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The Use of Rankine Power Cycle: A Pest Comparative Study in USA, Spain, China and South Korea

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Abstract

The power cycles are one of the most used methods to generate energy in the world in these cycles is the Brayton cycle which has presented an increase in their studies, for this reason in this work will be a PEST analysis which seeks to study the political, economic, technological and social aspects. This analysis will be carried out in 4 countries selected for their greater number of research outputs, these were found using metadata obtained by Web of Science. In Europe, the Spanish government made an investment of between 330,000 and 385,000 million euros for its programme between 2016 and 2050, showing the large investments in these countries motivated by the goals acquired by nations to reduce polluting gases by 2020.

INTRODUCTION

The generation of energy is currently one of the fundamental problems for society, due to the decrease in the production of fossil fuels, which is projected to fall by 2025 [1]. For this reason, alternative sources of fuel and more efficient modes and more rigorous energy production policies are being sought. These optimizations, which are carried out in search of better efficiency, are carried out at different power cycles with the aim of generating energy from fossil fuels, where the Baryton cycles are one of these.

In order to improve performance, a study was carried out based on the dimensionless mass flow parameter and using this parameter to feed a genetic algorithm to improve the output power [2]. Similarly, a Brayton cycle was used in which parameters were varied to find the sensitivity of these to improve resulting in maximum pressure and turbine efficiency having the greatest influence [3]. In addition, the Brayton cycle has been combined with solar energy [4], [5] and an advanced control strategy has stabilized the solar energy supply in the system On the other hand, exergy has been a highly studied variable in order to optimize the cycle. A parametric study analyzing the sensitivity of various performance indicators to the turbine inlet temperature and the compressor pressure ratio shows that thermal efficiencies and exergy increase as the temperature at the turbine inlet and the compressor pressure ratio increase [7]. The results show that the combustion chamber concentrates most of the exergy destruction (more than 62%), predominantly in an inevitable endogenous form that decreases by 11.89% and 13.12% In addition, a parametric study was conducted to investigate the effects of some decision variables on the effectiveness of the first and second law, resulting in the second effectiveness of the law and the total unit cost of the carbon dioxide recompression product [8]. Similarly, the analysis of exergy in combination with solar energy has been applied to the search for better yields in the cycles [9].

Finally, the contribution of this work is to carry out a political, economic, technological and social analysis for the Brayton cycle to generate energy. Here we will review the policies that control the process, which are focused on reducing emissions and increasing cycle efficiency. This study will focus on the countries that have presented the greatest number of studies between 2007 and 2018, and will investigate how their economic policies have positively influenced the increase or decrease of scientific production in this area.

METHODOLOGY

Review of concepts

The Brayton cycle is an expansion and compression process used for gas turbines and is used in rotating machines. Its simplest operation is in a simple open cycle in which fresh air is introduced, which is compressed and then combined with the fuel for its burning and then these gases are subjected to an expansion process for the generation of power in an axis as can be seen in figure 1, these gases after being expanded are expelled configuring this the open cycle [10]. In addition to the simple open cycle described above, there are many more complex cycles and realization schemes in which a variety of elements are combined: one or more compressors, one or more turbines, various heat exchangers, analogically as transistors, resistors, capacitors are combined in multiple ways in electronic circuits [11].

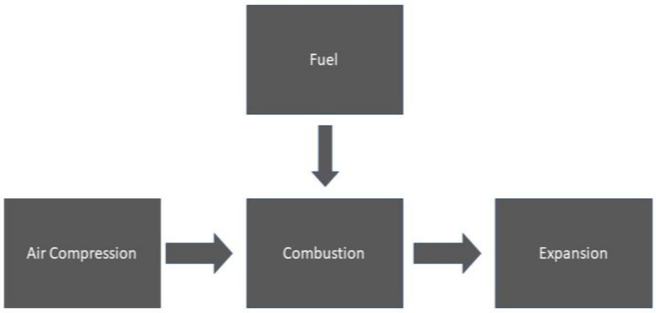

Figure 1. Basic process schematics

Components

For the operation of this cycle, 3 components are basically required. These three components are the compressor that increases the pressure of the fresh air enough to then enter the combustion chamber to be mixed with the fuel. The result of this combustion is the high temperature gases that are passed through the gas turbine where they expand.

