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PEST Analysis of a Rankine Organic Cycle for Energy Recovery

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Abstract

In this work is presented a state of the art of political and economic investments, technological developments, social and environmental impacts of the 4 countries that contribute more research on the Organic Rankine Cycles (ORC) from the application of PEST analysis. Taking into account that technologies for waste heat recovery such as ORCs have been very popular due to their friendly impact on the environment. Countries such as the People's Republic of China are carrying out a large number of research projects on ORCs with industrial applications, and their policies are in line with the need to reduce greenhouse gas emissions, as evidenced by the Top-1000 Energy-Consuming Enterprises program, which seeks to optimize the systems of the country's main production companies.

Keywords: Organic Rankine Cycle, energy recovery, PEST analysis.

INTRODUCTION

Dependence on fossil fuels in industry led to environmental factors such as global warming, ozone depletion and air pollution indicating that a change in the quality of the fuel used was necessary [1]. The research carried out in this area gained considerable attention due to the use of low-quality waste heat to reduce energy losses, since by means of heat recovery it is possible to reduce fuel consumption and achieve greater efficiency in energy conversion [2]. The advantage that the Organic Rankine Cycle (ORC) aims to offer over other available technologies is the production of between 15% and 50% more power for the same heat and an efficiency in the recovery of heat at low temperatures [3].

Taking into account the challenges presented in the energy sector with respect to the growth of energy demand and the impact this can have on global warming, various solutions have been developed, including renewable technologies and the improvement of process efficiency. [4].

ORCs have had a major impact on scientific production and are developed in a wide range of applications, for example. K Qiu et al. simulate the performance of the integrated thermoelectric power cycle and ORC system under multiple conditions, this configuration is known as dual cycle [5]. Yiji Lu et al. present the integration of an ORC cooling system and an Internal Combustion Engine (ICM), resulting in a system with the potential to improve the overall energy efficiency of ICM from 40% to 47% and reduce average fuel consumption [6]. D Geng et al. use low quality thermal energy to power desalination processes by coupling an ORC with reverse osmosis of seawater, a technology that aims to reduce the cost and environmental impact of using fossil fuel sources [7]. On the other hand, Pengcheng Li et al. propose an organic cascade system of the ORC that uses solar energy and Liquefied Natural Gas (LNG) to generate thermal energy, obtaining a maximum efficiency equivalent of 5.99%. [8].

Therefore, the methodology developed is based on the PEST (Politics, Economy, Society and Technology) analysis matrix, which describes the main government laws and regulations on the advances of the subject matter under study, taking into account the technological developments applied and their impact on society. [9].

METHODOLOGY

Review of concepts: Organic Rankine Cycle (ORC)

The Rankine Organic Cycle applies the Rankine Steam Cycle principle, with the difference that the ORC uses low boiling point organic working fluids to recover heat from low temperature sources [3]. ORC has emerged as an alternative in increasing energy efficiency by producing power from waste heat recovery [10]. The cycle in general consists of an expansion turbine, condenser, pump, evaporator and superheated if required, as shown in Figure 1.

