ABOUT THE COOLING CHARACTERISTICS OF THE MIXTURE POWDERS IN FLUIDIZED BED – SALT AND SAND BARBOTAGED WITH AIR

Carmen NEJNERU[1], Diana GHEORGHIU[2], Mihai BERNEVIG[3], Ion HOPULELE[4]

ABSTRACT

The paper presents some researches on the thermal transfer when cooling in fluidized beds. The experiments were carried out with different powder compositions, salt and sand in various percentages. The particle sizes for both powder compounds were: 1.) approximate sand particles 500 $<d_p <$ 1200 [μm]; and for 2.) salt: 500 $< d_p <$ 1400[μm]. The cooling curves were drawn with a silver control cylinder within a cromel-alumel thermocouple connected to a y-t recording apparatus.

KEYWORDS: fluidized bed, cooling velocity, cooling curve, heat transfer, sand / salt particle.

1. INTRODUCTION

Fluidization is a technique in which a particle bed is brought into a condition where it behaves like a liquid, each particle being separated by the others through a gas stream.

The fluidized bed is a heterogeneous, non-adiabatic system where the solid particles are executing a continuous motion on the enclosure, under the influence of a turbulent fluid stream.

The fluid strains among the particle layer without moving them at small speed. As long as the loss of pressure is smaller than the weight of the layer, reported to the fluidization surface, the layer remains fixed.

At a certain speed, the individual particles get a liberty degree, which allows an easy vibration of the particles round about the primary position. In this condition the particles mass behaves like a viscous liquid, the solid and the fluidization agent forming one phase (the dense phase).

The agent velocity which is completing this condition is called the minimum fluidization velocity (v_{im}) when appears the homogenous fluidization. Homogenous fluidization is characterized by an uniform distribution of the particles and an uniform expansion of the layer, the distance between the particles increasing together with agent velocity.

Increasing continuously the speed of the fluid ($v>v_{im}$) turns out that the layer explodes and the movement of the particles became violent and chaotic.

A part of the fluid goes through the layer like some irregular bubbles, which are breaking at the fluidized medium surface, throwing up a jet of particles, the whole layer looking like boiling water. This is the non-homogenous fluidization, which is interested in applications with a view to heating in thermo-chemical and heat treatment.

During fluidization can appear secondary phenomena, which produce the perturbation of the fluidized bed, specific to the non-homogenous fluidization such as: insistence and canalization.

The nature, size and form of the solid particles belonging to the fluidized bed influence directly the structure and the characteristics of yield of fluidized bed.

The size of the particles is one of the most important parameters of the fluidization, as well from hydrodynamic point of view, as heat and mass change. For the achievement of an optimum fluidization, it is necessary that the field scattering of the particles size must be as limited as it can.

If the fluidized bed is composed of particles whose size has a wide field scattering, the fluidization velocity grows so that it can lead to the appearance of the small particles entrainment phenomena.

The size of the particles influences directly the minimum fluidization speed, which grows proportionally with d_p^2, and also influences

the pressure loss and specific weight of the layer.
It has been experimentally determined that optimum density of the particles material is between 1280 – 1600 kg/m^3. Dense materials produce low coefficients of heat transfer and need a bigger velocity of fluidization gas.
In fluidization are used materials such as: sand, corundum, graphite, aluminum oxide and other particles which are physical and chemical stable at the work temperature. The volume weight of the particles determines the specific weight of the fluidized bed and influences the minimum fluidization velocity and also the loss of pressure in the layer.

2. OBJECTIVES AND RESULTS

The fluidized beds can be used in heat and thermo-chemical treatments as active mediums, as heating mediums, soaking steps, and also as cooling mediums.
The cooling velocity is an important parameter of the heat and thermo-chemical treatments.
The paperwork is presenting an experimental study concerning the cooling capacity of the fluidized bed using different solid mixture recipes and as fluidization agent: air.
As a disadvantage is the fact that they cannot be used for pieces bigger than 100 mm, the fluidization could be badly bred, the specific convection of the fluidized bed being clogged.
the most important advantage is that in certain circumstances they can replace the salt baths.
It was experimentally analyzed the factors which influence thermal transfer in fluidized bed.

