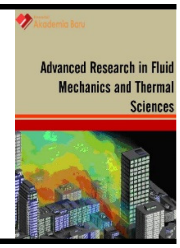
Journal of Advanced Research in Fluid Mechanics and Thermal Sciences 46, Issue 1 (2018) 147-152

Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



Multiphase Flow in Solder Paste Stencil Printing Process using CFD approach

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ARTICLE INFO

Article history:
Received 25 February 2018
Received in revised form 25 April 2018
Accepted 9 May 2018
Available online 15 June 2018

Keywords:
SAC387, Stencil Printing, Lead-free Solder

ABSTRACT

In this paper, Computational Fluid Dynamic (CFD) simulation approach is used to study the flowability of lead-free solder SAC387 in stencil printing process. The Volume of Fluid (VOF) method is used to simulate the multiphase flow between air and SAC387. The simulations are carried out at five different aperture area sizes. This paper focuses on the aperture filling of SAC387 where the result of the volume of SAC filling will be discussed. Results show that the volume error of the biggest aperture is 13.9% while the smallest aperture is 17.9%.

1. Introduction

Surface mount technology has been used widely in electronic parts manufacturing. It is a technology where electronic parts are mount to the PCB. The process generally starts from solder paste printing process, glueing process, pick and place process and lastly reflow-oven process. Solder paste printing process is the process where solder paste is dissipated on the solder pad by using squeegee and stencil. This process is crucial to make sure the sufficient of solder paste for part mounting.

Neural network approach model proposed by Yang *et al.,* [1] help to solve the fine pitch printing quality issue of the non-linear behaviour stencil printing. This is through the volume prediction of solder paste deposits. The volume deposited prediction error is less than 7%. The approach is an effective way to predict and control the printing quality in Surface Mount Assembly.

Tutar and Karakus [2] using Finite Volume Method (FVM) and VOF model to simulate the injection of polymer for a single and multi-cavity mould. This FVM and VOF technique can be used to simulate the solder paste printing process. Krammer [3] compared the result of FVM model using Non-Newtonian model and Newtonian model for solder paste. Krammer highlighted that Non-Newtonian model must be used and for the simulation of solder paste. The neglecting of real material properties will lead to calculation errors.

In stencil printing, a squeegee is used to transfer solder paste inside the stencil apertures to deposit a required amount of solder paste on pad of the substrate [4]. For metal blade squeegee, the angle of 60° is the most suitable angle to handle the ultra-fine and larger pitch size. The volume of solder paste deposits is proportional to the paste pressure and the highest region of the pressure is at the edge of squeegee [5]. The squeegee provides hydrodynamic pressures in the roll of solder paste that assists the filling of paste inside the apertures by shearing as it moves over the stencil [6]. Figure 1 shows the schematic diagram of stencil printing process [7].

Rolling of solder paste in stencil printing process gives considerable influent to the filling manner of solder paste in the apertures which could affect the printing quality that subjected to the printability of solder paste [8]. Solder paste could shear-thin until flux would separate from the metal if the pressure exerted by the squeegee is too high that could lead to poor solderability [9].

CFD approach has been using to study the effect of squeegee speed variation and solder paste with different density. It is found that the shear stress increment is proportional to the increment of solder paste's shear strain if the speed of squeegee being increase [10]. The high price of solder paste and high time consumption for trial and error makes the CFD as an alternative way to study the solder paste stencil printing process.

