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Enhancing Oxidation Process in Chemical Looping Combustion Applying Jet Fountain Fluidized Bed

تحسين عملية الاكسدة في تطبيق الاحتراق الكيميائي الدائر في المهد المميع ذي النافث النافوري

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الخلاصة

طبقا لدراسات الامم المتحدة فإن انبعاثات غاز ثانى أكسيد الكربون تعد أحد الأسباب الرئيسية لما يعرف بظاهرة الصوبة الزجاجية وبالتالى الارتفاع المستمر لدرجة حرارة الغلاف الجوى ومايترتب عليه من آثار سلبية، ومن ناحية أخرى فإن الوضع الحالى لمصادر الطاقة يحتم استمرار الوقود الإحفورى من غاز وبترول وفحم كمصدر رئيسى للطاقة خلال العقود القادمة، وفى هذا الإطار فإن فصل ثانى أكسيد الكربون الناتج عن حرق الوقود الإحفورى وتخزينه تحت الأرض يعتبر ضرورة لتقليص الإنبعاثات إلى الحد المطلوب.

ويعد الإحتراق الكيميائى الدائر أحد أفضل الطرق المستحدثة لفصل ثانى أكسيد الكربون الناتج عن عملية الإحتراق، ففى هذه الطريقة لا يكون هناك تلامس مباشر بين الوقود والهواء ولكن يتم نقل الأكسجين من الهواء إلى الوقود عن طريق وسيط عبارة عن حبيبات لمعادن كالحديد أوالنحاس أوالنيكل حيث يتم أكسدتها ثم اختزالها دوريا، وقدأشارت عدد من الدراسات أنها الطريقة الأفضل إقتصاديا، حيث فيها يتم فصل غاز ثانى أكسيد الكربون تلقائيا ودون فقد فى الطاقة.

ويهدف هذا البحث الى تحسين اجراء الاكسدة من خلال استخدام مفاعل لمهد مميع ذى نافث نافورى تم تصميمه وتصنيعه وتركيبه بالمعمل، المفاعل له قطر داخلي 105 ملم وارتفاع 4000 ملم . وقد استخدمت مادة الالمينيت النشطة كناقل الاكسجين. فى تجارب هذا البحث تم تغذية الهواء الجوى خلال مهد من حبيبات مادة الالمينيت،وتم قياس تركيزات الاكسجين بعد المهد لتقدير كميات الاكسجين المتحدة مع حبيبات الالمينيت، وقد أجريت التجارب فى المفاعل فى صورته التقليدية وفى الشكل المبتكر مع النافث النافورى لعمل دراسة مقارنة، وقد تم دراسة تأثير ظروف التشغيل على آداء المفاعل فى اتمام اجراء الأكسدة والتى تشمل درجة حرارة المهد، وسرعة التمييع، نسبة هواء النافث، وارتفاع فتحة النافث، وتشيرالنتائج التي توصلت اليها الدراسة الحالية الى ان المهد المميع ذي النافث النافوري هو اكثر فاعلية في اتمام عملية الأكسدة مقارنة بالمهد المميع التقليدى، حيث يزيد من معدلات الاكسدة ويقلل الوقت اللازم لكامل عملية التحويل، وذلك لأنه يحسن كثيرا من كفاءة التلامس بين الهواء وحبيبات الالمينيت الصلبة. وجد أيضا أن معدل الأكسدة يتحسن مع درجة حرارة المهد وسرعة التميع. على جانب آخر ولدراسة تأثير نسبة هواء النافث وارتفاع فتحة النافث ثبت ان هناك قيم بينية تكون عندها لعملية الاكسدة قيمة عظمى.

Abstract :

Chemical- Looping Combustion (CLC) has emerged as a very promising combustion technology for power plants and industrial applications with inherent CO_2 capture. CLC avoids the energetic penalty present in other competing technologies. The technology basis is to transfer oxygen from air to the fuel by means of a solid oxygen-carrier avoiding direct contact between fuel and air. It consists of two successive reactions, oxidation and reduction, in two interconnected fluidized beds. The aim of the current work is to enhance the oxidation process by applying jetting fountain fluidized bed. A jetting fountain fluidized bed reactor has been designed, fabricated and installed to carry out the experimental work. It has 105 mm ID and 4000 mm height. Activated ilmenite has been used as oxygen carrier. During the tests atmospheric air is fed through an ilmenite bed that reacts with oxygen. The oxygen concentrations are measured after the bed to estimate the quantities of oxygen that combined with bed materials. The influences of operating conditions including bed temperature, fluidization velocity, jet air ratio and jet orifice height on the process effectiveness have been studied.

