

Design of Bounding Head of IC Chip Bonder with Flexible Hinges

Straight-line Buffer Mechanism

Li Ketian Liu Ji'an Chen Xin Weng Jizhao

Guangdong University of Technology, China

Guangzhou, Guangdong, 510006

00860203932477, Liketian@gdut.edu.cn

ABSTRACT

Bonding head is the key part of the die-bonder, it picks up die in wafer, and transfers and places the die into leadframe. In the moment of picking and placing, it exerts force against die. In order not to shatter the die during the quick contact, the bonding head must not only have exact structure and be controlled by precise movement, it also must have good buffering function and rigidity. This paper puts forward a kind of bonding head with flexure hinge straight-line buffer mechanism, it discusses the structure principle and analyzing result. The approximation formula of the bonding head spring structure is deduced. a FEA analysis of the displacement and the stress by using COSMOSworks embedded in SolidWorks have been made. A serial of dimension was obtained.

Keywords: buffer, flexible, hinge, bonder, and FEA

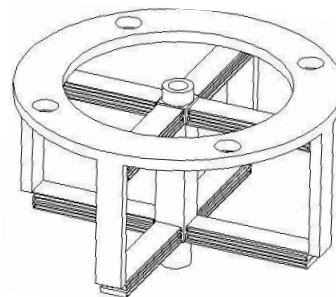
1. Introduction of the bonding head with flexible hinges straight-line buffer mechanism

Bonding head is the main component of the IC chip Die-bonder. The suction nozzle of the bonding head sucking the chip up from wafer, transmits it to the bonding position. And then the chip is bonded to the heated leadframe^[1]. When sucking and bonding the chip, the suction nozzle presses the chip. For the chip not be destroyed when the suction nozzle is touching the chip, the bonding head buffer mechanism must offer buffer function while pressing the chip.

Some traditional bonding heads use cantilever as buffer. Some put the bonding head in one end of the cantilever, while in the other end using hinge as buffer. The bonding head in those kinds of structures move in an arc trajectory. It will affect the performance of the bounding head. Some use linear

rolling guide between bounding head and the sustaining arm. This kind of structure is expensive and difficult to manufacturing. High frequency alternating between high and low temperature areas will invalidate the rolling element and the lubricant.

Flexible hinge is suitable to be used in Micro-electro-mechanical System. It has some advantage such as low volume, light weight, without any rigid kinematic join component, needn't



**Fig.1 Bonding head with Flexible Hinges
Straight-line Buffer Mechanism**

lubricating, avoiding pollution, without assembling, low maintenance, no wear, long life etc. ^[2]

A new kind of bounding head with flexible hinge is proposed in this paper. Fig.1 is the structure. In the middle of it is the suction nozzle (or bonding head). Around the suction nozzle there is some springs link with the frame. The suction nozzle can move in vertical direction in a short distance, but nearly can not move in horizontal direction. So it can avoid those disadvantages in traditional structure.

2. The thickness and the width of the spring

Define the vertical displacement of the bonding head is $s=1\text{mm}$, the force on it is P_{bond} . The number of the elbow is n . Assume the spring is constructed by beam. That how many beams there means there are how many elbows. So the number of the beam is $n+1$, only one beam more than the number of the elbows.

In estimation, every layer of the spring is assumed to be a single beam. The width of it is b and

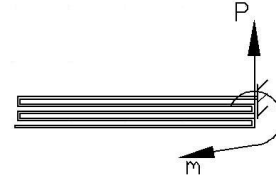
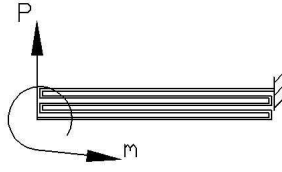
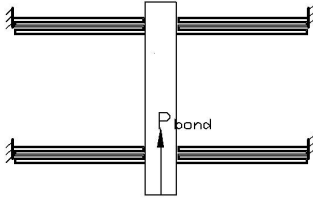


Fig.2 Force on the bounding head Fig.3 The force on one spring Fig.4 Force on the next to the last sheet

