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MODELING OF CUPPING SUCTION SYSTEM BASED ON SYSTEM IDENTIFICATION METHOD

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ABSTRAK

Model matematik reka bentuk bekam yang ditunjukkan dalam kajian ini adalah sangat baik. Dengan menggunakan teknik pengenalan sistem, kertas kerja ini membentangkan kaedah untuk memilih model matematik sistem sedutan bekam yang memenuhi keperluan pengawal. Data input dan output yang digunakan untuk mencipta pembolehubah keluaran yang dimodelkan untuk sistem sedutan bekam ini telah dikesan dengan melampirkan penderia tekanan pembezaan pada cawan, dan pembolehubah input ditentukan oleh kelajuan pam yang digunakan di lokasi yang berbeza. Banyak sistem masa nyata gelung terbuka wujud. Model pecahan tertib kedua didapati paling sesuai untuk sistem sedutan bekam ini. Pengenalpastian peranti sedutan bekam menggunakan model tak linear berdasarkan Algoritma Sinus-Kosinus Ubahsuai (mSCA). Selain itu, terdapat alat dalam MATLAB yang dipanggil 'System Identification Toolbox' yang boleh membantu mengumpul sampel data pengukuran sebenar.Plot kutub-sifar digunakan untuk menguji kejayaan rangka kerja yang dicadangkan dari segi tindak balas keluk penumpuan, tindak balas keluaran dan kestabilan model. Berbanding dengan kaedah mSCA, sistem sedutan bekam adalah stabil dalam senario ujian sebenar kerana outputnya hampir sama dengan anggaran output yang dijana oleh kotak alat. Sebagai contoh, input kasar hampir sama dengan output sebenar iaitu 90.75%. Parameter model tertib pecahan (ISE) telah dioptimumkan dengan meminimumkan ralat kuasa dua kamiran. Keputusan menunjukkan bahawa lebih baik ketepatan parameter sistem bekam pemodelan, lebih kecil ralat. Ini penting untuk memastikan ketepatan gelagat keluaran masa nyata dan ketepatan anggaran output yang dicipta oleh mSCA, yang menghasilkan keputusan yang agak lebih rendah daripada MATLAB SID toolbox, yang menghasilkan keputusan yang lebih konsisten dan lebih bagus.

ABSTRACT

The mathematical modelling for cupping design shown in this study is rather excellent. Using system identification techniques, this paper came up with a way to pick a mathematical model for a cupping suction system that would meet the needs of the controller. The input and output data were used to create this modeling output variable of the cupping suction system is detected by connecting a differential pressure sensor to the cup, while the input variable is determined by the speed of the pump applied in various locations. Many open loop real-time systems exist. The 2nd order fractional model was found to be the best fit for this cupping suction system. Cupping suction plant identification utilizing a nonlinear model based on the modified Sine Cosine Algorithm (mSCA). Moreover, there is a tool in MATLAB called System Identification Toolbox that can help to collect real measurement data samples. The transfer function model also makes use of a continuous-time transfer function. The pole-zero map is used to test the success of the suggested framework in terms of convergence curve responsiveness, output response, and model stability. Cupping suction system is stable in the real testing scenario, as its output was virtually identical to the toolbox-generated estimated output, as opposed to the mSCA approach. For instance, the input of hairy surface was virtually identical to the actual output at 90.75 %. By minimizing integral square errors, fractional order model parameters were optimized (ISE). The results reveal that the better the precision of the modelling cupping system parameter, the lower the error. This is important to ensure the correctness of the real-time output behavior and the accuracy of the output estimate created by mSCA, which produced a somewhat lower result than the MATLAB SID toolbox, which produced more consistent results.

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LIST OF ABBREVIATIONS

SID	System Identification
mSCA	Modified Sine Cosine Algorithm
CT	Cupping Therapy
kPA	Kilo Pascal
PWM	Pulse-width modulation
DP	Differential Pressure
IO	Input-Output
GA	Genetic Algorithm
ANN	Artificial Neutral Network
ARMAX	Auto regressive-moving average with exogenous
ARX	Auto regressive with Extra Input
OE	Output Error
FOPDT	First-Order Plus Dead time
NARX	Nonlinear auto regressive exogenous
ISE	Integral Square Error

LIST OF SYMBOLS

ỹ	output value from MATLAB
y	output of real experimental value
ub	upper boundary
lb	lower boundary
dim	dimension of coefficients
input	input data
output	output data
k	Maximum iterations
r	Design parameters
α	Alpha
γ	Gamma

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The cupping system early begin from Traditional Chinese Medicine, Greece and Egypt[1] but now it is one the famous therapy in health care modalities. Usually cupping used for athletes for relieve muscle pain, otherwise it also has been used for normal people when having some problem like neck pain, stiff shoulder, back pain and headache or migraine. There are few method suctions in cupping system such as by using animal torn, bamboo, bones, glass and plastic cup. Execute cupping currently using glass and plastic cup are excessive used in this era. In addition, technical type of cupping commonly utilized such as, wet cupping, dry cupping, water cupping, moving cupping, needle cupping, herbal cupping and flash cupping. Cupping help to stimulate the blood flow in human body and help to correct any imbalances arising from illness or injury. However, in cupping process required several procedures especially in wet cupping for effective effect of recovering and illness.

Cupping is usually divided into 2 type which is wet cupping and dry cupping. Cupping procedure include off they will put a flammable substance like alcohol, herbs, or paper in the cup and set it on fire. This is how both types of cupping work. As the fire goes out, they put the cup on your skin upside down. Apart from that, tension of skin must be classified whether it belong to clean, medium hairy and hairy surface. As the air inside the cup cools, it makes a hole. This causes your skin to rise and turn red because your blood vessels grow. For the most part, the cup is left in place for up to three minutes. A newer version of cupping doesn't use fire to make a vacuum inside the cup. Instead, a rubber pump is used to make the cup's vacuum. They may use silicone cups that they move around on your skin to make it feel like they're getting a massage, but this isn't always the case. In wet cupping, the cup is left in place for about 3 minutes to make the skin feel a little tighter. A small scalpel is then used to make small, light cuts on your skin. The cup is then removed. Next, they do a second suction to get a small amount of blood out of the body. First, you might get 3-5 cups. Wet cupping therapy removes harmful substances and toxins from the body to help people get better. Acupuncture needles are first put in, and then cups are put on top of them. This is called “needle cupping”.[2] However, in cupping process required the proper pressure in suction due to effect of skins.

On the other hand, electric automatic cupping pump are become the easiest way to execute this cupping process. Cupping can cause short-term wounds and sensitivity, but how much pressure is used in the suction cup can affect this. Glass or plastic cups should be placed on the skin to make a model that has the right amount of pressure. Cupping causes blood to flow to the area that has been measured (hypermedia).[3] The patient may feel hotter and also more blazing because vasodilation is taking place, and they may start to sweat a little. However to control the pressure need some controller that required model of cupping system.[4]

Model-Based Models are utilized in the design phase, and these models are reused throughout the development process to ensure consistency. When designing a control system, it is necessary to employ an exact plant model of the hardware. The plant model may also be utilized for real-time testing of the control algorithm, which is beneficial in many situations. This paper will be primarily concerned with models that describe the input/output behavior of a cupping suction system's input and output behavior. The practice of developing block diagrams for control systems in order to establish their performance and transfer functions is known as mathematical modelling of a control system. [5]

Thus, the modelling of system identification of cupping suction system is done using data driven methods, which means that the data input and output are decided by or depending on the collection or analysis of data input and output. Basic principle of system identification is to estimate the mathematical model or transfer function of a system using data acquired via experiments as the basis for the estimation. It is necessary to identify the system in order to construct the controller since the plant is presumed to be known. Overall, system identification is used to estimate the parameters of a cupping model.

1.2 PROBLEM STATEMENT

Cupping therapy usually apply negative pressure to the surface of skin at body. Measuring includes applying a warmed cup or siphon instrument to produce a partial vacuum that activates the blood stream. One of the most important things to control the system is the mathematical for modeling some product. Mathematical equation can be utilized to tackle complex issues such as modeling of cupping system.

Nowadays, there are existing cupping suction using manual gun cupping to control pressure pulsate. However, cupping electrical suction has been produce but without sensor to measure the actual pressure. Moreover, without correct parameters model of cupping suction it would become difficult to control the suction especially in heavy point. Thus, to control the pressure using pressure sensor need an accurate and suitable controller by proper mathematical modelling.

1.3 OBJECTIVES

The main objective of this development of modeling for cupping suction system are:

i. To develop suction mechanism system for cupping.
ii. To acquire input and output data for cupping suction.
iii. To develop the modeling of cupping suction by using data driven modified Sine Cosine method.
iv. To analyze the accuracy of cupping suction model.

1.4 PROJECT SCOPES

i. Design the cupping system using pump, pressure sensor, tube and cup.
ii. Calibration differential pressure sensor using manometer.
iii. Collecting data from the differential pressure sensor for clean, medium hairy, and hairy surfaces using constant speed pump input, unit step input, and random input.
iv. Using MATLAB software to find the System Identification model for cupping suction.
v. Find transfer function using modified Sine Cosine method.
vi. Analyzed the performance by using integral square error (ISE) technique.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

Traditionally, the cup of therapy has been used in one way or another in most cultures. In the UK, cupping therapy has long been referenced in a medical journal called The Lancet, referring to this practice. A lancet is a surgical instrument commonly used to remove excess blood. The Arabic name for the treatment is Al-Hijama, which means to reduce the amount needed to return the body to its normal state. The practice of Al-Hejamah has been part of the cultural system of the Middle East for a thousand years, and the poems date from the time of Hippocrates (400 BC). In the Western world, the first people to discover cannabis were only the ancient Egyptians, the oldest written book, the Ebers Papyrus, written in 1550 BC. in Egypt, was packaged [6] Cupping can be divided into two broad categories: dry cups and wet cups. Snake cupping Snake is widely used in the Far East, necessitating placement of waterfalls in the Middle East and Eastern Europe. For the purposes of this study, a review of breastfeeding will be conducted in a therapeutic setting, which will be referred to as cupping therapy.

2.1 CUPPING THERAPY

Cupping therapy (CT) is a common medical practice and thousands of years. It is an important part of communication with other chemicals the world like acupuncture. It is very popular in many places countries, especially in China, Korea, Japan and Saudi Arabia.[7] The importance of this analysis is that the bridge of the knowledge gap the history of cupping. It also provides a reliable source for knowledge of the history of various aspects of CT, which may use for training traditional and modern professionals to help researchers around the world[8]. Hopping is effective for many types of diseases. It has been reported that Persian cup therapy can be used for 1001 types of disorders. In recent years, dome therapy has been frequently used for pain, heart disease, immune system diseases and metabolic diseases such as migraine, lower back pain, fibromyalgia, shoulder pain, chronic non-specific neck pain, angina pectoralis, arthritis, hypertension, heart disease, ischemic and inflammatory myocardial condition, shingles, Behcet's disease, secondary amenorrhoea, depression and anxiety, fatigue, metabolic syndrome and acne vulgaris.[7] There are some improvements in the mechanism of cupping therapy. Cupping therapy can regulate blood circulation in the skin, alter the bio mechanical properties of the skin, raise the immediate pressure threshold in some areas, and rapidly reduce inflammatory conditions. In some studies, this suggests that wet tracing may restore sympathetically imbalance and provide protection to the heart by stimulating the peripheral nervous system. The cup appears to play a role in both activating the complement system and modulating the cellular portion of the immune system. Wet cupping has been shown to increase red blood cells and contribute to anemia caused by chronic kidney disease. In diabetics, blood sugar levels drop significantly even after childbirth. CT mostly used in Malaysia also medical purpose, it also reduces the pain of body and some disease.

Figure 1 Traditional Cupping Therapy

2.2 CUPPING SUCTION METHOD

This part of the agreement is categorized according to how professional construct its negative pressure into the cup. The most common method is the fire cupping, manual vacuum cupping and electrical vacuum cupping.

2.2.1 FIRE CUPPING THERAPY

Fire cupping are a form of domes create a vacuum inside the cups with fire. In glass, ceramics Bamboo cup without valves (valve is the mechanism to control the air through the cup). In China, the traditional cupping method usually carried out by fire; a piece of paper the cotton comes down and goes directly into the glass, or a piece of cotton is soaked with 95% alcohol, spread at the end of the stick and then inflamed. The cup is applied immediately Skin surface. The skin may burn in this type of cupping due to the use of fire.[9]

Figure 2 Fire cupping

2.2.2 MANUAL VACUUM CUPPING THERAPY

Manual cupping also have another name which are vacuum cupping and opening cupping[10]. This by creating negative pressure a cup with manual suction pump. Self-suction cups with rotator on top of the cup or for this type a pressed rubber top can be added. The main advantages of the method: experimental studies have shown this blood flow is more pronounced in this type cupping like a traditional fire. Further this cupping is also a new technique in the modernization of cupping [10]. The hand pump [11] without sterilization practitioners of this are the main drawbacks method.

