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DESIGN OF PLC CONTROLLED AUTOMATIC BAG PICKING MECHANISM FOR THE PACKAGING UNIT OF KMML

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ABSTRACT

This article reports the results of experimental study carried out at the automatic bagging unit of KMML Chavara. The automatic bagging unit used at present is inefficient and too much time is wasted while filling the bags with titanium dioxide which is their final product. The experimental study conducted revealed that the bag is not getting opened fully when titanium dioxide powder is to be poured onto it. This has lead to the invention of a new shape memory alloy gripper which is controlled by PLC. The integration of PLC with shape memory alloy actuator is the crux of this design.

1. LITERATURE REVIEW

The mechanical design of a dexterous robotic hand, which utilizes non-classical types of actuation, was presented in the article "Development of a shape memory alloy actuated robotic hand" by K. J. DeLaurentis, and C. Mavroidis [1]. The aluminum hand prototype, actuated with SMA artificial muscles, and that emulates human skeletal structures was described.

The thermo-mechanical behavior of shape memory alloys is studied in the article titled "Shape memory alloy under strain- and stress -controlled conditions thermo-mechanical aspects of the martensite and reverse transformations" by Wojciech K. Nowacki, Stefan P. Gadaj, Hisaaki Tobushi [2].The thermo-mechanical behavior of SMA reflects the exothermic character of the austenite into martensite transformation and endothermic character of the reverse one. The details regarding design and modeling of a shape memory alloy rotary actuator is given in the article titled "A new Shape Memory Alloy Rotary Actuator: Design and Modelling" by Amir Khajepour , Hamid Dehestani and Farid Golnaraghi [7].They conducted simulation , modelling and experimental study of stress ,strain relations and designed and developed a rotary actuator by using shape memory alloy springs. The paper titled "Frequency Response Analysis of Shape Memory Alloy Actuators" by Yee H. Teh and Roy Featherstone [6] describes a new method of characterising the dynamic behaviour of SMA wires based on small-signal frequency response analysis. Over a frequency range of 0.1 Hz to 100 Hz, detectable force responses from SMA wires are recorded and then processed to produce sets of Bode diagrams for different diameters of 75 ^{1}m, 100 ^{1}m and 125 ^{1}m. The experimental results show several invariant properties of the magnitude and phase responses, which allows a dynamic force model of the SMA to be determined. The paper titled “Analysis and design techniques for shape memory alloy microactuators for space applications” by Matthijs Langelaar, Gil Ho Yoon, Sham Gurav, Yoon Young Kim and Fred van Keulen [4] shows that topology and shape optimization techniques can be applied to design shape memory alloy actuators in an effective and systematic way.

2. RESEARCH GAP

While going through this survey it is found that research is being conducted in various areas of shape memory alloys like study of thermo elastic behaviour, design of actuators for robots etc. But an optimized design of robotic actuator with minimum heat transfer and maximum strain with optimized topology for a particular application is not found. In this project it is decided to design and develop an automatic bag picking mechanism which utilizes robotic gripper with shape memory alloy actuating plate. An automatic bag picking mechanism which can perform efficiently and also which can place the bag onto the spout of the automatic bag filling unit accurately is absolutely essential.A robotic gripper which utilizes shape memory alloy actuating plate can effectively grip and place the bag onto the spout of the machine and also it can handle delicate parts.

3.SCOPE OF THE PROJECT

Automatic bagging machine plays an important role in the company as any improvement in it leads to improvement in total production and profits. By employing new mechanism the overall production rate can be improved. The manpower used presently can be deployed for some other purposes. The employees also would feel happy as they would be relieved from highly polluted and dusty atmosphere. The overall profit of the company will also increase as the production rate increases.

4. METHODOLOGY

a)Design the various components of the new mechanism:The various component requirements are first analysed by using the movement requirements ,mechanism selection etc. Then the materials for the different components are to be selected by keeping in mind cost and strength requirements. By using the principles followed in design of machine elements ,the dimensions of various components are found out.

b) Make pro-e models of the various components and the final assembly:By using the dimensions already got from machine design principles ,pro-e models are made and then assembled to get the final product model.

c)Automate the mechanism by using PLC programs:Get the minimum number of effective movements and develop the PLC program and find the rpms of various motors so that the mechanism can function effectively.

d) Optimisation and validation of the design:Finally a prototype of the model is to be made and the design is to be optimised and validated.

