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Implementation analysis of vacuum area gripping system in pick and place machinery in wooden door company

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Abstract: Companies must grow in order to boost efficiency and production quality due to competition in the wood industry, particularly in the production of increasingly hard wooden doors. The issue that businesses face frequently is the occurrence of product flaws during the manufacture of wooden doors. A method for lifting, positioning, and moving door goods has been created by PT XYZ, one of the export-quality wooden door firms. By reducing product flaws, this study hopes to raise the quality of wooden doors. The pick and place machine's grasping system is the primary cause of the high prevalence of impairment. There are specific flaws in the door-gripping mechanism that increase the likelihood of product failures from falling and workplace accidents. After reworking the vacuum area gripping system, which uses suction technology, one of the Schmalz brands manufactured in Germany is outfitted with an external suction motor as a source of suction energy. The tool can lift loads up to 50 kg in accordance with specifications at a consistent speed, according to development results.

Keywords: Wooden door; pick and place; gripper; vacuum area gripping system; motor suction

1. INTRODUCTION

In PT XYZ, which is still in development, automated work systems are needed only in limited circumstances. Customers want businesses not to produce and deliver returned or damaged goods, which leaves them dissatisfied and might undermine their trust in the company [1][2]. It is usual for production movements to result in door flaws during the manufacturing process. There are three different kinds of defects: cracked, dented, and peeling skin defects. To get around this, the business must invest in development to boost output quantity and quality. Recall that competition arises because there is competition within each organization [3][4]. While the degree or level of excellence inside a firm is the quality of a product. Here, quality serves as a comparative indicator of goodness [5]. This study was carried out at the Vacuum Area Gripping System, a gripping vacuum that was required for the design of this machine at the export-quality wooden door manufacturer PT XYZ.

The Vacuum Area Gripping System is a tool that holds the load of the workpiece as the workpiece is moved from one position to another using a clamp vacuum as a suction mechanism. With dimensions of 1234 mm x 130 mm x 70 mm and a ball valve, this vacuum has a capability that other types of suction vacuums with a capacity of 800 L/min do not.

The challenge, according to this research, is how to build a tool that can stack, lift, and transport door products individually in a pack of 28 doors without causing damage to the doors. The quality of the door goods that are transferred without any friction or physical faults that occur during the transfer process, the desired speed when ideal conditions are at least 20 packs, or 560 doors, are the main criteria for the effectiveness of the vacuum area gripping system in this study.

2. METHOD

2.1 Field data collection

The actual weight of the wooden door was measured in the field and used as the dependent variable. Observations were taken in the area devoted to the grasping procedure once the door weight data had been gathered. In the real world, a gripper system utilizing pneumatic parallel was discovered. The gripper's operating mechanism, which uses the driving arm, gripper drive shaft, and pneumatic system as sources of movement to hold a production item, is known as the gripper [6]. Then gather information on the door manufacturing process, particularly regarding items that are moved utilizing the Pneumatic Parallel Gripper system. Additionally, gather information about damage (dented and defecsts) that happened at PT XYZ [7].

2.2 Creating a design concept (Conceptual Design)

Using the information gathered from the prior method, this method was used to develop a design idea for suction-based door raising. The Vacuum Area Gripping System design for this pick and place tool is created using solidwork software to facilitate tool manufacturing. shown in Figure 1.

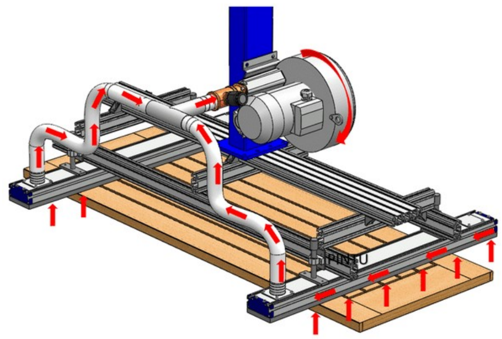

Figure 1. The design concept of the vacuum area gripping system

A suction device that is directly connected to the suction valve and suction motor, Figure 1 is a component of the Vacuum Area Gripping System. A flexible 2.5-inch hose is used as the connecting component, and an air cylinder with a 15mm stroke is used to move the suction valve mechanically.

This activity process's goal is to transport a workpiece from one location to another or to a specific location. If a production process activity involves manual material handling too frequently, this could negatively affect the productivity of the workers or lengthen the production process by causing fatigue, injury, and accidents [8].

