Research Progress in Mechanical and Manufacturing Engineering Vol. 4 No. 1 (2023) 347-358
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RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773 - 4765

Improvement of DLA Sealing Machine Monitoring Process: Mechanical Design and Prototyping of Automatic Alert System

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DOI: https://doi.org/10.30880/rpmme.2023.04.01.040
Received 23 June 2022; Accepted 23 June 2022; Available online 01 June 2023

Abstract: In recent times, automation has begun to take over production within the manufacturing industry as it serves to be cost and time efficient. Automated systems that are implemented within the industry are also reliable as they are programmed to work as intended. However, inputs from humans are still required as not all systems have fully transitioned into automated processes. Hence, errors made by humans may still occur from time to time as manual labour is still required within the industry. At TDK Electronics, a problem that has plagued the company during the production of their Surge Arresters, is when their operators mistakenly insert the wrong gas tank into the outlet port of the DLA Sealing Machine after a specified order has been acknowledged by the control panel. This in turn creates faulty products as there is no way of knowing that the gas composition within the surge arrester is incorrect up until the products go through their quality assurance process. Therefore, this project aims to provide a solution for the gas tank exchange problem during the operation of the DLA Sealing Machine. This project presents a case study on the development of a fool-proof gas tank exchange system which requires a step-by-step verification process in order to avoid potential errors with the integration of a barcode system while still adhering to the existing constraints of the DLA Sealing Machine. The mechanism is designed based on the specific dimensions of the existing gas cabinet of the DLA Sealing Machine and the current gas delivery system that is in place. In order to achieve its intended purposes, the new mechanism must be able to eliminate potential errors during the gas exchange process through the incorporation of a verification system that recognizes the gas tanks and their contents as well as alert the operator if any mistakes are made during the exchange process. After the design phase is completed, a simulation that utilizes SolidWorks is conducted on the gas tank exchange mechanism in order to obtain several values from multiple analyses to evaluate the choice of structure, materials and design. The mechanism must be able to withstand 1500 mbar of pressure for it to deliver the gas fluids from the gas tanks to the DLA Sealing Machine. It must also be able to withstand industrial use as the machine will be used extensively in the production line to manufacture the surge arresters. A prototype is also developed in order to evaluate the effectiveness of the verification and alert system that was put in place to notify the operator of a potential

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mistake. The appropriate recommendation is that the new mechanism should be able to meet all the requirements in order for it to be compatible with the currently existing system that has been operational since the 1990s.

Keywords: DLA Sealing Machine, Manufacturing, Industrial, Design

1. Introduction

TDK Electronics AG is a German electronic component, module, and system manufacturer. It is a subsidiary of the Japan-based TDK Corporation. They were previously known as Siemens Matsushita Components, then as EPCOS AG and currently as TDK Electronics. They develop and manufacture gas-filled surge arresters of which they are the global leaders with a market share of 70 per cent in this product technology, which is used primarily in telecommunications installations. TDK also manufactures capacitors, ceramic components, EMC filters, inductors, non-linear resistors, RF modules, surface acoustic wave components, and ferrites. It is a merchant wholesaler of household appliances and electrical and electronic goods. The company was founded on March 13, 2000.

At TDK Electronics, one of the products that are produced in-house, are surge arrestors and switching spark gaps. In order to obtain the final product, there are a few number of processes that need to be done beforehand. The process is shown in Figure 1.1 and starts with cold pressing, then pencil stroking, centre pasting and mounting. The process continues by inserting the components in the DLA Sealing machine, continued by activation & TL welding, Cl welding & bending, electrical testing and clip & pill assembly. Finally, the products undergo inspection, packing and quality assurance. One such process is the "Sealing" process, which takes place within the DLA Sealing Machine and can be seen in Figure 1.2, in which the electrodes and ceramics are heated and pressed together before being filled with gas. The gas compositions may change depending on customer preferences. The gas is supplied from a gas cabinet as shown in Figure 1.3 that is located near the DLA machine. There are three cabinets in total where the gas tanks are placed. Within these cabinets, there are ports installed that enable the gas to travel from the cabinet to the machine. These ports are used to supply some gases directly to the machine in order for the sealing process to take place.