In order to determine the cooling medium like fluidized bed, it was used a control cylinder from silver within a chromel-alumel thermocouple, which permits temperature measurement with a recording apparatus y-t. The control cylinder is heated up to the desired temperature (800^{o}C) and cooled down in the fluidized bed.
The silver test bar, figure 1, has the following sizes and characteristics: Ø=13 [mm], h=28 [mm], S=1408 [mm^2]; m=39.9[g], ρ_{Ag} =10.5 [g/cm^3]; λ_{Ag} =418.5 [W/m·K].
The equipment used in the experimental determination of the cooling curves is formed from, figure 2:

- air fluidization system;
- heating system of the silver test bar (circular pipestill with electrical resistance);
- measurement system represented by an y-t recording apparatus(with modification apparatus of the shifting rate of the recording apparatus);
- Transformer of the filling variation of the ventilator for modification the air velocity.

The tested dusty environments were fluidized with air.
The silver test bar was heated in a circular pipestill until 800^{o}C and then was introduced in the fluidized bed, the cooling curve being recorded by the y-t recording apparatus.
As powders there were used mixtures of sand and salt. The grain sizes for those powders were as follows: salt grain 500< d_p <1400 (fig. 3; sand 500<d_p <1200 (fig. 4) where d_p is the particle diameter (the eye sieve) - in µm.
The mixtures varied from 100% salt particles to 100% sand, with intermediate compositions of 75%, 67%, 50%, 33% and 25% of each.

