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Design and manufacture of a pick & place apparatus for manipulation of the SMD parts along with the glue head manipulation system

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Abstract. A pick & place apparatus is designed and manufactured to manipulate the Surface Mounting Devices (known as SMD) parts on the glue pattern on a flat surface. SMD parts are little resistors which transmit light whenever an appropriate voltage is applied on them. Manipulation of these small parts on a flat surface which is supposed to form an electric circuit is of a great importance. Also to locate the SMD parts on the flat surface, a glue pattern should have been produced primarily. These objectives are achieved by design and manufacture of an apparatus which manipulates the SMD parts on the flat surface. The flat surface is being located in the appropriate position under the apparatus by a CNC machine where the pick & place operations along with glue head operation is carried out.

Keywords: SMD, Pick and Place apparatus, Glue head.

INTRODUCTION

SMD is the acronym of Surface Mounting Device. The term is associated to the electronic parts which are mounted on the surface of the electric circuits, which includes the resistors, diodes, LEDs, etc. The SMD parts which are the matter of interest in this project are 2 × 1 mm resistors which have to be mounted on a flat surface to form an electric circuit. The method of mounting is by the use of glue. The apparatus contains two major actuation sections; the glue heads actuators and the pick and place actuators. This apparatus in comparison to the ordinary pick & place apparatus has the smaller volume, because of the related performance. Also the demand for integration of pick and place mechanism and glue head mechanism in on apparatus justifies a new design and manufacture.

Design problem

The SMD parts are available in the form of tapes each contains around 5000 SMDs located on a strip with a constant distance between one another. A transparent plastic cover is also protects the SMD strip which is located on the top of SMDs. While the cover is present on the SMD strip, the SMDs are in their position, but whenever the cover is removed the SMDs are loose and may be lost easily. There are small holes on the strip rather than those which are used for SMDs, of which the distance between two holes is precisely equal to the distance of two SMDs on the strip. Fig. 1a illustrates a SMD tape and Fig. 1b shows a section of SMD strip.

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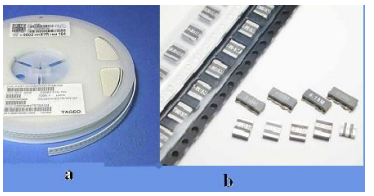

FIGURE 1a. A tape of SMD and b. A section of SMD tape with SMDs located on it

This apparatus is supposed to be assembled on a CNC machine which moves the Pick & Place apparatus to the appropriate position on the flat surface. The displacement acceleration and deceleration is about 2 m/s2. As mentioned above, while the transparent cover presents on the strip the dislocation of SMDs is prevented, but when it is removed the SMDs are loose. This makes the location where the cover is removed and the SMDs are picked very important. Also there are dimensional constraints at the position where the apparatus is supposed to be assembled; therefore the design should be as small as possible.

The other design problem is that since the SMDs are supposed to be located on a circuit on the flat surface, the perpendicularity of the placement mechanism to the flat surface is of a great importance and should be adjustable. There should be some adjustable mechanisms by which the fine tuning of the apparatus angle is possible.

The other design expectations are high reliability, beautiful appearance, appropriate cover, low cycle time, durability etc. the apparatus should be also user-friendly to the operator.

THE DESIGNED APPARATUS

The designed apparatus is illustrated in Figure 1.

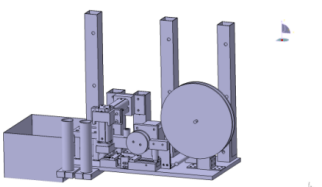

Figure 1. The designed apparatus

There are three major sub-assemblies in the apparatus: the operation unit, the apparatus cover and the power supply and control unit.

The operation unit

The apparatus is composed of the following sections: the base plate, the SMD tape, the SMD guide rail, the fork sensor, the stepper motor, the glue heads and their actuators, pick & place pneumatic actuators, SMD scrap box and the cover remover mechanism.

SMD tape

SMD tape is located on a bearing mechanism which allows the SMD tape to rotate easily. The cylindrical bar which is located near the SMD tape is used for opening and guiding the strip to the SMD guide rail.

