Die Attach Process using Adaptive ISPG in LS-Dyna

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1 Introduction

The die-attach process is a crucial step in electronic packaging, where semiconductor chips (dies) are securely bonded onto substrates (e.g., lead frames or printed circuit boards). The process typically involves applying an adhesive or solder material to join the die and substrate. It ensures electrical connectivity, dissipates heat, and protects the delicate semiconductor components. Precise die-attach (DA) techniques are vital to guaranteeing the reliability and performance of electronic devices, as improper bonding can lead to connection failures and reduced overall functionality of the packaged components. A series of experiments are required to obtain full coverage of the DA material while optimizing bleed out. To reduce the experimental trials, a 3D model is developed and simulated using Adaptive **ISPG (Incompressible Smooth Particle Galerkin)** technology in LS-Dyna. An Ansys Mechanical ISPG Plugin (ACT Extension) was developed to leverage Mechanical's user-friendly model-setup and solving environment for LS-Dyna solver. During the simulation displacement-based boundary condition is used to conduct an analysis of reaction force with varying Die velocities. A non-Newtonian fluid model (**Carreau Model**) is used for the epoxy material where the viscosity varies with the current shear rate which impacts the reaction force on the Die. The simulation results are validated against experimental data at NXP. The Validated model is further used to investigate the effect of different dispensing volume, dispensing pattern and die dimensions on coverage of die attach material in a subsequent study. The result of this parametric study can provide more insight into the die attach process and it can be used as an initial process parameter to reduce design of experiments.

2 Problem Statement

Use Simulation to predict the Bond Layer Thickness (BLT), Pressure Distribution underneath the Die and Fillet Shape (Height and Width).

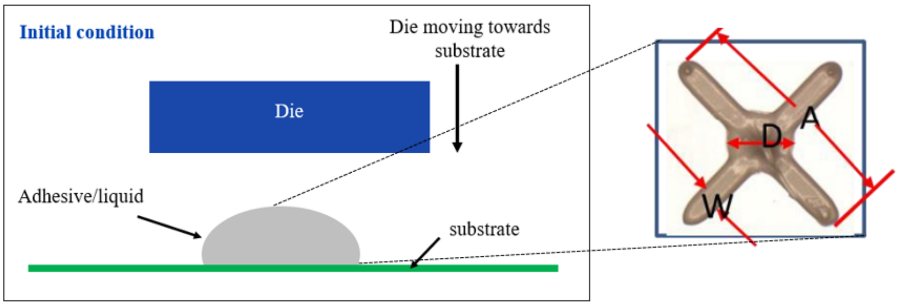

Fig.1: Die-Attach Process Set-up

3 ISPG Theory and Keywords

Free-surface flow problems involving strong surface tension like solder reflow, adhesive flow, compression moulding brings challenges to existing CFD solver:

- Difficulty in tracking free surface and interface (VOF technique, time-consuming)
- Very fine mesh must be used (capture interface and free surface)
- Difficulty to coupling with structure.

ISPG uses fully Implicit Lagrangian Particle Galerkin approach solving Navier-Stokes equations considering viscosity, surface tension and contact angles in liquid, it has a Momentum-Consistent smoothing algorithm. ISPG uses accurate surface tension model (in comparison to CSF or CSS model used by other CFD solvers)

The **surface tension** will lead to a pressure jump proportional to mean curvature κ where, γ is the surface tension coefficient.

$$\sigma_{\kappa}^{fs} = \gamma\kappa \qquad (1)$$

The wall adhesion force acts at the interface of the liquid and solid to satisfy equilibrium contact angle described earlier. This interfacial boundary condition is expressed as:

$$\vec{\boldsymbol{n}} = \vec{\boldsymbol{n}}_w \cos(\theta_{eq}) + \vec{\boldsymbol{t}}_w \sin(\theta_{eq}) \qquad (2)$$

Fig.2: Surface-tension and wall adhesion force effects on adhesive.

<u>ISPG Keywords in LS-Dyna:</u>

*DEFINE_ISPG_TO_SURFACE_COUPLING
*INCLUDE_ISPG
*ISPG_CONTROL_ADAPTIVITY
*ISPG_CONTROL_IMPLICIT
*ISPG_LOAD_GRAVITY
*MAT_ISPG_CARREAU
*MAT_ISPG_ISO_NEWTONIAN
*SECTION_ISPG

