

PAPER • OPEN ACCESS

Computer aided design and simulation of the amplification structure of 3D electronic packaging printer

To cite this article: Haitao Gao *et al* 2020 *J. Phys.: Conf. Ser.* **1650** 032160

View the [article online](#) for updates and enhancements.

You may also like

- [Metrological characteristics for the calibration of surface topography measuring instruments: a review](#)
Richard Leach, Han Haitjema, Rong Su et al.
- [Backscattering amplification of laser radiation in a medium with fluctuations of the imaginary part of permittivity](#)
R Kh Almaev and A A Suvorov
- [Calibration of the scales of areal surface topography measuring instruments: part 2. Amplification, linearity and squareness](#)
Claudiu L Giusca, Richard K Leach and Frank Helery



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Computer aided design and simulation of the amplification structure of 3D electronic packaging printer

Haitao Gao¹, Zhiwei Liu¹, Yu Meng², Qi Li¹, Xiong Yue¹, Fengmei Liu^{1,*},
Likun Li¹ and Yiyao Yong¹

¹Guangdong Provincial Key laboratory of Advanced Welding Technology,
Guangdong Welding Institute (China-Ukraine E.O. Paton Institute of Welding),
Guangzhou 510650, China

²Xi'an Jiaotong University Suzhou Institute, Suzhou 215123, China

*Corresponding author: liufm@gwi.gd.cn

Abstract. 3D electronic packaging printer can realize the transformation of electronic packaging from 2D to 3D, and it is a very important new device in the electronic industry. The amplification structure is the key part of it. In this paper, by means of geometric calculation, computer aided design and simulation, an improved rhombic 3D design drawing and key design parameters of the amplification structure are obtained. The rhombic amplification structure is simulated by finite element simulation method, and the simulation amplification coefficient is 9.05, which is consistent with the design amplification coefficient of 9.36. The displacement output diagram and stress cloud diagram show that the displacement and strength of the rhombic amplified structure conform to the service requirements of 3D electronic packaging printer.

Keywords: Computer aided design, amplification structure, 3D electronic packaging, printer.

1. Introduction

With the development of precision, miniaturization and high functional characteristics of electronic equipment and products, the circuit board integration is getting higher and higher. For example, the volume of Huawei 5G base station is only half that of 4G base station, while the capacity increases by 20 times. These changes pose a major challenge to surface assembly technology (SMT), which is the basic technology in the electronics industry [1]. More and more precision small-volume electronic devices can only meet the requirements of 3D and high-density packaging circuit boards, and 3D electronic packaging printer is a key device to realize 3D and high-density electronic packaging [2, 3]. 3D Electronic packaging printers have been on the market for less than 10 years, and it is not mature in terms of overall design, key structure and printing materials. There are some problems such as low service life of key parts, easy blockage of nozzle and poor printing quality [4, 5]. The amplification structure is the core structure of printing equipment, which directly determines the main action of solder paste spraying, the shape of printing solder paste spraying, the design of driving unit and the control of the whole machine. However, up to now, the design of the amplification structure is still immature, which has become the bottleneck of the whole machine performance of printing equipment. Therefore,



the study of the amplification structure is very necessary and urgent, which has important scientific value and practical significance. Based on the theory of piezoelectric ceramics and computer-aided design, this paper studies the working characteristics and main design parameters of a new improved rhombic amplification structure, and studies the displacement output diagram and stress cloud diagram of rhombic amplification structure with finite element method.

2. The research methods

Based on the calculation of piezoelectric ceramics, the 3D design software is used to design the amplification structure in the printing device, and then the mechanical analysis of the amplification structure in the printing device is carried out by the simulation analysis software.

3. The results and discussion

3.1. Selection and comparison of the amplification structure of 3D printer

The shape variable of the piezoelectric ceramics is only 0.1% of its own deformation length. The solder paste printing device requires the firing pin displacement to be 0.3-0.5mm. Therefore, it is necessary to amplify the structure to achieve the firing pin displacement. At present, the displacement amplification structure mainly includes lever structure, hydraulic amplification structure and triangle structure [6].

The advantage of lever amplification structure is that the response frequency is high, which can achieve a large amplification factor. The disadvantage is that the external size is large, which is not suitable for the design of micro-precision structure.

The hydraulic amplification structure can achieve a large amplification multiple, but its response frequency is low, which is not suitable for the design of rapid micro-jet structure.

Compared with lever amplification structure, triangular amplification structure is more compact and has good amplification performance and dynamic characteristics. However, coupling displacement will be generated when displacement amplification is realized. Therefore, based on the amplification principle of triangular structure, this paper adopts a symmetrical design method to avoid coupling displacement. The amplification structure is rhombic, which has the advantages of large amplification multiple and good linearity. At the same time, the enclosed structure can be assembled with the piezoelectric ceramics to form independent driving elements for easy installation.

