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A METHODOLOGICAL APPROACH TO SUPPORT THE OPTIMIZATION OF AN ORC PLANT DURING THE EARLY DESIGN PHASE

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The Organic Rankine Cycle (ORC) is a technology used to recover heat (300-450 °C) and convert it in electricity.

Possible applications are: waste heat recovery, biomass power plants, geothermal plants, solar thermal power, etc.

The main design issues concern the definition of operating cycle (temperatures, pressures, etc.) and the study of the optimal power sizing.

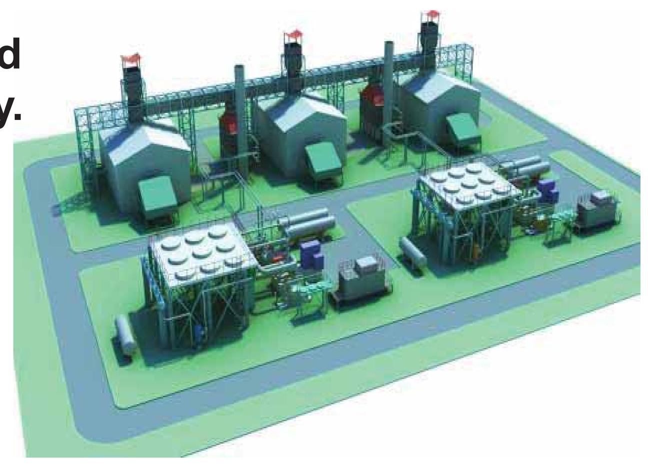

Fig. 1 ORC plant

OBJECTIVES

The aim of the proposed research is to define firstly a method and secondly a software tool to support the designer during the optimization phase. The context is the sizing of an ORC plant with the focus on the thermodynamic cycle.

Fig. 2 shows a standard ORC cycle used for waste heat recovery in industrial processes.

The optimization of an ORC plant regards the study of performance (power, efficiency, etc.) and cost. The parameters are many and are collected in two classes: thermodynamic (evaporation temperature, condenser pressure, etc.) and geometric (such as exchange surfaces). A simulation tool was required to simulate the thermodynamic status of an ORC and calculate the performance.

