Research on Application of Coal-Water Slurry Techniques to Disposal of Wheat Straw Pulping Black Liquor*

YUAN Kun, CHEN Li-fang, WU Cheng-kang
(Institute of Mechanics, Chinese Academy of Sciences, Beijing 100080, China)

Abstract: A pilot test on disposal of wheat straw pulping black liquor by Coal-Water Slurry (CWS) combustion technology as an alternative of traditional alkali recovery technique has been performed. Experimental study on combustion feature of several kinds of Coal-Blackliquor Slurry (CBS) was carried out in a 6.5 t/h chain-grate boiler. In the test flue gas, slag and dust were analyzed and the boiler's thermal efficiency was measured. The results demonstrate that the co-combustion of CBS with granular coal increases the boiler's thermal efficiency and decreases poisonous emission. The successful combustion of CBS demonstrates its promise as a key technique in a novel measure of comprehensive disposal of wheat straw black liquor.

Keywords: coal-water slurry; coal-blackliquor slurry; wheat straw black liquor

水煤浆燃烧技术用于造纸黑液处理的研究

原　鲲, 陈丽芳, 吴承康
(中国科学院力学研究所, 北京 100080)

摘　要: 对水煤浆燃烧技术用于造纸黑液处理进行了中试研究。多种不同组成的黑液煤浆在改造过的 6.5 t/h 的链条炉上进行了燃烧试验。对黑液燃烧产物如烟气、烟尘及灰渣进行了成分测试, 对锅炉混烧水煤浆前后的效率进行了分析比较。结果表明, 黑液煤浆与层燃煤混烧提高了锅炉效率并降低了污染。水煤浆燃烧技术在该领域的成功应用为造纸黑液的处理提供了新的思路。

关键词: 水煤浆; 黑液煤浆; 黑液
中图分类号: X793　　**文献标识码**: A　　**文章编号**: 1006-8740(2002)01-0013-04

The impact of continuous development of the paper industry on the environment is getting serious in China. The conventional alkali recovery system, however, works far less than satisfactorily in handling wheat straw black liquor due to its inherent drawbacks that lead to failure in the aspects of black liquor extraction, evaporation, combustion and causticization. But pollution caused by the paper industry must be solved urgently.

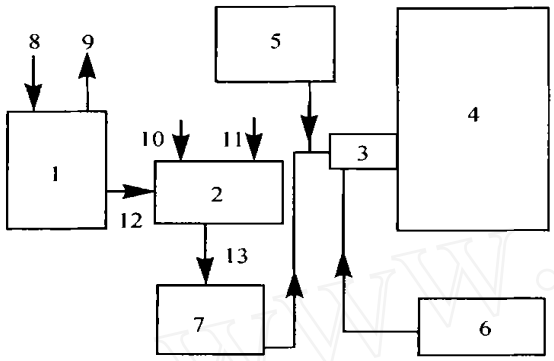
To overcome the difficulties, viability of disposal of wheat straw black liquor utilizing CWS technology as well as the effects of secondary pollution are investigated in this study. CWS arose as an alternative of fuel oil in the crucial oil crisis in 1970s. During the past two decades, CWS technology has matured in terms of preparation, transportation, atomization and combustion. As a substituent of the conventional disposal of wheat straw black liquor, the CWS technology possesses apparent advantages. Direct combustion of black liquor assisted by coal

* **收稿日期**: 2000-11-21。
作者简介: 原　鲲(1972-), 男, 博士, 中国科学院工程热物理所博士后。E-mail: kyuan@imech.ac.cn。

may naturally avoid some difficulties met in the conventional alkali recovery process.

1 Experimental

The system diagram for CBS preparation, storage, transportation and combustion is shown in Fig. 1. A double cone disc extruder was used to obtain black liquor with a concentration up to around 21%. Subsequently the black liquor was diluted to certain concentrations demanded by the test. Coal was pulverized and mixed with black liquor as well as additive in a vibrating ball mill.



