

การออกแบบและศึกษาเครื่องมือสำเลียงวัสดุแบบไซโคลน



นาย สมชัย โภชนจันทร์

005173

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาคำหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต

แผนกวิศวกรรมเครื่องกล

บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย

พ.ศ. 2520



DESIGN AND STUDY OF A CYCLONE CONVEYOR

Mr. Somchai POchanachuntara

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering
Department of Mechanical Engineering
Graduate School
Chulalongkorn University

1977

Thesis Title Design and Study of a Cyclone Conveyor
By Mr. Somchai Pochanachuntara
Department Mechanical Engineering
Thesis Advisor Asst.Prof.Dr. Variddhi Ungbhakorn

Accepted by the Graduate School, Chulalongkorn University
in partial fulfillment of the requirements for the Master's
degree.

Visid Prachuabmoh
..... Dean of Graduate School
(Prof.Dr. Visid Prachuabmoh)

Thesis Committee

K. Silapabhanleng
.....Chairman
(Asst.Prof.Dr. Kulthorn Silapabhanleng)

Variddhi Ungbhakorn
..... Member
(Asst.Prof.Dr. Variddhi Ungbhakorn)

Damrongsak Malila
..... Member
(Asst.Prof. Damrongsak Malila)

Chana Kasipar
..... Member
(Mr. Chana Kasipar)

Copyright of the Graduate School, Chulalongkorn University

หัวข้อวิทยานิพนธ์

การออกแบบและศึกษา เครื่องมือลำเลียงวัสดุแบบไซโคลน

ชื่อนิสิต

นาย สมชัย โภชนจันทร์

อาจารย์ที่ปรึกษา

ผศ.ดร. วรวิทย์ อิงภากรณ์

แผนกวิชา

วิศวกรรมเครื่องกล

ปีการศึกษา

2520



บทคัดย่อ

ไซโคลนเกิดขึ้นเมื่อบริเวณศูนย์กลางของไซโคลนมีความกดดันของอากาศต่ำกว่าบริเวณใกล้เคียง วัตถุประสงค์ของการวิจัยนี้ เพื่อต้องการออกแบบอุปกรณ์อย่างหนึ่งซึ่งเรียกว่า " ตัวลำเลียงแบบไซโคลน " (Cyclone conveyor) ซึ่งสามารถทำให้เกิด การหมุนตัวของอากาศภายในอุปกรณ์ดังกล่าวคล้ายไซโคลน จะทำให้ได้ vacuum เกิดขึ้นในอุปกรณ์ดังกล่าว ซึ่งนำไปใช้ลำเลียงวัสดุได้ ในที่นี้จะทำการสร้าง Cyclone 20 หน่วย โดยกำหนดให้ ขนาดเส้นผ่าศูนย์กลางของ bottom-end, inlet nozzle, suction pipe และ discharge pipe มีค่าคงที่

การศึกษาจะแบ่งออกเป็น 2 ส่วนในส่วนแรกเพื่อศึกษา characteristic ของ Cyclone ผลการศึกษาทราบว่า สำหรับ Cyclone ซึ่งมีค่า parameter บางค่าคงที่ ที่ความสูงของ Cyclone ต่างกัน ค่าของ Vacuum สูงสุดจะได้รับเมื่อ Cyclone angle มีค่าประมาณ 6 องศา และ Vacuum จะมีค่ามากขึ้นเมื่อขนาดความสูงของ Cyclone ลดลง

ในส่วนที่สอง นำ Cyclone ซึ่งกำหนดความสูงต่างๆกันและ Cyclone angle มีค่า 5 องศาไปทดลองลำเลียงทราย น้ำตาลทราย และเม็ดสาคู ผลการทดลองพบว่าอัตราการลำเลียงวัสดุจะมีค่ามากขึ้นเมื่อค่าความสูงของ Cyclone ลดลง และผลการศึกษาทำให้ทราบว่าระบบการลำเลียงวัสดุแบบไซโคลนนี้สามารถนำไปใช้ลำเลียงวัสดุได้ ข้อดีของการลำเลียงวัสดุแบบไซโคลนเมื่อเทียบกับระบบ vacuum-pressure ซึ่งเป็นระบบหนึ่งของการลำเลียงแบบใช้ลม (pneumatic conveyor) ที่มีอยู่เดิมแล้ว คือมี perational flexibility ดีกว่า และมี initial cost ต่ำกว่า.

Thesis Title Design and Study of a Cyclone Conveyor
Name Mr. Somchai Pochanachuntara
Thesis Advisor Asst.Prof.Dr. Variddhi Ungbhakorn
Department Mechanical Engineering
Academic Year 1977

Abstract

A cyclone occurs when the central area of air has lower pressure than the surroundings. The purpose of this research is to design a device called a cyclone conveyor which simulates the cyclonic motion of air. The vacuum created in such a device is used to convey materials. Twenty Cyclones with constant diameters of bottom-ends, inlet nozzles, suction pipes, and discharge pipes are built.

