Strain Correlation: Finite Element Modeling and Experimental Data

Mohammad Gharaibeh[1], James Pitarresi[1] and Martin Anselm[2]
[1]Department of Mechanical Engineering, Binghamton University
[2]AREA Consortium, Universal Instruments Corporation

Abstract: A proof-of-concept study was carried-out to demonstrate how existing drop testing data in the Consortium database could be used, in conjunction with finite element (FE) models, to estimate the stresses at various points in the assembly. The strain correlation procedure was implemented by matching the measured strain values obtained during drop testing of the samples to that in the FE model at the same location. Once the values matched, the stresses from the FE modeling were extracted. From these stresses and number of cycles to failure from experiment, a crude S-N curve was developed.

1 INTRODUCTION

The goal of this work is to provide a proof-of-concept exercise for the correlation of measured strain on the board between experimental results and FE models so that the models can subsequently be used to estimate stresses at critical points in the assembly. Specifically, we are interested in an estimate of the stress under the solder joint as this can be used with measured cycles to failure to produce a crude S-N curve for the assembly under drop test conditions.

2 FINITE ELEMENT MODELING

Table 1 presents the dimensions of the printed circuit board, solder joint, and component for the test assembly used in this study. The initial material properties used in this model for the PCB and component are listed in Table 2.

TABLE 1
DIMENSIONAL PARAMETERS

Parameter	Dimension
PCB width*Length	180*180 mm^2
PCB Thickness	2 mm
Solder joint height	0.53 mm
Pitch	1.27 mm
Component width*length	37.5*37.5 mm^2
Component thickness	1.0 mm

SAC305 properties are in Table 3. Note that the PCB is FR-4 material, the component is copper and SAC305 is the solder joint alloy. All the previously mentioned materials are assumed to be linear elastic.

TABLE 2
MATERIAL PROPERTIES FOR PCB AND COMPONENT

Material Property	PCB
E_x	25.8 GPa
E_y	25.8 GPa
ν_{xy}	0.136
G_{xy}	12.1 GPa
Density	3030 Kg/m^3

TABLE 3
MATERIAL PROPERTIES FOR SAC305

Material Property	Value
E_x	90.0 GPa
ν_{xy}	0.36
Density	7400 Kg/m^3

The element type used in the FE model is ANSYS element "Solid45," shown in Figure 1. This element is defined by eight nodes; each node has 3 translational degrees of freedom, namely, u_x, u_y and u_z. This element was attributed to PCB, solder joints, copper pads and component.

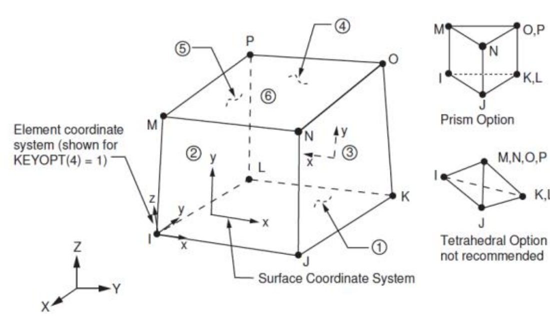

Figure 1. ANSYS Solid45 3D element.

The modeling procedure was started by building a "unit solder"model as shown in Figure 2. This unit was copied as needed for the geometry of the assembly (29×29 5-row Perimeter). The remaining portions of the component and PCB are then extruded up to the desired dimension. The total number of elements for this model is 241,238. Figure 3 shows the isometric view of the full model.

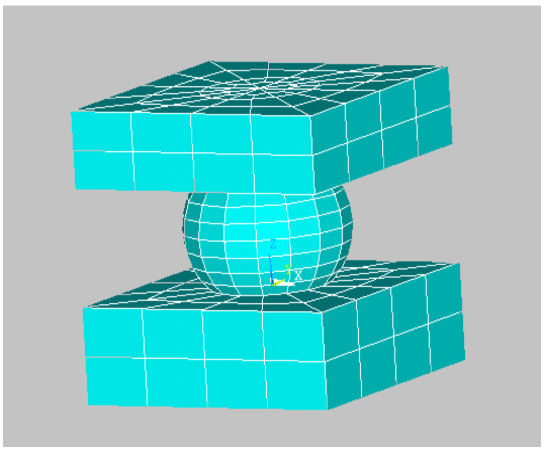

Figure 2. Typical solder joint unit.