1.1 Objectives

i. To provide the solution for the gas exchange problem during the operation of the DLA Sealing Machine.
ii. To automate the generation of alerts through condition monitoring for process improvements.
iii. To implement the proposed solution on the machine operation.
iv. To evaluate performance improvements after implementation of the proposed solution on the machine operation.

1.2 Scope of Study

The research focuses on machine understanding in which to understand the machining process from start to finish in order to understand how the current mechanism within the machine operates as well as their respective functions. Data collection regarding the machine will also be acquired as it is done in order to further the research for the machine improvements. The proposed system will be comprised of an alert system capable of notifying the machine operators of the gas tank configurations will then be integrated and monitored. The proposed controller is equipped with control elements that are capable of directly dealing with the issues related to the current systems, that is gas identification and the incorrect gas configuration made by the machine operator. The effectiveness of the proposed gas selection and exchange system is evaluated by measuring its performance during normal production.

2. Methodology

The project begins with a study of the machining process as it allows better insight and understanding of how the machine works. A literature review is then conducted to gather information and gain a sense of how the proposed ideas will be implemented. In order to ensure the project's success, the objectives, as well as the problem statement, are made clear. The next step is to research the machine's mechanisms and programming before making any crucial changes. Using software such as SolidWorks and PLC, a simulation for the model and gas recognition to alert the system is done in order to simulate real-life applications. Should the simulation be successful, it will be integrated into the DLA sealing machine. The simulation is key to this project as tweaks and improvements must be made for the project to run smoothly for it to be implemented.

2.1 Flowchart

We start the project by studying the machine and its overall process flow. Based on the initial study, the objective and problem statement is determined. Then a literature review is done in order to collect information pertaining to the machine. After a comprehensive review, the gas-changing mechanism solution is developed through concept design as well as simulations for the alert system using suitable software. If the simulation fails to meet its intended purpose, the process is reassessed once more. After the simulation is completed, the solution is then implemented on the machine. Then the testing and monitoring phase of this project commences. Should there be any problems during the testing phase, suitable corrections and adjustments are made until the implementation is a success. As the objectives are achieved, and the automatic alert system is functioning well, it marks the end of the process. The process flow chart for this project is shown in Figure 1.

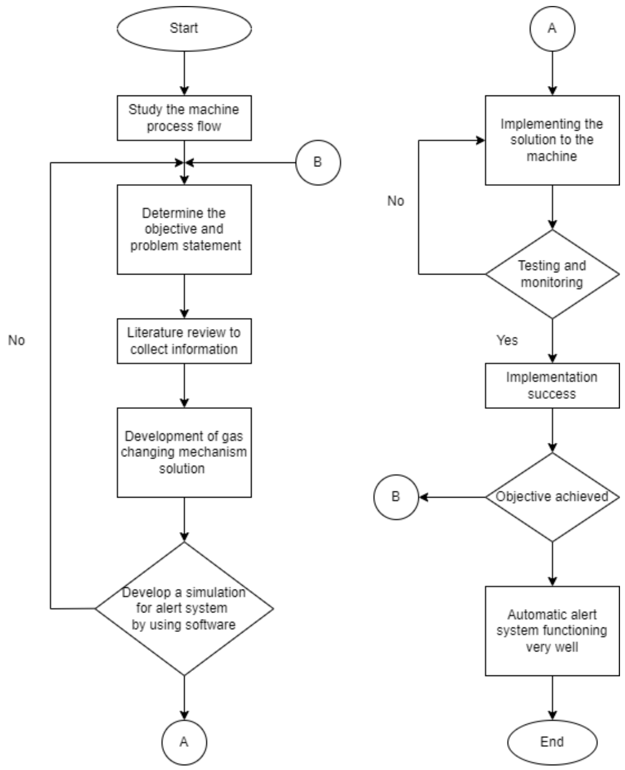

Figure 1: Flowchart of The Methodology to Automate the Alert System

Furthermore, SolidWorks is used for the simulation, and a simulation flow chart illustrates the steps to obtain the result shown in Figure 2.