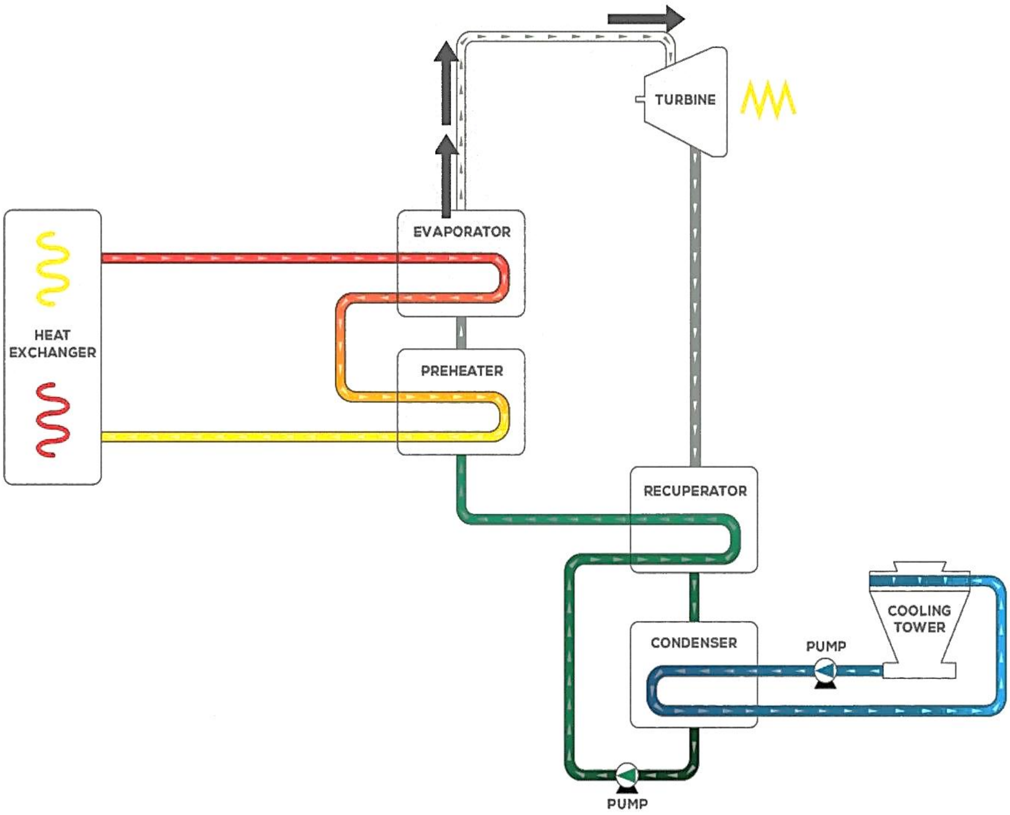

Figure 1. Configuration of Organic Rankine Cycle.

The turbine built for ORC generally requires only a single-stage expander, which results in a simpler and more economical system in terms of investment and maintenance costs. The challenge for this technology is energy conversion efficiency, which is around 8% to 12% [1]. Research advances in ORC currently focus on energy recovery from four types of sources: Energy from biomass combustion, industrial waste heat, thermal energy from geothermal sources and solar thermal energy [11]. Other energy production cycles are the Supercritical Rankine Cycle (SRC), the Kalina Cycle (KC) and the Trilateral Flash Cycle (TFC) in the area of waste heat recovery [12]. The main disadvantages of the other thermodynamic cycles are that the Kalina Cycle has a complex circuit, two-phase expansion is a disadvantage in the Trilateral Flash cycle, and high operating pressure and temperature conditions reduce the applications of the Supercritical Rankine Cycle [13]. The Organic Rankine Cycle (ORC) is characterized by a simpler circuit, easy reliability and maintenance.

Components of an Organic Rankine Cycle

The selection of efficient equipment taking into account its application will result in an increase in the net power produced by the cycle. The general structure of such a system is as follows.

Pump: In process 1-2 the organic working fluid stored in a tank will be pressurized to be sent to the evaporator. This equipment is characterized by lower power consumption compared to what the turbine produces, for this reason the contribution of the isentropic efficiency of the pump is not so significant, especially for pump efficiencies above 50% [10].

Boiler: In process 2-3 the high pressure working fluid is heated by the waste heat source, and the high pressure, high temperature steam formed is sent to the turbine. The effect of the temperature in the boiler in relation to the net output depends on the working fluid, as it is possible to work with wet or dry organic fluids**.**

Turbine: In process 3-4 the kinetic energy present in the high-temperature, high-pressure working fluid is converted to mechanical energy by rotating the turbine blades connected to a generator to produce energy. The efficiency of the turbine has a significant effect on the net power of the process, since as the isentropic efficiency of the turbine increases, so does the work. It is necessary to take into account some typical behavior of these equipment's in the ORC for example, the steam of the exhaust of the turbine will overheat in almost all cases due to the smaller specific volume and the high density of the fluid, in compact ORC systems the turbine can overcome the excess of speed, this generates a fall in the power, it is necessary to avoid leaks of the working fluid since this is flammable [1].

