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Numerical Investigation on the Effect of Squeegee Angle during Stencil Printing Process

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Abstract. The high requirement of smaller size, lighter weight, and high performance Printed Circuit Board (PCB) in electronic packaging has contributed to the wide application of stencil printing for soldering process. However, during stencil printing stage contributes major concern compared to other stages in Surface Mount Technology (SMT). Unsuitable process parameters can cause the soldering defects that can lead to product failure in further processes in the production line. An investigation has been conducted to predict the real-time observation of solder paste Sn96.5Ag3.0Cu0.5 (SAC305) filling process into stencil apertures as well as print quality in stencil printing by using Computational Fluid Dynamics (CFD) approach. A 3-Dimensional stencil printing model was developed and simulated in ANSYS Fluent 17 of different angles. It is found that squeegee angle 60° to 80° has potential to obtain the good print quality of solder paste.
1. Introduction

This Stencil printing is a process of depositing a viscous fluid which is solder paste onto a bare substrate such as PCB through the aperture openings of a stencil. It is originally adapted from the screen printing process. This process is one of the widely used methods of soldering in SMT today as a solution for higher pin count and fine pitch size. This is due to the high requirement of smaller size, lighter weight, and high-performance PCB in electronic packaging. The use of stencil printing for the deposition of conductive interconnects was developed during the late 1960s as companies looked to increase the densities of the products, improve assembly time and drive down production costs. This process was termed surface mount assembly (SMA) and is currently used at least 70% of electronic packaging nowadays. However, stencil printing is identified as the largest contributor to soldering defect by 60% averagely [1].

Numerical studies have been performed to simulate stencil printing process by using CFD approach at macroscopic and microscopic scales by using a 2-D model that involves Finite Volume Method (FVM), Lattice-Boltzmann Method (LBM), and Discrete Element Method (EDM). Unfortunately, the volume fraction of solder paste is far lower than normal due to the unrealistic representation of spherical particles by a 2-D cylinder that causes artificial blockage of fluid passage at greater volume fraction [2].

Neural network approach model has been proposed to solve the fine pitch printing quality issue of the non-linear behavior stencil printing through the volume prediction of solder paste deposits. The proposed approach is found to be an effective way to predict and control the printing quality in SMA such as paste volume deposited on PCB pad with small prediction errors which are less than 7% [3]. In stencil printing, the stencil experiences pressure exerted by the squeegee on its surface that might affect the behavior of the structure. The deformation behavior of the stencil which can affect printing quality has been investigated by using Finite Element Method (FEM) associated with the uneven surface of Printed Wiring Circuit (PWB). Higher surface gap differences between the stencil and PWB affect the stencil bending behavior that can lead to excessive solder paste deposits and solder bridges issue [4].

Moreover, the effect of squeegee speed variation and solder paste with different density on stencil printing process has been studied by using CFD approach through the flow characteristic of solder paste simulation. Based on the study, the increment of squeegee speed can cause the shear stress increase proportionally to the increment of solder paste’s shear strain [5]. Therefore, in this study a 3-Dimensional stencil printing model has been simulated numerically and analyze in order to solve the complex and unpredictable printing problems in SMT.

2. Methodology

The A stencil printing model is created in 3-Dimensional by using ANSYS Design Modeler. It consists of two significant components for the simulation which are aperture bodies and printing body as shown in Figure 1. The thickness of the aperture bodies is 0.1 mm as well as the thickness of the stencil. The angles tested in the simulation are 50°, 60°, 70°, and 80°. The angles is varied to create different pressure distribution along the stencil [6]. The specification of the selected apertures design is 225 I/O; 1.5 mm pitch.
Figure 1. 3-Dimensional stencil printing model

ANSYS Workbench meshing is used to mesh the model and name their boundary conditions accordingly (Figure 2). The filling of solder paste inside the solder deposit bodies due to motion of the angled squeegee is simulated in ANSYS Fluent 17. The element size of 2.8 mm is selected from several of grid dependency test. The model is run with transient calculation in the simulation. The Volume of Fluid (VOF) multiphase model is selected with the implicit formulation due to presence of air and solder paste, which is Sn96.5Ag3.0Cu0.5 (SAC305).

Figure 2. FLUENT structured meshed model and boundary conditions
3. Results and discussions

The flow front and filling of the solder paste into the apertures is observed with respect to the different angle of squeegee at constant print speed, 35 mm/s. The average volume fraction of solder paste inside the apertures through filling stages is shown in Figure 3. At 25% filling stage of apertures, the filling pattern among the squeegee angles was shown significantly on volume fraction. 50° squeegee angle has the highest volume fraction, while 80° squeegee angle has the lowest average volume fraction. The trend of the filling continues to 50% filling stage but started to have approximately the same average volume fraction at 75%. All squeegee angles achieved 100% filling stage except for 50° squeegee. However, a slight drop of average volume fraction has been observed due to the presence of unfilling aperture holes.

![Figure 3. Average volume (%) over apertures stages (%) at different squeegee angles, θ](image)

Figure 4 shows the SAC305 flow front at different squeegee angles and stages. Different squeegee angle has different solder paste pressure distribution along the stencil. Lower squeegee angle have higher solder paste pressure distribution [6]. The solder paste pressure is important for the filling of the aperture. With given same volume of solder paste, lower squeegee angle have bigger contact area between the solder and the stencil, hence it is found that the solder paste fill the aperture faster. Higher pressure distribution and higher contact area of the solder cause the 50° angle to fill faster than 80°.
| $\theta = 50^\circ$ | $\theta = 60^\circ$ | $\theta = 70^\circ$ | $\theta = 80^\circ$ |
|------------------|------------------|------------------|------------------|
| 25%              | 25%              | 25%              | 25%              |
| 50%              | 50%              | 50%              | 50%              |
| 75%              | 75%              | 75%              | 75%              |
| 100%             | 100%             | 100%             | 100%             |

Figure 4. SAC305 flow front by stages at different squeegee angles, $\theta$ in apertures.
4. Conclusion

The 3-Dimensional stencil printing modelling by using CFD approach shows good prediction on the stencil printing performance. All squeegee angles were successfully filled all the apertures with solder paste except for 50° squeegee angle. Thus, operating stencil printing process by using squeegee angle at 60° to 80° is possible to achieve good solder paste print quality.

References
[1] T. N. Tsai 2008 Comput. Ind. Eng 54 374
[2] G. P. Glinski, C. Bailey, and K. Pericleous 2000 International Symposium on Electronic Materials and Packaging (EMAP2000) 364
[3] T. Yang, T. N. Tsai, and J. Yeh 2005 Eng. Appl. Artif. Intell 18 335
[4] O. Krammer, L. M. Molnár, L. Jakab, and A. Szabó 2012 Microelectron. Reliab 52 235
[5] V. Thakur, S. Mallik, and V. Vuppala 2015 Int. J. Recent Adv. Mech. Eng 4 1
[6] O. Krammer 2015 38th International Spring Seminar on Electronics Technology (ISSE) 343