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SYNTHESIS

Of the research paper for financing contract 105 / 01.10.2007,
CNCSIS 618 code, named

“INTERDISCIPLINARY RESEARCHES FOR ESTABLISHING THE POTENTIAL LIMITS OF SOLAR ENERGY WITHIN SOLID CORPS ON HEATING-MELTING RANGE”

Introduction

Solar furnace is meant for use processes of solar energy within technological purposes. This installation belongs to thermal installations category. The advantages of thermal installations based on solar energy:

- In terms of conversion system it can be concentrated a powerful thermal source into a tight space with direct consequence on getting some hidh temperatures (over 2.000°C);
- As in any heating installation based on electric power, installations based on solar cells also have the possibility of accurate and rapid temperature adjustment;
- Electric system used for the conversion of solar power into thermal power allows a simple automation with reliability;
- Transfer from classical energetic sources (solid or liquid fuels or electric power achieved through their burning) to alternative sources that can be future alternative required by the endearment of classical sources and their powerful pollution.

As a result of these electro thermal installations’ advantages, installations based on solar energy sources, they can be used in different industrial processes such as

- Conduct of the steels and special alloys, melt of cast-iron, steels and non-ferrous metals casting;
- Metals heating for heat treatment (quenching and annealing, ageing, carburizing and nitro-carburizing) and hot deformation processing;
- Production of abrasive materials, lime and electro-graphite;
- Welding of metals and plastics;
- Glass and ceramics melting and heat treatment;
- Drying, preparation and sterilization of food products.

The documentation-research visits made by Assoc.prof.dr.eng. P. Vizureanu at Instituto de Soldadura e Qualidade, Lisabona, in 22-29 of March 2008 and at Ecole Européenne d'Ingénieurs en Génie des Matériaux, Nancy, in 11-23 of May 2008, opened new collaboration perspectives with redoubtable teams from abroad for achieving new results due to their experience in the domain.

1. The analysis of melting/burning/purifying process within solar furnaces

These objectives consist in developing some mathematical formalism, which allow a better capitalization of the advantages given by the evolution of **melting/burning/purifying within solar furnaces**. In the working-out of these mathematical formalism it was very useful the documentary stage from Universidad de Las Palmas de Gran Canaria, Spain as well as the discussions on this theme with Prof. Agustin Santana Lopez.

1.1. Mathematical model of the melting/burning/purifying process within work chamber of a solar furnace

Thermal efficiency η_t of an electro-thermal installation based on solar energy is given by the ratio

$$\eta_t = \frac{Q_u}{Q_u + Q_p + Q_a}.$$

- Q_u is quantity of **absorbed heat** necessary for heating the material;
- Q_p represents **heat loses** due to heating installation;
- Q_a is heat quantity necessary for heating the auxiliary components of the installation;

The furnace will situate in these work temperature classes that are considered as classification criteria in heating technology:

- Low temperature furnace (between 600-700°C);
- High temperature furnaces (until 1600°C).

In order to define the calculus model of the furnace based on solar energy is necessary to define the following **input data**:

- Material that will be heated with all its thermal and electric data;
- Charge shape and dimensions;
- Technological regime that consists in
  - Heating time until reaching solidus temperature,
  - Heating temperature,
  - Overheating time for generalizing liquid state in the entire mass of the charge,
  - Overheating temperature,
  - Holding time at casting temperature necessary for eventual alloying in liquid state;
  - Special technological conditions (protection atmosphere, vacuum etc.);
  - Furnace efficiency.