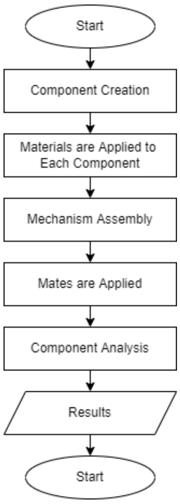

Figure 2: Flow Chart of Simulation

2.2 Component Selection

In order for the mechanism to operate and function for its intended use, several items must be procured for the overall system as shown in Table 1.

Table 1: Component Selection of Project

Component	Function
Gas Pipeline	To transport gases from each inlet into the port
Keyed Quick-Connects	Can prevent accidents caused by intermixing of different lines in multifluid and multi-pressure systems
Normally Closed Solenoid	To control the flow of gas.
Barcode Scanner	Scan and read Barcode labels on the gas cylinder, lot traveller and mechanism to notify the system and enable the solenoid to operate.
Pilot Light	To light up and indicate when the sequence is verified system.
Tower Lamp	To convey the state of the mechanism that is both visible and audible.
Pneumatic Valve	To turn on and off a single airflow route to precise proportional pressure and flow control.
Solenoid Valve Manifold	The manifold creates a valve bank by joining numerous solenoid valves together

2.3 Concept Procedure

The steps below show the operating procedure of the proposed system concept.

i. Scan lot traveller.
ii. Input details on the control panel of the DLA Machine.
iii. The system will notify the operator of which gas tank to be mounted on the port based on the order made.
iv. The operator must scan the barcode that is tagged on the gas tank to authenticate whether the gas tank is chosen or whether it is the gas tank required based on the order.
v. The operator then proceeds to scan the barcode that is tagged on the labelled ports.
vi. The barcodes must tally before the operator can proceed to mount the gas tank to the ports.

vii. If the codes do not tally with one another, the system will alert and notify the operator of the mistake. The operator must choose the correct port and make the codes tally before they can proceed.
viii. Insert the stem of the colour-coded keyed quick-connects into its respective port.
ix. The operator starts the DLA Machine. Solenoids will activate. Port 6 and valve 23.8 is opened.
x. DLA Sealing Machine begins operation.

2.4 Full Assembly of Gas Tank Exchange Mechanism

After completing the geometry of the gas tank exchange mechanism, SolidWorks is used to model the geometry based on the initial sketching.

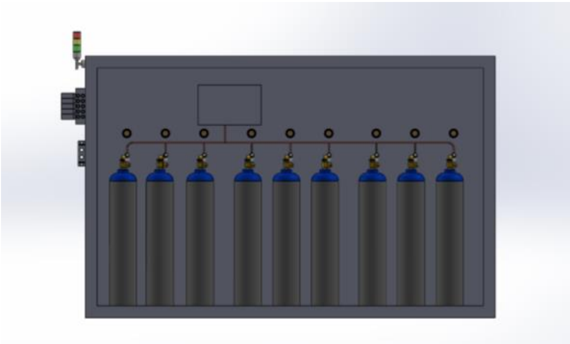

Figure 3: Full Assembly of DLA Cabinet Gas Tank Exchange Mechanism

A conceptual illustration of the new gas selection mechanism was shown. The materials required for the design to be implemented were also outlined and the mechanism procedure was defined. TDK Electronics agreed with the design concept that was presented and wanted to move forward with the design to be implemented in the DLA Sealing Machine for further research and test out the mechanism's capabilities when it is operated during production.