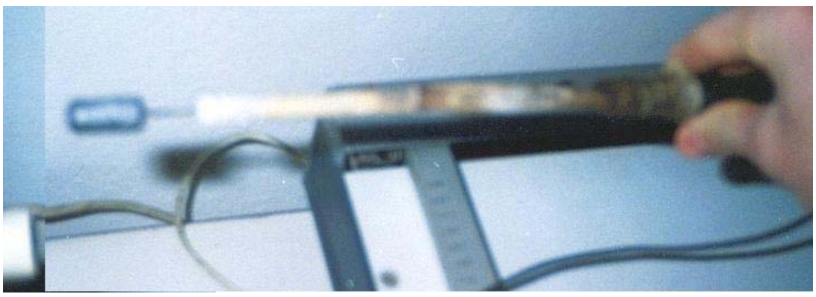


Fig.1 The silver test bar

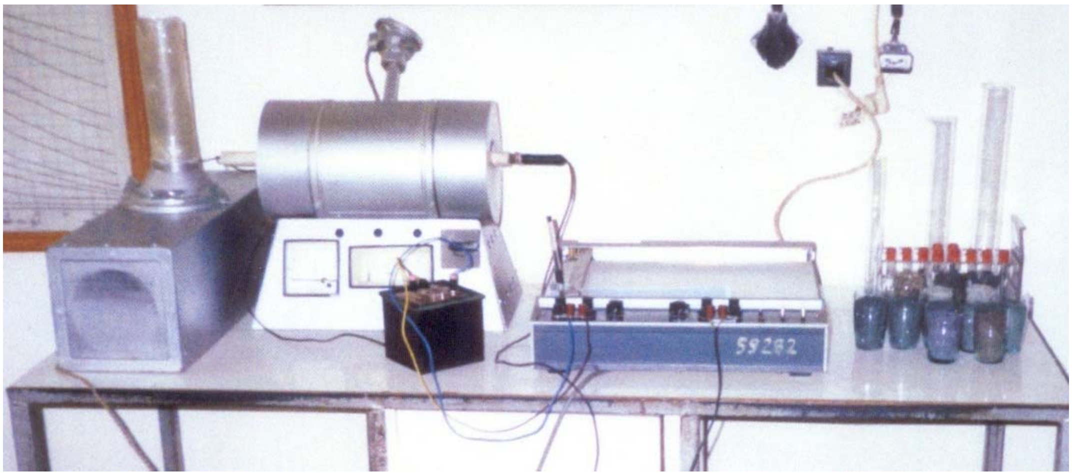


Fig.2 Equipment for the determination of fluidized beds cooling characteristics

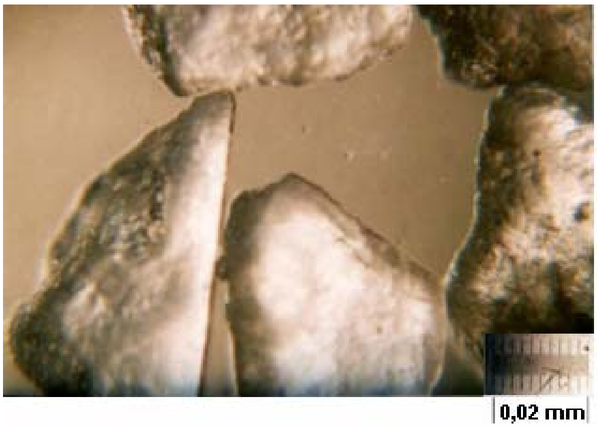


Fig3 Salt particles

Fig.3 Sand grains for fluidized bed.

For each cooling environment, that is different salt / sand percentage, were calculated:

- the maximum and medium cooling velocity;
- global factor of heat transfer;

$$\alpha_g = \frac{\alpha_1 \cdot \Delta t_1 + ... + \alpha_s \cdot \Delta t_8}{t_{total}} \quad (1)$$

Where:

$$\alpha_i = \frac{3600 \cdot m \cdot c}{\Delta t_i \cdot S} \ln \frac{T_i - T_o}{T_f - T_o} \quad [W/m^2K](2)$$

In the relations above:
m=0, 0399 kg, the test bar weight;
c=0,056 Kcal/kg ^{0}C specific heat capacity for silver;
S=0, 001408, [mm^2] test bar surface;
Δt= time interval, [s];
T_i, T_f and T_0 = the initial, final temperature interval and environment temperature, [^{o}C]

- cooling intensity, H, [m^{-1}]:

$$H = \frac{\alpha_g}{2\lambda} \quad (3)$$

Where $\lambda_{Ag} = 418{,}5\, W/mK$.

The results have been recorded in tables, Table 1 – the cooling curves, Table 2 – cooling velocities variations; 3 – thermal transfer coefficient, so we could calculate cooling intensities (H). For each parameter the adequate chart has been build-up.

3. CONCLUSIONS

It can be noticed from the graphics that salt and sand concentration into the fluidized powder influence the cooling velocity and the heat transfer coefficient in fluidized beds.
First, sand and salt, both good insulators, absorb the heat from the test bar and yields it

when the cooling velocity gets slower. The shapes of the grains, their irregularity have great influence: the velocity fluctuations between 700…400^{0}C have as support these grain features. As a first step, the sand, being a good insulator, absorbs the heat from the test bar and yields it when the cooling velocity gets slower.

- Using sand as solid medium, the highest cooling velocity is obtained, v_{max} = 27^{0}C/s;
- The smaller cooling velocity is for 100% salt as solid medium, v_{max} = 18^{0}C/s;
- For the tested mixtures v_{max} lies between 18…22^{0}C/s. All the studied environments are for annealing (they cannot be used for hardening because of the small cooling velocities.

Table 1 Cooling velocities for different mixtures salt sand, air fluidized; Solid particles size: salt 500<d_p<1400 and sand 500<d_p<1200

T[^{0}C]	Salt 100%	Salt 75%	Salt 67%	Salt 50%	Salt 33%	Salt 25%	Sand 100%
800	0	0	0	0	0	0	0
700	5.5	5.2	4.5	5	3	3	3.7
600	11.7	11	9.5	10.5	7.5	8.5	8.7
500	18	16.5	15	16.5	12.5	14.5	13
400	24.7	23	21	23.5	18	20.5	18.4
300	33	31	28	31	25	27.5	25.5
200	44	41	37.5	41	34.5	36.5	35
100	60	56	53.5	54.5	50	50	51.7
50	72.5	68	66.5	64.5	62.5	60	66
30	79	75	75	70.5	71	66.5	75.5