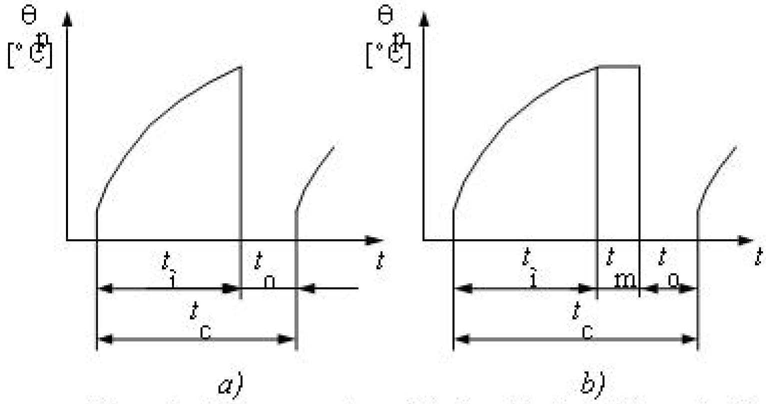


Figure 1. Diagrams of possible functioning of the solar furnace
a) melting without holding at constant temperature; b) melting by holding at constant temperature;
(t_c – a complete cycle; t_i – heating time; t_m – holding time at constant temperature; t_o – loading-unloading time).

Heat consumption calculated going from *functioning diagram* of the furnace that is in fact variation diagram of load temperature time function θ_p, taking into consideration the fact that this is a furnace with intermittent functioning the diagrams presented in figure 1 are the possible ones.

1.2. Determination of technological parameters implied in melting/burning/purifying process within a solar furnace

Temperature control. Within the furnace (figure 2 a) is introduced the thermometric transducer T that is transmitting information regarding the temperature within furnace towards AB adjusting block. In the comparator C a tension proportional with the desired value of the temperature θ_d, determined of the basis of the program imposed by technological process and controlled by the block of desired values BVD, is compared with a tension proportional with real value of the temperature within furnace θ_r. If $\theta_r < \theta_d$, on-off regulator RBP is transmitting the closing command to adjust block (connection switch to power supply) and the furnace is absorbing P power. If $\theta_r > \theta_d$ cutting-out command of the switch is transmitted. The adjustment makes with a dead zone $\Delta\theta$ given by regulator's characteristic (figure 2 b).

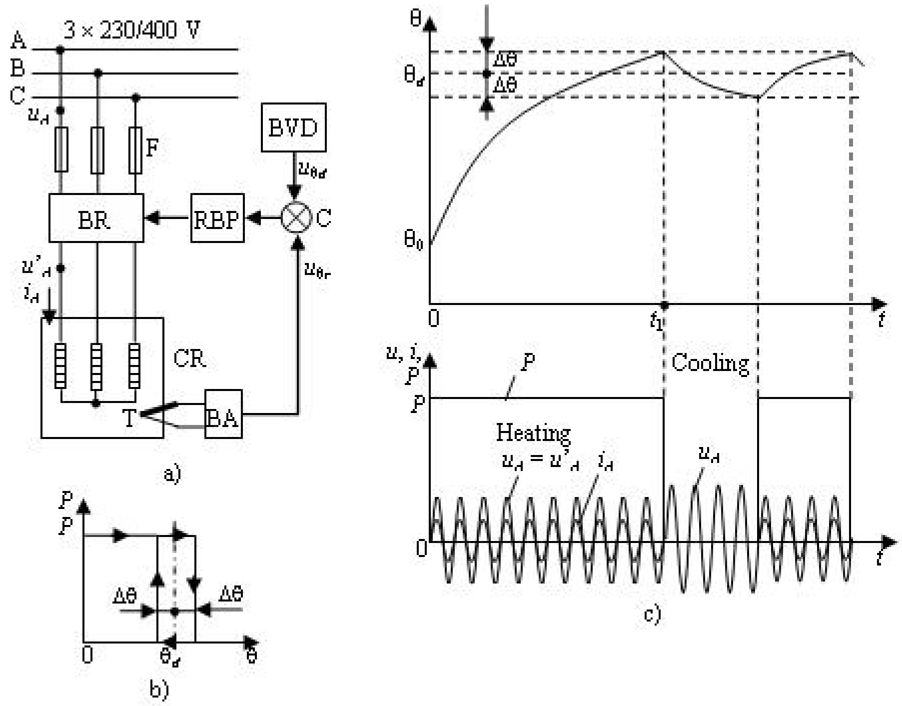


Figura 2. On-off adjustment of furnace temperature.