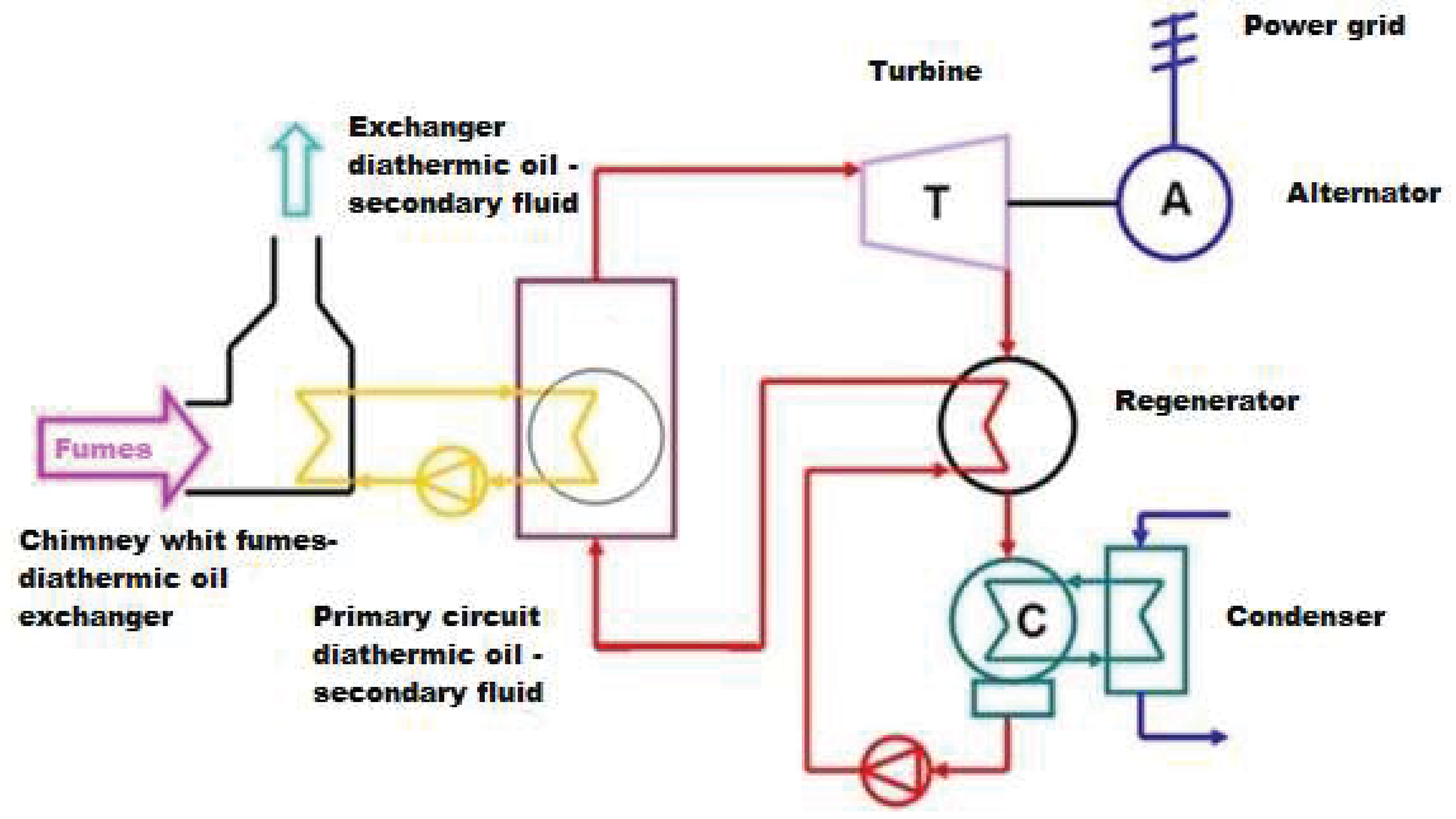

Fig. 2 A typical ORC cycle

APPROACH

Fig. 3 describes the optimization method elaborated in the proposed research work. The approach provides two kind of workflow. The first one is the basic optimization flow with the identification of parameters and the optimization loop, which is featured by genetic algorithms. The second one is related to the analytical solver (cycle calculator) to simulate the thermodynamic cycle related to the input configuration. Particularly, the cycle calculator solve the virtual experiments defined by the optimization tool.