The study is divided into two parts. In the first part, the characteristic of Cyclones are investigated. For the tested Cyclones with some fixed parameters, it is found that the maximum vacuum occurs in the Cyclone at the constant Cyclone angle of 6° with different Cyclone heights and the vacuum in the Cyclone increases as the Cyclone height is decreasing.

In the second part, the Cyclones with given heights and Cyclone angles of 5 degrees are used to convey sand, cane-sugar, and tapioca. The rate of conveying increases as the Cyclone height decreases. The investigation reveals that the design system is feasible. The system, when comparing with the existing vacuum-pressure system, has greater operational flexibility and lower initial cost.

ACKNOWLEDGEMENT

The author wishes to thank Asst. Prof. Dr. Variddhi Ungbhakorn for the supervision, giving valuable guidance, many helpful discussions, and the corrections of English. He also wishes to thank University Development Commission who awarded a scholarship to the author without which this work cannot be completed.

He also thanks Mr. Kamol Wacharayinyong gratefully for helpful writing English in the first draft of this thesis.

Thanks are also due to his friends and others who gave some valuable suggestions.

Finally, he wishes to thank Miss Yupin Direkwatana for typing the manuscript.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	Title page	i
	Thesis Approval	ii
	Abstract in Thai	iii
	Abstract in English	iv
	Acknowledgement	v
	Table of Contents	vi
	List of Tables	viii
	List of Figures	x
	List of Symbols and Abbreviations	xiv
I	INTRODUCTION	1
	1.1 Statement of the Problem	1
	1.2 Pneumatic Conveyor	2
	1.3 Scope of Research	9
II	SYSTEM DESIGN	11
	2.1 Design of Cyclone	11
	2.2 Design of Pickup Nozzle	13
	2.3 System of Cyclone Conveyor	15
III	EXPERIMENTAL INVESTIGATION	19
	3.1 Description of Apparatus	19
	3.2 Test Procedure	29
IV	EXPERIMENTAL RESULTS	36
V	DISCUSSION AND CONCLUSION	60
VI	RECOMMENDATION FOR FURTHER RESEARCH	65



CHAPTER	TITLE	PAGE
	REFERENCES	67
	APPENDIX	
	Appendix A Calibration of Orifice Meter	68
	Appendix B Sample of Calculations	72
	Appendix C Table of Data and Results	74
	Appendix D Power Consumption	99
	VITA	102

LIST OF TABLES

Table		Page
2-1	FIXED PARAMETERS OF CYCLONE	14
2-2	VARIABLE PARAMETERS OF CYCLONE	14
3-1	BULK DENSITY OF MATERIALS	29
A-1	CALIBRATION OF ORIFICE	71
C-1	DIMENSIONS OF CYCLONES	75
C-2	DATA AND RESULTS OF CYCLONE NO. 1	76
C-3	DATA AND RESULTS OF CYCLONE NO. 2	77
C-4	DATA AND RESULTS OF CYCLONE NO. 3	78
C-5	DATA AND RESULTS OF CYCLONE NO. 4	79
C-6	DATA AND RESULTS OF CYCLONE NO. 5	80
C-7	DATA AND RESULTS OF CYCLONE NO. 6	81
C-8	DATA AND RESULTS OF CYCLONE NO. 7	82
C-9	DATA AND RESULTS OF CYCLONE NO. 8	83
C-10	DATA AND RESULTS OF CYCLONE NO. 9	84
C-11	DATA AND RESULTS OF CYCLONE NO.10	85
C-12	DATA AND RESULTS OF CYCLONE NO.11	86
C-13	DATA AND RESULTS OF CYCLONE NO.12	87
C-14	DATA AND RESULTS OF CYCLONE NO.13	88
C-15	DATA AND RESULTS OF CYCLONE NO.14	89
C-16	DATA AND RESULTS OF CYCLONE NO.15	90
C-17	DATA AND RESULTS OF CYCLONE NO.16	91
C-18	DATA AND RESULTS OF CYCLONE NO.17	92
C-19	DATA AND RESULTS OF CYCLONE NO.18	93

Table		Page
C-20	DATA AND RESULTS OF CYCLONE NO.19	94
C-21	DATA AND RESULTS OF CYCLONE NO.20	95
C-22	TEST RESULTS OF CONVEYING OF SAND	96
C-23	TEST RESULTS OF CONVEYING OF CANE-SUGAR	97
C-24	TEST RESULTS OF CONVEYING OF TAPIOCA	98

LIST OF FIGURES

Figure		Page
1-1	NEGATIVE-PRESSURE, OR VACUUM SYSTEM	4
1-2	POSITIVE-PRESSURE, OR PRESSURE SYSTEM	6
1-3	COMBINATION VACUUM-PRESSURE SYSTEM USING A SINGLE BLOWER	8
1-4	COMBINATION VACUUM-PRESSURE SYSTEM USING SEPARATE BLOWERS	8
2-1	A CYCLONE	12
2-2	PICKUP NOZZLE DESIGN	12
2-3	SECTION VIEW OF PICKUP NOZZLE	16
2-4	SYSTEM OF A CYCLONE CONVEYOR	18
3-1	TEST MODELS	20
3-2	TEST STAND	20
3-3	AN ORIFICE	21
3-4	PRESSURE PROBE WITH A SCALE	23
3-5	MANOMETERS	24
3-6	A SET OF AIR-FILTER AND PRESSURE REGULATOR	26
3-7	A DESIGNED PICKUP NOZZLE	27
3-8	COMPARISON OF THE GRAIN-SIZE OF MATERIALS	28
3-9	SCHEMATIC DIAGRAM OF MEASUREMENT OF VACUUM IN CYCLONE	30
3-10	ARRANGEMENT OF TEST APPARATUS WITHOUT CONVEYING MATERIALS	31
3-11	SCHEMATIC DIAGRAM OF CONVEYING TEST MATERIALS	33