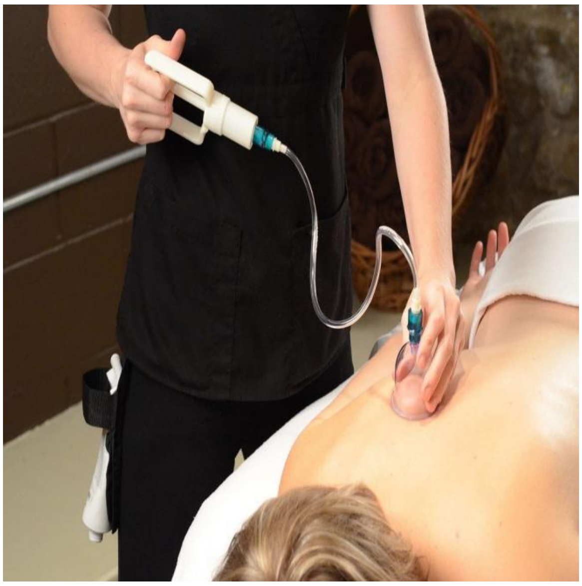

Figure 3 Manual cupping

2.2.3 ELECTRICAL VACUUM CUPPING THERAPY

Electric vacuum cupping [11]is a form of cupping which pressure is created in the glass using an electric suction pump or device. The advantages of this type are that a therapists can adjust the negative pressure can produce a free negative pressure pulse, and connect several cups. Can be used in medical examinations for measurement and adjustment negative pressure in cup. Electrical cupping system will be having two difference type of cupping pressure. Negative pressure will used for cupping therapy. Usually, the pump has two inlet and outlet ports. The inlet of the air pressure can be called a "negative pressure". In mathematics term, if the pressure in the medium is pushing the walls, it must be positive, then the pressure pulling the walls must be defined as negative. The latter can be called retrieval. At physical term, the pressure is always positive or zero. There is no negative absolute pressure. We can only have a relative negative pressure if the external absolute pressure is greater than the internal absolute pressure. There is no real suction. There are few levels of pressure that need to consider when cupping therapy occur. Basically ranging from 300–400 mm Hg to 540–660 mm Hg (using an electronic cupping device)[3]

Figure 4 Electrical Cupping

2.3 POWER OF SUCTION

This group of cupping is classified according to the acute pain conditions made in a cup. There are 4 type of cupping such as light, medium, strong and pulsate cupping.-the role cupping[12]

2.3.1 LIGHT CUPPING

Light cupping is defined as the pressure level between 10kPa and below than 30kPa. The doctor injected soft tissue into the vessel using one or two certified sets of manual pumps. It is often used for children, infirm patients, and sensitive human parts. The light cupping can be applied to the pot with solutions, dry and flash cupping therapy. Its extreme convenience leaves many patients without symptoms. Due to the clear light, however, the cup appears to fall off during the ceremonial treatment. [9]

Figure 5 Light Cupping

2.3.2 MEDIUM CUPPING

Medium cupping usually used for cupping therapy because it is sightly suitable for human skins. The pressure level is between 30kPa and <500kPa. If we using manual suction method it will take 3-4 fully pump to suck. Medium cupping will leave mark on body not like light cupping wont left any marks at all. Medium cupping is not so recommended used at sensitive places such as face. [9]

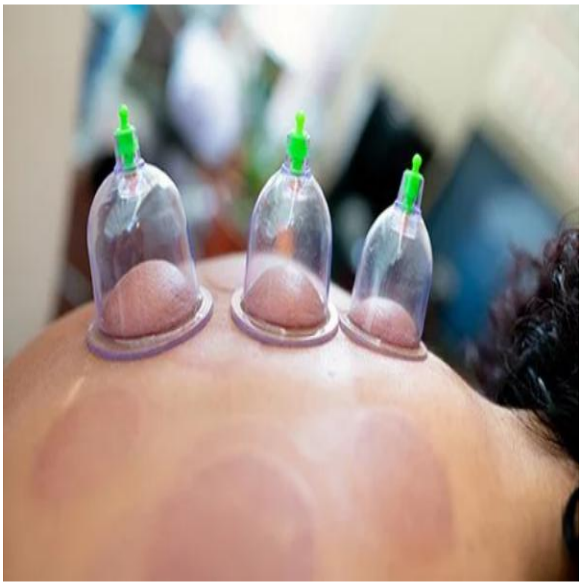

Figure 6 Medium Cupping

2.3.3 STRONG CUPPING

High negative pressure is created during strong cupping. This method is only suitable for elderly people and not recommended to children because their skin is too sensitive and it will hurt them. The negative pressure inside glass will be more than 50kPa. This power suction will make human body skin pain, redness and ache. If we using manual suction method it will take 5 or more fully pump to suck.[9]

Figure 7 Strong Cupping

2.3.4 PULSATILE CUPPING

This one of the new technologies applied tools for cupping method. It is because the negative pressure inside the cup is changeable to place that therapy should occur. The pressure is usually starting from 10kPa to 40kPa. The electrical suction pump is used to control this pressure. It will be using PWM method to do so. It can be suitable to many places of body. The mechanical device will used for this therapy.[12]

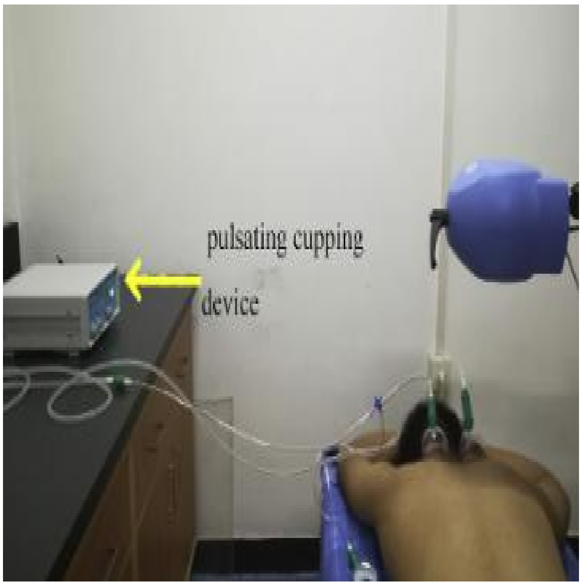

Figure 8 Pulsate Cupping

But, a study of the effectiveness of treatment as a toxin the pressure is not enough, so medical treatment is often inadequate. Because there is no clear standard for setting pressure during cup therapy, the researchers conducted a study an interference systems and physicians use the device differently often unhealthy.

Table 1 Analysis Data of Cupping Therapy

First author	Cupping device type	Cupping Position	Cupping Pressure(kPa)	Cupping duration(min)
Kim[13] (2013)	Electronic cup device Cups	Back-shu point	Constant negative pressure: 80kPa	1
Blunt[14] (2010)	Cupping device Cups	Neck	100kPa	-
Hubber[15] (2011)	Electronic cupping device Cups	Soft Surface	30kPa	-
Emerich[16]	Electronic cupping device glass cups	Lower back	33kPa	5

(2014)				
Duh[10] (2015)	Electronic vacuum chamber	Forearm	8kPa	6
Teut[12] (2018)	Electronic cupping device silicon cups	Lower back	35kPa	8
Kim[13] (2018)	Manual cupping device	Silicon surface	44kPa	10

Here is comparison of skin tension mainly for weak, medium and strong cupping.

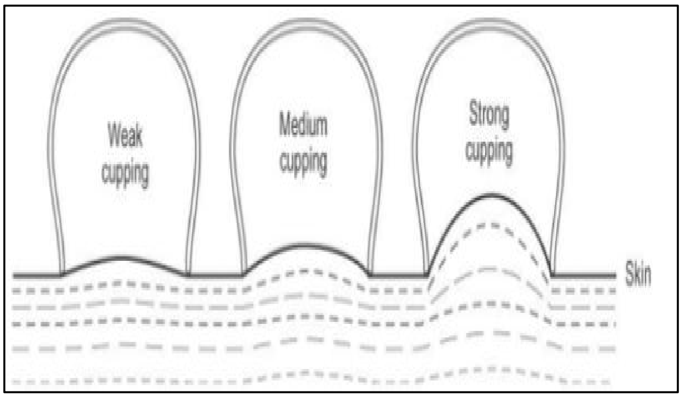

Figure 9 Cupping Skin Tension

2.4 MODELING

The way math is used to express real-world situations and how they are related to each other. Figure out how to solve the continuous cycle of translating real-world problems into mathematical language. Then, try out the mathematical solutions individuals came up with in the real world. In both cases, mathematical models are thought to be outside of the physical world so that math can be used to study the structural properties of things like buildings. This means that math models of difficult natural and social problems must be built that include math that is relevant to the problem-solving process. For an example development of a mathematical model that can be used to show how a real car frontal crash would happen. A double spring-mass-damper system is used to model the car.[17]

At a first example of the construction process, a math model is a food recipe. It will have information about every single ingredient with the correct measurements and how many people should the meal be made for. So, we go back to our math modelling of the cupping system to get the correct equation for the control system from there.

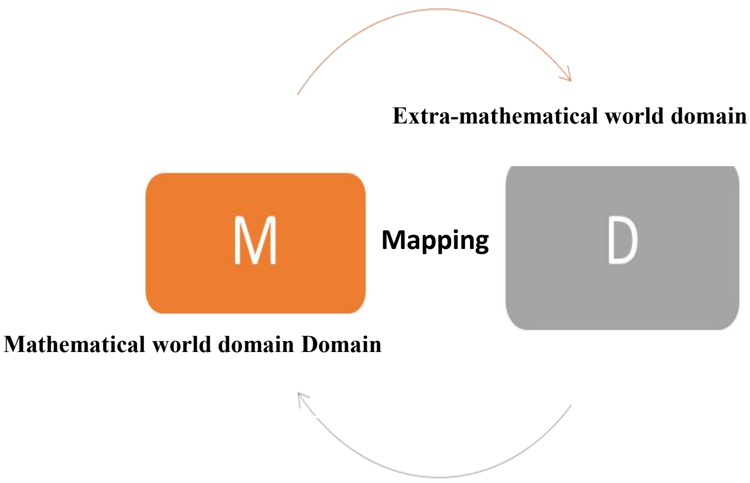

Figure 10 Cycle of Modeling

Moreover, mathematical modelling may be expressed as a modelling cycle. following figure 12 shows a philosophical point of view. The ‘extra-mathematical' domain (D) represents the ‘real world' important to an issue. It is then ‘mapped' - translated – into relations, phenomena, assumptions, problems, etc. in the mathematical realm (M). The results of these mathematical debates, manipulations, and inferences are subsequently translated back to D and understood as domain implications. Technology is used in this activity anytime it can improve the mathematical process, which is frequently. This modelling cycle may be repeated numerous times, depending on the model's domain validation and assessment, until the findings are satisfied.

2.4.1 CONVENTIONAL SYSTEM

These models are great for making and making operating systems. An operating system analysis is looking for input and output results that we know about because we have a mathematical model for them. It is important to figure out how to input and output a mathematical model so that we can design an operating system. Models like deferential equation, transfer function, and state space can be used to solve a lot of different kinds of problems. For the cupping therapy model to grow, the transfer function is very important. Let's see how this model works in our basic system of thought. Transfer function model is a mathematical model of control systems that works in the s-domain. Rules change when the conceptual model (entity/relationship) is shown in the practical model (generation) of the method. However, there are some non-technical resources as well as the ability to make and use different types of statistics based on the classification of other types of documents, so it's not all bad.

People use mathematical control when they set up a block diagram for operations and electronics so they can see things like how a shipment is going to work. Translations are moves that go in a straight line. There are three types of forces in this linear system: inertia, damping and spring. These are the three types of forces in this linear system. It is called rotation when the instrument stays in place after it moves. There are three types of resistors that can withstand rotation: spring torque, damping torque, and inertia torque, which are all different types of torque. That's all about the old-fashioned way of modelling. It is the basic transfer function used to find the solution for a small system.

2.4.2 SYSTEM IDENTIFICATION

SI is a process that includes taking time or frequency domain measurements of the system's IO signals, choosing a candidate model structure, and choosing and implementing a technique to estimate the value of the adjustable parameters in the candidate model structure. Then, the development and analysis of estimates to see if they work in the application, preferably with a new set of data. A large enough model can very well predict a measured result. It's important to see if the model can be used with more information, like data that wasn't used to make an estimate but was used for the same thing.

Table 2 Analysis Data of System Identification

No.	Author	Plant model	System ID Algorithm
1	Dirman Hanafi, Mohd Syafiq Suid, Mohamed Najib Ribuan, Rosli Omar, M Nor M. Than, M. Fua'ad Rahmat [17]	Quarter Car Passive Suspension System	Linear Least Estimation Algorithm
2	Sudep Sharma, Bharat Verma, Rishika Trivedi , Prabin K.Padhy [18]	First Order Plus Dead Time (FOPDT) process model	Artificial Neutral Network (ANN)
3	Carlos Roberto Chaves, Rodrigo Juliana C.G, and Claudio Garcia [19]	Petrochemical Furnace	Predictive Controller Algorithm
4	Piotr Nikonczuk and Slawomir Jaszcak [20]	Fan Dynamic in Spray Booth	Genetic Algorithm
5	M.H.Suid , M.Z.Tumari, and M.A. Ahmad [21]	Energy Production of Wind Plant	Modified Sine Cosine Algorithm(mSCA)
6	E. BELGE, H. K. KABA, A. PARLAK, A. ALTAN, R. HACIOĞLU [22]	Unmanned Aerial Vehicle	Autoregressive Exogenous (ARX), Autoregressive Moving Average with Exogenous Variable (ARMAX) and Output Error (OE)
7	Ahmad Jobran Al-Mahasneh, Anvatti SG, and Garratt M [23]	Quadcopter	Neuro-Evolutionary Algorithm
8	Ye Naung, Anatolii Schagin, Htin Lin Oo, Kyaw Zaw Ye, Zaw Min Khaing [24]	DC Motor	NARX

9	Pritesh Shah and Ravi Sekhar [25]	DC Motor	Genetic Algorithm (GA)
10	Julakha Jahan Jui, Mohd Helmi Suid, Mohd Riduwan Ghazali, Mohd Ashraf Ahmad and Mohd Zaidi Mohd Tumari [26]	Liquid Slosh	mSCA

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

Basically, this chapter will be discussed about the sequence of this project. First of all, the focused is on literature review about cupping and find a suitable component for development cupping suction and modeling. Moreover, design an electronic suction with concept of negative pressure applied. Then, suitable sensor was chosen based on objective of project. Differential pressure sensor is used for develop cupping system which is model MPX5100DP. The next step is calibrating the sensor using manometer and test it until get correct value. The electronic suction calibrating consists of motor driver, pump, Arduino uno, differential pressure sensor and suction cup.

Subsequently, generate input and output from the electronic suction mode and applied to system identification. Therefore, it will generate the transfer function for the cupping modeling. Finally conduct analysis based on performance of output data.

3.1 BLOCK DIAGRAM PROJECT

There are few steps to figure out this project generally to complete it. Firstly, develop a hardware and system of cupping suction which including sensor, cup, hose, pump, Arduino code and Arduino. In addition, record all of the cupping's input and output data from various input speed of motor pump. Employing system identification to find a mathematical model of a cupping system and using 2nd Oder transfer function criterion. For identifying the optimal parameters of cupping modelling, the MATLAB system identification toolbox and data-driven modified sin cosine method are utilized. In the last step, compare the actual output to the estimated output in order to validate the mathematical model transfer function of cupping.

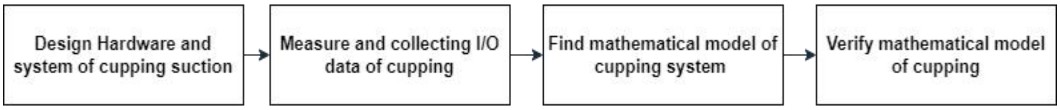

Figure 11 Block Diagram

3.2.DESIGN ELECTRONIC SUCTION

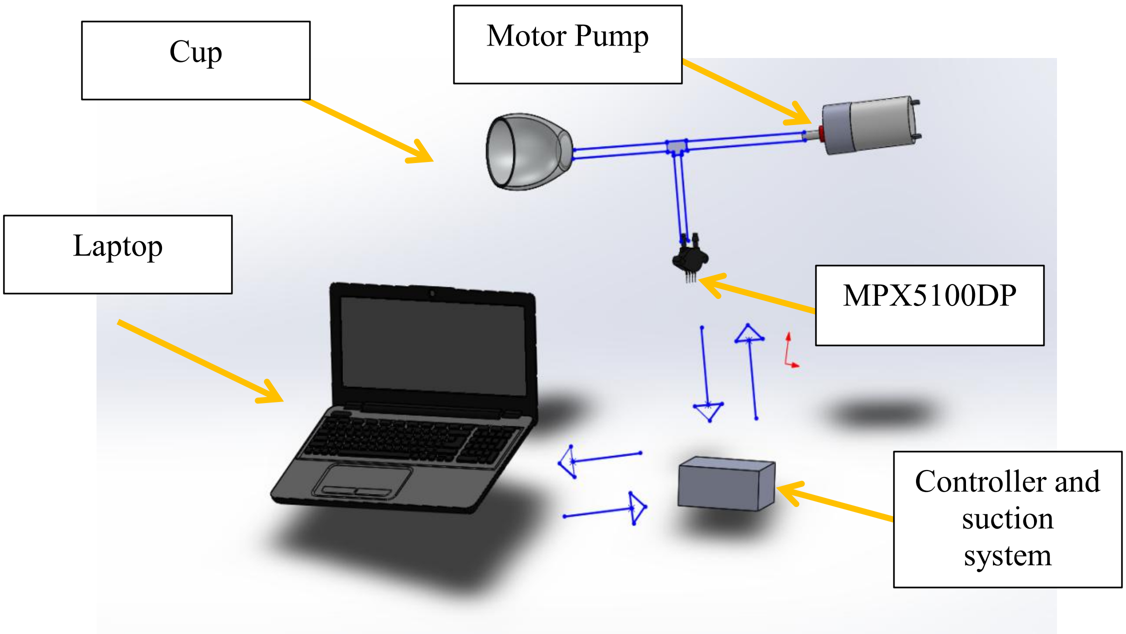

Figure 12 Development Cupping Suction System

In begin, create an electrical suction system uses the Arduino Uno, a cup, a T-connector, a motor driver, a breadboard, a tube, a pump, a 12v converter, a differential pressure sensor, and a jumper wire. Firstly, the MPX5100DP is connected to the Arduino through the 5v to the sensor's pin 3. The breadboard and the GND sensor pin 2 are connected to the GND Arduino. The curved junction on pin 1 indicates that it is the sensor's output pin, which is connected to the analogue pin A0 on the Arduino. The pump was then connected to Arduino digital ports 8,9, and 10 via a 12v adaptor to ensure that sufficient current was available to run the pump's suction power. Additionally, a T-connector in between the tubes was used to join the cupping cup to the sensor and motor pump. The differential sensor's port 2 is connected to the T-connector. This is because port 2 is referred to as the vacuum port and port 1 as the positive pressure port. Finally, a mechanism for electrical suction was developed.

