Dynamic Solder Management

M. Cummings & G. Lindsay

Napier Polytechnic, Colinton Road, Edinburgh

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Interim Report 0003

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Title of Proposal Dynamic Solder Management

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Principal Investigators M. Cummings & G. Lindsay

Abstract

Results from initial 2D steady-state isothermal simulations of wave soldering of DSM modified PCBs are presented. The effects of small (2mm) obstacles on solder flow paths can be clearly seen. More sophisticated, realistic models are under development and will be reported next quarter.

1 Introduction

This report gives an overview of work to date (mid-March 1992) and future work directions for the 1991-92 Napier AMC / DCMC International research project (Contract: DAJA 45-91-C-0016), 'Dynamic Solder Management Techniques'.

The work can be conveniently divided into two broad areas; computer modelling of solder flows and physical testing. Physical testing will be covered in subsequent reports, initial 2D computer simulations are described below.

2 Computer Modelling

This is the major area of effort for the first section of the research contract and involves computer simulations of solder flows across the underside of a PCB during a wave soldering operation. These simulations are being used to determine the effects of obstacles to flow (DSM profiles) placed on the underside of the PCB and the way in which the solder flow is modified.

Computational Fluid Dynamics (CFD) is now, with the advent of powerful, affordable computer systems, an established engineering tool and has been applied to many problems involving a variety of fluids and flow conditions, including liquid metal flows. In the UK, the Atomic Energy Authority (formerly UKAEA) market three CFD codes which were originally developed for modelling liquid metal flows in Fast Reactors (sodium cooled). There are many other codes available, from a variety of sources, academic and commercial but, at present, none of these commercially available codes can simulate the complicated mixed physics of the wave soldering process The software used for this project was developed in-house at Napier (Ref 1) and, although it suffers from the same limitations as the commercial codes and does not have built in sophisticated colour graphics facilities, it offers advantages in that the original source code is available permitting customisation to suit different types of flow problems.

The code solves, in finite difference form, the steady-state conservation equations of mass, momentum and thermal energy with presentation of the fluctuating velocity components made using the k-ϵ turbulence model. The code can be used to solve problems in either two or three dimensions. This report deals only with the two dimensional solder problem, three dimensional effects due to DSM profile geometries are currently being addressed.

2.1 Flow Solder Processes and the Simplified CFD Model

Flow soldering processes involve translating a PCB, and the components to be soldered into place, through or across a wave of solder which can be of variable height (different pumps, flow velocities) and geometry (symmetric or asymmetric). The situation is complicated by the fact the board and solder have different thermal properties and are initially at different temperatures, by wetting / surface tension effects and chemical reactions (fluxes are generally used and intermetallics are formed). A computer model encompassing all these factors (if possible) would be extremely complicated and would have to incorporate multi-phase turbulent flows with heat transfer and surface wetting/dewetting for complicated geometries, where surface tension effects may even dominate.This does not appear to be possible with currently available CFD codes although enquiries are continuing. Fortunately the basic factors governing DSM techniques and their effects on flows can be usefully demonstrated and investigated using a much simplified isothermal, two-dimensional lamellar, steady-state solder flow model given that appropriate flow parameters and boundary conditions can be chosen. The first step, therefore, to creating a useful CFD model of the wave soldering process and DSM was to measure/estimate/calculate the necessary flow and fluid parameters; velocities, viscosities, densities, temperature (assumed constant 250 deg C) etc..

This was done by reference to the relevant literature (Ref 2,3), metals data books (Ref 4) and by experimental observations involving filming of the soldering processes using transparent PCB mock-ups. Table 1 gives the relevant simulation data for the chosen Sn60 / Pb 40 solder composition. Figure 1 is a simplified diagram of the solder wave. Figure 2 shows the calculational grid, unobstructed flow, used for the CFD calculations.

Table 1 Wave Soldering Parameters for CFD Model

Solder temperature (PCB temperature)	250 deg C
density	8000 kg / m^3
*viscosity	$2*10^{-3}$ Pa s
velocity	0.1 - 0.5 m / s
*thermal conductivity	49 J / m s K
*surface tension (no flux)	0.5 J / m^2

* Ref 2

The data given in Table 1 and the simplified isothermal model being used are reasonable first approximations as the density, viscosity and surface tension of the solder alloy considered are not strongly dependent on temperature; at 250 deg C the density of Sn60 / Pb40 decreases by about 1 kg / K, viscosity changes little between 250 and 260 deg C (and was taken to be independent of shear rate i.e. Newtonian) and surface tension (although not modelled at this first stage) decreases by about 0.0001 J / m^2 per degree temperature increase.

