World Scientific Research Journal (WSRJ) ISSN: 2472-3703
www.wsr-j.org

Research on Orthogonal Experiment of Double Overflow Cyclone Based on Underflow

Bo Chen [a], Xuefei Zheng [b], Lei Feng [c]

College of Mechanical and Electronic Engineering, Shandong University of Science and Technology, Qingdao, 266590, China

[a] 1519730866@qq.com, [b] 2363567141@qq.com, [c]1197575640@qq.com

---

Abstract: The conventional cyclone can be classified into two grades, overflow and underflow. The product has a wide range of particle size and coarse particle size, and it is difficult to meet the requirements for the particle size of the subsequent separation equipment. double overflow cyclone can be classified into underflow, inner-overflow and outer-overflow by a single stage classification. In this paper, the underflow yield and underflow ratio are performance evaluation indicators, and four factors and three levels of orthogonal experiment are used to explore the optimal classification parameters for the double overflow cyclone.
Keywords: double overflow cyclone; orthogonal test; underflow yield; underflow ratio.

---

1. INTRODUCTION

Hydrocyclone is widely used in many industries such as petrochemical industry, mineral processing, and water treatment due to its advantages of small area, high separation precision, and simple operation and maintenance [1]. As a universal classification and sorting device, cyclones also have their own limitations. The three-product hydrocyclone is an important research direction for cyclone. Its research started late and has great development potential [2]. In this paper, an orthogonal test is conducted for double overflow cyclones to explore the influence of various parameters on their graded performance.

2. CLASSIFICATION MECHANISM AND EXPERIMENTAL DESIGN

2.1 Classification mechanism of double overflow cyclone

Double overflow cyclone is based on the traditional cyclone, inserting a small diameter coaxial overflow at the center to form double overflow tubes inside and outside. The schematic diagram of the particle size distribution of double overflow cyclone is shown in Fig.1.Under the action of centrifugal force and drag force, coarse-grained particles move down the side wall and enter the external swirling flow through the underflow opening. Fine-grained particles move upward spirally under the action of the internal swirling flow and are divided into

overflow flow by the overflow pipe. And within the overflow, the final grading to get different levels of underflow, overflow and overflow of three products [3].

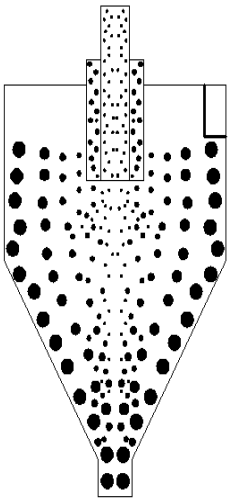

Fig.1 Schematic diagram of particle size distribution of double overflow cyclones

2.2 Orthogonal experimental arrangement

Orthogonal test is a kind of test method to study multi-factors and multi-levels. It selects some representative points from comprehensive tests for testing according to orthogonality. These representative points have uniformly dispersed and homogeneously matched. The characteristics of it are an efficient, rapid and economical test method.

In order to explore the graded performance of double overflow cyclones and explore the influence of various parameters on the double overflow cyclones, this paper selects four factors: pressure, cone angle, underflow orifice diameter, and inner overflow diameter. The three-level orthogonal test of factors, with the ratio of the underflow yield and the underflow shunt ratio as evaluation indicators, determine the best grade combination. Table.1 is the L^9 (3^4) test factor level table, a total of 9 groups of tests, and the specific test schedule is shown in Table.2.

Table.1 Test factor level table

Factor / Level	A Pressure (MPa)	B Cone angle (°)	C Underflow orifice diameter (mm)	D Inner overflow diameter (mm)
1	0.08	60	20	22
2	0.10	90	22	25
3	0.12	120	24	28

2.3 Test system design

The schematic diagram of the test system is shown in Fig.2. The slurry is pumped into the cyclone by the pump after being stirred in the drum by the stirrer. The internal and external overflows and the underflow are returned to the drum through the pipeline to ensure that the test system circulates. The frequency conversion control of the motor can adjust the feed pressure of the cyclone, after the operation is stable, Simultaneous sampling of underflow, overflow, outflow, and feed was performed. The concentration and yield were calculated by suction filtration, and the flow rate of each product was measured by the volumetric method.

Table.2 L^9 (3^4) Orthogonal Test Arrangement

Experiment number	Test Factor				Level combination
	A Pressure （MPa）	B Cone angle （°）	C Underflow orifice diameter （mm）	D Inner overflow diameter (mm)	
1	1（0.08）	1（60）	1（18）	1（22）	A1B1C1D1
2	1（0.08）	2（90）	2（20）	2（25）	A1B2C2D2
3	1（0.08）	3（120）	3（22）	3（28）	A1B3C3D3
4	2（0.10）	1（60）	2（20）	3（28）	A2B1C2D3
5	2（0.10）	2（90）	3（22）	1（22）	A2B2C3D1
6	2（0.10）	3（120）	1（18）	2（25）	A2B3C1D2
7	3（0.12）	1（60）	3（22）	2（25）	A3B1C3D2
8	3（0.12）	2（90）	1（18）	3（28）	A3B2C1D3
9	3（0.12）	3（120）	2（20）	1（22）	A3B3C2D1

