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Effects of Turbine Efficiency to Small-Scale ORC Process Electricity Production and Profitability

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Abstract

The Organic Rankine Cycle (ORC) consists at least of a turbine, a pump, a condenser and an evaporator. The optimal operation of all process components is important to the efficient performance of the ORC. This is especially true in case of small electrical output and low evaporation temperature processes where initial conditions are not supporting the high efficiency. The turbine efficiency can vary widely and it is affected by many factors e.g. the operation point, size, design and type of the turbine. Also when optimum operation of the turbine is sought, the maximum efficiency of the turbine is obtained using highly laborious and complex techniques. Therefore, it is important to study the necessity of achieving the top efficiency.

Introduction

In this study, the sensitivity of the turbine efficiency to the ORC process is evaluated. The ORC process (see Fig. 1.) is designed to produce about **10 kW** of electric power and the heat source temperature is about 400 degree of centigrade. The working fluid of the cycle is siloxane, MDM. The electric efficiency of the ORC process is rather insensitive for the turbine efficiency. **The change in the electrical efficiency of the process is about 0.2 percent while the isentropic efficiency of the turbine changes one percent** (see Fig. 2a) . The slope of the curve is linear, respectively.

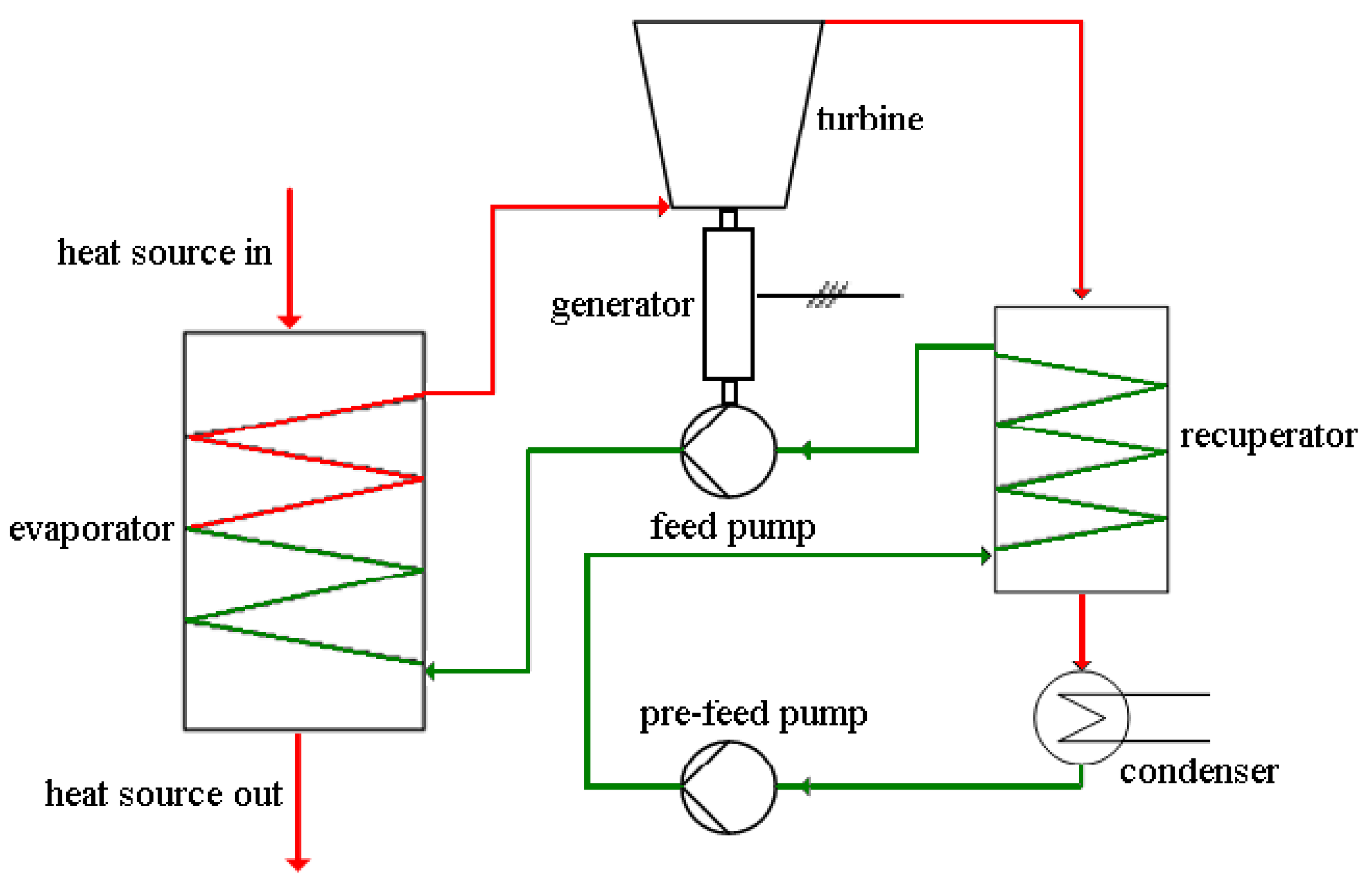

Fig. 1. Schematic diagram of the examined ORC process

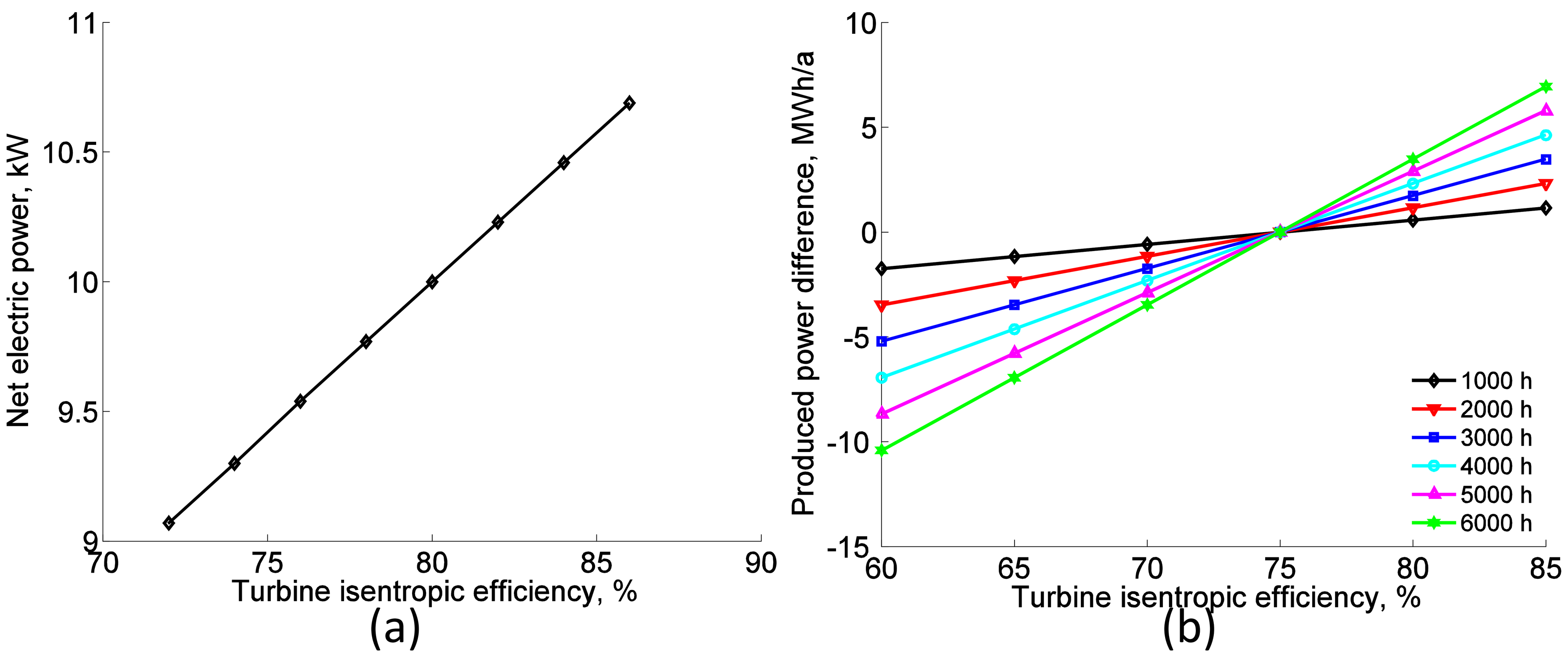

Fig. 2. (a) Electric power as function of isentropic efficiency and (b) produced energy as function of utilization period of maximum load and isentropic efficiency

