innovative materials, environmentally friendly production methods, and the process optimization applications of AI and machine learning. These trends suggest a shift towards more innovative and sustainable practices in the steel casting industry. Based on these findings, several future research directions were proposed, including the development of novel casting techniques, the use of alternative materials, and the integration of digital technologies for improved process control and efficiency. Additionally, the

study emphasizes the importance of collaboration among researchers, industry stakeholders, and policymakers to address the challenges and opportunities in the field of steel casting.

We draw attention to the fact that the industry's future expansion and viability depend on ongoing research and innovation. The study looked at the global research on steel casting challenges, including publishing trends, journal performance, content analysis, and bibliographical coupling of countries and sources. The data were gathered from Scopus. According to the data, international scholarly publications on steel casting have grown significantly. Of all the areas studied, Materials Science proved to be the most prolific field for steel casting publications. Nine clusters, including six essential subjects, were found by the global content analysis: continuous casting, solidification, computer simulation, moulds, steel metallurgy, and numerical simulation. Innovative casting environments with data-driven modelling, on the other hand, will enable dynamic fine-tuning of casting processes in the future and aid in obtaining desired results in today's competitive markets. Policies and regulations governing emissions and waste creation provide significant challenges to today's foundries.

CONCLUSION

Given the above explanation, it can be concluded that cognitive and digital technologies must be used to construct production platforms in foundries.

Limitations

We acknowledge that this study has limitations for various reasons. First, we solely used Scopus to gather studies and did not use other sources, such as the Web of Science [22-26]. Finally, China was the dominant subject in publications and affiliations, although Asia-based research on this area is still sparse, necessitating additional investigation.

Future Research Directions

From this article, we concluded that future research directions can be expanded to the steel casting industry and other aspects of metallurgy. Further, focusing on China and Indonesia as two fast-moving industrial countries in Asia can also be an advantage.

AUTHORS' CONTRIBUTIONS

The authors confirm their contribution to the paper as follows: study conception and design: MA. Author, GNH. Author; data collection: MRG. Analysis and interpretation of results: PP, HH, and MP. All authors reviewed the results and approved the final version of the manuscript.

ABBREVIATION

WFO = World Foundry Organization

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The dataset file is available from: the Harvard Dataverse at: https://doi.org/10.7910/DVN/H807B0

STANDARDS OF REPORTING

PRISMA guidelines and methodology were followed.

PRISMA checklist is available on the publisher's website.

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CONFLICT OF INTEREST

The authors declared no conflict of interest, financial or otherwise.

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SUPPLEMENTARY MATERIAL

PRISMA checklist is available as supplementary material on the publisher's website along with the published article.

Supplementary material, along with the published article, is available on the publisher's website.

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