A THERMODYNAMIC EVALUATION OF A POWER CYCLE THAT UTILIZES A COMBINATION OF AN AMMONIA WATER MIXTURE AND TRANS-CRITICAL CARBON DIOXIDE

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Abstract:

Introduction: The need for environmental conservation and the prevention of toxic greenhouse gas emissions from power generation systems have led to an increasing interest in utilizing waste heat resources such as low grade heat (LGH) sources, which are abundantly available from various industries and commercial sectors. However, the current conventional power cycle processes have limitations in utilizing these resources to their maximum potential. Trans-critical carbon dioxide has been found to be an effective option for low temperature processes due to its numerous benefits, including its low cost and availability. When used in combination with refrigeration, trans-critical carbon dioxide in a combined power cycle has been found to perform better than when used alone. Further research is needed to explore the potential applications of this process. This review article aims to provide a systematic and scholarly overview of the application areas and thermodynamic analysis of the combined power cycle of trans-critical carbon dioxide with ammonia water mixture. The article intends to offer useful insights and evidence to support the development and expansion of the use of this process.

Keywords; Ammonia Water Mixture,Trans Critical Carbondioxide,Simple Gas Turbine, Combined Cycle Power Plant, Heat Recovery Vapor Generator.

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1. Effect of Topping Cycle Parameters

1. Effect of Atmospheric Temperature And Humidity-

The performance of the combined cycle power plants has natural aspiration in the compressors, where the quality of the air entering it has a substantial impact on the amount of work required by the compressors. It is believed that cooling ambient air before it enters the compressor using the energy available in combined cycle power plants may help to improve the performance of the plant as a whole. A simple gas turbine's absorption chiller was used to cool the air entering the turbine, and Mohanty and Palosos (1995) studied this process. The writers of this paper gathered weather information for Bangkok. Thailand and found that lowering the ambient temperature to 15°C might increase electricity generation by a maximum of 13%. By comparing alternative intercooled reheat regenerative cycle designs. Bassily (2001) determined that the cycle with evaporative cooling of the compressor discharge might boost the cycle's efficiency by up to 5%.

Ibrahimet al (2017) Numerous authors have discussed the impact of ambient conditions, including humidity, temperature, and pressure, on the cycle's performance and have come to the conclusion that these factors have no impact. Bashaetal (2012) Analysis of the GE gas turbine frames led to the conclusion that the performance of the gas turbine is not significantly affected by relative humidity. Additionally, a 10 °F drop in atmospheric air temperature results in an increase of roughly 4% in net power production. Ameri and Hejazi (2004)It has been observed that the 170 gas turbine units in Iran lost 20% of their rated capacity due to variations in the ambient temperature. They looked at five gas turbines with an average 11.8 °C difference between ambient temperature and ISO conditions. They discovered that the power output decreased by 0.74% for every 1 °C increase in ambient temperature and suggested lowering the compressor's intake air temperature to increase the gas turbine cycle's efficiency.

Zhu, et al. (2020) the compressor, combustion chamber, gas turbine, HRSG, boiler, steam turbine, and heat generator are all incorporated in the combined cycle power plant. The entrance temperature of the steam turbine was measured at 540°C, while the exhaust pressure is atmospheric. Due to design constraints, the input temperature is constrained, and this cycle's efficiency is only about 40%. In a gas turbine, the entrance temperature is around 1100°C, while the exhaust temperature can be reduced to 500°C to 600°C, with 33% turbine efficiency. Gas turbine exhaust may be used to power a steam turbine with 60 percent efficiency.

Hosseini R et al.it has been demonstrated that the gas turbine compressor is designed for constant air volume flow, making the amount of electricity produced dependent on the surrounding temperature through the specific mass flow rate. Additionally, the output pressure of the compressor is reduced as a result of rising ambient temperature, which also lowers the efficiency of the gas turbine cycle. Meanwhile, the gas turbine's heat rate is decreased and its individual fuel consumption is increased. They said that the electric power output of the gas turbine decreases by 0.5% to 0.9% for every 1°C increase in the ambient air temperature, and by 0.27% for a combined cycle.

In order to analyse the performance of a straightforward gas turbine and combined power cycle, Kakaras et al. (2004) cooled the incoming air using an absorption chiller and evaporator. The author came to the conclusion that, in the case of a basic gas turbine, efficiency falls by 1.66% and power output falls by 14.48% with an increase in ambient temperature up to 40°C compared to ISO conditions. Additionally, productivity and efficiency both fall when humidity rises. Gas turbines perform less work than steam turbines in the case of combined cycles, yet the usage of absorption chillers has a significant negative impact on combined cycle efficiency.

With the power plant under consideration showing a fall in efficiency compared to not cooling the incoming air. A basic cooled gas turbine was examined by Wilcock et al. (2005), who came to the conclusion that the cycle efficiency is influenced by the polytropic A simple gas turbine cycle was examined by Erdem and Sevilgen (2006), who came to the conclusion that as the temperature of the inlet air decreases, the production of electricity rises. The increase in electricity production ranges from 0.27% to 10.28%, with the minimum ambient air temperature being 10°C. A combined cycle with input air cooling and evaporative cooling following the compressor discharge and ultimately before entering the combustion chamber was examined by Khaliq and Choudhary in 2007.efficiency of the turbomachine. the exhaust gas being released from the power turbine warmed the air. According to the authors, the relative humidity has no impact at all on first law efficiency. The scientists further observed that, with the exception of the HRSG, air humidifier, and water heater, energy destruction is also unaffected by relative humidity.