2.2 The CFD Calculational Grid and 2D Simulation Results

The first stage CFD model involves flow below an infinite length 5mm thick (irrelevant to this simple model) PCB with a calculational grid spacing of 0.5mm. This grid is sufficiently fine to show boundary layer effects where the flow velocity (taken to be constant at 0.1 m / s, falls off to zero at the solder / board interface - surface tension effects are neglected). The undisturbed flow is shown in Fig 2 and that with a 2mm section DSM profile present in Fig 3. The arrows are vectors indicating flow directions and velocities and it can be seen how the DSM profile greatly alters the flow patterns inducing downstream flow recirculation. This effect is better seen in Fig 4 although in this instance the physical scaling is incorrect and the magnitudes of the velocities require to be rescaled also.

It is important to realise these models are first stage approximations and principally serve as pointers to more sophisticated, and physically realistic, models now under development. The new models are three dimensional and incorporate heat transfer effects but do not involve surface tension forces.

3 Present / Future Work Directions

The three dimensional flow simulations for the basic isothermal model will show the effects of different DSM geometries and the observations from actual soldering runs will be used to validate these models. Heat transfer effects will then be incorporated. The effects of multi-phase flows (involving entrapped air or the evolution of gases or vapours at soldering) has been raised, Ref 5, and will be considered but will require additional resources and access to relevant external experts.

4 Conclusions

Simplified 2D models of solder flow have been developed and clearly show the effects of DSM profiles (obstacles) on solder flow. These models are currently being developed to more closely approximate actual soldering processes and conditions.

References

1 Awbi, Dr. H.B., Napier Polytechnic Internal, 1986

2 Klein Wassink, R.J.1984

3 Frear et al, 1990

4 Metals Handbook, 1990

5 Cummings, M., Internal Comm., Feb. 1992

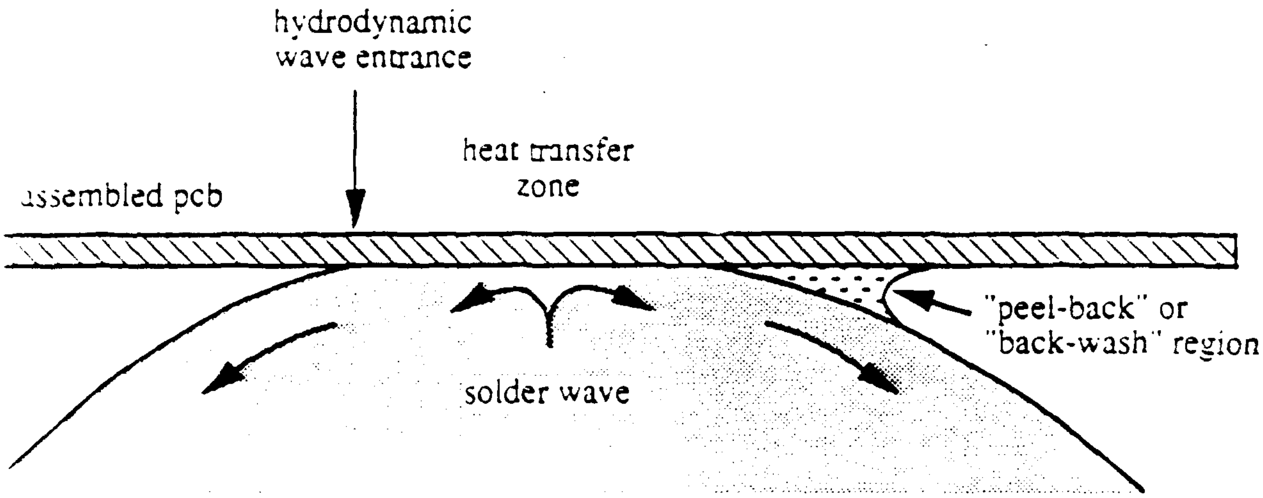
hydrodynamic
wave entrance
heat transfer
zone
assembled pcb
"peel-back" or
"back-wash" region
solder wave

