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Pneumatic Press Station Simulator for Skills Development Training

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Abstract
This study investigated the efficiency of the Pneumatic Press Station Simulator as a instructional tool to improve the students' mechatronic skills. A prototype machine was designed and developed based on existing industrial machinery. This prototype machine was subjected to several tests and used in actual laboratory activities to measure efficiency considering functionality and precision. Siemens S7-200 Programmable Logic Controller (PLC) was used in the control system. Findings revealed that pneumatic press station simulator could be used for instruction in conducting laboratory activities. Precision of the prototype machine reached 93.33% in terms of number of work pieces delivered over several trials. It could perform various tasks: wiring installation, commissioning, and operational sequence of the prototype thus, effective as a instructional tool for training purposes in relation to industrial automation and mechatronics. It was concluded with pedagogic implication that both teachers and students could enhance their respective technical skills. The use of pneumatic press station simulator was recommended to be used as instructional tool for training purposes in relation to industrial automation and mechatronic skills development.

Keywords: pneumatic, press station, technical skills, simulator, instructional tool.

Introduction

Technological advancement in process monitoring, control and industrial automation over the past decades had significantly contributed to improve productivity of manufacturing industries throughout the world. Automation in particular had notable impact in a wide range of industries beyond manufacturing to optimize productivity and delivery of services. In the scope of industrialization, automation is a step beyond mechanization. While mechanization provides human operators with machinery to assist them with muscular requirements of work, automation greatly decreases the need for human sensory and mental requirements while increasing load capacity, speed, and repeatability. Automation plays an increasingly vital role in world economy from industrial activities to service jobs in daily tasks.

The need for automation implies the demand for technicians to be fully equipped with the necessary skills in industrial automation. In fact, the skills shortage has been identified as one of the biggest obstacles for many countries to reach economic growth targets. Adam (2011) stressed the importance of skills development with two offshoots: 1) provision of training of employees in the workplace to be conducted by the employers themselves or training specialists; and 2) training for unemployed individuals who wanted to join the workforce. For both categories, it was imperative to involve transfer of skills, where existing skilled workers shared their expertise with trainees. This could be done in the form of mentorships, via formal training courses and through continuous on-the-job training.

The demand for automation and skills development have cascading impact in the offering of formal training courses and curricular programs in Industrial Automation and Mechatronics particularly in tertiary education. However, offering of these courses would require sufficient facilities to develop the students' skills. These facilities are quite expensive hence the need to devise and develop prototype equipment as instructional tool to facilitate the learning process. Harker (1988) had discovered that prototyping was an effective way of developing large-scale application. Prototypes and simulations had bridged the gap between theory and practice. They provided the students the opportunity to explore and respond directly to a given task.

There had been existing prototype equipment and gadgets, however, in the advent of technology, there was a need to upgrade instructional facilities. The rate of technological advancement had accelerated at unprecedented pace. New generation of technology specifically in automation has likely an effect not only in terms of productivity but also on the demand for highly skilled workers with broader workplace competencies who would demand for higher pay. Good enough, the introduction of recent technologies had reduced the demand for unskilled labor and raised the value of advanced skills and competencies in the industrialized economies. Cognizant to this, the development of skills through training must be the ultimate response to such technological changes, hence this paper had focused on the development of a prototype pneumatic punching station simulator as instructional tool to improve the mechatronics skills of students.

Review of Related Literature

Device Simulators

Different simulators in various industrial processes were used to mimic the actual scene or to show occurrences. In academia it is highly recommended to use several simulators to expedite the learning process. Wankat (2002) highlighted the use of simulators in teaching introductory computer engineering which he stressed the effectiveness of the simulators in the success of teaching-learning process in different computer applications. Another similar study by Ang et.al (2008) using Problems-Based Learning (PBL) approach to support and promote deeper student learning in a computer architecture course. The student responses showed that the PBL approach was successful in developing deeper learning experiences and general skills such as time management and teamwork while at the same time contributing to a more enjoyable learning experience. The study of Rivero et.al (2012) described the difference between using a teaching device, simulators or didactics versus a traditional teaching aids in municipal higher education institutes. The results showed that teachers make an occasional, non-systematic and reluctant use of teaching aids during the teaching-learning process, especially when it comes to ICT-based teaching aids thus in todays engineering teaching practices there's a need for the use of didactics or simulators. Another advantage of using a simulator as described in the study of Wankat (2002) the use of a modified form of Problem-Based Learning (PBL) to teach engineering students to use a simulation package in a computer laboratory attached to a "lecture" course is effective. The students learned how to use the simulator better and they learned the course material better than in the lecture course without the computer laboratory. The most important point is that simulation packages can be integrated into engineering lecture courses without requiring a large amount of lecture time.

