DESIGN AND DEVELOPMENT OF AN AUTOMATED METERED DOSE INHALER (MDI) FOR ASTHMATIC PATIENT

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For my beloved parent and family, friends, supervisor and co-supervisor, thank you.

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ABSTRACT

To date, infant with illness associated with the pulmonary airway is treated by a doctor using a spacer device with metered dose inhaler (MDI) to allow the infant to breathe in the medication known as salbutamol. Current asthma spacer does not provide systematic way of monitoring and displaying the percentage value of the propellant. Furthermore, user non-compliance is found to contribute towards longer recovery rate. Therefore, this product is designed and developed capable of detecting the propellant level inhaled by the infant by using a MQ-6 gas sensor and monitoring its percentage value. The display of available puffs of MDI canister and the battery indicator for the system are also included in the device. The automated actuation MDI was required a push button to press the MDI canister where this project utilised Arduino Nano as the microcontroller to control the system operation and all the reading values will be displayed on the OLED. RGB LED is also used to visualise the propellant level. The obtained results of the detection of propellant in voltage from the MQ-6 gas sensors were analysed in MATLAB to make comparison through the obtained results. Without propellant, voltage recorded is 0.640±0.024V whereas high concentration of propellant displayed voltage of 1.126±0.020V. The mean standard error rate of propellant detection is 5.584%. The first design of the actuation device and interface monitoring display of automated MDI were recorded the highest percentage which is 75% and 80%. The concentration of propellant depends on the ambient temperature due to the MQ-6 gas sensor required minimum working temperature between 20^{o}C to 22^{o}C. The mean weight of the MDI canister for each puff is 6.257mg and the standard deviation is 3.629mg. Due to experiment conducted, the speed and pressure of pressing MDI canister causes variability in the released of salbutamol and propellant. Observation proved that ambient temperature and propellant released amount also influenced the final reading from the automated actuation MDI.

ABSTRAK

Sehingga kini, bayi yang menghadapi penyakit yang berkaitan dengan paru-paru akan dirawat menggunakan *spacer device* dengan *metered dose inhaler* (MDI) oleh doktor untuk membolehkan bayi bernafas dalam ubat yang dikenali sebagai salbutamol. *Asthma spacer* semasa tidak menyediakan cara pemantauan yang sistematik dan memaparkan nilai peratusan propelan dalam masa sebenar. Selain itu, ketidakpatuhan pengguna didapati menyumbang kepada kadar pemulihan yang lebih lama. Oleh itu, produk ini direka dan dibangunkan yang mampu mengesan tahap propelan yang disedutkan oleh bayi dengan menggunakan pengesan gas MQ-6 dan memantau nilai peratusannya secara dalam masa sebenar. Paparan *available puffs MDI canister* dan penunjuk bateri untuk sistem juga dimasukkan di dalam peranti ini. *Automated actuation MDI* memerlukan butang tekan untuk menekan *MDI canister* di mana projek ini menggunakan Arduino Nano sebagai pengawal mikro untuk mengawal operasi sistem dan semua nilai bacaan akan dipaparkan pada OLED. RGB LED juga digunakan untuk menggambarkan tahap propelan. Keputusan yang diperolehi dari pengesan gas MQ-6 dalam voltan dianalisis di MATLAB untuk membuat perbandingan melalui keputusan yang diperolehi. Tanpa propelan, voltan yang direkodkan adalah di antara 0.640±0.024V manakala kepekatan tinggi propelan menunjukkan voltan 1.126±0.020V. Kadar piawai kesilapan min pengesanan propelan ialah 5.584%. Rekabentuk pertama peranti penggerak dan pemantauan paparan telah mencatat peratusan tertinggi iaitu 75% dan 80%. Kepekatan propelan bergantung kepada suhu ambien kerana pengesan gas MQ-6 memerlukan suhu kerja minimum di antara 20^{o}C hingga 22^{o}C. Purata berat *MDI canister* untuk setiap sedutan adalah 6.257mg dan sisihan piawai adalah 3.629mg. Bergantung eksperimen yang telah dijalankan, kelajuan dan tekanan menekan *MDI canister* akan menyebabkan kebolehubahan dalam pelepasan salbutamol dan propelan. Pemerhatian membuktikan bahawa suhu ambien dan jumlah propelan juga mempengaruhi pembacaan akhir dari *automated actuation MDI*.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	–	Ampere
AC	–	Alternating Current
ADC	–	Analogue to digital conversion
AED	–	Atomic emission detection
APP	–	Application
CFC	–	Chlorofluorocarbons
CH_4	–	Methane
cm	–	centimetre
cmH_2O	–	centimetre of water
CNT	–	Carbon nanotube
CO	–	Carbon monoxide
CO_2	–	Carbon dioxide
COPD	–	Chronic Obstructive Pulmonary Disease
CPAP	–	Continuous positive airway pressure
DC	–	Direct Current
DOAS	–	Differential optical absorption spectroscopy
EEPROM	–	Electrically Erasable Programmable Read-Only Memory
EN	–	Enable
GSM	–	Global System for mobile communications
H_2O	–	Hydrogen oxide
HFA	–	Hydrofluoroalkane
I/O	–	Input/Output
I^2C	–	inter-integrated circuit
IC	–	Integrated circuit
IDE	–	Integrated Development Environment