Figure 1

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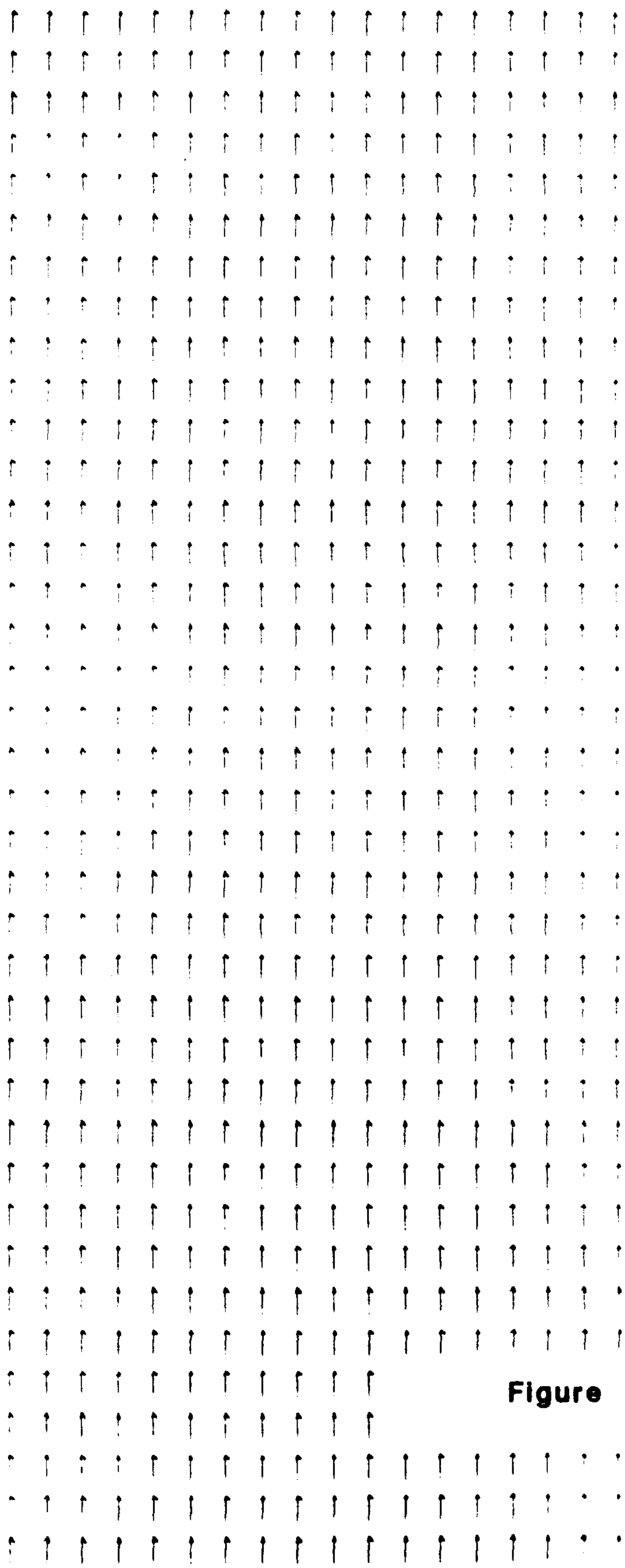

