# *Technology of Coke Granule Pure Oxygen Continuous Gasification*

**Jinhui Zhao[1], Lijun Zhang[1] and Meng Wang[1,a,*]**

*[1]School of Chemical Engineering, Zhengzhou University, Zhengzhou 450001, China*
*a. 17839927819@163.com*
**corresponding author: Meng Wang*

***Keywords:*** Coke particles, coking, pure oxygen gas, gasification.

***Abstract:*** In order to extend the product chain of coke granules and digest the excess capacity of coke granules, this technology adopts the fixed bed continuous gasification technology of pure oxygen, gasifies coke granules with pure oxygen and water vapor as gasification agent, and then produces pure oxygen gas through desulfurization and other processes. Pure oxygen gas is a kind of clean and efficient energy. As the fuel gas mixed with coke oven gas, the coke oven gas is returned to the furnace for the production and use of the coke oven gas.

## 1. Introduction

According to the state council's opinions: On the steel industry to reduce excess capacity to achieve development in February 2016, it is calculated that 0.5 ~ 0.75 billion tons of coke will be compressed in the next five years, and the coke industry is facing severe pressure to reduce capacity[1]. The technical key of coking enterprises lies in the extension of the product industry chain, and the direction of product structure adjustment is to improve the yield and utilization efficiency of gas and chemicals[2].The traditional coke oven gas is mainly used as gas fuel and chemical raw material or reducing agent. However, the output of coke oven gas is limited, and nearly half of the coke oven gas is used as the heat source of the coke oven. Qnly the remaining 50% of the coke oven gas can be used as the raw gas to extend the industrial chain, which limits the adjustment of product structure and the improvement in profitability of the coke enterprise.

This technology uses coking plant to produce surplus coke granules as raw materials, and adopts pure oxygen continuous gasification technology to produce pure oxygen gas. On the one hand, it can digest the excess capacity of coke granules and relieve the pressure of coke granules market. On the other hand, the output of pure oxygen gas is a clean fuel, mixing coke oven gas as fuel gas, replace part of coke oven gas as fuel use, be replaced high methane content of coke oven gas can be used as chemical raw materials or reducing agent processing and production of chemical products, help enterprise out of the plight of single coke products. In addition, the cost is less affected by the gasification coke price, economic advantages are obvious.

## 2. Overall Process Design

This technology adopts atmospheric pressure continuous pure oxygen technology (as shown in Figure 1). Fixed bed gasifier with pure oxygen is used to produce gas through partial REDOX reaction in fixed bed gasifier with small coke as raw material, pure oxygen with purity of 99.6% and superheated steam as gasifier[3], and pure oxygen gas is used as mixed fuel gas for coke oven and coke oven. The gasifier adopts the high purity oxygen and steam produced by oxygen production unit as gasification agent, mixed in a certain proportion in the mixing tank from the bottom of pure oxygen gasifier into the gas layer to produce gas. Under the condition of high temperature in the furnace, partial REDOX reaction is carried out with coke to produce gas continuously. The gas generated from the top of the furnace enters the cyclone dust collector and enters the combined waste heat boiler. The waste heat boiler gas into the gas wash tower, with a closed cycle cooling water spray cooling of washing, it is cool to 45 ℃ and after washing the entrained dust and tar, then the hydrogen sulfide is separated through the desulfurization system.

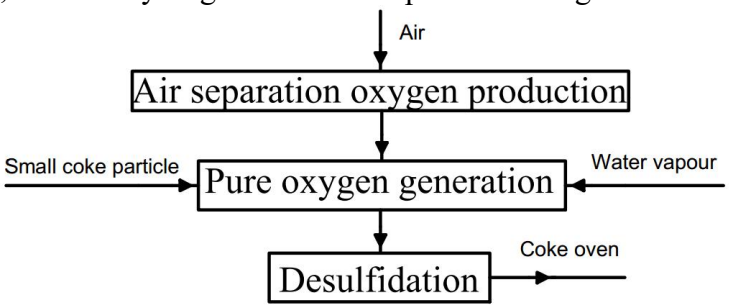


Figure 1: Flow chart of gas production from pure oxygen at atmospheric pressure.