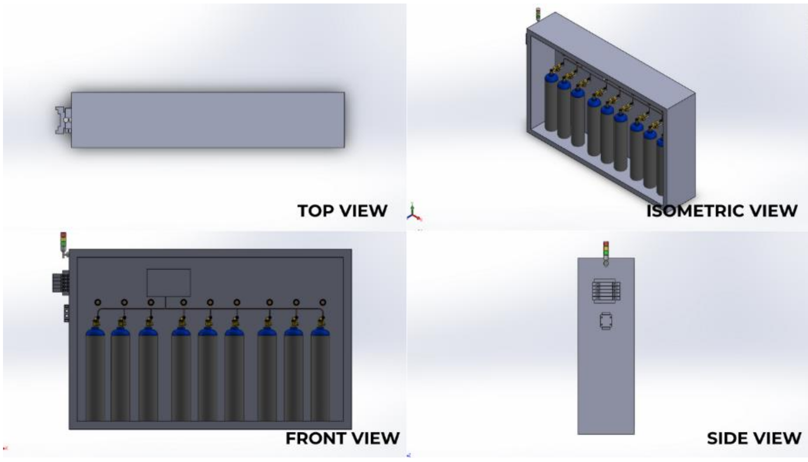

Figure 4: Views for DLA Cabinet Gas Tank Exchange Mechanism

3. Results and Discussion

The main objective for developing the mechanism is to create a foolproof system that assists the operator and eases the process of swapping the gas tanks within the DLA cabinet. There is a list of each component within the assembly and alterations made to the created 3D model. SolidWorks simulation feature will be used to determine the values of static analysis of the mechanism. A prototype of the system is also included as it served to test its capabilities and real-world application.