The science dealing with the handling, transfer, packaging, storage, and control of goods is known as material handling, according to the American Material Handling Association. While the organization often concentrates on vertical strength or lifting and lowering actions in manual handling operations. Among them, some of the MMH activities that employees perform the most frequently include:

a. Lifting process (Lifting Task).
b. Moving process (Carrying task)
c. Process push (Pushing task)
d. Pull process (Pulling task)

The pick and place machine is a gantry-style device that may be operated with a single button and automatically loads and unloads with the use of two or three axes of movement. The gantry type loading and unloading device is simple to use, which reduces labor costs and boosts productivity. The gantry handle lowers to the door, suctions and moves the wooden door to the desired location, and finally the handle lowers to the lowest point and places the door. The wooden door is transported to the roller table beneath the gantry type loading and unloading machine [9][10]. The manufacturers' specifications for pick-and-place machines can be used to calculate the necessary requirements, and estimates concerning the need for vacuum devices and suction motors can be used to gather data.

2.3 Equation

In order to construct this system, the formula is utilized to determine the necessary suction force against the vacuum to lift the wooden door.

$$\text{Vertical Suction Force } (F_s) = (m/\mu)\ x\ (g + a)\ x\ S \quad (1)$$

In equation (1), m is the workpiece's mass, is the wood's 0.4 coefficient of friction, g is gravity's acceleration, an is the workpiece's acceleration, and S is a safety factor with a minimum value of 1.5.

2.4 Calculation of the need for a vacuum device

The Latin term vacuum, which means empty, is where the word "vacuum" originates. However, in reality, this ideal vacuum cosmos contains neither empty space nor nothing at all. Therefore, a vacuum is a state of space where some air and other gasses have been ejected, resulting in a pressure lower than that of the atmosphere [11].

Vacuum Gripper is a mechanical controller that uses a vacuum to grab things that are moving in the work area. It is flexible and multifunctional in design. A vacuum gripper is a clamping tool with a suction pad. Frequently employed in the creation of wall-climbing robots that can adhere to smooth surfaces without endangering items' surfaces [12][13].

The vacuum device used in this vacuum area gripping system is a vacuum gripping device of the Schmalz brand with serial number FMP-SVK 1234 3R18 O10O10 F G60. is a vacuum-based clamping device that gets its suction power from a suction motor through a ball valve. as in **Figure 2**.

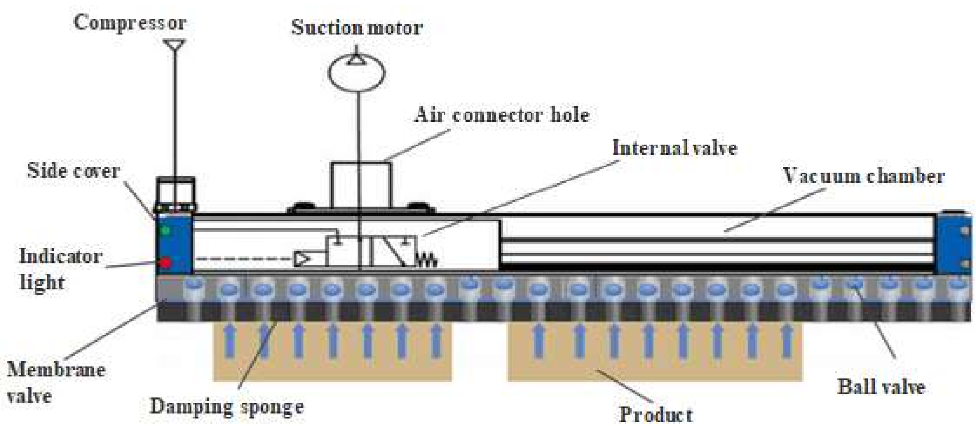

Figure 2. The working principle of the Vacuum area gripping system (VAGS)

Figure 2 demonstrates that the vacuum chamber's air pressure is 0.2 bar, meaning that the ball valve is in the above position. The ball shuts the valve opening, blocking the vacuum surface's suction force. One of the vacuum side covers has an internal valve that works to turn on the indication light when air pressure from the compressor is between 5.5 and 6.5 bar. The compressed air is directed through a 2.5-inch-diameter line from the suction pump into the air connector hole. In order to lessen the impact between the vacuum body and the object being sucked, the vacuum chamber is also fitted with a dampening sponge. A membrane valve that filters suction air from the outside so that debris does not enter the vacuum chamber is built into the top layer of the sponge. Considering that this kind of vacuum may lift medium things made of wood with uneven surfaces. Before choosing what kind of component to create, the author first consults with this kind of vacuum seller. Then, the author sketches out the shape of the tool that will be created. Finally, calculations are done to examine the components that will be utilized as needed.

2.5 Calculation of the suction motor power requirements

A suction motor is a device that raises the air pressure and suction that are passed into a certain space. Typically, a suction motor is utilized to circulate specific gasses across a space [14][15].