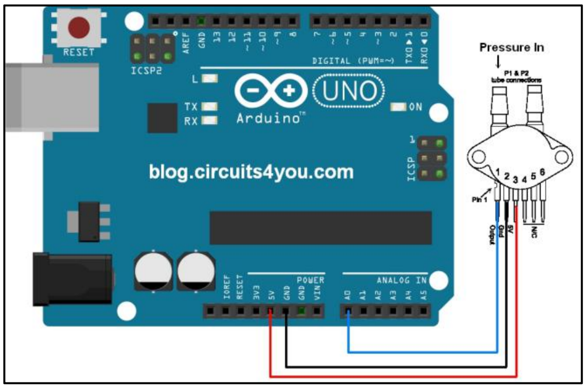

Figure 13 Connection Sensor with Arduino

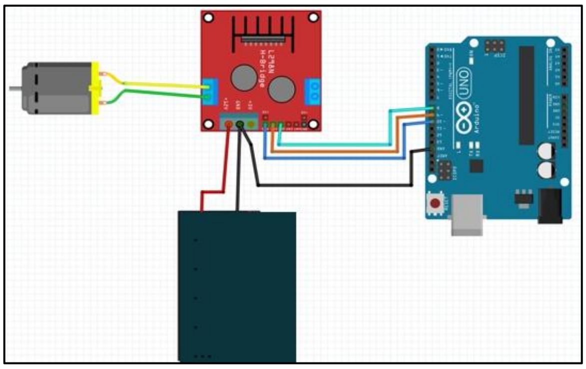

Figure 14 Connection Motor Pump

3.3 CALIBRATION MPX5100DP WITH MANOMETER

Calibration is the process that checking the standard measurement of the sensor. Calibrating sensors ensures that they are operating at the best possible rate and giving the best performance. Calibrating refers to the method which is used to check the accuracy of the sensor compared to the predefined standards. The manometer shown below. This calibration process is done to minimize uncertainly of measurement and to ensure both precision and consistency.

Figure 15 Manometer

Differential pressure sensor will be used as sensing the pressure in Pascal(kPa) which is converted to a unit value. The value is obtained by Arduino as output of the sensor. Since the value sense from sensor is an analog form, it as to be converted to digital signal first, before any DP with further process taken. The Arduino ADC, or Analogue to Digital Converter, turns a voltage into a digital value. When measuring analogue voltages, the basic configuration can measure a voltage between 0V and 5V with a precision of 4.9mV. The display will monitor in serial monitor for the pressure sensing. First and foremost, an experimental setup is used to calibrate the differential pressure sensor and to measure negative pressure using the manometer. This is the following calibration procedure:

i. Connect the motor driver to the power source.
ii. Set the pump speed to 50 and measure the digital pressure reading.
iii. Keep a record of the results in the table.
iv. Steps 2-3 should be repeated for each new speed value.
v. Once acquired all the result, connect the tube that is attach to pressure sensor with manometer.
vi. Attach the pressure sensor to the breadboard.
vii. Connect the multi-meter to the breadboard.
viii. After completing the connections in steps 5-7, measure the pressure (kPA) value acquired on the manometer, digital pressure value, and voltage (V) with the motor speed set to 50.

ix. Step 8 should be repeated with a different speed setting.

x. Keep a record of the results on the table.

xi. Plot the graph of digital value reading versus manometer reading.

xii. Apply a linear curve fit to determine the calibration equation.

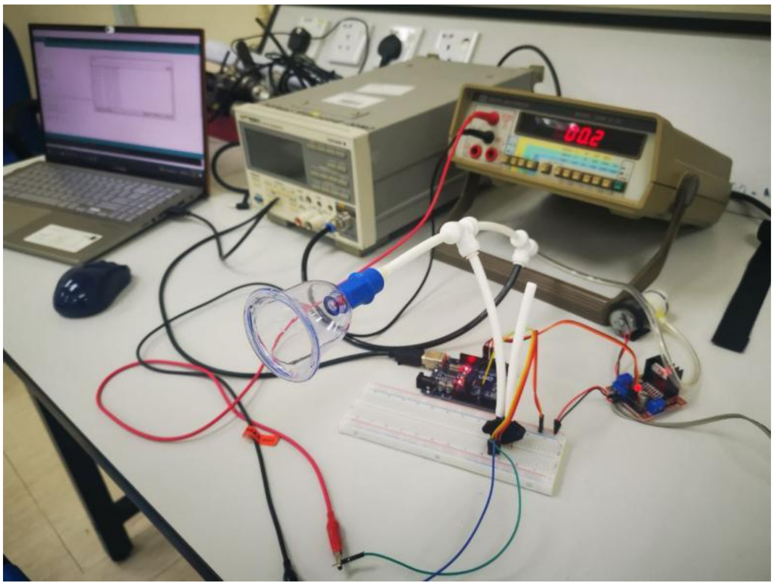

Figure 16 DP sensor connection with manometer

Table of Calibration:

Table 3 Calibration Table

Speed of motor	Voltage(V)	Digital value	Pressure (-kPA)
50	0.53	110	-7.9
60	0.75	150	-12.4
70	0.98	198	-17.5
80	1.28	257	-23.9
90	1.59	320	-30.2
100	1.94	393	-38.6
120	2.3	460	-46.6
140	2.57	520	-52.6
160	2.68	540	-55.1
180	2.75	555	-56.4
200	2.76	557	-56.6
220	2.78	560	-57.1
240	2.81	565	-57.8
255	2.83	570	-58.2

Calibration Graph:

The graph displayed the digital value and manometer's recorded value. This shows that both numbers are valid, and we can compute the proper pressure for the Cupping Suction System. The digital value and the manometer value are graphed. As illustrated in the graph below, the value of pressure in the cup is known as negative pressure.

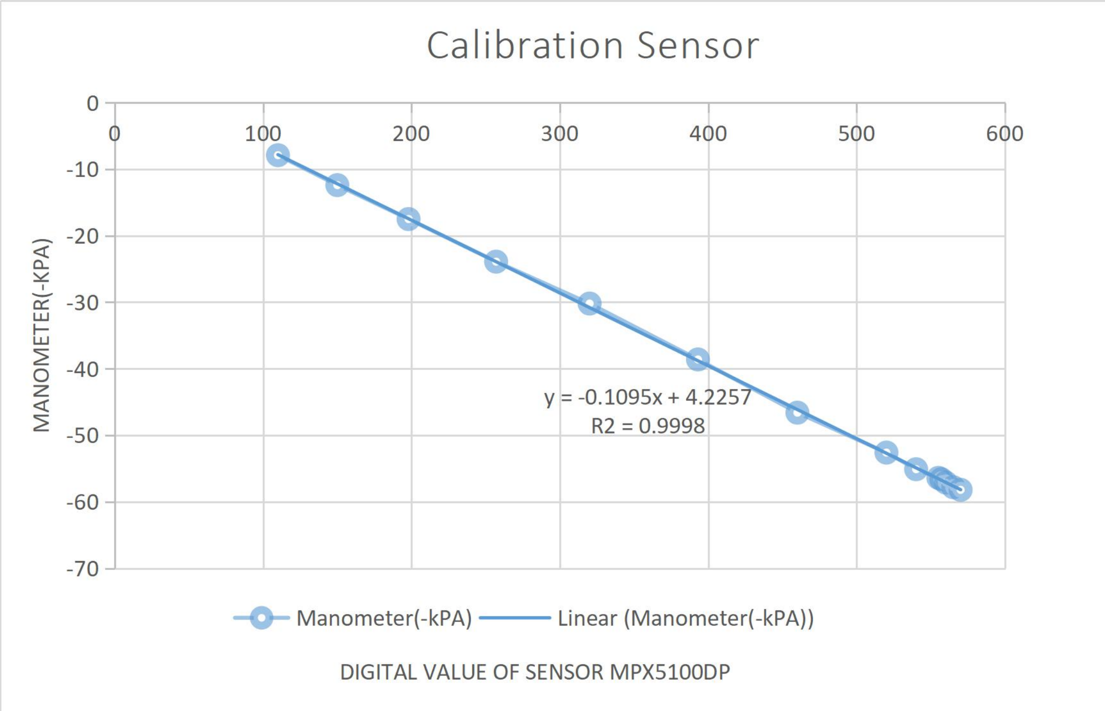

Table 4 Calibration Graph Plot

Equation formed from the graph plotted:

$$y = -0.1095x+4.2257 \quad (1)$$

Equation 1 Calibration

This equation was insert into Arduino code, and proceed to the validation process of the equation performance on reading of pressure value and reading with manometer.

3.4 GENERATE INPUT OUTPUT

Data collection may be defined as the process of gathering, assessing, and interpreting precise insights in order to conduct successful research with the use of best-suited procedures that identified an opportunity in evaluating the hypothesis. In a simulation project, the ultimate purpose of the input data is to drive the simulation in real time. In this process, the input and output data are collected, the input and output data are analyzed, and the analyzed input and output data are used in the simulation model. The input data for the simulation project was obtained from real-time data as part of a task in the project.

An Arduino UNO, in particular, is utilized as a data collection platform to process the input and output data. Here, we create a voltage from the Arduino UNO to the remote speed of the motor pump while simultaneously collecting additional data from the differential sensor. Using the serial monitor, both input and output data from the personal computer may be examined and evaluated. Suction must be administered for a certain amount of time in order to determine the model of cupping system. Then, we apply the input voltage of the motor pump to the suction at different points and the pressure data is captured. First and foremost, three distinct types of locations in the body have been identified for data collection. Purely clean surface point, medium hairy point, and hairy point were used in this project.

The data was divided into three categories based on the motor pump's speed: constant, unit, and random. Every speed was evaluated with the various types of surface bodies stated before. The data was collected in a continuous format that allows for any value within the observed range. For constant speed, the data was collected using a 180 RPM motor pump for a clean surface and a medium hairy surface, but a 255 RPM motor pump for a hairy surface. This is due to the fact that suction on a hairy surface necessitates a higher negative pressure. The data output was calculated using the sensor's digital value, which was then transformed to a pressure measurement on a serial monitor. Last but not least, with MATLAB software, create a comparison graph for all input and output data. Finally, the output data is stored and apply it on system identification for further process. The pictures below are the various point to applied with various input speed for pump.

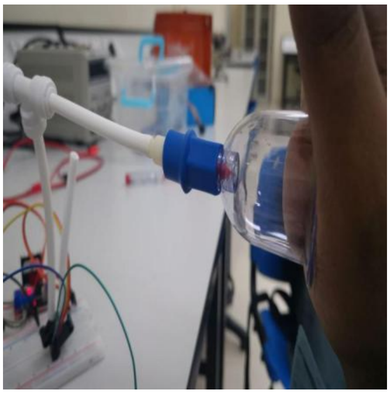
Figure 17 Clean Skin


Figure 18 Medium Hairy


Figure 19 Hairy Skin

3.5 GENERATE TRANSFER FUNCTION FROM SYSTEM IDENTIFICATION

For this project, the MATLAB software is used to generate the transfer function from system identification. MATLAB is a technical computer language with a high level of performance. It integrates computation, modeling, and computing in a graphical user interface, with problems and solutions represented in standard mathematical terminology. The design of algorithms, modelling, simulation, and development, statistical analysis, exploration, and other applications are all frequent. MATLAB is utilized for system identification in order to compare data input and output.

3.5.1 DATA DRIVEN METHOD

This study utilized a data-driven approach to process improvement of a cupping suction device. Because our system was an open loop, data-driven approach, we used data input and output to perform modelling for the cupping suction system. Data-driven techniques address this issue by enabling a system model to be made to fit to experimental data and assigned to a model class. In this part, we offer a data-driven modified Sine Cosine Algorithm (mSCA) for identifying cupped system plants.[26] To begin, a problem formulation for identifying the cupping suction system plant is presented. The sine cosine algorithm (SCA) is a novel optimization algorithm that starts with a solution set containing a specific number of random solutions, evaluates the fitness of the solution continually using the objective function, and then randomly updates the solution set to arrive at an optimal solution.