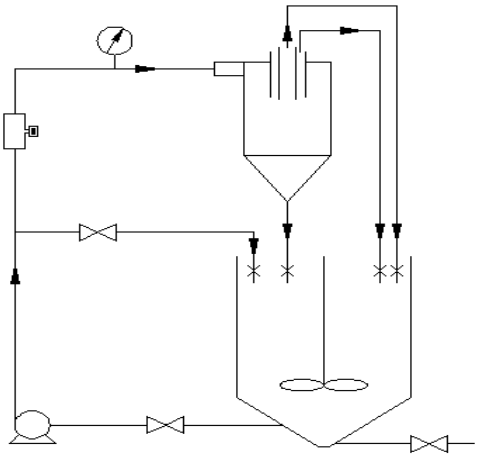

Fig.2 Test system schematic

The broad application of the rotary kilns in a variety of industrial branches for thermal processing of residual materials with a different origin and mostly for fire treatment of hazardous wastes [2-3]. The rotary kilns were used as rotary dryer to remove moisture and water from solid substances, primarily by introducing hot gases into a cylinder, it acts as a conveying device and stirrer.

3. TEST RESULTS AND PROCESSING

3.1 Underflow yield as an indicator

Underflow yield, which is the ratio of the solids underflow mass flow rate to the feed solids mass flow rate for all different particle sizes. For double overflow cyclones, most of the coarse particles are discharged from the underflow, and it is generally desirable that the greater the underflow yield, the better. The orthogonal test results are shown in Table.3.

Table.3 Underflow yield as the evaluation index data sheet

	A Pressure	B Cone angle	C Underflow orifice diameter	D Inner overflow diameter
K_{1j}	137.63	166.43	120.62	148
K_{2j}	133.79	127.34	137.07	143.97
K_{3j}	144.06	121.71	157.79	123.51
k_{1j}	45.88	55.48	40.21	49.33
k_{2j}	44.60	42.45	45.69	47.99
k_{3j}	48.02	40.57	52.60	41.17
R	3.42	14.91	12.39	8.16
Preferred solution	A3	B1	C3	D1

3.2 Evaluation of underflow split ratio

The split ratio is the ratio of the underflow volume flow to the feed volume flow. For the solid-liquid separation cyclone, we hope that more liquid will be discharged from the overflow, and more coarse particles will be discharged from the underflow. Therefore, for the double overflow cyclone, it is desirable that the underflow has a smaller split ratio, orthogonal the test results are shown in Table.4.

Table.4 Evaluation of the index data by the ratio of the underflow to the underflow

	A Pressure	B Cone angle	C Underflow orifice diameter	D Inner overflow diameter
K_{1j}	0.36	0.44	0.26	0.46
K_{2j}	0.36	0.37	0.36	0.4
K_{3j}	0.41	0.32	0.51	0.27
k_{1j}	0.12	0.15	0.09	0.15
k_{2j}	0.12	0.12	0.12	0.13
k_{3j}	0.14	0.11	0.17	0.09
R	0.02	0.04	0.08	0.06
Preferred solution	A1	B3	C1	D3

4. CONCLUSION

Two classifications of underflow, overflow and overflow can be obtained by a double-overflow cyclone at a time. In this paper, the underflow yield and underflow split ratio are used as evaluation indicators to perform four-factor and three-level orthogonal tests to explore double overflow tubes. The graded performance of the cyclone leads to the following conclusions:

(1) The influence degree of each factor on the underflow rate of the double-overflow cyclone was: taper angle> diameter of underflow port> diameter of overflow pipe> pressure. In order to maximize the underflow yield, the best parameters of the dual overflow cyclone are: feed

pressure 0.12MPa, cone angle 60°, underflow orifice diameter 22mm, and inner overflow diameter 22mm.

(2) The influence degree of each factor on the underflow ratio of the underflow cyclone of the double overflow pipe was in the order of underflow port diameter> inner overflow pipe diameter> cone angle> pressure. In order to maximize the underflow yield, the best operating parameters and structural parameters of the double overflow cyclone are: feed pressure 0.08 MPa, cone angle 120°, underflow orifice diameter 18 mm, and inner overflow diameter 28 mm.

REFERENCES

[1] Dikov.V.A, Sukhanoc.D.E. Feasibility of hydrocyclones for combined cleaning of circulation and waste water[J]. Chemical and Petroleum Engineering, 2014, 49(9): 619-623.

[2] Obeng.D.P, Morrell.S. The JK three-product cyclone-performance and potential applications [J]. International Journal of Mineral Processing, 2003, 69: 129-142.

[3] Mahmoud.M.A, Galal.A.I, Mohamed.G. F. Performance of a three-product hydrocyclone[J] . Miner Process, 2009, 91: 34-142.