NUMERICAL ANALYSIS OF THERMAL MODELS OF PLASTIC BALL GRID ARRAY COMPONENTS TYPE

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Abstract: *Currently, circuits using complex electronic components are becoming bigger and increasing the number of components, leading to an enhancement of thermal computer simulations because of the large amounts of elements needed in the mesh. This study compares the very detailed BGAs components with the simplifications usually made to reduce the processing time, but keep the results within a tolerable error range. It aims to show that even using a simplified model, it is possible to obtain consistent results, saving processing time. This comparison is to perform a thermal simulation with detailed components in a numerical wind tunnel (with the following quantities: pressure, velocity and temperature controlled), collect the results and its processing time, and then perform the same simulation, but with the simplified component, which is basically a block with the basic features of the component, such as junction temperatures (θjc and θjb), thermal emissivity of the material of the package, etc collect the same first data analysis. And finally, compare the results to gain insight into how different are the results of complex model for the simplified model and estimate the amount of error that exists in the simplified version.*

Keywords: *thermal model, PQFP, OpenFOAM*

1. INTRODUCTION

As geometries of ICs (Integrated Circuits) and lower density PBGAs (Plastic Ball Grid Array) increases, the power to manage these items becomes increasingly difficult. A dilemma for project groups is how to fit all the functions that market demands, without exceeding the power available. Although power is a concern of third or fourth order for most PBGA projects, is now a major concern for projects starting on scales of 90 nm and below because the more power a device consumes more heat it generates. To maintain an optimal operating temperature, it is necessary to dissipate heat.

There are three ways to dissipate heat from a device - radiation, conduction and convection. PCB Projects (Printed Circuit Board) utilizes heatsinks to improve heat dissipation. The transfer efficiency of heatsinks is due to low thermal resistance between heatsink and air.

Thermal resistance is a measure of a substance capacity to dissipate heat, or the efficiency of heat transfer across the boundary between different materials. A heatsink with a large surface area and good air circulation results in better heat dissipation.

The smaller and more complex ICs become, it gets more difficult to carry out tests and real experiments to find an optimal cooling system that allows it to operate safely. Thus, it becomes increasingly important and useful the numerical solutions for equipment development, reducing cost and providing potential problems.

But simulations are not cheap. When there are many components involved in the analysis, a large number of nodes (points where the calculations are performed to find the values of quantities at that point or node) is necessary, and the mesh becomes too dense, which increases time processing for analysis calculating, proportionally increasing its cost.

In this appear, the numerical simulation of a PBGA component will be performed, comparing a very detailed model of a component QFP (Quad Flat Package), simulating and collecting all relevant data such as number of nodes, processing time, and final results (temperatures and speeds in the component).
Then simulate the same component but modeled more simply, using manufacturer's data, such as thermal resistances, and reap the final results.

At the moment the data was acquired it can make a comparative analysis between them two, to evaluate the behavior of the component during the simulations.

2. DEFINITIONS

Some important information about the resources that were used in this work.

2.1. Quad Flat Package

A Quad Flat Package (QFP package or square), shows in Fig (1), is an encapsulation of integrated circuit with terminals extending from each of the four sides. It is only used in SMT (surface mount technology), it is not possible to use sockets or thru-holes. There are versions of from 32 to 200 terminals; with a pitch ranging from 0.4 to 1.0 mm. Special packaging includes LQFP (Low profile QFP) and TQFP (Thin QFP).

This type of packaging has become common in Europe and USA in the early 1990s, but QFP components have been used in japanese electronics consumer since the 1970s, often mixed with thru-hole components.

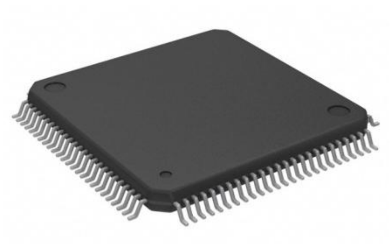

Figure 1. Package QFP

There are several specific types of packages MFF, particularly in this study will be used PQFP (Plastic Quad Flat Package), which is a standard package of plastics material, having its terminals welded directly into printed circuit boards using the SMT technique.

2.2. Open FOAM

The OpenFOAM ® (Open Field Operation and Manipulation) CFD Toolbox is a free software package produced by the open source CFD OpenCFD Ltd. He has a large user base in most areas of engineering and science, academic and commercial organizations. The OpenFOAM has an extensive range of resources to solve any problem in complex fluid flows involving chemical reactions, turbulence and heat transfer, the dynamics of solids and electromagnetism. It includes tools for mesh generation, including snappyHexMesh, a parallel mesh generator for complex geometries in CAD, and for pre-and post-processing. Almost all (including articulated, pre-and post-processing) is executed in parallel as standard, allowing users to take full advantage of computer hardware at your disposal.