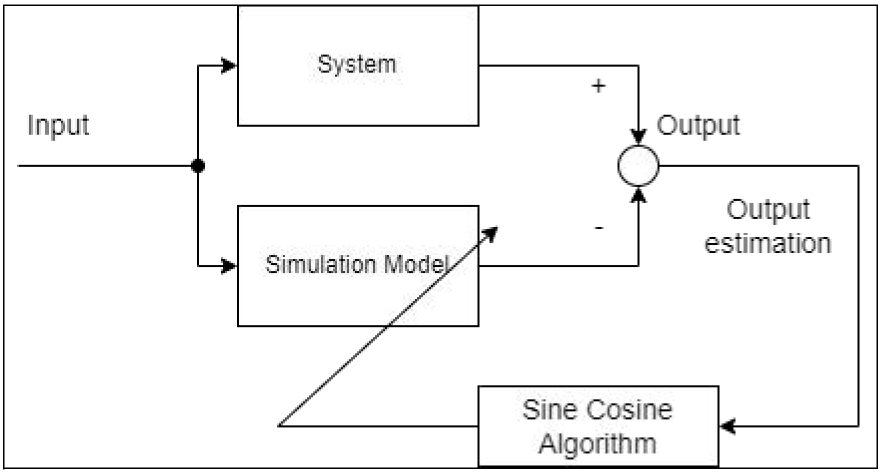

Figure 20 System Identification block diagram

The mSCA was included into the position-updating algorithm as a result of its acceptance. This is how the formula is updated.[27]

Moreover, the number of search agent updated with number of iterations for modeling cupping system. Parameters of modelling according to upper and lower boundary was determined. Calculate all the objective function in for search agent. After that, update the best parameters in $P_{i,j}$ table.

$$\mathrm{xx_{ij}} = \begin{cases} x_{i,j} + r_1 * sin(r_2) * \left| r_3 P_{i,j} - x_{i,j} \right| & r_4 < 0.5 \\ x_{i,j} + r_1 * cos(r_2) * \left| r_3 P_{i,j} - x_{i,j} \right| & r_4 \geq 0.5 \end{cases} \quad (2)$$

Equation 2 SCA equation of Objective Function

Here, $r_2 \epsilon [0,2\pi]$ is random variable, r3 is a random variable. R4 is used to choose different search paths, sine or cosine, according to different random values. Jgood is the objective function.[26]

r_1 is order the next position regions. It is shown as follows:

$$r_1 = a[(1 - (\frac{k}{k_{max}})^{\alpha}]^{\gamma} \quad (3)$$

Equation 3 r1 general form

After reach maximum iteration, record the best parameter P and obtained the continuous-time with transfer function of 2^{nd} order.

$$G = \frac{ax}{bx^2 + cx + d} \tag{4}$$

Equation 4 General Equation 2nd order

3.5.2 MATLAB SYSTEM IDENTIFICATION TOOLBOX

MATLAB System Identification toolbox was the technique used for estimating parameters of system. By using input-output data, the System Identification toolbox builds mathematical models of dynamic systems. Identification of the system used to estimate the parameters of a model specified by the user. Cupping suction system modelling may be predicted using system identification approaches.

Firstly, open the MATLAB system identification toolbox. Import data from the workspace before you begin calculating parameters. Import and rename the input and output data. By selecting data view time plot, you may inspect the data created at the data board. Additionally, data is entered into the working data set and a transfer function is estimated for mathematical modelling. Cupping suction systems are primarily modeled using second order transfer functions. Thus, depending on the transfer function employed in this research, calculate the number of poles and zeroes. Iteration for parameter estimation has been established in particular.

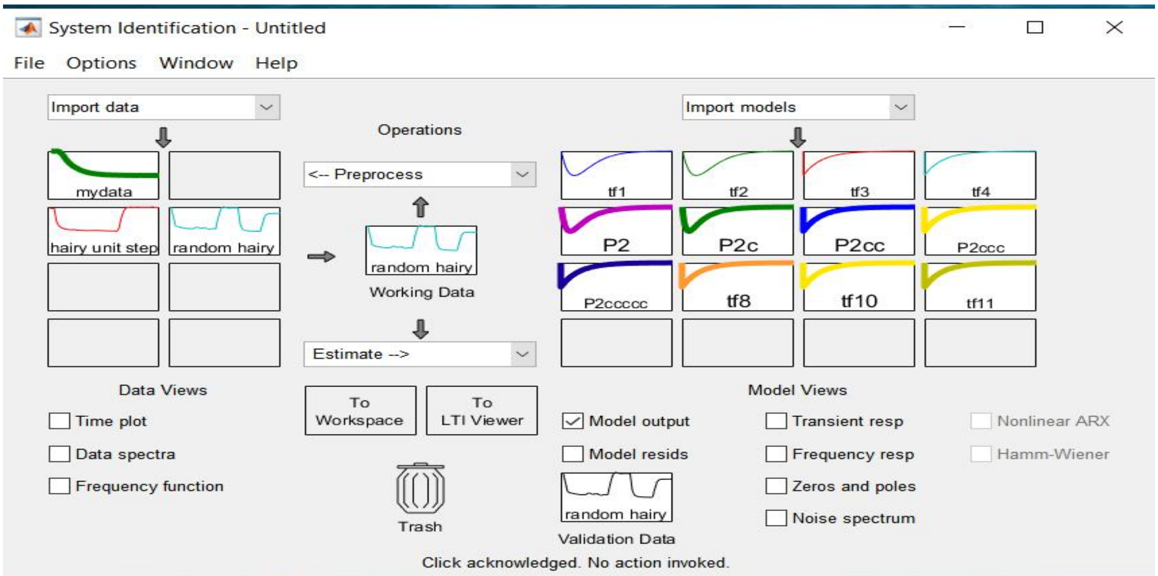

Figure 21 SID Toolbox

However, the results obtained was split into two parts, one for estimation and the other for testing. A few estimates have to be made to come up with the best model. Estimating parameters for cupping suction system by model validation and acceptance of model based on these stages: with low order and by assessing model performance using the following performance criteria: (1) minimizing FPE and LF, and (2) selecting a model structure that optimizes the percentage of model fit. If the validation not reached the maximum fitting, the process of determine model structure will be repeat. Finally, for displaying experimental data output and estimated data, choose show model plots.

CHAPTER 4

RESULTS

4.0 INTRODUCTION

In this chapter discussed about all the result that obtained from this project. The best fit modelling has been present for modeling cupping suction system. Different pulse volt was given to pump at various input location in body as input source. The pressure effect from the speed of motor pump was measured as output of this project. Analyzed performance of real output data and estimated output data.

4.1 HARDWARE DEVELOPMENT

The figure x shows that the original hardware design cupping system. This system was built up with combination of DP sensor, Arduino, Cupping Cup, T-connector, motor pump and motor driver. In this project, the real plant was developed in function to measure its behavior and present an upping modeling suction system. Thus, laptop is using to monitor the digital value the system.

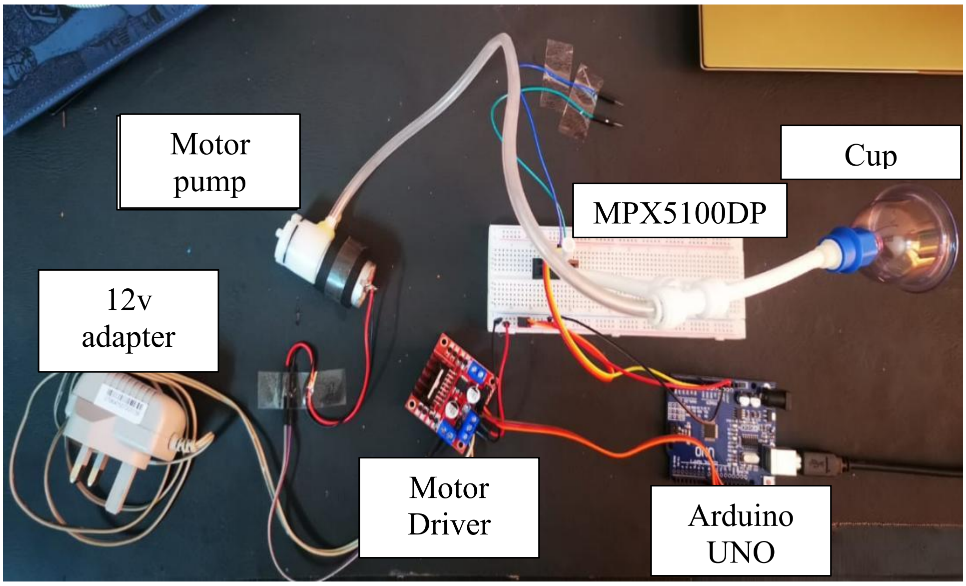

Figure 22 Design Development Cupping Suction System

4.2 CALIBRATION SENSOR

Sensor was calibrated successfully because it had error point in initial. During calibration process occur the speed of motor increase to certain value and measured the voltage from the sensor. The calibration equation was created in excel and insert it into Arduino code. Besides, the result obtained from manometer was exactly same with reading in serial monitor. Thus, MPX5100 sensor was calibrated with zero error.

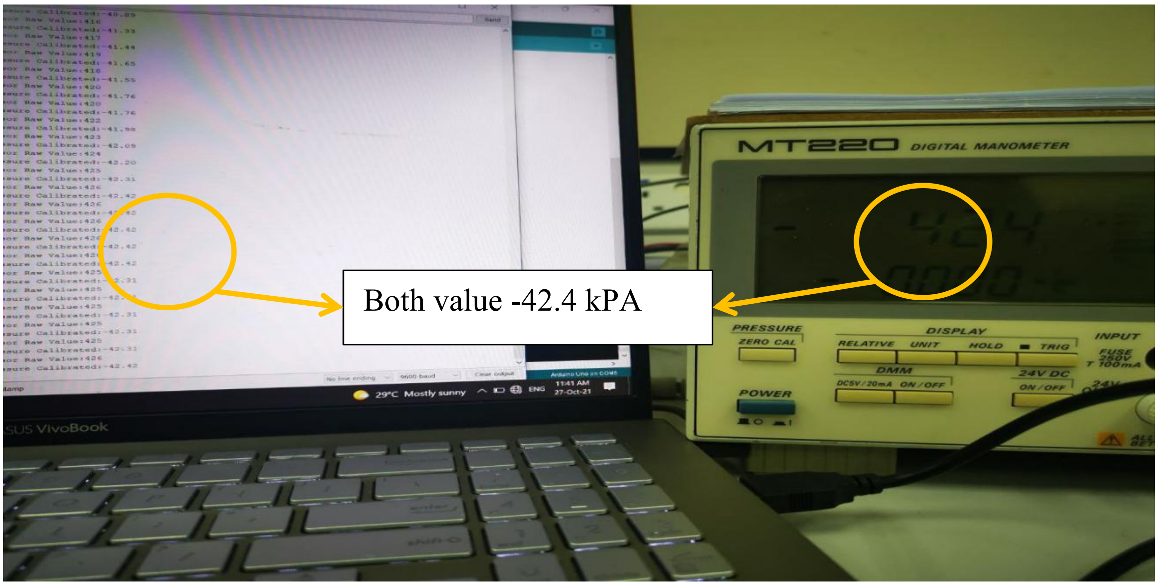

Figure 23 Calibration Validation

4.3 INPUT-OUTPUT DATA MEASUREMENT

The second element of this endeavor is the analysis of the data. The fundamental purpose of data analysis is to find the pattern of graph that occurs when negative pressure is applied to the system in question. In order to do this, cupping data analysis are divided into three components:

I. The following are the pressure measurements performed on a clean surface at three different speeds: constant, unit step, and random speed.

II. In the second stage, pressure measurements are made on a medium-hairy surface at three different speeds: constant, unit step, and random.

III. Three different speeds of constant, unit step, and random speed are used to quantify pressure on a hairy surface.

In this section, data was present for light and medium hairy only for constant speed. The medium hairy and light hairy surface react with the suction when the motor was in 180rpm speed. The figure 24 shown the comparison of both data below. The suction on clean surface was initially take time to adapt the negative pressure and after 10 second the skin tension become more elastic and reach higher negative pressure value compared to medium hairy surface. This occur based on skin tension of each location in body and the time influence of it. However, this experiment taken for first 30 second only. The relationship between time pressure is inversely proportional. The line is curved and does not pass through the origin.

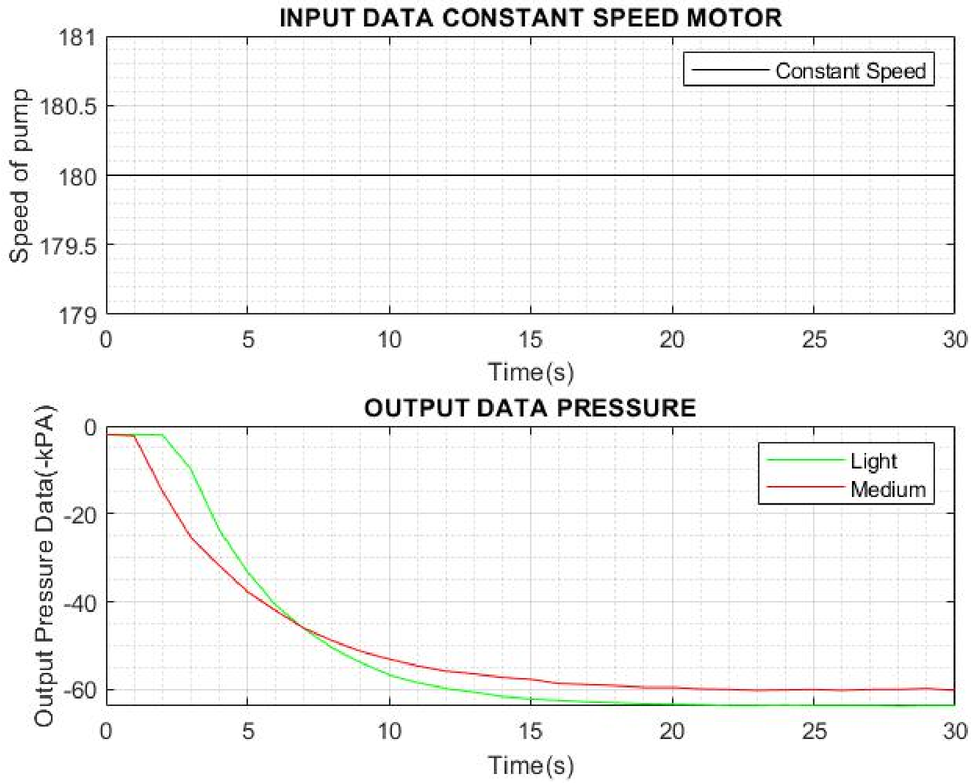

Figure 24 Data Collection of Constant Speed at Light and Medium Hairy

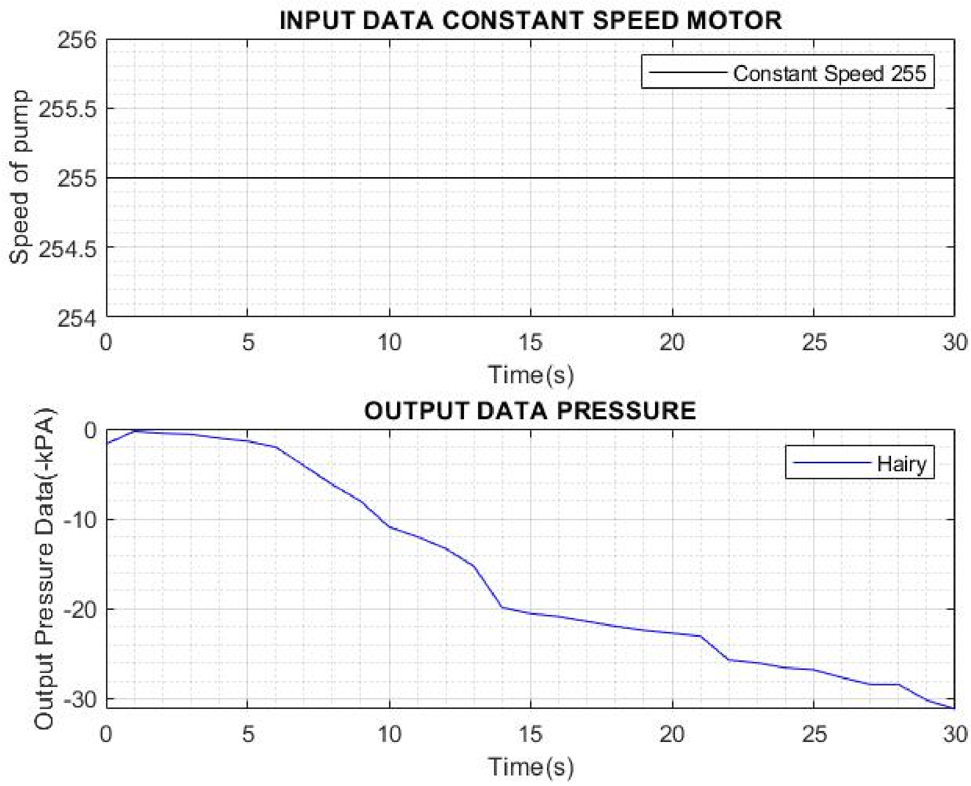

Figure 25 Data Collection of Constant Speed at Hairy Surface

Figure 25 was taken with higher speed of motor pump 255rpm compared to clean and medium surface. This is because hairy surface basically having losses when the atmospheric pressure collides with negative pressure due to the gap between the uneven surface and vacuum cup.

