

Study of Underfill Flow in Microchip Packaging Using Ansys

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ABSTRACT – The project was related to microchip application where adhesive fluid is used to stick the microchip onto the electrical flat base. In this project, 5mm of width and length of microchip with 3 different types of solder ball diameter sizes are used in this project. The objective of the project is to study the flow pattern and velocity of fluid during injection based on the decided parameters, which are initial velocity, fluid viscosity, and the diameter of the solder ball. Each parameter that has been set produces a different outcome in terms of flow pattern and velocity of fluid. To maximise the performance of fluid flow in the aspect of uniformity of the fluid flow to fill the gap around the solder ball, the flow pattern and the velocity are being observed and recorded throughout the simulation process.

ARTICLE HISTORY

Received: 27th July 2022Revised: 1st September 2022Accepted: 26th September 2022

KEYWORDS

*Underfill flow**Microchip packaging**Non-Newtonian flow*

INTRODUCTION

In this century, all sectors of technology are competing each other to be the finest and enhance their flaws in industry. They emphasize the capability of machines or materials used during the manufacturing process of a product to increase the productivity and efficiency. Fluids are widely used in industry since they are one of the aspects that contribute to machines performance. Metalworking fluids, which are mineral-based oils, are widely used as feedstock in the manufacturing industry for a variety of lubricating and cooling applications. However, the excessive consumption of it creating environmental and health problems. Crude Tamanu Oil (CTO) is one of manufacturing effort to improve 'greener' metalworking applications, including the world's agricultural and socioeconomic sectors [1].

Newtonian and non-Newtonian fluids are two different types of liquids that have different properties. Newtonians include air, water, steam, all gases, and most fluids made up of simple molecules and it follows Newton's law of viscosity which is the physical characteristic that describes flow resistance. The viscosity of Newtonian systems is independent of shear rate [2], while non-Newtonian fluid, such as resin solution and molten polymer does not necessarily follow a linear relationship with the shear strain rate. Non-Newtonian fluid behaviors can be characterized in one of four ways, dilatant, pseudoplastic, rheopectic and thixotropic fluid.

Die fitting, solderless connectors, component refurbishment, display connectivity, and heat dissipation are just a few of the areas where electrically conductive adhesives (ECAs) are used. Due to their eco-friendliness, ECAs attract the attention of scientific researchers as a green and sustainable lead-free connecting material that outperforms traditional solders [3]. This adhesive is used to stick the electrical components such as microchip onto the flat base. The injection fluid between the microchip surface and flat base is the same approach as the liquid injected between two plates and the parameters such as fluid viscosity and flowrate are being observed to ensure the conducting fillers or ECAs spread and solidifies uniformly. Lubrication in vehicles such as diesel emphasizes the rate of viscosity to ensure the efficiency of the engine. The viscosity of the lubricant impacts the friction, which affects heat and it influences the pace of oil consumption at the same time [4]. Manufacturing equipment generally requires proper lubrication. However, overly viscous lubricants can choke and block pipes. Too thin lubricants provide insufficient protection for moving components [5]. The viscosity of a product is measured in relation to its quality and efficiency. The study of fluids in motion lead to better understand the functional structure and behavior so that both elements can be manipulated. For example, the type of fluid that frequently used in electrical industries as a bonding technology is Electrically Conductive Adhesive (ECAs). Different viscosity of ECAs gives different solderable quality on the ECAs interconnection formation [7].

METHODOLOGY

A simulation study of fluid behaviors that will be carry out by observing the flow pattern and measuring the fluid filling time based on the parameters such as initial velocity, fluid viscosity and the diameter of solder ball. This project involves the study of underfill flow in microchip using Ansys workbench 2021 which is to observe fluid behaviors by observing the flow pattern and velocity of liquid injected. The dimension of microchip is 5mm length and width with pitch every solder ball is 1mm. Parameters include to conduct the simulation are the initial velocity, fluid viscosity and the diameter of solder ball. The flow pattern and viscosity were observed by all the dependence stated. Experiment will be conducted by CFD approach using Ansys software, fluid fluent.