In the context of safety , the use of simulator was highly recommended as proposed in the study of Van et.al (2011) the development of a motion platform for an educational flight simulator were regularly used in the undergraduate and postgraduate training of mechanical and aeronautical engineers. Due to advances in computing technology, several flight simulation-related tasks can now be accomplished in real-time using low-cost PC platforms and inexpensive commercial software. The difficulty in realising an educational flight simulator system with motion platform therefore lies with the design and construction of an effective motion platform. Costs become exorbitant when simulation platforms of more than two degrees of freedom (i.e. pitch and roll) were attempted. The system effectively simulated the pitch and roll motions of commercial airliners, using a low-cost, easily maintainable motion platform. The educational value of the simulator was twofold: first, it was to be displayed in the science exploratorium (SciEnza) of the University of Pretoria; and second, it provided a platform on which mechanical (as well as electrical, electronic and computer) enginering students could conduct practical work in courses such as dynamics and control, and on which final-year and postgraduate students could conduct researc

Pneumatics Technology

The use of pneumatics in advancing the manufacturing process plays a great role in modernizing today's products and materials. In the study of Shi et.al (2010), which proposes the development of a pneumatic booster to improve the mechanism and drive expansion of valves. Using Matlab/ Simulink for modelling the simulation, input pressure-reduced pneumatic booster valve was studied experimentally. The results have shown a clear impact on the simulation and experimental results have a good consistency; flow of air exported by expansion energy-used pneumatic booster valve is larger than that by input pressure-reduced pneumatic booster valve, and the maximum flow is 2.5 times of the flow of air exported by input pressure-reduced booster valve. Integrating pneumatic technology from manual drive lessens the time and money of the company and thus, there's greatly a need for skilled people who knows this operations.

For people to be knowledgable, there should also be an efficient teaching-learning process from the academe to propagate and innovate the different pneumatic technology processes. Since this technology uses air as a working medium and/or as a source of power in pushing and pulling several mechanical device, there has been several recent advancement in pneumatics technology that leads to the creation of humanoid parts to be used in numerous applications. In the study of Adegbuyi et.al (2013), the development of a relatively new type of the pneumatic actuator is the pneumatic artificial muscle (PAM) or pneumatic muscle actuator (PMA). Fluidic Muscle made by Festo Company was one of the most investigated commercially available PMA. Pneumatic muscle actuators can be used in industrial environment as well as in prosthesis or rehabilitation devices. In this paper a humanoid arm actuated by Fluidic Muscle is developed and presented. Another similar study conducted by Adegbuyi et.al (2013) which emphasizes the critical aspect of the need of the personnel acquiring knowledge in the maintenance, monitoring, and maintaining fluid cleanliness that involves a continuous cycle of testing and corrective action in order to reduce component failure . In his study, it also concluded that the cleanliness was an important factor hence pneumatic cylinders should be protected from contaminants entering the ports. Also before making connections to cylinder ports, piping should be thoroughly cleaned to remove all chips or burns which might have resulted from threading or flaring operations.

Press and Punch Mechanism

In various industries, the pressing or punching process had maintained strong popularity as essential manufacturing process that is used for making holes and stamp straightforwardly, specially on a thin workpiece made of metal (sheet metal) or any other material. For this instance, careful observation testing should be made to test the quality of the press process. The study of You et. al proposed the use of Finite Element Analysis or FEA technique using ANSYS workbench to determine and predict the quality of precision of press-fit assembly, press-fit curves, and maximum press-mounting force of press-fit assemblies. Different kinds of punching processes were suggested by Nandi (2004); Finckenstein, et.al (1998); Joo and Jeon (2001) for a variety of types of industrial application. A punching process, called in-process, based on pressure fluid for sheet metal works was developed. In this work, the punching operation takes place directly after a sheet metal forming process to avoid the extra requirements for tool and process equipment. In the context of manufacturing line holes, a microhole-punching system, developed by Joo et al. (2001) had the capability of making holes 100 μm in diameter. However, in those punching systems, there was no such facility for selective multipunching that performed either in a single operation or in successive multiple operations. Finckenstein, et.al (1998) have proposed a micropunching system by introducing micro wire electrodischarge machining into the electrode- making and punch-making process. Another similar study conducted by Raz (2015) which highlighted the importance of using the accurate press in forging and about the possibility of multidirectional forming. Forming with increased accuracy is nowadays highly requested by all companies and producers have to igmprove design of forging machines. These better forged parts can be produced with lower cost as normal parts. It is caused by fewer machining operations.

Schneider (2007), suggested the the Microplate Gang Punch developed by Engineering By Design (EBD), San Jose, Cal. This pneumatic punch had high-volume solution for filling microplates with small- to medium-size discs or frits. With a single stroke, the punch's air cylinder drived 96 hardened-and-ground pins through a sheet of raw material - held in a punching nest, then through a 96-hole die plate to cut the frits. The pins completed their strokes by placing the cut pieces into the wells in a standard microplate. Similar punches incorporated electrically operated controls and sensors. However, the National Electric Code (NPFA-79) and CE specified that electrical components must be segregated from pneumatic components - to prevent broken air hoses from spraying moisture and shorting the circuits. Since pneumatics was needed to generate the force, EBD decided to simplify the punch by eliminating anything electric and making it completely pneumatic.