In order to increase the efficiency of the Khangiran refinery in Iran through the use of air inlet cooling techniques, Gord and Dashtebayaz (2011) examined evaporative cooling, mechanical chillers, and expanders in place of the throttling valve. According to the authors' findings, using expanders results in an increase in net power output of 18338 MWh/year as opposed to mechanical chillers and evaporative cooling, which only produce 2501 MWh/year and 1132 MWh/year, respectively. According to an empirical relationship put forth by De and Al (2011), as the inlet air temperature increases by 1°C above ISO norms, there is a corresponding reduction in efficiency and power output of 0.1% and 1.47MW, Gas turbine cycles with evaporative inlet air cooling and air cooling of gas turbine blades were examined by Mohapatra et al. in 2012. The authors came to the conclusion that evaporative cooling resulted in a temperature decrease of 21°C, an increase in work output of 9.44%, and a 4.1% gain in plant efficiency. Pyzik et al. (2012) compared cooling by chillers and cooling by evaporative cooling over five frames and came to the conclusion that mechanical chillers are helpful in conditions where humidity is high and variation in humidity occurs over a wide range while evaporative cooling is appropriate for low relative humidity areas. GE's GE-6101FA and GE-6561B gas turbine frames were examined by Basha et al. (2012), who conducted the analysis using the simulation programme GT PRO. The performance of the gas turbine is not significantly affected or altered by relative humidity, according to the authors. Furthermore, the GE-6561B's net power production increases by 4.6% with a 10 °F drop in atmospheric air temperature and by 4.1% for the GE-6101FA.

The simple gas turbine was examined by Mohapatra and Sanjay (2014) who found that evaporative cooling of the input air and cooling of the gas turbine blades utilising air film cooling increased plant efficiency and specific work output. Ibrahim and Rahman (2013) compared the outcomes with the MARFIQ CCGT after analysing a combined cycle with triple pressure HRSG and duct burner. The authors came to the conclusion that as the temperature drops, more effort is performed for topping and less work is produced for bottoming (for fix CPR, TIT).

Zhang et al. (2014) analysed the performance of combined cycle power plants when comparing cooling by fogging evaporation system and absorption cooling of air. The \sauthors found that evaporative cooling is useful when bigger temperature drop is necessary. There are more applications for absorption cooling, however the coolant selection must be considered. Kilani et al. (2014) came to the conclusion that more extra air reduces the efficiency of all the cycles taken into account. González et al. (2017) examined how atmospheric temperature affects the production of power in Mexico. According to the authors, efficiency decreases from 50.95% to 48.01% as temperature rises from ISO condition to 45°C. The impact of atmospheric conditions, such as relative humidity, ambient pressure (where the power plant is installed), and ambient temperature of the atmospheric air, was discussed by Gu et al. (2016), Li et al. (2016), Jianxing et al. (2012), Zhang et al. (2015), Salahuddin et al. (2015), Jammazi and Aloui

(2015), and Erdem and Sevilgen (2006). Table 1 depicts the some of the key findings of papers.

2. Effect of cycle pressure ratio-

Sanjay (2013) came to the conclusion that there is a high exergy destruction at low cycle pressure ratios. Four distinct gas turbine cycles were examined by Kilani et al. (2014): the simple combined cycle with steam injection, the combined cycle with steam injection and compressed air cooling. Gordetal.(2011)reported that the use of a turbo expander increased electricity use by 18338 MWh/year when compared to evaporative cooling and absorption chillers. Fuel costs rise with a higher cycle pressure ratio, whereas environmental costs fall.

Mitsubishi (2011)A 1700°C turbine inlet temperature for the gas turbine proposed for use in combined cycle power plants is currently being developed.and the cycle pressure ratio of 40 is taken into account for the current investigation. Exergy destruction is shown to be substantial at low cycle pressure ratios, as determined by Huang and Shu (2022). For a certain TIT, Ibrahim and K., &Duan, Y. (2022) found that an increase in CPR results in higher overall efficiency up to 21 CPR but then a decline in efficiency beyond that point. Using existing power plant MARAFIQ in Saudi Arabia as a benchmark, Ibrahim and Rahman (2012) presented the combined cycle gas turbine's parametric thermodynamic analysis. They looked into how different operating factors, including as compression ratio, gas-turbine peak temperature ratio, isentropic compressor efficiency, and AFR, affected the performance of the entire plant. Their findings show that the combined cycle GTPP's total thermal efficiency has a clear impact on the compression ratios, air to fuel ratio, and isentropic efficiencies. Compression ratio, isentropic compressor efficiency, and turbine efficiency all contribute to an increase in overall thermal efficiency. However, the variation in overall thermal efficiency is negligible at lower compression ratios, whereas it is significant for both isentropic compressor and turbine efficiency at higher compression ratios.

Tiwari et al.(2013)performed an exergy analysis of the combined Brayton/Rankine power cycle for several power plant components. The biggest exergy losses were found to occur in the gas turbine's combustion chamber. When pressure ratios and turbine intake temperatures are changed, these effects on exergy losses change as well. According to research by Liu, L., Wu, H., and Liu, W. (2022), closed loop steam cooling provides more specific work output and increases combined cycle efficiency than any of the other methods studied. For plant operations above a cycle pressure ratio of 30, closed loop cooling is recommended. Due to the high turbine intake temperature, it is necessary to study the turbine airfoils in depth, since a temperature increase at any local area of the foil may cause it to fail (Liu, L., Wu, H., & Liu, W., 2022).

It was concluded by Kahraman, U., and Dincer, I. (2022) that a cycle pressure ratio of 38 may provide an efficiency of 56% in a reheat gas turbine using steam blade cooling, which opened a door of possibility for the gas turbine industry. The author also proposed a method of reducing the size of the combustion chamber/reheating combustion chamber via the use of coolant steam, which they say might be a game-changer.

