SYNTHESIS

of the research work for the financing agreement 105 / 01.10.2007,
618 CNCSIS code, named

"INTERDISCIPLINARY RESEARCHES TO DETERMINE THE POTENTIAL LIMITS OF THE SOLAR ENERGY IN SOLID BODIES ON HEATING-MELTING RANGE"

Introduction

The solar furnace is meant for usage processes of the solar energy under technological purposes. In consequence of the advantages that come from this type of electro-thermal installation, based on solar energy sources, it can be used in different industrial processes such as:

- The elaboration of the steels and special alloys, melting for cast-iron, steels and non-ferrous metals casting;
- Metals heating for heat treatments (hardening and annealing, ageing, carburizing, nitro-carburizing) and hot forming processing;
- Production of abrasive materials, calcium carbide and electrographite;
- The welding of the metals and plastic packages;
- Glass and ceramics melting and heat treatment;
- Food products drying, preparation and sterilization.

In order to obtain some precise work temperatures, an essential condition for achieving some quality materials, an optimum choice is represented by the use of electric resistor furnaces.

The documentary-research visit made by Prof. univ. dr. eng. P. Vizureanu at the Dipartimento di Ingegneria Aerospaziale e Meccanica, Secunda Universita degli Napoli, Italia, during the 12nd -25th of April 2009 has opened new collaboration perspectives with a redoubtable team from abroad for achieving new results due to their prior experience in the domain.

1. The characterization of the melting / burning / purifying process in solar furnaces

These objectives consisted in the development of some mathematical formalism that can allow a better exploitation of the advantages accomplished during melting /burning / purifying processes in solar furnaces. The documentary stages made up to now were useful in the elaboration of these formalisms.

1.1. The achievement of a design algorithm for a solar furnace used in melting / burning / purifying of the metallic and non metallic materials

The solar furnace is a laboratory experimental furnace. During the experiments, we propose to process small quantities of material until 1 kg.

Crucible dimensioning. In order to realize the crucible, it was chosen graphite as material due to its strength to high temperatures until 2000^{o}C and for the relative big thermal conductivity. For accomplishing the calculi it is chosen aluminum as test material due to the fact that its density at 1 kg occupies a bigger volume than other materials that will be processed.

The useful volume of the crucible calculates with the relation:

$$v = \frac{m}{\rho'} = \frac{\pi \cdot d^2}{4} \cdot h$$

where ρ’ is material density at ambient temperature of 20^0C, for example aluminum has $\rho'_{met\_topit} = 2.72$ kg/dm^3.

Dimensioning of the furnace masonry and thermal calculus. The furnace has cylindrical shape. Its disposal is on vertical, and on its walls it chose a configuration with multiple layers, considering the temperature, seen in figure 1:

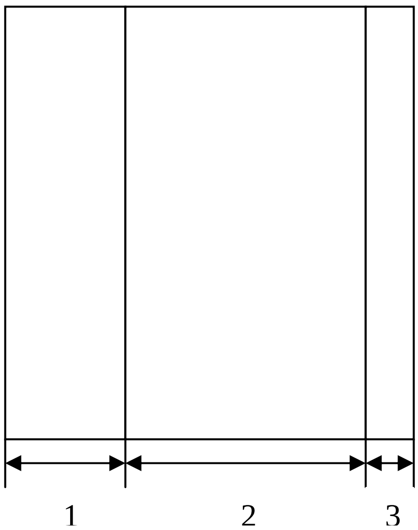

Figure 1. The diagram of furnace wall
1 – refractory coat made of chromium magnesite with thickness of 15 mm;
2 – thermal insulation made of 700 diatomite treated with binders with thickness of 30 mm;
3 – exterior shell made of steel plate with thickness of 2 mm.

Let it be the exterior temperature of the refractory coat of 1200^0C.

Resistors. The selection of the material from which the resistors are made, realizes so that the maximum work temperature exceeds with almost 2...10% the maximum temperature of the furnace. Knowing that the temperature within furnace can reach 1600 ^{0}C it chooses Kanthal for resistors.