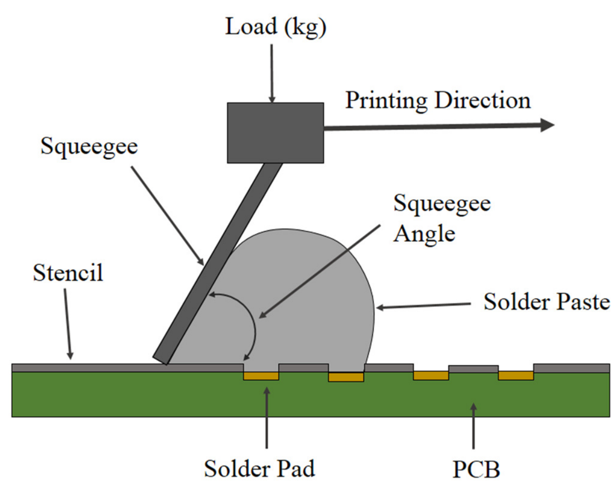

Fig. 1. Solder Paste Stencil Printing Process

2. Methodology

SAC387 with the composition of 95.5Sn/3.8Ag/0.7Cu was being studied. SAC387 is a Non-Newtonian fluid, therefore the Cross viscosity model was used to simulate the solder movement. The cross model data for SAC387 was taken from Durairaj *et al.,* [11]. The equation used to determine the viscosity of solder phase is shown in Eq. (1)

$$\eta(T,\dot{\gamma}) = \frac{\eta_0(T)}{1+\left(\frac{\eta_0\dot{\gamma}}{\tau^*}\right)^{1-n}} \quad (1)$$

with

$$\eta_0(T) = B\exp\left(\frac{T_b}{T}\right) \tag{2}$$

B is an exponential-fitted constant, T_b is a temperature-fitted constant, n is the power law index, η_0 is the zero shear viscosity and τ^* is the parameter that describes the transition region between the zero shear rate and power law region of the viscosity curve.

VOF model was used to track the two different phase of fluid [12]. If the cell contains only SAC387, the volume fraction, f will equal to 1(f = 1), in cells which are void of SAC387 (in this study the void is the air) the f will equal to zero (f = 0) and when the value is between 0 and 1 (0 < f < 1) it is referred to the SAC387 front. Equation (3) governed the equation of melt front over time [13]:

$$\frac{df}{dt} = \frac{\partial f}{\partial t} + \nabla \cdot (uf) = 0 \tag{3}$$

A 3-Dimensional model of stencil printing was designed and meshed using ANSYS Workbench. The mesh file than transferred and simulated using ANSYS FLUENT (Figure 2). Dynamic mesh was used to simulate the movement the squeegee with a constant speed of 35mm/s. The angle of squeegee was fixed at 60°. The fluid motion of SAC387 using CFD approach can be described by the governing equations of conservations of mass and momentum [14][15]. The aperture area is varied at 5 different area size (Table 1).

Table 1
The values of area and volume for a different type of Apertures

Aperture	Area (mil^2)	Volume (mil^3)
A	1085	5425
B	2000	10000
C	4000	20000
D	4300	21500
E	10000	50000