Calculating the vertical load that the vacuum receives from the thing being sucked allows one to determine the suction power of the vacuum motor. The load can be calculated using formula (1) as a starting point. The amount of loading and the amount of time the vacuum motor is utilized have an impact on its power. To sustain the weight of the workpiece, a suction motor with a greater capacity is required as the workpiece gets heavier. The type of goods to be lifted can be utilized to select the vacuum area grasping system to be used. to make it simple to identify the types and requirements required to support the pick and place machine. This is evident from the suction motor vendors' specs, which are displayed in **Table 1**.

Table 1. Specifications for suction motors

Suction Motor Specifications	
Brand	JINMU (Shang hai)
Power	2.3 KW

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Suction Motor Specifications	
Max pressure	35 Kpa
Max Output	270 m3/h
Freq	50 Hz
Volt	380V/220V
Current	5 Ampere
Speed	2800 r/min
Insulation Megohmmeter	E

Adjusting several key parts, such as pick and place devices, suction motors, and vacuum area grasping systems in **Figure 3**, allows for reflection on the five methods of data collecting, drafting, calculations, and references.

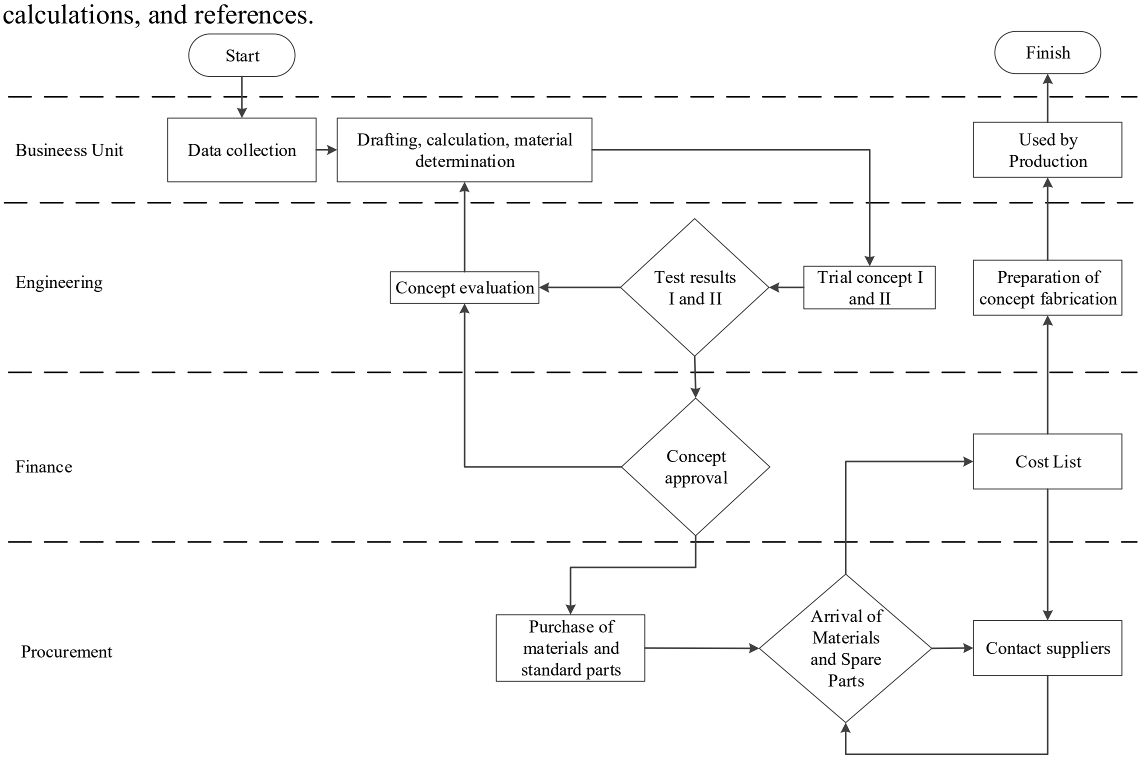


Figure 3. Research flowchart

Table 3 Step-by-step procedures are used to conduct the research. Beginning with gathering data from the field to serve as a foundation for conceptions, calculations, and material selection. At this point, two iterations of the design are done, the first of which makes use of a pneumatic parallel gripper mechanism. Discussions and assessments were conducted after the initial concept was finished, and the second design stage proceeded based on the evaluation of the first design made with the help of the Vacuum Area Gripping System. The following step is idea approval and consensus, after which material purchases are made based on the created lists and concepts, and material arrival inspections are completed. The fabrication process, or tool building, is the next step once all the materials have been delivered. Installation and handover are carried out in the manufacturing area when the second design is finished.

3. RESULTS AND DISCUSSION

All the door weight variations tested, if a resume is made, the final results are in **Table 2**.