SMD guide rail

The SMD guide rail is designed to guide the SMD strip to the sensing position and picking position while maintaining the straightness and flatness of the strip. This section is a two-part rail that the former is fixed on the base plate and the latter is assembled on the former. The reason of using such a two part rail is the exchangeability of different SMD strips which have different strip dimensions. While the flatness and straightness of SMD strip is of a great importance in sensing and picking operations, the accuracy of this part has to be ensured. Also a pusher is used to push the strip to the rail and a glass cover is used to maintain the flatness of the strip. This glass cover has some sluts and holes for picking and cover removal of the strip. The fork sensor is located at a position with an appropriate distance to the picking post.

Pick and place pneumatic actuators

This section uses two pneumatic linear actuators which places the picked SMD on the flat surface. A suction cup is used for picking mechanism. As the suction cup is located on the SMD part the suction mechanism is activated and whenever it is located on the flat surface the suction mechanism is deactivated. All the pneumatic actuators are facilitated with proximity sensors which detect whether the jack is in the fully open or fully close situation. Each time that the control unit receives signal from the sensors, the vertical actuator leads the suction cup on the top of one SMD, the suction cup is activated to pick the SMD part, the vertical actuator is closed, the horizontal actuator is opened, the vertical actuator leads the picked actuator to the flat surface, the suction cup is deactivated, the vertical actuator is closed and finally, the horizontal actuator is closed which locates the picking assembly above the SMD strip. Since the SMDs have to be located with an appropriate orientation, all the features in this sub-assembly are designed anti-rotational.Below is an example equation created with Word 97's Equation Editor. To move this equation, highlight the entire line, then use cut and paste to the new location. To use this as a template, select the entire line, then use copy and paste to place the equation in the new location. Equation labels should be flush right on line with the equation. Equations should be cited in the text as Eq. 1, Eq. 2, etc.

The fork sensor

Picking operation uses a suction cup which picks one SMD in each cycle. After picking, the SMD strip should move one step forward. The movement distance should be exactly the distance between two SMDs. As mentioned above, the SMD strip has equally distanced holes which are used for pitch sensing of the movement. A fork sensor is used therefore to sense the step movement of the strip. When a pick and place cycle is carried out by the actuators, the motor rotates until the sensor transmits a signal to the control unit. This signal stops the controller from sending pulses to the

stepper motor. In the other words, the step distance between two SMDs is detected by the rising edge signal detection in PLC program. As the PLC receives a rising edge signal, it stops sending signals to the stepper motor.

The base plate

The base plate is made of aluminum and all the fixed parts are assembled on it. The apparatus is mounted by bolts and nuts on the CNC machine using three columns located on the base plate.

The stepper motor and the cover removal mechanism

The stepper motor performs two major tasks. First, it detaches the transparent cover from the SMD strip; second, it moves the strip to the appropriate position. The cover is attached to the motor shaft in the beginning of the operation of the apparatus by the operator. The cover is removed and accumulated on a pulley mounted on the motor shaft. After a definite number of SMDs (which is counted by the fork sensor pulses), an alarm light indicates that the pulley is full and the apparatus should stop to remove the accumulated cover from the pulley.

Glue heads and their actuators

This section's task is to rub the glue on the flat surface. There are two glue heads that are being actuated by two vertical actuators located on the base plate. The glue head inject the glue pneumatically on the flat surface. The control units of the glue heads are located in the cover of apparatus at a position where the operator can check its parameters. The actuators act as the signal of activation of each glue head is transmitted to the PLC.

The cover of the apparatus

The cover of apparatus firstly protects the operation unit from pollutions and has to be beautiful. The pneumatic circuit containing all the valves, regulator, filter etc. is located in a separate floor of the cover. Some of the electrical wirings and the control units of the glue heads are also included in the cover. All the alarm lights and indicators are located on the external surface on the cover. The input, output and motor ports are also located on the top of the cover. The cover also has several doors to increase the accessibility to the apparatus parts. The electrical input and output ports are also included in the cover. The cover is illustrated in Figure 2. There are some control buttons on the cover which are used for controlling the application of the apparatus.

Figure 2. The cover of Pick and Place apparatus

The control unit

A PLC is used as the controller for the apparatus. The program contains all the actuations and sensing operations needed for performing such a cycle. The control unit also contains the power supply of the apparatus which is a 24V 5A DC power supply in which the relationship between the voltage variations versus current variations is linear and disturbing variations in the voltage are negligible. The wirings are also included in control unit. The control unit is illustrated in Figure 3. There are also some cable ports located on the upper surface of the control unit. These ports are connected to the cover and to the apparatus via 3 cables for inputs, outputs and the motor.

