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Design and Development of Inspection Test Rig with Stamping

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Abstract ***Stamping and inspection are tasks that have been done manually since the beginning of time. Doing these tasks manually is time consuming, there is a possibility of error in it and it gets hectic after a while so it cannot be performed continuously. Automation has been simplifying and reducing the possibility of error over the recent years. In this project we will be designing and developing a prototype for stamping and inspection of metal cans using pneumatics and programmable logic controller (PLC). The stamping is done using the mechanism of quick retrieval by pressurized air. We aim to inspect cans of different sizes and make the system compatible to a wider range of industries. Different sizes of cans will require different pressure while stamping which will be programmed and stamping will be done accordingly with the required pressure. We can further develop the system to automate the whole production including pouring of material in cans, lidding, packaging, stamping and sorting. This work will propose a 3D design on the electropneumatic system and all the components used will also be discussed. This article is unique due to the concept of using one conveyor belt for two different sizes of cans. With the help of this design we can design different systems which can be compatible for multiple products in different industries. This might turn out to be a great solution for small scale industries that want to automate their plants but have not been able to due to high initial cost.***

Keyword: *Automation, Inspection, Pneumatics, Stamping*

I. INTRODUCTION

Stamping and inspection are tasks that have been done manually since the beginning of time. Doing these tasks manually is time consuming, there is a possibility of error in it and it gets hectic after a while so it cannot be performed continuously. Automation has been simplifying and reducing the possibility of error over the recent years. In the modern years, industries use processes such as pneumatic stamping machine, PLC stamping machine, microcontroller-based stamping, metal sheet stamping, etc. This process is done on a conveyor belt in industries during mass production of various products. Inspection is a part of quality control in industries. There are various aspects based on which the quality of finished product is checked before finally passing it further. Traditional production lines are designed for one customized product and hence is not easily flexible. A checkweigher is a system that weighs items as they pass through a production line, classifies the items by preset weight zones, and ejects or sorts the items based on their classification.

Figure 1: Semi-automated production line [13]

There are usually 5 Main Types of Inspections in Quality Control

1. Pre-Production Inspection (PPI) where the quality control inspector visits the site of the supplier and evaluates the quality of raw materials, along with other preparations that the supplier makes for the manufacturing process.
2. First Article Inspection (FAI) during which the quality control inspector inspects the first mass productions of the product from the shop floor as well as the design documentation.
3. During Production Inspection (DPI) that is conducted once 20-50 % of the product run has been successfully completed and packed. The quality control inspector here verifies whether all agreed standards are followed during the production process and also check the consistency in the product.
4. Pre-Shipment Inspection (PSI) refers to random product checking after more than 80% of the order has been packed.
5. Container Loading Inspection (CLI) is the final stage of quality control inspection which is done during the loading of shipping containers to check if the packing is done precisely.

Conveyors have gained popularity in the recent years for different applications and modes of operations with the use of new technologies. Although conveyors play a very important role in most systems, sorting and inspection requires technologies like color sensors, robot vision, etc.