5. RESULTS AND DISCUSSIONS

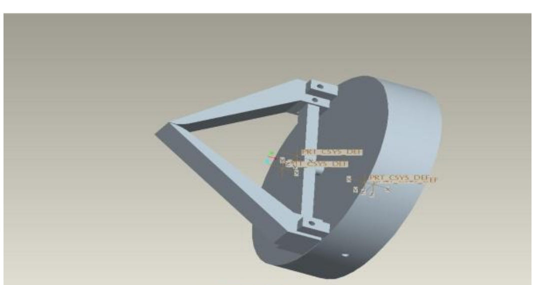

FIGURE1.GRIPPER ASSEMBLY

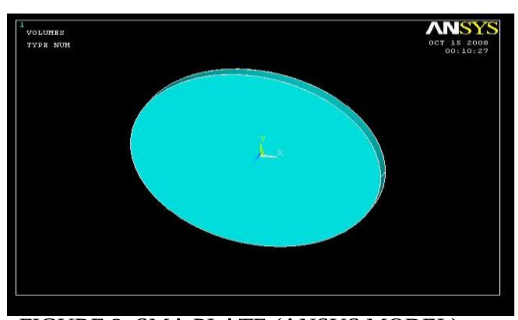

FIGURE 2. SMA PLATE (ANSYS MODEL)

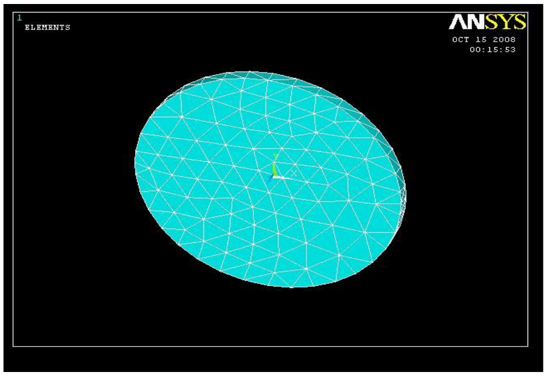

FIGURE 3. SMA PLATE (AFTER MESHING)

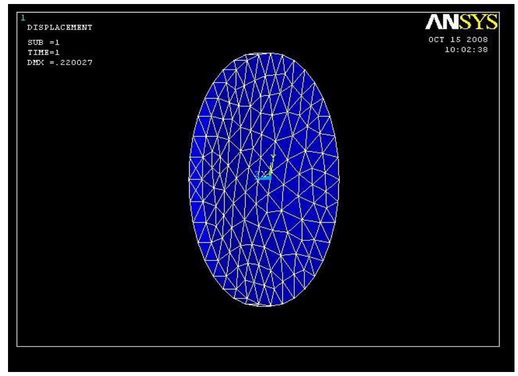

FIGURE 4. SMA PLATE(DEFLECTED VIEW)

The figures show modified gripper and SMA alloy actuating plate and its various stages of analysis by using ANSYS. Utmost care is to be taken to train SMA plate through a cycle of heat treatment. Once it is trained totally, it can be used as an actuating plate in gripper assembly.

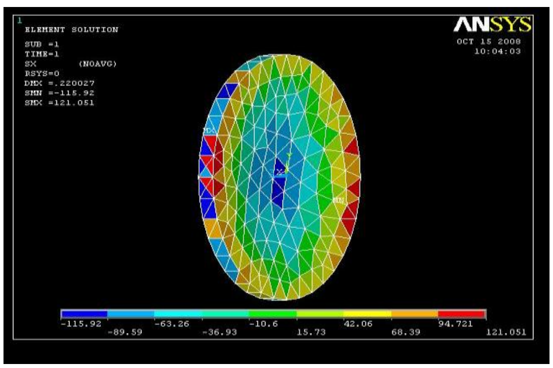

FIGURE 5. SMA PLATE(STRESS DEVELOPED IN DIRECTION)

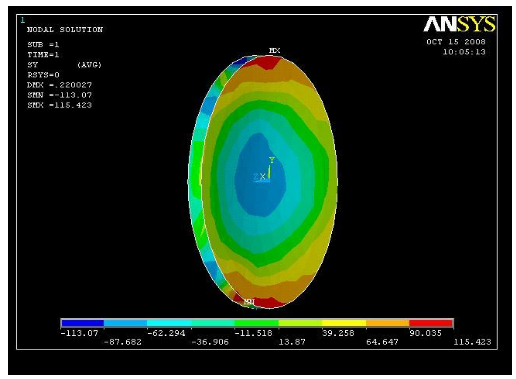

FIGURE 6. SMA PLATE(STRESS DEVELOPED IN X-Y-DIRECTION)

