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NEAR OIL SHALE SURFACE PARTICLE TEMPERATURE PROCESSES IN FLUIDIZED BED COMBUSTOR

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ABSTRACT

Tarfaya (Morocco) oil shale particle combustion has been carried out in laboratory fluidized bed reactor (0.1 m in diameter and 2 m in height). Fluidized bed material is quartz sand with mean diameter (0.4 -0.5 mm). Shale particle mass does not exceeds 0.5% of the total bed material. Tests are performed with air atmosphere. Particle temperatures have been measured near the vicinity of the surface for different bed temperatures. A very fine (Pt, Rh Pt) thermocouple (10µm) was used to detect all temperature variation near the solid shale particle. Particle size processed are (2.5 – 3.15 mm), (3.15 – 4 mm) and (4 - 5 mm) with density of 2.2. Fluidized bed temperature varies from 300 to 700°C. During test, shale particle does not fragment. Result shows that for bed temperature of 300°C, near particle surface temperature does not exceeds 290°C during all the time of fluidization and for all the particle size tested. If bed temperature is 300°C, surface shale temperature does not exceed bed temperature if particle size is in the range of (3.15 - 4 mm) and (4 – 5 mm) during all the process time. For bed temperature higher than 350°C near surface particle temperature exceeds bed temperature for the tested oil shale particle. Temperature excess varies from 20°C to 170°C during a period of time which can reach 2 min depending on size particle. This devolatilization time corresponds to a rapid gas escape from the in side shale particle to the surface. For bed temperature higher than 400°C experimental results show that surface particle increase rapidly for the smallest size particle. Surface temperature increases with bed temperature and decrease if shale particle size increases. Shale weight loss varies from 3 % to 10 % for operating bed temperature of 300°C and 700°C.

Important conclusions can be deduced from these experimental tests:
- The rapid contribution to the calorific fluidized bed energy is mainly due to the fresh particle entering the combustor.
- After 2 min of particle injection, the energy supplied by shale is from residual carbon inside the processed particles.

INTRODUCTION

There is no doubt that with actual petrol price (barrel of 80 $) Oil Shale will have a good place in world energy and economy. This high price increases the needs to find other energy resources other than petroleum. Research are directed towards alternative and others energy resources to contribute to energy supply security. The continuing decline of petroleum reserves and increasing consumption of petroleum, oil shale may present opportunities to supply some word fossil energy needs in the following years ahead. It is proved that oil shale can dominate a great part of energy economy if it is well processed. In Estonia this resource of energy is burned directly as a very low grade and country energy remains dominated by shale(1). It shows that oil shale will not remain as elusive energy. Morocco has very substantial shale reserves which are not exploited. Oil shale deposits are widely distributed in

north, centre and south of Morocco. Official reserves have estimated recoverable reserves of shale oil to 3.42 billion barrels.
In order to contribute to understand the process of Moroccan oil shale combustion in fluidized bed system laboratory experiments have been carried out in previous work (2), (3). It was found that shale particle fragments during fluidization. Experimental conditions have an important influence on particle size distribution (4). It was shown that shale particle reaction temperature, particle size evolution and heating rate are responsible of all the process of shale combustion in fluidized bed reactor. In the present experiments we are interested to measure the temperature evolution near the shale particle surface once introduced in the fluidized bed. Important results are deduced concerning efficient particle residence time in the fluidized bed combustor.

EXPERIMENTAL APPARATUS

We carried out experiments on shale particles fluidized in a cylindrical reactor (2 m in height and 0.1 m in diameter). Figure 1illustrates the fluidized bed reactor used. A mass of 400 g of silica river sand of 0.4-0.5 mm diameter size was introduced in the refractory stainless steel reactor. Air was dried in a packed bed of zeolith and heated through a calming section before entering the reaction zone. The distributor consists of a drilled stainless steel with void fraction of 2.2%. A high density kawool blankets insulates the reactor. An electrical heater supplies 6kW to the reactor. PID regulator control the bed temperature to vary from 573 to 973 K via a thermocouple inserted in the bed. The reactor can operate at different conditions of particle size, fluidization velocity and bed temperatures. Investigated shale particle was attached to a fine thermocouple (10 μ m Pt Rh Pt) and introduced in fluidized sand particle. Near surface temperature is recorded during all the processed time.

