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On a environmentally friendly supply of energy

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Abstract

In the paper a concept of enviromental compatible energy supply is discussed. A many aspects, theoretical comparison of organic Rankine cycle (ORC) and the Kalina process has been presented. The first cycle (ORC) deals low boiling point working fluid in power plants. The second cycle uses different mixtures of the circulated medium.

Keywords: Geothermal energy; ORC; Kalina power plant

1 Introduction

The energy production must meet not only the discussed criteria of security and lastingness, but also make available environmental conditions like [1]:

- to secure and improve the living conditions of the increasing population of world,
- to dam around further loads of the living conditions by environmentally hazardous materials,
- to be able to adapt around the future living conditions to inevitable changes of the environment.

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2 Effect of CO_2 on the environment versus geothermal energy

The carbon dioxide (CO_2) developing inevitably within the burn of fossil sources of energy is delivered into the atmosphere and there together with other trace gases and altogether still strengthened by water vapor those radiation of warmth into space, which must compensate the energy irradiated during the day by the sun [3, 6]. Since our use of the fossil fuels as main energy sources the carbon dioxide content of the atmosphere is around a third, of 0.28 parts per thousand of the air volume forwards approx. 200 years risen to at present 0.37 parts per thousand. In the same period the temperature rose on Earth in the global and seasonal means around a degree, which is attributed also to the risen carbon dioxide content of the atmosphere [1, 13, 15, 16].

With in the future still rising consumption of fossil fuels must be counted during unrestricted release by carbon dioxide on a reinforcement of the present greenhouse effect. Already the temperature stroke caused additional risks of a climatic change, which could have serious effects. To the possible risks belong, e.g., an increase of storms and strong precipitation, an expansion of subtropical drying zones, a rise of the sea level and rapid change of climate. The prognoses are mostly based on complex computer models, which consider important aspects of the climatic system of atmosphere, oceans, continents and biosphere. In particular in the past 10–15 years these computer models were constantly improved, not least by an extensive and better database and a refined parameterize. There are still numerous uncertainties nevertheless. Progress in restricting the prognosis uncertainties to the climatic course one expects, e.g., from refined flow models of the thermal circulation in the oceans. Also examinations of the climatic models due to genuine long-term observations, available now from the research development, can contribute to it. But it is possible to measure with difficulty nonlinear and abrupt reactions [1, 8, 10].

Thermal efficiency with reversible processes for geothermal power stations with secondary cycle the thermal efficiency is appropriately defined as quotient of the enthalpy difference during isentropic (more reversible) relaxation of the working medium to the enthalpy increase during preliminary heating and evaporation. However, the thermal efficiency of an ideal, completely reversible thermal engine, which works between two of reservoir with infinite capacity, is the Carnot efficiency. Geothermal power stations with secondary cycle (Fig. 1) are available with no reservoir of infinite capacity [9, 11, 12]. The heat source cools down by the heat supply to the process, while the heat sink warms up by the heat dissipation from the process. Thus at least a condition for the application of the Carnot efficiency is not fulfilled. Thus, for the estimation the upper border of the thermal efficiency of reversible thermal engines, which work between reservoir limited capacity, should be regarded firstly a strongly idealized model of the thermal engine and its environment.

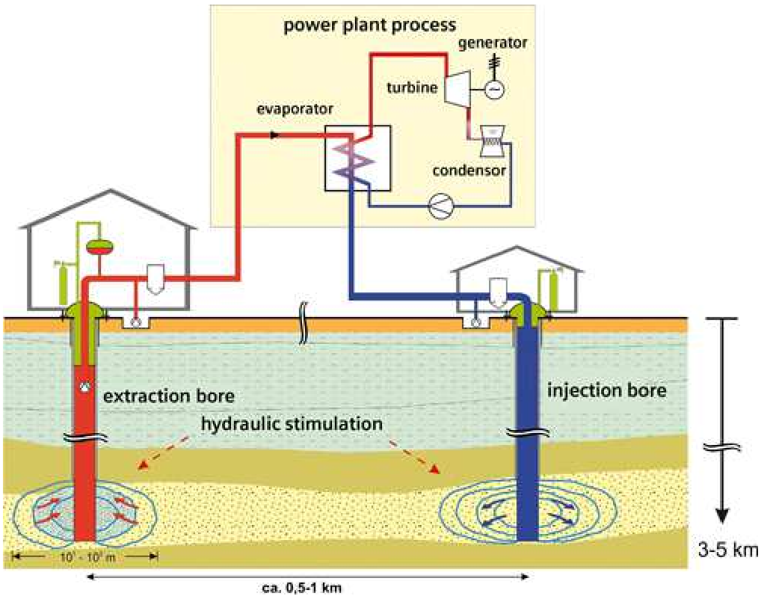

Figure 1. Characterized the upper and underground of the thermal water cycle as well as the power station cycle.