## 3. Analysis and Simulation

### 3.1. Air Separation Oxygen Generation

The main task of air separation is to supply oxygen and nitrogen for pure oxygen gasifier. After the raw air is inhaled, it enters the air filter to remove dust and mechanical impurities, and is compressed to a certain pressure in centrifugal air compressor. The compressed gas enters the air precooling system. The hot air enters the lower part of the air cooling tower and passes through the air cooling tower from the bottom to the top, successively contacts with the cooling water and the chilled water countercurrent for heat exchange, so as to achieve the purpose of cooling and washing the air. The air from the air precooling system enters the air purification system, where adsorbents are used to remove moisture, carbon dioxide and other hydrocarbons.

Several products produced by air separation plant can reach the quantity and quality described in Table 1.

Table 1: Output and purity.

| Product | Yield | Purity | Out zone pressure |
|---|---|---|---|
| Oxygen | 18000Nm3/h | 99.6% | 0.08MpaG |
| Nitrogen | 3000Nm3/h | 99.99% | 1.0MpaG |

The device flow chart is shown in Figure 2.

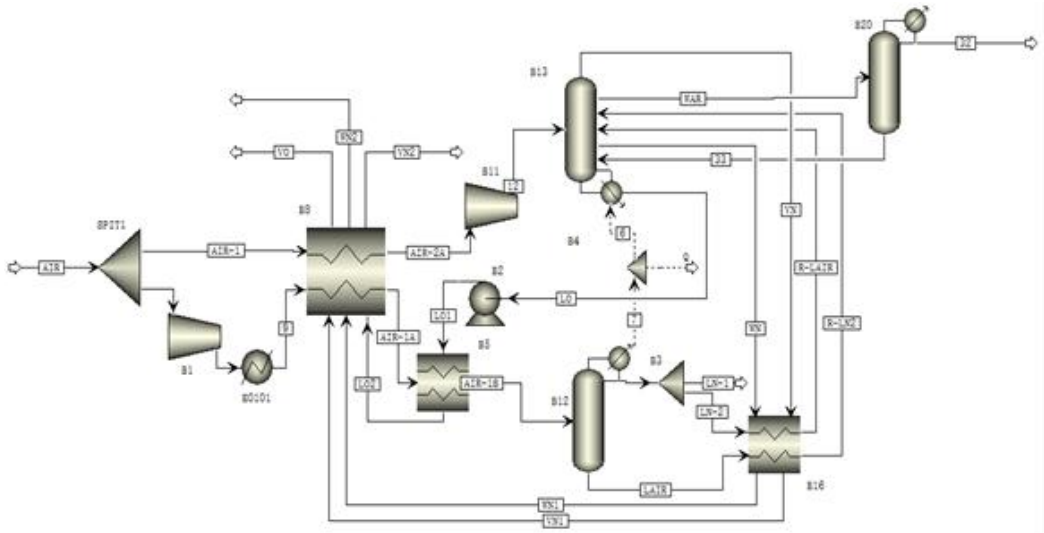

Figure 2: Simulation flow of air separation oxygen generator.

### 3.2.Pure Oxygen

Gasification adopts fixed bed continuous pure oxygen technology to produce clean gas with high calorific value. Steam gasification agent and from pure oxygen of air flow output under the condition of 200 ℃ by certain proportion from the bottom of the furnace into the gasifier, the two counter-current contact, raw coal after dry, carbonization, gasification, combustion process, such as production of high quality gas[4].

Gasification agent steam preheating, improve gasification efficiency, energy saving and consumption reduction. Continuous gasification, no exhaust emissions, good environmental benefits. Coke utilization rate of more than 96%. The production operation is easy to control, and the gasification layer and top temperature can be controlled by adjusting the H2O/O2 ratio. The gasification process simulated by Aspen Plus is shown in Figure 3.