Figure 2

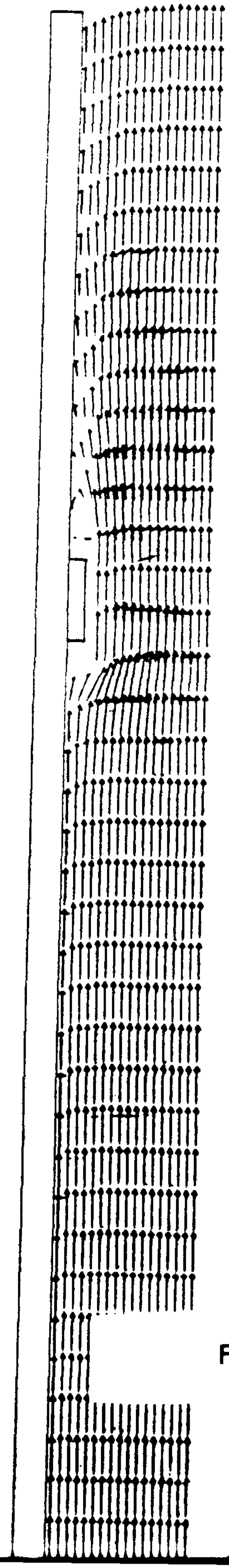

Figure 3

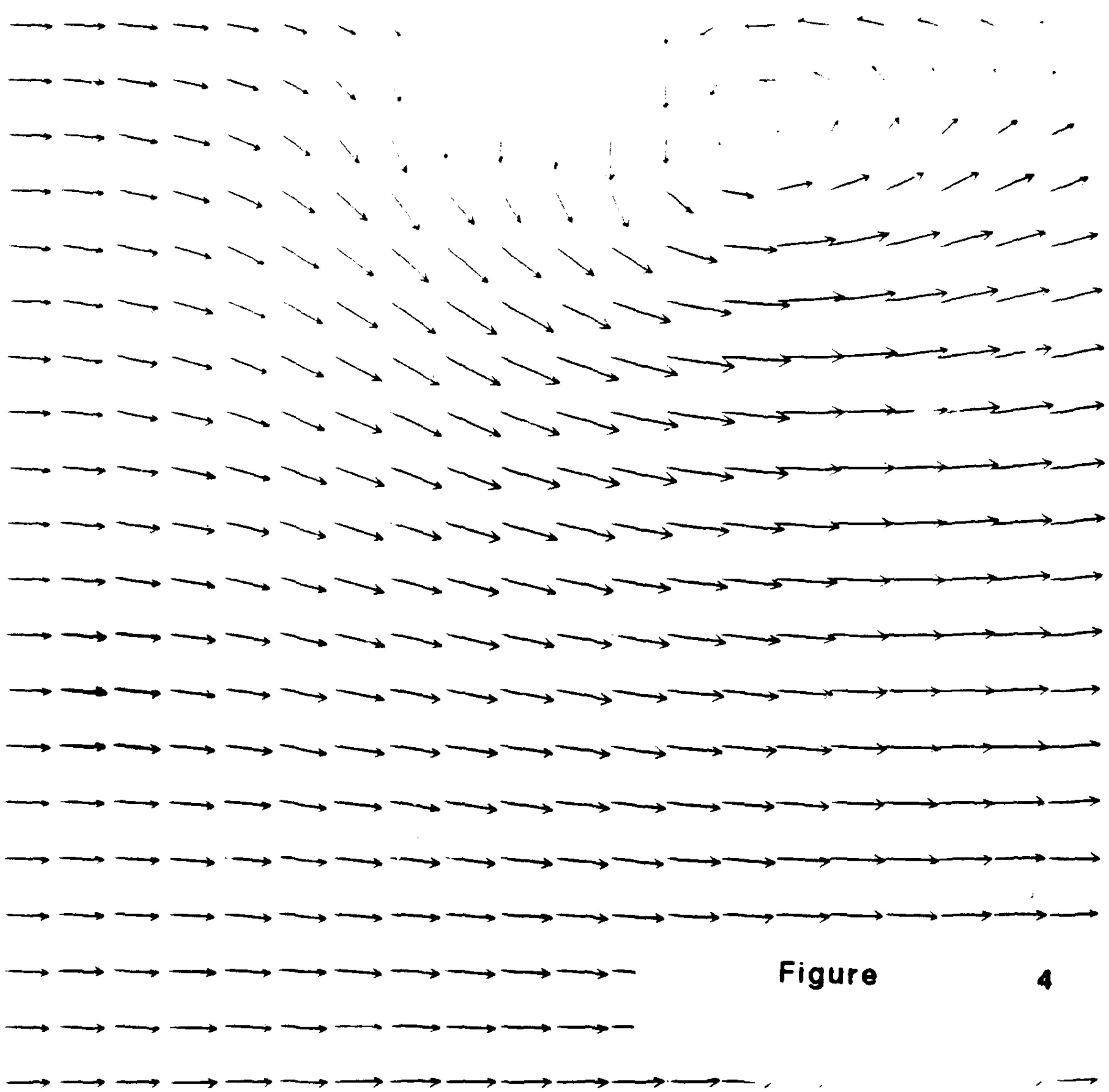

Figure 4

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