1. extruder 2. ball mill 3. precombustor
4. boiler 5. air compressor 6. air blower 7. CBS tank
8. pulp 9. fiber 10. coal 11. additive 12. black liquor 13. CBS

Fig. 1 Diagram of system

The self-stabilizing type CBS precombustor with eccentric jet is based on the method of flame stabilization by use of nonsymmetrical jets. The structure of the Eccentric Jet Burner and the inner recirculation zone[1,2], induced by interaction between the primary air & CBS jet and ash-blowing jet, is shown schematically in Fig. 2. Atomized CBS droplets get ignited in the precombustor, forming a stable flame at the exit of the precombustor and then burn out in the boiler synchronously with granular coal on the chain. A kind of low-pressure, multistage CWS nozzle (Fig. 3) was applied in the test[4].

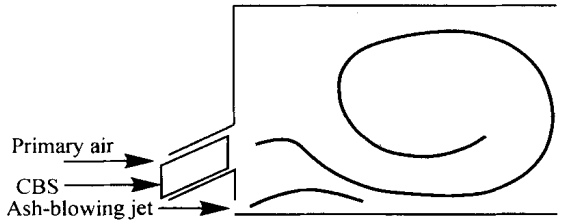


Fig. 2 Diagram of precombustor

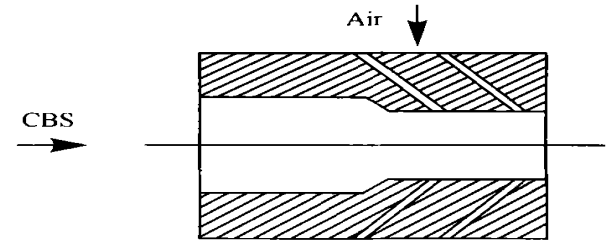


Fig. 3 Diagram of CBS nozzle

Contrary to the conventional CWS which, typically made up of about 70% coal, 30% water and 1% additive, was prepared aiming at a maximum coal content, CBS was prepared with a minimum coal content in order to increase the disposal output of black liquor. On the other hand, the apparent viscosity of black liquor, much higher than that of water, increasing significantly with a higher solid concentration, adds to difficulties in preparation of CBS. The rheologic characteristics of typical CBS is shown in Fig. 4.

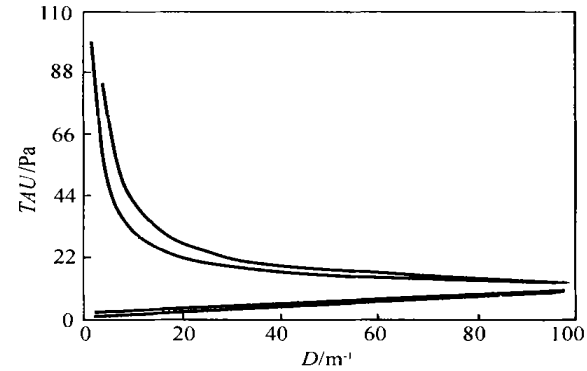


Fig. 4 CBS rheologic characteristics

2 Results and Discussion

2.1 Boiler efficiency

The degree to which CBS combustion is viable was determined in the test. The solute concentration in black liquor varied between 3%～20%, and the coal concentration in CBS varied between 35%～51% in the test. The proximate and ultimate analysis of the coal is shown in Tab. 1. Though CBS had a lower heat value than that of CWS with the same solid content, the result turned out that CBS meeting such criterion that heat value > 9 MJ/kg and apparent viscosity < 2 000 mPa·s (shear rate= 30 s^{-1}) could burn successfully and form stable flame jet at the exit of the precombustor. The efficiency of a typical chain-

grate boiler burning granular coal is relatively low. However, the setting of the precombustor enabled the CBS flame jet to flow toward the head of the chain to increase the temperature there and thus help the ignition of granular coal ahead, favorable for enhancement of the granular coal burn-out rate. On the other hand, the high-temperature environment caused by chain combustion compensated for the deficit of the boiler inner space needed for burnout of CBS. The synergistic interaction between granular coal and CBS worked effectively. With proper operation, 1 ton of CBS with a heat value of 10.8MJ/kg could supplant 0.8 t of coal with a heat value of 20.2 MJ/kg to maintain the stable boiler steam output. The boiler efficiency increased from 63.3% to 66.4%.