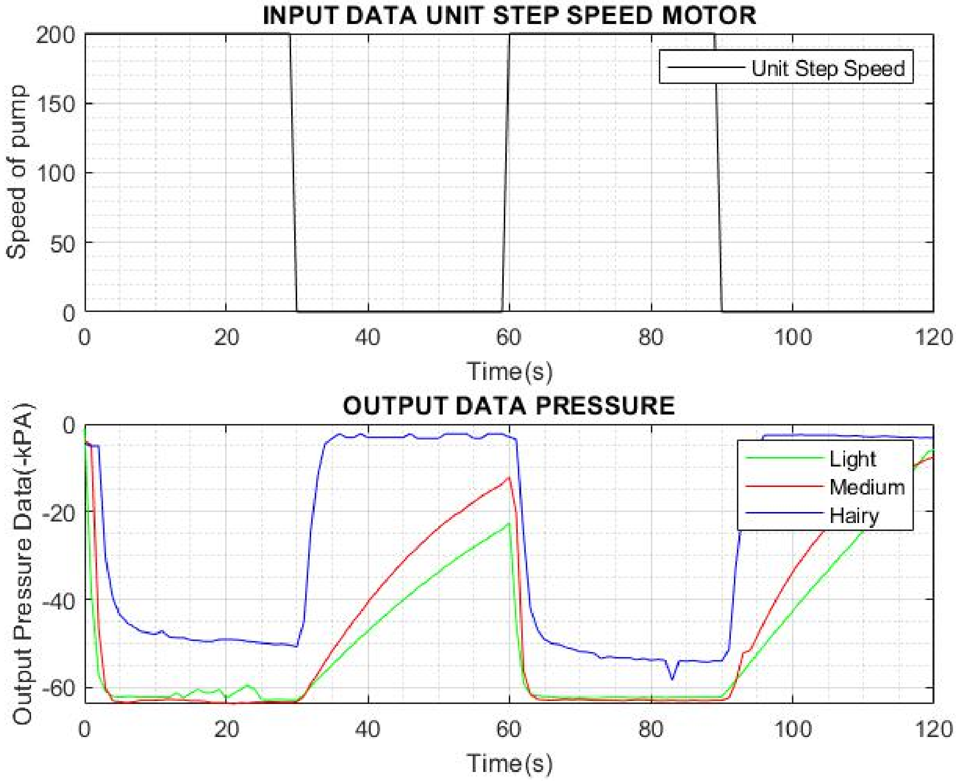

Figure 26 Data Collection of Unit Step Speed

Figure 26 presenting the result of data collection of unit step speed at applied to light, medium and hairy surface. This data collection was taken about 120 second which is equal to 2 minutes to form of two full cycles. The output of hairy data was closely to the input. When the higher-pressure suction applied the light and medium data was reach until -60kPA but the hairy only reach until not more than -60kPA. This shows that the fluctuation occurs on light and medium hairy surface than hairy. The negative pressure slowly reduces in the cup when the input 0 speed but the reading not fall dramatically for medium and light as hairy. Same concept was applied for random speed shown in figure 27 below. However, the data using for estimation is mainly for hairy surface as mentioned in objective of this project.

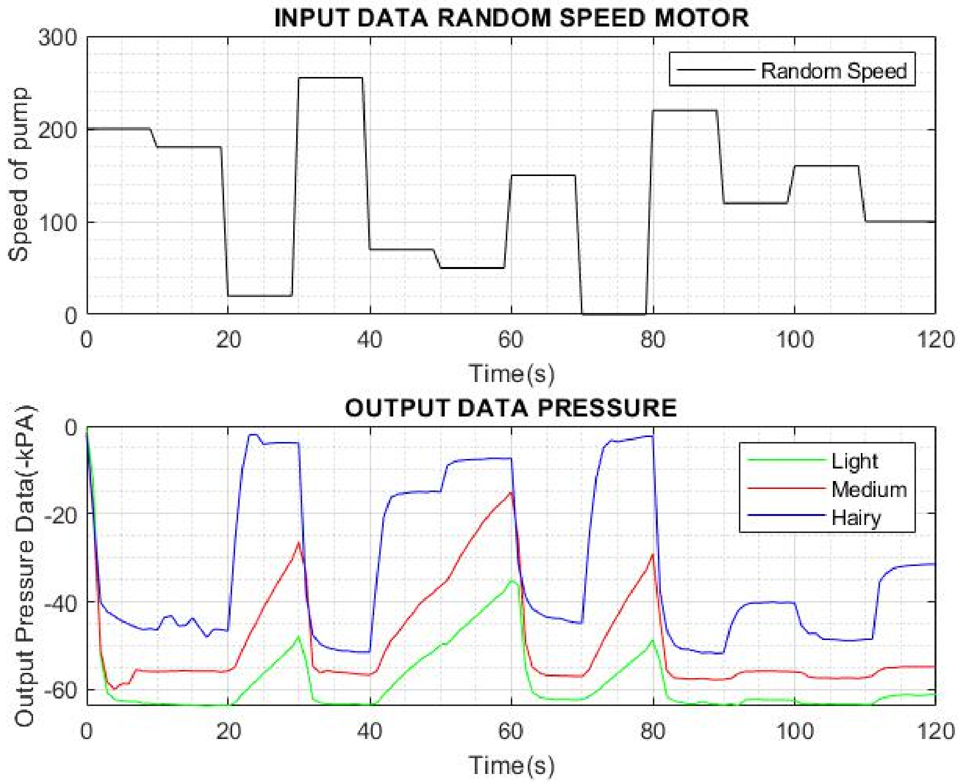

Figure 27 Data Collection of Random Speed

4.4. SYSTEM IDENTIFICATION

This section demonstrates the efficiency of a modified SCA and transfer function model based on a continuous-time technique for recognizing the cupping suction mechanism.

4.4.1 DATA-DRIVEN MODIFIED SINE COSINE ALGORITHM

This research will show and examine the convergence curve response of the goal function in Equation 1, the pole-zero mapping of a linear function, and the plot of a nonlinear function. The input response u(t) is applied to the cupping plant according on the experimental setup of this project, and the output value y(t) is recorded, as illustrated in figure 24-27.

Following that, the mSCA method is used to adjust the model parameters, with starting values of the design parameter chosen at random between upper bound up and lower bound lb. The boundary value is determined following a series of exploratory experiments. Here, we should choose count of agents Search Agents no=50, the maximum iteration =100, the variables lb.=-10, ub=3, and the values = 0.03 and = 0.9.

It demonstrates that the mSCA based technique is capable of minimizing the objective function in Equation 1 and producing a very similar output response y(t) to the actual output $\tilde{y}$(t), as shown in figure 28-32. It is worth noting that the discovered output response exhibits strong oscillation when input is delivered into the system and begins to decrease when the input is zero, which is nearly close to the response of genuine experimental output. We can state that the cupping suction system is stable in the actual experimental setting since the cupping suction output decreases progressively with t increases. We utilize the pole-zero map of the discovered transfer function, as presented in table 4, to verify our model in terms of stability.

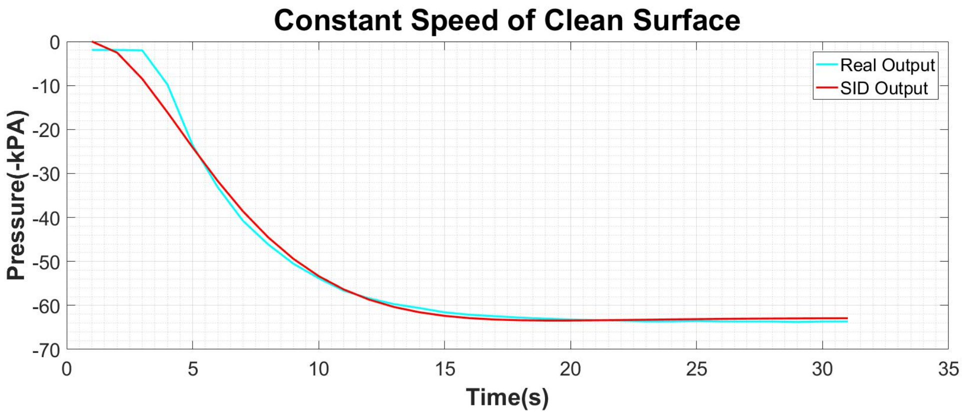

Figure 28 Estimation of clean surface with constant speed

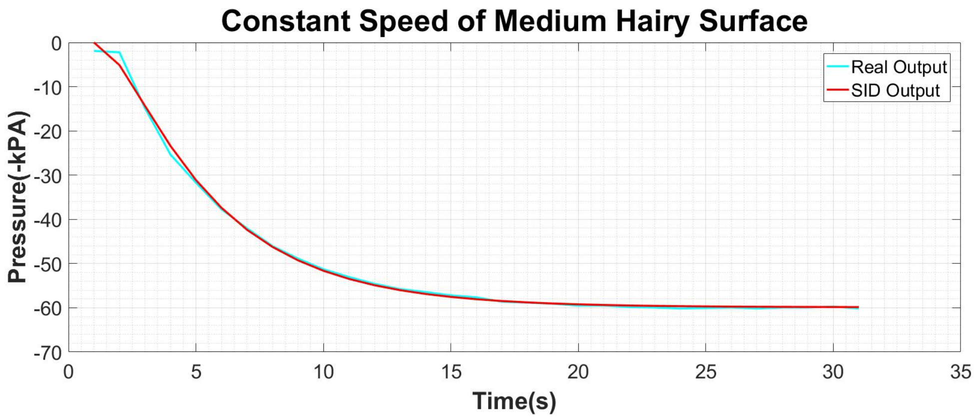

Figure 29 Estimation of medium hairy surface with constant speed

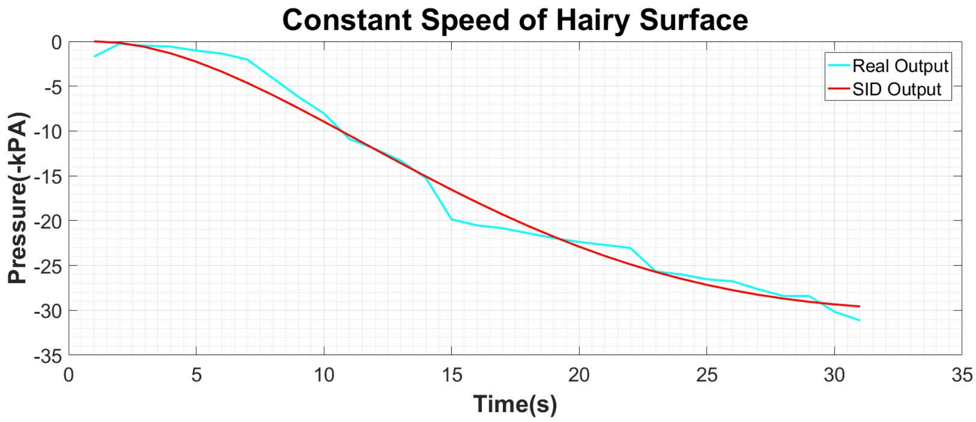

Figure 30 Estimation of hairy surface with constant speed

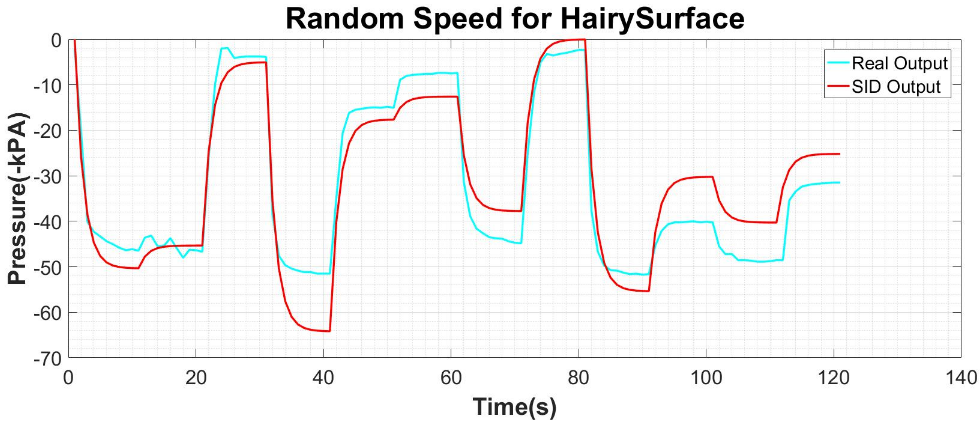

Figure 31 Estimation of hairy surface with random speed

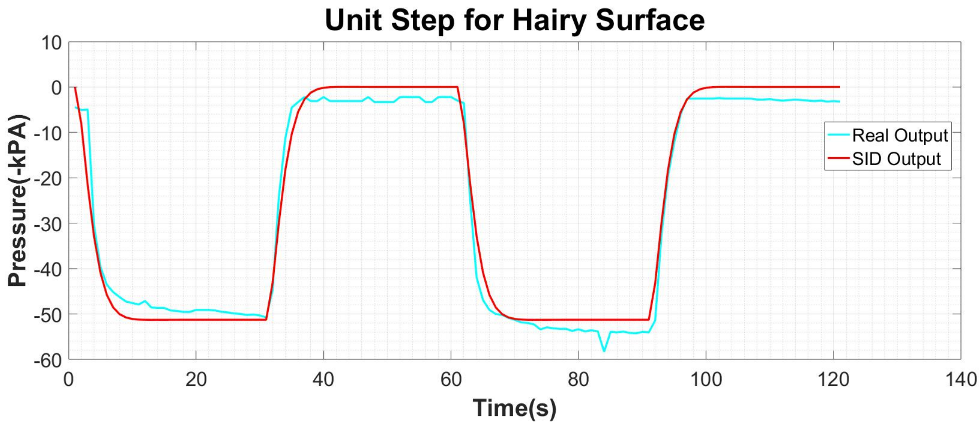

Figure 32 Estimation of hairy surface with unit-step speed

Table 5 Parameter of 2nd order for mSCA

Input (Hairy)	Iteration	Search Agent	Transfer Function	Objective function
Constant Speed	100	50	$GSI = \frac{0.7049}{-9.3566s^2 - 2.8111s - 0.7856}$	*53.3174*
Unit Step	100	50	$GSI = \frac{1.3486}{-0.1098s^2 - 1.4924s - 5.4673}$	*1.3479e3*

Random Speed	100	50	$GSI = \frac{2.3300}{-0.0026s^2 - 1.3284s - 9.6506}$	*4.7967e3*

In this particular, parameter of equation 2nd order as shown in table 4 above. It was tested using hairy input only rather than other input for our cupping system.