Kanthal resistors are like spiral wire. In each chamber of the furnaces, there are 27 resistors placed in the channels of the refractory material. These are disposed symmetrically on vertical and surround the crucible so that we have a uniform temperature in the entire chamber of the solar furnace. The length of each kanthal spiral is of 105 mm. The equivalent resistance on each chamber is 51,5 Ω. In figure 2 it can be seen the disposal of all 27 resistors.

The installed power of the furnace calculates with the relation:

$$P_i = k \cdot P = k \cdot \frac{Q_i}{t_i} \quad [W]$$

where k=1,1 ÷ 1,5 is safety coefficient that takes into account the possibility of forcing heating regime of the cold furnace, the possibility of decreasing network tension towards its nominal value, of time decreasing of the thermal insulation properties, of heating elements ageing – that determine a bigger strength than the one initially calculated and in addition a smaller developed power.

Figure 2. Chamber disposal of the resistors.

The furnace that will be built, will be on the first try a lab furnace, of small dimensions, with two chambers with crucible, the volume of each active chamber will be of 0,5 liters. The choosing of a furnace construction with two work chambers made for the optimization of the work time.

We opted for a chamber furnace with crucible because it presents some advantages that consist in the simplicity of the construction, the possibility of using it for different processes (for example melting, burning, purifying) as the possibility of realizing into the furnace some different thermal regimes, in essence is what we propose to accomplish.

The resistor furnace (in the future we will extend our research on an induction furnace too) has an alternate functioning regime because the functioning cycle consists in:

- Loading of the crucible with the metal that will be processed;
- heating;
- melting;
- burning;
- purifying;
- unloading.

The furnace will have the possibility of fitting in all work temperatures that are considered to be classifying criteria in heating electric heating technology:

- low temperature furnace (between 600-700 °C the maximum value of the temperature);
- high temperature furnaces (until 1600 °C).

1.2. Virtual design of a melting / burning / purifying solar furnace

The scheme of the resistor furnace is presented in figure 3. The components of the chamber furnace with crucible are:

- chambers made of refractory material 1 and thermal insulation 2;
- the heating elements 3 are placed on the lateral walls of the furnace;
- crucible 4;
- material that will be processed 5;
- the furnace presents the door 6, acted by the lifting device 7 where processed materials are introduced;
- furnace support 8;
- metallic shell 9.

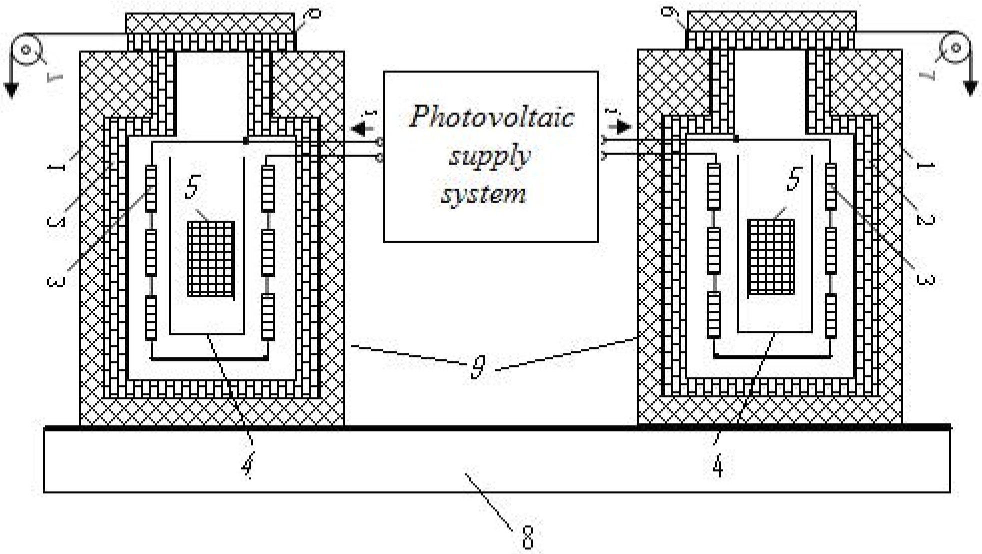

Figure 3. Scheme of the furnace supplied from a photovoltaic system with resistors for materials melting / burning / purifying

For the construction of the electro thermal furnaces there are used a series of specific materials, which are necessary for the achievement of the furnace chamber, for the heating elements as well as for the measurement systems of the temperature.

