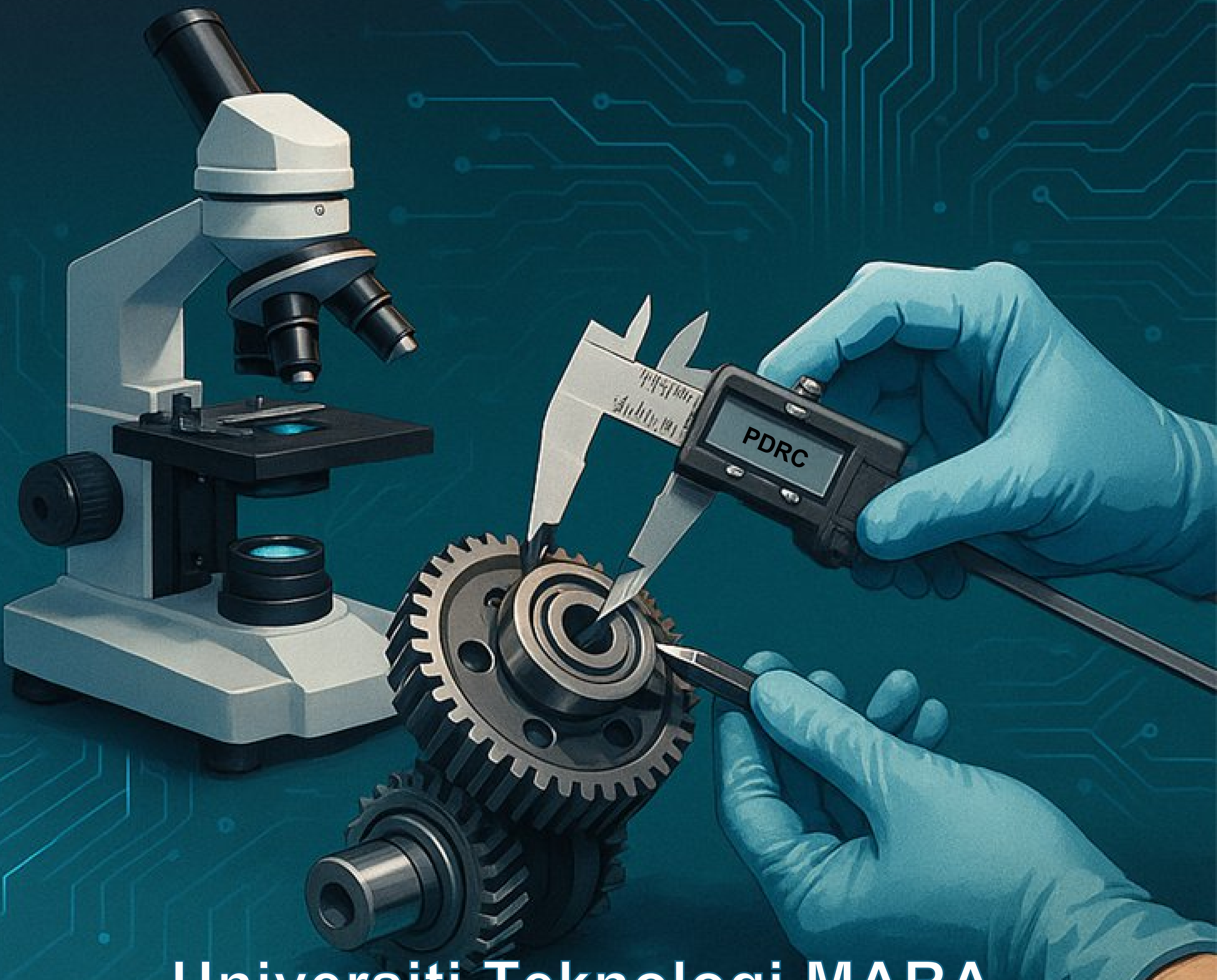
Prototype Design and Research Collection

Series 1



Universiti Teknologi MARA
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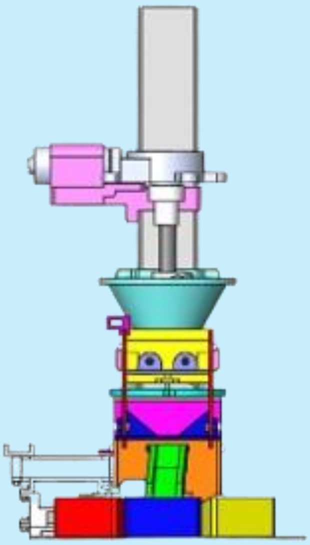