Four different gas turbine cycles were examined by Kilani et al. (2014): the simple combined cycle with steam injection, the combined cycle with compressed air cooling, the combined cycle with steam injection into the combustion chamber and steam extraction from the steam turbine, and the combination between the second and third cycles. One evaluation of the aforementioned cycles found that once an optimal CPR was reached, all of the cycles' efficiency began to decline. The fourth cycle has the highest efficiency [74]. An analysis of a combined cycle with dual pressure HRSG was done by Kaviri et al. (2013). The author's goal was to investigate how CPR affected thermal efficiencies, the environment, and the economy. The authors came to the conclusion that as the CPR rise, the cost of fuel and the cost to the environment decrease. A combined cycle with triple pressure HRSG and steam reheating was examined by Pattanayak et al. (2017). The authors came to the conclusion that when the CPR is raised, so is the amount of extra air needed to maintain a constant TIT. Table 2 shows key findings of the effect of topping cycle parameters

3. Effect of turbine inlet temperature-

Combination cycles were parametrically evaluated by Cerri (1987), who came to the conclusion that, providing the turbine inlet temperature is maintained, the cycle's efficiency is not greatly impacted by changes in pressure ratio. Until this value is quite high, the bottoming cycle's pressure has little impact on the combined cycle's efficiency. In his analysis of the internal combustion engine, Caton (2000) found that as combustion chamber temperature rises, energy destruction in the chamber falls. Pressure has a minimal impact on the destruction of available energy.

Sanjay(2011)indicated that the turbine inlet temperature (TIT) is the factor that most affects cycle performance. The TIT should be kept higher because the exergy demand is higher at lower values. Bassily (2006) examined a mixed cycle that used both air- and steam-cooled closed loops. The highest inflow temperature to the turbine and reheating are used by the author. In comparison to a non-cooled combined cycle with the identical configurations, the authors found that at maximum TIT, irreversibility are decreased to maximum by 1.45-1.65 percent (in terms of efficiency) and gain in specific work produced was 2.65% high. Additionally, according to Khaliq and Choudhary (2007), the combustion chamber of a combined cycle with input air cooling and evaporative cooling of the compressor discharge is where the majority of energy is lost.

The entire plant was separated into three portions by Sengupta et al. (2007) so that the contributions of each thermodynamic component could be examined. The authors also investigate the impact of changing the load. The authors came to the conclusion that exergy destruction is greatest in the combustion chamber (in this example, the boiler), and that operating the cycle at part load causes exergy destruction to rise. Sanjay (2013) investigated an HRSG mixed cycle with three different pressure levels. The exergy destruction is greater for low TIT, and at higher TIT, steam turbine rational efficiency is greater than gas turbine rational efficiency, according to the author's assessment. The opposite is true when labour is produced, though.

Alves et al. (2001) compared the intercooled cycle and the reheat cycle in order to determine which gas turbine cycle is superior. The authors came to the conclusion that reheating is a preferable alternative for combined cycle operation since the exhaust from intercooling is low temperature and not suited for the bottoming cycle. Ibrahim and Rahman (2012), 2013 and 2014 chose to boost TIT rather than CPR in order to increase output and cycle effectiveness. When examining the ATAER power plant in Turkey, Ersayin and Ozgener (2015) discovered that the combustion chamber is where the majority of energy is lost. They recommended that this loss can be reduced by using stronger insulators and by modifying the Sheykhlou (2016) examined a combined cycle that used a wind turbine to power a gas turbine compressor and a Rankine cycle pump. According to the author's findings, the combined cycle's combustion chamber is where the majority of energy is destroyed. The basic air-cooled gas turbine cycle and the gas turbine cycle with reheat were compared by Sahu and Sanjay (2017), who came to the following conclusions-

1. In comparison to a non-reheat type, the reheat gas turbine cycle requires more fuel and coolant air.
2. When compared to a reheat cycle using air cooling, the non-reheat cycle has higher first and second law efficiency.
3. Reheat type gas turbines have higher total investment costs and energy production costs (cents/kWh) than non-reheat types.

   According to research by Balku (2017), if the combustion chamber's efficiency can be raised from 90% to 99%, the plant's thermal efficiency will rise by 6.37%, or 135.5 MW additional thermal energy will be accessible.

4. Effect Of HRVG Pressure-

For figuring out the steam turbines ideal pressure, Carcasci et al. (2017) researched a two pressure level HRSG. For high pressure steam turbine and low pressure steam turbine, the authors arrived at pressures of 60 bar and 8 bar, respectively. ElMasri (1986) performed an exergy analysis of an air-cooled gas turbine cycle and provided detailed information on the exergy losses that occurred in each stage of the turbine, including the stator and rotor, as well as the mechanism of loss, including coolant throttling, main stream pressure loss, friction thermodynamics, and thermal degradation. Exergeticallyanalysing a combined cycle with two steam pressure bottoming cycles, Chin and El-Masri (1986) came to the conclusion that there is a reduction in availability loss from 15% to 8% when compared to the single pressure steam bottoming cycle.

According to Sanjay et al(2007) .'s sensitivity analysis of the combined cycle with triple pressure HRSG, adopting closed-loop steam cooling of the gas turbine blades resulted in an overall efficiency of 61.75% and a work output of 930 kJ/kg. Maheshwari and Singh(2014,2017,2018) found that at 0.7 ammonia mass concentration (in single pressure HRVG), 26.9% more mass of ammonia water mixture is formed than steam, and if just those thermodynamic factors are taken into account that are interacting with the ammonia-water combination, then maximal exergy is destroyed in HRVG (for a triple pressure HRVG).