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II. LITERATURE REVIEW

Numerous papers were referred for this project. We will be reviewing a few and then drawing conclusions based on them. Atharva Patil et al. in their paper "Automatic Stamping Machine" [1] have mention that the purpose of their study was to create a new ladder diagram for the implementation of a stamping technique. Because the stamping mechanism was controlled by a PLC, it may be used in both small and large companies for faster operation and lower labor costs. A rubber stamping kit with a Fatek programmable logic controller was employed in a physical simulation. This programming software was chosen since it has its own set of features and a unique symbol. Apurva Dhoble et al. in their paper "Design and Fabrication of Automatic Stamping Machine" [2] highlight that the stamping machine is one of the most important machines in the stamping and printing industries. It is mostly used to stamp the logo or any other symbols, as the name implies. Paper stamping mechanisms are used in a variety of settings, including universities, government offices, post offices, banks, and colleges. A roller mechanism was used to feed the paper, and a basic link mechanism was used to stamp the paper. They could easily simplify the construction by employing the Geneva mechanism and a simple crank mechanism. This design was completed based on mechanical implementations. Akshay Gundawar et al. in their paper " Pneumatic Stamping Machine" [3] describe the growing importance of pneumatic systems due to its low cost and precision. They also state that as it is simple to operate it can be done by semi-skilled labour. Because of the ease with which we can control the pneumatic system, they decided to design and manufacture this pneumatic-operated equipment as their project. The project is further developed to include the function of pneumatics as well as their behaviour in a variety of ways. This machine had the benefit of working at low pressures, i.e., a pressure of 6 bars is sufficient for operation. The piston was forced out by the pressured air going through the cylinder, and its power is supplied to the work piece via linkages. As a result, the work piece received the needed dimensions. By just modifying its arm, this project could also elaborate on various applications. The general goal of the project was to deliver a portable automatic pneumatic stamping machine with a number of low-cost benefits. The system's power consumption and effective performance, as well as many other specific qualities, are not expected. The system's other goal was to have a low production cost, both in terms of cost and in terms of time. As a result, such labour is sensitive to low pricing of sale to the general public, so making such automatic stamping machines are fairly affordable to the general population. Mauton Gbededo and Olayinka Awopetu in their paper "Design and Construction of Automated Stamping Machine for Small Scale Industries" [4] proposed an automated stamping machine that was designed, manufactured, tested, and operated using pneumatic systems that included an air compressor, directional control valves, and an air service unit. The pneumatic circuit was designed and stimulated using Festo didactic's FluidSim programme, which uses the cascade method. During the fabrication procedures, engineers selected materials and methods based on engineering properties and design criteria such as safety factor, force of rotation, stress analysis, bending moments, and speed of travels. The pre-packed product is positioned at the start of the belt travel before the stamping operation begins, and the belt guide prevents the packed work from moving out of its trip owing to any external constraints. They found the machine to be user-friendly but recommend the use of cam and lever over it due the power supply issues faced in Nigeria. Thae Thae Ei Aung et al. in their paper "PLC Based Pneumatic Stamping and Item Counting System" [5] use a device to replicate and demonstrate the pneumatic stamping and item counting process sequence. Kinco K2 series PLC controls and signals the system. KincoBuilder is the programming software used by Kinco PLC. The Kinco K2 series PLC was chosen since it has its own set of capabilities and symbols. The ladder diagram programme is used to control the system. There are five varieties of PLC programming languages. In addition, a control panel is put up in the hardware to be a systematic system. The control panel contains a Programmable Logic Controller (PLC), a 24V DC power supply, eight pin relays, and connectors, as well as push buttons and pilot lamps on the front cover. This machine is functional but the cost was high and hence there could be cheaper alternatives. Bankole I. Oladapo et al. in their paper "Experimental analysis of electro-pneumatic optimization of hot stamping machine control systems with on-delay timer" [6] mention that the on-delay timer functional valve of the hot stamping machine was investigated in order to determine the many process conditions that affect it. For both pneumatic and electro-pneumatic cylinder systems, a complete physical model of the pneumatic and electro-pneumatic cylinder systems was simulated and optimized for control. To evaluate the effective use of FESTO FluidSIM® 5.1, an experimental and simulation model were developed at the FESTO work station and FESTO FluidSIM® 5.1, respectively. On both systems, the pneumatic and electro-pneumatic actuators have velocity, accelerations, displacement, and flow rate. In order to optimize the process variables, comparisons were done between pneumatic and electro-pneumatic cylinder systems on their characteristic curves. The electro-pneumatic cylinder systems outperform the electro-pneumatic cylinder systems in terms of stability and design of hot stamping machines. The results acquired help to clarify the situation. Nanang Ali Sutisna and Reza Alfarisi Firmansyah in their paper "Design of automatic stamping machine for date and dash code marking using pneumatic system and plc controller" [7] design and develop an automatic equipment for stamping the date and dash code on the master carton for blister-pack manufacturing. Because the number of existing manual processes for making master cartons was insufficient to satisfy demand, a machine was required to improve the manufacturing process by making it faster, easier to use, and maintain. In order to support the cost-cutting effort, it had to also be economical. Pneumatics were used in the design to automate the procedure, they use a system with a PLC controller.