3.2. Parameter calculation and CAD of the amplification structure of 3D printer

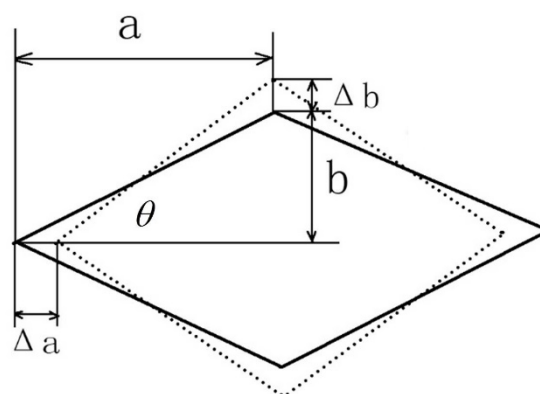


Figure 1. Calculation diagram of rhombic structure

Fig. 1 is the calculation diagram of rhombic structure. a is the long half axis of the rhombic structure, b is the short half axis of the rhombic structure, Δa is the change in the horizontal direction and Δb is the change in the vertical direction of the rhombic structure.

According to the calculation diagram of rhombic structure, the formula (1) can be obtained.

$$a^2 + b^2 = (a - \Delta a)^2 + (b - \Delta b)^2 \quad (1)$$

After sorting out the above formula, formula (2) can be obtained.

$$2a\Delta a = 2b\Delta b + \Delta a^2 + \Delta b^2 \quad (2)$$

After omitting the infinitely small quantities of Δa^2 and Δb^2 of high order in equation (2), the amplification factor A of the rhombic structure can be calculated, as shown in formula (3).

$$A = \Delta b / \Delta a = a / b = 1 / \tan \theta \quad (3)$$

The simplified rhombic amplification factor A is shown in formula (4).

$$A \approx 1 / \tan \theta = \cot \theta \quad (4)$$

As can be seen from formula (4), when the deformation of rhombic structure is smaller, the magnification factor A is only related to angle θ , and the magnification factor A decreases with the increase of angle θ . But when the deformation is larger, the error calculated by the above approximation method will be larger.

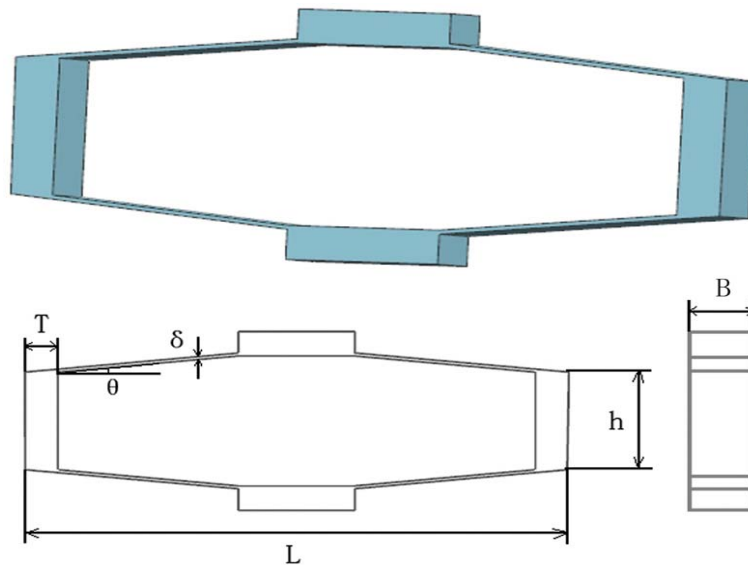


Figure 2. CAD optimization rhombus magnification structure drawing and engineering drawing

Fig. 2 is the optimized rhombic amplification structure diagram and engineering diagram. Angle θ is the horizontal inclination Angle, δ is the wall thickness, B is the outline width, T is the side thickness, and h is the side height.

When the length of the piezoelectric ceramics changes in the horizontal direction, the diamond-shaped structure deforms in the vertical direction. The deformation in the direction of the short axis of the rhombic structure is larger than that in the direction of the long axis. Therefore, the displacement amplification in the direction of the short axis can be realized by installing piezoelectric ceramics in the direction of the long axis of the rhombic structure.

The amplification factor of the improved rhombic structure is not only related to the inclination angle θ , but also to the wall thickness δ and the side thickness T . Moreover, the amplification factor decreases with the increase of δ and increases with the increase of μ .

When the length of the piezoelectric ceramics changes in the horizontal direction, the rhombic structure deforms in the vertical direction. The deformation in the direction of the short axis of the rhombic structure is larger than that in the direction of the long axis. Therefore, the displacement amplification in the direction of the short axis can be realized by installing piezoelectric ceramics in the direction of the long axis of the rhombic structure.

After calculation and design, the main parameters of the rhombus amplification structure are: dip angle $\theta = 6.1^\circ$, wall thickness $\delta = 0.62$ mm, side thickness $T = 5.10$ mm, shape width $B = 10.10$ mm, and magnification factor $A = 9.36$.

3.3. Mechanical analysis of the amplification structure of 3D printer

The rhombic amplification structure designed in this paper is made of spring steel 65Mn, which has high strength of extension and good elasticity.

The finite element analysis method was used to conduct mechanical analysis of the diamond shaped amplification structure. In the simulation process, full constraints were applied to the upper and top surface of the amplification structure, while the vertical degree of freedom was maintained for the lower end surface. The equivalent horizontal displacement of 20 mm was applied to the inner part of the amplification structure.

