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Recent research trends in organic Rankine cycle technology: A bibliometric approach

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ABSTRACT

This work describes the contribution of researchers around the world in the field of the organic Rankine cycle in the period 2000–2016. A bibliometric approach was applied to analyze the scientific publications in the field using the Scopus Elsevier database, together with Science Citation Index Expanded. Different aspects of the publications were analyzed, such as publication type, major research areas, journals, citations, authorship pattern, affiliations as well as the keyword occurrence frequency. The impact factor, h-index and number of citations were used to investigate the strength of active countries, institutes, authors, and journals in the organic Rankine cycle technology field. From 2000 to 2016, there were 2120 articles published by 3443 authors from 997 research institutes scattered over 71 countries. The total number of citations and impact factor are 36,739 and 4597, respectively, corresponding to 17 citations per paper and an impact factor of 2.168 per publication. The research articles originate primarily from China, the USA, and European countries. Results indicate that China, the United States, Italy, Greece, Belgium, Spain, Germany and the United Kingdom are the leading countries in organic Rankine cycle research and account for 64% of the total number of publications. The core research activities in the field are mainly focused on applications of the organic Rankine cycle technology, working fluids selection/performance, cycle architecture, and design/optimization. The most productive journal, author, institution, and country are Energy, Ibrahim Dincer, Tianjin University China and China, respectively.

1. Introduction

In the last two decades, the growing concern over energy efficiency, finite fossil fuel resources and their environmental impact has accelerated the research work in the field of clean and efficient energy technologies [1]. Efficient conversion of low temperature heat and waste heat into power can effectively reduce the greenhouse gas emission and significantly improve energy efficiency of energy systems [2]. However, conventional energy conversion technologies are not suitable for efficient conversion of low temperature heat sources [3]. The Organic Rankine Cycle (ORC) technology is considered viable technology, being progressively adopted as the premier technology for efficient conversion of low temperature heat into power [4].

Extensive research activities have been observed in ORC technology from 2000 onwards due to the increased attention to low-to-medium temperature heat recovery. The adoptability to various heat sources, low complexity, automated control and distributed power generation ability make the ORC technology an ideal choice for power production from low temperature heat and waste heat [5]. Potential applications of the ORC technology include biomass, solar, geothermal, ocean thermal energy and waste heat recovery from various thermal processes [6]. It appears that future regulations will focus more on CO2 emissions and energy efficiency, thus providing ample chances of further research and development in the ORC field.

A number of review articles have been published in the past covering different aspects of the ORC technology. Lion et al. [7], Sprouse III and Depcik [8], and Saidur et al. [9] reviewed the use of ORC power systems for waste heat recovery from internal combustion engines. Tocci et al. [10] and Rahbar et al. [11] investigated the small-scale applications of ORC power systems. Regarding working fluids for ORC units, Bao and Zhao [12] and Chen et al. [13] provided a comprehensive review and selection criteria of pure working fluids. Modi and Haglind [14] and Abad and Kim [15] investigated the potential and challenges of the use of zeotropic mixtures for ORC

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applications. Later, Dai et al. [16] analyzed the thermal stability of the working fluids. As for component level reviews, Imran et al. [17], Song et al.[18], and Bao et al. [12] provided comprehensive reviews of selection and performance of expanders for ORC power systems. Lecompte et al. [19] presented a generalized overview of cycle configurations and cycle architectures, and Zhai et al. [20] investigated the potential heat sources and categorized them for ORC applications.

With the advancement of ORC technology, the literature related to the ORC field has grown substantially. Therefore, it is of crucial importance to identify the core research themes, contribution of authors and institutes in the ORC field, and qualitatively assess the ORC publications. None of the previous review works on the ORC technology addresses these aspects. Moreover, there has been a significant increase in quantitative evaluation of the literature using scientometric and bibliometric approaches in recent years. A number of studies have been conducted in this regard to assess and evaluate the research activities in a certain field. A list of scientometric and bibliometric studies in the field of energy is shown in Table 1.