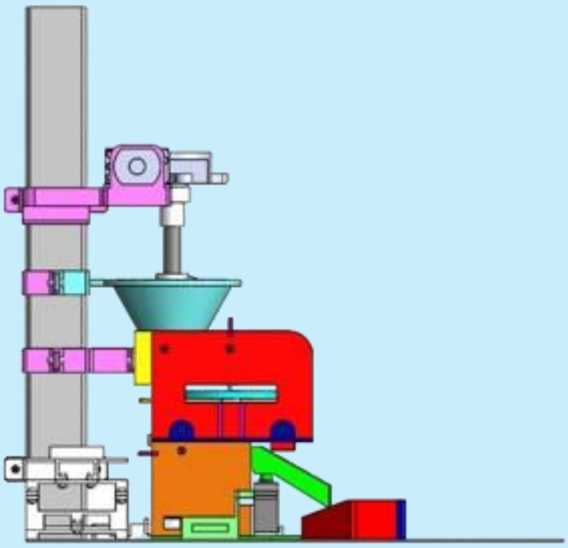

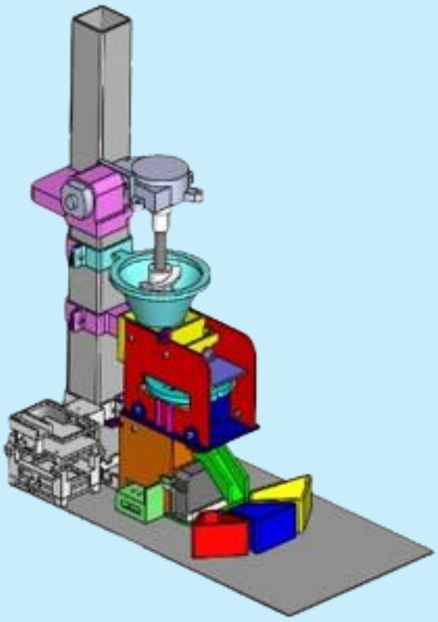

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FOREWORD

This digital book on Prototype Design and Research Collection Series 1 (PDRC Series 1), is designed as a comprehensive reference for mechanical engineering students. The designs featured in this collection undergo an extensive analysis process, incorporating both prototype development and research to ensure a thorough understanding of design principles. Each project is carefully analysed before the prototype fabrication with detailed summaries of the project description and design parameters. The design and research products presented in this series cover a wide range of tools and equipment for various applications including household, workshop and entrepreneurial purposes.

This collection aims to foster innovation by offering students valuable insights into both the technical and research aspects of product design. It is hoped that this book will inspire future engineers and designers to approach product development with a deeper understanding of the design and research processes.

CHAPTER 19

Floating Mechanism of The Passive Electronic Component of The Die-Side Capacitor

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ABSTRACT

Reflow soldering is a widely used process in mass production, particularly in electronic assembly lines. However, defects such as solder bridging, fillet lifting, and tombstoning often arise due to capillary forces that act on molten solder during the transient liquefaction phase. This study investigates the floating mechanism of passive electronic components, specifically the Die-Side Capacitor, by analyzing the wettability of molten solder under dynamic capillary wetting behaviour. The research employs analytical force equations to evaluate solder joint formation. Results indicate that controlling solder volume and optimizing surface tension properties can enhance capillary pressure, increase gap height and reduce defects such as solder bridging, ultimately improving soldering reliability in electronic components.

Keywords: Electronic component, Die-Side Capacitor, Reflow process

1 INTRODUCTION

Surface Mount Technology (SMT) has revolutionized electronic manufacturing by enabling high-speed and high-precision assembly of components [1, 2]. However, the reflow soldering process, a critical step in SMT, often encounters defects such as solder bridging, fillet lifting, and tombstoning. Figure 1 show the Die-Side Capacitor position on the electronic terminal. These defects are primarily caused by improper wettability and capillary forces acting on the molten solder during liquefaction. Solder bridging, for example, occurs when excess solder forms unintended connections between adjacent pads, leading to electrical shorts. Fillet lifting and tombstoning result from imbalanced surface tension forces, which cause components to shift or detach during reflow [3]. Addressing these issues requires a deeper understanding of the factors influencing solder behaviour, particularly the floating mechanism of passive components like Die-Side Capacitors [4].

Fig. 1: Die-Side Capacitor position on the electronic terminal

2 LITERATURE REVIEW

The reflow soldering process involves heating solder paste to a controlled temperature, allowing it to transition from solid to liquid and back to solid, forming strong electrical and mechanical bonds [3, 5]. During the transient stage of liquefaction, capillary wetting behavior determines how molten solder interacts with the component and substrate [6]. Factors such as solder volume, pad design, and heating profiles significantly impact joint formation and defect rates. Excess solder causes bridging, whereas insufficient solder weakens connections. This study investigates how dynamic forces, including capillary pressure and surface tension, influence component stability during reflows, with an emphasis on optimizing solder volume and wettability to reduce common SMT defects.

One of the key physical principles affecting solder behavior is surface tension, which governs the shape and distribution of molten solder [3]. Additionally, the buoyancy force exerted by the molten solder plays a crucial role in determining the floating behavior of passive components. If surface tension is not properly controlled, components may shift or misalign due to imbalanced forces. By analyzing the interaction between buoyancy and surface tension, this study aims to develop optimized soldering techniques that enhance component stability, reduce defects, and improve overall manufacturing quality.

3 METHODOLOGY

The schematic diagram as illustrates in Figure 2 shows the key forces acting on a passive electronic component, such as a Die-Side Capacitor, during the reflow soldering. These forces, gravity, surface tension, capillary pressure, dynamic friction, and hydrostatic force, collectively determine the floating behaviour and wettability of the molten solder. Understanding these forces is crucial for optimizing soldering conditions and minimizing common defects such as solder bridging and tombstoning.