4.4.2 TRANSFER FUNCTION MODEL

This part considers of the various input effect in hairy and to obtain the transfer function model. The figure below shows that the estimation parameter of cupping suction system and its best fits. The figure 33 shows 95.03%, figure 34 shows 98.14%, figure 35 shows 90.75%, figure 36 shows 87.19, and figure 37 shows 64.43% respectively. We can state that the cupping suction system is stable in the actual experimental setting since the cupping suction output was nearly to the toolbox generated estimated output.

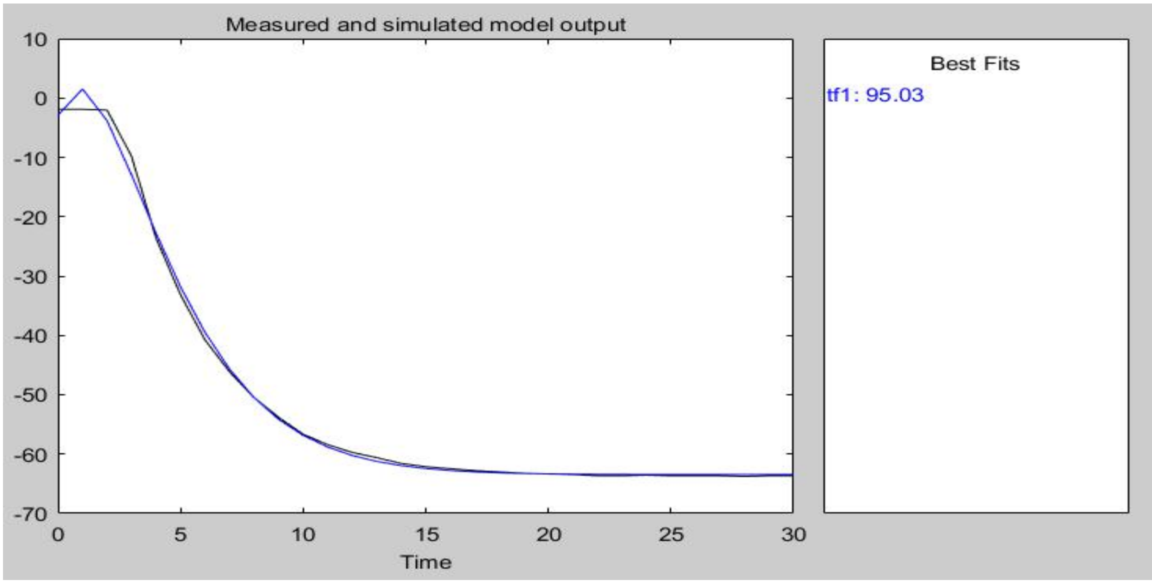

Figure 33 Transfer function model of clean surface using constant speed

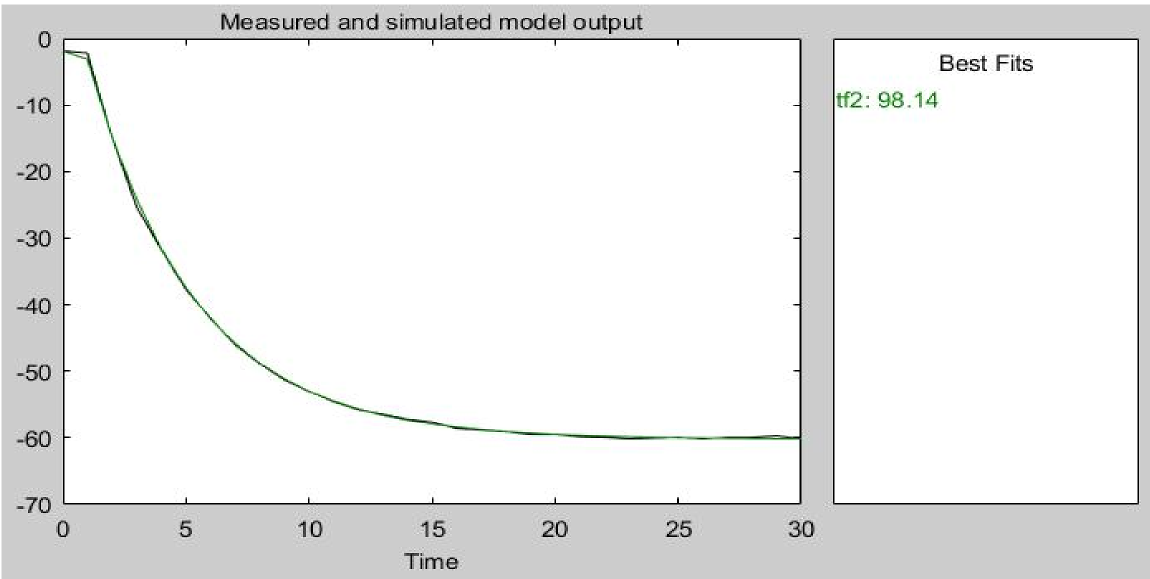

Figure 34 Transfer function model of medium hairy surface using constant speed

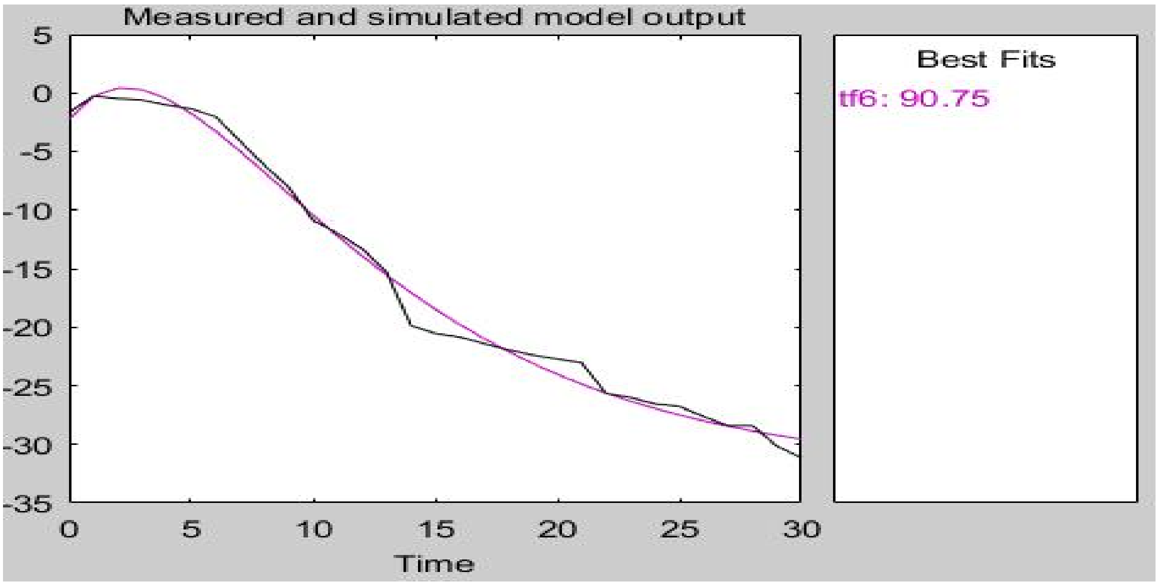

Figure 35 Transfer function model of hairy surface using constant speed

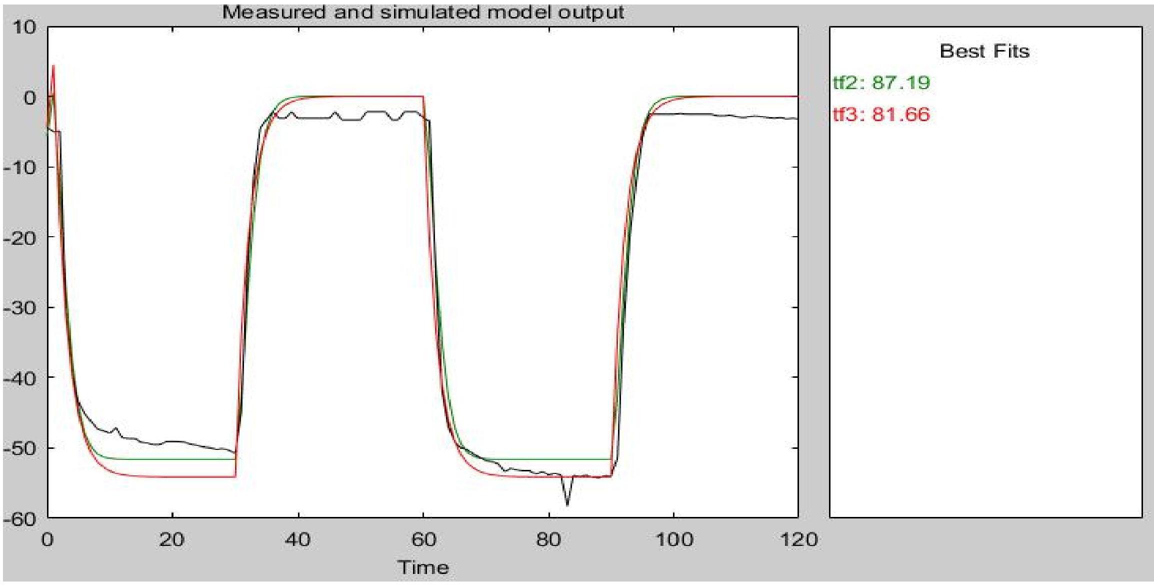

Figure 36 Transfer function model of hairy surface using unit-step speed

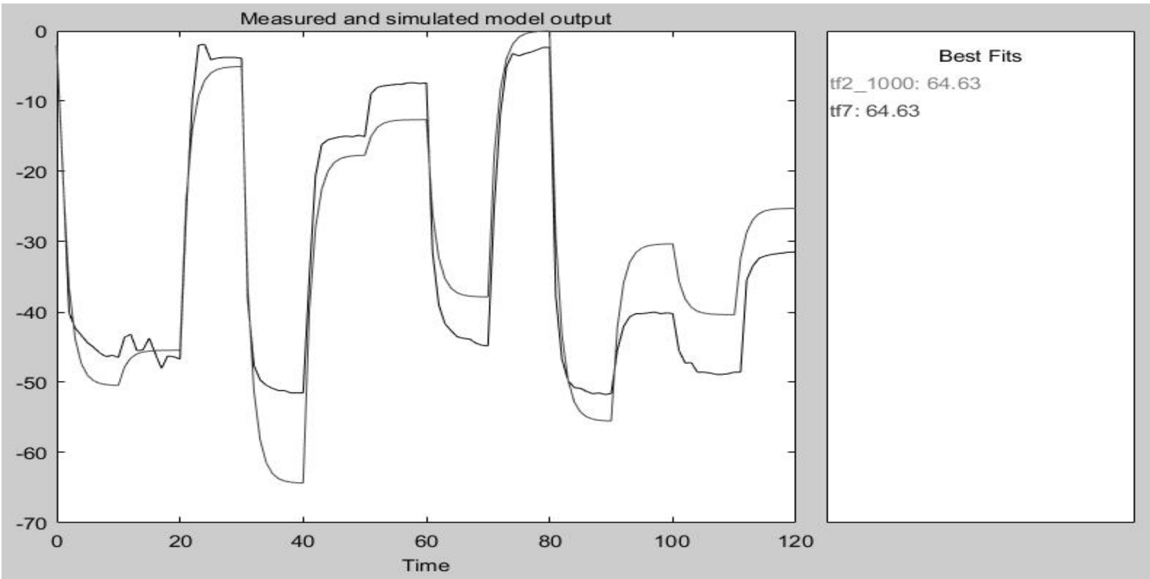

Figure 37 Transfer function model of hairy surface using random speed

This project mainly testing with hairy input which is based on objective and problem statement. Table 5 below stated the parameters of 2nd order equation of the modeling of cupping suction system.

Table 6 Parameter of 2nd order transfer function model

Input (Hairy)	Iteration	Transfer function	Best fit
Constant speed	100	$\frac{-0.0031}{s^2+0.3243s+0.02451}$	90.75%
Unit-step speed	100	$\frac{-0.1459}{s^2+1.428s+0.5655}$	87.19%
Random speed	100	$\frac{-1.77e^{05}}{s^2+9.345e^{05}s+7.028e^{056}}$	64.63%

4.5 INTEGRAL SQUARE ERROR

System identification for identifying the best model for cupping system with two different methods has been performed which is 1st using modified Sine Cosine algorithm and 2nd is transfer function model. It uses input-output data collected by running a real cupping suction system with various speed in various location. In this project, the system identification criteria have been fulfilled, and the responses of the identified models have more similar trends with that measured data. The comparison of both models has been present in table 7 below. Each method was validated by using ISE technique in MATLAB Simulink. On the other hand, the obtained best fit was proved by using transfer function model with least error when output data performance is acceptable.