4 Adaptive ISPG Plugin (ACT Extension) for LS-Dyna in Ansys Mechanical

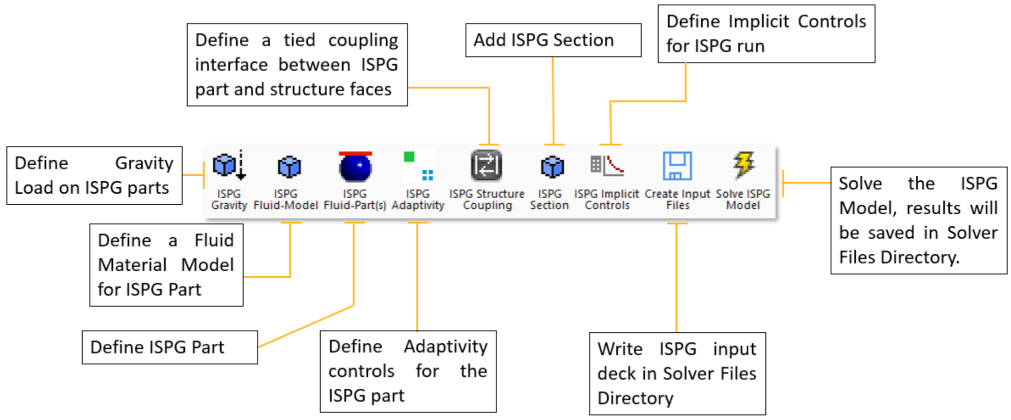

Fig.3: Adaptive ISPG Ribbon in Ansys Mechanical

5 Model Setup in Ansys Mechanical

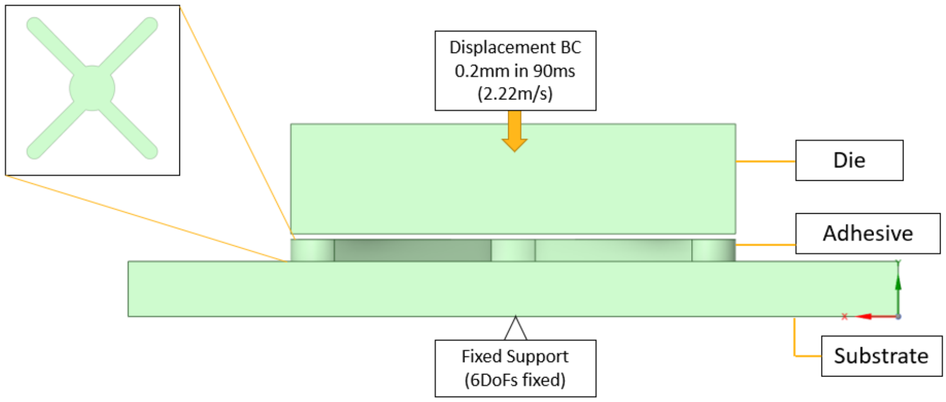

Fig.4: CAD prepared in Ansys SpaceClaim

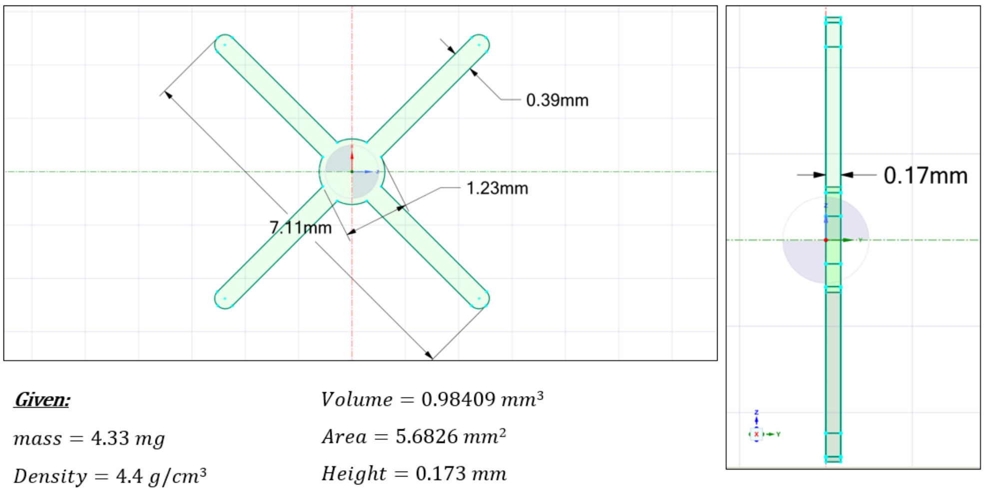

Fig.5: Adhesive measurements

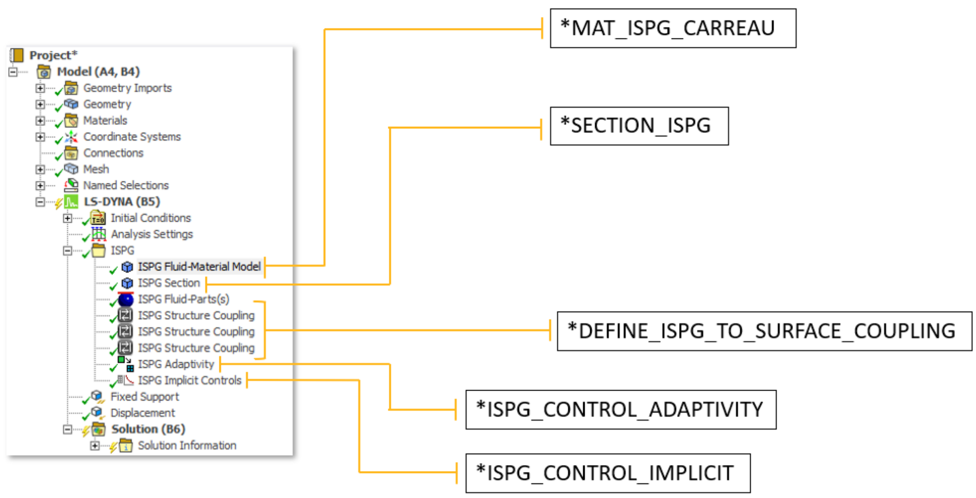

Fig.6: Model Setup in Ansys Mechanical using ISPG Extension

6 Results

The adhesive completely fills the Die under surface and the Bond Line thickness matches the reference paper. LS-Dyna also reports the reaction force on the Die and pressure distribution underneath the Die.