IFI	–	*Flow-Vu*® Inspiratory Flow Indicator
IR	–	Infrared
KB	–	Kilo Byte
Kg	–	Kilogram
KΩ	–	Kilo ohm
LCD	–	Liquid crystal display
LED	–	Light Emitting Diode
LIBS	–	Laser-induced breakdown spectroscopy
LIDAL	–	Raman light detection and ranging
LPG	–	Liquefied Petroleum Gas
LPN	–	Liquefied Natural Gas
mA	–	Milliampere
mbar	–	Millibar
MDI	–	Metered Dosed Inhaler
MHz	–	Mega hertz
mW	–	Milliwatt
MWCNTs	–	Multiwall carbon nanotubes
NH_3	–	Ammonia
NO_x	–	Nitrogen oxide
OLED	–	Organic light emitted diode
PAni	–	Polyaniline
PCB	–	Printed Circuit Board
PD	–	Partial discharge
PFPD	–	Pulse flame photometric detection
P_H	–	Heating consumption
PLA	–	Polylactic Acid
pMDI	–	Pressurized metered dose inhaler
Ppth	–	Parts-per-thousand
PPy	–	Polypyrrole
PTh	–	Polythiophene
PWM	–	Pulse Width Modulation

RFID	–	Radio-frequency identification
RGB	–	Red, Green. Blue
R_H	–	Heater resistance
R_L	–	Load resistance
RPM	–	Resolutions per minute
SCD	–	Sulphur chemiluminescence detection
SCL	–	Clock line
SDA	–	Data line
SF_6	–	Hexafluoride gas
SIL	–	Single in line
SMT	–	Surface mounted technology
SnO_2	–	Tin oxide
SPI	–	Serial Peripheral Interface
SRAM	–	Static random-access memory
SWCNTs	–	Single-walled carbon nanotubes
TC	–	Thermal conductivity
TDLAS	–	Tunable diode laser absorption spectroscopy
TNB	–	*Tenaga Naional Berhad*
USB	–	Universal serial bus
V	–	Voltage
val	–	Digital signal from MQ-6 gas sensor
V_C	–	Circuit voltage
V_H	–	Heating voltage
Vin	–	Input voltage
VOCs	–	Volatile organic compounds
WSNs	–	Wireless Sensor Network
x	–	Minimum value of digital signal from MQ-6 gas sensor
y	–	Different value of digital signal from MQ-6 gas sensor
β2	–	Beta 2
%	–	Percent
µF	–	Micro Farad

3D	–	Three dimensional
^oC	–	Degree Celsius

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CHAPTER 1

INTRODUCTION

This chapter is structured as the follow: background of study for asthma in section 1.1 and section 1.2 presented the problem statement. The aim and objectives of this research are presented in section 1.3 and 1.5. The scopes of this work present in section 1.5. Lastly, the contribution of the research and thesis organisation are mentioned in section 1.6 and 1.7.

1.1 Background of study

To date, the common problem in healthcare industry is the diagnosis of disease precisely at inexpensive price [1]. According to the Global Asthma Report 2014, around 334 million of people in the global suffering from asthma [2, 3]. In Malaysia scenario shows that five percent of adults have asthma, while children recorded 10 percent but the numbers are growing over the years [4]. Asthma is the leading chronic childhood disease with albatross on affected children and their families [5, 6]. It occurs when the pulmonary airway is blocked or the airways become narrowed. This may affect the person and result in difficult breathing and shortness of breath [7]. Pulmonary airway is the channel that oxygen and carbon dioxide passes through before or after entering the lungs [8]. The diameter of the channel or the size of the channel for the gasses to pass through it is known as pulmonary airway calibre. If asthma attack is severe the person need to take an emergency treatment to restore the normal breathing.

A study shows that asthma disease is the most frequently occurs in town or city than rural community [5, 9, 10]. Asthma more occurs in urban areas due to often there are haze and air pollution such as fumes from vehicles, factories and so on. Asthma can categorized into two categories which are allergic asthma and non-allergic asthma. In Malaysia, around 80 percent to 90 percent people suffers allergic asthma where it mostly occurs in infant, children and young adults [11, 12]. In Malaysia context analysis shows that the response of the allergic asthma is caused by house-dust, cockroach, cat dander or dog epithelium and cow milk, soya bean, egg, peanut, fish, shrimp, crab, banana and wheat [12].