Cooling curves for mixtures of salt with 500<d_p<1400 and sand with 500<d_p<1200

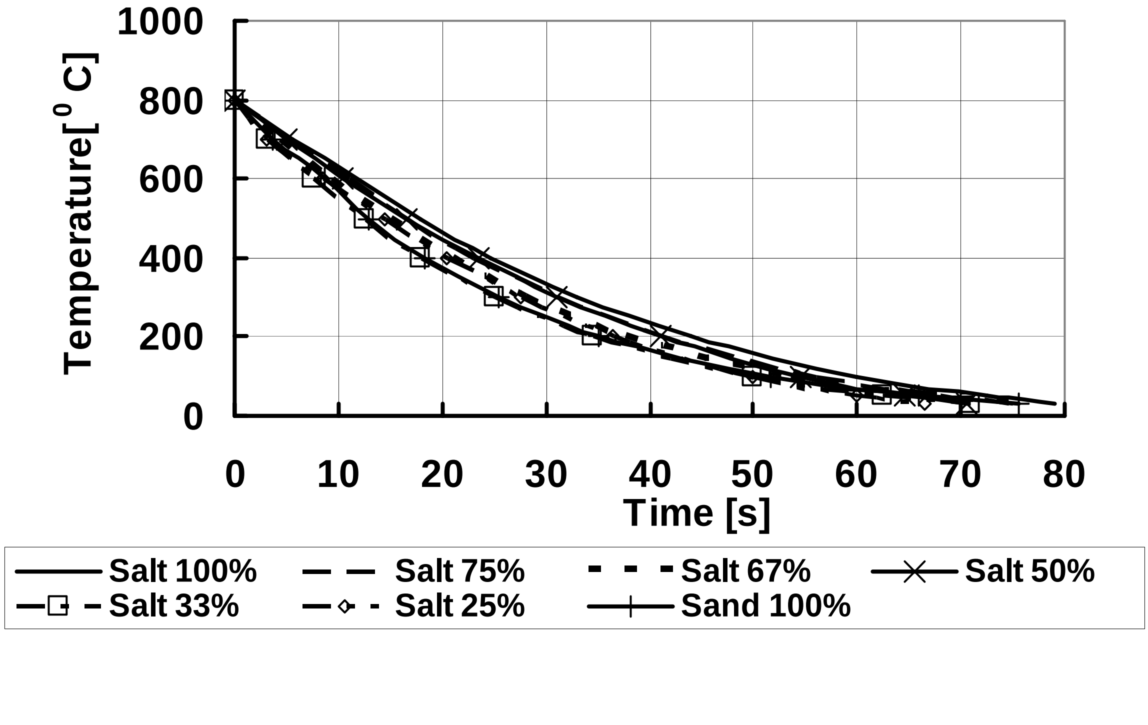


Table 2 Cooling velocities variation [^{0}C/s]

T[^{0}C]	Salt 100%	Salt 75%	Salt 67%	Salt 50%	Salt 33%	Salt 25%	Sand 100%
800	0.00	0.00	0.00	0.00	0.00	0.00	0.00
700	18.18	19.23	22.22	20.00	33.33	33.33	27.03
600	16.13	17.24	20.00	18.18	22.22	18.18	20.00
500	15.87	18.18	18.18	16.67	20.00	16.67	23.26
400	14.93	15.38	16.67	14.29	18.18	16.67	18.52
300	12.05	12.50	14.29	13.33	14.29	14.29	14.08
200	9.09	10.00	10.53	10.00	10.53	11.11	10.53
100	6.25	6.67	6.25	7.41	6.45	7.41	5.99
50	4.00	4.17	3.85	5.00	4.00	5.00	3.50
30	3.08	2.86	2.35	3.33	2.35	3.08	2.11