The simulation results are shown in Fig. 3. In figure (a), the maximum output displacement of the lower end face of the amplifying structure is $362.13 \mu\text{m}$, and the amplification factor is calculated to be 9.05, which is consistent with the design amplification factor of 9.36. In figure (b), the maximum stress value of the amplifying structure is 69.89 mpa, which is far less than the tensile strength of the spring steel material. It has a sufficient safety margin difference and meets the design requirements.

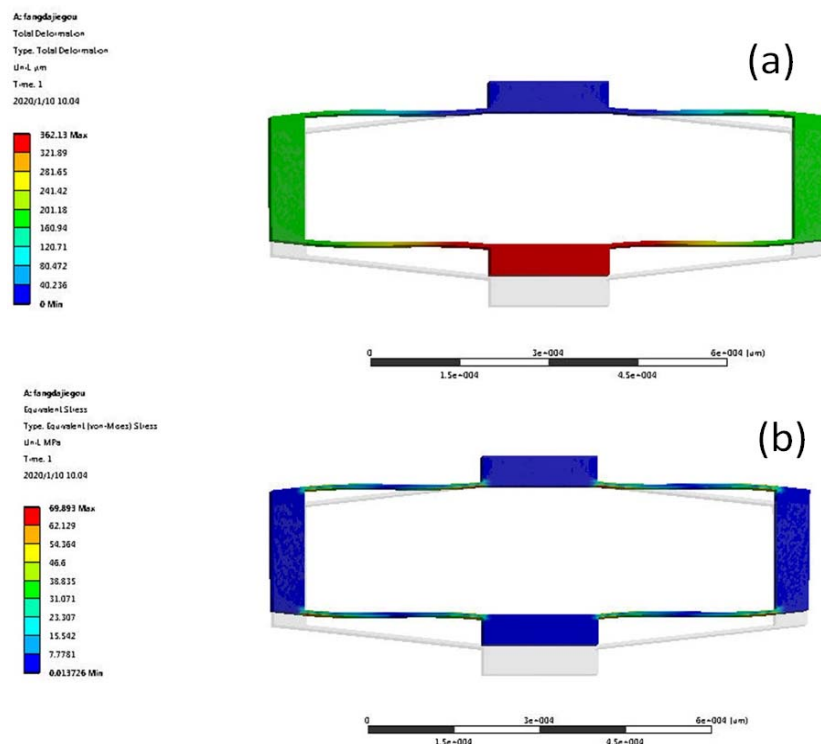


Figure 3. Mechanical simulation diagram of rhombic amplified structure: (a) is the output diagram of the amplification structure displacement, (b) is the stress cloud diagram of the enlarged structure.

4. Conclusions

According to the working characteristics of 3D electronic packaging printer and the working principle of piezoelectric ceramics, the optimized rhombic structure was selected for the amplification structure of printer. Main design parameters of rhombic amplification structure: dip angle $\theta = 6.1^\circ$, wall thickness $\delta = 0.62$ mm, side thickness $T = 5.10$ mm, shape width $B = 10.10$ mm, and amplification factor $A = 9.36$. The amplification factor of finite element simulation is 9.05, which is consistent with the design amplification factor of 9.36. The displacement output diagram and stress cloud diagram show that optimization rhombus magnification structure meets the service requirements.

Acknowledgments

This work was financially supported by the GDAS' Project of Science and Technology Development (2020GDASYL-2020103123, 2020GDASYL-20200402006, 2017YFB0305700, 201807010029) and the Natural Science Foundation of Jiangsu Province (BK20180240).

References

- [1] Alejandro H. Espera Jr., John Ryan C. Dizon, Qiyi Chen, 3D-printing and advanced manufacturing for electronics, *Progress in Additive Manufacturing*. 4 (2019) 245 – 267.
- [2] Siddharth Ravichandran, Shuhei Yamada, Tomonori Ogawa, Design and Demonstration of Glass Panel Embedding for 3D System Packages for Heterogeneous Integration Applications, *Journal of Microelectronics and Electronic Packaging*. 16 (2019)124 - 135.
- [3] C Bailey, S Stoyanov, T Tilford, 3D-printing and electronic packaging, 2016 Pan Pacific Microelectronics Symposium (Pan Pacific).
- [4] Nathan Lazarus, Sarah S. Bedair, Sami H. Hawasli, Selective Electroplating for 3D-Printed Electronics, *Advanced Materials Technologies*. 4 (2019) 1900126.
- [5] Saikat Mondal, Mohd. Ifwat Mohd. Ghazali, Kanishka Wijewardena, 3D Printed Interposer Layer for High Density Packaging of IoT Devices, 2019 IEEE 69th Electronic Components and Technology Conference (ECTC).
- [6] Lu S Z, Yao Y F, Liu Y X, Zhao Y T, Design and experiment of a needle-type Piezostack Driven Jetting Dispenser based on lumped parameter method. *Journal of Adhesion Science and Technology*. 29(2015) 716 - 730.