Orientation of photovoltaic system. Orienting the system to an optimum angle of inclination a significant increase of radiation can achieve, which can be used, instead of positioning the panels on horizontal or at a random angle in general, place latitude. If a tracking system is used an increased quantity with approximately 40% will achieve, see figure 3 where system losses are also considered.

PV electricity generation for: Nominal power=1.0 kW, System losses=24.0%				
	Inclin.=37 deg., Orient.=0 deg.		2-axis tracking system	
Month	Production per month (kWh)	Production per day (kWh)	Production per month (kWh)	Production per day (kWh)
Jan	44	1.4	54	1.7
Feb	61	2.2	77	2.7
Mar	94	3.0	120	3.9
Apr	99	3.3	131	4.4
May	119	3.8	169	5.4
Jun	115	3.8	167	5.6
Jul	122	3.9	174	5.6
Aug	123	4.0	171	5.5
Sep	103	3.4	135	4.5
Oct	86	2.8	109	3.5
Nov	48	1.6	58	1.9
Dec	37	1.2	45	1.5
Yearly average	**88**	**2.9**	**117**	**3.9**
Total yearly production (kWh)		**1050**		**1410**

Figure 3. Comparison between a fixed system at a optimum angle of 37^0 and tracking system

The use of sensors for orientation can lead to delicate situations in case of sun-clouds alternances if the system is not properly calibrated and to high energy consumptions.

Taking into account these, it chose for the achievement of solar tracker the variant that uses mathematical algorithm for positioning. The orientation makes after the two directions namely E-V and S-N.

2. Characterization of metallic materials heating process within solar furnaces

Materials heating within furnace. Equation of energetic balance for the furnace can be written as:

$$\mathrm{d}Q_2 = \mathrm{d}Q_u + \mathrm{d}Q_a + \mathrm{d}Q_{pd} + \mathrm{d}Q_z$$

where dQ_2 is elementary heat quantity transmitted towards furnace interior by the heating element:

$$\mathrm{d}Q_2 = P_2 \cdot \mathrm{d}t = \alpha \cdot A_1 \cdot (\theta - \theta_0) \cdot \mathrm{d}t$$

dQ_u – elementary heat quantity that leads to the heating of the useful material within furnace (absorbed heat):

$$\mathrm{d}Q_u = c_u \cdot m_u \cdot \mathrm{d}\theta$$

dQ_a – heat quantity that leads to heating the attached pieces (stands, supports etc):

$$\mathrm{d}Q_a = c_a \cdot m_a \cdot \mathrm{d}\theta$$

dQ_{pd} – elementary thermal losses through furnace walls, opening, leakiness etc;
dQ_z – quantity of elementary heat that gather in furnaces walls:

$$\mathrm{d}Q_z = c_z \cdot m_z \cdot \mathrm{d}\theta$$

It noted with:
P_2 - thermal energy (thermal flow) transmitted by photovoltaic systems;
α - heat exchange superficial coefficient;
A_l – aria of total lateral surface of heating elements;
θ – temperature of heating elements;
θ_0 – temperature inside the furnace;
dt - interval of elementary time.
c_u, c_a, c_z – massic heats (temperature dependant) of the heated materials, attached elements and crucible,
m_u, m_a, m_z – pieces weight, attached elements and crucible,
dθ – elementary interval of temperature.

2.1. The achievement for a design algorithm for a solar furnace used in metallic material heating

Solar panel positioning by implementing the mathematical model need the introduction of astronomic considerations.

In order to determine real position of the sun on the sky the following angles are important θ_z – Zenith angle and γ_s Azimuth angle, see figure 4.