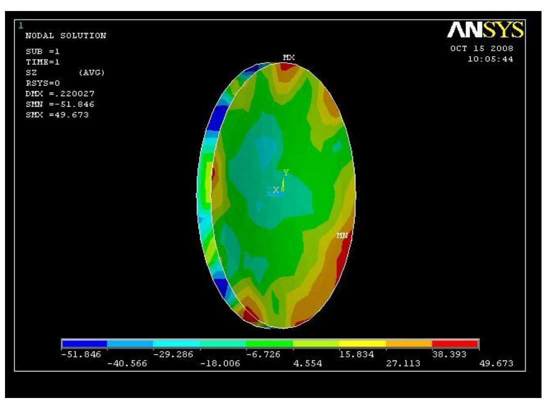

FIGURE 7. SMA PLATE(STRESS DEVELOPED IN Z-DIRECTION)

Stress analysis is done in X,Y and Z directions and found that the stresses developed are within limit in all directions for the maximum required deflection to actuate the plate. Hence the given design of actuating plate is safe.

6.THE WORK LAYOUT

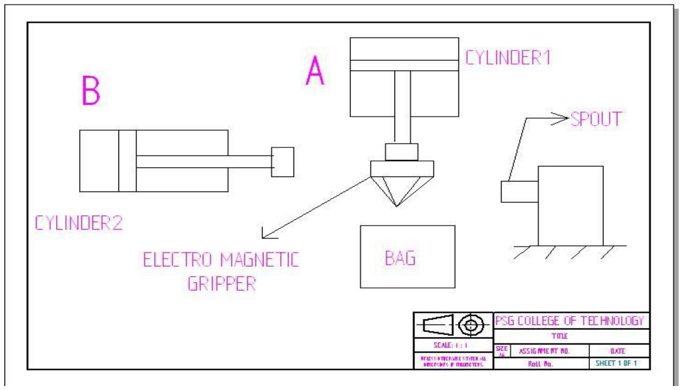

FIGURE 8. THE WORK LAYOUT

To identify the various important members of the system a work layout is created. This can be utilised to develop the sequence of various operations .The work layout consists of the following:

A) Pneumatic cylinders: They are the actuators used in the mechanism.Two numbers of pneumatic cylinders with stroke lengths of 300 mm and 600 mm are required in the mechanism.The duty of 300 mm cylinder is to move the sliding block containing the 600 mm cylinder to left and right directions.The duty of 600 mm cylinder is to raise and lower the shape memory alloy gripper.The air pressure used to actuate the cylinders is 6 bars.

B)Shape Memory Alloy Gripper:The various parts of this gripper are the gripper handle, outer shell,shape memory alloy plate and fasteners.When the shape memory alloy disc is being heated by electric current, it gets deflected and this deflection is transferred to the gripper handle through the connectors.Then the gripper handle opens up.When the shape memory alloy plate gets cooled, it goes back to its original shape and the gripper handle closes down.By using this phenomenon,shape memory alloy gripper can be used to pick and place delicate objects.This facility is utilised in the current mechanism since it has to handle delicate paper bags to fill titanium dioxide pigment.

7. PNEUMATIC CIRCUIT

Initially the circuit design was carried out by using cascade and k-v map methods.In these methods limit switches are used to automate the motion of
cylinders and as explained in the previous report, it is found that any two limit switches are in the engaged positions for different initial conditions of cylinders and because of this problem any two solenoids would be in position initially.When the press button is own,the signal comes to the respective solenoid and since the solenoid

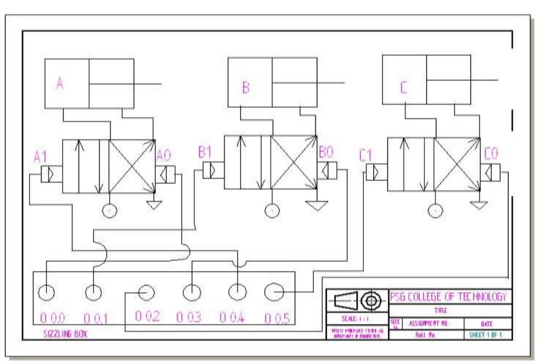

FIGURE 9. PNEUMATIC CIRCUIT DIAGRAM

on other side is already on the cylinder won't get actuated.To tackle this problem, all limit switches are eliminated in the current circuit design and the PLC program itself changed to suit the new circuit. Here timers are used to trigger different solenoids with one second time interval as per the sequence requirements.Three solenoid valves and sizzling box are required as shown in figure.As per the sequence requirements in the PLC program the connections are given to the sizzling box.If on off control is required a press button switch also can be used in conjunction .This circuit is found to be working .