According to Khaliq and Kaushik (2004), the second law's efficiency falls when the pinch point rises, but it considerably rises as process steam pressure rises. By examining a 1000MW CCPP in Turkey, Cihan (2006) also came to similar conclusions. For the various demands for steam, Colpan and Yesin (2006) computed the rate of available energy destruction. After examining a combined cycle with a triple pressure HRSG, Xiang and Chen (2007) came to the conclusion that the steam turbine's efficiency gradually increased above 590°C at the HRSG's inlet temperature.

Martnez et al. (2011) investigated the impact of excess air on turbine inlet temperature and, consequently, gas turbine power and efficiency at various pressure ratios and excess air. Three HRSGs working under three different conditions—double pressure, triple pressure, and triple pressure with reheating—were examined by Mansouri et al. in 2012. The authors came to the conclusion that the cycle's first and second laws work more effectively when the pressure level of the HRSG is raised. Bassily (2012) optimised a two-reheat combined cycle with a triple pressure HRSG (from GE and Mitsubishi), and came to the conclusion that 62% minimum stack temperature is required to achieve optimal efficiency. Additionally, Bassilycame to the conclusion that the combined cycle's optimization is also influenced by the coolant steam temperature and steam flow ratio. Sanjay (2012) examined the various cycles that were functioning as the combined cycle's bottoming cycle and came to the conclusion that the HRSGs that are operating at the three distinct pressure levels experience the least amount of energy destruction.

A combined cycle with a single pressure HRSG and steam injection, a combined cycle with a single pressure HRSG, steam injection, and cooling of combustion air, a combined cycle with a triple pressure HRSG and steam injection, and a combined cycle with a triple pressure HRSG, steam injection, and all four of the aforementioned components were studied by Kilani et al. in 2014. For all four cycles, natural gas was taken into consideration as the fuel. According to the authors, a triple pressure HRSG with steam injection and air cooling of pre-combustion air attained a maximum efficiency of 52.59%, while a single pressure HRSG with steam injection had a minimum efficiency of 46.59%. In their 2014 study, Mokhtari et al.2016 examined dual pressure HRSG firing with a duct burner. The authors came at the conclusion that the net power output of the CCPP diminishes as the steam turbine pressure rises. The usage of duct burner makes up for this reduction.

In their 2015 analysis of operational data from the Turkish ATAER Energy Power Plant, Ersayin and Ozgener discovered first law efficiency of 56%. The authors recommended installing a unit for cooling the inlet air to the compressor in order to increase the network produced and thereby the efficiency, increasing the heat transfer rates within the HRSG, or installing a preheater unit for heat recovery. Flue gases that are discharged from the HRSG into the atmosphere can also be used for district heating.

Zhang et al. (2016) examined a combined cycle power plant with a triple pressure HRSG and proposed empirical relations for assessing the bottoming cycle's performance. When these empirical relations were compared to the actual data, the errors produced when the bottoming cycle was taken into account were within 1.5%. With regard to exergy destruction in dual pressure HRSG, Sharma and Singh (2016) presented their findings and came to the conclusion that in greater dead states, both the high pressure and low pressure evaporator sections exhibit the greatest exergy destruction. Key findings are depicted in table 4.

Effect of Bottoming Cycle Parameters-

1. Effect of condensor pressure-

Chuang and Sue (2005) examined the air cooled condenser pressure in a combined cycle power plant. The authors came to the conclusion that when cooling air temperature declined by 1°C, the CCPP's power output increased by 0.6% and its efficiency increased by 0.1%. Additionally, a combined cycle power plant's power output will increase by 2.5% if the condenser's pressure is dropped by 0.1bar. In their 2011 thermo-economic analysis of a dual pressure HRSG with additional firing, Ahmadi and Dincercame to the conclusion that a reduction in condenser pressure increases the cycle's overall exergy efficiency. Condenser pressure increase reduces the cycle's ability to use energy effectively. In 2016, Mokhtari et al. examined a dual pressure HRSG firing with a duct burner. The authors further determined that, given a constant duct burner flow rate, work produced by the steam turbine increases as the condenser pressure decreases. According to Pattanayak et al. (2017), steam turbine production falls when cooling water temperature rises due to a drop in condenser pressure. According to Kumar et al(2017) .'s analysis, the exergy efficiency of the condenser.

2. Effect Of Ammonia Concentration –

Multi-component working fluids were advocated for use in the bottoming cycle by Kalina (1984). El-Syed and Tribus (1985) examined the Rankine cycle and the ammonia-water mixture cycle for the identical boundary conditions and came to the conclusion that the ammonia-water mixture cycle will have 13.39% more energy available than the Rankine cycle. Ricardo Vasaquez Padilla et al., Shaouguang et al.,(2014)The thermodynamic cycle was used to assess the ammonia water mixture for cooling and electricity. Sun et al.,(2013)determined that the system performs better when the ammonia content is higher. Maheshwari and Singh (2014,2017,2018,2019) found that at 0.7 ammonia mass concentration (in single pressure HRVG), 26.9% more mass of ammonia water mixture is formed than steam, and if just those thermodynamic factors are taken into account that are interacting with the ammonia-water combination, then maximal exergy is destroyed in HRVG (for a triple pressure HRVG)

Bian et al He discovered that the ammonia concentration affects the cycle's performance parameters, among other parameters, in his work, which presented a combined power and cooling cycle based on an ammonia-water ". mixture and isobutene. Nag et al(1998)emphasised the influence of separator temperature in the ammonia water cycle for minimising the exergy losses and discussed the significance of ammonia mass fraction in reducing the exergy losses. Liuli Sun (2013) they came to the conclusion that a higher ammonia concentration increases system performance and offered a second law efficiency of 36.4% for the configuration taken into consideration in their investigation. Kalina et al(1984)advised using multiple working fluid components in the bottoming cycle. Since the ammonia water mixture does not freeze at very low temperatures, it is employed both for power generation and for cooling purposes.