Once it is opened, the OpenFOAM provides the users with complete freedom to customize and extend their existing functionality, either by themselves or through the support of OpenCFD. The following is a highly modular code design in which sets of functionality (e.g., numerical methods, mesh, physical models ...) are compiled into its own shared library. Executable applications are then created, which are simply related to the functionality of the library. The OpenFOAM includes more than 80 applications that simulate specific problem solvers in mechanical engineering and more than 170 utility applications that perform pre-and post-processing tasks.

2.3. Terms of thermal analysis

According to the model by Moghaddam et al (2003), the resistance θJ_C measures the resistance to heat flow between the die surface and the surface of the package (coating). That is an important finding for components used with external heat sinks. He assumes that the heat is flowing through the top. In the ideal case, all the heat is forced to escape from the package where the case's temperature is acquired. The lateral heat flow is not allowed or minimized such that the temperature differential source is attributable to the known total heat input.

The thermal resistance of the joint to the plate θJ_B is defined as:

$$\theta_{JB} = (T_J - T_B)/PD \tag{1}$$

Where T_B is the plate temperature measured in equilibrium state in the specified location and T_j is the junction temperature of the component. PD is the real power in watts, which produces the temperature change.

The temperature T_B is monitored on a plate with a thermocouple in a specific location in the vicinity of packages or cable connections. As an example, for the BGA package, the thermocouple is connected laterally along the side of the package with the attachment point within 1 mm from the body thereof.

As θJ_C, θJ_B depend on the limited flow in a preferential direction on simulations or actual measurements of the heat flow, it is forced to move, preferably through the plate and not on others paths with insulation.

The junction temperatures are represented by a network of thermal resistance which is adapted to analyze the variation in the average temperature of components and cooling capacity due to changes in insulation thickness.

From the chip, two paths of heat can be identified. The first path originated from the chip to the surface. The second way, also originating from chip, extending through substrate interface to board interface. And eventually, two distinct paths in branches that are terminated in rear insulation and an enlarged portion of the PCB. It is worth mentioning that all paths of heat play an important role in the development of a great insulation thickness. The coefficients of lateral heat transfer in the PCB, in absolute, are determined using similarity solution to natural convection.

3. METHODOLOGY

The simulation process was based on three stages, initially was chosen a component whose manufacturer provides information regarding the characteristics of thermal dissipation for models of two resistors (θ_{JB}, θ_{JC}), thus working with approaches from actual data, also using information from dimensions described in the catalog (all data on materials and components were obtained by manual and datasheet's).

The second step consisted in modeling for the simulation cases. The method of reproducing the first component PQFP was used with a model based on detailed scheme present in datasheet and shown in Fig. (2), then a block with dimensions of the model using a resistance network (two resistances: θ_{JC} e θ_{JB}), and finally a solid block of aluminum (density = 2.800 kg/m^3, Specific heat = 900 J/kg.K, Conductivity = 205 W/m.K, Isotropic) and another solid block of *epoxy* (density = 1.120 kg/m^3, Specific heat = 1.400 J/kg.K, Conductivity = 0.2 W/m.K, Isotropic), heating both from inside out dissipating heat, all three models are fixed on a PCB of material FR-4 and 1.6mm thick, with two inner layers of copper (circuit) and they were placed in a virtual wind tunnel 200x100x25mm, in which it was possible to obtain relationships number of elements and nodes, and processing time results. Versteeg et al (1995) explains the finite volume method, used in performed simulation.

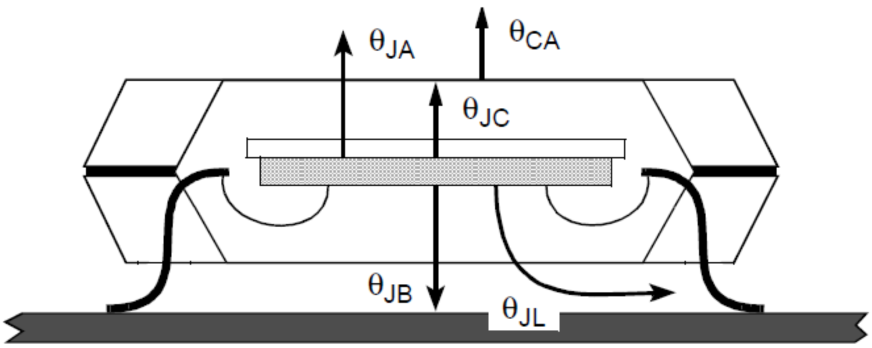

Figure 2. Scheme of the package PQFP component studied.