The findings of the present work indicate that the jetting fountain fluidized bed is more effective in ilmenite oxidation where the oxidation conversion rate increases and the time required for full conversion reduces. Applying jetting fountain configuration enhances gas solids contact and improves the interphases mass exchange between bubbles and emulsion. The oxidation conversion rate was found to improve with bed temperature and fluidization velocity. On the other side, studying the influences of jet air ratio and jet orifice height demonstrate that there is an intermediate value at which the oxidation process records an optimal.

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Keywords

Fluidized bed, Chemical- Looping Combustion (CLC), CO_2 capture ilmenite.

1.Introduction

According to the United Nations Intergovernmental Panel on Climate Change (IPCC), greenhouse gas emissions, especially CO_2, have already made the world warmer [1]. Some significant actions should be taken to control the increase in global temperatures to avoid serious ecosystems consequences. However, current scenarios and projections indicate that there will be an increase in worldwide energy demand while fossil fuel resources will continue to dominate. [2]. In this context CO_2 capture and storage (CCS) for application to power plants offers a sound technical basis to achieve the necessary emissions reductions. The target of CCS technology is to produce a concentrated stream of CO_2 from industrial and power plants, transport it to a suitable storage location, and then store it away from the atmosphere for a long period of time. The development of CCS technologies to market maturity is essential for the production of clean energy from fossil fuels both to ensure a continued role of these fuels, in particular coal, as well as to reduce CO_2 global emissions [3].

Concerning CO_2 capture, three main approaches are considered for industrial and power plants applications: post-combustion systems, oxy-fuel combustion, and pre-combustion systems [4]. However, those approaches suffer a high energy penalty, which results in a reduction of overall energy efficiency of the system and an increase in the price of the energy. Alternatively, CLC process was suggested among the best alternatives to reduce the economic cost of CO_2 capture [5, 6]. The EU project “Enhanced Capture of CO_2” (ENCAP) focused the research in the development of cost efficient approaches, including CLC [7]. The incremental in the electricity cost for CLC was found lower than the calculated for other technologies of CO_2 capture. Additionally, if the environmental impact is also considered, CLC is even more preferred to other CO_2 capture options [8, 9].

The CLC basis is to transfer oxygen from air to the fuel by means of a metal oxygen-carrier avoiding direct contact between fuel and air. The process consists of two successive steps. In a first step, the metal is oxidized with oxygen air (reaction 1). In the second step, the fuel is oxidized to CO_2 and H_2O by a metal oxide (Me_xO_y) that is reduced to a metal (Me) or Me_xO_{y-1}. The global reduction process may be given by reaction (2) considering that the fuel gas is expressed as $C_nH_{2m}O_p$; the flue gas contains mainly CO_2 and H_2O.

Eliminating H_2O by condensation and purification, a highly concentrated stream of CO_2 is obtained which is ready for transport and storage. This concept is the main advantage of the process in relation with other CO_2 capture technologies. In this sense, CLC is a combustion process with inherent CO_2 separation, i.e. avoiding the need of CO_2 separation units and without any penalty in energy.the reaction equations are:

$$(2n+m-p)Me_xO_{y-1}+\left(n+\tfrac{m}{2}-\tfrac{p}{2}\right)O_2 \rightarrow (2n+m-p)Me_xO_y+\Delta H_O \qquad \mathbf{(1)}$$

$$(2n+m-p)Me_xO_y+C_nH_{2m}O_p \rightarrow (2n+m-p)Me_xO_{y-1}+nCO_2+mH_2O\ +\Delta H_r \qquad \mathbf{(2)}$$

$$C_nH_{2m}O_p+\left(n+\tfrac{m}{2}-\tfrac{p}{2}\right)O_2\ \rightarrow nCO_2\ +mH_2O\ +\Delta H_c \qquad \mathbf{(3)}$$

where $\Delta H_c = \Delta H_o + \Delta H_r$

The net chemical reaction over the two steps, and therefore the combustion enthalpy, is the same to conventional combustion where the fuel is burned in direct contact with oxygen from air (reaction 3). Therefore, the total amount of heat evolved in the CLC process is the same as in conventional combustion.

The Chemical-Looping concept been proposed to be accomplished in different type of reactors and configurations.

Currently, the two interconnected fluidized-bed reactors configuration is used in the majority of the CLC plants existing worldwide. It is composed of two reactors, one of them being the fuel-reactor and the other is the air-reactor. In the so-called fuel-reactor conversion of the fuel happens (reaction 2), whereas the regeneration of the oxygen carrier (reaction 1) is carried out in the air-reactor. This configuration has several advantages over alternative designs, considering that the process requires a good contact between gas and solids as well as a flow of solid material between the fuel-reactor and air-reactor [11-15].