2. Heating process simulation of the metallic materials within solar furnaces

2.1. Identification of the optimum geometric arrangement of the components of a solar furnace for heating metallic materials

The photovoltaic system will be composed of (see figure 4):

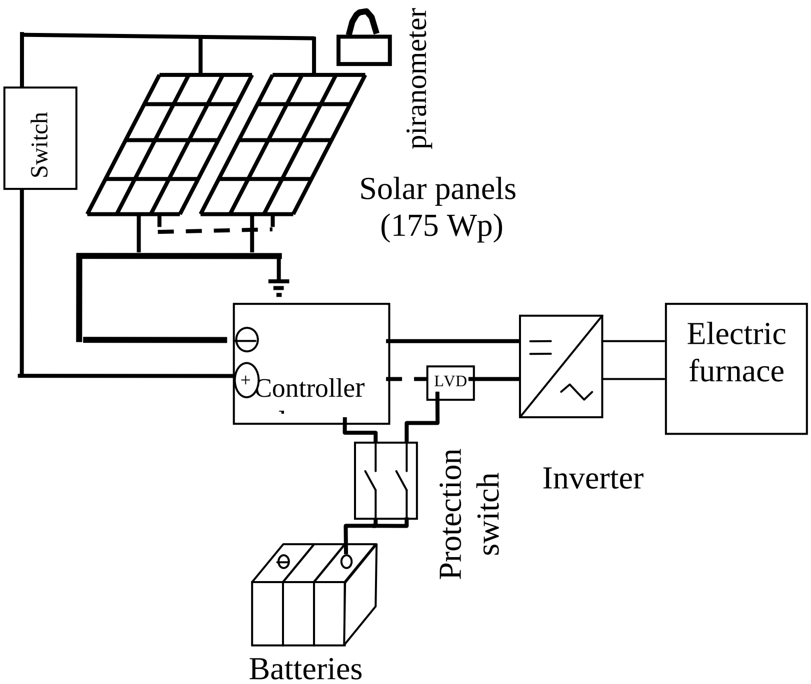

Figure 4. Photovoltaic system necessary for supplying the solar furnace with resistors

- solar panels (it chose panels made of polycrystalline silicon with a very good price/quality ratio and which have a guarantee until 20 years) assuring the required energy necessary;
- batteries system necessary for energy storage and furnace usage under adverse conditions in terms of solar radiation (in the evening or in cloudy days);
- tension regulator;
- inverter necessary for transforming continuous current into alternative current;
- accessories;
- sun-tracker system (optional – necessary for obtaining a better efficiency of the photovoltaic system, which is permanently oriented so that the solar radiation would drop perpendicular on solar panels).

The temperature control in resistor furnaces has a special influence on the quality of the final products and on the specific energetic consumptions. With respect to the specific conditions of the technological process, especially the allowed temperature variations in the furnace and in the material, there are used adjustment systems with intermittent action or continuous one. The assembly image of the built solar furnace is given in figure 5 a) and b).

a)

b)

Figure 5. Assembly images of the solar furnace

It will be used a PID control algorithm for temperature control using PtRh-18 class thermocouple as a sensor. The maximum work temperature of these thermocouples is 1820 ^{0}C. The implementation of the PID algorithm makes in LabVIEW graphic programming language. In figure 6 presents the panel, program interface, PID application and in figure 7 presents the diagram, the proper program.

2.2. Interpretation of the achieved results

The solar furnace supply makes by using electric energy produced by a photovoltaic system, which converts solar energy, solar radiation into electric energy. For realizing a feasibility study for the solar radiation in Brasov area, it was purchased a SPN1 pyranometer in 2008. It measured global and diffuse solar radiation using this device; it could be calculated direct solar radiation too. Solar radiation monitoring made starting with February 2009.

Global and diffuse solar radiation monitoring realized at each five minutes.