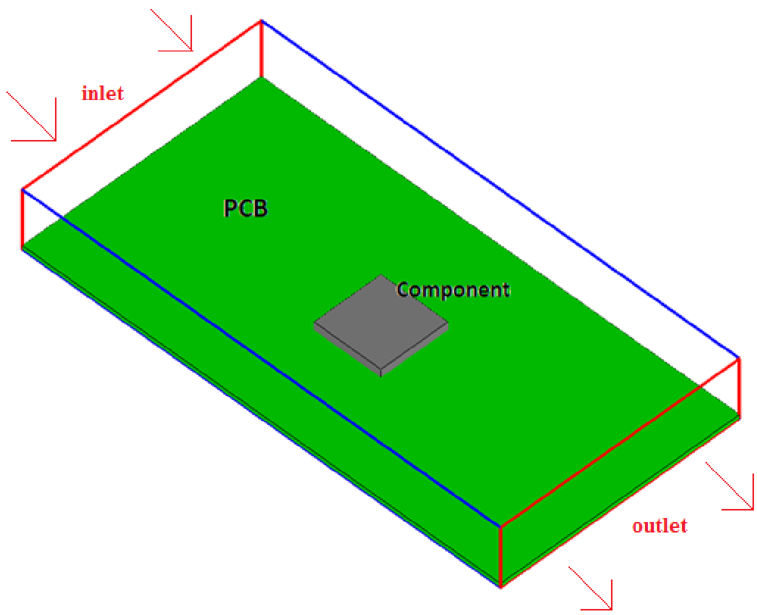

Figure 3. Layout of modeling simulations.

The simulations were made with air inlet speed which ranging from 0.5 m/s to 2 m/s an increasing of 0.5 m/s, ambient temperature of 25 ° C, and for each speed, to simulate multiple work points of the component, it was used a power dissipation ranging from 1W to 10W with an increment of 1W.

Figure (3) shows the wind tunnel used in the simulations.

The convergence parameters were adopted with $1x10^{-3}$ to flow and $1x10^{-7}$ to energy, and a maximum of 70 iterations. It was used the zero-equation model of convergence.

The simulations were performed on a computer with the following configurations: Intel i5 2.27 GHz processor, 6GB DDR3 memory.

From then to the third step, in comparison based on data obtained in the simulations, comparing the final results and "cost" of the simulation, which basically consists in processing time. Looking at these comparisons, it is possible to conclude whether the simplification is feasible, and what margin of error exists in the final result.

4. OUTCOMES

The obtained results were as expected. Table (1) below shows the number of nodes and elements of each case.

Table 1. Number of nodes, elements and and processing time of each case.

Componente type	Detailed	Al Block	Network	Epoxy Block
nº of Elements	135.000	122.895	121.995	122.895
nº de Nodes	144.228	131.624	131.036	131.624
Average time [min:sec]	02:55	01:19	02:00	01:53

In each trial was performed the simulation and acquired the temperature in a single point of control, adopted on the center of the analyzed block.

Figure (4) illustrates a graph of obtained results of the four cases with air inlet speed of 0.5m/s, in a similar way, the Fig. (5) illustrates the results using a range of speed of 1.0m/s , Fig. (6) using speed of 1.5m/s and the Fig. (7) which the experimental speed is 2.0m/s.