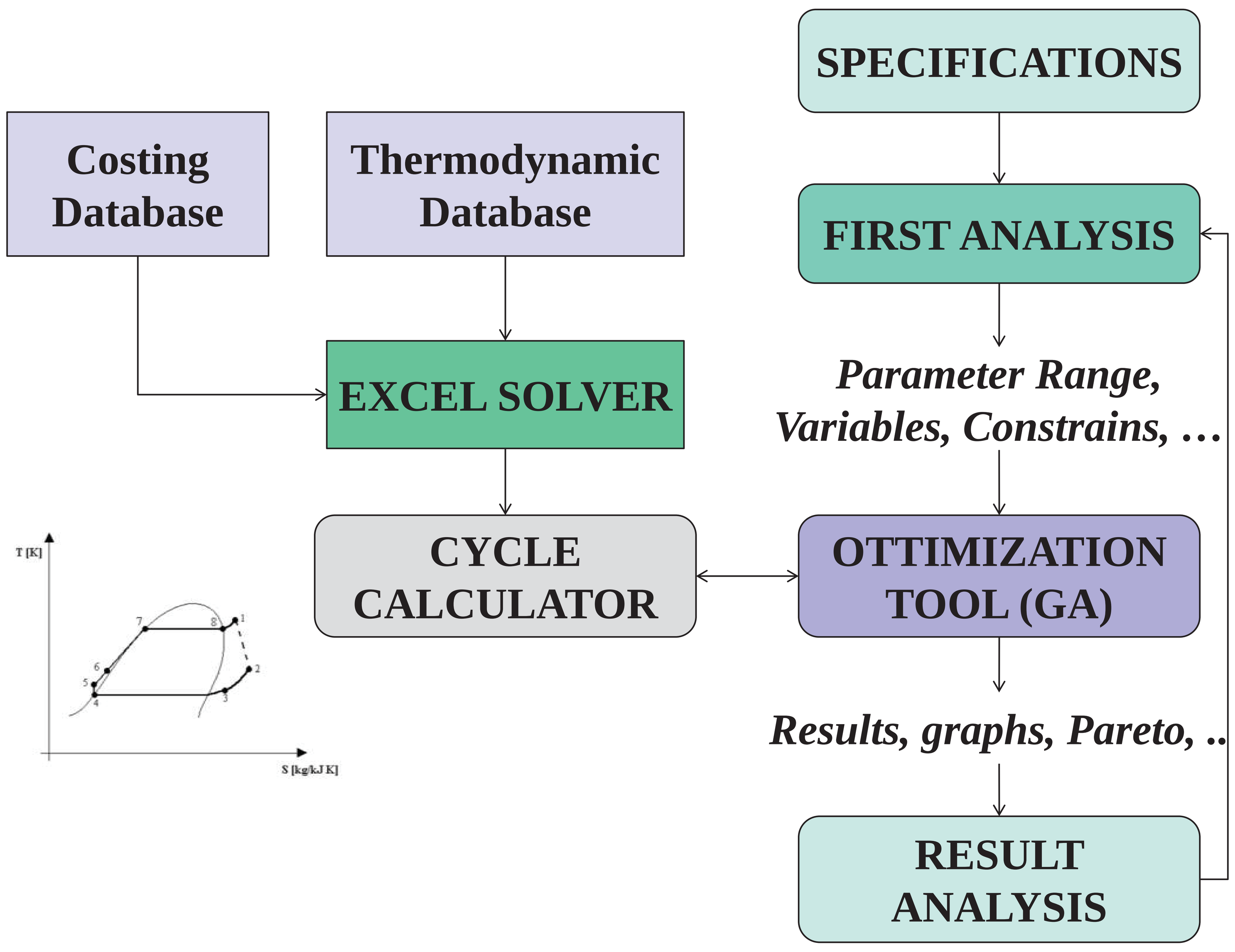

Fig. 3 The proposed method

SYSTEM IMPLEMENTATION

The approach was implemented in a platform-tool developed with the software modeFRONTIER®. The output platform-tool uses a Genetic Algorithms solver to optimize geometric and thermodynamic parameters of an ORC cycle. Analytical formulas were implemented in a spreadsheet to simulate an ORC cycle. This analytical tool, developed in Microsoft Excel® environment, was connected with the optimization loop elaborated. Thermodynamic properties were calculated automatically by the mini-REFPROP NIST tool, which is connected in the proposed platform.
Every input parameter studied was considered in the optimization analysis. However, the set of thermodynamic parameters depend on the physical laws and principles of the ORC design. Therefore, each parameter can change value within a reasonable range during the optimization analysis.
Fig. 4 shows the platform developed to analyze and optimize an ORC cycle. Two kind of logical optimizations were elaborated: performance (efficiency) and cost (€/kW).