Ansys is a flexible CFD program that may be used for a variety of applications. Ansys used to generate, and import meshes, set boundary conditions, parameterize cases, run simulations, and post-process results. Ansys software is a complete numerical tool that can handle compressible and incompressible fluid flows which is suitable for observing the flow pattern of Newtonian fluid that is incompressible without having a change in viscosity which means they need pressure or high temperature to change their viscosities. But for Newtonian fluid such as water, the viscosity will not change even the pressure and temperature applied.

RESULTS AND DISCUSSION

Effects of initial velocity

High initial velocity values affect the continuity of the flow pattern that passes through the space between the solder balls. The higher the initial velocity, the more tapered the fluid flow pattern becomes, and this can be observed at the beginning of the injection. By visual observation based on Figure 1, the fluid flow pattern, or to be more precise, the front flow pattern, may be seen clearly when the fluid breaks a barrier in front, which is a solder ball with high velocity, and the volume of fluid filled at the edges exhibits a more tapered flow pattern than in the centre, and this also shows that the volume of fluid filled unevenly in the middle of the plate. The parameter considered in this case is only dependent on the initial velocity.

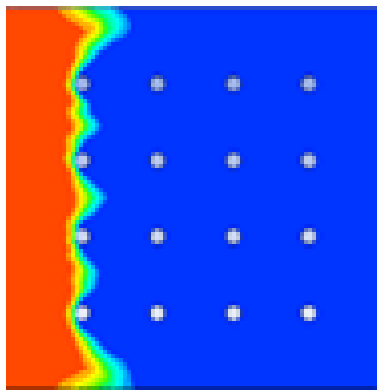


Figure 1. Flow pattern at initial velocity 0.5m/s with viscosity 0.165 kg/ms at 0.006s.

Figure 2 shows that the front flow pattern is more uniform as the initial velocity is lower, which is 0.1 m/s, and the fluid spreads evenly even if it breaks the barrier or the solder ball. The volume of fluid was filled at the centre evenly but narrowed at the edges. The tapered flow pattern cannot be seen at the beginning of the injection or at the first 0.001 mm. Past research used a constant initial velocity for both cases, having a uniform flow at the beginning of injection but a different filling time depending on the gap between the 2 plates or the thickness of the solder ball, while Figures 1 and 2 show a different initial velocity but the thickness is neglected as it is in a 2D simulation. The comparison that can be made is by visual observation, specifically at the front flow, whereby increasing the initial velocity can increase the probability of the fluid to taper at the edges and spaces around the solder ball. is by visual observation specifically at the front flow weather by increasing the initial velocity can higher the probability of the fluid to tapered at the edges and while break through solder ball.

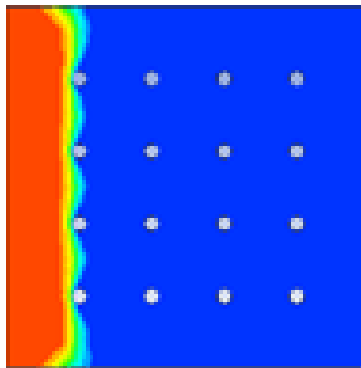


Figure 2. Flow pattern at initial velocity 0.1m/s with viscosity 0.165 kg/ms at 0.012s.

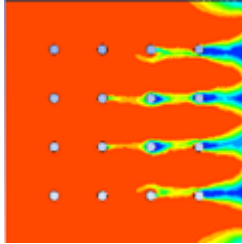
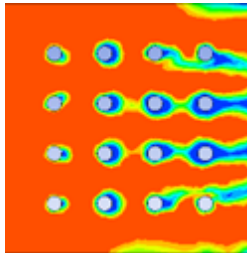
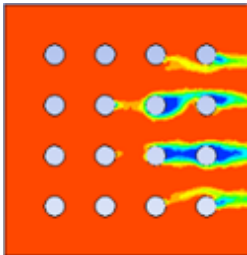
Effects of solder ball diameter

There are 3 different diameters of solder ball, which are 0.2 mm, 0.3 mm, and 0.4 mm with a pitch of 1 mm, and the observation can be made in relation to the flow pattern around the solder ball. The pitch is bigger than the previous simulation because the recent simulation only focuses on the diameter of the solder ball that might influence the flow pattern of the fluid and only replicates the microchip with a solder ball.