The key element in the CLC system performance is the oxygen-carrier material. The most important features of oxygen-carrier includes sufficient oxygen transport capacity, high reactivity for reduction and oxidation reactions, resistance to attrition to minimize losses of elutriated solids, good fluidization properties. Most of the oxygen-carriers proposed in the literature are synthetic materials. In general, the oxygen-carrier is based on a transition state metal oxide, e.g. CuO, NiO، Co_3O_4, Fe_2O_3 or Mn_3O_4, which is supported on different inert materials, such as Al_2O_3, SiO_2، TiO_2 or ZrO_2. A selection of oxygen-carrier materials for natural gas and syngas combustion has been summarized by Hossain and de Lasa [16] and Lyngfelt et al. [17] and recently by Adánez et al. [18].

Many CLC units have been successfully applied. Two experimental models of 10 kWth were installed and operated for about 1300 h at CHALMERS and ICB-CSIC. Ni and Fe based particles have been used awhile natural gas is used as a fuels. [19-22]. A pressurized system at 3 atm has been tested at d Xi’an Jiaotong University [23]. A test rig of 15 kWth has been installed and operated by ALSTOM [24] where natural gas and different nickel based oxygen carrier were used. A prototype of 50 kWth at the Korea Institute of Energy Research [25,26] was successfully run using methane and cobalt oxides as oxygen carrier. A 120 kWth pilot system has been tested at Vienna University of Technology [27,28].

The CLC processes requires a good contact between gas and solids as well as a flow of solid material between the fuel-reactor and air-reactor. In 2001 Lyngfelt et al. [29] proposed a design based on the circulating fluidized bed (CFB) principle. Other works [19, 30-32] showed that CLC can be designed in different configurations, mainly consists of a high velocity riser for air reactor and a low velocity bubbling fluidized bed as fuel reactor. In other designs, fuel and air reactor were proposed in the bubbling regime [33,34].

The aim of the present work is to apply a novel configuration of fluidized bed, namely, jetting fountain fluidized bed (JFFB) in oxidation process of chemical looping combustion. JFFB was proposed by Okasha and presented in many articles [35-41]. JFFB is characterized by excellent gas-solids contact due to creating a jet in the upper part of the bed, establishing a fountain in the freeboard and moderating bubbles size in the main bed. The present work presents a comparison study between the JFFB and the conventional fluidized when applied to the oxidation process of CLC. The influence of different operating conditions including bed temperature, fluidization velocity, jet air ratio and jet height have been tested.

2. Experimental

2.1 Apparatus

The apparatus used in this work is a bubbling fluidized-bed combustor that has been designed to adopt the jetting-fountain configuration as shown in Fig. 1. It has a fluidization column of 105 mm ID and 4000 mm height. The fluidization gases are distributed using a nozzle-type plate. A stainless steel pipe is used to introduce jet air. It proceeds from top to bottom. The pipe has two parts of different diameters. The first part has 2.75 m length and 19 mm diameter to reduce the pressure drop and to have good strength. The second part has

0.75 m length and 10 mm diameter. The later part is curved to allow the jet to issue vertically upward at the center of fluidization column. The tube is designed to be movable in vertical direction. Thus the jet orifice can be adjusted with respect of bed surface and distributor plate. On the other hand the tube is avoided to move in redial direction as it fixed to the fluidization column at two points.

Different electric heaters are used to heat the fed air. Three heaters with 5 kW are used to preheat the distributor air and two heaters with 3 kW are used to preheat the jet-air. An orifice meter is used to measure the flow rate of distributor-air while the flow rate of jet-air is metered using a rotameter.

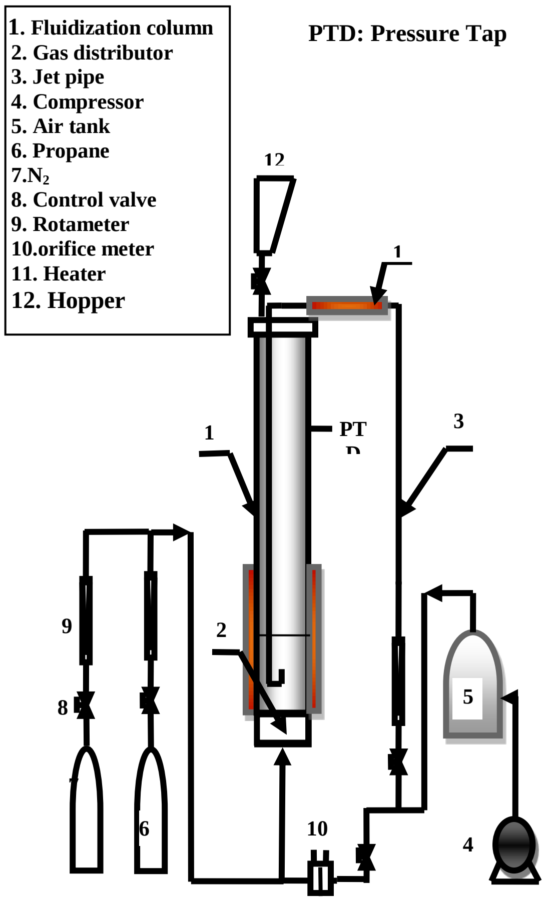

Fig .1 A schematic diagram of the experimental set up.