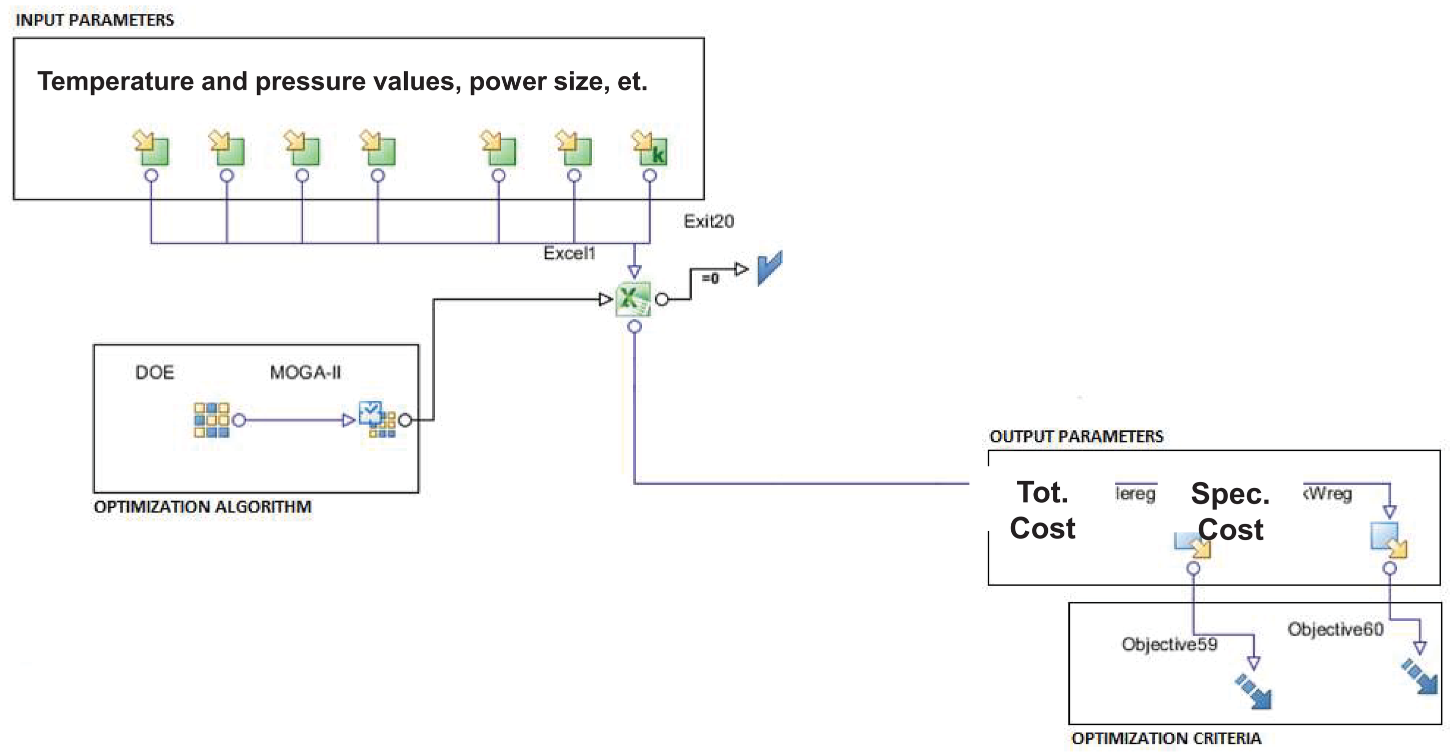

Fig. 4 The optimization platform developed

SYSTEM EXPERIMENTATION

The proposed approach was experimented in two studies about the same ORC configuration. Data were provided by a company which design ORC plants. The research studies were focused on two master degree theses. Test cases were not used to design real plants. However, the output results confirm the usual design practices.

The first study considers as fixed values both the recovery heat value and the nominal electrical power (Fig. 6). The main parameters are all operating values such as the evaporation temperature, the overheating temperature, the condensing pressure, the regeneration efficiency, etc. The optimization focuses on the ΔT of the heat exchangers which minimizes the cost of the plant. An important cost saving was simulated in this case and design guidelines were carried out. In Fig. 5 the relation between cost (€/kW) and thermodynamic efficiency is shown.