Technical Skills Development

There is no doubt that continuous practice makes an amateur individual to become professional in his chosen field. In the case of engineering, theories and concepts should be applied to visualize and enhance the understanding and learning. Realization of hard skills in combination of soft skills opens up new ideas and innovations that leads to improvement. This was proven true in the study of Parasuraman et.al (June 2015) which highlighted the perfect blend of soft skills and hard skills that shapes an aspirant into a person of employable skills. In his study, the identification of employable skills paves way for perfection towards the designed profession. It identifies, suggests and modifies some sets of skills which only can be learned through experience and to make use of the prospective opportunities available. Taking the recommendations made by the NASSCOM survey as cited on the study of Parasuraman et.al (2015), on identifiable skills into consideration to gain employability skills, which can be summed up on nine important factors namely: training needs, personal traits, academic skills, communication skills, soft skills, corporate skills, technical skills, job-seeking skills.

Technical skills developed among Fresh Engineering Graduates (FEG) are one of the most important attributes the employers are looking in hiring candidates during job hunt. This was proven true in the study of Jeswani (2016) that aims to develop, derive, and test the best fit model for employability skills present among FEG. Exploratory Factor Analysis, Confirmatory Factor Analysis and Structural Equation Modeling techniques were used to analyze the data gathered through a structured questionnaire from 305 employers conducting campus recruitment for FEG as well as employing FEG of engineering institutes/universities of Chhattisgarh State of India. The results revealed that management skills are the most important skills, followed by technical skills and communication skills as perceived by the employers. The results also suggest that employers are satisfied more with communication skills (no skill gap exists), followed by technical skills (skill gap exists) and then management skills (skill gap exists). Hence, it is also evident that the employers are least satisfied with the most important skills, i.e., management skills and more satisfied with the least important skills, i.e., communication skills.

Looking at the higher perspective of job supervision, technical skills were also investigated if it has incremental a value when it comes to the credibility of handling people. In the study conducted by Hysong (2008) which determines whether technical skill provides incremental value over managerial skill in managerial performance for first-tier managers, and explore potential mediators of this relationship. A total of 107 first-tier supervisors from local petrochemical and engineering companies completed an online survey about their professional background and managerial skills; subordinates rated supervisors' technical skill, power, and influence tactic habits. Managerial performance was measured as: production output, subordinate job satisfaction, and subordinate ratings. Salient findings showed that technical skills incrementally predicted subordinate perceptions of managerial performance over managerial skill. Referent power mediated the relationship between technical skill and both subordinate ratings and job satisfaction; expert power only mediated for job satisfaction. Technical skills were valuable to managers as a source of credibility and a means to identify with subordinates.

Another similar study conducted by Male (2010) which refers to the view that improving the development of generic competencies or skills in engineering graduates has met with barriers. One identified problem is that a relatively low status assigned to generic competencies in engineering education. The study focused on the competencies that were required by professional engineers across all engineering disciplines, in Australia, Europe, New Zealand, and the USA. The literature suggest that engineering educators should focus on developing "generic engineering skills or competencies" rather than separate generic competencies. In an eleven factor competency model developed from the importance ratings for competencies, the competency factors with the highest factor scores were Communication, Teamwork, Self-Management, Professionalism and Ingenuity. The method has been adopted within other professions to date.

Objectives and Significance of the Study

The main objective of this study was to design and develop a Pneumatic Press Station Simulator as instructional tool to improve the technical skills of students. Specifically, it aimed to determine the design specification of the simulator and its quality characteristics as well as the capability to simulate the standard functions of the machine. It also aimed to determine the level of students' skills development using the simulator.

This study would be helpful to both students and instructors. As a simulator, it would be a powerful tool for analyzing, designing, and operating complex systems. The students will be able to improve their Mechatronics skills by simulating the trainer which was based on industrial machineries. This prototype simulator could be used as instructional tool for training purposes in relation to Industrial Automation and Mechatronics. It could be a cost-effective means of exploring new processes, without resorting to pilot programs. Simulation would be a method for checking students' understanding of the world around them and helps produce better results in a faster way. It could be an efficient communication tool, showing how an operation would work while stimulating creative thinking about how it could be further improved in the future.

Methodology

This study consisted of two phases: Phase 1: the design and development of pneumatic press simulator. Phase 2: testing its efficiency, its actual use as instructional tool in developing the students' skills (Figure 1). The development of the simulator underwent a sequence of events which started with the design specification of the conveyor system. In between the conveyors was the swivel motor that was attached to the aluminum which would carry the workpiece after pressing from the conveyor 1 to conveyor 2 for distribution. The cylinder above the aluminum serves as an ejector to eject the workpiece to conveyor 2. Next task was to design the feeder magazine which included a cylinder that would push the workpiece from the magazine to conveyor 1. The housing for the cylinders that would push the workpiece from the conveyor 1 towards the swivel motor before pressing was also designed (Figure 2A). The puncher was placed in the side of the housing with a vertical clearance of 50 mm from the conveyor 1 (Figure 2B and 3A). For the purpose of simulation the cylinder was used as the puncher.

The construction of the prototype involved the assembly of the mechanical parts and both the electro-pneumatic and pneumatic as well as electrical and electronic components. Programming was done using the Siemens S7-200 Programmable Logic Controller (Figure 3B). The prototype simulator was tested at various laboratory tasks it could perform. The first task was wiring installation to show how the inputs and outputs of the system were connected. Inputs such as: start, stop (pause), reset/emergency stop pushbuttons, auto/manual switch, feeder cylinder, feeder magazine, conveyor 1 and 2, cylinders A and B, swivel cylinder, puncher and swivel motor sensors would be connected to the input area of PLC. Lamps, cylinders and motors which were considered as outputs would be connected in the output area of the PLC. The second laboratory task was commissioning to determine if outside inputs and outputs would correspond to the inputs and outputs in the PLC. The third task was the operation sequence to assess if the prototype machine can perform for auto or manual operation as well as its automatic function.