SHALE PREPARATION AND ANALYSIS

Tarfaya oil shale deposit is located along the Atlantic coast of Morocco Sahara. It belongs to class of carbonate fuels. The R2B2 seams was ground and sieved to prepare the initial size fractions. The ultimate analyses (wt.) give carbon 15.5, hydrogen 1.17, nitrogen 0.28, oxygen 23.65, and sulphur 1.6. The heat of combustion value is 3386 kcal/kg, the density 2 g/cm3. Mineral matter and organic matter represent 15% and 85% of weigh respectively. Total CO_2 evolved at 900°C is approximately 22% of total solid particle weigh. Oil shale and ash analysis of Tarfaya oil shale R2B2 deposit is presented in table 1. Calcite is the main mineral in the carbonate constituent of oil shale.

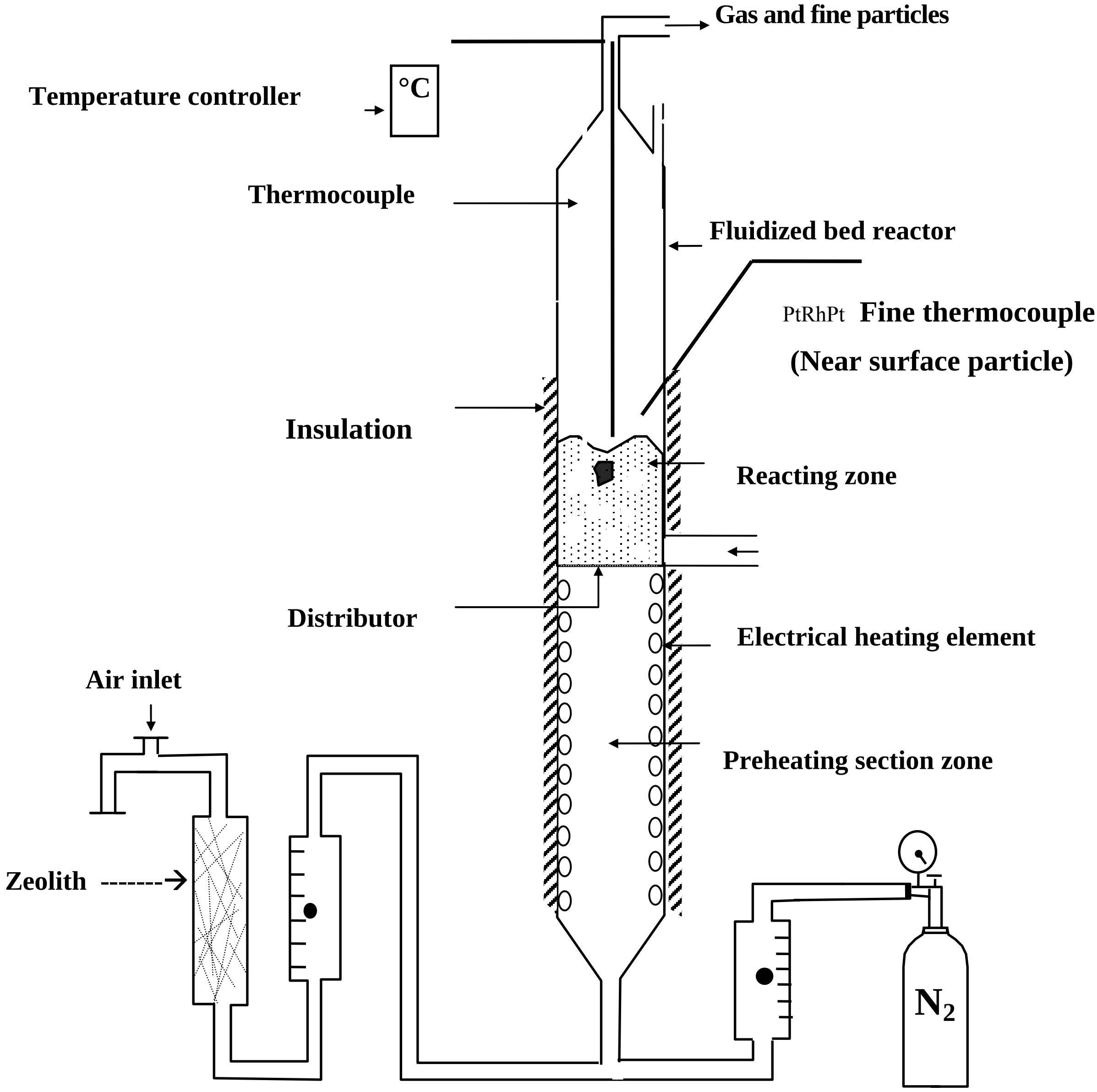

Figure 1: Flow diagram of experimental apparatus set-up

Compound	Shale Chemicals Analysis	Ash Chemicals Analysis
SiO_2	6.25	11.61
Al_2O_3	0.83	1.55
Fe_2O_3	0.54	1.00
CaO	40.42	75.08
MgO	0.41	0.76
SO_3	3.43	6.38
K_2O	0.05	0.09
Na_2O	0.10	0.19
P_2O_5	0.08	0.15
TiO_2	0.05	0.09
Other	1.67	3.10

Table 1: Oil shale and ash analysis, (wt. %) R2B2 deposit

Experimental conditions are as follows: Original particle size of randomly shaped fragments of size (4-5 mm), (3.15-4 mm) and (2.5-3.15 mm). Bed temperature varies from 300 to 700 °C. Fluidizing velocity is 2Umf. Bed material composed of 400 g of quartz and minimum fluidizing velocity Umf varies from 6.95 to 11.55 m/s depending on bed temperature.

RESULT AND DISCUSSIONS

A typical size distribution profile of shale particle processed at 700°C is presented in Fig. 2. It shows that initial size change during the process time.