3.1 Static Analysis

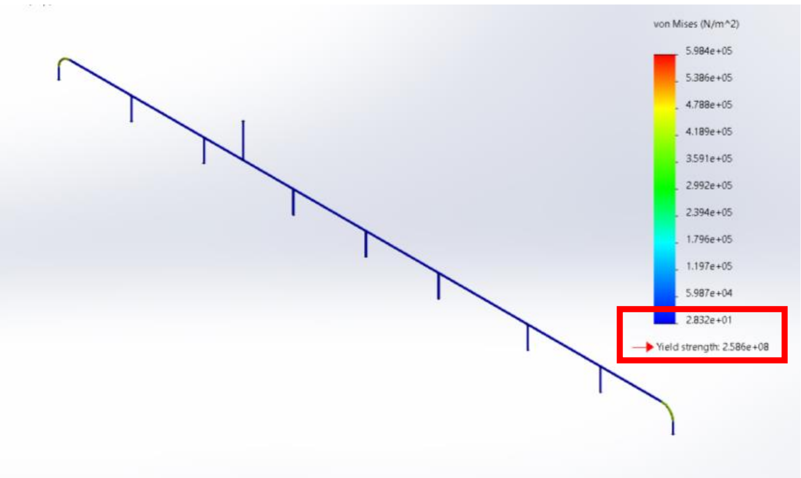

Figure 5: Von Mises Stress Analysis of Main Pipe

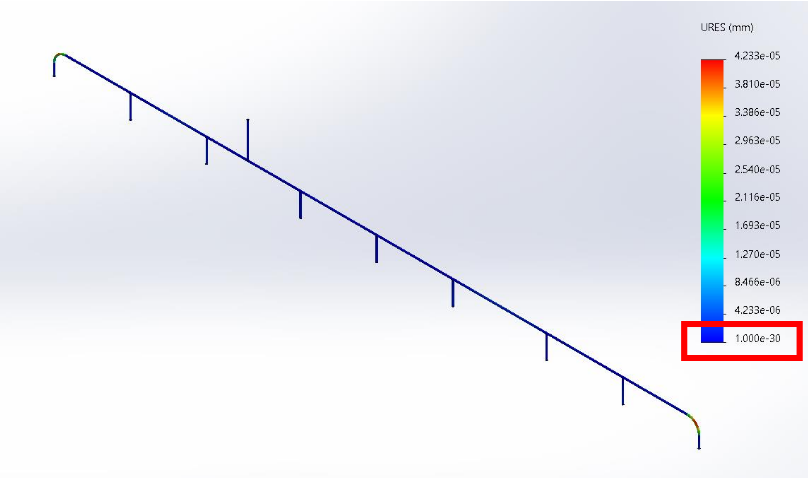

Figure 6: Displacement Analysis of Main Pipe

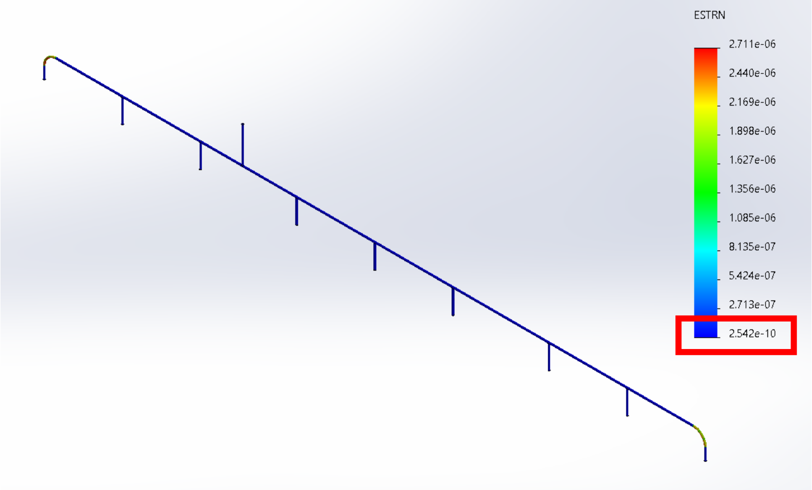

Figure 7: Strain Analysis of Main Pipe

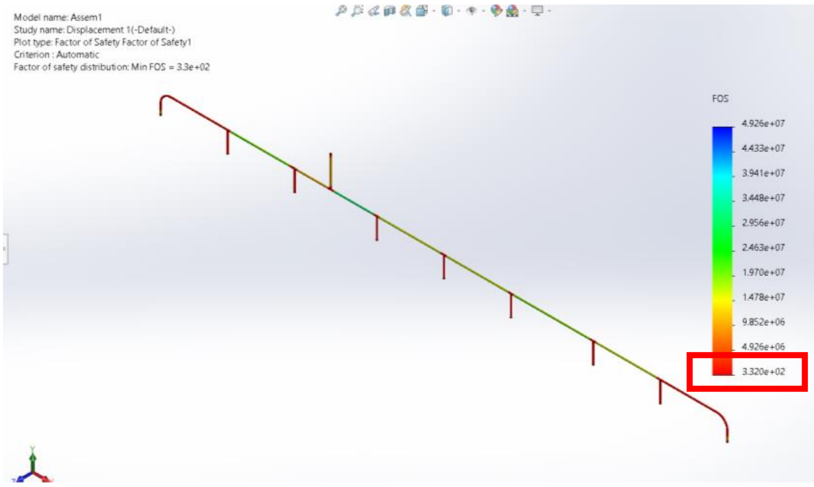

Figure 8: Minimum Safety Factor of the Main Pipe

From the results obtained from the simulation, Figure 5 shows the Von Mises Stress Analysis on the main pipe and the maximum stress obtained is 2.586e+02MPa. Moreover, Figure 6. shows the displacement analysis and the maximum displacement obtained is 1.000e-30mm. The next result obtained as shown in Figure 7 shows the strain analysis with the value of 2.542e-10mm/mm. The final result was the factor of safety of the main pipe with the value of 3.320 as shown in Figure 8.

Table 2: Static Analysis for the Main Pipe

Static Analysis	Value
Von Misses Stress Analysis (MPa)	2.832e+01
Yield Strength	2.586e+08
Displacement Analysis (mm)	1.000e-30
Strain Analysis	2.542e-10
Factor of Safety	3.320e+02

3.2 Structural Analysis

The main pipe of the mechanisms spans over 3 meters in length and therefore a closer look is required to have a further understanding of the pressure acting inside the pipe. A section depth of 5mm from the main pipe was used for the structural analysis as the thickness of the pipe was 1mm with an outer diameter of 9.5mm.