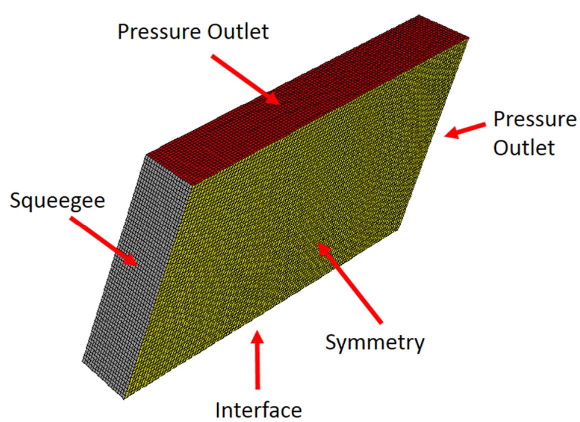

Fig. 2. Mesh and Boundaries Conditions

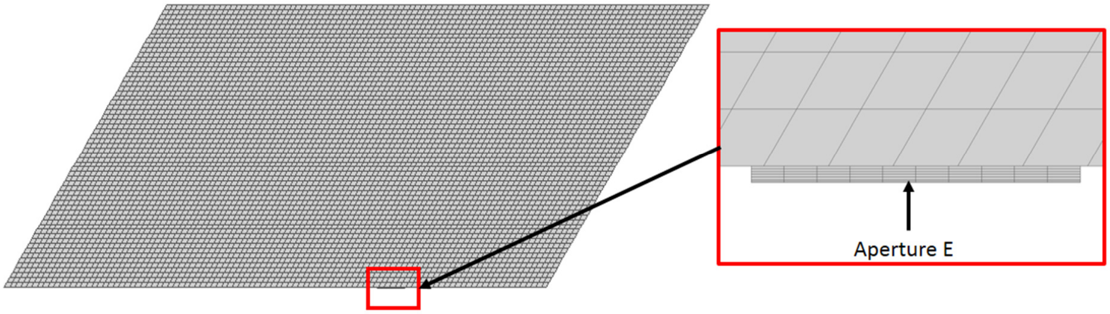

Fig. 3. Cross-section plane showing Aperture E location and mesh

3. Results

Figure 4 shows the simulation result that compares the aperture E filling before the printing process started and after the process had finished. From the figure, the volume of aperture is almost fully occupied with SAC387 with some void at the four corners. This show the capability of CFD to simulate the solder paste printing process.

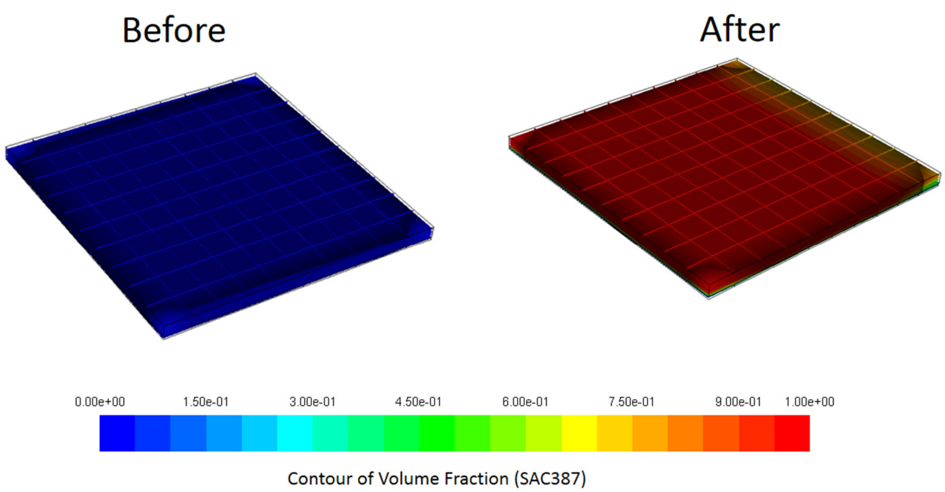

Fig. 4. Aperture E before and after the printing process.

There are five different of aperture sizes with different volumes. Figure 5 shows the difference of actual aperture volume against SAC387 volume after stencil printing simulation. From Figure 5 we can see the difference of the volume is higher at the bigger size of aperture compared to a smaller aperture. Aperture E shows largest different with 6951.5 mil^3 of volume compared to Aperture A with 972.4 mil^3 of SAC387 volume. Bigger the size, higher the volume shortage.

Even though Aperture E shows higher volume difference but Aperture E has the lowest percentage of error at 13.9% followed by Aperture D (16.3%), Aperture C (16.4), Aperture B (16.5%) and Aperture A (17.9%) (Figure 6). The difference of volume error can be related to the opening area of the aperture that allows the solder paste to enter the aperture. The difference of error can be considered small with the maximum and minimum difference is at 4% (between Aperture A and E). The difference could be smaller if we use lower viscosity solder paste. Lower viscosity solder paste will improve the flowability of the solder paste and eventually increase the volume of solder paste to enter the aperture area.