The prototype machine was also subjected to various tests for its quality characteristics in terms of efficiency, as measured by a comparison of expected output and actual output. Another quality characteristic was to test its functionality specifically the set of functions or capabilities associated with computer software or hardware or an electronic device. Each piece of equipment was tested by observing if it performed the respective tasks during operation. The precision of the prototype machine was determined. Precision was the degree to which the simulator could repeat the same measurement over a period of time. The number of workpiece that entered the system was compared with the number of workpiece that have holes. There were three trials conducted in each test for its quality characteristics.

The second phase of the study was to determine the students' level of skills development using the simulator as instructional tool. Competency skills of students were assessed in terms of installation, configuration and programming. A performance-based rubric was used as an assessment tool to determine their actual performance in the laboratory (Appendix A).

Results and Discussions

Test for Operational Sequence

The pneumatic press station simulator was found to be efficient in terms of its operational sequence for auto or manual selection as observed in all its indicators (Table 1). Using the selector switch, one can choose between automatic and manual operation. If manual mode was selected, manual lamp would turn on otherwise turn off. Likewise, if auto mode was selected, auto lamp would turn on otherwise turn off. If one of the modes was activated, one can just press reset/emergency stop pushbutton to switch the mode of operation. If emergency stop/ reset pushbutton was pressed, emergency/reset lamp would turn on otherwise turn off.

In terms of operational sequence for manual operation, all of the testing made was found to be generally efficient (Table 2). The manual lamp would turn on to signify that the operation was in manual mode. One can press start pushbutton in every sequence until the one cycle was completed. In every press of the start pushbutton, start lamp would turn on. The cylinders can be operated manually by pressing the start push button consecutively. To initiate the first press of the start pushbutton, the magazine sensor detected an object, feeder cylinder would extend and conveyor motor would turn on. Second press, feeder cylinder would extend. Third press, feeder cylinder would retract. Fourth press, conveyor 1 would run. Fifth press, conveyor 1 would stop if the conveyor sensor detects an object. Sixth press, cylinder A would extend. Object will be pushed to the swivel. Seventh press, puncher cylinder would extend. Puncher cylinder would create a hole in the object. Eighth press, puncher cylinder would retract. Ninth press, cylinder A would retract. Tenth press, swivel motor would rotate in the distribution station. Eleventh press, swivel cylinder would extend. Twelfth press, conveyor 2 would run. Thirteenth press, swivel cylinder would retract. Fourteenth press, swivel motor rotates to its initial position. The next press would start again in the first operation considering that the feeder magazine had an object. The system would not work if there was no object sensed by the feeder magazine. Pressing the reset/emergency stop pushbutton would initialize the system. If emergency stop/reset pushbutton was pressed, emergency/reset lamp would turn on otherwise turn off.

In terms of operational sequence for automatic operation, results had shown that all the testing made were found to be generally efficient (Table 3). The AUTO lamp would turn on to signify that the operation was in auto mode. Press the start pushbutton to start the operation, start lamp would turn ON otherwise turn OFF. When the feeder magazine sensed an object, feeder cylinder extended. When feeder cylinder reached its maximum position, it retracted automatically. When feeder cylinder was already in retracted position, the conveyor 1 would run. When conveyor sensor detected an object, conveyor 1 would stop and cylinder A would extend. When cylinder A reached its maximum extended position, puncher cylinder would extend.

After pressing the object, punching cylinder would automatically return in its initial position, followed by cylinder A. Swivel motor would rotate 90^0 to the right. Swivel motor would rotate 90^0 to the right. When swivel motor reached 90^0, swivel cylinder would extend to transfer the object in the conveyor 2. After transferring the object in the conveyor 2, swivel cylinder would retract, conveyor 2 would run and swivel motor would return to its initial position. After 1 cycle, the operation would start again at the beginning considering that there was an object in the feeder magazine. If there was no object sensed by the feeder magazine, the system would immediately stop working. Pressing the reset/emergency stop pushbutton would initialize the whole system.

The summary of the total cost of building the prototype included the cost of major materials, cost of minor materials, labor cost and other miscellaneous fees. (Table 4)

Test for Quality Characteristics

The pneumatic press station simulator was tested for its quality characteristics in terms of its efficiency, precision and functionality. Results had shown that the simulator was found to be 93.33% efficient in conveying the workpieces (Table 5). This could be traced back in three trials made during the testing. The simulator was found to be 86.67% precise in pressing the workpieces (Table 6). It was clear that among the three trials, both first and second trial had one error because of the improper placement of the objects in the swivel area. All throughout the testing of the equipment's functionality, it was found out that the simulator was generally functional (Table 7). Results revealed that each input and output devices of equipment performed their respective tasks effectively during testing and assessment of students' skills development.