The column contains 13 portals for measuring probes. Two taps, PTD are used to measure the pressure drop from the plenum to the freeboard. Temperatures have been measured in the bed using a thermocouple of type K. The manufacturer's accuracy specification for the thermocouple is ±0.4% of the temperature. Measurement of gases concentrations has been carried out using IMR2800P gas analyzer. The gas analyzer is able to indicate the concentrations of O2, CO2, CO, SO2 and NOx. The measurement accuracy is ±1% for O_2 and ±2% for all other species.

2.2. Oxygen carrier

The oxygen carrier used in this study is ilmenite which is a Norwegian natural ore. Ilmenite is mainly composed of FeTiO3 (FeO·TiO2), where iron oxide is the active phase that behaves as an oxygen-carrier. The particle size used was 150-300 µm. Natural minerals offer a low-cost alternative for oxygen carriers, which is a desirable characteristic in CLC with solid fuels. Ilmenite has been widely investigated due to low cost, good fluidizability, high melting point and low production of fines. Table 1 shows some general properties of the ilmenite oxygen carrier.

Table. 1 Ilmenite properties.

Property	Value
Average particle diameter, dp, µ	**171**
particle density, kg/m^3	**3600**
Min. fluidization velocity, u_{mf}: steam, 850 ^oC, m/s	**0.025**
Terminal velocity, u_t: air, at 850 ^oC, m/s	**0.83**
Oxygen transport capacity, R_{OC}	**0.03**

2.3. Technique and operating parameters

The used reactor is a batch operation fluidized bed. The operation is based on successive reduction-oxidation (redox) processes. The atmospheric air is used in oxidation process while propane is used in reduction one. First a bed of ilmenite is heated to a preset temperature. Nitrogen is introduced for a period of five min to purge the reactor and avoid the direct contact between propane and air. At this point propane is fed through the distributor plate. Feeding propane continues until the concentration of CO and CO_2 in exhaust gases becomes close to zero. This means that ilmenite bed is completely reduced. Again nitrogen is introduced for a period of five min to purge the reactor. At this point the air is introduced and the oxygen concentration in exhausted gases is measured and recorded. During the first period the oxygen concentration steps down to lower values as the ilmenite bed reacts with oxygen. Feeding of air proceeds until the oxygen concentration in flue gases restores its value in the fed atmospheric air. To this end the first cycle of redox is completed. The next cycle begins with feeding N_2 to purge the reactor and avoid the contact between propane and air.

In this work the influences of operating conditions on the effectiveness of oxidation process have been explored. The bed temperature of 800 ^oC, 850 ^oC, 900 ^oC has been considered. Fluidization velocity has been tested at three cases 0.15 m/s, 0.20 m/s and 0.25 m/s. In jetting fountain configuration, a part of air is fed through the jet while the remaining part is fed through the distributor. Jet air ratio is varied from 0.2 to 0.6. The orifice height of introducing jet air above the distributor plate is also an important parameter. It is varied from 8 cm to 16 cm. In all tests the static bed height is fixed to 15 cm.

3.Results and Discussion

The installed reactor allows the conventional operation and the novel jetting-fountain configuration. In conventional operation, all air is delivered through the gas distributor. In the jetting-fountain configuration, on the other hand, only a part of air passes through the gas distributor. The remaining part proceeds through the jet pipe to create a jetting-fountain zone. The ratio of jet-air mass rate to the total air mass rate is defined as jet air ratio, JR. Mathematically, it may be expressed as:

$$\mathbf{JR} = \frac{\text{jet air mass rate}}{\text{jet air mass rate+distributor air mass rate}} \qquad (4)$$

Several experimental runs have been conducted to investigate the oxidation process for chemical looping combustion. A comparison between the jetting-fountain configuration and the conventional operation is presented.

As discussed above some of parameters are directly measured, however, some quantities are calculated. Based on the measured concentration of oxygen before, C_{O2i}, and after, C_{O2o}, the ilmenite bed in addition to air flow rate, m_a the mass rate of oxygen that combines with the ilmenite particles, m_{O2},p may be calculated as:

$$m_{o2,p} = m_a * \left[C_{o2i} - \frac{(1 - C_{O2i})}{(1 - C_{O2o})} C_{O2o}\right] \quad (5)$$

The conversion ratio, CR, after time t is defined as the mass of oxygen combined with ilmenite bed particles after time t to the mass of oxygen that combines with ilmenite particles at maximum conversion, M_{O2},p ,

$$CR = \frac{\int_0^t m_{O2,p} dt}{M_{O2,P}} \qquad (6)$$

Where M_{O2},p may be calculated as

$$M_{O2,P} = R_{OC}\, M_b \qquad (7)$$

Where M_b is mass of ilmenite bed and R_{OC} is oxygen transport capacity which is the mass fraction of oxygen to oxygen carrier (ilmenite) at the condition of maximum conversion.