Cases 1, 2 and 3 in Table 1 show the flow pattern at 0.03s with constant viscosity and initial velocity with different solder ball diameters. The fluid flow pattern that passes through the gap between the solder balls can be seen reacting with the solder ball diameter when the fluid hits obstacles or the solder ball during injection. The fluid surrounds the solder ball with different continuity from 0.006s up to 0.03s. The front flow pattern at diameter 0.2 mm with initial velocity 0.1 m/s and viscosity, 0.165 kg/ms conclude the same result as previous research which is lower velocity produce curvy line at the edges to the middle at the first 2mm distance and the filling time increases with an increase of the solder diameter.

In case 1, the fluid flow permeability is less than in cases 2 and 3 because the smaller solder ball diameter makes the fluid flow more uniform and there is no frequent collision with the solder ball wall, making the fluid pass through neatly between the solder balls. In case 2, the fluid flow pattern around the solder balls is different with case 1 as it is not uniformly filled with fluid. There is a space that is not passed by the fluid, causing there to be empty space around the solder ball. This phenomenon shows that increasing the diameter of the solder ball in the underfill process causes non-uniform flow as the fluid collides with the wider area of the solder ball's wall and the fluid bounces back and forth, making the velocity in the area increase, causing the fluid to spread unevenly around the solder ball. The fluid spread wider than the solder ball diameter, causing the empty space to occur during the fluid flow passing through the solder ball. For the last case, which is case 3 with the largest solder ball diameter, the flow pattern at 0.03s shows that there is empty space at the end of the flow where the fluid does not fill the space around the solder ball evenly. The same goes for case 1 at 0.03s, but the consistency of the flow is better than in case 3, and the volume of fluid filled in case 3 is higher than in cases 1 and 2, as both cases still have unfilled space at 0.03s, while case 3 almost fills the plate surface area at 0.03s.

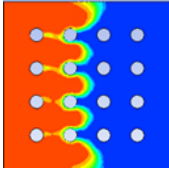
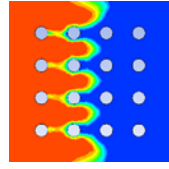
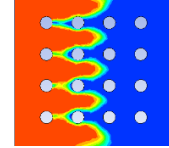
Table 1. Fluid flow pattern for diameter 0.2mm,0.3mm and 0.4mm.

Experimental conditions	Flow pattern
<p>Case 1</p> <p>Diameter = 0.2mm Initial velocity = 0.5 m/s Viscosity = 0.165 Filling time = 0.03s</p>	
<p>Case 2</p> <p>Diameter = 0.3mm Initial velocity = 0.5 m/s Viscosity = 0.165 Filling time = 0.03s</p>	
<p>Case 3</p> <p>Diameter = 0.4mm Initial velocity = 0.5 m/s Viscosity = 0.165 Filling time = 0.03s</p>	

Effects of viscosity

The last parameter used in the recent simulation involves fluid viscosity. Previous research used 3 viscosities of fluid: 0.165, 0.34, and 0.7 kg/m s and this simulation also used the same parameter but used different solder ball diameters, different from previous research where it used the factor of the thickness of the solder ball using the viscosities stated. However, a comparison can still be made by looking at the dependence of the flow pattern on the viscosity of the fluid, whether it has a large impact or not on the fluid flow pattern.

Table 2. Comparison of fluid flow pattern for viscosity 0.165,0.34,0.7 kg/ms.