Table 2. Variable weight of wooden doors

No	Nama pintu	Dimension(mm) P	L	T	Door Weight (kg/Pcs)
1	Primed Dordogne	1981	610	35	28

2	Primed Dordogne	1981	762	35	34
3	Primed Dordogne	1981	838	35	37
4	Primed Moda Au Panel	2040	520	35	19,09
5	Primed Moda Au Panel	2040	720	35	26,44
6	Primed Moda Au Panel	2040	770	35	28,27
7	Primed Moda Au Panel	2040	820	35	30
8	Primed Moda Au Panel	2040	820	35	30
9	Primed Moda Au Panel	2340	820	35	34,54
10	Primed Moda Au Panel	2340	720	35	30,33
11	Primed 1P Shaker Panel	2040	726	40	26,5
12	Primed 1P Shaker Panel	2040	826	40	28,9
13	Primed Pattern 10	2040	726	40	23,8
14	Primed Pattern 10	2040	826	40	26,2
15	Primed 1P Shaker Panel	2040	726	40	26,5

There are 15 different types of doors, as shown in **Table 2**, based on differing weights and sizes. With an average input of 2 kg, the door's weight starts at 19.09 kg. The Primed Moda Au Panel door, which weighs 19 kg, has the lightest door weight while the Primed Dordogne door, with dimensions of 1981x610x35, has the smallest door size. This test is carried out manually on each type of door in order to obtain accurate findings.

Causes of failure in the Pick and Place Fortran FQ-LMJT2 machine as well as an elevated RPN (Risk Priority Number) value of product problems. The observations and conversations with relevant parties, such as the maintenance, engineering, and production parties, yield the numerical weight employed in FMEA. The data from the FMEA study was used to calculate RPN values from the highest to the lowest value, with the result that the engine system had a larger RPN value than the other systems. Development is carried out with the purpose of minimizing the issue of door quality on the Fortran FQ-LMJT2 machine from occurring again based on the findings of the RPN & the results of the FMEA analysis, then from the results of the largest RPN value.

Table 3. Proposed improvements

Potential causes of failure	Factors causing failure	Proposed Improvements
Increased product defects due to friction and falling	Using a pneumatic parallel gripper system, wooden doors are stacked, lifted, and moved. Because the weight of the door varies, this method is the primary reason for the door falling frequently if the clamping force is insufficient. Continuous use of this technology poses risks to the operator's safety as well as the quality of the door	Implement development with modifications to the vacuum area grasping system from the pneumatic parallel gripper system

The suggested improvements as a result of the RPN and FMEA study results are shown **Table 3**. The 5W+1H analysis table for the suggested change to the potential failure modes is then presented, along with increased product defects caused by friction and falling. **Table 4** shows the outcomes as a result.

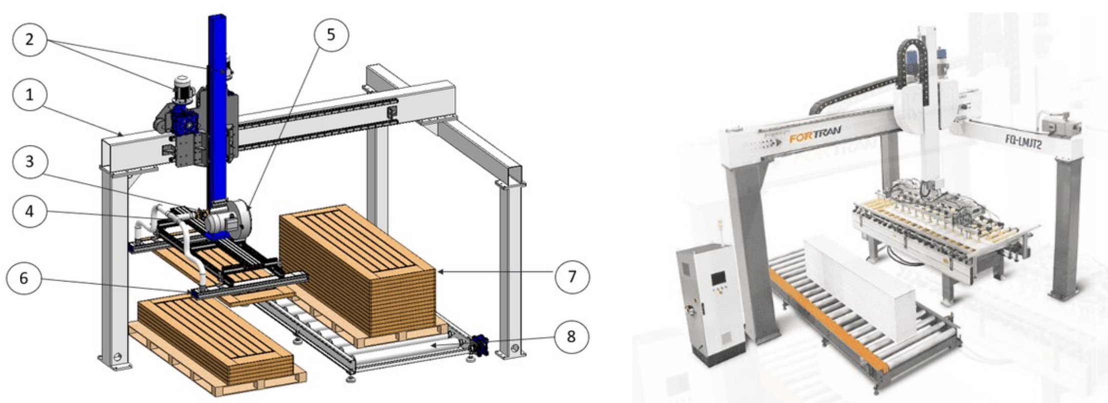
Table 4. 5W+1H analysis

WHAT	WHY	WHERE	WHEN	WHO	HOW
Changing the Gripper system into a vacuum suction system	To prevent product defects from increasing due to friction and falling	Done in a pick and place machine	As soon as possible	Maintenance department	Change from Pneumatic Parallel gripper system to Vacuum area gripping system

Since 2019, PT XYZ has been employing this technique and system, however because doors come in a variety of sizes and weights, this methodology has caused issues, particularly damage to the sides of wooden doors. Actual images of the Pneumatic Parallel Gripper system are shown in **Figure 4**.