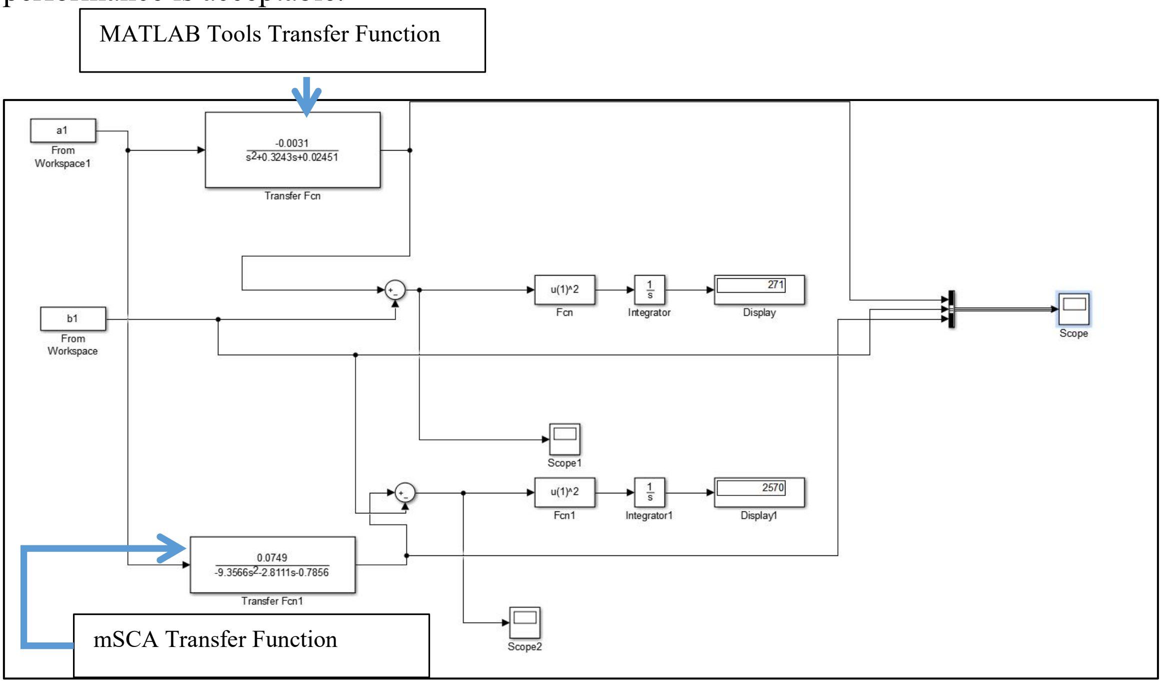

Figure 38 ISE Simulink for constant speed of hairy input

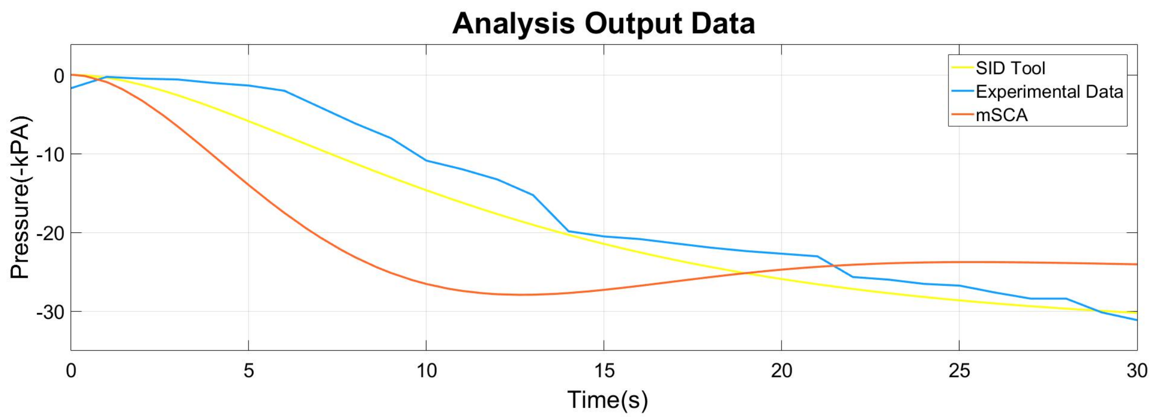

Figure 39 Output performance ISE (constant speed)

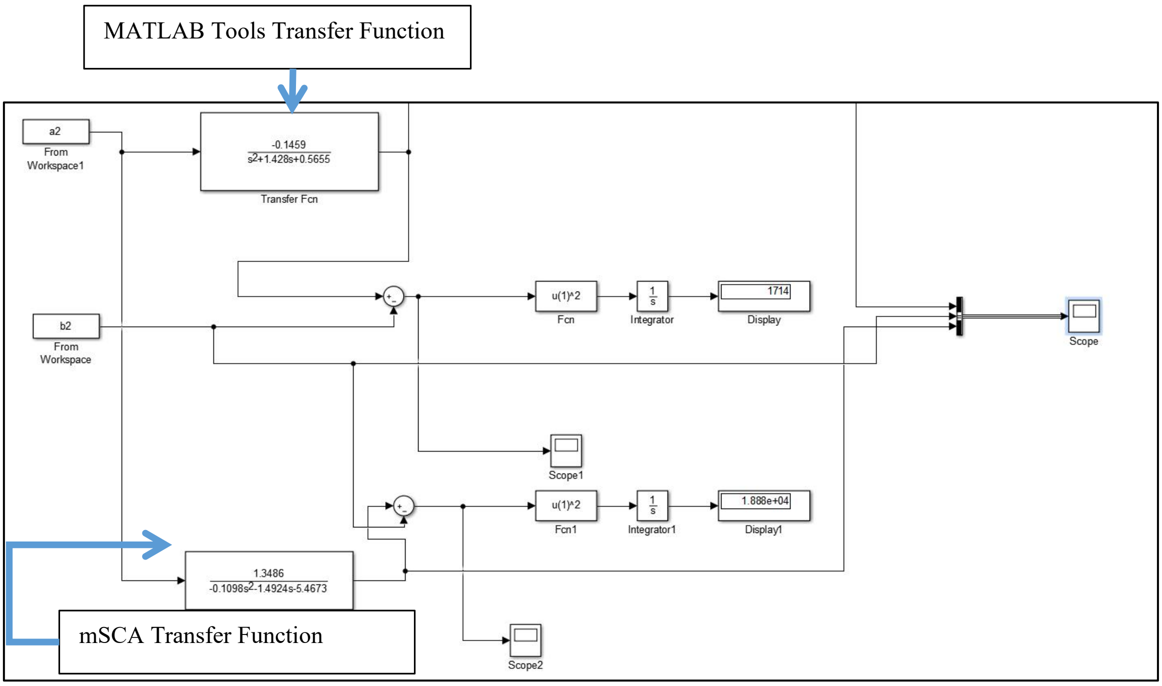

Figure 40 ISE Simulink for unit-step speed of hairy input

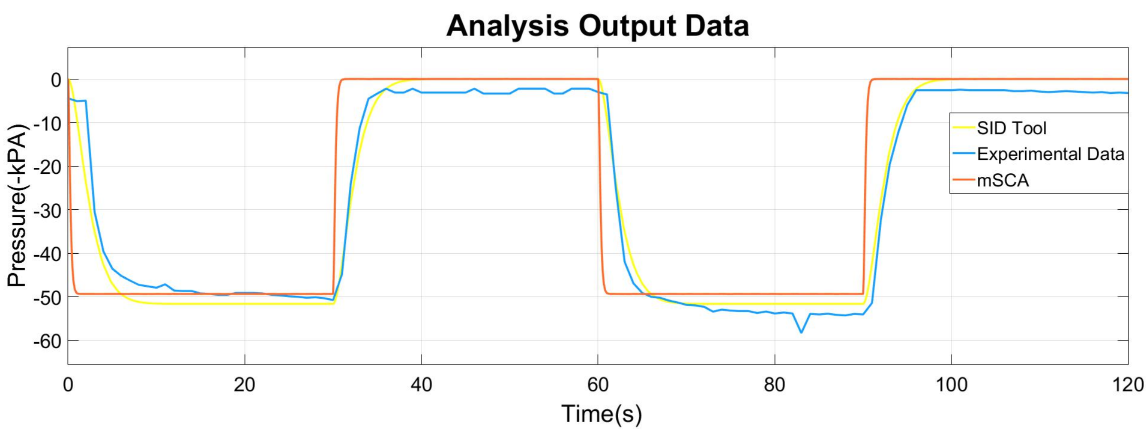

Figure 41 Output performance ISE (unit step speed)

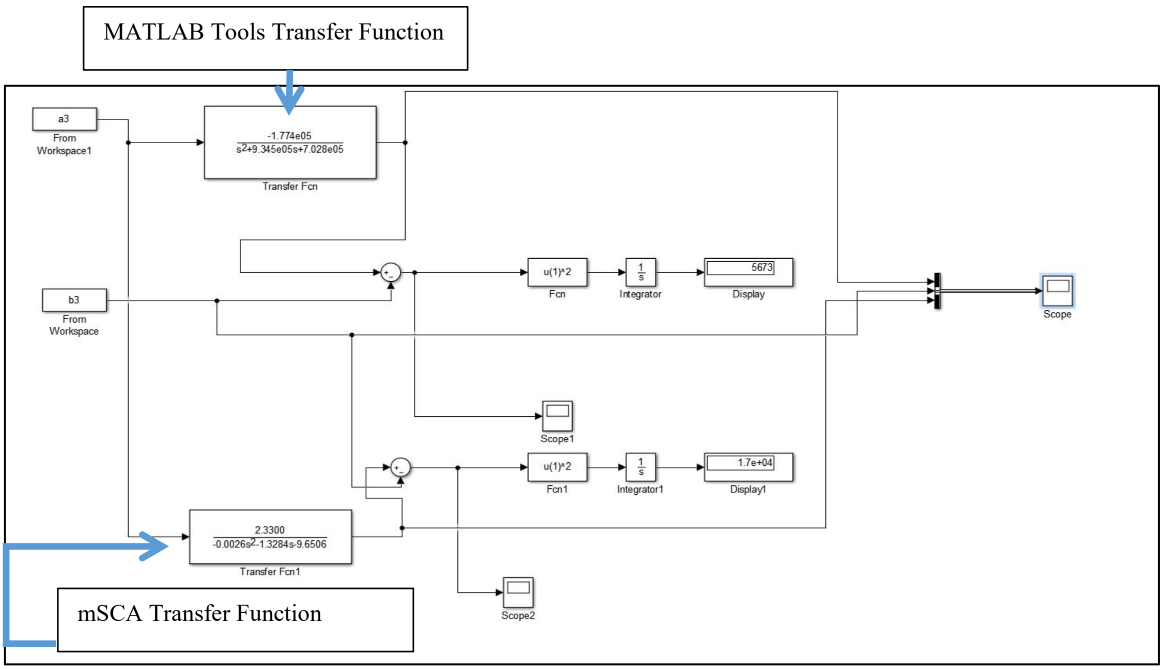

Figure 42 ISE Simulink for random speed of hairy input

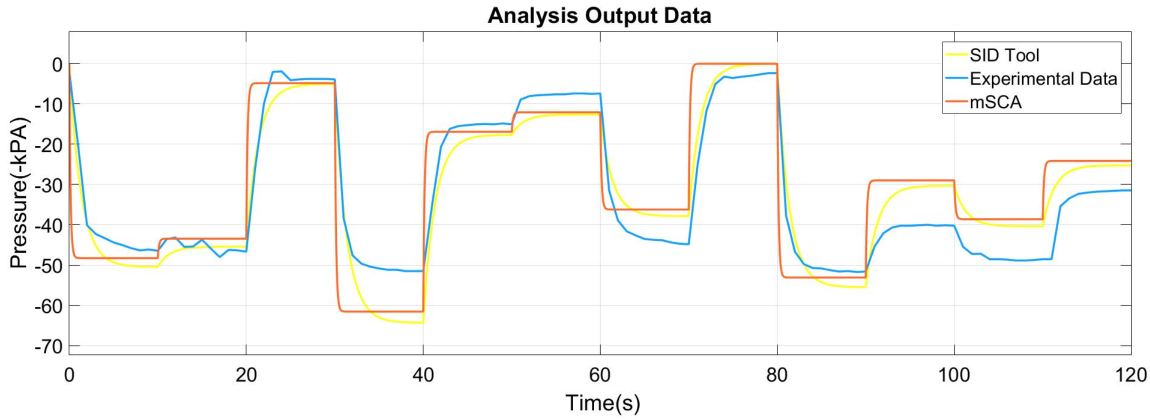

Figure 43 Output performance ISE (random speed)

Table 7 Integral Square Error of both method

Input (Hairy)	mSCA	Transfer function model
Constant speed	2570	271
Unit step speed	$1.888e^{04}$	1714
Random speed	$1.7e^{04}$	5673

CHAPTER 5

CONCLUSION AND RECOMENDATION

In this chapter, the modelling cupping suction system's conclusion is briefly presented. As a result of this project's accomplishments, some of its goals have been met. Cupping suction mechanism systems are being developed as the initial goal of this research. The cupping system has been created in accordance with the requirements that have been identified.

The second objective is to collect data on the input and output of the cupping suction system. The data was taken in real time using a calibrated sensor using the real mode. Light, medium, and hairy surfaces were used to evaluate the suction. Three different types of motor pump speeds were used to test the suction in each of the three primary locations. All of the information was collated in the optimized way for analysis.

Following that, the objective is to construct a model of cupping suction utilizing system identification to aid in the development of the model. In order to acquire the cupping suction model, the system identification approach was used to generate input variables such as motor speed in a variety of inputs and an output variable that was effective under negative pressure. It has been shown in this work that a novel modified Sine Cosine Algorithm (mSCA) may be used to represent a cupping suction system. In order to compare this system with others, the MATLAB System Identification toolkit was also included in this research.

In the last objective, we will examine the precision of the cupping suction model. The accuracy of the findings has been shown via the use of the Integral Square Error (ISE) approach. This is necessary in order to verify the accuracy of the real-time output behavior and the accuracy of the output estimate by mSCA has generated a somewhat lower result than the MATLAB SID toolbox, which has given more consistent results, in particular.

In the future, we will be able to simulate the cupping suction system and tune the PID controller, which will be beneficial. Make adjustments to the transfer function in order to get the most accurate controller for this plant.

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APPENDIX

1. DATA SHEET DP SENSOR

NXP Semiconductors
Data Sheet: Technical Data

Document Number: MPX5100
Rev. 14, 12/2018

RoHS

MPX5100, 0 to 100 kPa, Differential, Gauge, and Absolute, Integrated, Pressure Sensors

MPX5100

The MPX5100 series piezoresistive transducer is a state-of-the-art monolithic silicon pressure sensor designed for a wide range of applications, but particularly those employing a microcontroller or microprocessor with A/D inputs. This patented, single element transducer combines advanced micromachining techniques, thin-film metallization, and bipolar processing to provide an accurate, high-level, analog output signal that is proportional to the applied pressure.

Features

- 2.5% maximum error over 0 to 85 °C
- Ideally suited for microprocessor or microcontroller-based systems
- Patented silicon shear stress strain gauge
- Available in absolute, differential and gauge configuration
- Durable epoxy unibody element
- Easy-to-use chip carrier option

Typical applications

- Patient monitoring
- Process control
- Pump/motor control
- Pressure switching
- White goods

Unibody packages


MPX5100AP/GP
98ASB42796B


MPX5100DP
98ASA42797B

Small outline packages


MPXV5100DP
98ASA99255D


MPXV5100GP
98ASA99303D


MPXV5100GC6U
98ASB17757C


MPXV5100GC7U
98ASB17759C

Ordering Information

Device name	Shipping	Package	# of Ports			Pressure type			Device marking
			None	Single	Dual	Gauge	Differential	Absolute	
Unibody Package (MPX5100 Series)									
MPX5100AP	Tray	98ASB42796B		•				•	MPX5100AP
MPX5100DP	Tray	98ASB42797B			•		•		MPX5100DP
MPX5100GP	Tray	98ASB42796B		•		•			MPX5100GP
Small Outline Package (MPXV5100 Series)									
MPXV5100DP	Tray	98ASA99255D			•		•		MPXV5100DP
MPXV5100GC6U	Rail	98ASB17757C		•		•			MPXV5100G
MPXV5100GC7U	Rail	98ASB17759C		•		•			MPXV5100G
MPXV5100GP	Tray	98ASA99303D		•		•			MPXV5100GP

NXP reserves the right to change the detail specifications as may be required to permit improvements in the design of its products.

NXP

1 General Description

1.1 MPX5100AP/DP/GP Block diagram

Figure 1 shows a block diagram of the internal circuitry integrated on a pressure sensor chip in a unibody package.

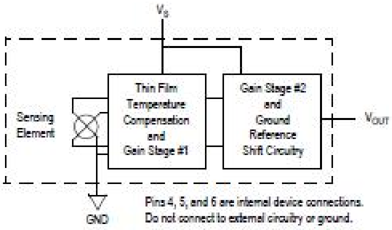


Figure 1. Integrated pressure sensor block diagram

1.2 MPX5100AP/DP/GP Pinout (Unibody)

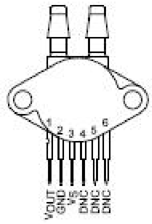


Figure 2. Device pinout (top view)

Table 1. Pin functions

Pin	Name	Function
1	V_{OUT}	Output voltage
2	GND	Ground
3	V_S	Voltage supply
4	DNC	Do not connect to external circuitry or ground.
5	DNC	Do not connect to external circuitry or ground.
6	DNC	Do not connect to external circuitry or ground.