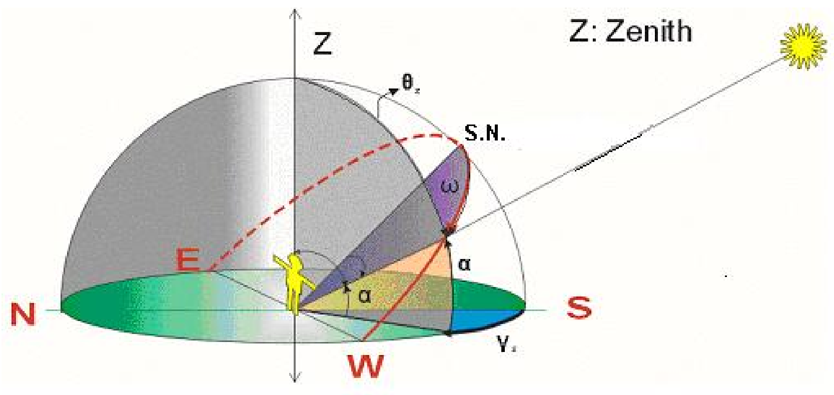


Figure 4. Sun's trajectory on sky. Important angles

The calculus of these angles is made with mathematical formulas. Calculus formula for Zenith angle is given by relation:

$$\cos\theta_z = \sin\phi\sin\delta + \cos\phi\cos\delta\cos\omega$$

where φ is latitude and is constant for the place where solar tracker is positioned, for example for Brasov is $45^0 39'$, δ is declination and ω is hour angle.

2.2. Virtual design of a heating solar furnace

In order to determine the minimum dimensions of the solar panel it considered a concave mirror situated as in figure 5. The calculi are made on shading intervals as well as on illumination optimum of the mirror in order to create maximum thermal flow towards furnace's crucible.

Determination of minimum dimensions of the solar panel

AC = Φ concave mirror

$\hat{C} = 90\text{-}21{,}34 = 68{,}26$

$AC = \sin\hat{B}\cdot BC \rightarrow BC = \dfrac{AC}{\sin\hat{B}} \rightarrow BC = \dfrac{AC}{0{,}363}$

$AB = \sin\hat{C}\cdot BC \rightarrow AB =$

$0{,}928\dfrac{AC}{0{,}363} \rightarrow AB = 2{,}558\cdot AC$ (AB minimum)

$BD = AC$

$BD = BE\cdot\sin\hat{E}$

$BE = \dfrac{BD}{\sin\hat{E}} = \dfrac{AC}{0{,}98} = AC\cdot 1{,}0183$

$BE_{max(45^\circ)} = AC\cdot\sqrt{2}\cdot 1{,}15$; 1,15=const.

$BE_{min} = AC\cdot 1.0183$

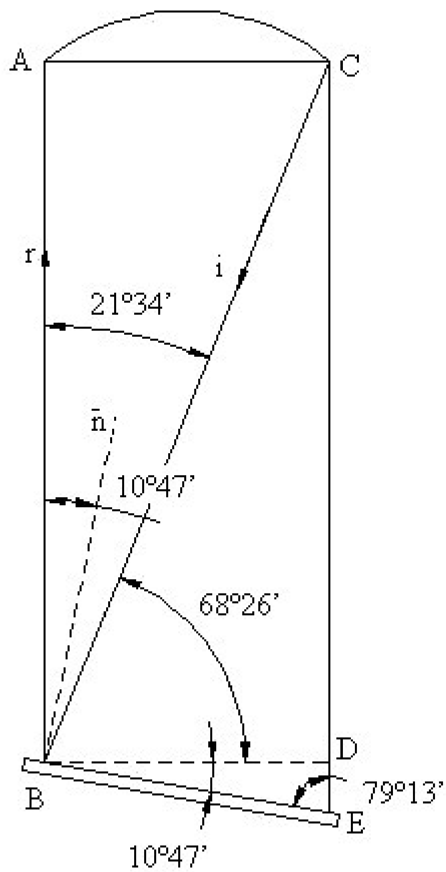
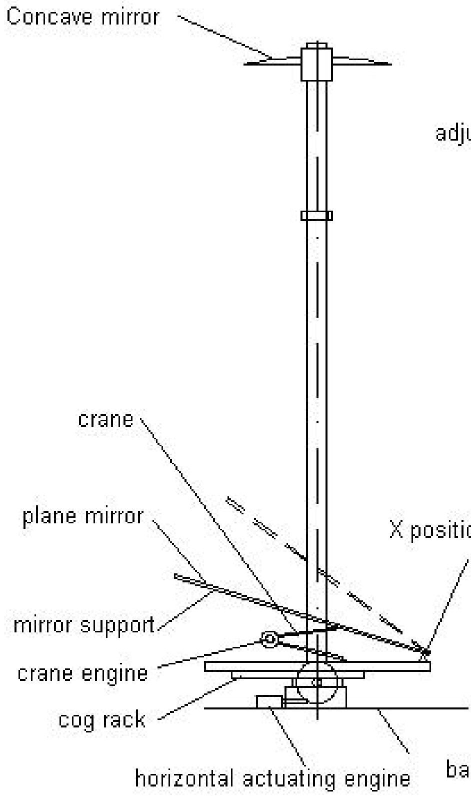