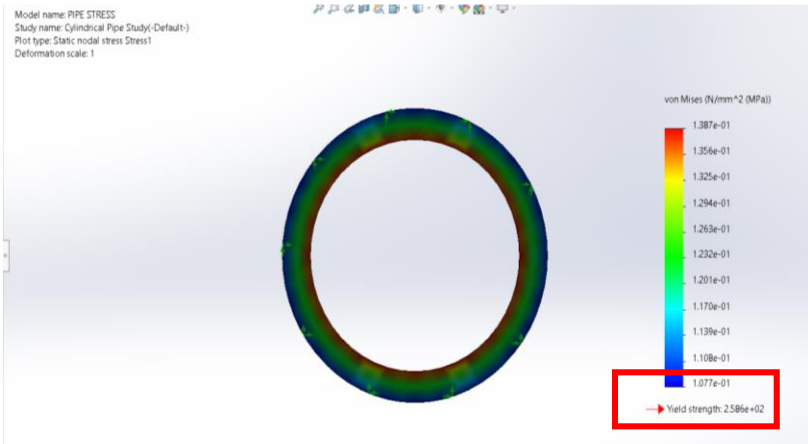

Figure 9: Von Mises Stress Analysis of Main Pipe with Section Depth

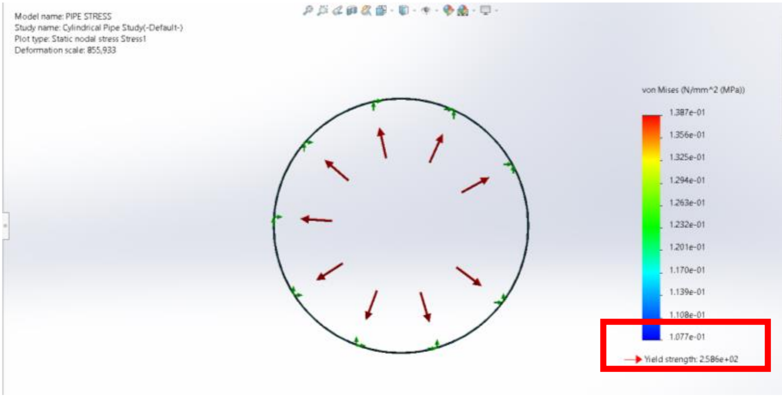

Figure 10: Deformed Main Pipe with Section Depth

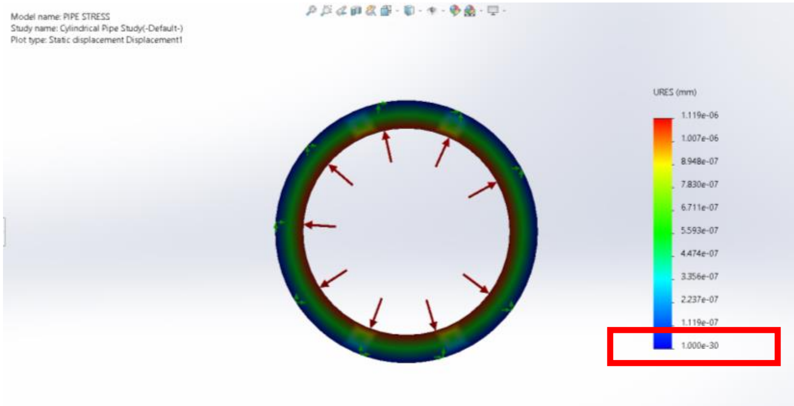

Figure 11: Displacement Analysis of Main Pipe with Section Depth

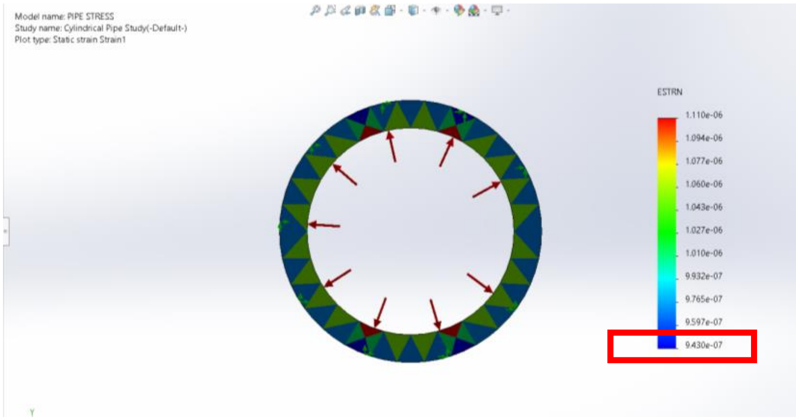

Figure 12: Strain Analysis of Main Pipe with Section Depth

Table 3: Structural Analysis for the Main Pipe

Structural Analysis	Value
Von Misses Stress Analysis (MPa)	1.077e-01
Yield Strength	2.586e+02
Displacement Analysis (mm)	1.000e-30
Strain Analysis	9.430e-06

From the results obtained from the simulation, Figure 10 shows the Von Mises Stress Analysis on the main pipe and the maximum stress of the section depth obtained is 2.586e+02 MPa. Moreover, Figure 11 shows the displacement analysis and the maximum displacement of the section depth obtained is 1.000e-30 mm. The final result obtained as shown in Figure 12 shows the strain analysis of the section depth with the value of 9.430e-06 mm/mm.