Assessment of Students' Level of Skills Development

Students' performance was assessed to determine their level of skills development in terms of installation, configuration and programming. Results had shown that almost half of the students comprising 42% were able to finish the installation with proper placement, correct functionality of the component and have perform all the professional practices within the specified time limits- rated as "highly skilled". A good number of students comprising 44% were marked "skilled" as they performed almost the same with those evaluated as highly skilled but lagging in the installation of some parts of the mechanical device. Moreover, only very few- 7% had fair level of skills developed as manifested in their ability to install with proper placement but incorrect function of the components. Results further revealed that not one among the students was rated as "less skilled" or no skill at all.(Table 8).

In the assessment of skills developed in terms of configuration, results showed that majority of the students, or 64% were found to be skilled. This proved that they were able to connect all the wires needed to communicate the machine and controller but some of the inputs were not configured based on the practice task within the specified time limit. This result implied that there was a need to enhance these students' skills in configuration. However, only a few number of the students comprising 3% were able to perfectly perform the configuration and were rated as "highly skilled". Results further revealed that only a small number of students- - 10% were found to have less skills in configuration. Less skilled students were those who were able to connect all wires but not able to establish communication between the machine and the controller. Students who were evaluated with no skill in configuration were those who were unable to configure the machine. (Table 9).

On assessment of students' skills in programming, majority of the students' population was found to be generally fairly skilled (Table 10). Highly skilled students were those able to program and run all the operational sequence on the practice task within the specified time limit. Students are marked as skilled individuals had performed almost the same with those regarded highly skilled but there were some operational sequences they programmed that were not able to perform their functions. Students who were regarded as fairly skilled were those who finished but unable to configure some of the input and output devices needed in the practice task. Less skilled students were those able to program but unable to run the operational sequence based on the given practice task within the specified time limit. Students evaluated with no skill in programming were those who were unable to program nor able to run the simulator.

Result showed the overall performance of students in terms of skills development, majority was found to be generally skilled (Table 11). This could be traced back to their performance in the individual skills category in installation, configuration and programming.

Conclusion and Recommendations

The prototype output was found to be efficient, the equipment's parts and operational sequences were functional and the ability of the simulator's puncher was precise. The use of pneumatic press station simulator was recommended to be used as instructional tool for training purposes in relation to industrial automation and mechatronic skills development. The ability of the students to run the machine considering installation, configuration and programming were generally stated as "skilled".

It was recommended that the Pneumatic Press Station Simulator be used as device for training purposes in relation to industrial automation and mechatronics skills development. Furthermore, for further improvement of the prototype simulator, it was recommended that another control panel to station's first table part be installed to have a separate control of said devices. It would be useful if the simulator would be reproduced to accommodate a huge population of students in the process of assessing their respective skills development.

Impact of the Study

In this era of rapid technological change, skills development is always required to achieve every goal. Thus, it is inevitable that every individual has to undergo training, but skills can only be developed with appropriate and available tools and equipment, Hence the presentation of this paper.