Condenser: In process 4-1 the exhaust from the turbine outlet will be cooled by an external source to bring the fluid to its initial condition, and thus continue the cycle. The contribution of the condensing temperature is fundamental in the net power produced, as it decreases as it condenses at a higher temperature [14].

RESULTS AND DISCUSSION

The Citation Impact of Scientific Production and International Collaboration

The production of scientific research has progressively changed from individuals to groups, both institutionally and internationally. This means that the contributions have a greater impact on future publications on related topics. The research capacity of a country goes hand in hand with its research production, the analysis carried out in this work is a way of seeing how the main contributing countries have advanced academically and also presents the scientific trend of the countries with respect to the ORC. A total of 77 countries in this study contributed academically to the development of energy recovery technologies. Figure 2 shows the People's Republic of China, which heads the list of published articles with a total of 611, and also leads the list of local citations (TLCS) with 4284, these are the most cited articles of the selected group of documents, demonstrating that this country is committed to technological advances in the field of ORC, as it sees in these the opportunity to improve its production processes and that its research is also efficient.

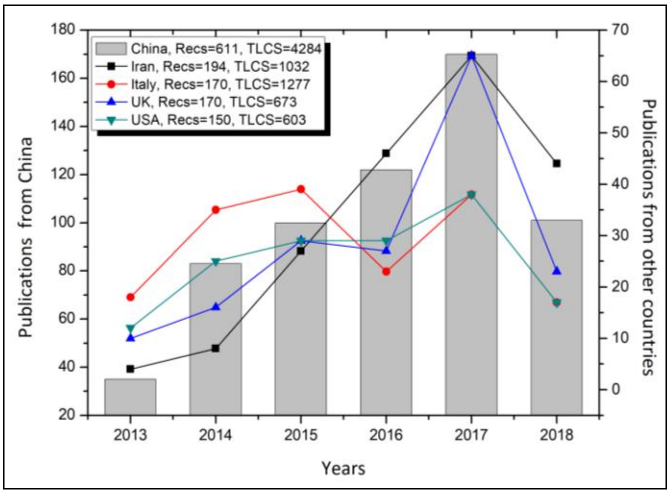

Figure 2. Distribution by country.

The People's Republic of China accounts for 30.6% of publications, taking into account the 2000 results obtained in the database. To this we must add research from countries such as Iran, which has 194 contributions representing 9.7% of the total data and an TLCS=1032, Italy with 170 records contributing 8.5% and an TLCS=1277, and highlighting the work of Belgium who with a production of 57 articles achieved an TLCS=1034, which indicates the great impact that have generated their research and the assessment that other authors give to quality work.

On the other hand, a different way to know the quality of research production is to make a relationship between the number of citations at the local level and the number of published articles, as shown in Table 1, which indicates the average number of times a document is cited.

Table 1. TLCS/Recs relationship by country.

Country	TLCS	Recs	TLCS/Recs
Peoples R China	4284	611	7,01
Italy	1277	170	7,51
Belgium	1034	57	18,14
Iran	1032	194	5,31
United Kingdom.	673	170	3,96

Figure 3 shows how the most important research countries interact, the size of the circumference is proportional to the impact generated by each country and the lines that unite them indicate the level of collaboration between them, so the thicker the line, the more collaborations there are between them.