The following representation orients itself at the derivation of Bejan (Fig. 2). The grey rectangle marks a range with adiabatic borders, from which mechanical achievement is exhausted. The system works in the stationary condition. Within the grey range reversible processes take place excluding, i.e., no entropy is produced. The range is flowed through by two fluxes with same mass flow. With both fluxes it acts around ideal a gas with identical material properties. The pressure of the flux is with ambient pressure and changes not. The warm flux occurs with a firm temperature and serves as heat source for a power station process. The cold flux serves as heat sink, its inlet temperature is likewise fixed. The heat supply to the power station process as well as the heat dissipation from the process take place reversibly. The power station process is not represented in the illustration [18]. However the cold flux is to warm up only little, while the warm flux is cooled down. Idealized model of this heat characteristic consists therefore of a heat source with finite capacity [17, 18]:

- i.e., variable temperature of the warm flux,
- and a heat sink with constant temperature of the cold flux.

For illustration the Carnot efficiency and the efficiency of the reversible thermal engine, which works between a finite warm and an infinite cold heat reservoir in the point of the maximum achievement, over the temperature of the heat source laid on. The temperature of the heat sink amounts to 15 °C. The Carnot efficiency achieves nearly twice as high values in the entire regarded temperature range. With increasing temperature the relationship becomes smaller slightly. With 100 °C water temperature 53% of the Carnot efficiency amounts, with 200 °C it is 59%.

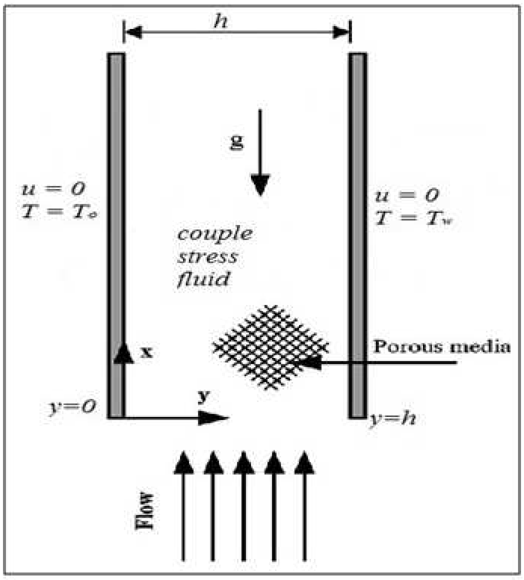

Figure 2. Model of derivation of Bejan [18].

2.1 The organic Rankine cycle

The organic working fluid is vaporised by application of a heat source in the evaporator. The organic fluid vapour expands in the turbine and is then condensed using a flow of water in a shell-and-tube heat exchanger (alternatively, ambient air can be used for cooling). The condensate is pumped back to the evaporator thus closing the thermodynamic cycle (Fig. 3). Heating and cooling sources are not directly in contact with the working fluid nor with the turbine. For high temperature applications (e.g., combined heat and power CHP, biomass-powered plants), high temperature thermal oil is used as a heat carrier and a a regenerator is added, to further improve the cycle performance [7, 9, 11].

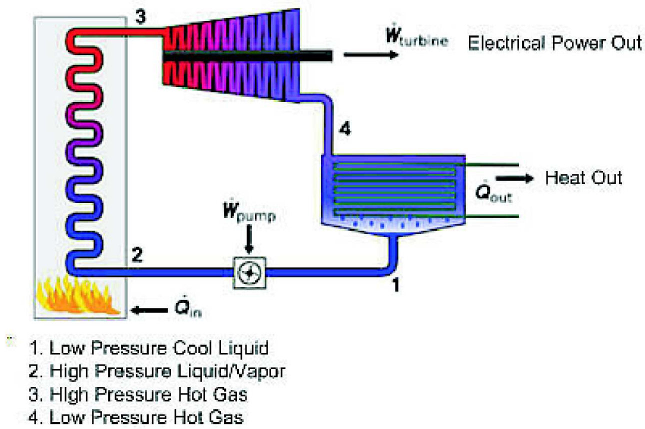

Figure 3. An idea of organic Rankine cycle.