An ammonia and water combination was the focus of Cao et al(2017) .'s investigation into a combined power and cooling cycle. The authors determined that HRSG is the most efficient exergy-destroying technology when the expander's input temperature is raised. Using experimental methods, Kumar et al. (2017) calculated the first- and second-law efficiency of the combined cycle in generating electricity and cooling. After doing the math, the authors determined that the power to cooling ratio should be 0.14, with first law efficiency at 13% and second law efficiency at 48%. Using a binary combination has been recommended as one method by Chin and El-Masri (1986) to lessen the exergy loss. When Marston and Hyre (1995) compared the single ammonia-water mixture cycle with the triple pressure steam bottoming cycle, they came to the conclusion that the ammonia-water mixture cycle produced about 2% more network. When compared to the triple pressure steam cycle, the net work increased by 11.16% when the triple pressure ammonia-water mixture cycle was used. The steam bottoming cycle, the single stage ammonia-water mixture cycle, and the triple pressure ammonia-water mixture cycle's respective efficiency levels were found to be 49.93%, 50.29%, and 51.88%. The authors also used the Monte Carlo approach to determine the ammonia mass fraction optimum values at various state points of the triple pressure ammonia-water mixture cycle, and they reported a value of 0.75 as the optimum value as opposed to the 0.70 original value.

Heppenstall (1998) evaluated the relative relevance of several power generating cycles, including the combined cycle, ammonia-water mixture cycle, gas/gas recuperation, steam injection, evaporation, and chemical recuperation cycles. The author made a note about how the fuel prices and the availability of natural gas or other fuel for power cycles could alter the future scenario, but the ammonia-water mixture cycle is unaffected by these factors and can provide higher efficiency. In addition to highlighting the impact of separator temperature in the ammonia-water cycle for minimising exergy losses, Nag and Gupta (1998) discussed the significance of ammonia mass fraction in lowering exergy losses.

Several authors examined the ammonia-water mixture cycle and came to the conclusion that, if the cycle is operating at low to moderate temperature, a mixture of 70% of ammonia concentration by mass is best suited for the cycle. These authors included Valdimarrson et al. (2003), Wall et al. (1989), Desideri and Bidini (1997), and Leibowitz and Mlcak (1999). In their 2003 study of a combined power and cooling cycle (combined Rankine cycle and absorption refrigeration cycle), Vijayaraghavan and Goswami suggested a revised first law and second law definition that takes cooling impact into account. This binary mixture is employed for both power generation and providing a cooling effect because ammonia-water does not freeze at very low temperatures.

Liuli Sun (2013) came to the conclusion that an increase in ammonia concentration improves system performance and discovered second law efficiency of 36.4% for the configuration taken into account in their investigation. The combined power and cooling cycle was examined by Armando Fontalvo et al. (2013), who came to the conclusion that the boiler and absorber are where the majority of energy is lost. In their analysis of the heat recovery vapour generator (HRVG), Kim et al. (2014) came to the conclusion that the ammonia-water mixture exhibits a non-linear temperature distribution when the ammonia mass percentage and pressure are varied while the other HRVG parameters are held constant. Additionally, the second law efficiency of HRVG declines with increasing ammonia content or lowering mixture pressure as the entropy generation rises. Shankar and Srinivas (2014) investigated the solar-heated combined vapour power and cooling cycle. According to the authors, a temperature of 150°C and an ammonia mass fraction of 0.99 result in a power output of 14.05 kW and a cooling effect of 73.58 kW, respectively. However, this number can be altered by changing the ammonia mass fraction at the turbine's input. According to Chen et al., a three pressure level ammonia-water cycle should be utilised if the source temperature is greater than 145°C, and a two pressure level ammonia-water cycle should be used if the source temperature is lower than the stated temperature (2017).

The study of G. Solemani Alamdari (2007), which calculates the mole fraction in the vapour phase for a pressure range of 0.2 bar to 100 bar and ammonia mass fraction in the liquid phase in the range of 0 to 1 inclusive of both values, has estimated the ammonia mole fraction in vapour phase. The efforts of Patek and Klomfar (1995) have been used to estimate the mixture's bubble point and dew point temperature. Based on the Gibbs approach, Ziegler et al. (1984) develop the equations for calculating the thermodynamic characteristics of the ammonia-water combination.

3.Effect of deaerator pressure-

In addition to removing dissolved gases from supply water, a deaerator's placement also impacts the efficiency of the combined cycle. Srinivas (2009). When comparing a deaerator with a flash chamber system, Varma and Srinivas (2016) found that the deaerator temperature ratio should be kept low for maximum power, whereas the cycle's efficiency increases up to a deaerator temperature ratio of 0.5 and then begins to decline, for a given HRSG pressure. Srinivas(2009) discovered that in order to increase the efficiency of a combined cycle, a deaerator should be inserted in between the low and intermediate pressure heaters (of a triple pressure HRSG).

4. Effect of Separator Temperature-

The study of Ganesh, N. S., & Srinivas, T. (2012)Thermodynamic and parametric modelling and analysis have been done for a solar thermal power plant based on the Kalina power system. At the separator temperature of 110–150 C, strong solution concentration of 0.65–0.8, turbine inlet concentration of 0.92-0.955, and solar beam radiation of 400–700 W/m2, the plant's performance has been examined. For conditions of greatest efficiency and highest power, the ideal separator temperature differs.In comparison to the highest efficiency conditions at a fixed strong solution concentration, the maximum power can be attained at a lower separator temperature. While the strong solution concentration affects the low pressure, the turbine inlet concentration affects the high pressure. High solar beam radiation and ideal cycle conditions can be used to get the lowest collector cost. By comparing the available plant readings and the literature, the thermodynamic model has been proven to be accurate.