Experimental conditions	Flow pattern
Case 1 Viscosity = 0.165 Initial velocity = 0.1 Filling time = 0.03 Solder ball diameter = 0.4	
Case 2 Viscosity = 0.34 Initial velocity = 0.1 Filling time = 0.03 Solder ball diameter = 0.4	
Case 3 Viscosity = 0.7 Initial velocity = 0.1 Filling time = 0.03 Solder ball diameter = 0.4	

Through visual observation regarding the viscosity used for cases 1, 2 and 3, the fluid flow pattern as can be seen in Table 2 is more uniform at low viscosity at 0.165 kg/ms and unevenly at 0.7 kg/ms. However, the viscosity factor does not significantly influence the flow pattern because only a small change occurs in the flow pattern when high viscosity is used but the empty space around the solder ball can still be seen and the tapered pattern can also be detected using different viscosities, which at 0.7 kg/ms, the flow pattern is more tapered than at 0.34 kg/ms and 0.165 kg/ms.

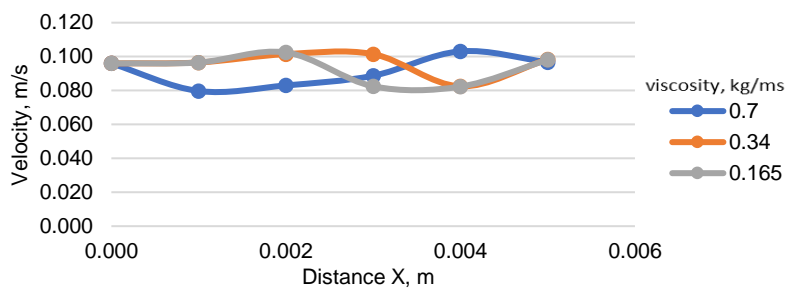


Figure 3. Velocity vs distance x for diameter 0.2mm with initial velocity 0.1m/s.

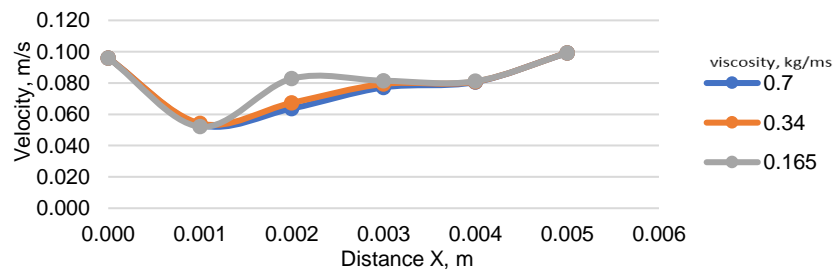


Figure 4. Velocity vs distance x for diameter 0.3mm with initial velocity 0.1m/s.

Fluid in Figure 3 with viscosity 0.7 kg/ms having a lower velocity at initial injection and increase at distance 0.003mm while for viscosity 0.34 kg/ms and 0.165 kg/ms having a decreasing pattern at distance 0.003 m. This occur when fluid passes through the solder ball and the velocity changes depend on how hard the collision happened towards the solder ball's wall that influence the fluid to move back and forth to push the fluid forward. C.Y. Khor previous research was regarding the pressure drop and the gap height plotted graph which the pressure drop increased with decreased gap height. Thus, the gap height changes significantly affected the filling time and pressure drop in the underfill process. For this project, the plotted graph is referring to velocity, viscosity, and distance x with different diameter solder ball. Solder ball distract the fluid flow from going forward and by increasing the solder ball diameter, the velocity will be decreasing at the initial distance of injection but rose at the end of plate, 5 mm as shown in Figure 3 and 4.

Solder ball with diameter 0.4 mm show a different pattern of plotted graph shown in Figure 5 as the velocity is increasing at the initial of injection but going down at the end of the plate, 5 mm because the fluid passes through larger obstacle and collision occur more frequently causing the velocity at start higher than diameter 0.2 mm and 0.3 mm. The velocity for viscosity 0.7 kg/ms is almost constant and consistent at viscosity 0.165 kg/ms from 0 mm to 5 mm and been shown in Figure 6 because the initial velocity is higher, and the solder ball diameter is also small than others causing the laminar flow to occur directly from inlet to outlet. However, for viscosity 0.34 kg/ms, the velocity rose at distance 4mm because the inconsistency of fluid flow passes through solder ball and make a tapered flow pattern causing some area uncovered with fluid. For Figures 7 and 8 have a same condition as Figures 4 and 5 that show a same pattern for plotted graph but only with a different initial velocity that cause the velocity is higher than them.

