THE EFFECT OF HAND DRYER FAN PARAMETER ON NOISE AND AERODYNAMIC LEVEL

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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I hereby, declared this report entitled "The Effect of Hand Dryer Fan Parameter on Noise and Aerodynamic Level" is the result of my own research except as cited in references.

Signature : .....

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for the degree of Bachelor Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRAK

Matlamat penyelidikan ini adalah untuk menambah baik reka bentuk semasa pengering tangan dengan memanipulasi parameter input berbeza yang boleh dilaksanakan untuk mengoptimumkan tindak balas output. Parameter input ditakrifkan dari segi dua aspek iaitu jenis reka bentuk muncung dan jenis penebat. Manakala tindak balas keluaran yang akan dinilai termasuklah halaju udara (MPH), tahap kebisingan (dB) dan masa pengeringan dalam (s). Kaedah menjalankan penyelidikan ini adalah dengan melaksanakan reka bentuk Faktor Penuh dalam Reka Bentuk Eksperimen (DoE) di mana jumlah eksperimen adalah sebanyak 9 kali berdasarkan 2 faktor pada 3 tahap. Muncung krom, muncung penumpu dan muncung peresap mewakili jenis reka bentuk muncung manakala kadbod telur, baji dan buih akustik piramid mewakili jenis penebat. Keputusan menunjukkan bahawa kombinasi terbaik yang dicadangkan oleh perisian Design Expert adalah kombinasi muncung krom dengan buih baji dan buih piramid sebagai muncung yang dipasang di saluran keluar udara dan juga digunakan sebagai penebat dalam perumah motor dalaman pengering tangan, masing-masing. Ketiga-tiga gabungan parameter ini telah memberikan output yang paling diingini dan telah mencapai matlamat projek ini iaitu untuk mempunyai tahap kebisingan yang paling rendah, masa pengeringan yang paling singkat dan halaju udara yang paling tinggi. Tambahan pula, ini juga telah membuktikan bahawa kesan parameter kipas pengering tangan yang melibatkan gabungan muncung krom dengan buih baji dan buih piramid telah menghasilkan kesan yang paling besar terhadap pengurangan tahap kebisingan dan tahap aerodinamik pengering tangan.

ABSTRACT

The aim of this research is to improve the current design of the hand dryer by manipulating different input parameters that can be implemented to optimise the output responses. The input parameters are defined in terms of two aspects which are the type of nozzle design and the type of insulation. Whereas the output responses to be evaluated are the air velocity in (MPH), noise level in (dB) and drying time in (s). The method of conducting this research is by implementing the Full Factorial design in the Design of Experiment (DoE) with a total of 9 runs of experiments provided with 2 factors at 3 levels. The chrome nozzle, concentrator nozzle and diffuser nozzle represent the type of nozzle design whereas the egg carton, wedge and pyramid acoustic foam represent the type of insulation. The results revealed that the best combination suggested by the Design Expert software are the chrome nozzle with wedge foam and pyramid foam as the nozzle installed at the air outlet and also used as insulations in the internal motor housing of the hand dryer, respectively. All three of these parameters combination has given the most desirable output and have achieved the aim of this project which is to have the lowest noise level, shortest drying time and highest air velocity. Furthermore, this has also proven that the effect of hand dryer fan parameter which involved the combination of chrome nozzle with wedge foam and pyramid foam has produced the greatest impact on the reduction of noise level and aerodynamic level of the hand dryer.

DEDICATION

Only

my beloved father, Eric Cheak Yoong Peng

my appreciated mother, Tay Siok Eng

my adored sister and brother, Diana, Christina and Jason

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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3D	-	3-Dimensional
ADA	-	Americans with Disabilities Act
DoE	-	Design of Experiment
Et.al	-	Et alia
HEPA	-	High-Efficiency Particulate Absorbing
n.d.	-	No date
N/A	-	Not Applicable
NIOSH	-	National Institute for Occupational Safety and Health
NRC	-	Noise Reduction Coefficient
OSHA	-	Occupational Safety and Health Administration
PCB	-	Printed Circuit Board
PSM	-	Projek Sarjana Muda
PU	-	Polyurethane
SLM	-	Sound Level Meter
SPL	-	Sound Pressure Level
STC	-	Sound Transmission Class
Std.Dev.	-	Standard Deviation
VFD	-	Variable Frequency Drive
Vs.	-	Versus
WHO	-	World Health Organisation
Std.Dev	-	Standard Deviation
Obs	-	Observations
2FI	-	Two-Factor Interaction
ANOVA	-	Analysis of Variance
Prob > F	-	Probability of full model is true
DF	-	Degrees of Freedom
PRESS	-	Prediction Sums of Squares
C.V.	-	Coefficient of Variation
Adj R-Squared	-	Adjusted R-Squared