2.2 The Kalina process

The Kalina process is based on the use of a binary active medium, a mixture of water and ammonia. The mixture ratio of the circulated medium can be varied as required. In contrast to single active media, such as water or pentane, the ammonia-water mixture boils over a wider temperature range at a given pressure level. The efficiency of a Kalina geothermal power plant (Fig. 3) is thus significantly higher than that of a water-steam cycle or an organic Rankine cycle (ORC) and provides good efficiency even at low temperatures [13, 14]. Electricity cannot be economically produced using conventional technologies from low temperature sources, such as thermal water with temperatures between 100 °C and 150 °C. Kalina technology, in contrast, can generate approximately 4.1 MW rated output from 100 l/s at a temperature of 150 °C.

The technique is named after Dr. Alexander Kalina. The 'Kalina' technology has been developed over two decades, however the commercial marketing of the technique started only a few years ago. Behind the developed technique was the idea to use the waste heat of different industrial sources, like gas turbine or other combustion processes.

Ammonia and water, as well as other single component media vaporises and condensates at a stable/constant temperature. But the technical feature of the 'Kalina' technology is coming from the ammonia-water mixture, which evaporates over a large temperature range (see Fig. 4). This feature gives the opportunity to utilize sensible heat sources more effectively compared to a single component media. This leads to an effectiveness increase of the electrical power generation by 20–40% compared to the well known ORC [2]. Comparison of efficiency of Carnot, ORC and Kalina process is presented in Fig. 5.

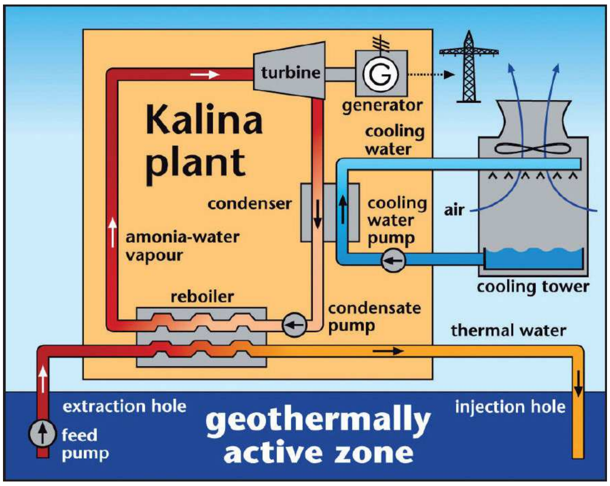

Figure 4. Model of Kalina power geothermal plant.

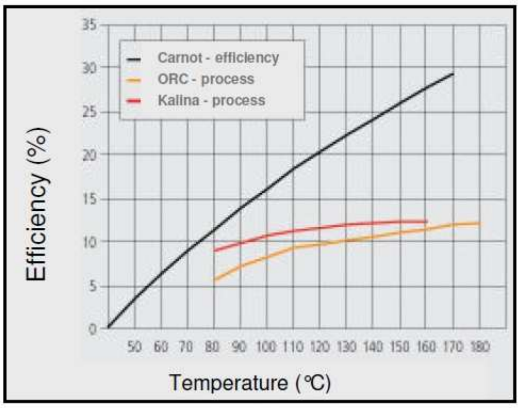

Figure 5. Comparison of Carnot, ORC and Kalina efficiency as a function of geothermal temperature.

3 Electrical generator achievement and internal requirement of a geothermal power station

Generator achievement and internal requirement for the estimation of the economy of a power station at a certain location are crucial, which generator achievement can produce a geothermal propelled of power station with the heat source, characterized by temperature and mass flow of the thermal water.

The straight lines for water cooling and air-cooling form in each case the upper and/or lower limit of the generator achievement. The generator achievement of the ORC plants shows a larger sensitivity than the generator achievement of the potash well plants in relation to the kind of the cooling. Besides the kind of the cooling has larger influence on the generator achievement than with small temperature of thermal water. This expresses itself in each case in the larger surfaces between the straight line for air-cooling and water-cooling. For the ORC plants thus straight in the lower temperature range should be put in the kind of the cooling value. The larger sensitivity of the ORC plants in relation to the kind of the cooling results from the cooling down efficiency, which likewise depends for the ORC plants more strongly on the kind of the cooling than for the Kalina plants. The generator achievement is proportional to the product of thermal efficiency and cooling down efficiency. The thermal efficiency of the potash well plants is higher than the thermal efficiency of the ORC plants. Their cooling down efficiency against it is in particular in the upper temperature range clearly under the cooling down efficiency of the ORC plants. Consequently the ORC plants straight for thermal water temperature of 150 make °C and more highly a larger generator achievement possible than the Kalina plants.