The vertical force on the bounding head is P_{bond} . There are 8 pieces of spring totally. Every piece of spring bears the force $P=P_{\text{bond}}/8$. The elasticity modulus of the material is E . The displacement of each piece of spring can be calculated as follow:

$$s_1 = \frac{Pl^3}{3EI}$$

As there is no hinge between the spring and the suction nozzle, the spring can not rotate relatively with the suction nozzle. Here assumes they are perpendicular with each other. The torque each layer of the spring bear is $m=P \times l/2$. The displacement of each layer is:

$$s_2 = -\frac{ml^2}{2EI} = -\frac{Pl^3}{4EI}$$

the thick is h . The moment of inertia can be calculated as follow:

$$I = \frac{bh^3}{12} \quad (1)$$

The vertical force on the bounding head when it works shows in Fig.2. Define the displacement of the bounding head is s . For it is easier to be calculated, assume every lay of the spring is the same length l . When the bounding head is loaded, the load in every sheet of the spring is nearly the same. The force on the last sheet of the spring and the force on the next to the last layer of the spring are shown in Fig.3 and 4. They all sustain the same quantity of strain p and torque m . There are $n+1$ layers of spring sheet. The distance between them must insure that they will not touch each other. The displacement of every layer is $\frac{s}{n+1}$. The minimum

of the distance can be calculated as follow:

$$d = \frac{2s}{n+1} \quad (2)$$

The displacement of the joint between the edge of the spring and the suction nozzle is as follow. It is the sum of every layer's displacement.

$$s = (s_1 + s_2) \times (n+1) = \left(\frac{Pl^3}{3EI} - \frac{Pl^3}{4EI} \right) \times (n+1) \quad (3)$$

According to Equation (1) and (3), the width is as follow:

$$b = \frac{l^3 \cdot P \cdot (n+1)}{s \cdot E \cdot h^3} \quad (4)$$

According to the practical needs, the stress $P_{\text{bond}} = 0.05\text{kgf}$. So $P = P_{\text{bond}}/8 = 6.25\text{gf}$. The length $l = 20\text{mm}$. Vertical displacement is $s = 1\text{mm}$. Material is chosen as aluminum 201.0-T6 (SS)

from COSMOS material library. Elasticity modulus of know from Equation (1) that inertia moment is it is 70.999997GPa. The yield strength is 435MPa proportional with the width of edge dimension in cross According to the calculation by COSMOS, it is section. To insure the vertical stiffness is 10 times chosen that the vertical stiffness is ten times as much larger than the horizontal stiffness, so $b/h > \sqrt[3]{10}$, as the radial stiffness, then the quantity of the spring Data are educed in Tab.1~3.

elbow must be fewer than 6. If the thickness and the number of the elbow are decided, the width of the spring can be calculated by Equation (4). We can

Tab.1. The width of the spring	Width b (mm)	6.0387	3.4946	2.2007	1.4743	1.0354	long and dimension of with six elbows
	Thickness h (mm)	0.2	0.24	0.28	0.32	0.36	

Tab.2. Long and width dimension of the spring with four elbows

b (mm)	4.3134	2.4962	1.5719	1.0531
h (mm)	0.2	0.24	0.28	0.32

Tab.3. Long and width dimension of the spring with two elbows

b (mm)	2.588	1.4977	0.94316
h (mm)	0.2	0.24	0.28

3. Stiffness of the model in COSMOS

It is chosen that spring with four elbows, the thickness is 0.2mm for example. COSMOS which is the plug-in of SOLIDWorks is used for analysis^[3]. Blend grid is used. Shell grid is used in the spring, and solid grid is used in the bounding head. Choose FFEPlus option and large displacement option in COSMOS.