These three components are the basic ones, but only using them would generate a low efficiency in the cycles. In order to increase efficiency, different configurations are available, among the many that exist, the one shown in figure 2 stands out

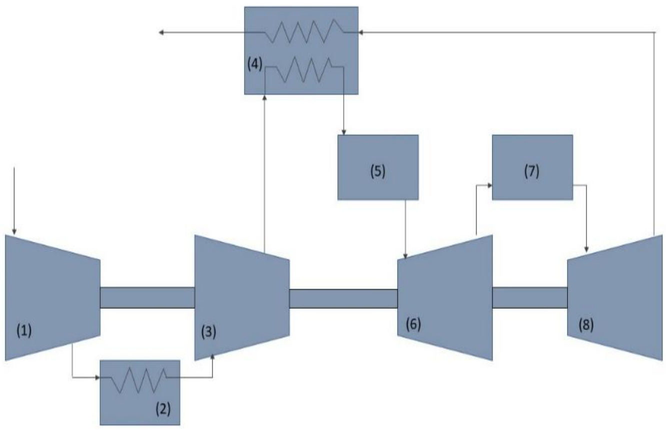

Figure 2. Components of the process

There is a primary compressor (1) that increases the pressure to the fresh air in a first stage, then follows a cooler (2) that lowers the temperature of the compressed air to enter the second compressor (3) and thus reduce the work of the compressors. The compressed air then passes through a regenerator (4) which increases the air temperature before entering the combustion chamber (5) where it mixes with the fuel and then enters turbine I (6) after which it passes the expanded gas through a reheater (7) to prepare the gas for entering turbine II (8). These gases are then passed through the regenerator (4) at a still considerable temperature and expanded to give heat to the compressed air before the combustion chamber.

PEST analysis

For this study, a comparative analysis was made taking into account four fundamental aspects. These aspects were studied for the countries that have presented the most research on the Brayton cycle in the last 10 years. Each of the four countries underwent a review of the policies that control this issue, the economic aspect in which the investments made by these countries were looked at, the social aspect was studied, the impact of these laws and investments on society and the technological aspect was reviewed.

To select the countries for which the study was conducted, metadata was downloaded from the Web of Science, Cycle Brayton was used as the search phrase, and after obtaining the metadata, it was processed through HitCite. In this way, the ranking of countries that contributed the most research on this subject was obtained.

RESULTS AND DISCUSSION

Through the analysis of the metadata obtained by Web of Science it was determined which countries have contributed more research between 2007 and 2018. These data were processed and presented in Figure 3, in this figure you can see the important contribution of the USA and People's Republic of China contributing 18.8% and 24.6% respectively. These two countries accounted for 43.4% of the total publications in these years, which shows the interest in looking for better technologies in the Cycle Brayton.

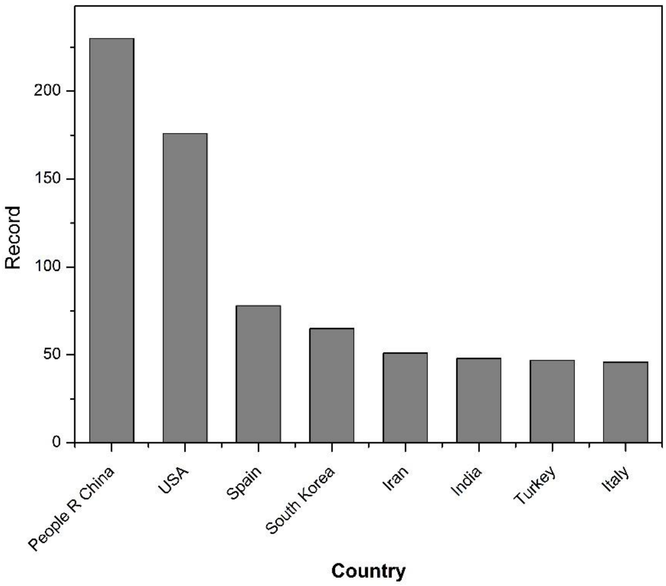

Figure 3. Top 8 Most Published Countries

Taking into account the results shown in Figure 3, the first four countries in this top four were selected to analyze their annual progress, results shown in Figure 4.