Tab 1　Proximate and ultimate analysis of coal

M_{ad}/%	A_d/%	V_{daf}/%	S_{dt}/%	$Q_{qr,ar}$/(MJ·kg^{-1})	C_{daf}/%	H_{daf}/%	N_{daf}/%	O_{daf}/%
6.28	6.89	31.79	0.42	20.2	80.59	3.64	1.54	15.24

2.2　SO_2 and H_2S emission characteristics of CBS combustion

With the increase of solid content of wheat straw black liquor in CBS, emisson of SO_2 measured at the rear port of the boiler decreased drastically, as shown in Fig. 5, due to its neutralization reaction with ionized alkali which originated from the solid content of black liquor. The same reason caused the H_2S content in the gas to become negligible.

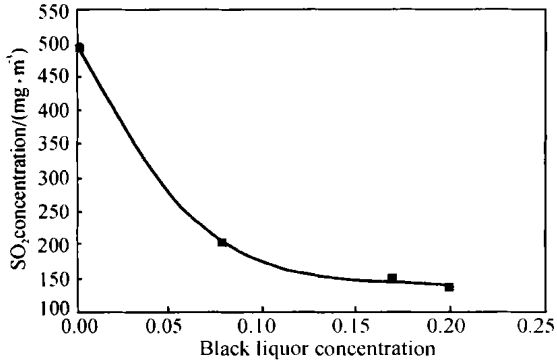


Fig 5　SO_2 emission characteristics

2.3　NO_x emission characteristics of the eccentric jet burner

The NO_x content in the air *vs* CBS feeding rate is shown in Fig. 6. With the increase of CBS input rate and simultaneous decrease of the feeding rate of granular coal to maintain the stable boiler steam output, the NO_x content in the gas decreased due primarily to the low-emission characteristics of combustion in the eccentric jet burner. But with further increase of CBS feeding rate after that of granular coal having been decreased to a lower limit to maintain stable combustion on the chain, NO_x content increased as a result of the increase of overall fuel nitrogen. The low NO_x emssion characteristics of the eccentric jet burner originate from its particular designation of reaction zones responsible for both efficient combustion and low NO_x emission. Certain study shows that[3], in the upper part of the upstream portion of the combustor is a zone of high temperature and vigorous combustion, whereas in the upper part of the downstream portion is a reducing zone where NO_x formed in combustion can be converted to N_2.

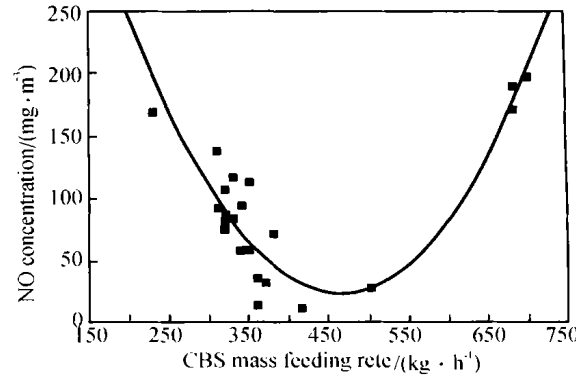
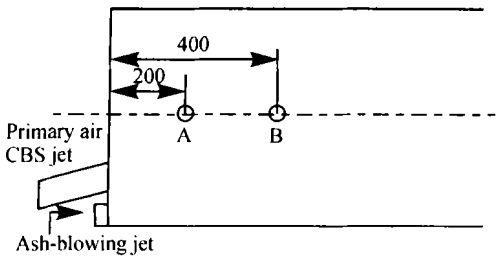


