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A NOVEL INERTIAL SEPARATOR FOR CFB BOILERS

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Abstract

Besides several cyclone separators, some inertial separators had also developed and applied in the circulating fluidized bed (CFB) boilers. The inertial separators have some advantages such as simple structure, small volume, low pressure drop, easy scale-up and so on. But almost every existing inertial separator has great difficulty in solving the main shortage of lower separation efficiency especially for fine particles.

Based on the research for the separation mechanism and performances of inertial separators, the State Key Laboratory of Coal Combustion (SKLCC) had developed a novel inertial separator for CFB boilers. The patented separator improves the structure of the U-beam that is the separation element of U-beam separators of Studsvik Energiteknik (Sweden) and Babcok & Wilcox (USA). A ash channel is added to avoid re-entrainment of the separated solid downward along the U-beam. Test result indicates that the novel separator has great higher separation efficiency with the same pressure drop, compared with the U-beams at same conditions. The novel separator is more suitable for a larger CFB boiler or repowering projects as primary separator than the U-beams. The novel inertial separator had been used for designing 25 ~ 420 tons of steam per hour (t/h) two-stage-recirculation CFB boilers. The two-stage-recirculation CFB boilers in capacity of 25 t/h and 65t/h had been put into operation.

This paper presents the work on research, development and application of the novel inertial separator with high separation efficiency and low pressure drop.

INTRODUCTION

The CFB combustion has been rapidly developed in recent years. As the key component of a CFB boiler, gas-solid separator plays an important role in economy, reliability and flexibility of CFB boilers. Basic requirements of a separator are that it has enough high separation efficiency and lower pressure drop. In addition, it should be simple and compact in structure.

In the development and application of CFB combustion technology, no doubt the cyclone separator is a widely used and mature technology. But it has several obvious shortages. The colossal and heavy insulated cyclone has great thermal inertia and difficulties to hang up and resist abrasion. Although the cooled cyclone overcomes the disadvantages to a great extent, the shortages of high cost and difficulty in manufacturing remain.

Therefore, the search for new design of the separator for CFB boilers is generating increasing interest among researchers and engineers. Some two-stage-recirculation CFB boilers with both inertial separators and cyclones have developed. To taking the inertial separator as first stage separation at high temperature, makes good use of its advantages of simple structure, small volume, low pressure drop and easy scale-up. In the meantime, thanks to taking the cyclone as second stage separation at low temperature, the merits of small volume, high separation efficiency and easy arrangement were brought into play effectively. So, the two-staged separation technology has great potential. But its current application is unsatisfactory. Besides the fly ash recirculation system is more complicated, the separation efficiency of the first stage hot inertial separator is much lower. The great lot fly ash has to be collected by the second stage cyclone, which leads to serious abrasion of the heat surface between the two stage separators. In the mean while, the great lot collected particles at lower temperature has to be partially sent to the furnace, which influences harmfully on ash recirculation and even on the operation performance of the boiler. The reason is that the recirculation of the great lot ash at lower temperature will cause the bed temperature decrease and even flame failure. All of these seriously restrict the development of the two-stage-recirculation technology to large scale.

Although the inertial separator usually consists of series separation elements and is scaled up easily in principle, in company with the increase of the boiler capacity, the separation efficiency decreases with the increase of the height of the separation element due to the re-entrainment of collected particles fallen downward along the separation elements.

It is obvious that for the development of its large-scale, the key is to increase the separation efficiency of the inertial separators besides rational temperature choice of the each stage ash recirculation.

Since the 1980's, combining with the National

Key Research Program of Science and Technology, SKLCC has carried out the research and development of gas-solid separators suitable for CFB boilers with Chinese characteristics. A set of test board of separator system and various types of separators had been set up. A large number of test and research for separators have been completed (such as choice of various types, optimization of structure and size, research for separation mechanism, improvement on separation performance, resistance to wear and the refractoriness, adaptability for CFB boiler operation in varying load, and so on). Then a wealth of design experience has been accumulated.

Based on the research for the separation mechanism and performances of inertial separators, the SKLCC had developed a novel inertial separator for CFB boilers. The re-entrainment of the collected particles in the separator is prevented effectively and the separation efficiency increases obviously.

The novel inertial separator had been used for designing 25 ~ 420 t/h two-stage-recirculation CFB boilers. The two-stage-recirculation CFB boilers in capacity of 25 t/h and 65t/h had been put into operation.

