Biodesulfurization of Tabas Coal in Pilot Plant Scale

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ABSTRACT: *Sulfur emission from coal combustion presents many environmental problems. The techniques used to reduce the amount of sulfur in coal before combustion, include physical, chemical and biological processes. Biological processes based on degradation of sulfur compounds by microorganisms offer many advantages over the conventional physical and chemical processes. The processes are performed under mild conditions with no harmful reaction products and the value of coal is not affected. In this article the progress achieved to date in biodesulfurization of Tabas coal in pilot plant is reviewed. Effect of particle size and pulp density at constant temperature on coal biodesulfurization investigated in this research. The best results obtained was 45% of pyritic sulfur and 20% of total sulfur in reduction at pulp density of 10% and 0-0.5 mm particle size within 14 days.*

KEY WORDS: *Coal, Biodesulfurization, Thiobacillus ferrooxidans, Pyrite, Pilot plant.*

INTRODUCTION

Coal is the most abundant and widely distributed fossil resource of the world. For China, about 70% energy requirements are currently satisfied by burning coal. Coals containing high sulfur concentration are unsuitable for carbonization, combustion, gasification, liquefaction purposes, and utilization of such coals leads to serious environmental pollution and other deleterious effects. Many phenomena threatening the natural environment, such as acid rains, are mainly caused by coal combustion and processing [1]. Therefore, exhaust gas from burning process with high sulfur coal must be treated by installations for removal of SO_2. Due to the high cost of these installations and under the increasing limitations of SO_2 emissions, pre-desulfurization of coal is essential [1].

High sulfur containing coals present many environmental problems. When coal is burnt its sulfur content combines with oxygen to produce sulfur oxides which contributes to both pollution and acid rain. The best possible way to prevent our environment from sulfur oxides is to reduce the amount of sulfur in coal before combustion. There are several techniques including physical [2], chemical [3] and biological processes [4]. Biological processes are based on the degradation of coal using microorganisms.

Recently, the use of microorganisms able to oxidize sulfur compounds present in coals constitutes a clean

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Table1: Composition of media for growth and maintenance of T. ferrooxidans used in different studies at constant temperature [6].

Component	Silverman and Lundgren	Tuovinen and Kelly	Ahonen and Tuovinen	Barron and Luecking	Okereke and Stevens
$(NH_4)SO_4$ (g)	3.0	0.4	0.4	3.5	2.0
$MgSO_4.7H_2O$ (g)	0.5	0.4	0.4	0.06	0.25
K_2HPO_4 (g)	0.5	0.1	0.4	0.06	0.25
KCl (g)	0.1	-	-	0.12	0.1
$Ca(NO_3)_2$ (g)	0.01	-	-	0.002	0.01
$FeSO_4.7H_2O$ (g)	44.25	24.6-147	29.8	74.5	167
H_2SO_4	to pH 2.3	to pH 1.9	to pH 1.5	to pH 1.9	to pH 2.4
Water (mL)	1000	1000	1000	1000	1000

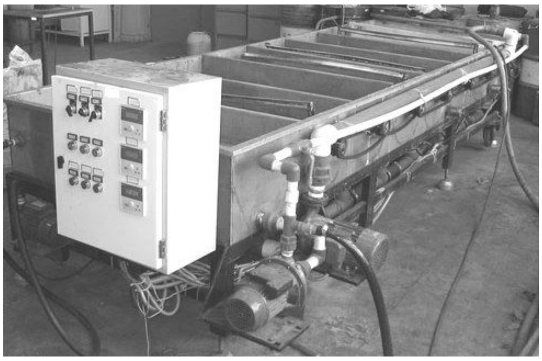

Fig. 1: Biodesulfurization pilot plant.

alternative to remove sulfur from coal, because they promote the oxidative conversion of the reduced forms of sulfur to soluble, easily washed-out compounds. Besides, some microorganisms can operate at ambient temperature and pressure, making them convenient for use [5].

Bacteria of the *Acidithiobacillus-sp* (*Acidithiobacillus ferrooxidans* and *Acidithiobacillus thiooxidans*) have been the most frequently used for the removal of inorganic sulfur compounds in coal. It is considered that *A. ferrooxidans* can oxidize ferrous (Fe^{2+}) iron to ferric iron (Fe^{3+}) and reduced sulfur compounds, while *A. thiooxidans* is able to oxidize sulfur compounds but iron [5].