Figure 4. Pneumatic Parallel Gripper

A pick-and-place device A machine called Fortran FQ-LMJT2 moves objects. The capabilities of this machine extend to all wood-based products, including particle board, MDF, and so on, in addition to wooden doors. The tool is created by constructing a machine with a vacuum area grasping system and mechanical means. Pick and Place machine with a main frame made of three-foot stands, rail sleeper mounts made of square hollow material measuring 200mmx150mmx5mm, and foot foundations made of square hollow material measuring 150mmx150mmx5mm. The vacuum holder has an aluminum profile-like shape. A servo motor actuator coupled to a belt with teeth is used to lift and move wooden doors. A vacuum blower motor is used as the vacuum energy source, and a 2.5-inch flexible hose transfers that energy to the vacuum area gripping system. Figure 5 is a representation of the author's entire design.



(a) (b)

Figure 5. 3D mechanical description, (a) Design, (b) Actual

Remarks:

1. Pick and place machine frame6. Vacuum
2. Servo Motors 7. Wooden door
3. Air cylinder valves 8. Conveyor rollers
4. Flexible Hoses
5. Suction motor

3.1 Calculation and analysis of vacuum requirements

The acceleration of door movement a = 0.5 m/s^2 and the cross-sectional area of material A = 29.6 mm2 are employed as the dependent variables in the grip theory's calculation of the force for vertical strength in the gripper vacuum. This value is used to make a variable acceleration of motion since it considers the door's size, which is huge and necessitates sluggish motion. In the meantime, the cross-sectional area is calculated using the standard area of the material, which is (114 mm x 130 mm) x 2, which is 29.6 mm^2. Doors with a thickness of 35 mm and 40 mm are the two independent variables that are compared, and each of them employs two samples. In order to determine the actual mass of the material, the mass of the material was measured and calculated using the formula m = p x l x t x 720 kg/m^3:

Table 5. Calculation of the mass and vertical force of the vacuum

Door type to	**Thickness(mm)**	**Weight (kg)**	**Vertical suction force (N)**	**Pad pressure intensity (p) (kg/mm²)**	**Pressure intensity in each pad @2 pcs (p) (kg/mm²)**
Sample	Size	m	Fs = (m / μ) (g + a) . S	p = Fs / A	p' = p/2
1	35	28	1082,6	365,7	731,45
2	35	34	1314,5	444,1	888,19
3	35	37	1430,5	483,3	966,56
4	35	19,09	738,1	249,3	498,69
5	35	26,44	1022,2	345,4	690,70
6	35	28,27	1093,0	369,3	738,51
7	35	30	1159,9	391,8	783,70
8	35	30	1159,9	391,8	783,70
9	35	34,54	1335,4	451,1	902,30
10	35	30,33	1172,6	396,2	792,32
11	40	26,5	1024,6	346,1	692,27
12	40	28,9	1117,3	377,5	754,96
13	40	23,8	920,2	310,9	621,73
14	40	26,2	1013,0	342,2	684,43
15	40	26,5	1024,6	346,1	692,27

According to **Table 5**, the needed vertical suction force for the door with the lightest weight, 19.09 kg, is 738.1 N, with a vacuum chamber's intensity being 249.3 kgmm2. Due to the usage of two vacuum devices in this design, the intensity of the vacuum space is amplified by two, or 498.69 Kg/mm. A vertical suction force of 1335.4 N is needed for the door with the maximum weight, which is 34.54 kg. A vacuum gripper device will be used to test all calculations that account for differences in the size of the door.

One pallet can be produced in an hour by machines that have been designed to increase throughput and decrease rejections from collisions. In this experiment, 3 different sizes of the same type of door were used to discern between size and weight. The synchronization of the suction motor speed as well as the effectiveness of the VAGS system will both be tested. In **Figure 6**, the prototype shape is displayed.

Figure 6. Pick and Place Machine and VAGS System

3.2 Overall system design

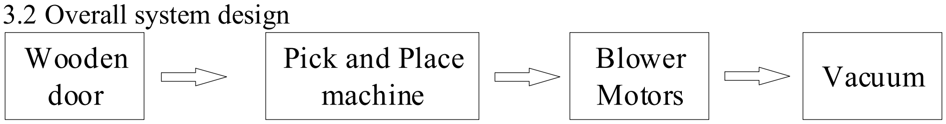


Figure 7. Block diagram of the vacuum system.

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Figure 7 the VAGS system as a whole. A push button is used as the primary operating input to turn on and off. The Pick and Place Machine is activated by pushing a button, using a motor with two speeds configured for up-down and left-right motions with a belt transmission, and using a suction motor for the vacuum system's suction power source.