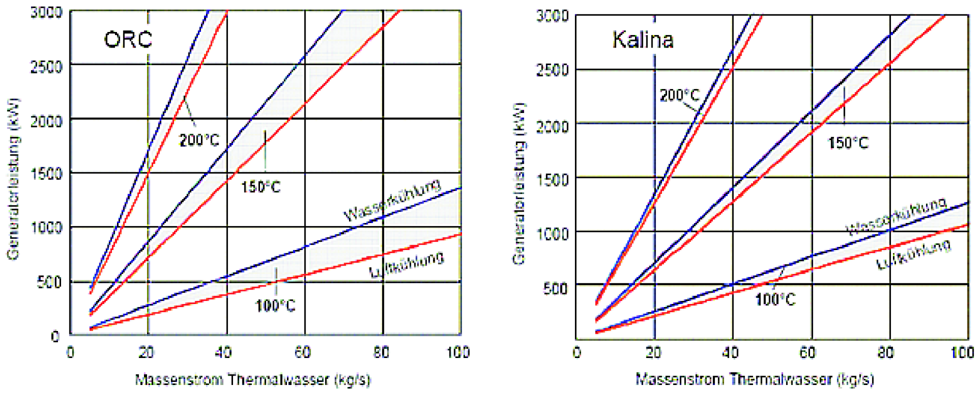

Figure 6. Comparison of ORC and Kalina processes.

Comparison of ORC and Kalina process (Fig. 6) show the generator achievement as a function of the promotion rate for 100, 150 and 200 °C warm thermal water generator achievement depends linear on the promotion rate of the thermal waters. The straight lines for water cooling and air-cooling form in each case the upper and/or lower limit of the generator achievement. The generator achievement of the ORC plants shows a larger sensitivity than the generator achievement of the potash well plants in relation to the kind of the cooling. Besides the kind of the cooling has larger influence on the generator achievement than with small temperature of warm water. This expresses itself in each case in the larger surfaces between the straight line for air-cooling and water-cooling. For the ORC plants thus straight in the lower temperature range should be put in the kind of the cooling value.

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With water-cooled plants the deep pump causes the largest part of the internal requirement, with air-cooled plants against it is the drives of the fans the largest consumers. The small thermal efficiency of the ORC plants leads compared with the Kalina plants, in particular during air-cooling, to a higher internal requirement with the heat dissipation. For thermal water temperatures around 100 °C the internal requirement can rise over the generator achievement and become smaller so the system efficiency zero with unfavorable cooling conditions. In the regarded system configuration this is for the air cooling the case: with 100 °C thermal water temperature and the accepted dynamic water level of 200 m under area upper edge the total output of the pumps and fans exceeds the generator achievement around 17%.

4 Conclusions

Considered in all following views power plant configurations will not become large, for air-cooled ORC plants in the following hot water temperatures of at least 125 °C assumed. The internal requirement of the watercooled ORC plants amounts to scarcely 50% to 12 % of the generator achievement. With 100 °C hot water temperature the deep pump uses 24% of the generator achievement. With rising thermal water temperature decreases the portion of the internal requirement of the generator achievement, to it with the 200 °C hot water temperature altogether approx. 12% amounts to. Each of aggregate contributes the same part (4%). The internal requirement of air-cooled ORC plants lies in all cases clearly over the internal requirement of water-cooled ORC plants. With a hot water temperature of 200 °C the internal requirement of air-cooled ORC plants amounts to still over 40% of the generator achievement. For the drive of the fans 62 becomes – 31% of the generator achievement needs.

The internal requirement of the potash well plants in the point of the maximum achievement is clearly under the internal requirement of water-cooled ORC plants. Also the air-cooled Kalina plants off the point of the maximum achievement (hot water temperature 175 °C and 200 °C) have a smaller portion of the internal requirement than the appropriate ORC plant. Only for the water-cooled Kalina plant with 200 °C thermal water temperature the portion of the internal requirement of the generator achievement is more highly than with the appropriate ORC plant.

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