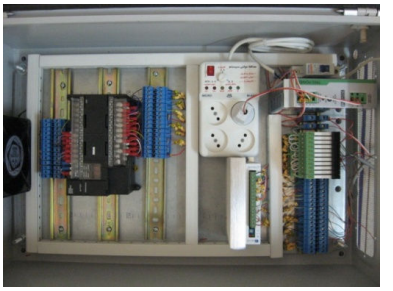

Figure 3. The control unit including power supply, PLC, relays, wirings, etc.

The apparatus cycle

Whenever the apparatus is placed in the desired position by CNC, the CNC transmits a signal to the PLC. The cycle starts as a signal is received by the PLC from the CNC machine. In the first step, the vertical actuator comes down on the top of the SMD and the suction mechanism is activated. Then the vertical actuator goes up and picks the SMD. In the next step, the horizontal actuator is activated to move the mechanism forward. Then, the vertical actuator is opened to place the SMD on the flat surface. In the next step, the suction mechanism is deactivated. There is a delay here in the cycle which is regarded to ensure that the SMD is mounted on the flat surface. In the next step, the vertical actuator is closed and then, the horizontal actuator is closed. In this moment, the motor rotates until a rising signal is received by the PLC from the fork sensor which means that the SMD tape is moved forward by one step.

Whenever it is supposed to pour the binder from the glue heads, two signals are necessary. The first signal activates the glue head actuators that moves the glue heads down on the flat surface, and the next signal activates the pneumatic actuation of the glue heads which pours the binder on the flat surface. As the second signal is removed, the pneumatic actuator is deactivated and the glue head actuator goes up to the starting point simultaneously.

In the PLC program, it is defined that whenever the counter number exceeds from 1000, an alarm light is turned on and the apparatus stops working. This is regarded for the evacuation of the trash can from the SMD tape scraps. The apparatus should be restarted again after evacuation. It is also defined that if the motor rotates 3 turns and the PLC receives no rising edge signal from the fork sensor, which means that the SMD tape contains no more SMD, the apparatus stops working and another alarm

light is turned on. After changing the SMD tape, the apparatus have to be restarted. There are also some emergency buttons and alarm lights on the apparatus cover.

MANUFACTURING OF THE APPARATUS

All the pneumatic, electric and electronic parts are provided from the best manufacturers to ensure the durability of the apparatus. Aluminum is used as the material for the other parts of the apparatus due to its low density, good machinability and beautiful appearance of the manufactured parts. The parts are assembled on the base plates. In manufacturing of the apparatus some adjustable parts are predicted to enable the user to adjust the sensors (i.e. fork sensor and actuator sensors). All the wirings in the control unit and cover are ducted to have better appearance and prevented from being cut. The input and output ports are standard ports which makes the assembly easier. The manufactured apparatus is illustrated in Figure 4.

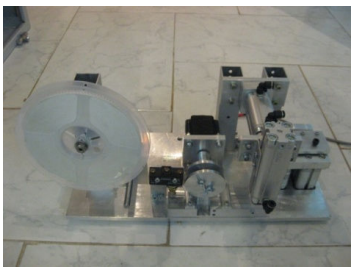

Figure 4. The manufactured apparatus

RESULTS AND DISCUSSION

The designed apparatus is manufactured and tested on the CNC machine. All the requirements are achieved due to a perfect design. The pick and place operation cycle time is about 3 seconds which is acceptable in the process. To control the pneumatic actuators speed some flow control valves are used, therefore the movement of the pneumatic actuator is quite smooth which is necessary for its operation. Since the pneumatic, electric and electronic parts (i.e. pneumatic actuators, PLC, power supply, sensors etc.) used in this apparatus are from the best manufacturers [1,2], the durability of the apparatus is ensured.

The apparatus is tested on CNC. 1000 SMD parts picked and placed without any fault. The precision of the apparatus is 0.02 mm and the accuracy is 0.01 mm. This ensures the application of the apparatus.

The perpendicularity of the suction cup to the flat surface achieved using some jack bolts located in the four locations around the apparatus. For this purpose, a frame is designed which is mounted around the apparatus and can change the orientation of the apparatus precisely and finely.

REFERENCES

1. The pneumatic catalog, FESTO.
2. www.omron-industrial.com