The effectiveness of oxygen conversion, η is defined as the mass rate of oxygen combined with ilmenite bed to the mass rate of oxygen fed to the bed.

$$\eta = m._{O2.p} /(C_{O2i} m_a) \qquad (8)$$

The average effectiveness of oxygen conversion, η_{av} over the conversion time t is given by

$$\eta_{av} = \int_0^t m_{O2,p} dt /(C_{O2i} m_a t) \qquad (9)$$

Typical profiles of oxygen concentration in exhaust gases are shown in Fig. 2. The oxygen concentration appears much lower than the concentration of atmospheric oxygen, in particular at the first period. In fact, the oxygen reacts with the reduced ilmenite particles; most probably according to the following chemical reactions [42].

$$4FeTiO_3 + O_2 \rightarrow 2Fe_2TiO_5 + 2TiO \quad (10)$$

$$4Fe_3O_4 + O_2 \rightarrow 6Fe_2TiO_3 \quad (11)$$

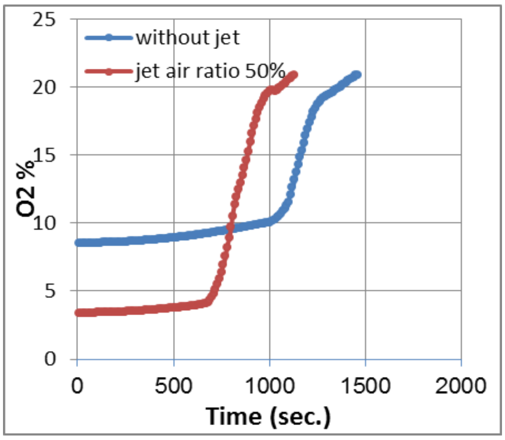

Fig.2: Oxygen concentration in exhaust gases.

The end-product is a mixture of Fe_2TiO_5, Fe_2O_3 and TiO_2 in a ratio which depends on the reacting time and temperature. The first part of the profiles in Fig. 2 has approximately constant concentration with slightly increase with time. During this period the reaction is mainly mass transfer controlled. The mass transfer resistance is principally due to external mass transfer resistance. The internal mass transfer inside the particles is relatively small as the activated ilmenite is highly porous [42]. As the conversion proceeds the internal porosity slightly reduces due to the increase in molecules size since they are combined with oxygen atoms. Thus the internal resistance for mass transfer slightly increases that reduces the rate of oxygen conversion and increases slightly the oxygen concentration in exhaust gas as mentioned above. After this period, the breakthrough curve of oxygen appeared. In this period the porosity of ilmenite significantly reduces while the number of ilmenite molecule available for reaction becomes very few. The oxygen concentration steps up as the consumption due to reaction with ilmenite becomes very slow. In the last period the ilmenite particles continue to react with oxygen until complete conversion. To this end the oxygen concentration restores its value in atmospheric air.

The effectiveness of the reactor is shown in Fig. 3 for the two configurations. The findings demonstrate that the jetting fountain configuration is more effective in oxygen conversion process. These results should be ascribed to the better hydrodynamic characteristics by jetting fountain configuration that enables higher contact efficiency between particles and air. Actually, the creation of a jet in the upper part of the bed, establishing a fountain of particles in the freeboard and moderating bubbles size in the main bed are very beneficial for contact efficiency hat increases the external mass transfer.

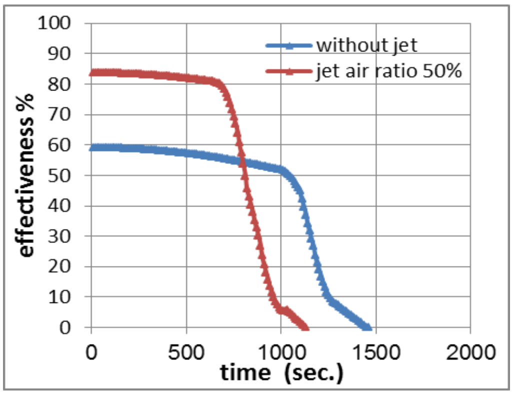

Fig.3: Process effectiveness as a function of time.

Fig. 4 presents the variation of conversion ratio with time. About 90% conversion completes during the first period which is important during continuous operation.