3.3 Prototype of the Project

Figure 13 shows the prototype of this project in order to determine whether the program that was made in order to open the control valve after scanning the related barcode was successful. Figure 13 shows the equipment with a visual representation of the overall gas mechanism when it is installed in the cabinet of the DLA Machine.

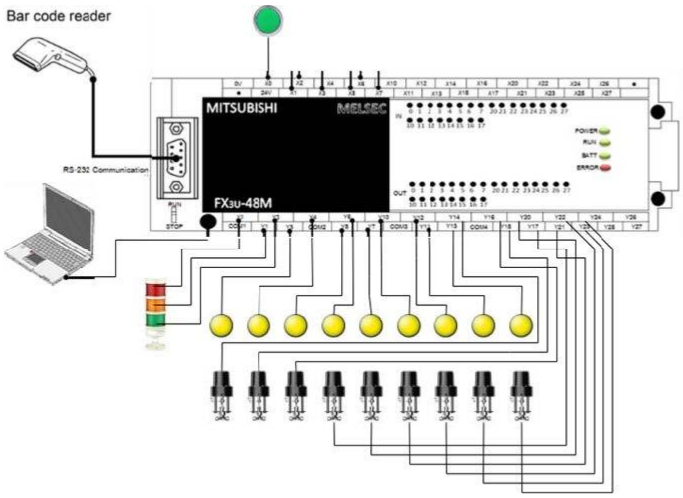

Figure 13: Connection Diagram of Equipment and Device

For the prototype, the actual hardware had to be replaced with hardware that was able to simulate the real process. This was due to the limitations of testing as the alternative hardware was inexpensive. The tower lamp was substituted with a pilot lamp in this prototype, as indicated in Figure 3.10, and the valve actuator is left out for the prototype to be made and tested within a reasonable cost. The prototype was connected as shown in Figure 3.11. A wired barcode scanner was also used in place of a cordless one as shown in.

