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Research status of nuclear power: A review

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ABSTRACT

The purpose of this study is to provide the latest research information through atomic power literature analysis for people who are interested in research advancement on nuclear power, and to motivate more discussion and attention on nuclear power. The research on nuclear power has attracted much attention and the literature expanding substantially. This paper characterizes the nuclear power literature during 1996 and 2015 by archiving the data from Science Citation Index Expanded and its implications applying the bibliometric method at country level. Using the bibliometric techniques, we first investigate general spatial distribution, and then explore cross-country comparisons of scientific production, focusing on the country productivity distribution analysis, and institution analysis and research topics analysis. Furthermore, using the bibliometric indicators of the activity index and attractive index, we calculated citation score to further explore research efforts, influence and quality among the 10 most productive countries. First, the results indicate that the USA, Germany and Japan are the three top countries contributing to nuclear power literature, which published 24.34%, 11.04%, 10.87% of all literature, respectively. The great majority of countries come from America and Europe, and there are no African countries significantly involved in this area in the top 30 countries. Second, performance ranking of these countries by institutions echoes the countries' publication performances. U.S. Department of Energy (DOE) is the leading institution by contributing/sponsoring 1061 articles. Overall, American, Japanese and South Korea institutions are the major ones, publishing nuclear power papers. Third, the correlation network and pattern of research topics forms five clusters, the hot and core research topic is model representing simulation. Fourth, we find that Japan holds the leading position with the highest research production, impact and citation score. England and France balance their cost and benefit situation. However, the USA is the only country whose research effort and impact has been continuously declining. China shows a sharp increase in research production but with declining citation score. China should improve production quality and citation score in this field.

1. Introduction

Atomic energy has been an essential part of world energy mix, even though the 2011 Fukushima nuclear disaster shed clouds on the future perspectives on nuclear energy [1–3]. Some 24 reactors are currently being constructed in China, the global biggest energy user [4,5]. And 5 new reactors are considered or being constructed in the USA, the global second biggest energy consumer [6]. Moreover, Japan rebooted the first nuclear reactor in August 2015 since 2011 Fukushima disaster. Being the largest energy consumption country, China has paid more attention on the growing of non-fossil energy [7,8]. In addition, China prefers to develop nuclear power due to the superiority comparing to other clean energy resources [9]. Existing review literature has focused on in the introduction of specific technologies and the development environments. Carlos provides a state-of-the-art review of the SPS / in nuclear engineering [10], Shunsuke elaborates water chemistry control technologies to establish safe and stable operation of nuclear power plants [11]. Advantages in ONPPs have also been reviewed in the literature, containing general arrangement, design parameters, and safety features [12–16] and the application of on-line monitoring [17], martensitic/ferritic steels applied as boiler and turbine materials in power plants [18]. In addition, there are many papers analyzing and presenting the development environments, policies and historical stages [8,19], development statuses, problems, countermeasures, and system dynamics analysis [20–22]. Papers using bibliometric analysis are focused on the alternative energy sources, but not nuclear power. Guozhu Mao

Abbreviations: SCIE, Science Citation Index Expanded; AI, Activity index; AAI, Attractive index; ONPPs, Ocean Nuclear Power Plants; DOE, United States Department of Energy; USA, United States of America; SPS, Seismic protection systems technology

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provides bibliometric analysis of research to carry out scientific production activities, as well as future emphases of alternative energy [23–27].

Bibliometric analysis of nuclear power is not found in the literature, and little is known about the characteristics of utilization literature on nuclear power, including the development and organization in this field of study. Bibliometric method provides a useful quantitative perspective to measure the growing and directions of research in nuclear power field. Awareness of the significance and benefit of technologies related to nuclear power has attracted a growing research attention. Thus, it's essential to measure the sharply increasing literature on the nuclear power.

Using bibliometric method, this study aims to characterize the trends of nuclear power literature in order to study the spectrum and characteristics of nuclear power research, and forecast dynamic directions by investigate nuclear power literature from 1900 to 2015 and its implications. The objectives of this study are: (1) To identify major contributing countries producing most of nuclear energy articles; (2) To discover the growth of nuclear power literatures and recognize the productivity distribution of countries on nuclear power; (3) To identify core institutions that contribute most in journal literature on nuclear power, and to determine the productivity distribution by institutions in this field; (4) To discover relevant research efforts, influence and quality of 10 most productive countries. Based on the analysis results from these four aspects above, we can explore this subject to promote international collaboration and innovations, and more clearly understand the research profiles in the nuclear power technology fields, and provide systemic and current information in nuclear power research.

