Cavity receiver model and exergy analysis for PEGASE at THEMIS

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A detailed macroscopic model of a cavity receiver, called RECSOL, has been developed. It is interfaced with SOLTRACE ray-tracing code to take into account flux maps on any element of the receiver (absorber, insulation, reflective surfaces, …). Parametric studies allow us to choose a design maximising useable thermal power and to assess the thermal inertia of the component. Then a preliminary layout of PEGASE at THEMIS cavity is proposed. At design point of the installation (1000 W/m² DNI, 101 aiming heliostats, solar noon at equinox, turbine full load operation), the thermal power gained by the fluid is about 3,75 MW_{th} with an exit air temperature of 760 °C, as required in the PEGASE project. Under these conditions the energy efficiency of the receiver is 85%. The chosen algorithm, flexible and adaptable to a large variety of receivers, calculates temperature ranges, losses and power levels through the receiver that are useful to a detailed design of this component. If RECSOL enables designers to imagine numerous attractive solutions to meet the specifications of PEGASE at THEMIS while limiting the absorber temperature, technologic feasibility can hardly be assessed. Indeed in these ranges of flux densities, temperatures, and pressure, many designs of cavities, absorbers, flow distributions, and module assemblies will be abandoned for the sake of reliability.

Secondly an exergy analysis of solar thermal power components and installations was performed and applied to PEGASE receiver and system, in order to distinguish which processes are mainly responsible for the degradation of exergy efficiency. For each component of a thermodynamic system a second level of analysis is possible, enabling designers to know which physical phenomena (energy exchanges or conversions) cause the most exergy losses. By this way the design of a thermodynamic component or subsystem can be improved. The exergy source entering a concentrated solar system can be chosen at the temperature of the surface of the sun, or at the temperature of an ideal collector equal to the equilibrium temperature of a black body and thus only depending on the mean geometric concentration factor on the receiver aperture. The temperature of the real absorber will be reduced because of optical losses caused by the surface imperfections of the concentrator, convection and conduction losses. The exergy losses breakdown of a solar collector is estimated in the case of the PEGASE receiver, using the RECSOL model. If the temperature of the source is taken equal to the temperature of the surface of the sun, the exergy efficiency is 57%, whereas if the source is considered at the temperature of the ideal collector, this efficiency reaches 66%. Finally exergy losses of the whole PEGASE system are also assessed, showing that the main losses occur in the solar collector.