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Figures

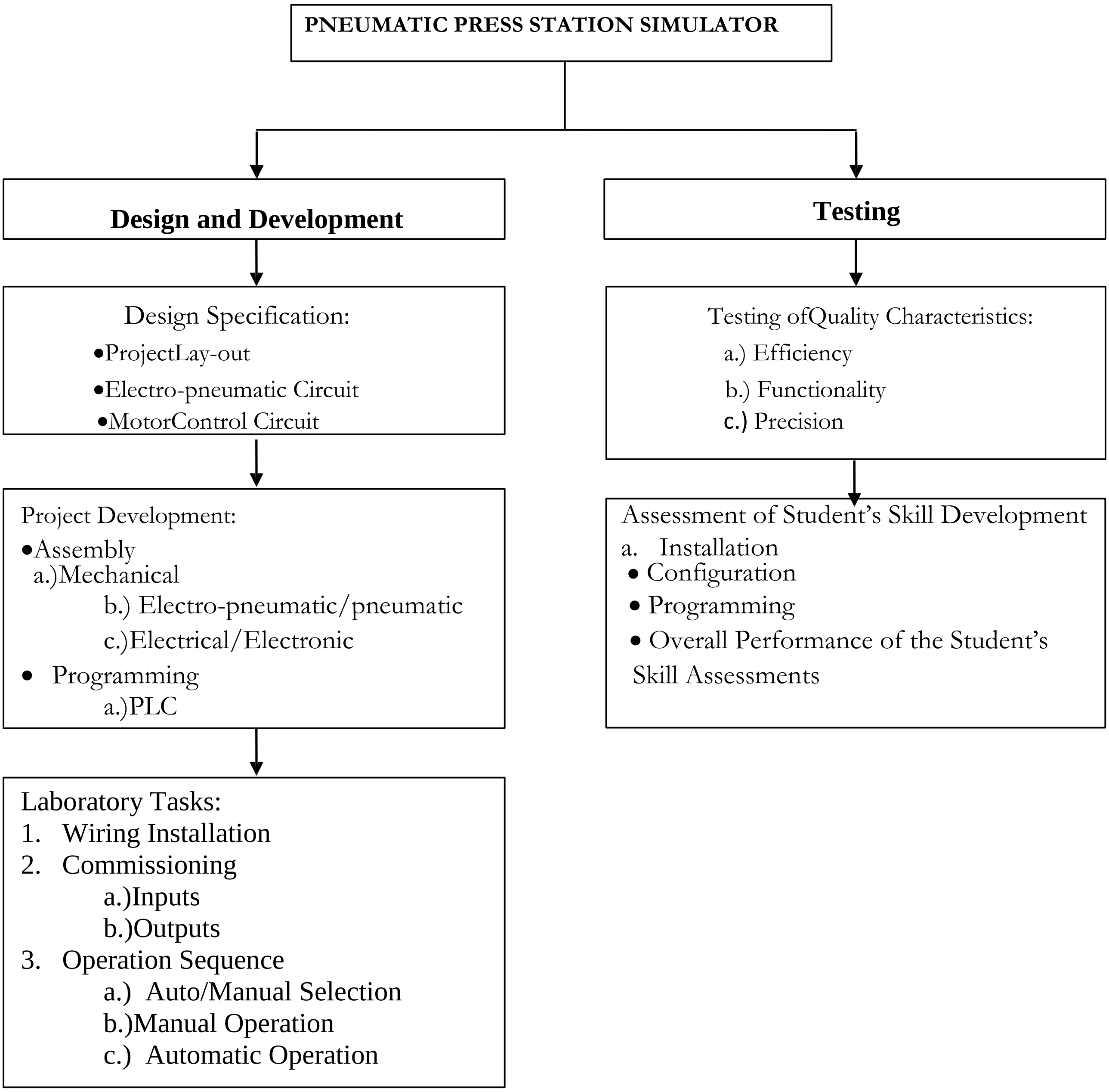
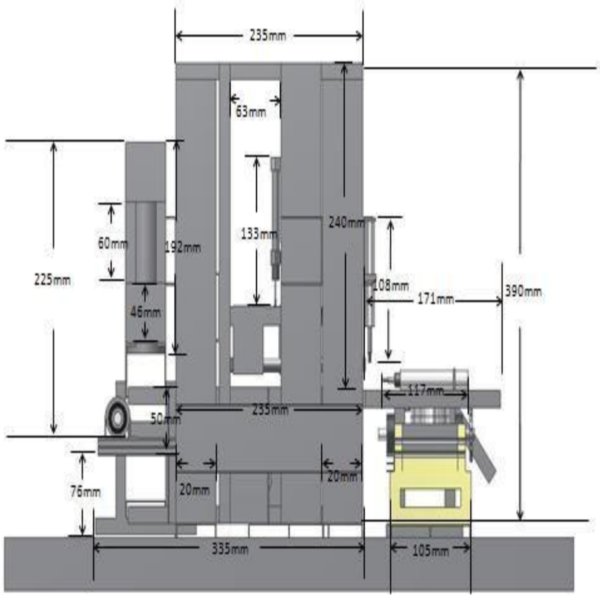


Figure 1: Conceptual Framework

Figure 2A: Project Specification (Front View) **Figure 2B:** Project Specification (Side View)



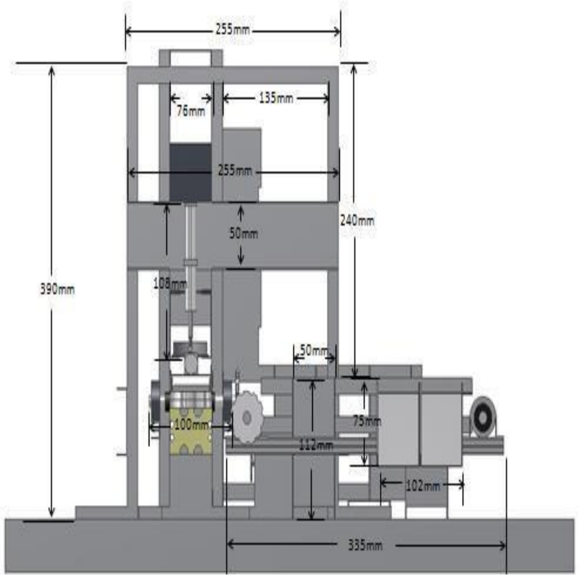


Figure 3A: Project Specification (parts)