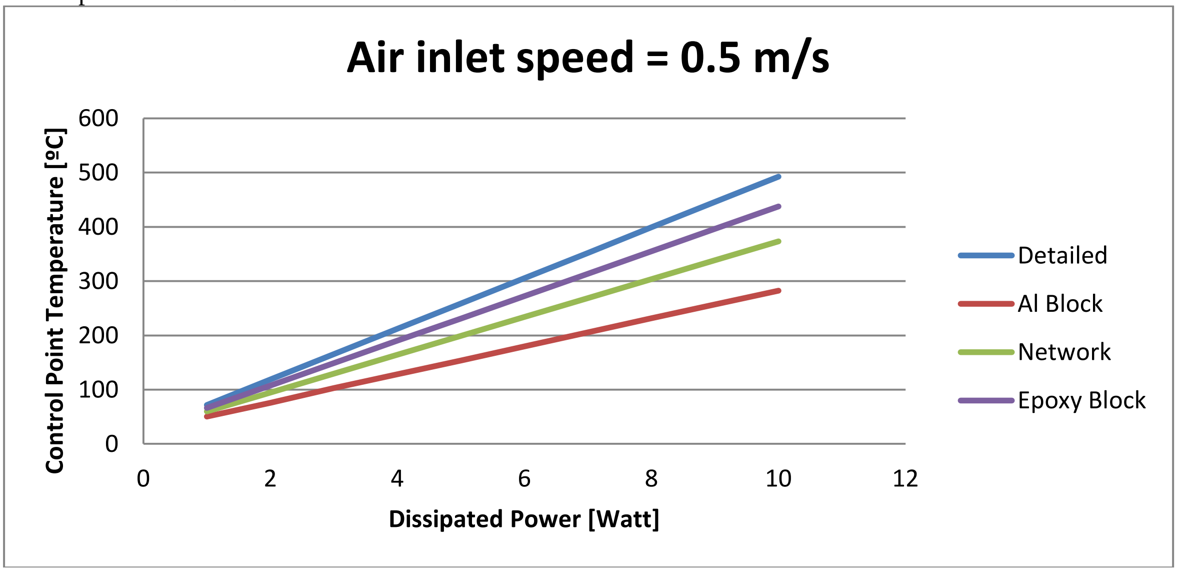

Figure 4. Power x Temperature for air inlet speed of 0.5 m/s.

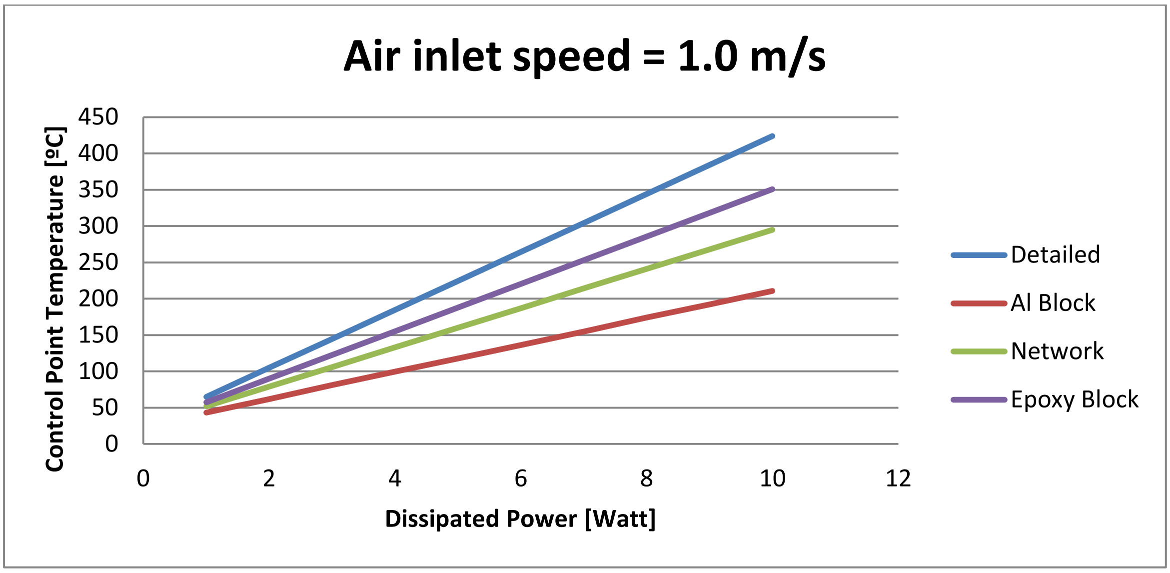

Figure 5. Power x Temperature for air inlet speed of 1.0 m/s.