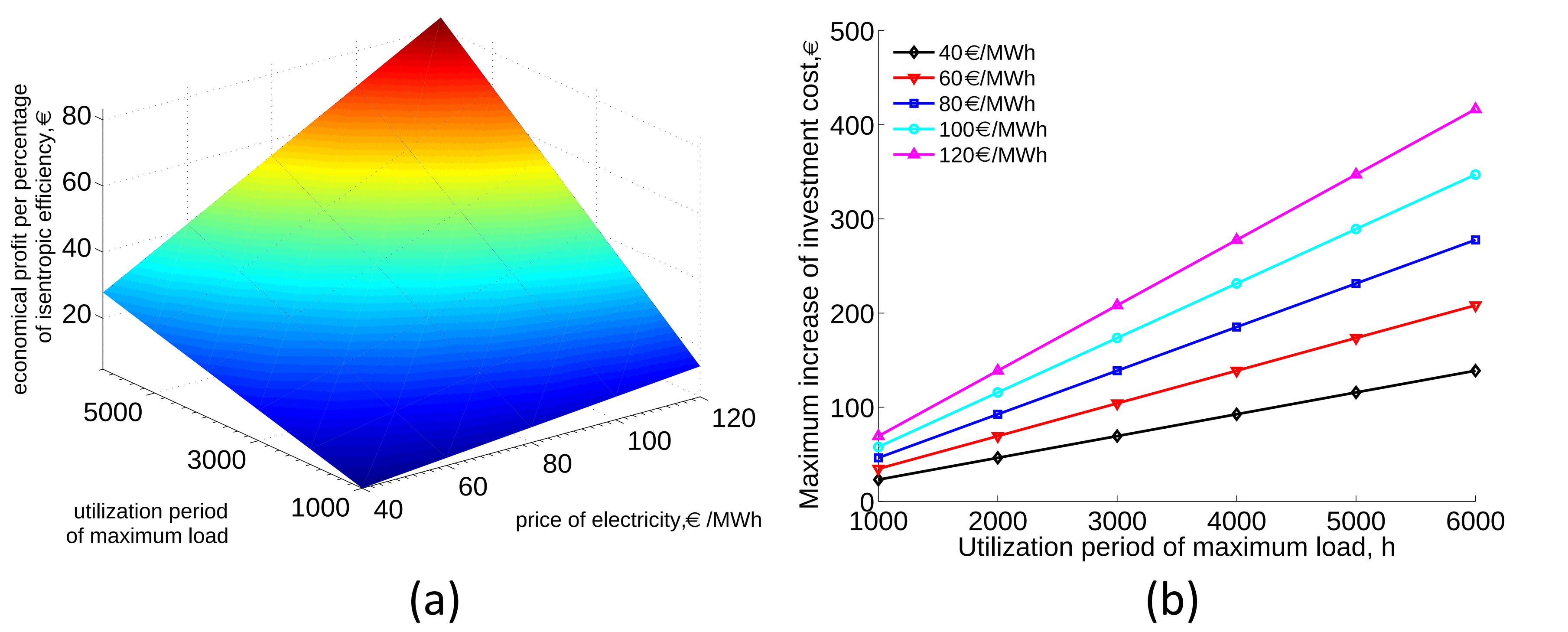

Fig. 3. (a) Economical benefit of increased turbine isentropic efficiency and (b) maximum rise of investment cost with interest rate 0 % and repayment period of 5 years

Profitability

Economical benefit of increased isentropic efficiency of the turbine is rather small in the ORC plant of small size. **With energy price of 120 €/MWh and operation hours of 6000 the benefit of one percent in turbine isentropic efficiency is ca. 80 € per year** (Fig. 3a). The price of the ORC unit for the customer could be ca. 420 € more if turbine isentropic efficiency is increased one percent and energy price and operation hours are above mentioned (Fig 3b). The interest rate is 0 % and repayment period is 5 years .

Discussion

The benefits of improving the turbine efficiency using laborious methods and resulting complex geometry are not economically essential in units where the electric power is small. The financial benefit of increasing the turbine isentropic efficiency by 5 percent is 174 € - 347 € per year with the electric price varying from 60 €/MWh to 120 €/MWh and 5000 operation hours per year in the unit studied in this article. The financial benefits of the higher turbine efficiency are larger when the unit size is larger but in units with the small electric power the financial benefits are very low. **Therefore, the main focus should be paid to the manufacturing costs of the turbine/unit rather than to optimize the turbine efficiency.**