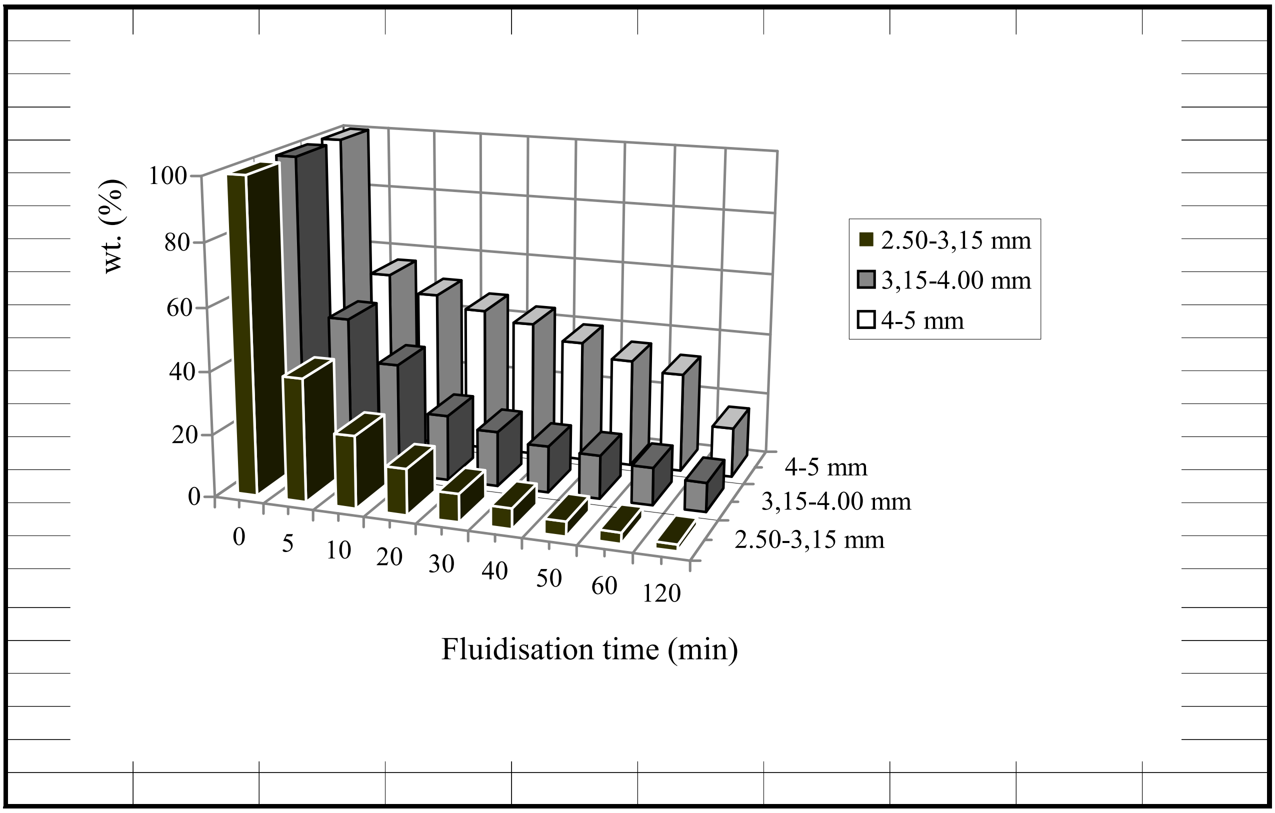

Figure 2: Evolution of particle size in bed holds at 700°C

Fig. 3 illustrates the evolution of temperature near surfaces particles for bed temperature hold at 300°C. Particle temperature is reached for small particle size in a period less than 10 seconds and exothermal process stay for more than 15 seconds. For large particle size particle near surface temperature never reach bed temperature in the operating conditions. Evolved organic gas from the reacting particle is not enough to supply heat to the external medium (bed). Residual organic matter continues to react but not sufficiently to get bed temperature.

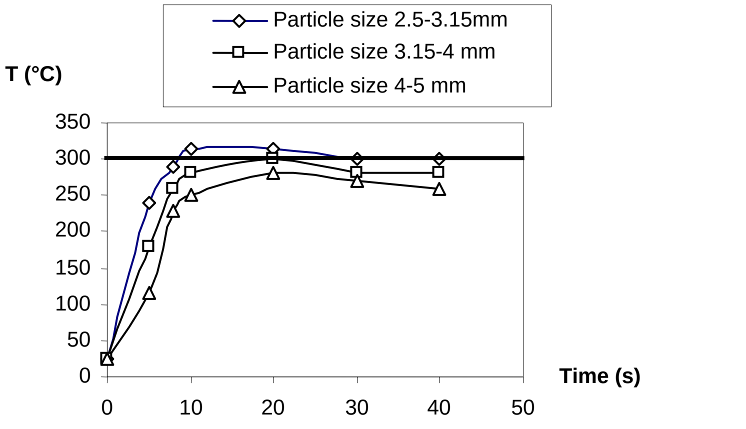

Figure 3: Near particle surface temperature. Bed Temperature 300°C

Fig. 4 shows the temperature evolution near surface particle when bed temperature is hold at 350°C.

As it can be seen solid particles temperatures reach bed temperature in all the case. However thermal resistance is always presents for large particle size: temperature never exceeds bed temperature. For small tested particle, surface temperature exceeds bed temperature after 15 seconds of introduction in the fluidized bed. The reacting shale supplies medium by heat which increases temperature of surrounding medium by more than 30°C for a period exceeding 50 seconds.

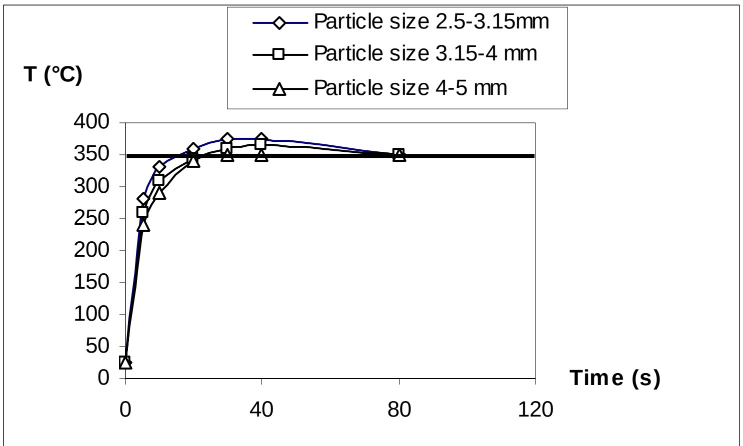

Figure 4: Near particle surface temperature. Bed Temperature 400°C

For bed temperature hold at 400°C, all the particle size processed reach bed temperature 20 seconds after injected in the fluidized bed. The particle reacts during a period of 90 seconds and maximum temperature varies from 50°C for small particle to 30°C for large particle. Fig.

5 illustrates all the temperature variation during fluidization process for different particles size. Particle temperature exceeds bed a temperature for a period of 60 seconds.

