Based on workbench simulation to research the influence of different pin structures on the assembly of silicone rubber buttons and PCB

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Abstract. At present, one silicone rubber button and no pins nozzle structure that can be used for automatic sticking group have been developed, but the pin’s structure of the silicone button greatly affects the success rate of the sticking group and the stability after the sticking group is completed. Therefore, it is very important to research the assembly process of silicone rubber buttons with different pin structures and PCB, which has great research significance. In this paper, we used Solidworks to create three silicone rubber buttons with conical, arc, and cylindrical node pin structures respectively, used workbench to simulate the process of button pins and PCB assembly. By comparing the pressure changes of different pin structures in the process of fitting and analyzing the influence of different pin structures on the assembly process. It is concluded that the arc node pin structure is more effective.

1. Introduction
Silicone buttons were born in the 80-90th centuries \cite{1}. As a kind of connector, they are widely used in the electronics industry. Almost all electronic products require silicone rubber buttons \cite{3}, Such as electronic toys, mobile phones, computer keyboards, remote controls, controllers, car center console and other electronic products. In recent years, many researchers have done a lot of research on the silicone rubber buttons, mainly in the design and optimization of the button structure and so on. Gao \cite{3} studied the problems of buckle, stiffness, button linkage and other issues that occurred in the use of silicone rubber buttons, and proposed design principles and improvement methods. Chen et al. \cite{4} proposed a new SMT silicone rubber button and conducted a mechanical simulation analysis. He et al \cite{5} proposed a patch type silicone rubber button.

Most of the current silicone buttons are manually assembled. The traditional silicone rubber button structure generally includes positioning pins and corresponding positioning designs. During assembly, the positioning pins are manually inserted into the through holes of the PCB, and then drag the entire pin into the through hole. This assembly has the disadvantages of high cost, low efficiency, and need large work space. Although there are also buttons for SMT assembly that have been developed, they all need to change the PCB circuit according to the buttons. Moreover, most of the silicone rubber buttons assembled by SMT are patch type, and there is no corresponding technical means for plug-in
silicone buttons. Our team has invented a new button structure and no pins nozzle to solve these shortcomings, as shown in Figure 1(a), which can be used without changing the original PCB circuit and production line. Only need to use this new type of nozzle and button to achieve automated assembly, and has been successfully used in production.

2. Materials and Methods

The no pins nozzle and the new structure buttons has designed in the previous work are shown in Figure 1(a), and Figure 1(b) is the three-dimensional model of the button built by Solidworks. The button structure is mainly composed of button briquetting, an elastic oblique wall, button Pedestal, and two button pins. The main problem of this structure in the process of use is that it takes a long time to complete the assembly from the interference part to the PCB, which affects the assembly effect. The button is fixed by interference connection, which is prone to silica gel fatigue failure for a long time. Long-term use may also cause the key to slip from the PCB through hole. In view of these problems, this paper improved the design of the pin of this key structure, hoping that it can be better applied to automatic assembly.

The improved pin is no longer an overall interference connection. The interference part is designed as a node. The diameter of the upper part of the node is the same as the PCB aperture. This node can function as a fixed button. At present, there are three types of node shape designed, namely conical, arc and cylinder, as shown in Figure 2. The maximum interference is 0.1mm.

In order to verify whether the new pin structure can better adapt to the assembly, the model of the silicone button with different pin structures was established through solidworks, and the assembly process of the button inserted into the PCB was simulated by static displacement simulation of the workbench. By comparing the stress changes of different pin structures in this process, considering the actual production and manufacturing conditions and the reliability of assembly, we obtained a relatively optimal pin structure. The finite element model established according to the three different pin structure buttons is shown in Figure 3. The size of the button pedestal is 10×8×1mm, the height of button briquetting and elastic oblique wall is 2.5mm, the total length of the pin is 2.8mm, and the node height is 0.8mm.
Fig.3. The finite element model, (a) Button pin with conical node (b) Button pin with arc node (c) Button pin with cylindrical node

The material property settings of the silicone rubber buttons are shown in Table 1. Compared with the silicone rubber buttons, the PCB will have minimal impact and can be ignored. So that we used structural steel instead of the simulation. Considering the non-linear contact between the pin and the PCB through-hole contact process, the contact area is changing, and there is also a process of interference contact. The large deformation switch is turned on during simulation. The focus of the contact area is the contact between the pin node and the through-hole.