The study of Assad, M. E. H.et al.(2021),To establish the ideal separator temperature, which led to the steam turbine's maximum power production, a new thermodynamic methodology was utilized. It was discovered that the separator performs at its maximum power when the condenser and production well temperatures are averaged out. Therefore, given the range of geothermal well temperatures taken into account in this study, the optimum separator temperature occurred at a temperature between 9 and 12%. where the power plant's thermal efficiency was at its highest. For the examined ranges of geothermal well temperatures of 175 and 150°C, the exergy destruction rates of the expansion, steam turbine, mixing process, and pump were in the range of 2726 and 1789, 1780 and 1060, 690 and 362, and 5 and 7 kW, respectively. As a result of the findings, it is advised that the separator run at the ideal temperature for all geothermal well temperatures. The study of Nag, P. K., & Gupta, A. V. S. S. K. S. (1998)The current paper analyses the Kalina cycle from both the first and second law points of view and offers a logical method for calculating the parameters of the NH3-H2O mixture. The separator temperature and the turbine inlet condition (i.e., x9, T9) have been identified as the crucial variables that influence the cycle as a whole (T4). A collection of other operational parameters, however, have an ideal value for x9 such that the cycle's exergy loss is minimal.

5. Effect of Bottoming Cycle Pressure-

The study of Maheshwari, M., & Singh, O. (2018), concluded that maximum work output is 2058kJ/kg of compressed air at ambient temperature of 20°C and ammonia mass fraction of 0.9, with first law efficiency of 62.71% and second law efficiency of 60.03% for CCAWC. At a CPR of 40, TIT of 2000K, an ammonia mass fraction of 0.6, and an ambient temperature of 30°C, a combined cycle configuration utilising steam and an ammonia water mixture as coolant (CCSAWC) generates 2.6% more work than a combined cycle configuration using only an ammonia water mixture (CCAWC). For a combined cycle design employing steam and ammonia water combination as coolant, it is 0.057 for cycle pressure ratio of 40, turbine inlet temperature of 2000K, and ammonia mass fraction of 0.7. Coolant to gas flow ratio rises as turbine inlet temperature rises. With regard to an 8 configuration employing steam and an ammonia water combination, the gains in work produced, first law, and second law efficiencies are 2.8, 0.8, and 0.4 percentage 9 point basis, respectively. In the combustion chamber and the heat recovery vapour generator, the most energy is lost.

Parametric studies of the combined cycle by E. Y., da Silva, R. L., and Higa, M. (2022) showed that a very small change in the pressure ratio of the cycle had no effect on the efficiency of the cycle, provided that the turbine intake temperature was held constant. Even at this extreme number, the bottoming cycle pressure has little effect on the combined cycle's performance. The study of Zhonget al.(2021)The outcome demonstrates that the bottom cycle system, while operating under sliding pressure, has the optimum thermal performance when the gas turbine load decreases. But for the sliding pressure operational mode, the HP approach point temperature difference significantly decreases and drops to less than 2 °C below 74.21% load. It can be clearly increased by the constant HP operational mode at the expense of an increase in the irreversible loss of the bottom cycle system. For the constant HP operational mode, the exergy destruction of the HPsh1 and HPeva is 1.38 MW and 3.15 MW, respectively, which is 0.29 MW and 0.84 MW less than that for the sliding pressure operational mode.However, for the constant HP operational mode, the exergy destruction of IPeva, mixing steam, and HPST is 0.98 MW, 1.18 MW, and 4.04 MW, respectively, which is 0.28 MW, 1.08 MW, and 1.41 MW greater than that for the sliding pressure operation mode. The HP approach point temperature difference is equal to 2 °C bellow 74.21% load after the new steam turbine operational mode taking into account both sliding pressure and fixed HP is implemented. The bottom cycle system has a higher energy efficiency and output power, though. Thermal efficiency and output power of the bottom cycle system drop as the gas turbine load rises to 26.47% and 71.23 MW at 40% load, respectively, which are 0.53% and 1.45 MW higher than those for the constant HP system.

Sanjay (2012) evaluated the various cycles that were working as a bottoming cycle in a combined cycle (in terms of energy and exergy), and came to the conclusion that exergy destruction is minimal for the HRSGs that are running at three different pressure levels. Meeta et al.,(2016)Further analysis of the exergy destruction data in the dual pressure HRSG led to the conclusion that the high pressure and low pressure evaporator sections exhibit the greatest exergy destruction at higher dead states. The study of Maheshwari, M., & Singh, O. (2017).The heat recovery vapour generator accounts for roughly 54.2% of the total availability destroyed among the various combined cycle components under consideration. The low pressure gas turbine comes in second with exergy destruction at 23.6% of the total exergy destroyed. The absorber experiences a maximum availability destruction of 10% of the total availability destruction when taking into account the low pressure turbine cycle (or the ammonia-water mixture cycle).