The previous work deals with biodesulfurization of Tabas coal in laboratory scale, in which two strains of *Thiobacillus ferrooxidans* (PTCC1646 and PTCC1647) were used for desulfurization. The effect of various parameters including pulp density, initial pH , contact time and type of acids that used for pH reduction has been studied [4].

This paper is continues previous work and the objective is to study the effect of some parameters such as particle size and pulp density on biodesulfurization of Tabas coal in pilot plant at a constant temperature reaction during 2 weeks.

EXPERIMENTAL SECTION

Coal

Coal from Tabas Mine was used for the present study. It was grinded and sieved to generate below 0.5 mm and 0.5-1.0 mm size fractions.

Organism and inoculums preparation

In numerous studies the 9K medium, developed by Silverman and Lundgren has been applied for growth and maintenance of *T. ferrooxidans* (Table1).

Thiobacillus ferrooxidans (PTCC1646 and PTCC1647) obtained from the Persian Type Culture Collection (PTCC, Tehran, Iran) was grown in a 250 mL Erlenmeyer flask in a shaking incubator at 30°C and 130 rpm using 100 mL 9K medium with following composition (in g/L):

$(NH_4)_2SO_4$, 3; KCl, 0.1; K_2HPO_4, 0.5; $MgSO_4.7H_2O$, 0.5; $FeSO_4.7H_2O$, 44.2. The medium pH was adjusted to 2 using 10N H_2SO_4.

Conventional batch biodesulfurization

Conventional batch biodesulfurization study was conducted in a 525 L bioreactor with 7 cultural stank at 30°C constant temperature. This device is schematically shown in Fig. 1.

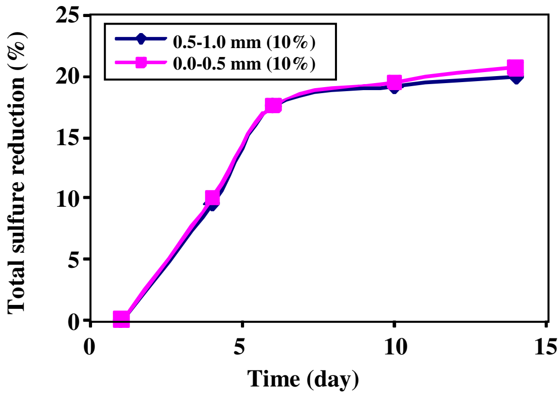

Fig. 2: Effect of particle size on total sulfur reduction.

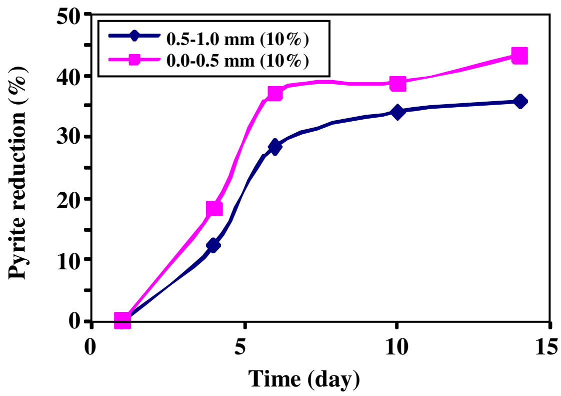

Fig. 3: Effect of particle size on total pyritic reduction.

This device include 1) One tank to Culture of microorganism, 2) 7 culture stank for reaction, 3) one stank to separate of media from treatment coal, 4) One water bath to adjust of temperature media, 5) One pump to circulate of media, 6) One pump to circulate of water in water bath and 7) A jack panel to adjust water bath temperature, verification of mixer cycle and another parameters.

Sulfur analysis

The amount of total sulfur and the sulfate and pyritic sulfur forms of coal samples were determined by the Eschka method (ASTM D3177) and by the ASTM 2492 procedure, respectively. The organic sulfur content was calculated by the difference between the total and pyritic sulfur content of the coal [4].

RESULTS AND DISCUSSION

Effect of particle size on coal desulfurization

To evaluae of particle size effect on biodesulfurization process, the representative sample has divided to the fractions of 0 – 0.5 and, 0.5-1.0 mm.

The results are illustrated in Fig. 2 and 3.