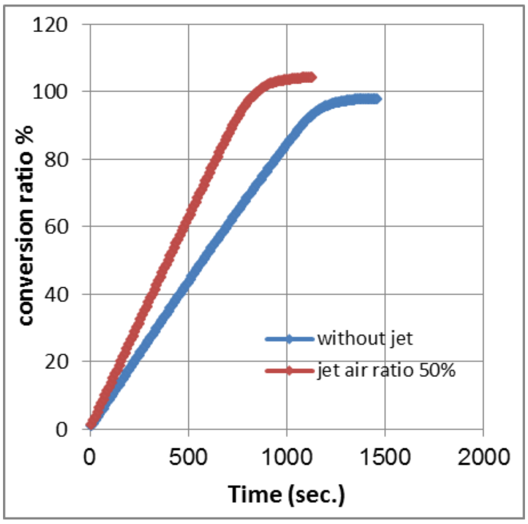

Fig.4: Conversion ratio as a function of time.

Effect of fluidization velocity

Effect of air velocity on oxidation conversion process has been investigated. Three different velocities have been considered 0.15, 0.2 and 0.25 m/sec maintaining bed temperature at 850 ^{o}C.

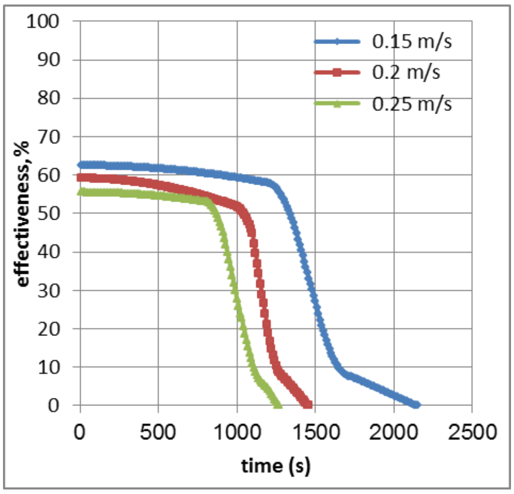

Fig.5 Effect of fluidization velocity on the process effectiveness at conventional operation.

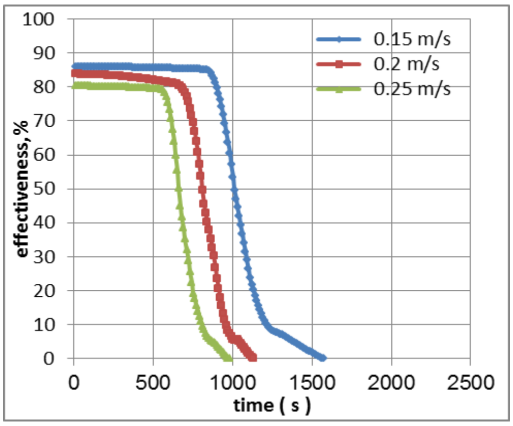

Fig.6 : Effect of fluidization velocity on the process effectiveness applying JFFB.

Figs. 5 and 6 illustrate the effectiveness of oxygen conversion versus time at various inlet fluidization velocities for the two considered configurations. The results indicate that at lower fluidization velocity the effectiveness increases in the first period as the air residence time increases. However, the conversion process needs longer time to attain the full conversion as the available oxygen is lower. At lower velocity the effectiveness has much lower values in the last period. Therefore, the average effectiveness doesn't exhibit notable changes with fluidization velocity as shown in Fig 7.

Fig. 7 also gives a comparison between the conventional operation and jetting fountain operation with 50% jet air ratio. The presented results demonstrate that jetting fountain configuration performs better than conventional operation. The average conversion increases from about 44% for conventional operation to about 59% for jetting fountain configuration achieving 35% increase. It is obvious that jetting fountain configuration enhances mass transfer and gas-particles contact due to creating a jet in the upper part of the bed, establishing a fountain in the freeboard and moderating bubbles size in the main bed.

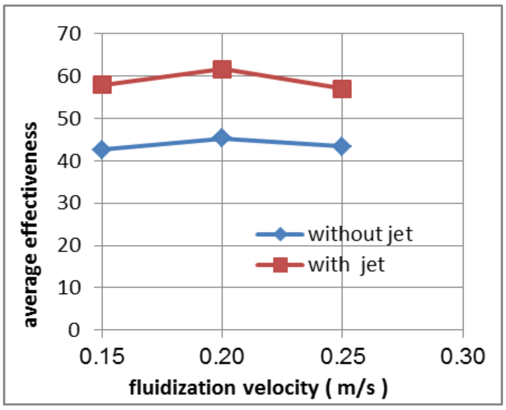

Fig.7: Effect of fluidization velocity on the average effectiveness.