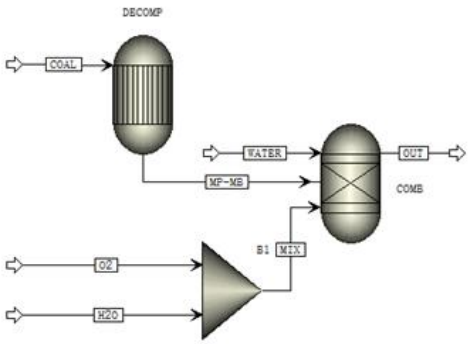


Figure 3: Flow chart of gasification.

The conversion rate is given in a stoichiometric reactor, and every element in the converted coal except ash is converted into elemental substance, which is then transferred into Gibbs free energy reactor to achieve the theoretical equilibrium of Gibbs free energy minimum. The simulation results are shown in Figure 4, 5, 6 and 7.

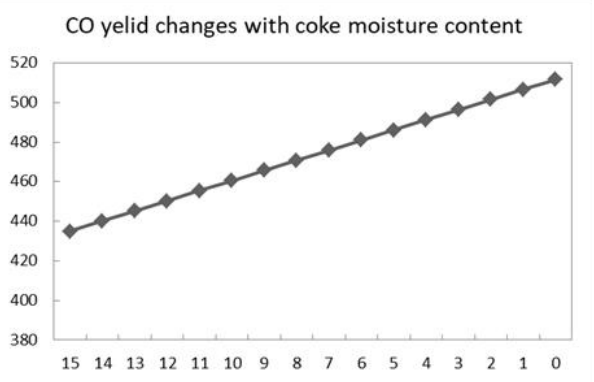


Figure 4: CO yield changes with coke moisture content.

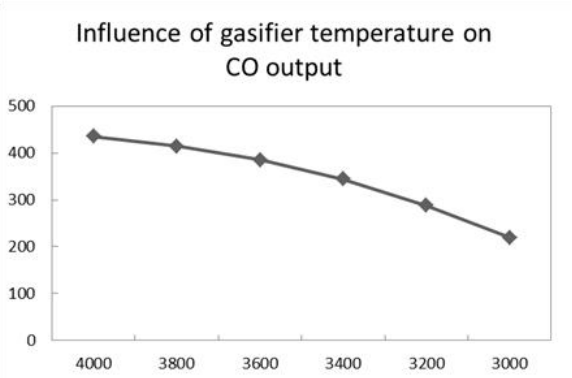


Figure 5: Influence of gasifier temperature on CO output.

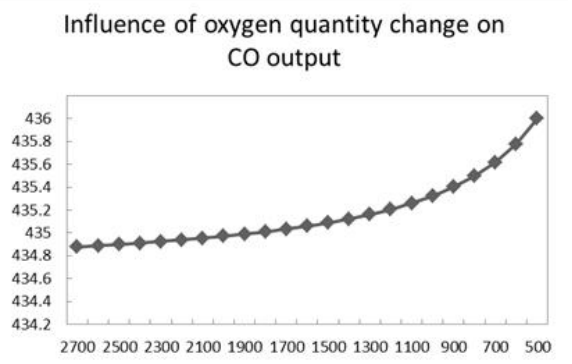


Figure 6: Influence of oxygen quantity change on CO output.

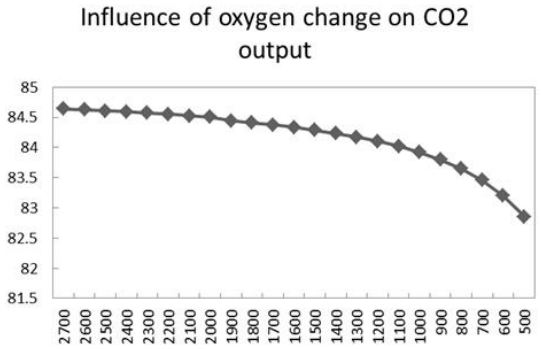


Figure 7: Influence of oxygen change on CO2 output.

As can be seen from the figure, when other conditions remain unchanged, when coke moisture increases, CO output decreases accordingly. As the gasifier temperature increases, CO output increases. With the increase of oxygen, CO output increases and CO2 decreases.