Pred R-Squared	-	Predicted R-Squared
Adeq Precision	-	Adequate Precision
CI	-	Confidence Interval
PI	-	Prediction Intervals
VIF	-	Variance Inflation Factors
LSD	-	Least Significant Difference
SE Mean	-	Standard Error of the Mean
SE Pred	-	Predicted Standard Error

LIST OF SYMBOLS

"	-	Inch
%	-	Percent
µPa	-	Micro Pascal
A	-	Ampere
CFM	-	Cubic Feet per Minute
dB	-	Decibels
dBA	-	A-weighted decibels
ft	-	Feet
h	-	Hour
Hz	-	Hertz
I	-	Current
k	-	Kilo
LFM	-	Linear Feet per Minute
m/s	-	Meter per second
MPH	-	Miles per hour
P	-	Power
rpm	-	Revolution per minute
s	-	Seconds
V	-	Voltage
V	-	Volts
W	-	Watt
+	-	Plus
-	-	Minus

CHAPTER 1
INTRODUCTION

1.0 Overview

The Chapter 1 Introduction basically comprises seven subtopics. The subtopics include the background of study, problem statement, objectives, scope, importance of study, organization of the thesis and lastly the summary. The details of each element will be discussed comprehensively in the following subtopics.

1.1 Background of Study

The effects of the noise levels for the high speed hand dryers have been investigated on the population. The most common concerns that have been raised among these studies are the loudness of the hand dryer itself and the high frequency content of the noise (Desvard et al., 2014). High level of noise can be considered as an unsettling influence that can impact indirectly to the human environment (Owoyemi et al., 2017). In industries, noise is always aimed to be reduced since it is an occupational hazard that can gives impacts on workers' wellbeing for a long run.

In terms of industrial operations, noise also presents the wellbeing and social issues whereby the source is most often related to the utilization of machines or appliances within the industries (Owoyemi et al., 2017). In general, noise can be found everywhere including the workplace especially in industries whereby most of the noise sources came from either the machines or the appliances. The sound pressure level (SPL) which is measured in decibels (dB) generated differs from one another depending on several aspects which include the type of the noise source, distance between the noise source and the receiver, and the working environment nature (Therrien & Tummala, 2020).

At the same time, noise can also cause stress, discomfort and even worst with some degree of disorder to an exposed individual which may potentially affect one's privacy and concentration in performing tasks within the affected working environment (Becker & Lavee, 2003). Additionally, those workers who works in heavy industries that involve particularly higher noise level are more prone to have health at risk (Bamane et al., 2019). Hence, it is very crucial to find out effective yet harmless methods for noise control in order to improve the workplace environment and reduce unwanted noise in industries (Bamane et al., 2019).

1.2 Problem Statement

Fundamentally, the general rule of thumb for a hand dryer states that the fastest the hand-dryer, the louder the sound will be (J. L. Drever, 2017). In other words, it also means that when the fan speed in (rpm) increases, the noise or the sound pressure level (SPL) which is measured in decibel (dB) will also increases. Since the fan speed is operating at a high speed, thus it operates efficiently with a shorter drying time but also produces a lot of noise at the same time (*Fan Speed, Bearings, and Noise*, n.d.). Thus, the general rule of thumb for the hand dryer is not fully applicable in this study since the noise level will not be reduced but instead it has high probability that the noise level might increase.

Apart from that, noise can also be a great concern when it comes to deal with applications such as the industrial ventilation as high acoustic levels tend to promote worker fatigue (IOSH, 2018). In some cases, parameters such as the airflow rate, type of fan, and pressure may also generate noise in fan motor. Often, inefficient fan operation will be indicated by a relatively high noise level for a specific type of fan. Still, an oversized fan or motor assembly creates an opposite set of operating problems which include excess airflow noise, inefficient fan operation, poor reliability, and duct or pipe vibrations (Lawrence Berkeley National Laboratory Washington, 2003).