2. Methodology and data

2.1. Data source

Compared to patent, articles take shorter time from submission to publication with citation on the SCIE database [28,29]. We use journal articles which contain more latest information comparing with patents as the data. The SCIE provided by the Thomson Scientific, is considered as the leader in providing indexing services and literature information in multidiscipline fields [30–32]. It is used to retrieve data from 1900 to 2015, sorted by titles, countries, and institutions. In this study, only the Articles are considered, due to that article is the biggest scientific contributor. Despite review owes more citations, the scientific contribution of reviews are less, and may arise meaningless noise related to vast topics [33]. The earliest research paper on nuclear power was published in the Journal of Naturwissenschaften in 1937 by Jordan, P, from Germany. Although Nuclear power research started a long time ago, it had increased rapidly over the past two decades. In this study, searching the SCIE database using the retrieval conditions, which are "topic = (nuclear power) and document type = (article) and time span = (1996–2015)", 22,224 papers from 1996 to 2015 are collected totally.

In addition, an article may have co-authors from different institutions and countries. Collaboration is identified through the address of every author, "independent" is accessed to papers with authors from the same institution or country, in contrast, 'international collaboration" is accessed to articles with authors from at least two institutions or countries. Therefore, the sum of paper numbers for the three areas (Country productivity distribution, Institution Analysis) published by each institution or country is larger than the total number of publications [34].

2.2. Methods

Bibliometrics, especially the evaluation of bibliometric methods introduced by National Science Council in 1973, are used to measure the scientific and technical profile and performance [35]. Bibliometric has been considered as an effective method for scientific production evaluation [36,37], and is used widely as a quantitative evaluation for many disciplines in the recent years [32,38–41]. The fast and systematic development are attributed to Price and Garfield [39,42]. Later, extended and definite meaning provided by White and McCain [42,43] reflects and explores the further information implicated literature in order to offer evolutionary models of scientific production.

The bibliometric indicators are more urgently demanded due to the sharp growth of scientific production in this century. Numerous literature publications enable bibliometric indicators to characterize research activities [35].

3. Analyses and results

3.1. Country and region productivity distribution

As described above, the data in this paper is extracted from 1996 to 2015. During this period, the SCIE database includes 22,224 papers on nuclear power. The scientific production and contribution of studied country (at least one author from the country published a paper on nuclear power) is measured.

The data indicates that over 133 countries or regions participated in research on nuclear power. Fig. 1 shows that the world map with 30 most productive countries based on the total number of papers on nuclear power, each with more than 170 papers published. The size of each node represents the total number of paper published. The bigger the node, the larger total paper number of papers. The nodes of the USA, Germany and Japan are the biggest, which means they are the top three countries contributing on nuclear power research, 24.34%, 11.04%, and 10.87% of papers, respectively. The following countries include South Korea, France, China, Russia, England, Italy, and India, with published and contributed over half of the papers. In addition, we can see from Fig. 1 that the great majority of countries come from the America and Europe, and there are no countries in African significantly involved in research in this emerging area in the top 30 countries. Two emerging countries play a stronger research role in nuclear power research, namely China and India, which rank in high positions being the 6th and 10th overall.

To provide an overview of nuclear power research, and demonstrate the growth of nuclear power literature, the annual number of articles during 1996 and 2014 is represented in Fig. 2. Fig. 2 reveals that the literature growth rate increases fast over time. USA has always been the largest paper contributor from 1996 to 2014. In addition, since 2011 after Japan's 2011 Tohoku Earthquake, a great deal of studies on nuclear power have been carried out all over the world, including rapid increase in USA and China.

From 2011–2015, research in Japan was growing more sharply than ever before. Particularly, it increases exponentially during 2011–2015 as demonstrated in Fig. 2. The 2011–2015 was crucial stage of development, most articles in Japan were published during this period, which illustrates that nuclear power is really rapid growth subject.

Unsurprisingly, the USA has a leading position in this field, which always predominated, however the share of world publications declines. The USA holds the leading position from 1996 to 2015. The first German paper on nuclear power was published in 1937. However, the second paper appears in 1973. Germany is the second most active nation, where the number of articles grew quickly, Japan ranks the 3rd in the world. After 2012, Japan outrun the Germany ranks 2nd and reaches 355 in 2015, which means that public opinion in Germany is still strongly opposed to nuclear power, and there has been little support for the construction of new nuclear power plants in recent years. Research in Japan, France, South Korea and England on nuclear power started in 1973. The first Russian English-version paper on nuclear energy was published in 1992. China, a rapidly growing country, jumped from the 8th to 6th position in 2014.

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