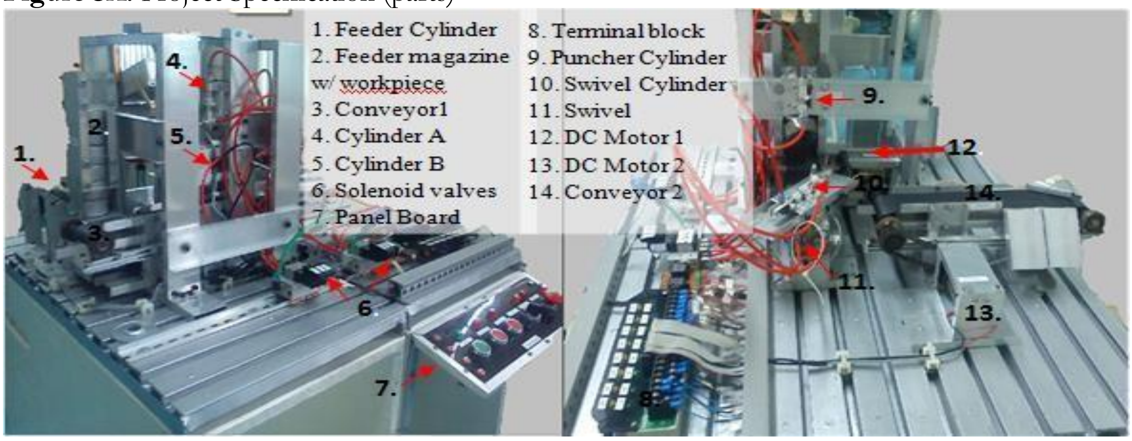
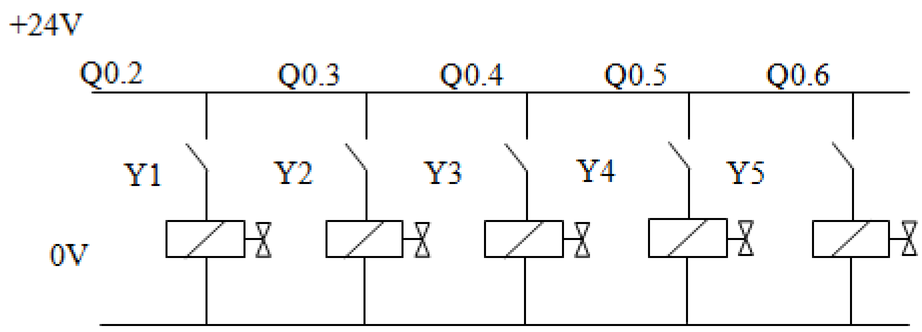
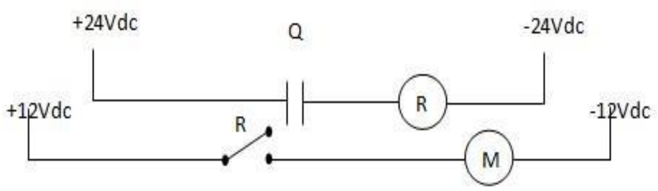


Figure 3B: Electro-pneumatic Circuit



The electro-pneumatic circuitry used in the project. The Y's represents the solenoid valve and the Q's are the actuators. These components were activated with the use of compressed air.

Figure 3C: Motor Control Circuit



The motor control circuit shows how the motors were configured in order to produce the rightful voltage rating. There were two DC motors used in the project. The DC motor was attached to the relay in order for it to produce a 12VDC rating.

Tables:

Table 1: Results of the testing made, to test the operational sequence of the simulator.

SEQUENCE	OK	NOT OK
Using the selector switch, choose between automatic and manual operation.	✓	
If manual mode was selected, MANUAL lamp would turn ON otherwise turn OFF.	✓	
If auto mode was selected, AUTO lamp would turn ON otherwise turn OFF.	✓	
If one of the modes was activated, press reset/emergency stop pushbutton to switch the mode of operation.	✓	
If emergency stop/ reset pushbutton was pressed, EMERGENCY/RESET lamp would turn ON otherwise turn OFF.	✓	

Table 2: Result of the testing made for the manual operation.

SEQUENCE	OK	NOT OK
MANUAL lamp would turn on to signify that the operation was in manual mode.	✓	
Press start pushbutton in every sequence until the one cycle was	✓	

completed.		
In every press of the start pushbutton, START lamp would turn ON.	✓	
Cylinders can be operated manually by pressing the start push button consecutively.	✓	
Initiating the first press of the start pushbutton, if the magazine sensor detects an object, feeder cylinder would extend and conveyor motor would turn ON.	✓	
Second press, feeder cylinder would extend.	✓	
Third press, feeder cylinder would retract.	✓	
Fourth press, conveyor 1 would run.	✓	
Fifth press, conveyor 1 would stop if the conveyor sensor detects an object.	✓	
Sixth press, cylinder A would extend. Object will be pushed to the swivel.	✓	
Seventh press, puncher cylinder would extend. Puncher cylinder would create a hole in the object.	✓	
Eighth press, puncher cylinder would retract.	✓	
Ninth press, cylinder A would retract.	✓	
Tenth press, swivel motor would rotate in the distribution station.	✓	
Eleventh press, swivel cylinder would extend.	✓	
Twelfth press, conveyor 2 would run.	✓	
Thirteenth press, swivel cylinder would retract.	✓	
Fourteenth press, swivel motor rotates to its initial position.	✓	
The next press would start again in the first operation considering that the feeder magazine has an object.	✓	
The system would not work if there is no object sensed by the feeder magazine.	✓	
Pressing the reset/emergency stop pushbutton would initialize the system.	✓	
If emergency stop/reset pushbutton was pressed, EMERGENCY/RESET lamp would turn ON otherwise turn OFF.	✓	

Table 3: Result of Testing the Operational Sequence Using the Automatic Operation.