3.1 Vertical and radial force on the nozzle at the same time

For calculating the ratio of the vertical and radial stiffness, the same large force $P_{\text{bond}} = 0.05\text{kgf}$ is applied on the bottom of the bounding head. The computing results of vertical and the radial displacement of the bounding head are shown as Fig.5 and Fig.6:

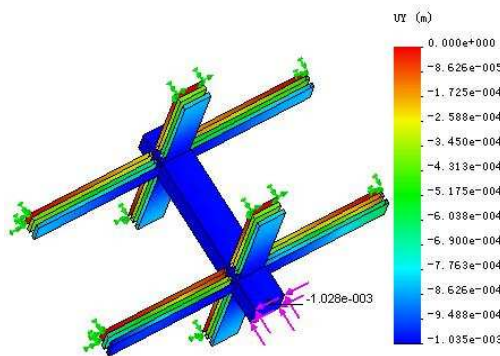


Fig.5 Vertical displacement

Several random points in the bottom of the bounding head is detected; the result could

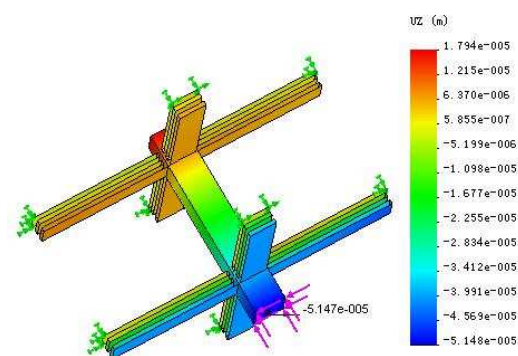


Fig.6 Radial displacement

be seen in Tab.4:

Tab.4. Several random points in the bottom of the bounding head

Nod	Vertical displacement(m)	Radial displacement(m)	X(mm)	Y(mm)	Z(mm)
4938	-1.028E-03	-5.147E-05	-2.8	5	2.4
4948	-1.028E-03	-5.147E-05	-2.4	5	2.4
713	-1.025E-03	-5.147E-05	-1.6	5	3.84
4906	-1.030E-03	-5.146E-05	-1.2	5	1.44
4861	-1.031E-03	-5.146E-05	-3.6	5	0.96

3.2 Radial force on the nozzle only

Choose spring with four elbows to calculate. But this time only radial force 0.05 kgf is exerted on the nozzle. The calculation result of

radial displacement could be seen in Fig.7. Several random points in the bottom of the nozzle is detected. The result could be seen in Tab.5:

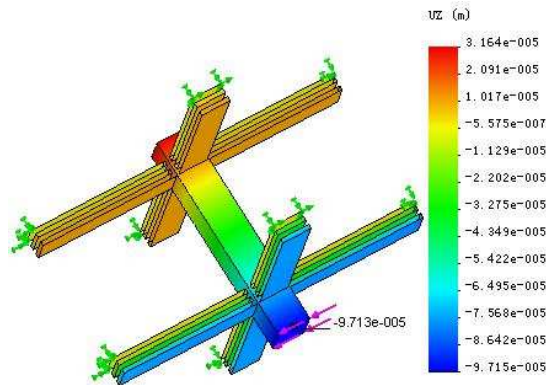


Fig.7. The radial displacement while only radial force used

Tab.5 Several random points in the bottom of the nozzle

Nod	Radial displacement(m)	X (mm)	Y (mm)	Z (mm)
5332	-9.713E-05	-2.4	5	2.4
5307	-9.713E-05	-1.2	5	3.36
5317	-9.711E-05	-2	5	0.96
740	-9.711E-05	-3.2	5	0.96
5303	-9.713E-05	-1.6	5	2.4

3.3 Analysis the bounding head with different amount of spring elbow

The calculation result of the others

bounding head with different amount of spring elbow is showed in Tab.6 and Tab.7:

Tab.6 Dimension of bounding head with four elbow spring

Width b (mm)		4.3134	2.4962	1.5719	1.0531
Thickness h (mm)		0.20	0.24	0.28	0.32
Vertical and radial force exerted at the same time	Vertical displacement (m)	1.03×10^{-3}	1.04×10^{-3}	1.03×10^{-3}	1.07×10^{-3}
	Radial displacement (m)	5.15×10^{-5}	6.30×10^{-5}	8.22×10^{-5}	1.00×10^{-4}
	vonMises stress	29.1MPa	35.9MPa	44.5MPa	55.6MPa
Vertical force exerted only	Vertical displacement (m)	9.7×10^{-5}	1.19×10^{-4}	1.5×10^{-4}	1.98×10^{-4}

stiffness ratio of radial and vertical	10.6	8.7	6.8	5.4
--	------	-----	-----	-----