### 3.3. The Desulfurization

Sulfur exists mainly in pure oxygen gas in the form of hydrogen sulfide, which is harmful and corrosive to equipment and pipelines. Therefore, it must be removed in the purification of pure oxygen gas. After the gas from pure oxygen gasification enters the desulfurization section, the hydrogen sulfide rich liquid absorbed from the bottom of the tower flows into the rich liquid tank through the regulating valve in the desulfurization tower. The regenerative pump is driven into the self-priming jet oxidizer to conduct oxidation reaction with the air inhaled by the injector. The oxidized solution enters the regeneration tank for oxidation and regeneration, and the sulfur foam is flotation. The recycled lean liquid enters the lean liquid tank through the liquid level regulator, replenishes the needed new lye in the lean liquid tank, pressurizes through the lean liquid pump, and enters the top of the desulfurization tower for recycling.

The wet desulfurization solution can be recycled after regeneration and can produce sulfur. The desulfurization efficiency of PDS method with auxiliary agent is high, the desulfurization cost is low, and the sulfur recovery rate is generally above 85%. After desulfurization, the H2S content is less than 20mg/Nm3, which meets the requirements of gas environmental protection.

### 3.4.Gasification Circulating Water System

The suspended matter in the gasification circulating water system is relatively high and contains some large particles. In order to ensure the normal and stable operation of the subsequent treatment device, a hot water tank is set for pre-sedimentation. After pre-sedimentation, the circulating water is lifted into the integrated water purifier through the hot water pump to remove suspended matter. The fresh water flows into the cooling tower for cooling, and the cooling water flows into the reuse pool and is sent to the reuse water system by the cooling water pump. The quality of incoming and outgoing water and the amount of treated water are shown in Table 2. Circulating water treatment process is simple, smooth and reliable, which can ensure the quality of circulating water gasification requirements. The suspension layer generated by the integrated water purifier has excellent removal ability for the suspended substance with high turbidity, which can ensure the effluent quality[5].

Table 2: Quality of incoming and outgoing water and quantity of treated water.

| Project | Inflow | Outflow |
|---|---|---|
| suspended solids | ≤1000mg/L | ≤50NTU |
| Temperature | ≤55℃ | 32℃ |
| Pressure | Atmospheric pressure | 0.4MPa |
| Treatment of water | 1700m3/h， Closed cycle | |

## 4. Technical Feasibility Analysis

### 4.1. Environmental Impact Analysis

When the device is in normal production, there is no direct exhaust emission, and there is a small amount of air emission during starting and parking maintenance, that is; No process waste water is produced, and the waste water is mainly the clean sewage and floor washing waste water produced by the circulating water station. The waste slag is mainly gasifier slag, which can be discharged intermittently and used as raw material or backfill for building. Coal gas desulfurization produces sulfur which can be sold together with the original desulfurization section of coking plant.

### 4.2. Analysis of Energy Saving Effect

This technology optimizes the process, fully recovers the waste heat of the process, and achieves the goal of energy saving. In cyclone import set up efficient heat pipe waste heat boiler of type combination, the period of using gas in 450 ℃ will be saturated steam heated to 240 ℃ into the furnace, reduce the steam consumption, saving energy consumption; Out in lower temperature and waste gas into the pot, to enter the waste pan soft water is heated, it will produce saturated steam mentioned soft water temperature 107 ℃, the gas temperature to 150 ℃ scrubber into contact with cooling water cooled to 40 ℃.Through the recovery and utilization of waste heat in the first two stages, the gas temperature into the scrubber is reduced, so that the cooling water is greatly reduced and the power consumption is reduced. Taking a gas producing company in Henan Province as an example, the small coke particles are not only fully utilized, but also the energy consumption is reduced. Energy consumption calculation of the device is shown in Table 3.

