Automatic Hot Pressing System for Indium Packaging

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Abstract. Hot pressing is one kind of effective assembly technology to join two parts together. Automatic hot pressing need control both temperature and pressing force precisely and programmable. In this paper, an automatic hot pressing system for indium packaging is presented, the design motivation is to made the system reliable for application in industry and reach the accuracy requirement. A screw jack with servomotor is selected to actuate the hot pressing head to generate the pressing force, a linear encoder is used to detect the displacement of the screw jack to improve its motion accuracy. A force sensor is mounted underneath the 2-D platform to feedback the pressing force in real time. The hot pressing head is made up of four heating rods and a temperature sensor to control the pressing temperature. The exchangeable manipulator is designed to pick up parts with different size and shape. The machine vision is employed to calibrate the first set of parts to make the system flexible to product variety. The experimental results shown that the maximum force error is 9 N at working load of 2000 N and the temperature error is less than ±0.3°C. The cycle time is 630 s.

1. Introduction

Assembly is the capstone process in manufacturing [1]. Currently, many efforts are made to change assembly processes from manual to automatic. Hot embossing or hot pressing is one kind of assembly technology to join two parts together. Automatic hot pressing need control both temperature and pressing force precisely and programmable. Kurita [2] proposed laser embossing complex machining for glass, and experimentally demonstrated by changing the laser irradiation conditions used to heat a mould. Lee [3] developed a hot press machine for manufacturing complex contoured components using super plastic forming and diffusion bonding technology. The maximum working height is 1500 mm and platen size is 1700×1700 mm². The capacity is 200 ton, and the maximum operating temperature is 1200°C. Chen [4] reported a press device used for hot embossing and thermal bonding of PMMA micro fluidic chips which is suitable for the fabrication of PMMA microchips. Hale[5] developed a hot embossing system for manufacturing micro scale parts, the layout of the frame is a welded steel press frame in an arch shape, The actuator is a pneumatic cylinder which can produce a maximum force of 9800 N. The heating components are two ceramic heaters. The minimum cycle time is two minutes, and the maximum embossing area is 25mm by 75mm.

Hot embossing can joining two parts made of same or different materials, and the interface material should relieve the mechanical stress and absorb the strain cause by mismatch of coefficient of thermal expansion. Indium with the low melting point of 157°C is a good candidate for interface material [6]. It is also a good choice for cryogenic joint (below -55°C) [7]. However, indium also has one serious
drawback. The bonding quality drops dramatically when indium is oxide. So place the indium to the right place automatically and pressing immediately is critical to the bonding quality. However, there are not commercialized hot pressing device for indium packaging yet. In this paper, an automatic hot pressing system was designed. Indium was selected as the interface material to hermetic package parts made of glass and aluminum alloy. Machine vision was employed to calibrate the first set of parts to make the system flexible to product variety. Screw jack with servomotor was used to actuate the pressing head to apply pressing force. Four heating rods and a temperature sensor was selected to control the pressing temperature.

2. Indium packaging system and working principle

2.1 The diagram of the hot pressing system

The designed automatic hot pressing system is used to realize hermetic packaging between an aluminum part and a glass base with indium as interface material. The requirements for the bonding system are: bonding temperature is range from room temperature to 150°C with the accuracy of ±2°C, the maximum pressing force is 1500 N with the control accuracy higher than ±10 N. To meet the requirements, the design diagram of the pressing system is shown in figure 1.

![Figure 1. The automatic hot pressing system for indium packaging (a) the diagram and (b) the setup of the hot pressing module](image)

The hot pressing system is made up of three modular. The hot pressing modular is the key component to generator pressing force and pressing temperature precisely. The machine vision and manipulator is consisted of machine vision unit and exchangeable manipulator unit. The CCD camera and the manipulator are fix together and actuated by an X-Y-Z linear stage. The worktable is a 2-D platform to support the glass base part, which can be adjusted in X and Y directions.

The indium packaging procedure is as follows: Firstly, the glass base is placed on the two-dimensional platform, then move the CCD camera to get a clear image of the hole on the glass base, record the position information of the X-Y-Z linear stage. Secondly, take the indium ring from alcohol, placed on the glass base and made the hole and ring concentric, follows by picking the aluminum part by the manipulator, the computer calculate the its displacement according to the position of the CCD camera to make the aluminum part align to the glass base part correctly. Finally, the hot pressing head is heated to the pre-set temperature, the screw jack moves down to apply the pressing force for a period of time, the hermetic packaging between aluminum part and glass base thus realized.
2.2 Pressing force applying strategy

Pressing force is the key parameter to get successful indium packaging. Servomotor drive has the advantage of high precision and easy to regulate the speed. In the designed pressing system, pressing force is applied and controlled indirectly by the hot pressing head which is actuated by the servomotor. That is, the force is controlled by the displacement of the hot pressing head and system stiffness, the pressing force applying strategy is shown in figure 2.

![Figure 2. Screw jack speed and displacement combination control for pressing force applying](image)

The servomotor and screw jack is mounted on the upper fixed plate to actuate the hot pressing head, while the latter is mounted on the movable plate to exert temperature and pressing force to the parts. Since the displacement of the hot pressing head is a crucial to packaging quality, to reach the close loop control, a linear encoder is integrated in this system. The read head of the encoder is fixed to the movable plate to get the displacement information.