The test research in the SKLCC and the application in the two-stage-recirculation CFB boilers indicate that the novel inertia separator is of fine performances.

THE NOVEL INERTIAL SEPARATOR

During the development of CFB combustion technology, the inertial separation technology has been paid great attention to. Comparing with the cyclone separators, the inertial separators with advantages such as simple structure, small volume, low pressure drop, easy scale-up and so on, had also developed and applied in CFB boilers. There are various types of inertial separators adopted in CFB boilers. The mains include U-beam impact separator of Studsvik Energiteknik (Sweden) and Babcok & Wilcox (USA), U-beams with hamulus of Steinmuller (Germany), louvers separator of Institute of Engineering Thermophysics (China), Planar Flow Separator of Tsinghua University (China) and so on. But almost every existing inertial separator has great difficulty in solving the main shortage of lower separation efficiency especially for fine particles. Besides the inherent shortage in separation mechanism or effect of all the inertial separators is that the inertial effect is not enough to collect fine particles, the improper design of structure is the other dominating reason. The collected particles are not segregated effectively from the gas flow, which leads to serious ash re-entrainment. As shown in Fig.1, when the ash-laden gas flow enter the U-beams, the collected particles will form ash layers in the U-beams and will be easily re-entrained by the gas flow entering in the U-beams while they fall downward along the U-Beams. The larger capacity of CFB boiler, the more height of the U-beams, the more re-entrainment will be occurs. Although the ash layer is beneficial to the abrasion of the U-beams, it also brings the serious re-entrainment. In addition, because the gas flow will also easily enter the ash hopper of the separator, the collected particles in the ash hopper will also be re-entrained.

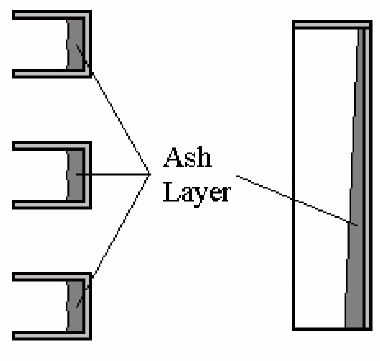
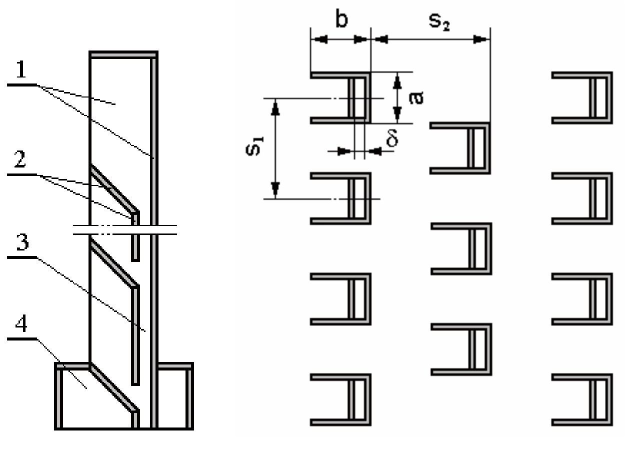


Fig. 1 U-Beams and Ash Layer

In order to search effective measures to increase separation efficiency of the inertial separators, the inertial separation process was investigated deep. The inertial separation process includes two successive phases, i.e. impact and collection. Firstly, the particles impact the separator elements under the force of inertial and other effects, and then the impacted particle are collected into ash hopper. For the impact phase, in order to improve the impact probability or efficiency, the separation elements are generally arranged in alternate order and the structure characteristics of the elements such as shape, ratio of width and depth, transverse and longitudinal pitches and so on, are investigated. And some positive conclusions are obtained. In general, the U-beams are much better with advantages of simple structure, good impact effect and so on than the others. For the collection phase, in order to reduce the ash re-entrainment and to increase the collection efficiency, some investigations are carried out and the special structures such as U-beams with hamulus are adopted. But research on this side is really not enough and the problem of the lower collection efficiency is not solved ultimately.