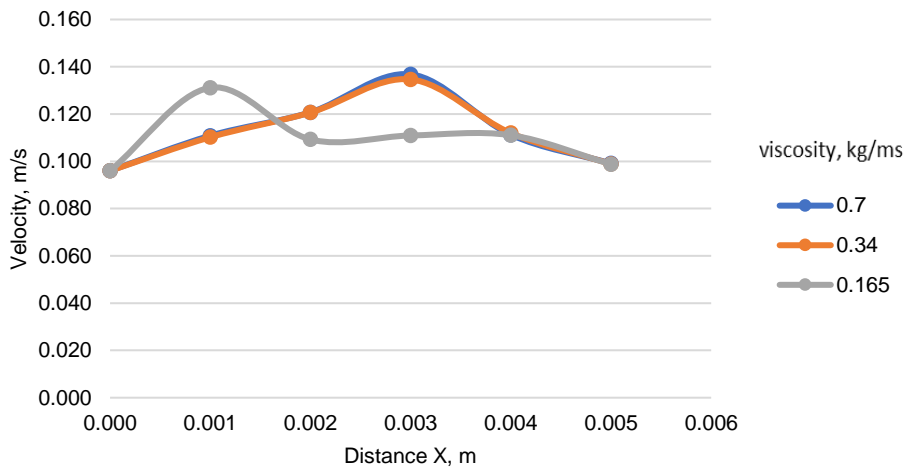


Figure 5. Velocity vs distance x for diameter 0.4mm with initial velocity 0.1m/s.

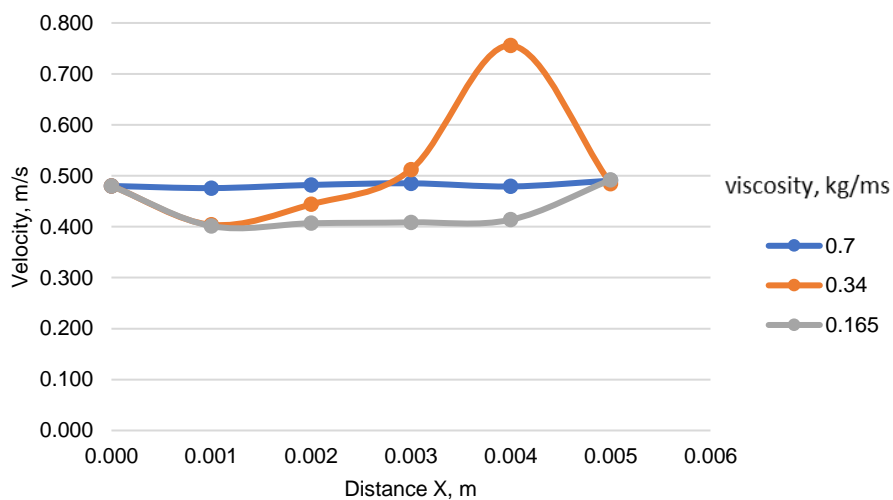


Figure 6. Velocity vs distance x for diameter 0.2mm with initial velocity 0.5 m/s.