Fig.7: Adhesive flow in different time-states

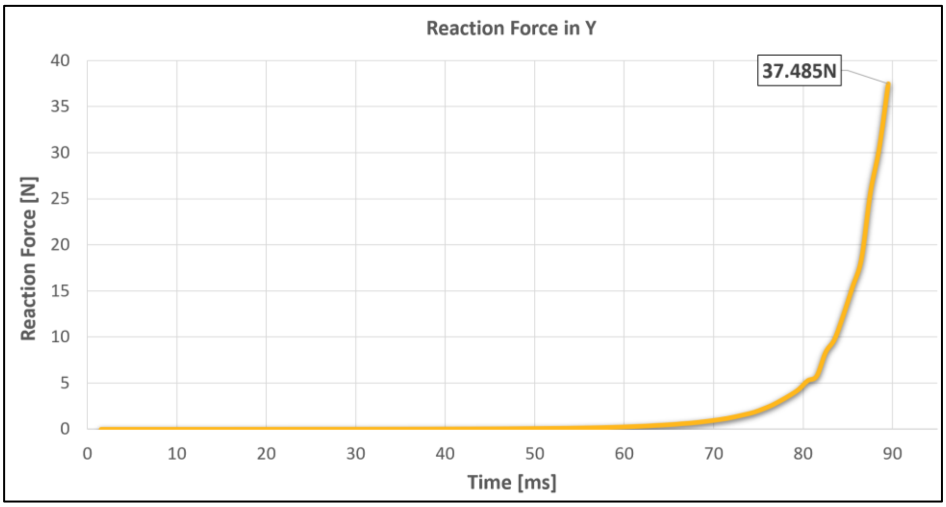

Fig.8: Reaction force on Die with time.

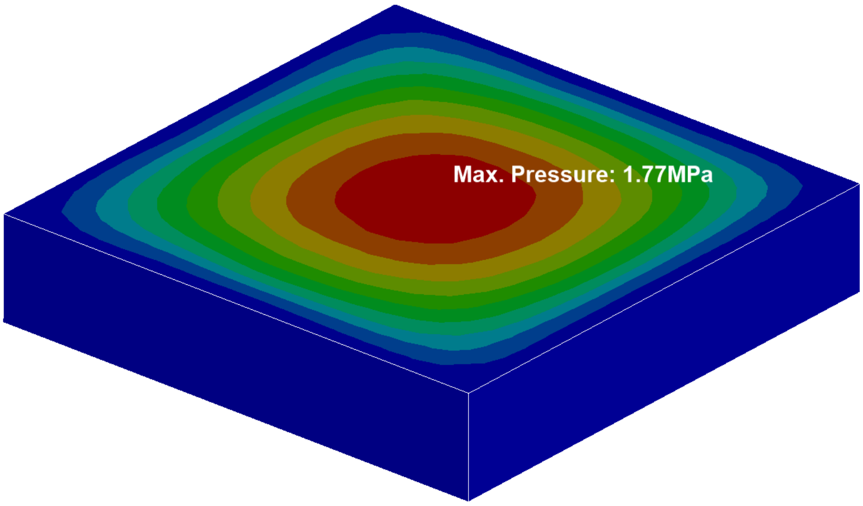

Fig.9: Pressure distribution on the Die.

7 Literature

[1] Lin Bu, Wai Leong Ching, Ho Siow Ling, Min Woo Rhee, Yong Puay Fen, “3-D Modeling and Characterization for Die Attach Process”: "IEEE", Volume: 6, Issue: 10, October 2016

[2] X Pan, CT Wu, W Hu, Y Wu, “A momentum-consistent stabilization algorithm for Lagrangian particle methods in the thermo-mechanical friction drilling analysis”, Computational Mechanics (2019)

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