The research in the SKLCC for the separation mechanism indicates that the key to increase the inertial separation efficiency is to increase the efficiency of the collection phase and reduce the ash re-entrainment. The SKLCC improved the structure of the U-beam and developed a novel inertial separator with ash channel. As shown in Fig. 2, the special compartment plates are added to form ash channel so as to avoid the ash re-entrainment. The ash channel can segregate the collected particles



(a) (b)

Fig. 2 The Novel Separator and its Elements
(a) Separation Element (b) Arrangement of Elements
1. U-beam 2. Compartment Plates
3. Ash Channel 4. Ash Hopper

from the gas flow and prevent effectively the ash re-entrainment in the separation elements. So, the separation efficiency is heightened and not affected by the increase of separation element height, which benefit to the large-scale development of the inertial separators and the CFB boilers. In addition, an isolation hopper is mounted under each separation element, which prevents effectively the gas flow entering into the hopper and the ash re-entrainment in the hopper.

Test result indicates that the patented separator has great higher separation efficiency with the same pressure drop, compared with the U-beams at same conditions. The more height of the separation element, the more obvious improvement of the separation performances occurs. So, the novel separator is more suitable for a larger CFB boiler or repowering projects as primary separator than the U-beams.

TEST RESEARCH

To verify and improve the good separation performances of the novel separator in order to get successful application in CFB boilers, a series of tests for the novel separator and U-beams were carried out in the SKLCC.

1. Experimental Set-up

Fig. 3 shows a schematic diagram of the experimental set-up that consists of 5 main parts: dust feeder, acceleration zone, separation zone, ash hopper and ash filter. The system works under negative pressure. The about 1.8m acceleration zone is long enough for particle accelerating. The cross-section size of the air flue is 330×500mm. In the separation zone, separation elements are mounted in alternate order most with 5 rows transversely and 6 rows longitudinally. The transverse and longitudinal pitches are adjustable. The separation elements and the both sides of the air flue are all made out of organic glass in order to observe particles’ motion.

The dust used in tests was fly ash collected from

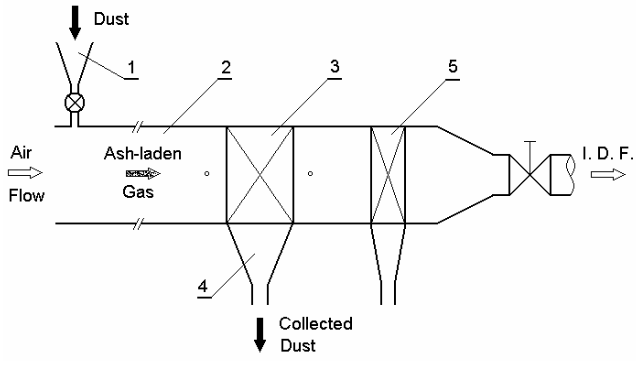


Fig. 3 Experimental Set-up
1. Dust Feeder 2. Acceleration Zone
3. Separation Zone 4. Ash Hopper 5. Ash Filter

CFB boilers. The density of the dust was about 1800 kg/m^3. The average particle diameter was about 0.15 millimeter and the particle diameter submitted to a normal distribution.

2. Test Results and Discussion

The ratio of depth *b* and width *a* of U-beam, *b/a* has influence on separation efficiency. The less *b/a*, the more particles' rebound and re-entrainment, the less separation efficiency will be. With the increase of *b/a*, the separation efficiency heightens. If increasing *b/a* further, to heighten the separation efficiency is limited but crossly, the pressure drop and material consumption will increase. The above similar conclusions are drawn by different researchers. Generally, the optimal *b/a* is about 1.0~1.2. In the following test, the ratio *b/a* keeps 1.15.

2.1 The effects of transverse and longitudinal pitches on separation efficiency

Fig. 4 shows the influence of the pitches on separation efficiency. From Fig. 4, it is clear that:

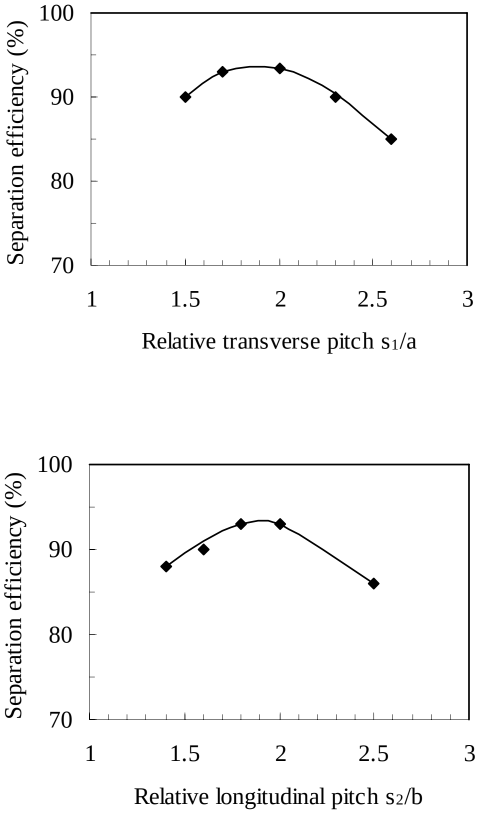


Fig. 4 The variation of separation efficiency with relative transverse and longitudinal pitches