Effect of bed temperature

The effect of bed temperature on the oxidation process has been tested at three different temperatures of 800, 850 and 900 ^{o}C. Fig. 8 and 9 present the effectiveness of oxygen conversion in ilmenite-bed versus time at various bed temperatures in the case of conventional operation and jetting fountain configuration, respectively. It is evident that increasing the bed temperature improves the oxidation as the effectiveness increases and the time for full conversion reduces. This appears reasonable as rising the temperature improves the mass transfer and intensifies the chemical reaction.

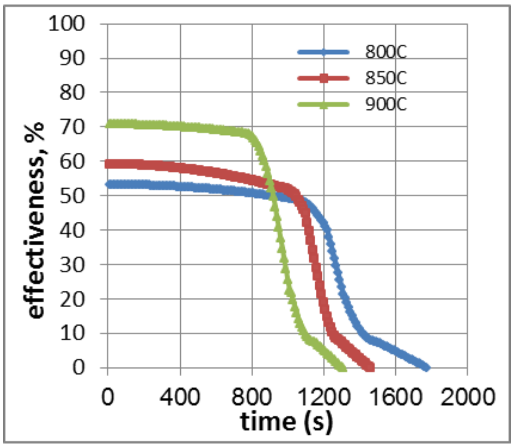

Fig.8: Effect of bed temperature on the effectiveness for conventional operation.

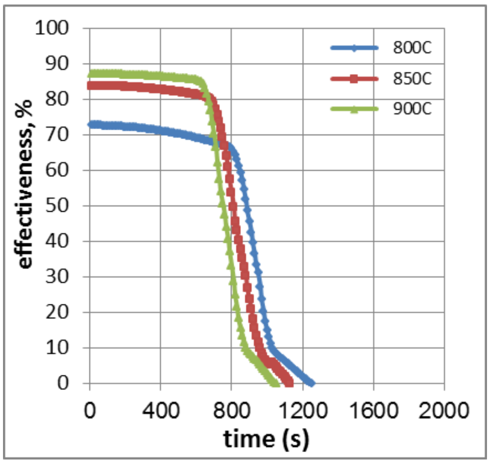

Fig.9: Effect of bed temperature on the effectiveness for JFFB configuration.

Fig. 10 illustrates the average effectiveness of oxygen conversion versus bed temperature. The figure compares the findings of conventional operation with that of jetting fountain configuration with 50% jet air ratio. The findings indicate that jetting fountain configuration yields greater average effectiveness for all considered temperature. It appears that applying jetting fountain configuration enhances the external mass transfer for the reason discussed above.

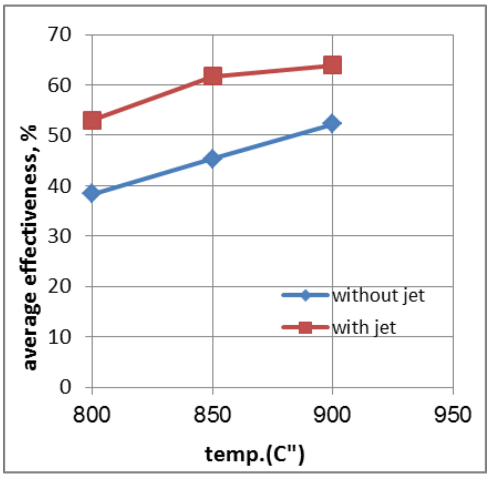

Fig.10: Effect of bed temperature on the average effectiveness .

Effect of jet air ratio

In jetting fountain configuration a part of air is fed through the jet pipe to create a fountain of particles. Jet air ratio is used to express the fraction of air that is delivered via the jet pipe as discussed above. Fig. 11 shows the influence of jet air ratio on the effectiveness of oxygen conversion. It appears worth to indicate that the conventional operation of fluidized bed is the case at JR=0.

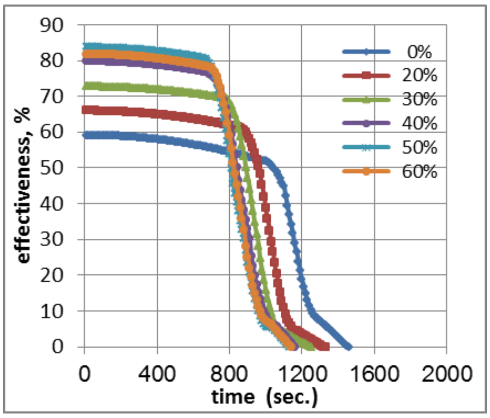

Fig.11: Effect jet air ratio on effectiveness.

The data presented in Fig. 11 reveals that increasing JR improves the oxidation process and the time required for full conversion. However, the average effectiveness of oxygen conversion attains an optimum at 50% JR, and then deceases for a higher value as shown in Fig.12.