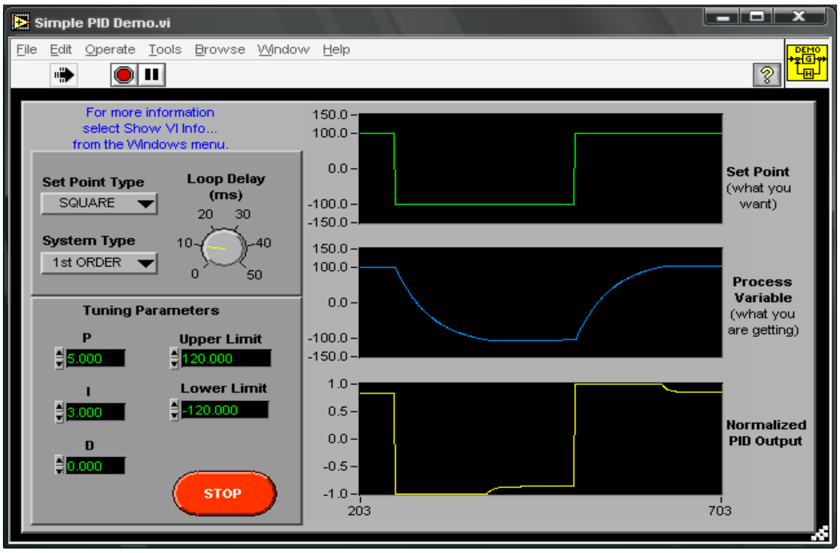

Figure 6. Interface of PID application

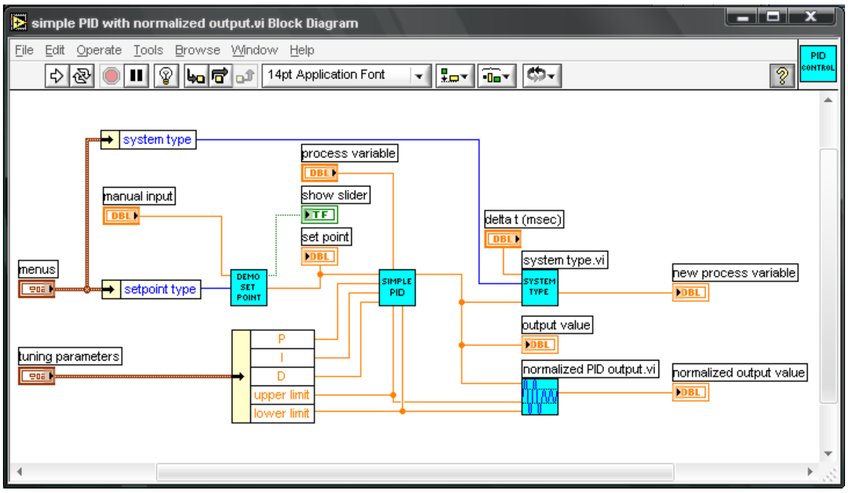

Figure 7. Diagram of PID application.

The conclusions that can be reckoned after monitoring the solar radiation are as follow:

- the maximum number of cloudy consecutive days was of five, but in those day there were time intervals where horizontal global solar radiation exceeded the value of 400 W/m^2, value that gives the possibility to the photovoltaic panels system to offer enough energy so that the solar furnace with resistor would function under optimum conditions;
- the photovoltaic system will be capable to produce almost 6.8 kW into a clear sky day (see figure 8); this fact, allows, the use of the furnace at maximum capacity and the possibility for the energy excess to be storage with the help of the solar batteries;
- in cloudy days, see figure 9, the quantity of energy generated by the system reduces considerable, so that in such days it only produces 1.5 kW, which would be enough under conditions of judicious usage of the furnace;
- yet, if there are longer periods of times, as we exemplified in figure 10, then the system will need the energy stocked in the solar batteries; batteries system is designed to assure an autonomy up to five days without raising very much the costs of the system;

- for example, for the weakest days energetically speaking, 12.06.2009, the energy quantity a system can generate is under 800 W.