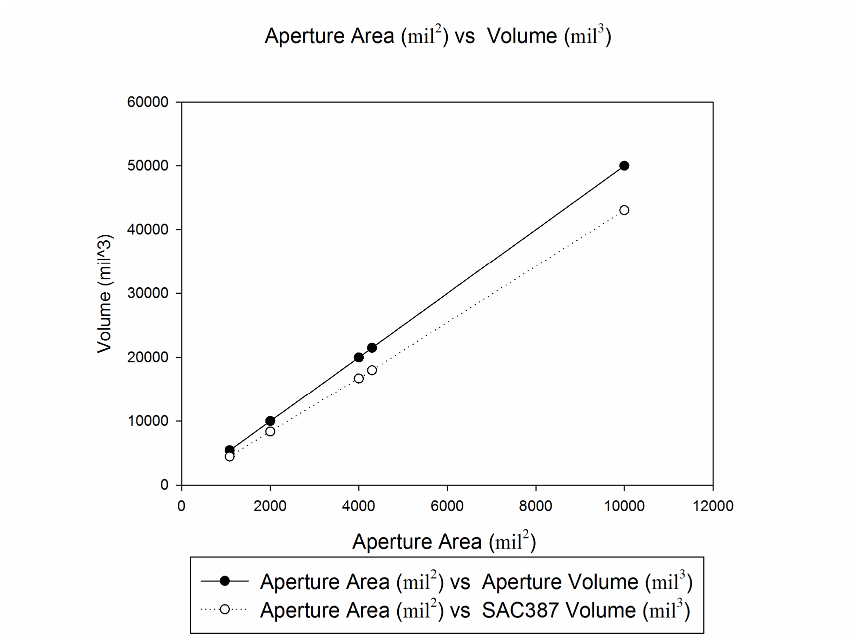

Fig. 5. Aperture Area (mil^2) versus Volume (%)

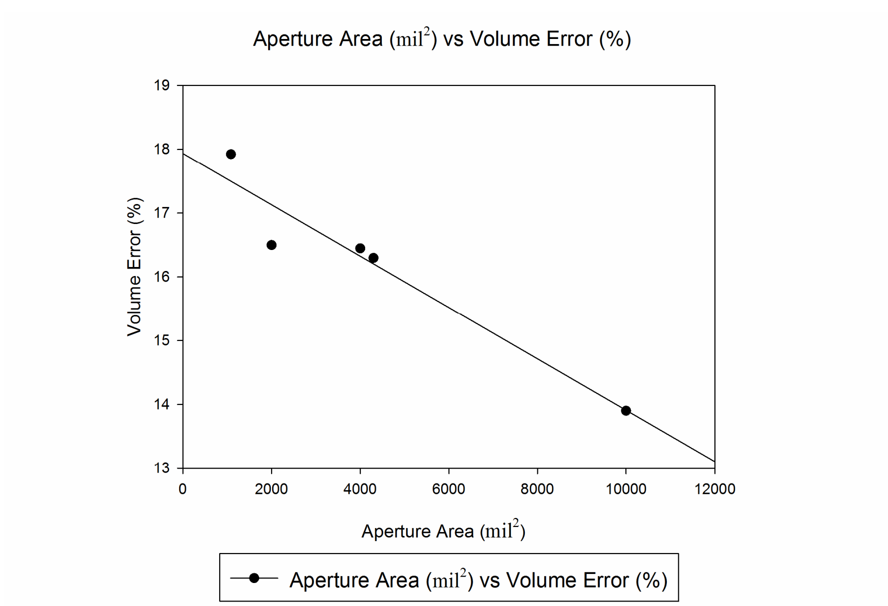

Fig. 6. Aperture Area (mil^2) versus Volume Error (%)

4. Conclusions

The CFD simulation with VOF model shows a good alternative to study the flowability of lead-free solder SAC387 in stencil printing process. Comparison between actual aperture volume and SAC387 volume was presented in this paper. With CFD approach, SAC387 have higher solder paste volume error or shortage by percentage at smaller aperture size compared to bigger aperture size. The volume error of Aperture E (50000 mil^3) is 13.9% compared to Aperture A (5425 mil^3) with 17.9% error.

Acknowledgement
We would like to thank Universiti Sains Malaysia for funding this research with Universiti Sains Malaysia Short-Term grant (304/PMEKANIK/6315031).

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