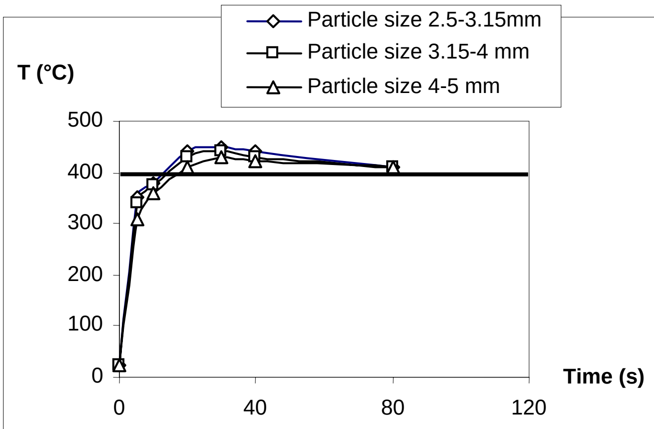

Figure 5: Near particle surface temperature. Bed Temperature 400°C

Fig.6 and Fig.7 and Fig.8 correspond to temperatures generally used to shale pyrolysis (450, 500 and 550°C). In these experiments we can see that effective heat generated from reacting organic matter increase medium temperature by 100°C after 20 seconds after particle injection in the bed. Near particle medium profits of exothermal shale decomposition for a period of at least 60 seconds in all the tested particles.