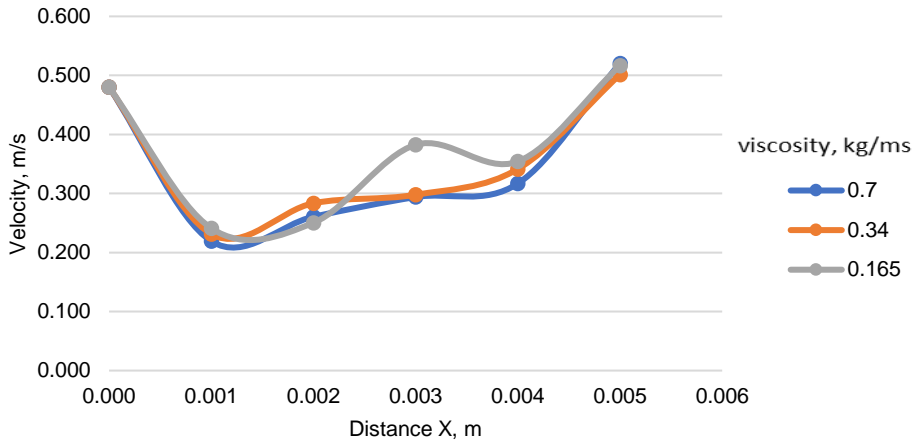


Figure 7. Velocity vs distance x for diameter 0.3mm with initial velocity 0.5 m/s.

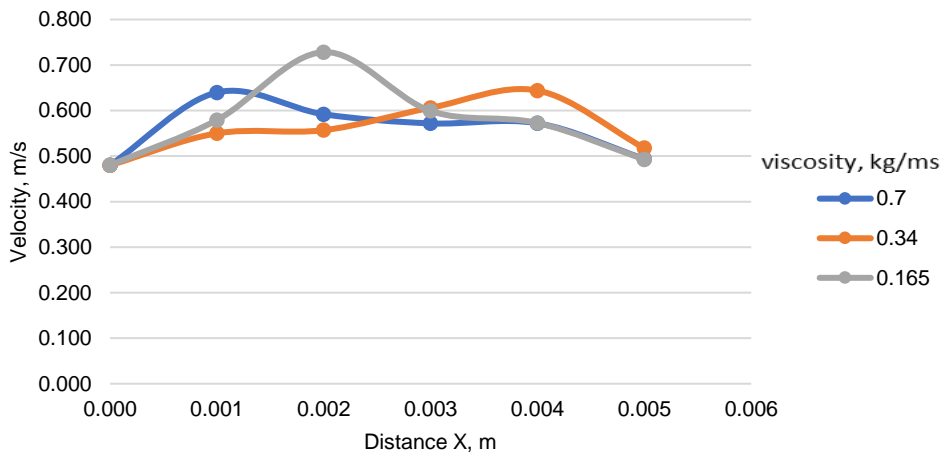


Figure 8. Velocity vs distance x for diameter 0.4mm with initial velocity 0.5 m/s.

CONCLUSION

In conclusion, all objectives have been achieved with respect to flow pattern and filling time. The simulation that has been carried out shows that the initial velocity affects the uniformity of the fluid flow pattern. The higher the initial velocity, the less uniform the fluid flow pattern between the two plates. Initial velocity, which is 0.1 m/s, produces a better and even flow than 0.5 m/s. The diameter of the solder ball also proves that the larger the size of the solder ball, the bigger the empty space around the solder ball when fluid passes through and most probably leads to tapered flow, causing the surface of the plate to not be covered with fluid evenly and the probability of the microchip losing grip is higher. Other than that, with respect to fluid viscosity, which can be seen through visual observation where the response of the flow pattern to the viscosity is not very significant, as only slight differences can be seen in 0.7 kg/ms, 0.34 kg/ms, and 0.165 kg/ms for all cases.

Filling time takes longer at 0.1 m/s than at 0.5 m/s, but in terms of uniformity of fluid flow, the lower the initial velocity, the higher the time taken to fill the plate, and the better the front flow and flow pattern from 0 mm to 5 mm. Solder ball diameter influence the velocity in fluid flow. The larger the diameter of solder ball, the collision of fluid with solder ball make the velocity decrease while when the fluid spread to fill the gap around the solder ball, the velocity become increase.

ACKNOWLEDGEMENT

The authors would like to thank International Islamic University Malaysia and Universiti Malaysia Pahang for funding this work under the IIUM-UMP Sustainable Research Collaboration Grant (RDU223221).

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