Table 3: Calculation table of unit energy consumption after the completion of the proposed project.

| Serial number | Designation | Yearly consumption | Reduced energy consumption | The energy consumption /kgce |
|---|---|---|---|---|
| Input | Power consumption | 54707200kWh | 0.1229kgce/kWh | 6723515 |
| | Steam0.6Mpa，160℃ | 190400000kg | 0.0900 kgce/kg | 17136000 |
| | Steam0.5Mpa，saturated | 28000000kg | 0.0900 kgce/kg | 2520000 |
| | Fresh water | 340000t | 0.0857 kgce/t | 29138 |
| | Deoxygenated water | 218400t | 0.0857 kgce/t | 18717 |
| | Small coke grain | 235200t | 0.9714kgce/kg | 228473280 |
| | Subtotal | | | 254900650 |
| Output | Fuel gas | 560000000Nm | 0.3571 kgce / m3 | 199976000 |
| | Nitrogen | 24000000 Nm3 | 0.4000 kgce / m3 | 9600000 |
| | Subtotal | | | 209576000 |
| | Summation | | | 45324650 |

### 4.3. Economic Analysis

Coke grain of pure oxygen gasification technology continuously by coking enterprise existing production transformation, mainly for product industry chain extension, after the completion of can use pure oxygen gas displacement is more high quality of the coke oven gas, used in the production of chemical products. Based on this technology, the enterprise will form a modern coal chemical industry chain of comprehensive new energy recycling and utilization, such as coal chemical industry, chemical production recovery, fine chemical industry, etc., which meets the requirements of sustainable development of circular economy, has a reasonable product structure, full utilization of resources and strong core competitiveness.

## 5. Conclusions

Through the above analysis, this paper believes that this technology adopts advanced, mature, reliable and reasonable technological process in the selection of technological process, and has the following advantages by using small coke particle pure oxygen continuous production gas to replace coke oven return gas.

(1) The production scale is reasonable, and the project construction can be carried out by relying on the existing resources of the coking enterprise and combining with the production status. The construction period is short and the operation cost is low.

(2) After the project is completed and put into operation, the industrial chain of the enterprise can be extended and the industrial structure can be optimized, which is conducive to improving the market competitiveness of the enterprise, with high resource utilization rate and good environmental and economic benefits.

(3) In terms of national conditions, this technology is committed to the comprehensive utilization of coal resources, which is suitable for the improvement of China's energy consumption structure with more coal, less oil and less gas.

(4) In terms of compatibility, it is not only suitable for gasification of small coke particles, but also can be used for gasification production of other forms of resources, such as crushed coal.It is suitable for the production of industrial raw material gas, such as synthetic ammonia, methanol,

hydrogen, process conditioning gas, etc., or for the production of water gas in the field of industrial gas to replace natural gas, with significant energy-saving and emission reduction benefits and economic benefits[6].

## References


*[1] Xiuli Xu, Yu Jiang, Li Zhan, et al. Discussion on technical economy of gasification coke production and coke granule gasification process [J].Coal processing and comprehensive utilization, 2016 (6) : 37-40.*

*[2] Maoqian Miao, Jianjun Lu, Zhiyong Niu, et al. The scientific emission reduction and low-carbon development path of Shanxi coking industry under the new normal [J].Coal processing and comprehensive utilization, 2015 (10) : 16-18, 28.*

*[3] Wanjin Tang. Technology for continuous gasification of fixed bed pure oxygen to produce gas [J].Nitrogen fertilizer technology, 2016 (1) : 8-10, 37.*

*[4] Siwei Liu, Ding Zhu, Wanjin Tang, et al. Simulation of fixed bed pure oxygen continuous gasifier based on ASPEN PLUS [J].Coal processing and comprehensive utilization, 2017 (12) : 75-79.*

*[5] Zhengqing Li, Suan Long, Shouhua Jian. Research and exploration on the production of methanol from coke pure oxygen reforming gas and coke oven gas [J].Energy and chemical industry, 2016,37 (03):28-31.*

*[6] Shouguo Tian. Crushed coal (UGI) pure oxygen continuous gasification technology promotes the transformation and upgrading of coal gasification technology in chemical industry and gas industry [J].Medium nitrogen fertilizer, 2018 (3): 1-6.*