SEQUENCE	**OK**	**NOT OK**
AUTO lamp would turn on to signify that the operation was in auto mode.	✓	
Press the start pushbutton to start the operation, start lamp would turn ON otherwise turn OFF.	✓	
When the feeder magazine senses an object, feeder cylinder extends.	✓	
When feeder cylinder reaches its maximum position, it retracts automatically.	✓	
When feeder cylinder was already in retracted position, conveyor 1 runs.	✓	
When conveyor sensor detects an object, conveyor 1 would stop and cylinder A would extend.	✓	
When cylinder A reaches its maximum extended position, puncher cylinder would extend.	✓	
After punching the object, punching cylinder would automatically return in its initial position, followed by cylinder A.	✓	
Swivel motor would rotate 90^{0} to the right.	✓	

When swivel motor reaches 90°, swivel cylinder would extend to transfer the object in the conveyor 2.	✓	
After transferring the object in the conveyor 2, swivel cylinder would retract, conveyor 2 would run and swivel motor would return to its initial position.	✓	
After 1 cycle, the operation would start again at the beginning considering that there is an object in the feeder magazine.	✓	
If there was no object sensed by the feeder magazine, the system would immediately stop working.	✓	
Pressing the reset/emergency stop pushbutton would initialize the whole system.	✓	

Table 4: Summary of Total Cost

Name of Cost	Amount of Cost
Cost of Major Materials	**P 9, 610.00**
Cost of Minor Materials	**P 7, 050.00**
Labor cost and other miscellaneous fees	**P 1,525.00**
Total Amount of Cost	**P 18, 185.00**

Table 5: Result found in testing the efficiency of the machine.

Trials	**Expected Output (E_0)**	**Actual Output (A_0)**	**Efficiency (A_0/E_0) x 100%**
1	5	5	100%
2	5	4	80%
3	5	5	100%
		Average Efficiency	**93.33%**

Table 6: Precision of the Simulator's Puncher

Trials	**No. of Work piece (W)**	**Time (min)**	**With Hole (WH)**	**Error**	**Precision (WH/W x 100%)**
1	5	1	4	1	80%
2	5	1	5	0	100%
3	5	1	4	1	80%
				Average Precision	86.67%

Table 7: Result of Machine's functionality

Equipment	**Functional**	**Not Functional**
Feeder Cylinder (extended/retracted position)	✓	
Cylinder A (extended/retracted position)	✓	
Cylinder B (extended/retracted position)	✓	
Conveyor 1	✓	
Conveyor 2	✓	
Puncher (extended/retracted position)	✓	
Swivel Cylinder(extended/retracted position)	✓	
Swivel motor	✓	

Table 8: Assessment of Students' Skills Development in terms of Installation

Skill Indicators	Frequency	Percentage
Highly skilled	21	42%
Skilled	22	44%
Fairly Skilled	7	14%
Less Skilled	0	0%
No skill	0	0%
	Total:	**100**

Table 9: Assessment of Students' Skills Development in terms of Configuration

Skill Indicators	Frequency	Percentage
Highly skilled	3	6%
Skilled	30	60%
Fairly Skilled	12	24%
Less Skilled	5	10%
No skill	0	0%
Total:	**50**	**100%**

Table 10: Results of Student's Assessment of Skill Development in Programming

Skill Indicators	Frequency	Percentage
Highly skilled	2	4%
Skilled	12	24%
Fairly Skilled	22	44%
Less Skilled	13	26%
No skill	1	2%
Total:	**50**	**100%**

Table 11: Result of Student's Overall Performance of Skills Development Assessment

Skill Indicators	Frequency	Percentage
Highly skilled	1	2%
Skilled	31	62%
Fairly Skilled	16	36%
Less Skilled	0	0%
No skill	0	0%
Total:	**50**	**100%**

Appendix

Rubric for Skills Assessment

LEARNING OUTCOMES	**CRITERIA**					
	HIGHLY SKILLED (5 points)	**SKILLED (4 points)**	**FAIRLY SKILLED (3 points)**	**LESS SKILLED (2 points)**	**NO SKILL (1 point)**	**Total Score**
Installation	Finished the installation of simulator with proper placement and correct functionality of the components based on the practice task, and able to perform all the professional practices within the specified time limit.	Finished the installation of simulator with proper placement and correct functionality of the components based on the practice task, but unable to perform all the professional practices within the specified time limit.	Finished the installation of simulator with proper placement having some incorrect function of the components based on the practice task and unable to perform all professional practices within the specified time limit.	Finished the installation of simulator with improper placement having some incorrect function of components based on the practice task, and unable to perform all the professional practices within the specified time limit.	Unable to perform the installatio n of the simulator.	
Configuration	Able to connect all the wires needed to communicate all the inputs and outputs of the machine and controller based on the practice task within the specified time limit.	Able to connect all the wires needed to communicate the machine and controller but some of the inputs are not configured based on the practice task within the specified time limit.	Able to connect all the wires needed to communicate the machine and controller but some of the inputs and outputs are not configured based on the practice task within the specified time limit.	Able to connect all the wires needed but there is no communicatio n between the machine and the controller within the specified time.	Unable to configure the simulator.	

Programming	Able to program and run all the operational sequence based on the given practice task within the specified time limit.	Able to program and run but some operational sequence are unable to perform its function based on the given practice task within the specified time limit.	Able to program and run but unable to follow the operational sequence based on the given practice task within the specified time limit.	Able to program but unable to run the operational sequence based on the given practice task within the specified time limit.	Unable to program and run the simulator.	
					Total Score	