8. PLC PROGRAMMING

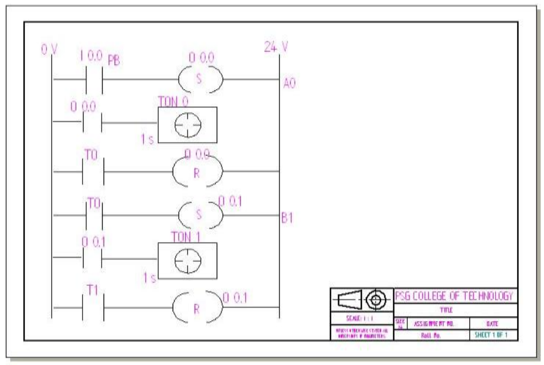

FIGURE10.PLC LADDER DIAGRAM

The figure shows various steps of PLC ladder logic programs used to automate the elements of the work lay out. Even it is a single ladder logic program it is given as three steps in diagram for the sake of simplicity.

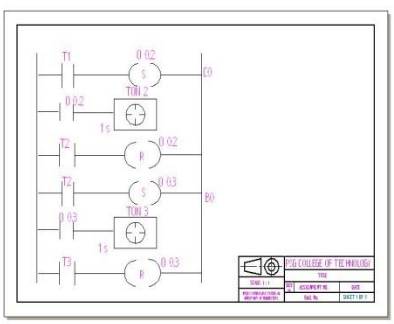

FIGURE 11.PLC LADDER DIAGRAM (CONTINUED)

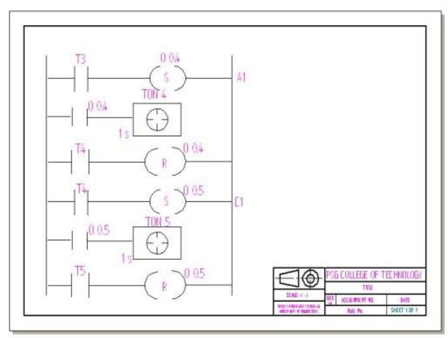

FIGURE 12.PLC LADDER DIAGRAM (CONTINUED)

The PLC ladder logic program was done separately on the installed PLC software and then downloaded to the PLC for simulation purpose.

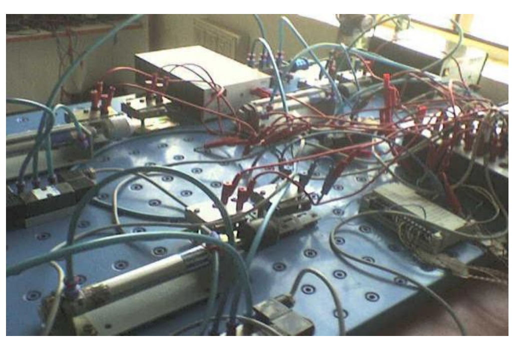

FIGURE 13. EXPERIMENTAL SET UP FOR SIMULATION

9. VALIDATION OF EXPERIMENT

As per the work layout there are two cylinders and a gripper in the work layout. Actually gripper was not available to use in the simulation set up.So to make it logically correct a third cylinder also introduced which will make the sequence of operations logically correct.PLC program for the required motion is developed by using FESTO FST 4.1 software .It is downloaded to FESTO COMPACT PLC.As per the pneumatic circuit diagram ,the circuit is made and connected to power supply and air supply.When the press button is put on ,it was found that the cylinders are working as per the required sequence.Hence it is ascertained that the PLC program is correct.

10. CONCLUSION

The various parts of the automatic bagging unit is studied during data collection at KMML and found that the existing bag picking mechanism is absolutely inefficient due to high cycle time and improper bag picking system employed.It is also found that a mechanical gripper which can pick delicate objects is absolutely essential.In this regard an extensive literature review is conducted and found that shape memory alloy robotic gripper can be actuated by external power supply source and which will serve the purpose. Therefore, in the first phase of the project a robotic gripper which uses shape memory alloy actuating plate is designed. Stress analysis of the actuating plate is carried out by using Ansys and modeling is done by using Pro-E. During sequence analysis, it is found that two numbers of pneumatic cylinders are needed for the pick and place operations. While developing the PLC program, timer relay is used to avoid the usage of limit switches, because limit switches will increase maintenance requirements and are less flexible to further programming changes. While conducting experimental validation of the PLC program, because robotic gripper was not available at that time to include in the experimental set up.So a third cylinder is used in the experimental set up to make it logically correct. The design of various components of the mechanism ,cost benefit analysis ,selection of various components as per the requirements, sequence of operations, pneumatic circuit design, development of PLC program and its validation by using simulation in lab etc carried out as per the requirements of KMML. Fabrication ,erection,c onnection with main PLC system,pneumatic system,testing and commissioning are to be done by KMML further to this project.

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