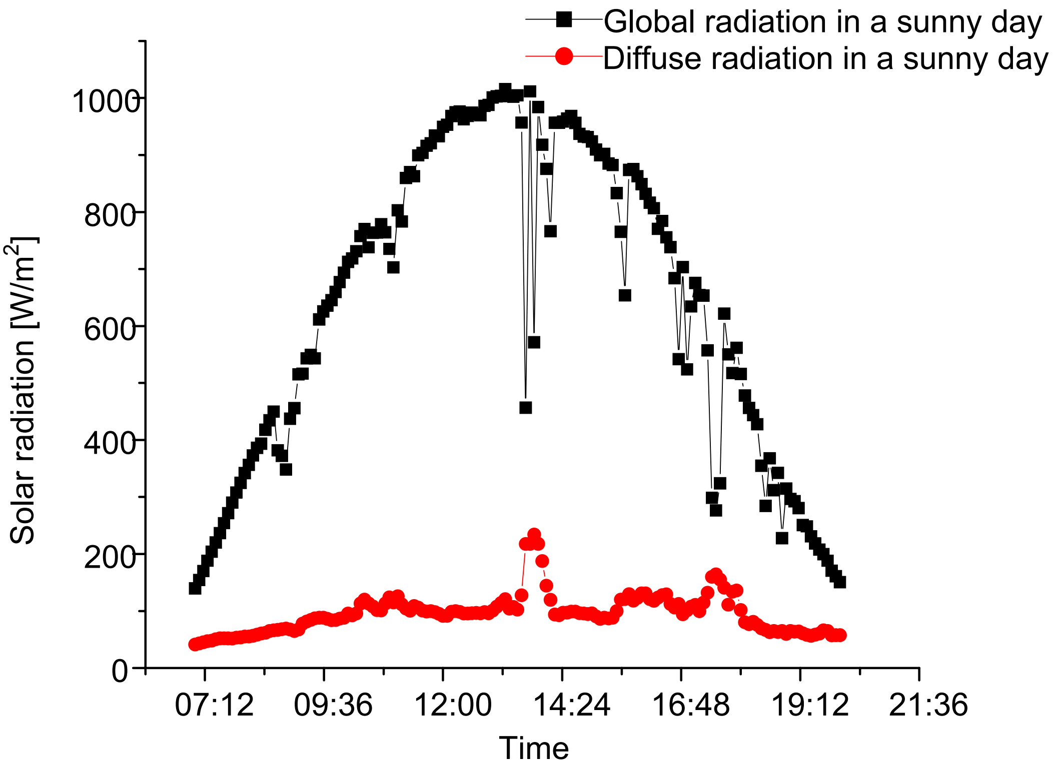

Figure 8. Distribution of global and diffuse solar radiation in a sunny day (14th of June 2009)