The 2-D platform is mounted on the lower fixed plate to carry the parts. A force sensor is located underneath the lower fixed plate to get and feedback the force information in real time. The hot pressing head is move at a constant speed when it does not contacted the part. When the hot pressing head reaches the part, the control method changed to the stiffness-displacement method.

$$F = \int_0^d K_{eff} \cdot \Delta s$$  \hspace{1cm} (1)

Where F is the pressing force exerted by the hot pressing head; $K_{eff}$ is the equivalent coefficient of elasticity, it is depends on the system material and structure, can be measured by experiment; \( \Delta s \) is the small displacement increment of the hot pressing head.

Experiments shown that in this system, when the screw jack actuated hot pressing head is steadily contacted the part, 0.5 \( \mu m \) increment in the displacement results to about 3 N in pressing force.

2.3 Temperature control of the hot pressing head

The detailed structure of the hot pressing head is shown in figure 3. The main components are four heating rods and one temperature sensor, which are insert into the hole in the hot pressing body and fixed by the thermal conductive silica glue. The power of each heating rod is 44 W. The temperature sensor is a platinum resistance thermometer, the working temperature range from -70°C to 300°C with the accuracy class of 1/3B.

2.4 The exchangeable manipulator

If the parts with different size and dimension need to be assemblies, different manipulator should be easily changes. The exchangeable manipulator is shown in figure 4. Different tools insert into the tool change hole on the manipulator and fixes the screw, thus the tool exchange completes.
2.5 Machine vision
Machine vision was employed to calibrate the first set of parts to make the system flexible to product variety. Meanwhile, it also solves the problem of visual occlusion in alignment if the part was opaque. Put the glass base on the 2-D platform, turn on the CCD camera and adjust the 2-D platform to make the assembly mark on the glass base at the center in the image. The green line is the scale bar and the red circle is the alignment mark, as shown in figure 5. Record the exact position of the X-Y-Z linear stage and add the offset of the CCD camera and the tool, the manipulator then knows how to move the part to the right position.

![Figure 3. The explosive view of hot pressing head](image)

![Figure 4. The exchangeable manipulator](image)

3. Experiments results and discussion

3.1 The pressing force control
The pressing force is the important parameter in indium packaging quality control. Below the pre-set value may result to poor sealing performance, while large pressing force potentially harmful to the aluminum part and the glass base.

Standard force sensor was selected to measure the pressing force simultaneously with the force sensor of the system. The standard force sensor’s working range is from 0 to 5000 N, the repeatability is 0.02%FS. It is place on the 2-D platform and the two force sensor are coaxial. Moving the hot pressing head downwards to apply force and read the values of the two sensor, the experiments repeated seven times and the data listed in Table 1.

| The system value (N) | The value of the standard force sensor (N) | Max. error (N) |
|----------------------|------------------------------------------|---------------|
|                      | 1 | 2 | 3 | 4 | 5 | 6 | 7 |                      |
| 100                  | 101 | 101 | 103 | 101 | 101 | 101 | 3 |                      |
| 500                  | 507 | 508 | 508 | 507 | 507 | 508 | 8 |                      |
| 1000                 | 1004 | 1006 | 1002 | 1006 | 1001 | 1006 | 1004 | 6 |                      |
| 1500                 | 1507 | 1507 | 1505 | 1506 | 1507 | 1508 | 1505 | 8 |                      |
| 2000                 | 2009 | 2006 | 2007 | 2008 | 2006 | 2002 | 2006 | 9 |                      |

According to Table 1, the maximum error is 9 N at working load of 2000 N and can meet the design requirement, which is ±10 N at working load of 1500 N.

The fluctuation of the real pressing force may be caused by the control system, it read the force sensor each 200 ms, and calculating and feeding back the signal also need time. Reduce the reading interval may benefit the force accuracy, however it also put forward stricter demand for computer and algorithm. So concerned of economy and stability, the force control parameters were selected.

3.2 The temperature control of the hot pressing head
The temperature at the surface of the hot pressing head also influence the sealing quality. The temperature testing results is listed in Table 2. The temperature error is less than ± 0.3°C, much less than the equipment of ± 2°C. The aluminum part and the indium ring have small thermal capacity, glass base is not a good conductor, so the temperature will not have a large fluctuation when the hot
pressing head just contacts the part, the heating power also sufficient to make up the heat loss in the force holding process.

In indium packing experiment, the temperature is controlled at 120°C constantly, the pressing force is ramped increased to 900 N, and the results is shown in figure 6. The cycle time for each packaging is 630 s, including 300 s as hold time required by the packaging technique.

| Sensor temp. (°C) | 30 | 50 | 70 | 90 | 110 | 130 | 150 |
|-------------------|----|----|----|----|-----|-----|-----|
| Thermometer temp. (°C) | 30.2 | 49.8 | 70.1 | 89.7 | 109.8 | 129.9 | 150.2 |
| Deviation (°C) | 0.2 | -0.2 | 0.1 | -0.3 | -0.2 | -0.1 | 0.2 |

Figure 5. The alignment of the parts

Figure 6. The packaging result

4. Conclusions

An automatic hot pressing system for indium packaging is presented in this paper. The motivation is to make the system reliable for industry application, meanwhile meet the design requirements. The pressing force is generated by screw jack with servomotor. The force sensor is mounted underneath the 2-D platform to get the pressing force in real time. The hot pressing head is made up of four heating rods and the temperature sensor to control the pressing temperature. The exchangeable manipulator is designed to pick up parts with different size and shape. The machine vision is employed to calibrate the first set of parts. The maximum force error is 9 N at working load of 2000 N and the temperature error is less than ±0.3°C. The cycle time of packing is 630 s. Future work will be focus on study the sealing quality of the indium and adjust the pressing parameters.

5. Reference

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Acknowledgments

Authors wishing to acknowledge the financial support of Major Project of Basic Scientific Research of Chinese Ministry (Grant No. JCYK 2016 205 A003).