2 Mechanical and Electrical Specifications

2.1 Maximum ratings

Table 3. Maximum ratings[1]

Rating	Symbol	Value	Unit
Maximum pressure	P_{max}	400	kPa
Storage temperature	T_{stg}	-40 to +125	°C
Operating temperature	T_A	-40 to +125	°C

1. Exposure beyond the specified limits may cause permanent damage or degradation to the device.

2.2 Operating characteristics

Table 4. Operating characteristics (V_S = 5 Vdc, T_A = 25 °C.)

Characteristic	Symbol	Min	Typ	Max	Unit
Pressure range[1] Gauge, differential: MPX5100G/MPXV5100G Absolute: MPX5100AP	P_{OP}	 0 15	 — —	 100 115	kPa
Supply voltage[2]	V_S	4.75	5.0	5.25	V_{DC}
Supply current	I_O	—	7.0	10	mAdc
Minimum pressure offset[3], (0 to 85 °C) @ V_S = 5.0 V	V_{OFF}	0.088	0.20	0.313	V_{DC}
Full-scale output[4], differential and absolute (0 to 85 °C) @ V_S = 5.0 V	V_{FSO}	4.587	4.700	4.813	V_{DC}
Full-scale Span[5], differential and absolute (0 to 85 °C) @ V_S = 5.0 V	V_{FSS}	—	4.500	—	V_{DC}
Accuracy[6]	—	—	—	±2.5	$\%V_{FSS}$
Sensitivity	V/P	—	45	—	mV/kPa
Response time[7]	t_R	—	1.0	—	ms
Output source current at full-scale output	I_{O+}	—	0.1	—	mAdc
Warm-up time[8]	—	—	20	—	ms
Offset stability[9]	—	—	±0.5	—	$\%V_{FSS}$

1. 1.0 kPa (kiloPascal) equals 0.145 psi.
2. Device is ratiometric within this specified excitation range.
3. Offset (V_{OFF}) is defined as the output voltage at the minimum rated pressure.
4. Full-scale output (V_{FSO}) is defined as the output voltage at the maximum or full-rated pressure.
5. Full-scale span (V_{FSS}) is defined as the algebraic difference between the output voltage at full-rated pressure and the output voltage at the minimum rated pressure.
6. Accuracy (error budget) consists of the following:
   - Linearity: Output deviation from a straight line relationship with pressure over the specified pressure range.
   - Temperature hysteresis: Output deviation at any temperature within the operating temperature range, after the temperature is cycled to and from the minimum or maximum operating temperature points, with zero differential pressure applied.
   - Pressure hysteresis: Output deviation at any pressure within the specified range, when this pressure is cycled to and from minimum or maximum rated pressure at 25 °C.
   - TcSpan: Output deviation over the temperature range of 0 to 85 °C, relative to 25 °C.
   - TcOffset: Output deviation with minimum pressure applied over the temperature range of 0 to 85 °C, relative to 25 °C.
   - Variation from nominal: The variation from nominal values, for offset or full-scale span, as a percent of V_{FSS} at 25 °C.
7. Response time is defined as the time for the incremental changed in the output to go from 10% to 90% of its final value when subjected to a specified step change in pressure.
8. Warm-up time is defined as the time required for the product to meet the specified output voltage after the pressure has been stabilized.
9. Offset stability is the product's output deviation when subjected to 1000 hours of pulsed pressure, temperature cycling with bias test.

3 On-chip Temperature Compensation and Calibration

Figure 5 shows the sensor output signal relative to pressure input. Typical, minimum, and maximum output curves are shown for operation over a temperature range of 0 to 85 °C using the decoupling circuit shown in Figure 7. The output will saturate outside of the specified pressure range.

Figure 6 illustrates both the Differential/Gauge and the Absolute Sensing Chip in the basic chip carrier. A fluorosilicone gel isolates the die surface and wire bonds from the environment, while allowing the pressure signal to be transmitted to the sensor diaphragm.

The MPX5100 series pressure sensor operating characteristics, and internal reliability and qualification tests are based on use of dry air as the pressure media. Media, other than dry air, may have adverse effects on sensor performance and long-term reliability. Contact the factory for information regarding media compatibility in your application.

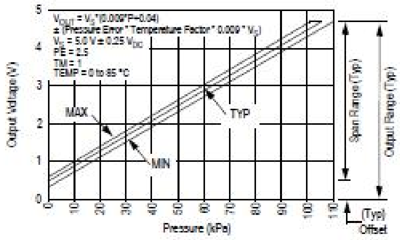


Figure 5. Output versus pressure differential

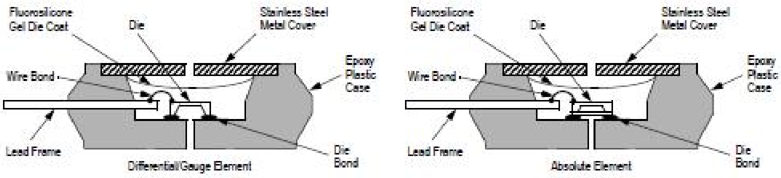


Figure 6. Cross-sectional diagrams (not-to-scale)

Figure 7 shows the recommended decoupling circuit for interfacing the output of the integrated sensor to the A/D input of a microprocessor or microcontroller. Proper decoupling of the power supply is recommended.

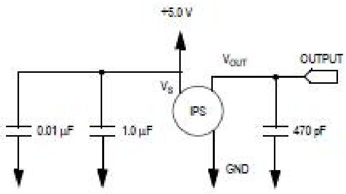
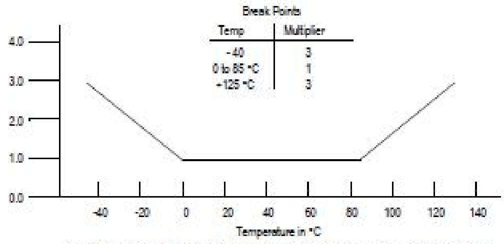


Figure 7. Recommended power supply decoupling and output filtering
(For additional output filtering, please refer to application note AN1646.)

The following figures show the nominal transfer function, temperature and pressure error over the operating range for the MPX5100D,MPX5100G and MPXV5100G devices.

Nominal Transfer Value: $V_{OUT} = V_S$ (P x 0.009 + 0.04)
± (Pressure Error x Temp. Mult. x 0.009 x V_S)
V_S = 5.0 V ± 0.25 V

Figure 8. Transfer function (MPX5100D, MPX5100G, MPXV5100G)



Note: The Temperature Multiplier is a linear response from 0 to -40 °C and from 85 to 125 °C.

Figure 9. Temperature error multiplier (MPX5100D, MPX5100G, MPXV5100G)

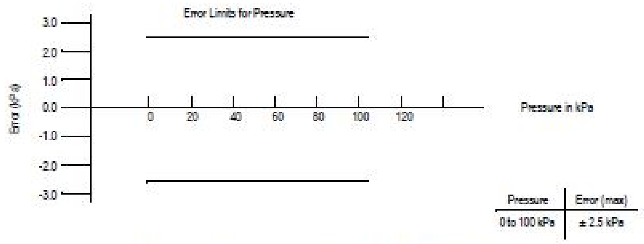


Figure 10. Pressure error band (MPX5100D, MPX5100G, MPXV5100G)

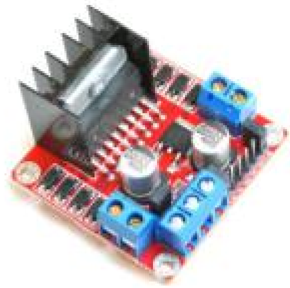
2. DATA SHEET MOTOR DRIVER

Handson Technology

User Guide

L298N Dual H-Bridge Motor Driver

This dual bidirectional motor driver, is based on the very popular L298 Dual H-Bridge Motor Driver Integrated Circuit. The circuit will allow you to easily and independently control two motors of up to 2A each in both directions.It is ideal for robotic applications and well suited for connection to a microcontroller requiring just a couple of control lines per motor. It can also be interfaced with simple manual switches, TTL logic gates, relays, etc. This board equipped with power LED indicators, on-board +5V regulator and protection diodes.

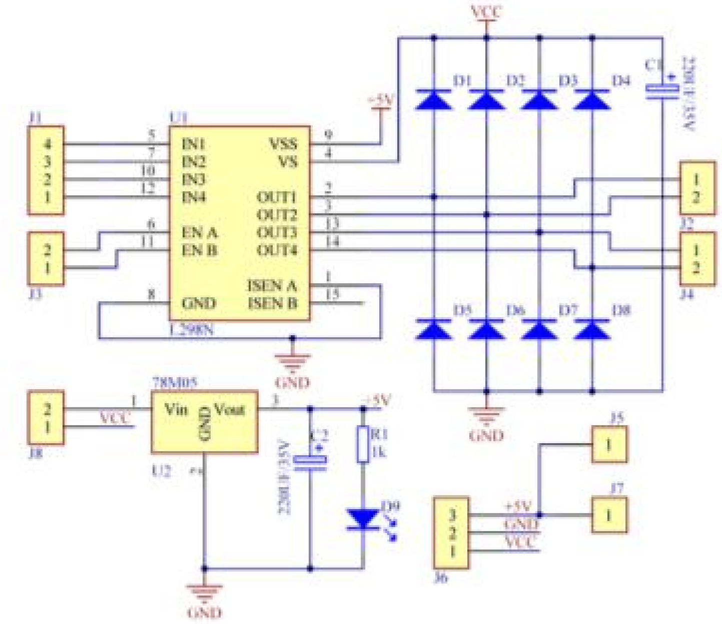


SKU: MDU-1049

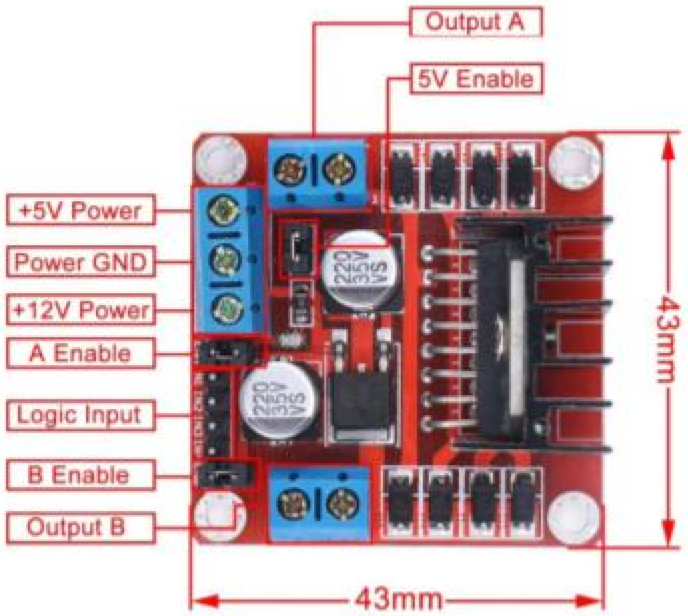
Brief Data:

- Input Voltage: 3.2V~40Vdc.
- Driver: L298N Dual H Bridge DC Motor Driver
- Power Supply: DC 5 V - 35 V
- Peak current: 2 Amp
- Operating current range: 0 ~ 36mA
- Control signal input voltage range :
- Low: -0.3V ≤ Vin ≤ 1.5V.
- High: 2.3V ≤ Vin ≤ Vss.
- Enable signal input voltage range :
  - Low: -0.3 ≤ Vin ≤ 1.5V (control signal is invalid).
  - High: 2.3V ≤ Vin ≤ Vss (control signal active).
- Maximum power consumption: 20W (when the temperature T = 75 ℃).
- Storage temperature: -25 ℃ ~ +130 ℃.
- On-board +5V regulated Output supply (supply to controller board i.e. Arduino).
- Size: 3.4cm x 4.3cm x 2.7cm

Schematic Diagram:



Board Dimension & Pins Function:



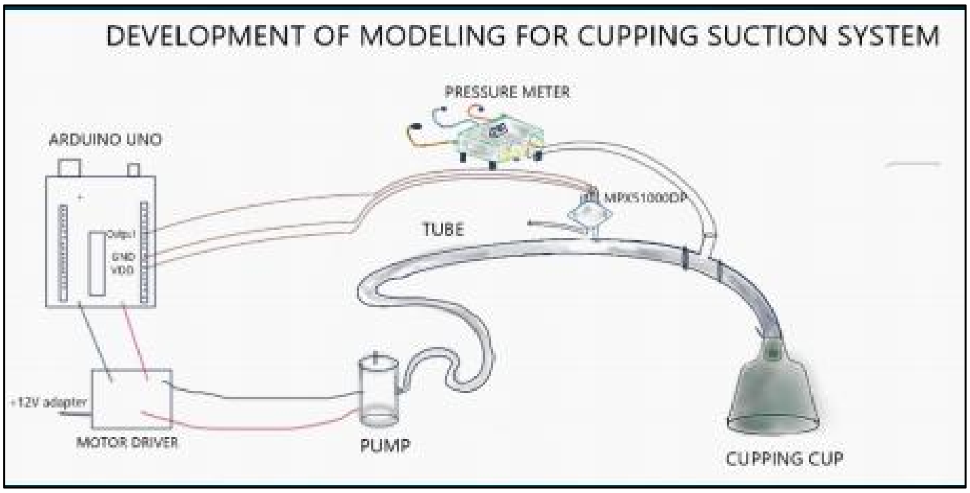
3. CALIBRATION CODE

```
//23nov.2021 latest square

int sensor=A0;
int valueSensor;
int value;
int pressure;                                   //Motor A
const int inputPin1  = 8;    // Pin 15 of L293D IC
const int inputPin2  = 7;    // Pin 10 of L293D IC
                              //Motor B

int EN1 = 9;                 // Pin 1 of L293D IC

void setup()

{

    pinMode(EN1, OUTPUT);   // where the motor is connected to
 pinMode(sensor,INPUT);
    pinMode(inputPin1, OUTPUT);
    pinMode(inputPin2, OUTPUT);

    Serial.begin(9600);
    Serial.println("Enter values between 0 - 255");
}

void loop()

{
  if(Serial.available())
    {
      int speed = Serial.parseInt();  //Receive Value from serial
monitor
      Serial.println(speed);
        analogWrite(EN1, speed);      //sets the motors speed

        digitalWrite(inputPin1, HIGH);
        digitalWrite(inputPin2, LOW);
```

```
  }{
       valueSensor=analogRead(sensor);
value= valueSensor;
Serial.print("Sensor Raw Value:");
Serial.print(valueSensor);
Serial.print("\n");
Serial.print("Pressure Calibrated:");
float pressure;
pressure=-0.1095*value+4.2257;
Serial.print(pressure);
Serial.print("\n");
delay(1);

   }
```

4. CUPPING DESIGN PREVIEW

Project Sketch Overall with manometer



Preparing testing pressure sensor and controlling motor pump speed.