- To increase or decrease the pitches excessively will lead to decrease of separation efficiency.
- The optimal transverse and longitudinal pitches are all around 1.8~2.0.

2.2 The influence of longitudinal rows on separation efficiency

The test results are shown in Fig. 5. It is obvious that :

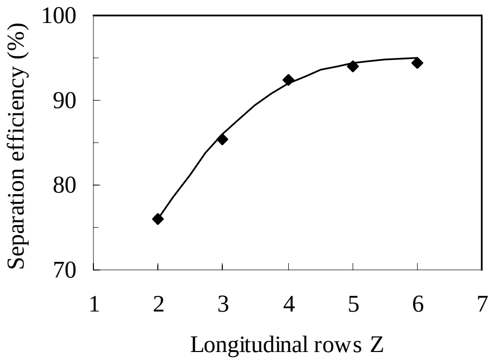


Fig. 5 The variation of separation efficiency with longitudinal rows

- The separation efficiency heightens while the longitudinal rows add.
- The preceding 4 rows play great important roles in dust separation.

The rational value of longitudinal row is about 4~6 in order to get both enough high efficiency and low pressure drop as well as small volume.

2.3 The effects of inlet gas velocity and dust concentration on separation efficiency

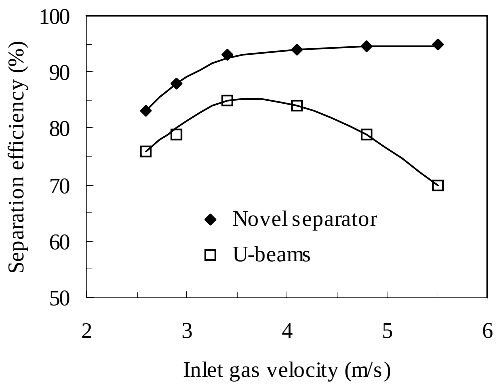


Fig. 6 The relationship between inlet gas velocity and separation efficiency

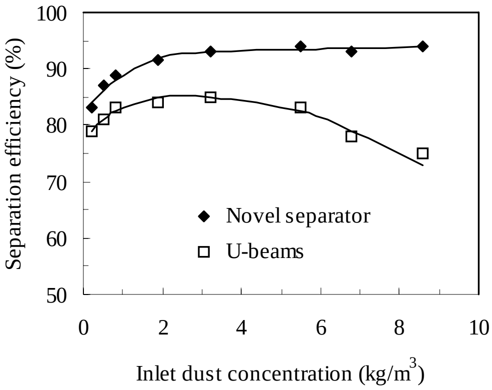


Fig. 7 The relationship between inlet dust concentration and separation efficiency

As shown in Fig. 6 or Fig. 7, while the inlet gas velocity or increases, from beginning the separation efficiency of two kinds of separator heightens rapidly, and then the efficiency increases slowly for the novel inertia separator and reduces sharply for the U-beams. These results indicate that the ash re-entrainment is prevented effectively in the novel inertia separator.

2.4 The grade efficiency

Fig. 8 shows the influence of particle diameter on separation efficiency. From Fig. 8, it can be got that

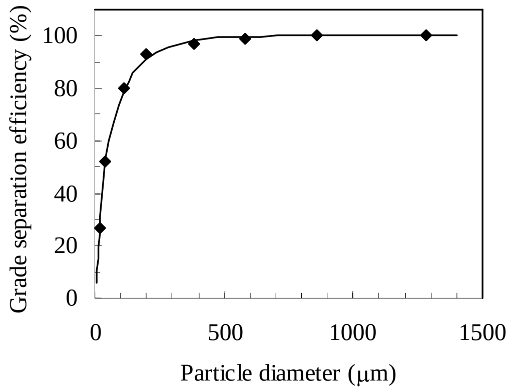


Fig. 8 The grade efficiency

the critical diameter dc_{50} in which the grade efficiency is equal to 50%, is approximately 35μm.