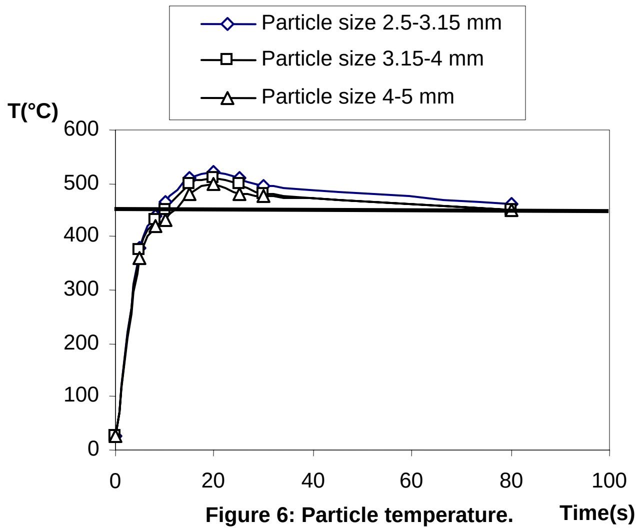

Figure 6: Particle temperature. Bed temperature 450°C

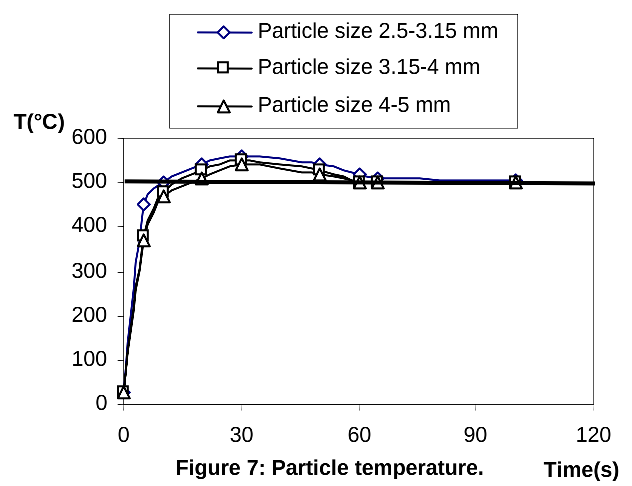

Figure 7: Particle temperature. Bed temperature 500°C

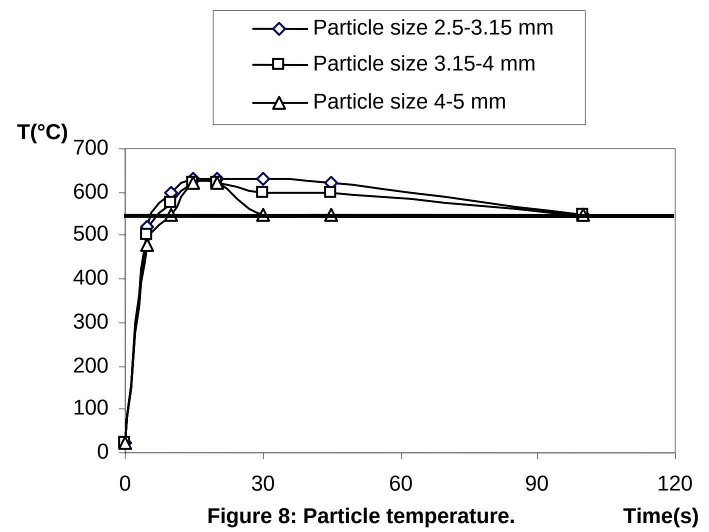

Figure 8: Particle temperature. Bed temperature 550°C

For bed temperature greater than 550°C the same trends of thermal process occurs in the reactor. Peak temperature is more than bed temperature by 120°C in the case of bed temperature of 600°C. However peak temperature in the particle vicinity exceeds bed temperature by more than 170°C in the case where bed temperature is 700°C. Solid particle supplies heat for a duration of 2 minutes. High thermal bed obliges internal organic matter to react rapidly and contributes to increase external particle surface temperature. Fig. 9 and Fig.10 illustrate all the temperature variations for the tested particles sizes.

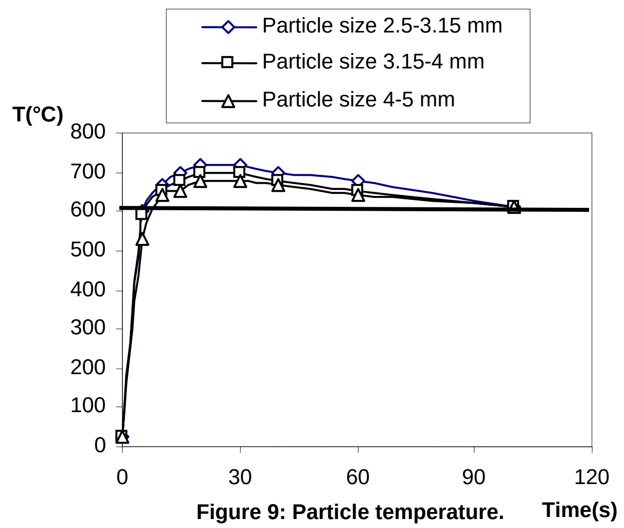

Figure 9: Particle temperature.