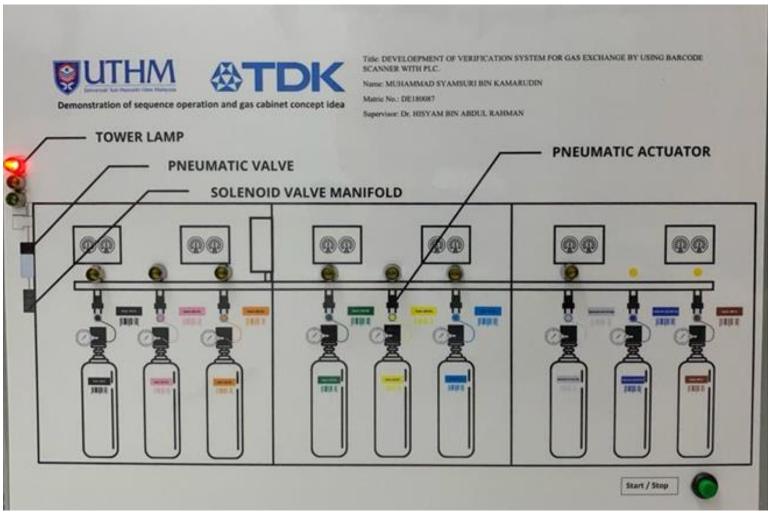

Figure 14: Hardware Simulation with Visual Layout of Mechanism

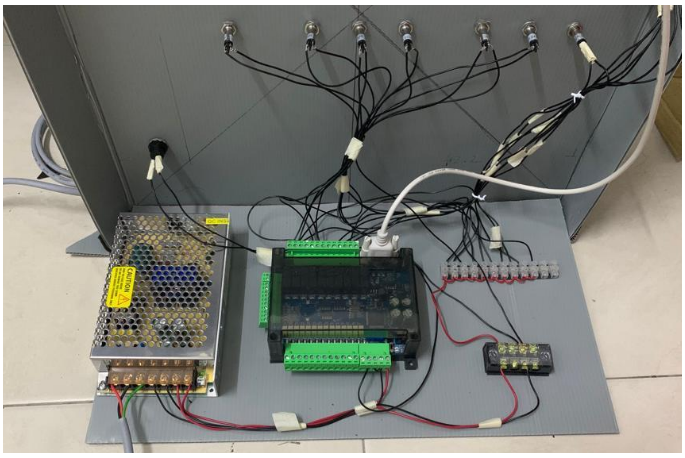

Figure 15: Prototype Connection

The barcodes in the prototype were assigned to individual gas tanks to simulate the actual process after the mechanism is implemented in the cabinet. The barcodes indicate Gas Tank 1, gas Tank 2 and Gas Tank 3. The barcodes were then copied to the lot traveller, and labels were made to serve as an alternative to the gas tank and valve as shown in Figure 16. These were then used to test out the system as the system calls for multiple barcodes in various stages before the gas is released into the DLA Machine without fault. The figure shows the green light of the tower lamp as it indicates the overall process was a success.

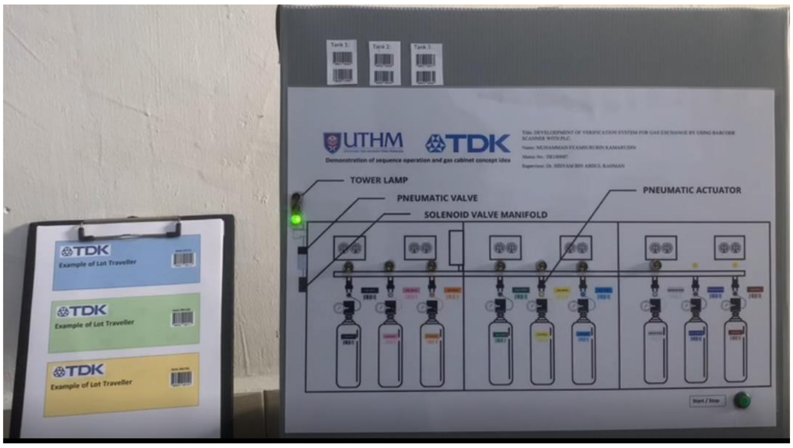

Figure 16: Green Light on Tower Lamp Turns on To Indicate Success

3.3 Bill of Materials

Table 4 shows the bills of material which is the list of items required to complete the DLA Cabinet gas tank exchange mechanism build.

Table 4: Bill of Material

Structural Analysis	Value
Gas Main Pipeline with 9 Inlets & 1 Outlet	1
Quick Connect Coupling	9
2-Way Normally Closed Solenoid	9
Quick Connect Body	9
Quick Connect Stem	9
Stainless Steel Flexible Hose	9

Pilot Lamp	9
Tower lamp	1
Solenoid Valve Manifold	1
Pneumatic Valve	1

4. Conclusion

In conclusion, the scope and the objectives of improvement of the DLA sealing machine monitoring process: mechanical design and analysis of automatic alert system components have been achieved. This thesis presents the design and comprehensive performance evaluation of a model-based, automated system for the improvement of the DLA Sealing Machine at TDK Electronics Sdn. Bhd. located in Johor Bahru. This project was made in part due to the desire to eliminate human errors while operating the DLA Machine during the gas tank exchange process as the current manual system in place is not fool-proof which may lead to losses within the company in terms of time and cost. Therefore, reducing the manual efforts in favour of a reliable system through the creation of an automated process must be developed is much needed. A design concept was made and several tests were conducted to ensure the system was a success should it be implemented in the production line. The process which includes the use of a pipeline that includes several inlets for the gas tanks to be connected to only one outlet due to the constraints of the machine had been created. A system was also developed in order to eliminate potential errors as a verification process is required each time a gas tank needs to be replaced.

Through virtual simulation, the appropriate components and dimensions were able to be determined as the constraints and requirements were considered and applied. The materials chosen as well as the analysis of the overall mechanism structure was made possible and the results obtained throughout were very encouraging. The prototype made by gathering alternative components was tested in the laboratory to simulate its real-life application and implementation manage to garner a satisfying result and prove that such a system was feasible.

Acknowledgement

The authors would like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for the support in accomplishing this research

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