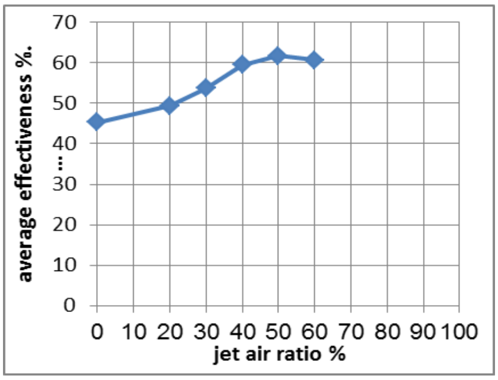

Fig.12: Effect of jet air ratio on average effectiveness.

It appears that the beneficial of increasing contact efficiency due to creating a fountain and decreasing bubbles sizes start be offset. At high jet air ratio, the jet velocity becomes very high that decreases the air contact time. Moreover, under this condition a large fraction of air bypasses the lower part of the bed without contact. However, lowering the jet orifice down in the bed could allow higher jet air ratio with greater contact efficiency.

Effect of jet orifice height

The jet pipe was designed to be movable in vertical direction to adjust the position of jet orifice with respect to the air distributor. The Effect of jet orifice height above the distributor on oxidation process has been investigated and the obtained results are plotted in Figs. 13 and 14.

Fig. 13 illustrates the effectiveness of oxygen conversion versus time at various jet orifice heights. The results demonstrate that the effectiveness of oxidation improves with applying jetting fountain configuration.

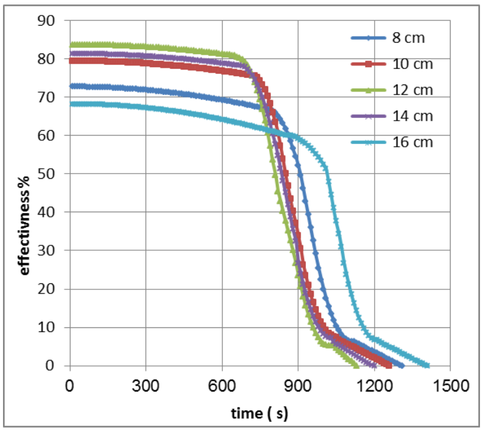

Fig.13: Effect of jet orifice height on effectiveness .

Fig. 14 shows average effectiveness of oxygen conversion versus jet orifice height. The trend line is not monotonic but rather exhibits a maximum point at 12 cm jet height. It is evident that there is a certain height for the jet orifice based on the applied jet velocity at which the performance of oxidation process attains its optimum. It is a matter of compromise for different competitive factors. The enhancement in contact efficiency due creating a fountain of particles and reducing bubble size have positive impacts. On the other side, the lower part of bed that is bypassed by jet air becomes greater which has a negative impact.

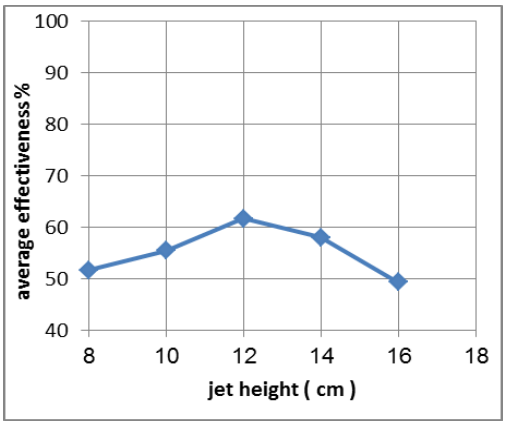

Fig.14: Effect of jet orifice height on average effectiveness.

Conclusion

An experimental study on oxidation process in the jetting fountain fluidized bed has been performed. The experimental tests have been also carried out in the conventional fluidized bed for comparison purpose. The influences of different parameters have been tested and evaluated. Based on the obtained results and the above analysis, the following conclusions can be drawn:

- Jetting fountain fluidized bed enhances the oxidation process. The effective of the oxygen conversion increases while the time required for full conversion reduces. This good findings should be ascribed to the hydrodynamic features of jetting fountain favorable configuration that favor much better gas-solids contact.
- The effectiveness of the oxygen conversion at the higher temperature is faster than at the lower temperature. This result appears reasonable as the higher temperature enhances the mass transfer and intensifies the chemical reaction.
- Decreasing fluidization velocity increases the effectiveness along the first period of oxygen conversion, mainly due to the longer gas residence time. However, the required time for full conversion becomes longer. The overall effectiveness of oxygen conversion doesn't exhibit a notable change with fluidization velocity.
- The influence of jet air ratio on electiveness of oxygen conversion is not monotonic but rather it has an optimum value. The optimum jet air ratio is found to be 50% under the considered conditions.
- The effect of the orifice height of jet on electiveness of oxygen conversion has also an intermediate optimum value. The optimal jet height is found to be at 12 cm under the considered conditions.

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