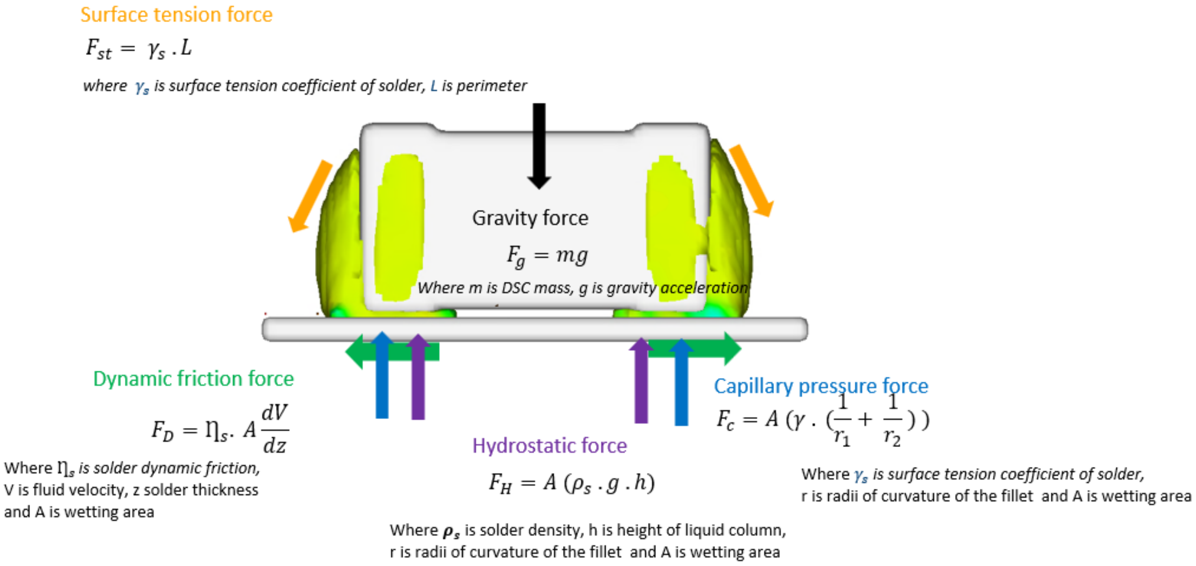

Fig. 2: Acting Forces on a passive electronic component

Gravity force, F_g acts downward on the component, where m is the mass of the Die-Side Capacitor, and g is the gravitational acceleration.

$$F_g = mg$$

Surface tension force F_{st} helps stabilize the component on the molten solder by balancing external forces, where γs represents the solder's surface tension coefficient, and L represents the contact perimeter.

$$F_g = mg$$

Capillary pressure force, F_c influences the solder flow around the component,

$$F_c = A\ (\gamma .\ (\frac{1}{r_1} + \frac{1}{r_2}))$$

where A is the wetting area, and $r_1$and r_2 are the radii of curvature of the solder fillet. Proper control of this force helps prevent defects such as solder bridging.

Dynamic friction force, F_D plays a role in the movement of the molten solder,

$$F_D = \eta_s .\ A \frac{dV}{dz}$$

where ηs is the solder's dynamic viscosity, V is fluid velocity, and z represents the solder thickness.

$$F_H = A\ (\rho_s .\ g . h)$$

Additionally, Hydrostatic force provides buoyancy support, where is the solder density and *h* is the liquid column height.

4 RESULTS AND DISCUSSION

The manual calculation of forces acting on the Die-Side Capacitor (DSC) during the reflow soldering process highlights the dominant forces influencing component stability. The surface tension force, a function of the solder geometry, was calculated where the surface tension coefficient of the solder was 530 µN, and the perimeter was 1.5e-3 m. This results in a surface tension force of 795 µN, which counteracts external disturbances to maintain the component's position. The gravitational force acting on the DSC was computed where the mass of the DSC was 1.64e-6 kg, and gravitational acceleration was 9.81 m/s^2. The resulting gravity force was 16 µN, which was relatively small compared to surface tension and capillary forces, indicating minimal gravitational influence on component movement during soldering.

Additionally, the capillary pressure force, which depends on the wetting area and the curvature of the solder fillet, was calculated using the equation. Assuming r1=r2, and using values A=2.92e−7 m^2, γ_{LG} = 530 mN/m, and r=5.42 e−4 m, the capillary force was determined to be 570 µN. This force was critical in ensuring proper solder joint formation by influencing the molten solder's ability to wet the component leads and pads. The calculations emphasize that surface tension and capillary forces were significantly larger than gravity, indicating their dominant role in determining the floating mechanism of passive electronic components during reflow soldering.

5 CONCLUSIONS

The analysis confirms that surface tension and capillary forces dominate the floating mechanism of passive electronic components during reflow soldering, significantly outweighing gravitational effects. Proper control of solder volume and wettability is crucial to minimizing defects like solder bridging, ensuring stable component placement, and improving overall solder joint quality in SMT assembly.

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