| Material of the button | Elastic Modulus (Pa) | Poisson's ratio | Density (Kg/m³) |
|------------------------|----------------------|----------------|-----------------|
| Silica gel             | 2.14E6               | 0.480          | 1200            |

3. Result & Discussion
For the simulation of the coordination between the key and PCB, the contact between the pin and PCB is mainly considered. For this pin structure with nodes, the stress states of the node at the beginning of contact with THE PCB and the node completely enter the through-hole are mainly studied. Figure 4 and Figure 5 are the pressure simulation results under these two states respectively.
Fig. 4. The pressure simulation results when the pin node is in contact with the PCB, (a) the node is a conical structure; (b) the node is an arc structure; (c) the node is a cylindrical structure

Fig. 5. The pressure simulation results when all the pin nodes enter the PCB through holes, (a) the node is a conical structure; (b) the node is an arc structure; (c) the node is a cylindrical structure
From the figures, we can see that the force-bearing area of the button and PCB assembly is concentrated in the contact position of the pin and the PCB through hole. Without considering the placement machine, other areas are basically free of force. It can also be seen that the conical structure began to contact the PCB need a little more time than arc and cylindrical structures, this is because the magnitude of interference changes faster in the conical structure.

Table 2 lists the maximum pressure values that pin nodes of three different structures are subjected to when they just contact with PCB and when they completely enter the through hole. By comparison, it can be seen that the conical structure is subjected to the minimum pressure when they just enter the through hole, which indicates easier insertion and more convenient coordination. The circular arc structure suffers the minimum pressure after the node completely enters the through-hole, which indicates that the circular arc structure is not easy to be destroyed in the process of fitting.

Table 2. The pressure on the buttons with three different pin structures when they start contact the PCB and when the node is fully entered

| Pin’s Structure                  | Conical node (Mpa) | Arc node (Mpa) | Cylindrical node (Mpa) |
|----------------------------------|-------------------|---------------|-----------------------|
| Star contact                     | 0.149             | 0.352         | 0.395                 |
| Node fully entered               | 0.746             | 0.173         | 0.202                 |

It can be seen in Table 2 that when the node is fully inserted, the pressure on the conical node pin is significantly higher than that of the arc and cylindrical node pins. This may be due to the fact that when the node is fully inserted into the through hole, the contact area between the conical shaped node and the through-hole wall is too small, almost a line is in contact with it, the stress is concentrated on this side, and the dangerous surface also appears near this side. while the contact area of the arc-shaped and cylindrical nodes is relatively larger, the pressure can be evenly distributed on the contact surface, and the dangerous position also appears in the center area of the pin node. From the simulation results in Figure 6, it can also be seen that the dangerous surface of the conical pin is on the edge of the extrusion conical and the through hole. Arc-shaped and cylindrical node pins’ dangerous surface are in the center of the pin. From this point of view, the arc-shaped and cylindrical nodes are safer and more reliable than conical nodes.

We can also see the pressure change of the conical structure is increased and the increased value is relatively large in Table 2, which is different from the change of the arc and cylindrical structures. This may be because the contact surface of the conical structure is an inclined surface. When it began to touches the through hole, the interference does not reach the maximum, and the corresponding pressure is small. When it enters completely, the through hole squeezes the inclined surface, but the actual contact surface has not increased much, the pressure is still concentrated near the maximum position of the cone diameter, and because the interference has increased to the maximum, the pressure received has increased and increased a lot. Due to the deformation of the silica gel, the arc-shaped and cylindrical structures make the non-contact position and the through hole contact and share the pressure, so the average pressure will be smaller and the change will not be large.

Through the simulation analysis of the coordination of three different pin structures with the PCB, combined with the consideration of manufacturing feasibility, the silicone button with the arc-shaped node pin structure can be better adapted to assembly, and samples were made and assembled, as shown in the figure 6.
Fig. 6. The left is the PCB assembled with this button; the right is the silicone button with the arc-shaped node pin structure

4. Conclusion
Based on the problems of the previously studied and designed buttons, the structure is improved, and a pin structure with nodes is proposed, and the buttons with conical, arc and cylindrical nodes are modeled and simulated. By comparing the pressure when the button is inserted into the PCB when using different pin structures, the pin structure of the button with the arc shape as the node is determined. Fabricated silicone buttons with Arc node pins and assembled them on the PCB.

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