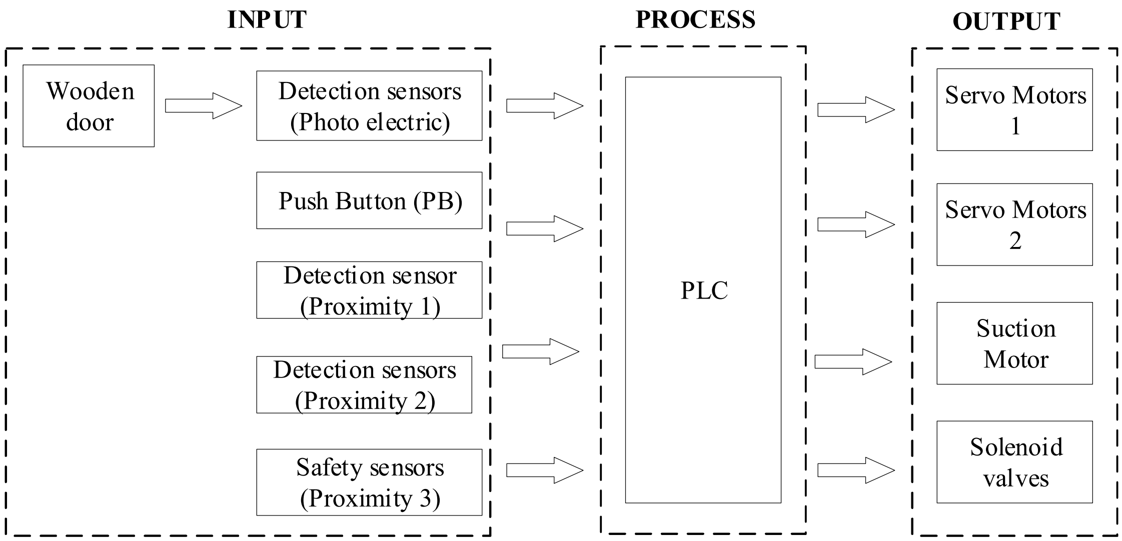

Figure 8. System block diagram

Figure 8 the layout of this machine, which includes 1 push button, 3 sensors, and a PLC whose PB function controls the servo motors that move the X and Y axes as well as the vacuum blower motor. PLC performs as an input to output processing module. The gathering of proximity sensor data and commands from PB electronic devices are the two ways that input is obtained. Analog sensor data is transformed into digital data. A voltage divider circuit helps to facilitate this modification. The PLC input pin receives the voltage that results. A servo motor, a blower motor, and a solenoid valve make up the PLC's output. The blower motor serves as a source of suction energy to turn on the vacuum device, while the servo motor moves the X and Y axis arms.

3.3 Mechanical design

This Pick and Place machine mechanic employs three foot stands as the primary frame, rail sleeper mounts made of square hollow material measuring 200mmx150mmx5mm, and foot foundations made of square hollow material measuring 150mmx150mmx5mm. The vacuum holder has an aluminum profile-like shape. A servo motor actuator coupled to a belt with teeth is used to lift and move wooden doors. The VAGS gadget receives vacuum energy from a suction motor through a 2.5-inch flexible tube. The author's whole design is depicted in **Figure 9** in its entirety.

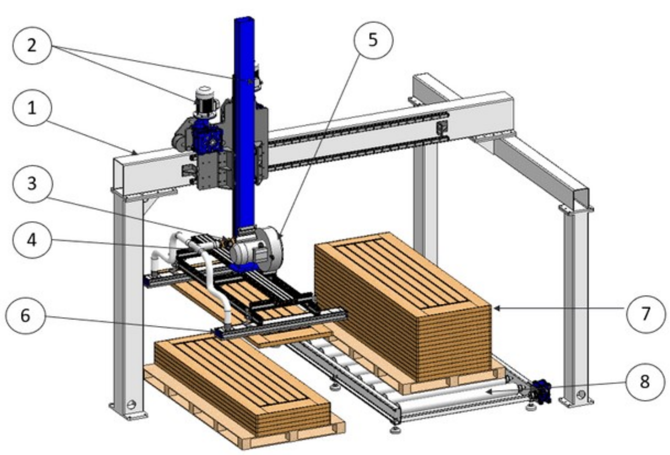

Figure 9. 3D mechanical description

Remarks:

1. Pick and Place Machine Frame
2. *Servo Motors*
3. *Air cylinder valves*
4. *Flexible Hoses*
5. Suction motor
6. Vacuum
7. Wooden door
8. *Conveyor rollers*

3.4 Planning tool programming

In order to test how the tool moves, you can refer to the program flow chart. **Figure 10** depicts the program flow diagram for this tool. The pick and place machine's Y axis moves down toward the target as soon as the PB button is depressed, activating the blower motor and turning on the green indicator light. Following the activation of the valve sensor, pressured air suction is directed toward the vacuum device. The X axis moves to the right up to the limit position, then the Y axis moves back down to the limit position, the Y axis moves up again until it returns to the home position, and the X axis also moves back to the home position. This movement continues continuously until the OFF button is pressed.