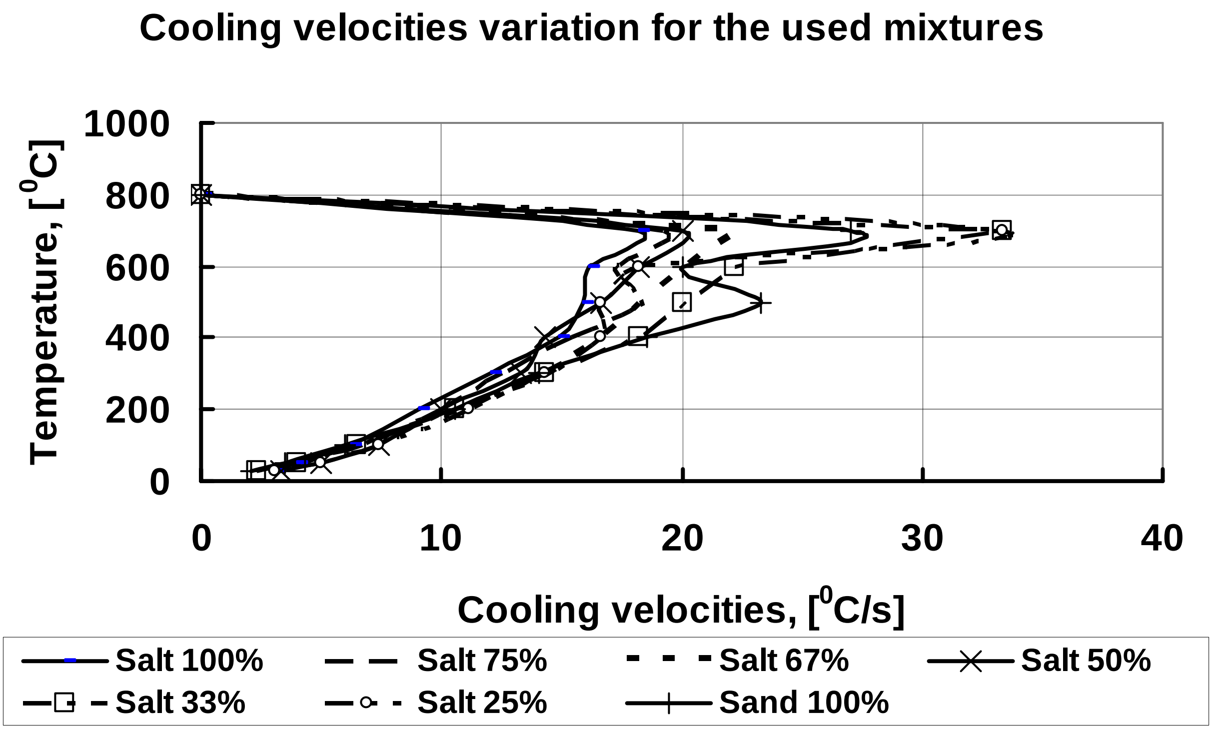
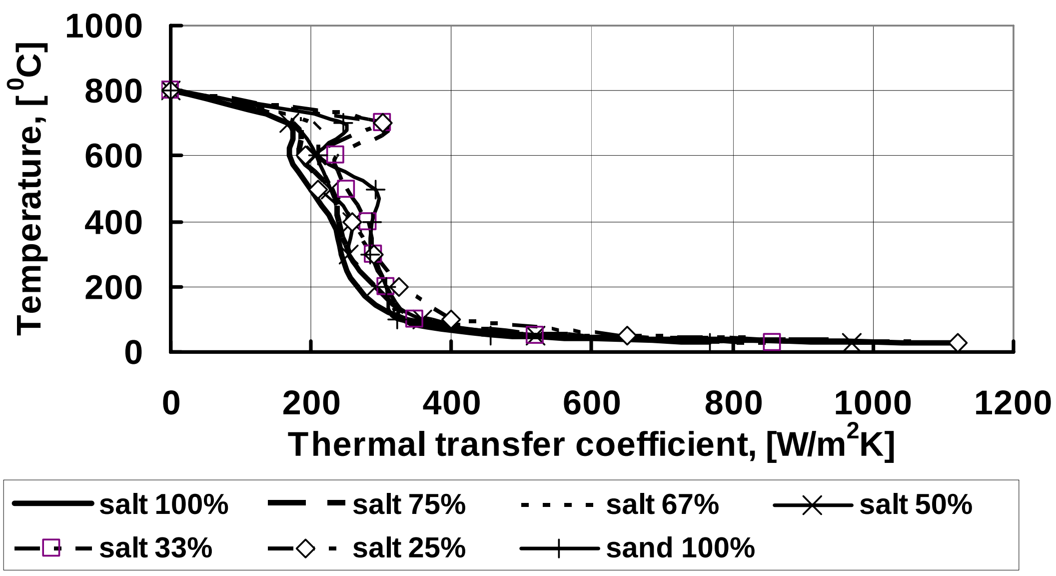