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According to the break event point calculation, the machine saved a lot of money because it was built at a low cost and saved a lot of time. S. Kaliyaperumal et al. I their paper "Pic Microcontroller Based Automatic Stamping Machine" [8] design a machine that could stamp a greater number of papers in a given time as compared to manual work. Also, the stamping position on the paper could be adjusted according to our needs. The machine worked at a constant speed as designed in the program unit of Arduino controller. The speed could be increased or decreased by slight modification in the design procedure. The paper was fed using a roller mechanism, and the stamping was done using a basic link mechanism. Using a crank shaft and screw rod mechanism, the structure could be simplified. Bankole I. Oladapo et al. in their paper "Model design and simulation of automatic sorting machine using proximity sensor" [9] use capacitive sensors for sorting of complex manufacturing of objects having different chemical properties. As a result of this research, an automatic conveyor belt sorting item was conceived and constructed. The developed automated sorting machine could incorporate flexibility and separate species of non-ferrous metal objects while also automatically moving objects to the basket as defined by the regulation of the Programmable Logic Controllers (PLC). Plastic, wood, and steel were sorted into their correct positions with an average sorting time of 9.903 seconds, 14.072 seconds, and 18.648 seconds, respectively. Zheyao Wang and Huan Hu in their paper "Analysis and optimization of a compliant mechanism-based digital force/weight sensor" [10] explain how a thickness-shear quartz crystal resonator (QCR) and a unique compliance mechanism were used to optimize and implement a revolutionary digital force/weight sensor. The compliant mechanism, which is made up of eight flexure hinges, is utilized to secure the sensitive QCR and transfer the force detected. The inherent digital output, high resolution, great dependability, and low cost of such a sensor are all advantages. Conventional trial methods are ineffective in establishing the size of the compliant mechanism due to its complex structure and multivariable. An optimization method based on the rigid-body model, finite element method, and nonlinear programming techniques has been devised to handle this problem. It is more efficient than trial approaches in optimizing complex compliant mechanism-based sensors, according to experimental results. This technique can be used to optimize force sensors with compliant mechanisms in order to achieve the desired specifications. With the help of these and a few more papers we formulated that,

1. The stamping process is automated mostly for large scale industries and small scale industries still perform the traditional manual procedure.
2. The automated stamping processes are designed for one kind of product at a time which works with a fixed pressure and according to the code fed to the system.
3. Automation in small scale industries has to be made more affordable.

This brought upon us the idea of using a single conveyor belt for stamping of two different sizes of paint cans and then sorting them separately according to their sizes. It was also noticed that with the introduction of industry 4.0, all scales of industries are looking for automating their production process. The field of cognitive robotics is also bringing into light a huge area for research in numerous fields such as science, finance, engineering, defence, etc.

III. METHODOLOGY

After reviewing the papers and defining the scope of the project, steps to followed for the project were planned as follows:

- Review research papers
- Design of conveyor belt system
- Design of stamping system
- Validation of pneumatic system
- Design of inspection test rig
- Perform calculations and select appropriate components.
- Assemble the prototype
- Programming of PLC
- Validation of PLC program
- Testing and simulation of system
- Setup modification as per results

Metal paint cans of 2 different sizes were to be used for inspection and stamping as shown in Fig 2. Net weight of cans is 50 ml and 200 ml.