It can be seen due to increasing in external surface area per unit mass of coal the rate of sulfur removal increased with decreasing of particle sizes from 0.5-1.0 mm to 0-0.5 mm. Because of fine distribution of pyrite in organic matrix the said results could be predicted with attention to fig. 3. So these results indicate that grinding to small particle size is necessary to enhancing the level of desulfurization.

For the different size fractions, the removals of total sulfur were in the ranges of 19–20%. It should be noted that removal of the pyritic sulfur, namely 43.3% and 35.6%, were obtained when their particle sizes decreased from 0.5-1.0 to 0-0.5 mm, respectively. It means that decreasing the particle size affected on the pyritic sulfur removal more than two times of total sulfur. The possible explanation might be that, Jarosite is performed on the coal surface which acts as a preventer and as a result, no significant reduction is observed in total sulfur by changing the particle size.

Effect of pulp density on coal desulfurization

The coal pulp density affects the rate of sulfur removal. It has a close relationship with operating cost of biodesulfurization process and the concentration of coal in the slurry during the biodesulfurization process is an important parameter to evaluate the economy of this process. High concentrations of coal decreases the amount of slurry to be processed and the water required. However, concentrations above 20 %(w/v) have been reported to inhibit the growth of microorganisms [8]. Furthermore, high concentrations of coal reduce the extent of sulfur removal. It may be due to: (a) Extensive sheer stress on the microorganisms due to attrition, (b) Build up of compounds leached from coal (which may inhibit the growth of microorganisms) and (c) Poor heat and mass transfer due to difficulties in agitating the slurry and agglomeration of coal particles [9]. In order to study the effect of pulp density, a series of 75 L suspensions at various pulp densities (10%, 15%, and 20 %(w/v)) were used for biodesulfurization processes.

Figs. 4 and 5 show the amount of pyritic sulfur and total sulfur reduction in coal samples at various pulp densities after 14 days of bioprocess.

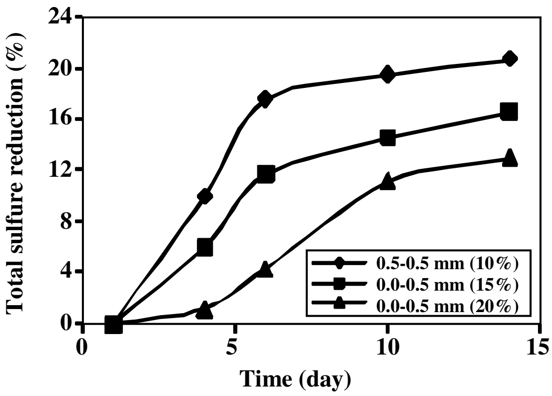

Fig. 4: Influence of pulp density on total sulfur reduction.

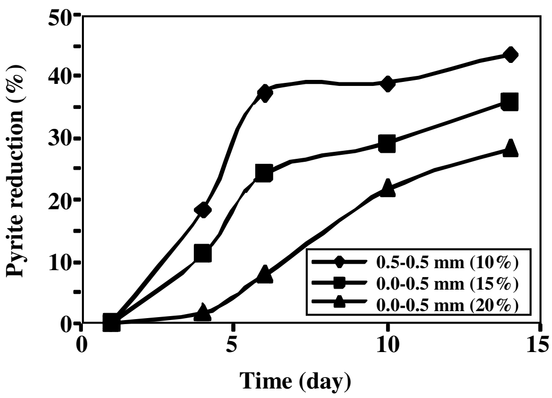

Fig. 5: Influence of pulp density on pyritic sulfur reduction.

The maximum sulfur removal is observed at 10% pulp density. As these figures show, the amount of sulfur removal increases with decrease of pulp density. The increasing of desulfurization rate in high pulp density is same for pyritic sulfur and total sulfur because there are fewer microorganisms can be available on coal area unit.

CONCLUSIONS

The results indicate that the efficiency of biodesulfurization is affected by particle size and pulp density. Area contact between pyrite and microorganisms is rather for small free pyritic particles so more sulfur react by them. Also, major microorganisms can be recoil on unit area in low pulp density. The best results we achieved was 45% of pyritic sulfur and 20% of total sulfur in reduction at pulp density of 10% and 0-0.5 mm particle size within 14 days. This study shows that biodesulfurization process has no effect on coking number of coal after 6 days treatment.

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