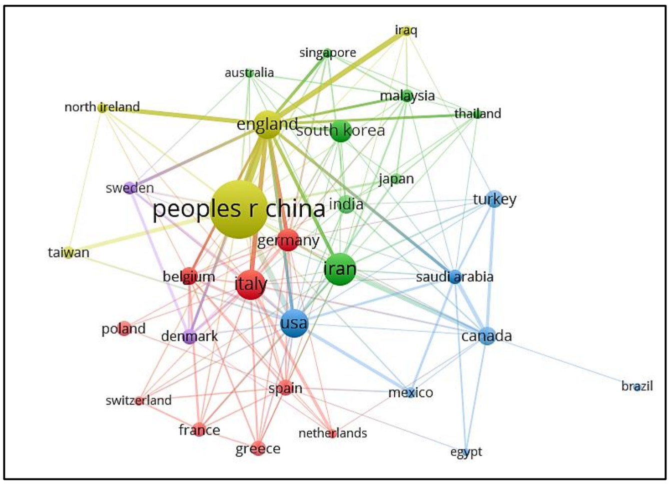

Figure 3. Network of collaboration between countries.

PEST Analysis

The analysis of political, economic, social and technological factors (PEST) is a simple and effective tool that is used to assess the current situation of a company or country in a specific topic, identifying the main rules or laws, economic investments, the use of advanced technology in the development of projects and their impact on society. The PEST analysis of the Organic Rankine Cycle is presented in Table 2, carrying out a general review of the government involvement of the countries that have the most scientific input with respect to energy recovery and fuel economy systems.

Table 2. PEST Analysis of a Rankine Organic Cycle.

Criteria	**People's Republic of China**	**Italy**	**Belgium**	**Iran**
Policies	To improve energy conservation, reduce pollutant emissions and promote the construction of energy recovery systems, the Government of the People's Republic of China is promoting a number of measures.[15] For example, the Ministry of Industry and Information Technologyc (MIIT) issued the *12th Five-Year Development Plan* and the *Guidebook of Advanced and Applicable Energy Savings and Emission Reduction Technologies* both for the steel industry and for the industry in general [16].	The Italian government through the *National Energy Strategy 2017* seeks to reduce final energy consumption by a total of 10 Mtoe by 2030, through the use of renewable energy and with systems that gradually replace the use of coal in electricity generation. The aim is to reduce the energy price gap, promote sustainable public mobility and environmentally friendly fuels. European countries seek to achieve the EU 2020 targets (Directive 2009/28/EC and Effort Sharing Decision – ESD) [17].	The European Commission in its European Integrated Pollution Prevention and Control Bureau provides information on best available techniques (BAT) for manufacturing processes, carried out in accordance with Article 17(2) of Directive 2008/1/EC of the European Parliament and of the Council (IPPC Directive) [18]. For its part, Belgium as a member of the EU, in addition to complying with the previous regulations, has set itself the objective of reducing primary energy consumption by 18% by 2020, promoting energy generation systems such as the ORC [19].	Iran proposed in a five-year plan in 2011 to improve the efficiency of its power stations by increasing the number of wind energy projects and by using systems capable of capturing waste gases from the oil and gas industries. Iran's carbon trading has been limited to the Kyoto Protocol's Clean Development Mechanism, which allows carbon reduction projects in developing countries to make money by selling off off offsets to rich countries with binding targets.
Economic Aspects	The Chinese central government allocated a total of RMB 23.5 billion (B) de RMB ¥ to optimize the systems in the Top-1000 Energy-Consuming Enterprises Program the Ministry of Finance (MOF) and the NDRC use this funding to award RMB 200 RMB ¥ for each year saved. [16].	European governments plan to invest USD 36 billion by 2050 to achieve 2DS, which identifies the technology options and energy policies that ensure an 80% chance of limiting the long-term global temperature increase to 2°C by reducing emissions from 2°C, reduciendo las emisiones de CO_2 and other greenhouse gases [20].	The federal government does not directly promote energy efficiency, but indirectly has fiscal measures in place for this purpose. For example, companies that invest in energy recovery systems in the industry will pay less tax on corporate profits [19]. For energy saving investments made in 2018 (fiscal year 2019), the increased deduction amounts to 13.55% The cost of the KWh in the country under study is an index of the total cost of implementing energy recovery technologies, for countries such as Belgium a value of 10,900 € is estimated as a maximum investment at the residential level and 102,200 € at the industrial level [21].	Currently, the Middle East has a high rate of energy consumption, the main reasons for this event being economic growth (5% in the last 4 decades), population growth (approximately 2%) and subsidies to energy markets that represent around 12% of PIB [18]. Iran began a reorganization in December 2010, but remains the world's largest fossil fuel subsidiary [22]. Taking into account that this country is the third largest producer of oil and gas in the world, the measures adopted will have a great impact on the development of systems capable of recovering energy.
Technology	In heat recovery technologies it is of vital importance that energy efficiency measures are taken in equipment such as boilers and heat distribution systems, among the most important measures are the fuel savings used, the potential for implementation and the recovery period (years). The advantages of efficient energy recovery systems are that they provide greater competitiveness of industry and lower consumption of fossil fuels. Of the changes promoted by the government, the most striking is the shift from traditional fuels to organic fuels in the various processes designed for this	Well-known technologies are being applied to power plants for the purpose of waste heat recovery, and thanks to the sensitive policy of the Middle East, ORC's power plants have seen significant growth in recent years. The feasibility of an ORC recovery system for heavy-duty automotive applications is explored [24]. Italian researchers consider that for small-scale recovery systems the use of positive displacement expanders is preferred over turbines for power generation, taking into account the automotive and residential application that is intended for the future.	Currently, there are plants that combine PTC with ORC by investing 5730 €/kWe, a technology that involves a cost of 17 c€/kWh [21]. In addition, the performance of the ORC cycles with low and medium temperature collector panels has been evaluated, obtaining acceptable results in terms of efficiency [25]. The cost of a 1 MWe commercial ORC module used in cogeneration technology applications is around 1600 €/kWe, so plants for production purposes can be economically competitive with an electricity value of more	The sanction on the petrochemical industry promises to facilitate Iran's access to cleaner fuels. The Iranian government announced plans to increase imports of high-level gasoline (EURO 4-grade), replacing the 8-10 million gallons of fuel produced in this country. One of the most ambitious plans is the renovation of an oil refinery in the Persian Gulf region, a project that was on hold due to corruption problems. In addition, the investigation of the operating parameters in the economic indicators for Iran concludes that the value of the