Figure 2: Metal paint cans

Initially the idea was taken by noticing a CNC machine spindle which holds multiple tools and performs operations as programmed by the operator. The basic idea was to use one single conveyor to perform stamping on both sizes of cans using a single pneumatic cylinder. The hand drawn rough sketch of the initial idea of the project architecture is shown in figure 3.

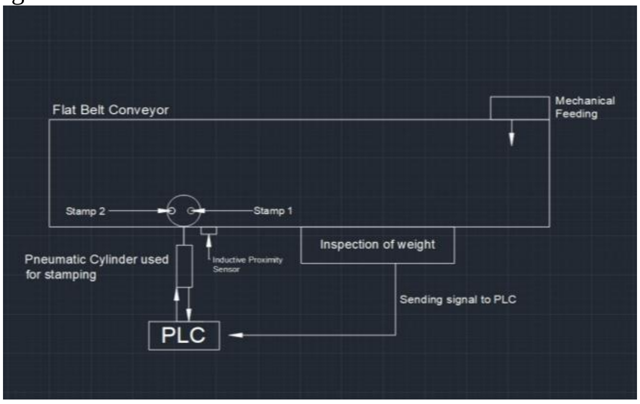

Figure 3: Initial proposed AutoCad Sketch

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After conducting further research it was deduced that a single conveyor could perform stamping on different sizes by sorting the cans initially and then either pushing them to an adjacent T conveyor or stop at the respective stamping stations at the same conveyor. The cad model was made using this ideology. We visited a local paint manufacturing company in Chakan. It is a company that manufactures paint on small scale and hence all the operations are performed manually. As the paint mixing is done by the master mixer, they mix only a single paint at a time and fill it in different sizes of cans i.e., 500ml, 1 litre and 2 litres. This operation has to be done quickly as paint dries up quickly is not packed properly. We hence, are collecting the daily production numbers and cost of production of this industry and will be developing our skid to automate their plant and will be aiming to provide them a good ROI (Return on Investment).
We also considered all the safety protocols that the industry follows and made sure our skid complies with them. We designed our model on catia v5. Figure 4 shows the design of the proposed model.

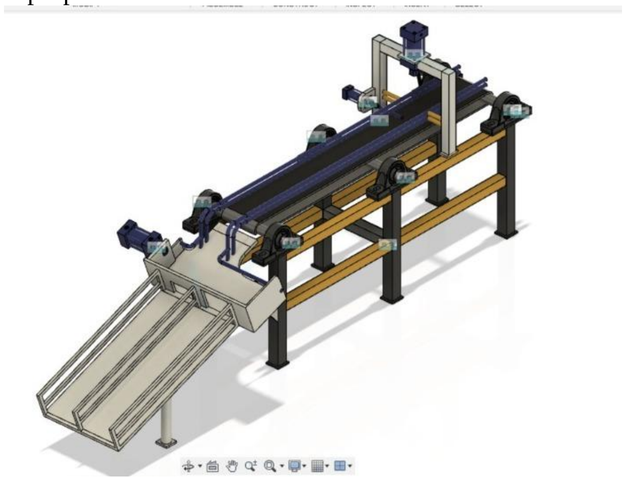

Figure 4: Design of model using catia v5

Components of the proposed skid :

1. Bearings : The basic function of bearings is to reduce the friction at the end of the conveyor belt roller for it to rotate smoothly. We used 6 permanantly lubricated mounted ball bearing for this project which is shown in Figure 5.1.
2. Supporting legs : Supporting legs were made using square tubes of thickness 1.5mm. These are responsible for supporting the skid. Figure 5.2 shows the supporting legs.
3. Belt : We will be using a belt of thickness 5mm, 105mm wide and 800mm length made of polyurethane. We decided the belt parameters with the help of standard conveyor journal. Figure 5.3 shows the belt.
4. Supporting tubes : These tube were used to connect the supporting legs and are of square thickness with 1.5mm. These are shown in Figure 5.4.