6. Effect of Cooling Load-

The study of Chen et al.(2017)For the first time, a comparison of theoretical and actual cooling load is suggested based on whether mass correction factor mw is taken into account. When the inlet air temperature falls below the dew point, the cooling load will increase significantly as a result of the air dehumidification. The practical cooling load is greater than the theoretical cooling load 2.76 MW when ambient temperature is 30 °C and ambient RH is 0.6

Combined Power Cycle Using Trans critical Carbon dioxide-

Zhang et al., (2021) thermodynamic study was performed, and the suggested system was compared to the normal reference cycles for various operating modes. The proposed system utilises the waste heat from the main engines of a large cruise ship cruising in the Baltic Sea to power a transcriticalCO2 Rankine cycle and an ejector refrigeration cycle. Despite producing less net power under design circumstances, a parametric analysis shows that the proposed ETCRC in Mode-SAW outperforms the traditional RORC using R123 as the working fluid in terms of exergetic efficiency and heating capacity. • In Mode-S operation, the maximum cooling effect and net power of ETCRC are 863.3 kW and 202.9 kW, respectively, as shown by the optimization findings.

A combined cycle system combining two supercritical CO2 (S-CO2) cycles and one organic Rankine cycle (ORC) is presented. We explore how several factors, such as thermal efficiency, exergy efficiency, and unit cost, affect the overall performance of the system. Using Propane as addition in CO2-based binary mixture may not only boost thermodynamic performance, but also is conductive to its exergoeconomic feature. Thermodynamic research reveals the biggest overall capital cost occurs in the gas turbine system which accounts for 71.61%. Parametric analysis reveals that choice factors have distinct influence on the total system performance. Sun et al (2021), after the optimization for exeroeconomic performance, thermal efficiency, exergy efficiency and unit cost are 48.56%, 51.90% and 3.66 cent/kW h, respectively. The findings also demonstrate the usefulness of employing Propane as addition in CO2-based binary mixtures of S-CO 2 cycle to increase the system performance for waste heat recovery. Liu et al.(2020)The primary goals of the s-CO2 power cycle are to increase the quantity of waste heat regenerated and to increase the cycle's thermodynamic efficiency. The technological challenges between heat source properties, system thermodynamic performance, and cost are targeted for resolution.

Zhao et al (2020) modified CO2 power cycle with internal heat recovery is simpler to execute than the ideal cycle. Maximum net work production of 109.99 kW is achieved in the modified cycle with high-pressure of 15 MPa and low-pressure of 2.25 MPa for flue gas at 500 °C and cooling water at 15 °C. In the case of waste heat recovery, the performance of the modified cycle is enhanced above that of the conventional cycle.

Karki (2020) There is a linear relationship between the amount of power generated and the inlet air temperature and volume of the gas turbine. The compressor pressure ratio and the waste heat boiler steam amount are the most critical elements after the natural gas and power use for a reduced payback in a gas turbine-based CHP. Future work on this research study entails the construction of a dynamic DSS by expanding the number of parameters for the boilers and the steam turbine. Develop a dynamic DSS procure outcomes of a topping cycle CHP system over time.

Table 1 depicts some key findings of the literature review considered in paper

Table 1: Key findings of the literature review considered in paper

S.N.	Year	Title Of Paper	Author	Key Finding

1	2020	Energy and exergy analysis of the combined cycle power plant recovering waste heat from the marine two-stroke engine under design and off-design conditions.	Zhu, S., Ma, Z., Zhang, K., & Deng, K.	the compressor, combustion chamber, gas turbine, HRSG, boiler, steam turbine, and heat generator are all incorporated in the combined cycle power plant
2	2017	Thermal performance of gas turbine power plant based on exergy analysis.	Ibrahim, T.K., Basrawi, F., Awad, O.I., Abdullah, A.N., Najafi, G., Mamat, R. and Hagos, F.Y.,	Numerous authors have discussed the impact of ambient conditions, including humidity, temperature, and pressure, on the cycle's performance and have come to the conclusion that these factors have no impact
3	**2022**	Theoretical and experimental study on the performance of a high-efficiency thermodynamic cycle for ocean thermal energy conversion.	Peng, J., Ge, Y., Chen, F., Liu, L., Wu, H., & Liu, W.	closed loop steam cooling provides more specific work output and increases combined cycle efficiency than any of the other methods studied.For plant operations above a cycle pressure ratio of 30, closed loop cooling is recommended
4	**2022**	Performance analysis of a solar based waste to energy multigeneration system	Kahraman, U., &Dincer, I	that a cycle pressure ratio of 38 may provide an efficiency of 56% in a reheat gas turbine using steam blade cooling, which opened a door of possibility for the gas turbine industry
5	2017	Comparative exergoeconomic analysis of basic and reheat gas turbine with air film blade cooling.	Sahu, M.K., Sanjay	The power plant's second law efficiency was determined to be 50.04%.
6	2017	Comparative exergoeconomic analysis of basic and reheat gas turbine with air film blade cooling.	Sahu, M.K., Sanjay	In comparison to a non-reheat type, the reheat gas turbine cycle requires more fuel and coolant air.