	purpose, since of the main fossil fuels, coal has the highest emission factor in relation to its available energy: 96 kg de CO_2e by GJ.[23]		than 16 c€/kWh.	return on investment increases as the evaporator temperature and the degree of overheating increase, therefore, the optimization of these factors will lead to an improvement in plants equipped with ORC-type systems.
Society	The initiatives of environmentally friendly policies have turned the amount of CO_2e produced annually around, taking into account the high number of people in this country, these regulations improve the quality of life of everyone.	Italy based on Article 9 of the EED seeks to generate a friendly residential energy consumption, as around 18.75% of the houses are being supplied by a common source of central heating. This is why the adjustment of the heating plant itself is of vital importance, this is where energy recovery systems such as ORCs make a difference thanks to the advantages in terms of working fluid.	The CIRCA Executive Report promotes Environmental Management Systems (EMS) that incorporate the functions listed in BAT1, with the aim of reducing the level of channeled emissions of particulate matter from manufacturing operations in the cement, glass, oil and gas industry.	Iranian lawmakers have been inconsistent on the enforcement of clean air laws, inadequate coordination has delayed Tehran's Air Pollution Control Master Plan, preventing the city from meeting its energy recovery targets.

CONCLUSIONS

In general, the development of systems with the capacity to recover energy from waste heat is increasing, thanks to their favourable environmental impact. Currently, the largest investments in technology and subsidies are made by the European Union, which includes countries such as Italy and Belgium that have clear emission reduction targets by 2050.

The PEST analysis identifies the trend in the use of heat recovery technologies in power generation processes and in cement and related products manufacturing plants, which represents the environmental impact of these systems.

The scientific production of the researches regarding the Organic Rankine Cycles presents the People's Republic of China as the country that made the most contributions, this represents the level of commitment of this country with respect to the development of technologies. However, the quality of publications from countries such as Belgium whose articles were cited on average 18 times by the authors of this study is noteworthy.

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