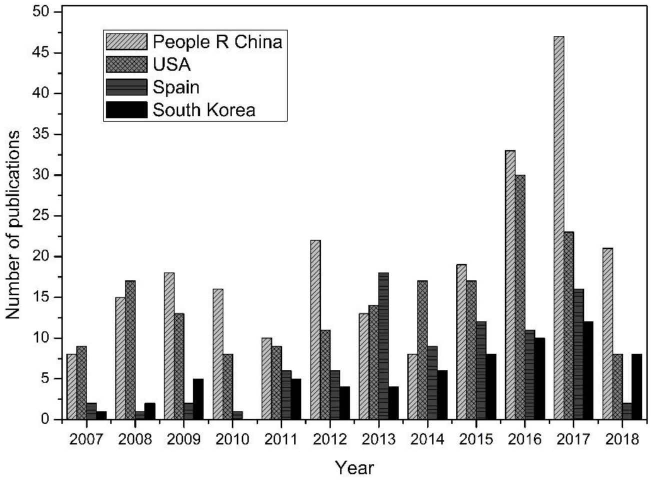

Figure 4. Number of publications per year

Similarly, such growth was only halted in 2014 and 2011 for China where it had a decrease in production of 38.46% and 37.5% respectively. Likewise, the USA presented a drop in its research in 2010, when it experienced a 38.46% decrease, reaching its lowest point in the years studied. On the other hand, Spain and South Korea showed a slightly more stable performance with a constant trend towards growth from 2012 onwards. This behavior was explained by a PEST analysis.

For Cycle Brayton there is no clear and direct regulation in each of the countries studied, the regulation of this process is found in the control of emissions generated by combustion for power generation. After the commitments made in the Kyoto Protocol [12] the countries began to adopt policies to seek CO2 reduction, the European Union provided guidelines that were reinforced by the PARIS agreement [13] in which it set a target for 2020 of limiting global warming to well below 2% and the ambition of governments is to communicate their contributions every five years to set new, more ambitious targets.

Because of these agreements, each of the nations that made these commitments designed government policies and investment plans to achieve these objectives taking into account the specific conditions of each nation. Countries such as People R China and USA, due to their power status and high rates of consumption and production, are the countries with the highest rates of pollution [14] have carried out a great deal of research to achieve these objectives, as shown in Figure 3. All the policies implemented by the governments of the four countries selected for the study are shown and explained in Table 1, which presents the PEST analysis, in addition to economic policies and investments, which shows the use of technologies and the social impact of the projects carried out by the nations.

Table 1. PEST Analysis

Criteria	**USA**	**Spain**	**China**	**South Korea**
Policies	The Obama administration has implemented the Clean Energy Plan as a policy to reduce the carbon footprint of generation processes. This plan was implemented on August 3, 2015 and aims at a 32% decrease and its success is due to the nation's encouragement to states to create their own emission reduction targets and plans for compliance with national targets. Likewise, the implications of these policies in terms of reducing the use of coal and natural gas are not as great as the influence of the cost of these fuels The Clean Energy Plan, through shared federal and state regulatory responsibilities, requires state-based plans that significantly reduce greenhouse gas emissions, particularly CO 2, from fossil fuel power generation units (EGUs). These plants are responsible for almost 40% of total U.S. CO 2 emissions. The largest source of carbon pollution [16].	Spain's policy to reduce greenhouse gas emissions was formally implemented in 2008 but some of its policies were unfortunately discarded in 2012 due to the country's economic problems, such as the Arancel de Admisión scheme. The Sustainable Economy Act specifically encourages innovation and efficiency in the energy industry and supports research efforts [17]	China's goal is to reverse the increase in CO 2 emissions related to energy generation by 2030 and to increase the share of non-fossil fuels in primary generation to 20%, also by 2030, from just over 11% in 2015. In June 2015, China officially submitted its nationally planned contribution (NCD) to the UNFCCC, adding a target to reduce CO 2 emissions per unit of GDP by 60-65% since 2005. To achieve this, two models were adopted, the first of which is a continuous effort model in which the progression is slower and less ambitious than the accelerated effort model [18].	South Korea's announced target for GHG reduction was set at a 30% reduction, with this target projected to be reached by 2020. To achieve these the government created the Greenhouse Gas Inventory & Research Centre of Korea (GIR) and has the mission to manage the national GHG inventory and analyse GHG reduction potential. It is also responsible for providing the guidelines for Measurement, Reporting, and Verification (MRV) for the National GHG Inventory, and supporting the operation of the ETS plan. In addition, the Second Energy Master Plan, launched in January 2014, reaffirms the goal of an 11% renewable energy deployment rate, and calls for the establishment of 15% of energy from distributed generation by 2015, for the application of advanced GHG reduction technology to new power plants. In 2012 Korea introduced a renewable portfolio standard [19]