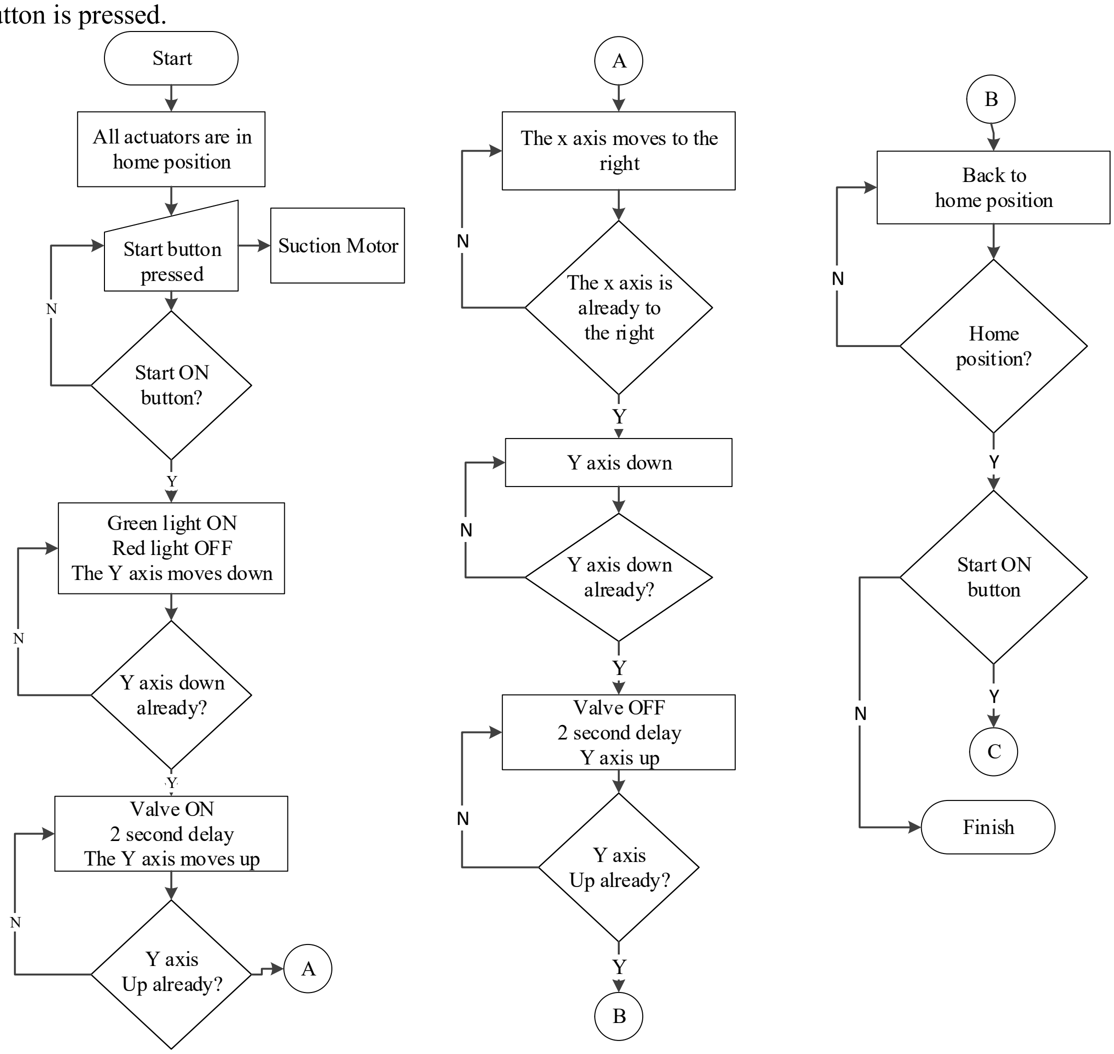

Figure 10. Tool programming flowchart

3.5 Electronic planning

The Push Bottom (PB), Magnetic Contactor (MK), and an AC motor are the main components of the electrical circuit design plan used to regulate this vacuum equipment. An electronic circuit created for application is shown in **Figure 11**.