7	2017	Effect of a real steam turbine on thermoeconomic analysis of combined cycle power plants.	Carcasci, C., Cosi, L., Ferraro, R. and Pacifici, B.,	For high pressure steam turbine and low pressure steam turbine, the authors arrived at pressures of 60 bar and 8 bar, respectively.2017
8	2016	Thermo-Economic Analysis and Multiobjective Optimization of Dual Pressure Combined Cycle Power Plant with Supplementary Firing	Mokhtari, H., Esmaieli, A. and Hajabdollahi, H.,	The authors came at the conclusion that the net power output of the CCPP diminishes as the steam turbine pressure rises.2016
9	2016	Thermodynamic performance simulation and concise formulas for triple-pressure reheat HRSG of gas–steam combined cycle under off-design condition.	Zhang, G., Zheng, J., Yang, Y. and Liu, W.,	examined a combined cycle power plant with a triple pressure HRSG and proposed empirical relations for assessing the bottoming cycle's performance.2016
10	2017	Thermodynamic analysis of a Kalina-based combined cooling and power cycle driven by low-grade heat source.	Cao, L., Wang, J., Wang, H., Zhao, P., & Dai, Y	investigation into a combined power and cooling cycle.The authors determined that HRSG is the most efficient exergy-destroying technology when the expander's input temperature is raised.Using experimental methods
11	2014	Energy and Exergy Analysis of the Kalina Cycle Based Combined Cycle Using Solar Heating.	Maheshwari, M. and Singh, O.,	found that at 0.7 ammonia mass concentration (in single pressure HRVG), 26.9% more mass of ammonia water mixture is formed than steam, and if just those thermodynamic factors are taken into account that are interacting with the ammonia-water combination, then maximal exergy is destroyed in HRVG (for a triple pressureHRVG)
12	2014	Assessment of pinch point characteristics in heat exchangers and condensers of ammonia–water based power cycles.	Kim, K.H., Ko, H.J. and Kim, K.,	came to the conclusion that the ammonia-water mixture exhibits a non-linear temperature distribution when the ammonia mass percentage and pressure are varied while the other HRVG parameters are held constant

13	2022	Performance improvements on energy and exergy basis for an ammonia-water absorption refrigeration system in a coffee industry.	Yamamoto, E. Y., da Silva, R. L., &Higa, M	showed that a very small change in the pressure ratio of the cycle had no effect on the efficiency of the cycle, provided that the turbine intake temperature was held constant
14	2021	New steam turbine operational mode for a gas turbine combine cycle bottoming cycle system.	Zhong, Z., Huo, Z., Wang, X., Liu, F., & Pan, Y.	The outcome demonstrates that the bottom cycle system, while operating under sliding pressure, has the optimum thermal performance when the gas turbine load decreases.For the constant HP operational mode, the exergy destruction of the HPsh1 and HPeva is 1.38 MW and 3.15 MW, respectively, which is 0.29 MW and 0.84 MW less than that for the sliding pressure operational mode.
15	2018	Effect of atmospheric condition and ammonia mass fraction on the combined cycle for power and cooling using ammonia water mixture in bottoming cycle.	Maheshwari, M., & Singh, O	Concluded that Maximum work output is 2058kJ/kg of compressed air at ambient temperature of 20°C and ammonia mass fraction of 0.9, with first law efficiency of 62.71% and second law efficiency of 60.03% for CCAWC.
16	2017	Exergy analysis of intercooled reheat combined cycle with ammonia water mixture based bottoming cycle.	Maheshwari, M., & Singh, O	The heat recovery vapour generator accounts for roughly 54.2% of the total availability destroyed among the various combined cycle components under consideration.The low pressure gas turbine comes in second with exergy destruction at 23.6% of the total exergy destroyed.
17	2016	Power-Augmented Steam Power Plant in a Cogeneration Cement Factory	PradeepVarma, G.V. and Srinivas, T	When comparing a deaerator with a flash chamber system, Varma and Srinivas (2016) found that the deaerator temperature ratio should be kept low for maximum power, whereas the cycle's efficiency increases up to a deaerator temperature ratio of 0.5 and then begins to decline, for a given HRSG pressure.

18	2017	Peaking capacity enhancement of combined cycle power plants by inlet air cooling—Analysis of the critical value of relative humidity.	Chen, J., Huang, H., Li, W., & Sheng, D.	For the first time, a comparison of theoretical and actual cooling load is suggested based on whether mass correction factor mw is taken into account.When the inlet air temperature falls below the dew point, the cooling load will increase significantly as a result of the air dehumidification.
19	2021	Thermodynamic analysis and multi-objective optimization of a transcritical CO2 waste heat recovery system for cruise ship application.	Zhang, Q., Luo, Z., Zhao, Y., Pavel, S.	Thermodynamic study was performed, and the suggested system was compared to the normal reference cycles for various operating modes. The proposed system utilises the waste heat from the main engines of a large cruise ship cruising in the Baltic Sea to power a transcriticalCO2 Rankine cycle and an ejector refrigeration cycle.
20	2021	Thermodynamic and exergoeconomic analysis of combined supercritical CO2 cycle and organic Rankine cycle using CO2-based binary mixtures for gas turbine waste heat recovery.Energy.	Sun, L., Wang, D., Xie, Y	. After the optimization for exeroeconomic performance, thermal efficiency, exergy efficiency and unit cost are 48.56%, 51.90% and 3.66 cent/kW h, respectively.
21	2020	Supercritical Carbon Dioxide(s-CO2) Power Cycle for Waste Heat Recovery:	Liu, L., Yang, Q., Cui, G	The primary goals of the s-CO2 power cycle are to increase the quantity of waste heat regenerated and to increase the cycle's thermodynamic efficiency.
22	2020	Transcritical carbon dioxide power cycle for waste heat recovery.	Zhao, D., Zhao, R., Deng, S., Zhao, L., Chen, M.	Modified CO2 power cycle with internal heat recovery is simpler to execute than the ideal cycle. Maximum net work production of 109.99 kW is achieved in the modified cycle with high-pressure of 15 MPa and low-pressure of 2.25 MPa for flue gas at 500 °C and cooling water at 15 °C.
23	2020	Evaluation of Process and Economic Feasibility of Implementing a Topping Cycle Cogeneration System (MS).	Karki, U	There is a linear relationship between the amount of power generated and the inlet air temperature and volume of the gas turbine. The compressor pressure ratio and the waste heat boiler steam amount are the most critical elements after the natural gas and power use for a reduced payback in a gas turbine-based CHP.

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