Bed temperature 600°C

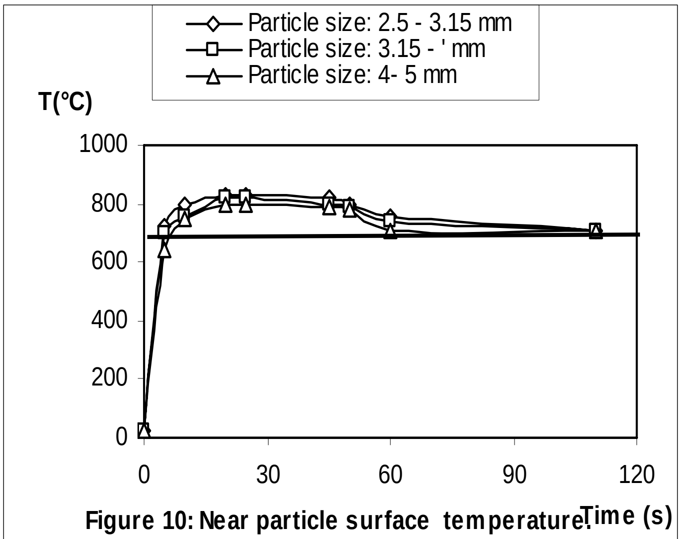

Figure 10: Near particle surface temperature.
Bed Temperature 700°C

CONCLUSIONS

Important conclusions can be deduced from these experimental tests:

- The rapid contribution to the calorific fluidized bed energy is mainly due to the fresh particle entering the combustor. The early devolatisation time of shale is important to supply instantaneous heat to the reactor.
- After 2 min of particle injection, the energy supplied by shale is from residual carbon inside the particle for the processed particles sizes.

- Surface temperature increases with bed temperature and decrease if shale particle size increases. Shale weight loss varies from 3 % to 10 % for operating bed temperature of 300°C and 700°C.
- Particle size distribution in the reactor feed will play an important role in the heat balance, solid residence time and combustor efficiency.

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