The primary objective of this study is to evaluate quantitatively and qualitatively the global trend of research activities within the ORC field, considering scientific papers published in the period from 2000 to 2016. The publication statistics, geographical distribution of authors and institutions, list of authors, institutions and journals with significant contribution in the field of ORC technology, citations and authorship pattern are investigated in the present study. Effective performance parameters are selected for the comparative evaluation of the contribution of authors, institutions, and countries. This is the first review paper on ORC technology taking a bibliometric approach, and by providing a very useful overview for researchers active in the field, it may influence researchers' future research directions.

The paper is divided into four sections. The research methods are briefly explained in Section 2, while Section 3 covers the results and discussion. Finally, a few concluding remarks are outlined in Section 4.

2. Methods

A complete search in the Scopus database was carried out using the words "organic Rankine cycle" in the search bar in "article title, abstract, and keywords", considering the period 2000–2016. The search results were further filtered using the language "English" and document type as "article and conference proceedings". Finally, the complete data of 2124 documents whose topics (titles, keywords and abstracts) contain the word "organic Rankine cycle" and 4221 patents in the ORC field were obtained. The results were further filtered to remove irrelevant and incomplete data. Finally, the refined data consisting of 2120 articles and 3472 patents were considered for the scientometric study of the ORC technology.

2.1. Research output indicators

Impact factor, h-index, and source normalized impact factor were chosen to analyze the influence of the journals, authors, institutions and countries. The quality of modern research is measured on the basis of impact factor; the impact factor of a journal in the nth year is the number of citations in nth year divided by the number of publications in the same year. The impact factor was introduced by the Institute for Scientific Information (ISI) and is indexed in the Journal Citation Reports (JCR) yearly. The h-index measures both the productivity and citation impact of the publications. The h-index is N if N publications, each of which has been cited in other papers at least N times. The source normalized impact factor measures contextual citation impact by weighting citations based on the total number of citations in a subject field. In the present study, the impact factor of a given journal was determined as reported in the 2016 Journal Citation Report.

In order to measure the qualitative research output at the institution and country level, a number of research indicators have been used. These research indicators include the i-10 index, productive authors, productive institution, and hot articles. The i-10 index is the number of publications having more than 10 citations. The authors and institutions having more than five publications are termed as productive authors and institutions, respectively. Articles with more than 50 citations are entitled hot articles. For comparative assessment of research output, the impact factor per publication (IFPP) and citation per publication (CPP) were also used.

2.2. Collaboration degree

Three indicators were chosen to investigate the effect of research collaboration. These factors are the auctorial collaboration degree, institutional collaboration degree, and national collaboration degree and can be represented as

$$D_a = \frac{\sum_{i=1}^{n} \alpha_i}{N} \tag{1}$$

$$D_i = \frac{\sum_{i=1}^{n} \beta_i}{N} \tag{2}$$

$$D_n = \frac{\sum_{i=1}^{n} \gamma_i}{N} \tag{3}$$

D_a, D_i, D_n are the auctorial collaboration degree, institutional collaboration degree, and national collaboration degree, respectively, and α_i, β_i, and γ_i are the number of the authors, countries, and institutions for each paper. The parameter N represents the total number of papers. It needs to be noted that the number of countries is the sum of all authors' countries, and similarly the number of institutions is the sum of institutions of all the authors.

2.3. Research output indicators

In order to analyze the qualitative research output at the institute and country levels, a comprehensive approach was adopted. Eight research output indicators were chosen, namely, the number of publications, number of citations, h-index, cumulative impact factor,[1] number of productive authors,[2] number of productive institutions,[3] number of hot articles,[4] and the number of citations of hot articles. These indicators were used to calculate the standard research score of each country:

$$S_{pq} = \frac{x_{pq} - \bar{x}_q}{\bar{x}_q} + 1 \tag{4}$$

where S_{pq} is the standard research score of indicator q in country p, x_{pq} is the original score of indicator q in country p, and $\bar{x}_q$ is the average score of indicator q. The sum of all standard research scores of a country is

$$S_p = \sum_{q=1}^{8} S_{pq} \tag{5}$$

where S_p is the cumulative research output score of country p, and q is the research output indicator. There are eight research indicators used in the present study.

[1] Sum of impact factors of all the publications from 2000 to 2016 in the ORC technology field.

[2] Authors who have published more than four research articles in the ORC technology field.

[3] Institutions which have more than four research articles in the ORC technology field.

[4] Articles that have more than 50 citations.