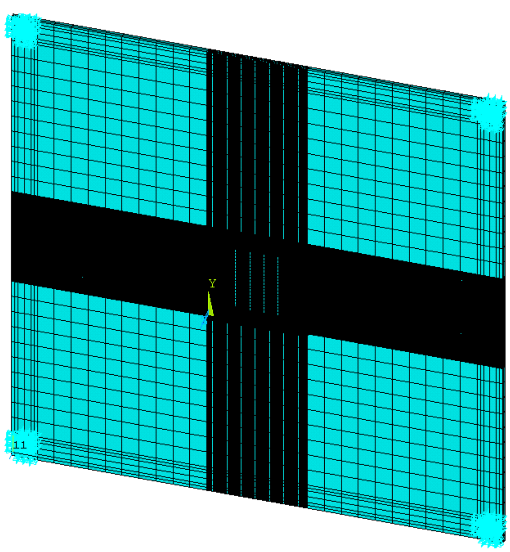

Figure 3. Full model mesh.

The boundary conditions applied on the model was to fix the internal surface of the standoff holes in model in all directions, namely, *x, y* and *z*. This simulates the bolts inside the holes when they are mounted on the drop table. This was similar to that used in other FE modeling studies for test boards mounted in a similar fashion.

4 STRAIN CORRELATION PROCEDURE

The simple correlation method used herein is based on systematically comparing the peak strain values from drop test measurement with those at the same location in the model.

In the drop test experiment, three acceleration levels were applied to the assembly, 125, 300 and 600 G's. The strain on the PCB was measured during the experiment using strain gages. Table 4 summarizes the maximum principal strain for each G level.

TABLE 4
STRAIN MEASUREMENT IN DROP TEST.

G Level	*Max. Principal Strain ($\mu\varepsilon$)*	*Cycles to Fail*
125	900	165
300	1,600	14
600	1,700	1

In the FE model, the shock loading was approximated by a static gravity load. The applied gravity loading has been systematically adjusted on the FE model till the FE strain matched the target strain as observed in the drop test data. Once this was achieved, the stress value at any location in the model can be easily determined. Of particular interest was the stress in region directly beneath the solder joints due to the observed failure mode of pad cratering.

5 RESULTS AND DISCUSSION

Table 5 shows the strain levels achieved in the FE model and the corresponding strain value from the drop test.

TABLE 5
CORRESPONDING STRAINS FROM TEST AND FEA.

Max. Principal Strain (µe) Measured	*Max. Principal Strain (µe) FE*
900	893
1,600	1573
1,700	1690

(1)

After correlating the model to the actual strain values, stresses were then estimated in the region below the solder joint. These stresses were used in developing S-N curve appears in Figure 4. As can be seen, a simple linear relation was plotted through the three data points. Clearly, additional testing and further analysis are required yet the basis for a rational approach to exploiting the UIC test data has been presented.

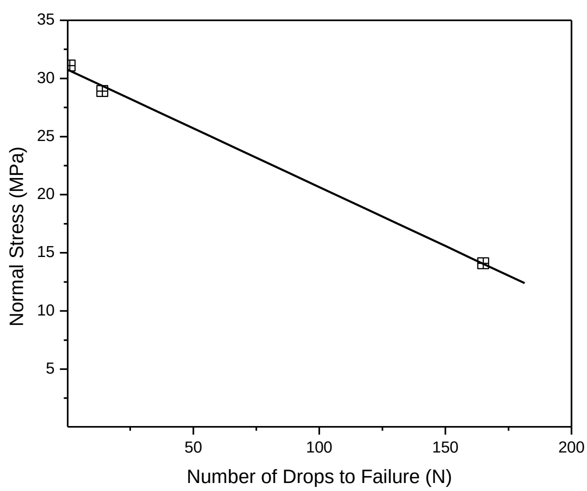

Fig. 4. S-N Curve obtained from FE stress and experimental cycles to failure.

CONCLUSION

A simple study was carried-out to demonstrate how existing drop testing data in the Consortium database could be used, in conjunction with finite element models, to estimate the stresses at various points in the assembly. A simple strain correlation procedure was used wherein the measured strain values obtained during drop testing of the samples was matched to that in the FE model at the same location. This was achieved by simply inducing a "gravity load" on the model. Once the strain values matched, the stresses from the FE modeling were extracted and in conjunction with the number of cycles to failure from experiment, a crude S-N curve was developed. Further studies can expand on this simple proof-of-concept idea thereby leveraging existing (and future) data to provided expanded usefulness to Consortium members.