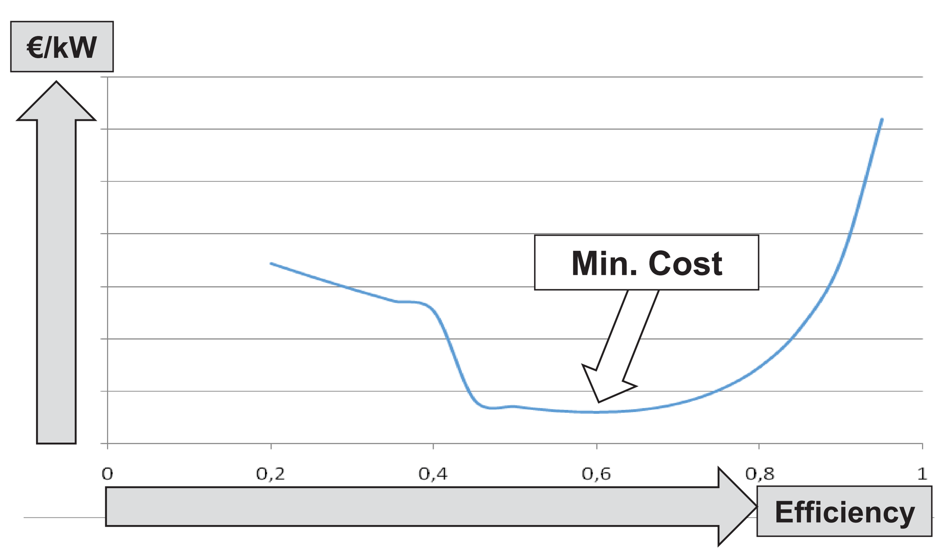

Fig. 5 Relation between cost and cycle efficiency

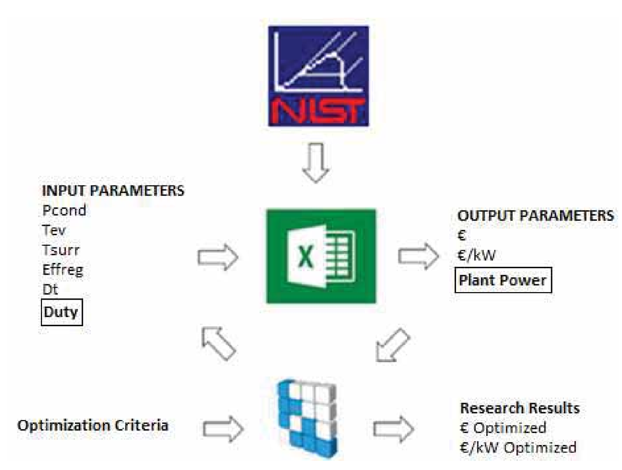

Fig. 6 First Experimentation

The second case regards the study of the minimum cost of an ORC plant within different ranges of size (Fig. 8). The focus was on the input values which reduce the cost of plant (€/kW). Generally, a big plant provides lower specific cost (€/kW) than a small one (Fig. 7). That trend was confirmed by real values.

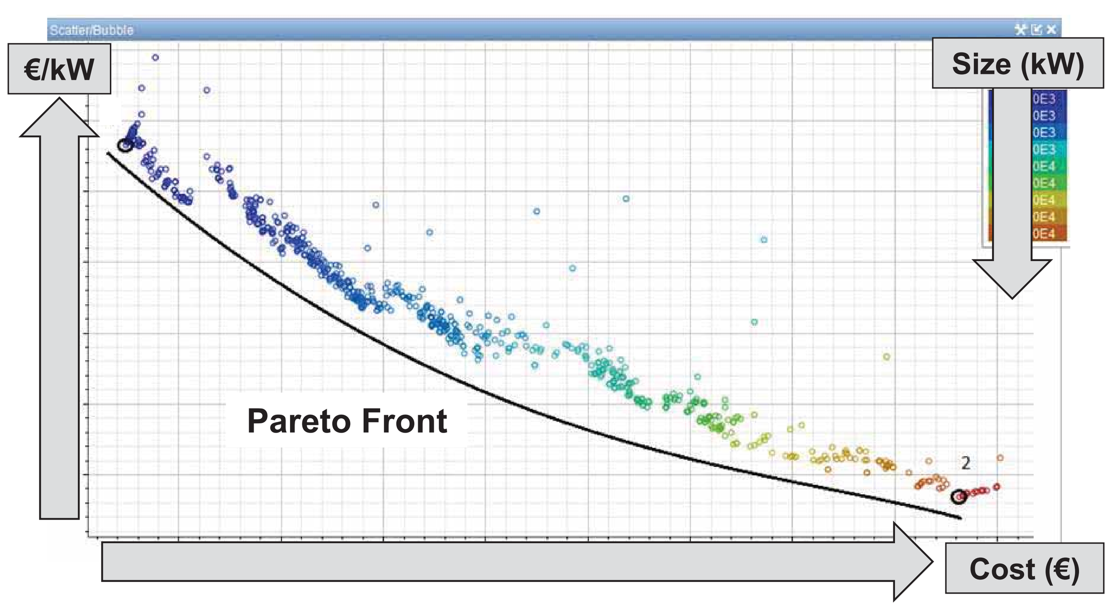

Fig. 7 Relation between: tot. cost, specific cost and power size

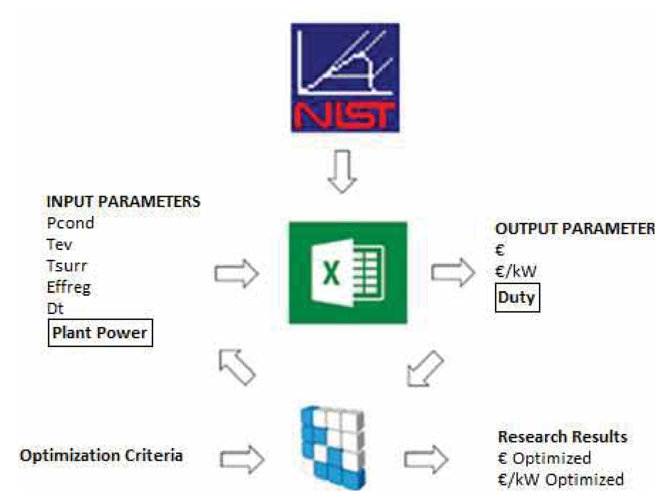

Fig. 8 Second Experimentation

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