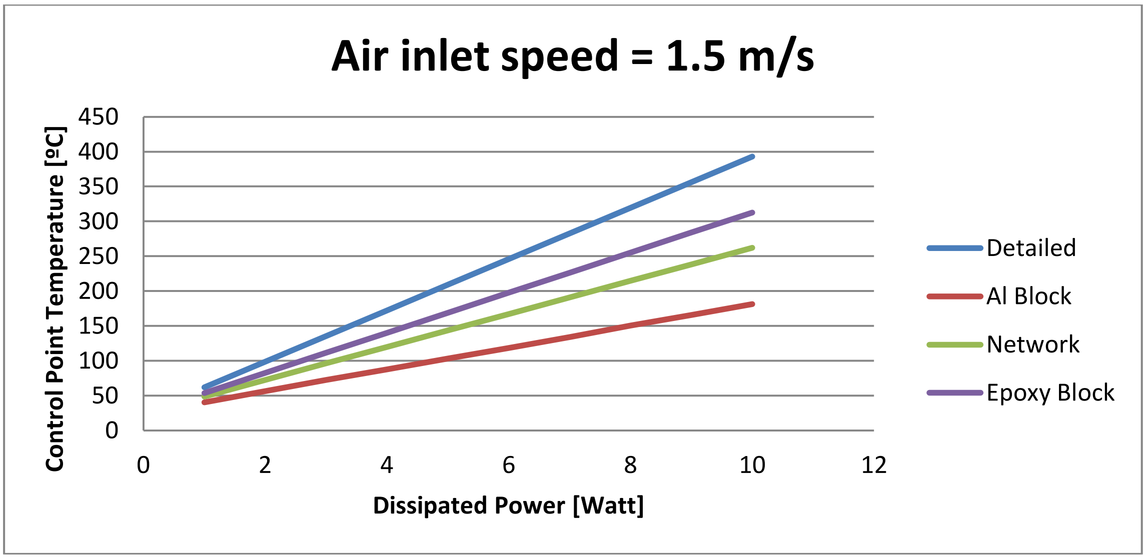

Figure 6. Power x Temperature for air inlet speed of 1.5 m/s.

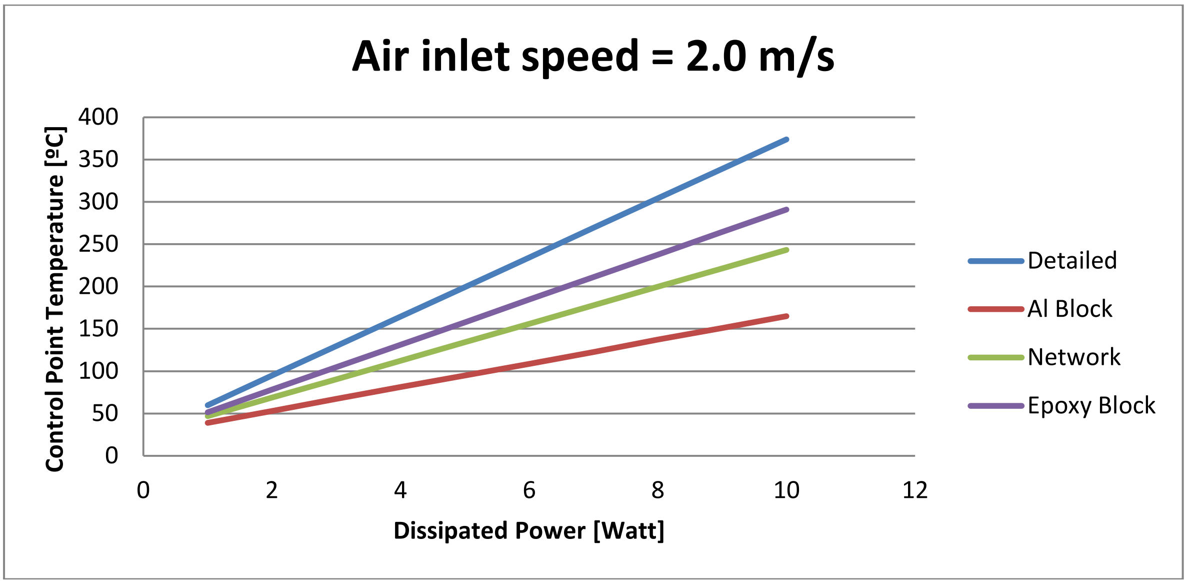

Figure 7. Power x Temperature for air inlet speed of 2.0 m/s.

As it shows, the gain in processing speed is substantial, reaching up to 50% of the time of detailed model. However, the difference of temperature is also considerable, reaching about 50% of the temperature of more detailed model, what was expected in the case of these simplifications.

Considering the gain in processing speed, especially knowing that would be much more complex circuits involved in this type of simulation, and being aware of the error that this type of simplification inserts in the model with reference on the performed analysis, the model can be adjusted for the final results and meet the specifications, even with the error, thus justifying the use of simplified models in order to reduce the cost of the simulations.

Often, these simplifications are also influenced by the processing capability of the equipment available and therefore need to be able to perform them.

5. ACKNOWLEDGEMENTS

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7. RESPONSABILITY NOTICE

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