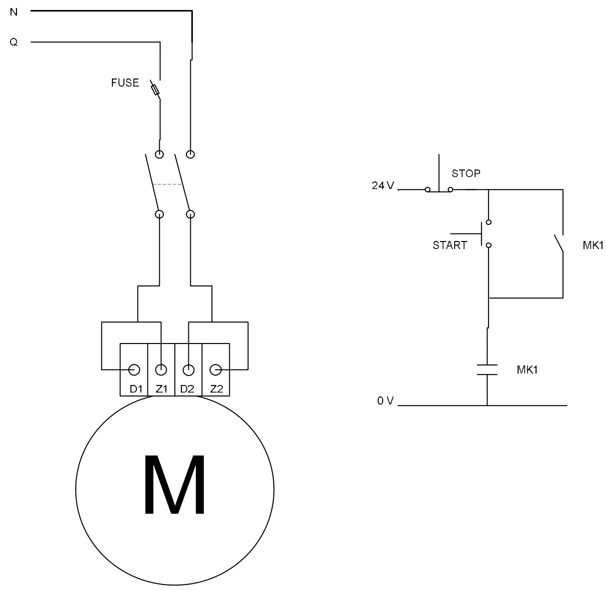

Figure 11. Blower motor driver circuit

3.6 Testing the speed synchronization of the suction motor and the vacuum device

Knowing the optimal speeds for this equipment will help with the synchronization test of the vacuum suction capabilities and prevent suction failure. **Table 6** provides the test findings.

Table 6. Suction motor speed synchronization test and vacuum device

Suction motor speed (rpm)	Door weight (Kg)													
	19,09	26,44	28,00	34,00	37,00	28,27	30,00	34,54	30,33	26,50	28,90	23,80	26,20	26,50
1700	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1750	√	X	X	X	X	X	X	X	X	X	X	X	X	X
1780	√	√	X	X	X	X	X	X	X	X	X	X	X	X
1800	√	√	√	√	√	√	√	√	√	√	√	√	√	√
1850	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Remarks:
√: The door was successfully lifted and moved
X: The door failed to lift

Based on **Table 6**, it can be deduced that if the suction motor rotation is less than 1800 rpm, the vacuum will not be strong enough to lift the door; this may be changed by adjusting the frequency on the motor inverter.

3.7 System success testing of workpieces

The weight of the load utilized in this test is information gathered from the three methods that have been used to assess whether the workpiece was successfully moved without any manufacturing flaws. To obtain results that are appropriate for the test's goals, it is manually conducted. The test results are shown in **Table 7**.

Table 7. Table of the success of testing the vacuum area gripping system (VAGS)

Tested system	Door weight (Kg)	Dimension(mm)			Time (Seconds)	Survey test results as much as 5 times					
		P	L	T		1	2	3	4	5	Conclusion
Pneumatic	28	1981	610	35	40	√	√	√	√	X	Succeed
Parallel	34	1981	762	35	35	√	√	√	X	X	Succeed
Gripper	37	1981	838	35	30	√	√	X	X	X	No

Tested system	Door weight (Kg)	Dimension(mm)			Time (Seconds)	Survey test results as much as 5 times					
		P	L	T		1	2	3	4	5	Conclusion
Vacuum	28	1981	610	35	10	√	√	√	√	√	Succeed
Area	34	1981	762	35	10	√	√	√	√	√	Succeed
Gripping System	37	1981	838	35	10	√	√	√	√	√	Succeed

Remarks: √: Succeed
X: No

Results of the testing with two systems are shown in **Table 7**. The size, weight, and other characteristics of the door are changed during the testing procedure. When manually weighed, the weight of the door used ranges from 28 kg to 37 kg. The exam makes use of the most highly recommended VAGS system to make it fit for purpose.

Table 7 demonstrates that the Pneumatic Parallel Gripper system failed for one type of dimension, namely for a size of 1981 mm x 838 mm x 35 mm with a weight of 37 kg. This was because the gripper strength was insufficient since the door load was too great, as illustrated in **Figure 12**.

Figure 12. Pneumatic parallel gripper

Due to the blower motor's ability to raise every type of door as shown in **Figure 13** and its ability to suction up to a load of 50 kg, **Table 7** shows the Vacuum Area Gripping System system that was successfully used for all types of dimensions and weight.

Figure 13. Vacuum Area Gripping System (VAGS)

3 CONCLUSION

The statistics in Table 7 and the experimental findings on the gripper's vacuum capability show that the system's purpose was accomplished. A pallet of 30 doors may be moved utilizing the pick and place machine's capacity in 3 minutes using the vacuum area gripper technology. According to the success rate calculated using the door's weight, this system is capable of lifting and moving every type of door made at a consistent speed. If the speed is insufficient, the suction motor won't be able to lift, according to its capacity, which has been estimated based on needs at 1800 rpm. The vacuum gripper does not harm or damage the door surface, so the problem of door product flaws is resolved. A door load more than 50 kg can be supported by the motor's 2.3 kW output and 270 m3/hour suction power.

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