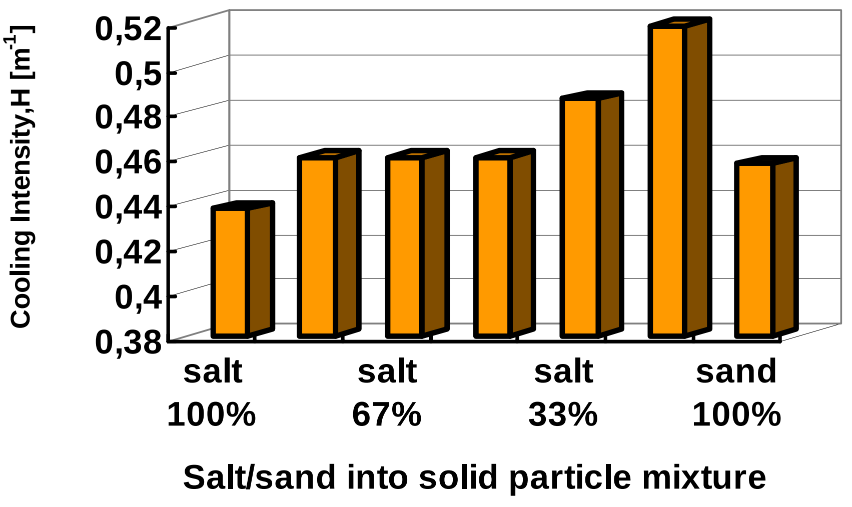
Table 3 Heat transfer coefficient, α_i, [W/m^{2}K],
Calculated global factor of heat transfer, α_g, [W/m^{2}K], and cooling intensities, H, [m^{-1}]

T [^{0}C]	salt 100%	salt 75%	salt 67%	salt 50%	salt 33%	salt 25%	sand 100%
800	0	0	0	0	0	0	0
700	165.3	174.9	202.1	168.4	303.1	303.1	245.7
600	170	181.7	210.8	206.7	234.3	191.7	210.8
500	199.1	228	228	228	250.8	209	291.7
400	231.1	238.2	258	258	281.5	258	286.7
300	243.8	253	285.1	253	289.1	289.1	285
200	266.2	292.8	308.2	292.8	308.2	325.3	308.2
100	335.9	358.3	335.9	358.3	346.7	398.1	321.8
50	520	541.7	500	520	520	650	454.5
30	1120.1	1040.1	856.5	970.1	856.5	1120.1	766.4
α_g	365.48	384.98	384.58	384.90	406.64	434.17	382.40
H	0.44	0.46	0.46	0.46	0.49	0.52	0.46

Variation of the thermal transfer coefficient



Cooling intensity dependence on the solid mixture composition



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AUTHORS

[1]Lecturer Ph.D. Carmen NEJNERU, Technical University „Gh. Asachi" Iasi, Romania, 0232-278683/2280.
[2]Lecturer Ph.D. Diana GHEORGHIU, Technical University „Gh. Asachi" Iasi, Romania, dagheorg@tuiasi.ro 0232278683/2127.
[3]Drd. Mihai BERNEVIG, Technical University „Gh. Asachi" Iasi, Romania.
[4]Cons. Prof. Ion HOPULELE, Technical University „Gh. Asachi" Iasi, Romania, 278683/2280