Criteria	USA	Spain	China	South Korea
Economic aspect	The EPA estimates that total CPP investment ranges from \$3.5 billion to \$8.1 billion in 2020 and from \$34 billion to \$48 billion in 2030. In addition, the agency estimates that the health and climate benefits will exceed the estimated annual costs of meeting the standards, which are expected to rise from \$5.1 billion to \$8.4 billion in 2030 [16].	In economic terms, the Spanish government made an investment of between 330,000 and 385,000 million euros for its programme between 2016 and 2050, of which between 185 and 251 million euros per year are for emission-free electricity generation. [20].	To achieve the expected results, these policies have relied on fossil fuel prices and tariffs. For the ongoing effort, carbon pricing was set to achieve the reduction (3% per year, \$26 per tonne in 2030 and \$58 per tonne in 2050) and for the accelerated effort the price of carbon increases to achieve the reduction (4% per year, \$38 per tonne in 2030 and \$115 per tonne in 2050). As for tariffs for continued effort crude oil / natural gas they are assigned a tax of 10% of the price and for coal coal: 4 CNY / ton (~ \$ 0.6 / ton), on the other hand, in accelerated effort crude oil / natural gas is allocated 8% of the price and for coal 10% of the price [18].	A tax reform that adjusts energy taxes to reduce the imbalance between the consumption of electricity and other energy sources is proposed (Imposing a tax on bituminous coal used for generation, providing tax incentives for LNG, etc.). In addition, incentives will be provided depending on the level of participation of related domestic industries at the development stage. Such incentives may include the preference of resource development firms when applying for loan programs [19]. Four trillion won will also be invested by 2035 in developing technologies, such as distributed generation and demand management technologies.
Society	The benefits to society are projected towards health and climate. In terms of health, it would cause a decrease in respiratory diseases such as asthma, bronchitis and pneumonia/pulmonia, which would also be reflected in a decrease in public spending due to the treatment of these diseases. On the other hand, it will contribute to the reduction of greenhouse gases, which will lead to a slowdown in global warming.	Society benefits in its quality from these standards and research because it is encouraged to improve these cycles seeking greater efficiency and above all the reduction of greenhouse gases that negatively impact not only on the climate but also on the health of the population.	For Chinese society these changes will not reflect significant changes in its economic growth. The government's strategy seeks to generate as little economic impact as possible in order to maintain a lifestyle that does not deteriorate by continuing its social programs. By 2050, the policy cost due to the additional measures amounts to 1.2% of the value of economic consumption (a component of GDP used to approximate the impact of household consumer welfare) [18]	The social benefits of these laws imposed by South Korea are manifold. This country thought of complementary policies to help the population, seeks to minimize the impact of energy price adjustments by offering energy coupons and increasing investment in energy efficiency, and aims to expand energy efficiency projects for vulnerable households, and eradicate welfare blind spots by expanding infrastructure, such as the revision of the system [21].
Technology	The benefits of CO2 reduction lead us to keep the Brayton cycle present in the technological processes used. Thanks to this technology, such as the desalination of seawater by means of one of these cycles [22] or solar reception for heating in the Brayton cycle [23].	The integration of solar energy as a factor in increasing cycle efficiency is very often used. Concentrated solar energy is implemented to increase the compressed air temperature before entering the combustion chamber in order to have air in better condition for the search for a complete combustion.	These policy changes force power plants that use the Brayton cycle to move toward increasing the efficiency of their cycles. New boiler designs for a coal-fired power plant with turbine input parameters of 32 MPa / 600 ° C / 620 ° C are considered for this purpose. The conventional economizer [24].	R&D investment will be expanded to make fossil fuel-based energy sources cleaner. Generation of thermal energy (Brayton cycle) seeking the development of highly efficient and ecological generation systems. In addition, use 300MW integrated gasification combined cycles [21].

CONCLUSION

Cycle Brayton's power generation is increasing due to the global climate situation. The targeting of state policies established by the Kyoto Protocol first and by the PARIS agreement has subsequently intensified investment in energy generation sources to achieve greater process efficiency and better use of combustion in the cycle leading to more complete combustion.

Countries such as the USA have an investment base of 3.5 billion dollars, many of which are directed to research, which guarantees the growth of the studies carried out in the Brayton cycle and also shows a growth panorama in other technologies that offer cleaner energy such as the use of solar panels, biodiesel, solar concentration plants, etc. On the other hand, China forces to make the cycle more efficient by limiting the use of fuel, making a progressive increase to coal for the boilers that use this compound as fuel, which requires maximizing the efficiency of the cycle in order to ration its use in the plant.

To conclude this study and its results are used to analyze trends and select research topics for a new PEST analysis, because it shows the destination of economic investments made by nations and can predict which technology has a great future projection.

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