Figure		Page
3-12	ARRANGEMENT OF TEST APPARATUS FOR CONVEYING MATERIALS	35
4-1	CALIBRATION CURVE FOR ORIFICE METER	38
4-2	TYPICAL CURVE OF FLOW RATE OF COMPRESSED AIR V.S. PRESSURE	39
4-3	VACUUM IN CYCLONE FOR CONSTANT CYCLONE ANGLE AND HEIGHT, $H = 7.5$ cm	40
4-4	VACUUM IN CYCLONE FOR CONSTANT CYCLONE ANGLE AND HEIGHT, $H = 15$ cm	41
4-5	VACUUM IN CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT, $H = 30$ cm	42
4-6	VACUUM IN CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT, $H = 45$ cm	43
4-7	MAXIMUM VACUUM PRODUCTION IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE HEIGHT, $H = 7.5$ cm	44
4-8	MAXIMUM VACUUM PRODUCTION IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE HEIGHT, $H = 15$ cm	45
4-9	MAXIMUM VACUUM PRODUCTION IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE HEIGHT, $H = 30$ cm	46
4-10	MAXIMUM VACUUM PRODUCTION IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE HEIGHT, $H = 45$ cm	47

Figure		Page
4-11	VACUUM IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE ANGLE, $\alpha = 0$	48
4-12	VACUUM IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE ANGLE, $\alpha = 5$	49
4-13	VACUUM IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE ANGLE, $\alpha = 10$	50
4-14	VACUUM IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE ANGLE, $\alpha = 15$	51
4-15	VACUUM IN CYCLONE FOR CONSTANT FLOW RATES OF COMPRESSED AIR AND CYCLONE ANGLE, $\alpha = 20$	52
4-16	RATE OF SUCTION AIR OF CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT, $H = 7.5$ cm	53
4-17	RATE OF SUCTION AIR OF CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT, $H = 15$ cm	54
4-18	RATE OF SUCTION AIR OF CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT, $H = 30$ cm	55

Figure		Page
4-19	RATE OF SUCTION AIR OF CYCLONE FOR CONSTANT CYCLONE ANGLES AND HEIGHT, $H = 45$ cm	56
4-20	CONVEYING CAPACITY OF CYCLONES (FOR CONVEYING OF SAND)	57
4-21	CONVEYING CAPACITY OF CYCLONES (FOR CONVEYING OF CANE-SUGAR)	58
4-22	CONVEYING CAPACITY OF CYCLONES (FOR CONVEYING OF TAPIOCA)	59
A-1	ORIFICE METER WITH RADIAL TAPS	69

LIST OF SYMBOLS

B	Vacuum
C	Coefficient of discharge
d	Orifice diameter
d_s	Suction pipe diameter
D	Pipe diameter of orifice
D_1	Bottom-end diameter of Cyclone
D_2	Top-end diameter of Cyclone
g	Gravitational acceleration
H	Cyclone height
h	Pressure drop across orifice
h_w	Pressure drop across orifice in cm of water
Δh_1	Pressure drop across orifice when suction pipe closed
Δh_2	Pressure drop across orifice when suction pipe open
h_1	Discharge pressure when suction pipe closed
h_2	Discharge pressure when suction pipe open
Hg	Mercury
P	Pressure of air at flowing conditions
P_0	Pressure of air at standard condition (101.33 kN/m ² , or 760 mm Hg).
Q	Volume flow rate of fluid at flowing conditions
Q_1	Volume flow rate of compressed air supplied at standard condition

Q_2	Total volume flow rate of air entering suction pipe at standard condition
Q_3	Volume flow rate of suction air at standard condition
T	Temperature of air at flowing conditions
T_0	Temperature of air at standard condition
V_s	Air velocity in suction pipe
α	Cyclone angle
ρ	Density of air

ABBREVIATIONS

acfm	Actual amount of air in cubic feet per minute
C	Celsius
cf	Cubic foot
cm	Centimeter
cmW	Centimeter of water
cm WG	Centimeter of water gauge
hr	Hour
I.D.	Inside diameter
k	Ratio of specific heat C_p/C_v
Kg	Kilogram
kN	Kilo-Newton
kW	Kilowatt
lb	Pound
Lit	Liter
m	Meter
min	Minute
mm	Millimeter
O.D.	Outside diameter
psi	Pound per square inch
psig	Pound per square inch gauge
r	revolution
rpm	Revolution per minute
S	Second
scfm	Volume of free air in cubic feet per minute