The effective of air flow in human body depends on the pulmonary airway calibre. Abnormal changes in the size of pulmonary airway calibre will cause Chronic Obstructive Pulmonary Disease (COPD) and asthma. Adult patients normally use metered dose inhaler (MDI) to take inhalation of salbutamol through the mouth to recover from the asthma attack due to the MDI only require to shake for 10 seconds before use it [13]. For infant of the age one to twelve months who are unable to speak, when experiencing the asthma attack they also require dosage of salbutamol to recover from asthma attack. However, infants are unable to use the inhaler to take salbutamol directly because they are unable to inhale. In this case, normally doctor or medical staff will use asthma spacer (aero chamber) together with the salbutamol to recover from asthma attack [14].

1.2 Problem statement

The COPD and asthma are the health condition as a result in lack of oxygen entering the lungs. This will cause shortness in breath and if left untreated it can lead to death. For infant with illness associated with the pulmonary airway, doctor will use an asthma spacer device with MDI to allow the infant to breathe in the medication known as salbutamol [14]. It is a short-acting β2-adrenergic receptor against use for the relief of bronchospasm which helps to relax the smooth muscles in the air passages in the lungs, opening the airways to assist breathing. When using the asthma spacer to inhale the salbutamol, some infant is frightened by the mask and fight the treatment [15]. The use of this device is inconvenient among parents when giving treatment due to the application of the corresponding device which is bound to cause discomfort in infants.

Research has shown that drug delivery is highly dependent on the patient's inhaler technique and ability of inhalation of propellant [16]. Therefore, it is difficult for the infant since they have not developed the technique and ability to properly inhale the salbutamol. In addition, it is also difficult to coordinate actuation within the inhalation when using MDI and asthma spacer. All the problems stated may result in insufficient amount of salbutamol inhaled by the infant and low lungs deposition of the medication [16].

Furthermore, current asthma spacer only indicates manually the inhalation of salbutamol by using *Flow-Vu®* Inspiratory Flow Indicator (IFI) as shown in Figure 1.1. After the MDI canister is pressed, parent required manually to count the number of *Flow-Vu* indicator reaches to 5 flips to 6 flips [17] where maintain seal 5 breaths to 6 breaths. The *Flow-Vu* indicator is moving forward and reverse during the inhalation of salbutamol. Hence, this problem was very cumbersome where the parent required manually to count the number of flipped by the *Flow-Vu* indicator. Therefore, there is no systematic method of monitoring the level of propellant in the asthma spacer after the MDI canister is pressed. Hence, a systematic device to monitor the level of propellant in the asthma spacer will be develop to overcome the problems as been listed.

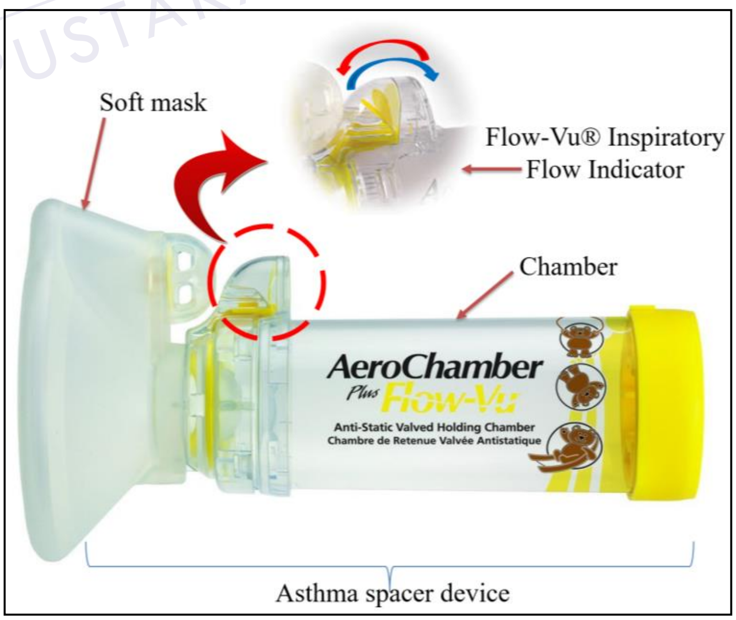

Figure 1.1: Flow-Vu® Inspiratory Flow Indicator (IFI) [18]

1.3 Aim

The aim of this research is to design and develop of an automated actuation device for MDI capable of monitoring the level of propellant in asthma spacer inhaled by infant and to count the available puffs in the MDI canister.

1.4 Objectives

The objectives of this research are as follows:

a) To design operation system which capable of monitoring the level of propellant inhaled by infant, a counter to represent the number of puffs available in MDI canister and RGB LED as visualisation to indicate the level of salbutamol in MDI canister.

b) To develop a prototype for asthma spacer with a automated actuation device for metered dose inhaler (MDI).

c) To analyse the obtained results from gas sensor and counter for available puffs.

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