2.5 The effects of inlet gas velocity and longitudinal rows on pressure drop

The variations of pressure drop with inlet gas velocity and longitudinal rows are shown in Fig. 9.

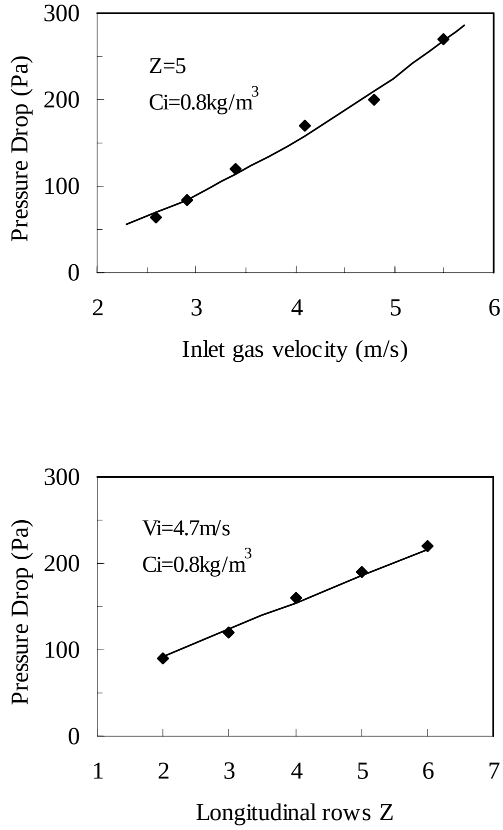


Fig. 9 The variation of pressure drop with inlet gas velocity and longitudinal rows

The pressure drop increases while the gas velocity or the longitudinal row adds.

DEVELOPMENT AND APPLICATION

Based on a series of test and research, the novel inertial separator had been used for designing 25 ~ 420 t/h two-stage-recirculation CFB boilers. The two-stage-recirculation CFB boilers in capacity of 25 t/h and 65t/h had been put into operation. The boilers can reach the guaranteed performance parameters. The capability of load adjustment is good enough from 30% to 120% rated load to meet the user's special requirements. Due to the high separation efficiency, the combustion efficiency is higher and coal consumption is lower, as well as the abrasion of heat surfaces is limited. The successful application provides foundation for further development of this technology.

Fig. 10 shows the 25t/h two-stage-recirculation CFB boiler.

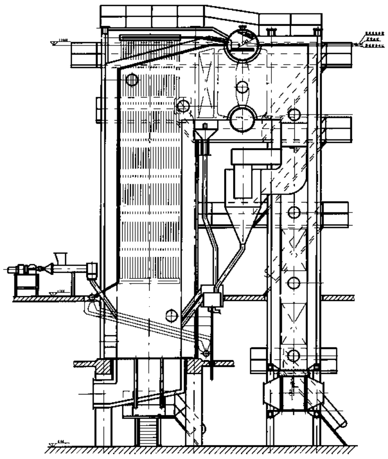


Fig. 10 The CFB Boiler with Two-Staged Separators

CONCLUSION

(1) The patented separator has great higher separation efficiency (about higher 10%) with the same pressure drop, compared with the U-beams at same conditions.

(2) The more height of the separation element, the more obvious improvement of the separation performances occurs. So, the novel separator is more suitable for a larger CFB boiler or repowering projects as primary separator than the U-beams.

REFERENCES

[1] Johns R. F and Wascher R. E, Design and Construction of A Wood-Fired Circulating Fluidized Bed Boiler, in Proc. of 9th Int. Conf. on FBC, 385~391, 1987

[2] Belin F. and Flynn T. J., Circulating Fluidized Bed Boiler Solids System with In-Furnace Particle Separator, in Proc. of 11th Int. Conf. on FBC, 287-294, 1991

[3] Belin F., CFB Boilers with an Impact Particle Separator Design and Operating Experience, in Proc. of 4th Int. Conf. on CFB, 233-238, 1993

[4] Liu Canhua, et al, Demonstration of China's a First Two-Stage Separation CFB Boiler, In Proc. of 4th Int. Conf. on CFB, 221-225,1993

[5] Yue Guangxi, et al., The Design of 50MW CFB Boiler with Planar Flow Separator, in Proc of 4th Int. Conf., on CFB, 1993