Fig 6　NO_x emission characteristics

2.4　Temperature distribution in the precombustor

Fig. 7 presents the positions where thermal couples were mounted. Thermal couples were placed in protecting cannulas and then inserted into holes A, B respectively. When cannulas move horizontally along the hole, the temperature distributions on the track of the thermal couple were measured. The results are presented in Fig. 8. The *R* axis denotes the distance between the measured point and the central axis of the precombustor. The temperature on the central axis of the combustor is relatively low due to the evaporation of the CBS droplet in the central jet. The temperature on the inner boundary of the precombustor is also low due to heat transfer. The



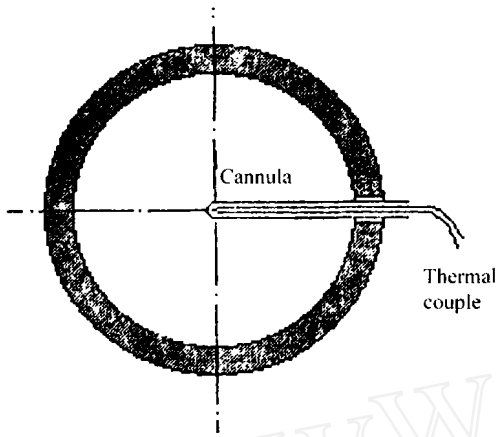


Fig. 7 Placement of thermal couples

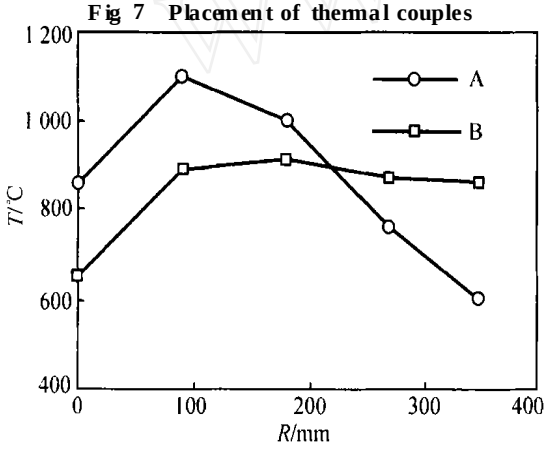


Fig. 8 Temperature distribution in the precombustor

highest temperature happens at about the edge of the CBS jet where combustion has taken place. But even the highest measured value is about 150 ℃ less than that of combustion of pulverized coal at the same point[2] with the same burner, more favorable to diminished production of thermal nitrogen.

3 Conclusions

1) Introduction of CBS combustion system to a 6.5 t/h chain-grate boiler can enhance the overall combustion intensity and thus causes increase of boiler efficiency.

2) The emissions of both nitrogen oxides and sulfur oxides conform to the environmental regulation.

3) Successful combustion of CBS may introduce a novel viable and economic measure to the disposal of wheat straw pulping black liquor.

References:

[1] Wu Chengkang, Chen Lifang, Li Jun *et al*. The use of nonsymmetrical jets for the stabilization of low grade coal flames[R]. 22nd *Symposium (Int) on Combustion*. USA, 1988

[2] Chen Lifang, Zhang Huanqing, Sun Wenchao *et al*. An experimental study on CWS combustion in a industrial boiler designed specially for burning CWS[R]. 3rd *Asian-Pacific Symposium (Int) on Combustion and Energy Utilization*, Hongkong, 1997

[3] Qin Feng. Experimental study and analysis on generation of NO_x in nonsymmetrical coal precombustor[D]. Beijing: Institute of Mechanics, Chinese Academy of Science, 1991

[4] Yuan Kun, Chen Lifang, Wu Chengkang. A study on the characteristics of CWS (coal-water slurry) air-blast atomization[R]. 14th *Annual Pittsburgh Coal Conference (Int) on Clean Coal Technology and Coal Utilization*, Taiyuan: 1997. 23-27