The 6th International Conference on Applied Energy – ICAE2014

Thermodynamic Analysis on a Pre-Dried Lignite-Fired Power System: Comparison on Energy Supply Systems for Dryer

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Abstract

Pre-drying is a potential way to improve the electric generation efficiency of lignite-fired power plant, and steam is a main kind of drying heat source. In conventional pre-dried lignite-fired power system, the steam extraction of regenerative system is led to the dryer directly. The steam extraction must be used by the dryer after throttling, if the energy mismatch exists between the supply of steam extraction and the need of dryer. Two systems of energy supply for the dryer, that the energy of the steam extraction is supplied to the dryer via compressor or ejector, were proposed in this paper to further increase the energy utilization efficiency. These systems were thermodynamic analyzed, and the electric generation efficiencies of these systems were compared. The energy saving boundary was gotten.

Keywords: thermodynamics; lignite pre-drying; compressor; ejector

1. Introduction

Lignite is the youngest kind of coals with high moisture content sometimes as high as 66% [1]. It is hard to transport and easy to ignite, so it is used almost exclusively as a fuel for electric power generation near the coal mine. However, a conventional lignite-fired power system (CLPS) always faces some shortcomings, including low thermal efficiency and high construction investment. A number of researches have been undertaken to use lignite effectively for electric generation, which are also in the requirements of energy efficiency and environmental protection.

Pre-drying is a potential way to improve the thermal efficiency of lignite-fired power plant [2]. Pre-dried lignite-fired power system (PLPS) is theoretically analyzed [3]. Steam drying, i.e. using steam as the drying heat source, has a higher potential of electric generation efficiency ($\eta_e$) improvement than flue gas drying [4]. In conventional PLPS, the steam is led directly to the dryer. The steam extraction must be used

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by the dryer after throttling, if the energy mismatch exists between the supply of steam extraction and the need of dryer. To further increase the $\eta_e$ of conventional PLPS, two energy supply systems for the dryer were proposed in this paper, and also been thermodynamic analyzed.

2. Energy Supply Systems

The PLPS is shown in Fig. 1 (a). Raw lignite is pre-dried in the dryer first. Then the pre-dried lignite is fed to the boiler. The steam extraction is led to the dryer directly, and the condensation is recovered in the de-aerator. The steam extraction must be used by the dryer after throttling, if the energy mismatch exists between the supply of steam extraction and the need of dryer. Therefore, the improvement of electric generation efficiency ($\Delta\eta_e$) steps down with the drying temperature ($t_d$), as shown in Fig. 1 (b). The drying temperature is defined as the saturated temperature of steam extraction led to the dryer. To further increase the $\eta_e$ of PLPS, two energy supply systems for the dryer were proposed. In PLPS using compressor to provide heat source (PLPSC), low pressure steam is led to the compressor first, then the compressed steam is led to the dryer. In PLPS using ejector to provide heat source (PLPSE), a high pressure steam is used to eject the low pressure steam in the ejector, and the mid-pressure steam is led to the dryer.

Fig. 1. (a) PLPS; (b) $\Delta\eta_e$ changing along with $t_d$

3. Reference case analysis

The reference case and theoretical models in reference [3] are used in this paper.

3.1. PLPSC

The steam extractions for No.6, No.7, No.8 heaters and turbine exhaust were used as the compressor input steam, respectively, as shown in Fig.2 (a). After the compressor, the pressure of the steam is compressed as the same as steam extraction for No.5 heater, and led to the dryer. The $\Delta\eta_e$ with different pressure steam extractions as inlet steam of compressor were calculated and also shown in Fig.2 (a). The $\Delta\eta_e$ is 1.82% for PLPS compared with CLPS. For PLPSC, the $\eta_e$ could be increased by 1.58%, 1.89%, 1.35% and 1.14% when No.6, No.7, No.8 and turbine exhaust are used as the compressor inlet steam, respectively. So the PLPS has a higher $\eta_e$ when the steam extraction meets the dryer need. And the PLPSC with a higher pressure steam as compressor inlet steam has a higher $\eta_e$. 
So when the drying temperature is between the steam saturated temperatures of two regenerative system heaters. For PLPS, the high temperature steam should be used as heat source, but for PLPSC, low temperature steam should be used as heat source after being compressed by the compressor as shown in Fig. 2 (b). The $\Delta \eta_e$ changes along with the drying temperature. In some special temperature range the $\eta_e$ for PLPSC is higher than PLPS, e.g. when isentropic efficiency of compressor ($\eta_{cs}$) is 0.8, $t_d=105^\circ C-131^\circ C, 145^\circ C-167^\circ C, 181^\circ C-203^\circ C$.

3.2. PLPSE

In PLPSE, two steams are mixed in the ejector, and the mixed steam is led to the dryer as shown in Fig.3. Different pressure steams could be used as the primary and secondary flow for the ejector.

The steam extraction of No.6 heater ($P_s=0.01167MPa$) is used as the secondary flow, while the steam extraction of No.5, No.4, or No.3 heater is used as the primary flow, respectively, as shown in Fig. 3(a). The PLPSE with No.5 steam extraction as the primary flow has the highest electric generation efficiency. The steam extraction of No.5 heater (0.402MPa) is used as the primary flow, while the steam extraction of No.6 or No.7 heater is used as the secondary flow, respectively, as shown in Fig.3 (b). The PLPSE with No.6 steam extraction as the secondary flow has the highest electric generation efficiency.

So when the drying temperature is between two regenerative system heaters, for PLPS, the high temperature steam should be used as heat source, but for PLPSE, these two steam extractions should be used as the primary and secondary flow, respectively, as shown in Fig. 4. The $\Delta \eta_e$ changes along with the drying temperature is calculated and shown in Fig. 4. In some special temperature range ($t_d=105^\circ C-125^\circ C, 145^\circ C-159^\circ C, 181^\circ C-197^\circ C$) the $\eta_e$ for PLPSE is higher than PLPS.
4. Conclusion

To further increase the electric generation efficiency of PLPS, two energy supply systems for dryer of PLPS were provided. Some meaningful conclusions were gained:

(1) The thermodynamic analysis of PLPSC and PLPSE shows that the energy supply with the compressor or ejector could not increase the electric generation efficiency when the steam extraction meet the dryer’s need compared with PLPS.

(2) When the steam extraction does not meet the dryer’s need, the compressor or ejector could increase the electric generation efficiency in some certain drying temperature range.

Acknowledgements

This work was supported by National Natural Science Foundation of China (Grant Number 51125027, U1261210) and Doctoral Fund of Ministry of Education of China (Grant Number 20120201110048).

References


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He Received Ph. D. degree in Power Engineering and Engineering Thermo-physics from Xi’an Jiaotong University in 2013. Research interests mainly focus on the simulation and optimization of thermal system, and multiphase flow. He has published more than 20 papers in energy and power engineering.