Commonly, the type of fan found in the hand dryer motor is the axial fan which is typically moves airstream along the axis of the fan. The working principle of the axial fan is by pressurizing the air alongside with the aerodynamic lift generated by the fan blades which is similar to an airplane wing and propeller. In addition, an axial fan tends to be noisier since it has higher rotational speeds compared to an in-line centrifugal fans of the same capacity (Gustafson et al., 2003). Nonetheless, this noise can be controlled by high frequencies and reduced gradually (Lawrence Berkeley National Laboratory Washington, 2003).

1.3 Objectives

1) To investigate the existing default design of the hand dryer model.
2) To analyse the correlation between the input parameters and the response.
3) To suggest the best combinations of input parameters that gives the optimum response in order to obtain the best result.

1.4 Scope

The aim of this project is to improve the current design of the hand dryer. The scope of the project will be focusing based on the following:

1) To find the optimum fan speed at minimum noise level with acceptable drying time.
2) To propose optimum flow directing outlet design (shape and dimension) with respect to air flow rate.
3) To propose additional damping mechanism and noise insulator on the component.

In order to find the optimum fan speed at minimum noise level with acceptable drying time, the detail works comprises of the design and fabrication of test rig, experimental setup or the speed controller. The elements that can be used to reduce noise to the minimum level with optimum fan speed are including the speed controller, soundproof container, sound level meter, acrylic, insulator foam, anemometer, printed circuit board (PCB), and labour. The cost needed to accomplish this method is RM3000 in which it gives an outcome with a new optimum fan speed value and PCB speed controller.

Secondly, to propose optimum flow directing outlet design (shape and dimension) with respect to air flow rate, the detail works comprises of design and fabricating flow directing outlet whereby the factor to be considered in this case will be the air flow shape and speed. In order to perform this method, sound level meter, drying time, anemometer, and moisture meter will be needed. There are various types of design for the outlet shape whereby all of the design shapes can be produced by using 3D printing for prototyping which gives a various shape design and size as the output. The outcome is a new optimum flow directing

outlet design with cost of RM 3500. Please refer to Appendix A for image of the various types of air outlet design shape.

Lastly, to propose additional damping mechanism and noise insulator on the component, the detail works comprises of installing rubber coupling between the motor and fan shaft and also to install rubber motor mounting. In this case, the factors to be considered are the type of material, damping coefficient and size. Apart from that, soundproofing acoustic foam inner cover can also be introduced. The factors to considered in this case will be the type of material, type and shape like pyramid, egg carton, wedges and pyramid. Also, rubber seal can be installed in between the matting part. The total cost required to perform this method is RM1300 provided that the outcome produced are the damping mechanism and noise insulator to minimize vibration and noise. Please refer to Appendix A for the images of rubber coupling and motor mounting and the various soundproofing acoustic foam.

1.5 Importance of Study

According to the experts, any noise level which is higher than 85 decibels is equivalent to a heavy traffic. Thus, there might be chances that long term exposure to this level of noise might causes hearing damage (TRC, 2019). In other words, the risk of hearing loss increases as the decibels increases. Likewise, people who experience long term exposure to extremely loud noises will have a much higher possibility in developing hearing problems. In order to prevent hearing problem, ones should always obey to the general rule of thumb which is to never take in sounds that are above the decibel threshold for longer than two minutes (TRC, 2019).

Nothing is more irritating at work for many people than a lot of noise, whether it comes from outside or inside the house. Excessive occupational noise has a variety of negative effects, including lower efficiency, more difficult communication, permanent hearing loss, and a rise in health conditions and hearing-related injuries among workers (TRC, 2019). To prevent these negative effects, it is important to assess the noise levels at the workplace on a regular basis and fix anything that is too noisy to be disruptive or dangerous. There are a variety of indicators of disruptive workplace sounds, as well as a variety of approaches and control measures. By understanding how the ear functions and the noise levels that are suitable for the workplace while still complying with OSHA are the first steps are very essential to prevent hearing impairment (TRC, 2019).