Tab.7 Dimension of bounding head with two elbow spring

Width b (mm)		2.588	1.4977	0.94316
Thickness h (mm)		0.20	0.24	0.28
Vertical and radial force exerted at the same time	Vertical displacement (m)	1.07×10^{-3}	1.08×10^{-3}	1.10×10^{-3}
	Radial displacement (m)	3.90×10^{-5}	4.60×10^{-5}	5.40×10^{-5}
	vonMises stress	46.3MPa	58.1MPa	70.1MPa
Vertical force exerted only	Vertical displacement (m)	8.40×10^{-5}	1.00×10^{-4}	1.19×10^{-4}
stiffness ratio of radial and vertical		12.7	10.8	9.2

Calculation result is: Bounding head with six elbow spring is not a suitable choice. The bounding head that with maximum thickness 0.20mm and four elbow spring is suitable, if the thickness is larger than 0.20mm, it will be eliminated. The maximum thickness in bounding head with two elbow spring is 0.24mm, if the thickness is larger than 0.24mm, it will also be given up.

The conclusion is that with the decrease of the sum of spring or the distance between the layers, the stiffness ratio between the radial and vertical direction will be increased.

4. Discussion

Take the one with two elbow spring as example, its width is 1.4977mm, and the thickness is 0.24mm. If only the 50gf radial force is exerted, the radial displacement is 0.1mm, if change the force to be 10gf, then the displacement is 0.02mm. The displacement is proportionate with the force. So the radial stiffness is constant when there is no vertical force.

If the vertical and radial forces are exerted at the same time, the radial displacement will be 0.046mm. This indicates that the radial stiffness will become larger if the vertical force is increased.

If only exert 50gf radial force, which is parallel with the spring, the radial displacement is 0.0840mm. If the direction of the radial force is changed to be 45° with the spring in horizontal

plane, the displacement will become 0.0611mm. It is smaller than that of the first one. So it can be proved that the stiffness will not change much in different radial direction. So the design is feasible.

The prototype is manufactured and achieves the anticipated performance. Patent for utility model has been possessed for this mechanism.

5. Conclusion

In this paper, FEM is used for checking the displacement of the bounding head of the IC Chip Bonder with Flexible Hinges Straight-line Buffer Mechanism. The conclusion is as following:

1. The thickness, width, distance between spring layers, and the quantity of elbows are the key factors to the structure. If the layer of the spring is thinner and wider, and the elbow is fewer, it will be good for enhancing the radial and vertical stiffness ratio of the mechanism.

2. If the length of the spring is 20mm, and there are four elbows, the thickness can be chosen as 0.20mm, and the width is 4.3134mm. If there are two elbows, the thickness can be chosen as 0.20mm, width is 2.588mm, or thickness is 0.24mm, width is 1.4977mm.

Acknowledgments

Fund projects:

- 1) Support by National Natural Science Foundation of China, No: 50475044.
- 2) Support by Natural Science Foundation of Guangdong and Guangzhou, No: 2006A10401003, No: 2006Z3-D9071

References:

- [1] LI Ke-tian, CHEN Xin, WU Xiao-hong, WANG Xiao-chu, HE Han-wu. Moving Structure Design of the Bonding Head for a Die Bonder with Oblique Plane and Quadrilateral Connecting Rods [J]. Xi'an: Mechanical Science and Technology , 24(5): pp. 570-571,608, 2005.
- [2] XIE Xian-hai. Study of Compliant Mechanism analysis and design method[D]. Beijing: Huazhong University of Science and Technology, 2002
- [3] LIU Guo-liang, LIU Luo-qi. SOLIDWORKS 2006 HAND BOOK COSMOSWORKS[M]. Beijing: Publishing House of Electronics Industry, 2006