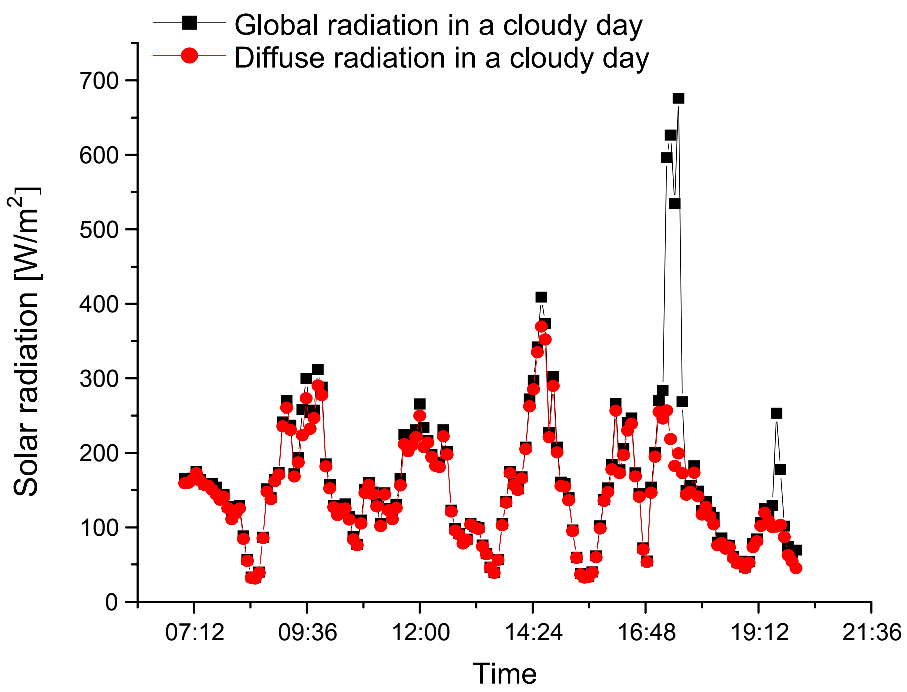

Figure 9. Distribution of global and diffuse solar radiation in a cloudy day (12nd of June 2009)

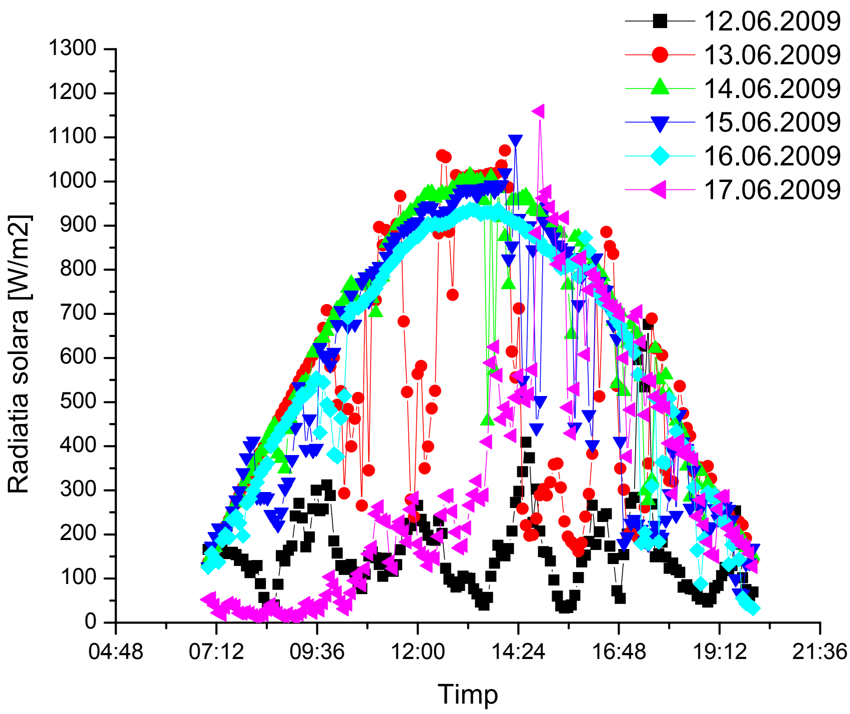

Figure 10. Distribution of horizontal global radiation in the interval 12-17.06.2009

Conclusions

The project approaches a dynamic subject, of high interest, both by problems consistency and by the large area of applications. The results achieved up to this moment are / will be capitalized by their content in articles already accepted or in course of publishing in ISI reviews or in international data bases (SCOPUS), and presented at different national and international conferences, as well as in the Self-evaluation report.

The objectives provided in this stage were completely reached.

The project manager coordinated the accomplishment of the proposed objectives of these phase. The results are already achieved within this stage and they belong to our collaboration with researchers from Italy, more precisely Secunda Universita degli Napoli.

The fulfillment of the objectives supposed an ample activity of information. It was necessary a good control of some different mathematical methods as well as a better control of the experimental researches concerning materials melting / burning / purifying. The importance and complexity of this subject exacts a detailed interdisciplinary research. Thus, the team consists in specialists from two top domains of actual fundamental research: material science and physics. The teamwork contributed to the coagulation of a powerful research nucleus. The results already achieved due to research activity from these years open the perspectives of fulfilling all the objectives of the project during the last year in the approached theme.

Project manager,
Prof. univ. Dr. eng. Petrică VIZUREANU