(a) **(b)**

(c) **(d)**

Figure 5 : (a)Bearing, (b)Supporting legs,(c)Belt, (d)Supporting tubes

5. Solenoid Valve : The most used direction control valves are 5/2 and 5/3. We used a 5/2 solenoid valve which had one pressure port, 2 to connect the devices to be controlled (in our case, pneumatic piston and plc) and 2 ports for exhaust. This is shown in Figure 6.

Figure 6: 5/2 Solenoid Valve

6. Indicator lights : These lights are responsible for indicationg whether there is current flowing in the skid or not. They turn red and green to indicate the same.
7. Relay Switch : They are used to open and close the circuits electronically.
8. Pressure control valve : These valves are used to contol and regulate the system pressure and hence adjust the force on a piston rod. They also make sure that the pressure is always below the upper limit of the safe pressure of the system.
9. Pneumatic piston : These will be used to for the stmaping process. They will be powered when the limit switches sense the size of the can and sends signal to the PLC.
10. Compressor : The role of compressor is to provide pressure to the pneumatic piston. We set the desired pressure according to our application and the stamping was performed accordingly.
11. Pneumatic pipes : These pipes were used to connect the piston and compressor as well as all the other pneumatic connections.
12. PLC : We used Siemens PLC for operating te system. The PLC provided 24V of input to the solenoid valve which further activated all the other parts as programmed using the ladder diagram.
13. Limit Switch : Limit swtiches are basically used to detect the absense and presence of an object in a system. We used two limit switches in te systme. One placed at the height on bigger can and one below. Due to this, when only one limit switch is acitvated, we knew it was the smaller can while when both the switches sensed presence of on object, it indicated that the bigger can is being sent.
14. Chain and sprocket : The chain and sprocket mechanism is used to transmit the power.

The block diagra m of the pneumatic circuit used in the system is shown in Figure 7.

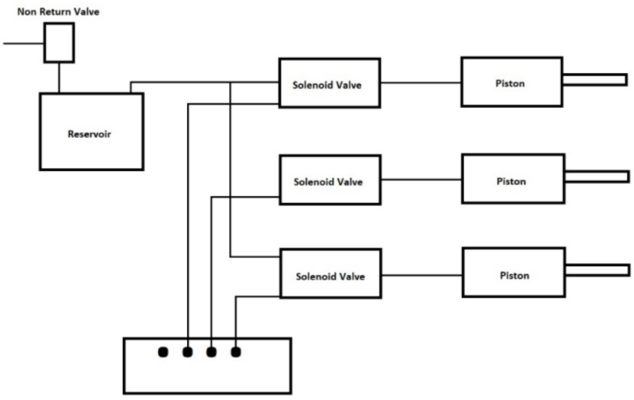

Figure 7: Block diagram of proposed pneumatic circuit

IV. RESULT AND DISCUSSION

The design of the system was validated using softwares such as ansys and fusion 360. Wherever there are support structures, we performed static structural analysis. For conveyor and shaft, modal analysis was performed which helped in vibration validation. For further safety, we performed thermal stress analysis where shaft and bearings are placed to make sure the system does not overheat. We further validated our pneumatic circuit and PLC ladder diagram using simulation in automation studio. This validated that the processes performed by us are working as expected and made it easier to test and modify the system as and when required. We aimed to increase the productivity of the local paint company. For this we performed comparative analysis by using the production quantity before automation and after automation.

V. CONCLUSION

The proposed system is compatible to all scales of industries as the initial cost might be a little high but this is a very good solution in the long run. Due to shortage of labor and the disadvantages of accuracy and long working hours not being possible, a lot of industries are aiming to move towards automation. This field opens a huge scope for research. The system can further be enhanced by using computer vision which is a complex but accurate solution. Intelligent systems are preferred due to improvement in productivity, longer hours and also preferred in areas where human lives might be at stake. This is going to be a major advance in the near future.

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