Figura 5.



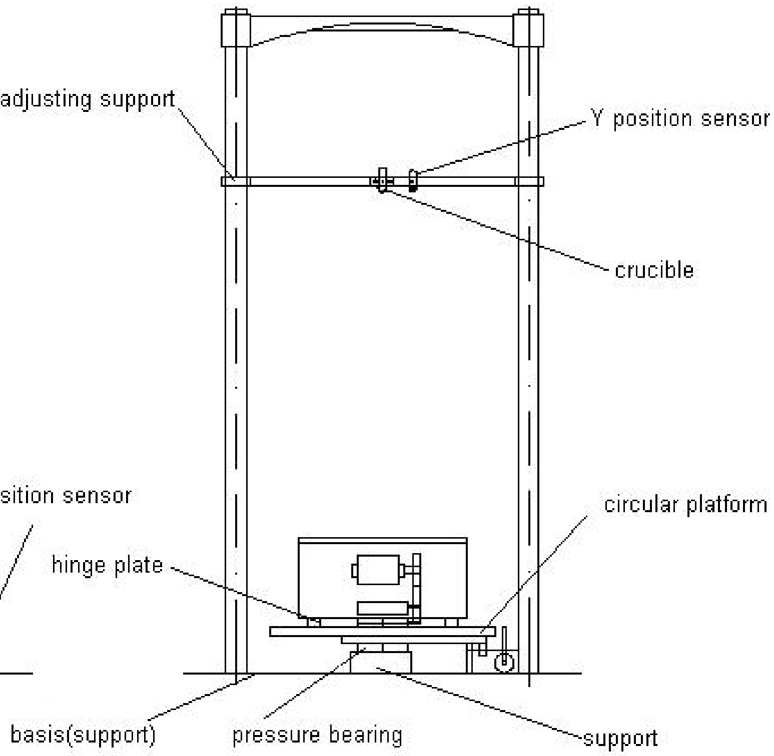


Figure 6.

Conclusions

The project approaches a dynamic thematic of high interest for problems consistence and for the wide aria of applications. The results achieved in this stage are or will be capitalized in articles already accepted or on the verge of publication in journals that are ISI indexed or in international data bases and communicated at different national and international conferences presented in self-evaluation report.

The objectives provided in this stage were totally reached.

Project manager coordinated the achievement of the proposed objectives. The results already achieved within this stage are also realized with the help of the collaboration with researchers from the renowned research institute from Spain, Almerian Solar Platform.

Objectives' fulfillment supposed an ample information activity. It was necessary a well control of some different mathematical methods as well as a good information regarding the experimental researches in materials melting/burning/purifying. The importance and complexity of this thematic make necessary a detailed, interdisciplinary research. Thus, the team consists in specialists from top domain of actual fundamental research such as materials science and physics. Team work contributed to the binding of a powerful research nucleus. The results already achieved open new work perspectives for the next years within the project in the approached thematic.

Project manager,
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