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MAKING OPTIMAL DESIGN DECISIONS FOR NEXT GENERATION DISPENSING TOOLS

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ABSTRACT

The competitive environment faced by semiconductor equipment suppliers leaves no room for error when designing next generation tools. In addition, time to market, footprint, and equipment capabilities are all key to a successful product. At Cookson Electronics Equipment, tool designers used simulation to answer some difficult design questions, improve time to market, and lower development costs. This paper explains how simulation was used in designing the new High Volume Batch (HVB) dispensing platform. It also discusses the flexible simulation model and simulation results for various prototype equipment designs.

1 INTRODUCTION

Cookson Electronics Equipment is an industry innovator dedicated to the development and manufacturing of products for the electronics assembly and semiconductor packaging industries. Specific to this study, Cookson provides dispensing systems for surface-mount electronics and chip scale packaging applications. These systems dispense solder paste, SMT and conductive adhesives, encapsulants and flip-chip underfill with precision, speed, and reliability.

In normal production, magazines are loaded into an indexer or elevator. Magazines contain a fixed number of slots in which metal or plastic boats are held and transported, as shown in Figure 1. A boat is used to hold a specific number of substrate carriers which become the final product. Each carrier contains circuitry and one or more device, such as a bonded chip, and will be the focal point of the dispensing activities.

Throughput is defined as the rate at which a dispensing system can process carriers (given in carriers per hour). Throughput is a key factor in determining a tool's productivity index. There are two main design issues involved with achieving a high throughput for a tool. First, the system must be capable of quickly moving boats between the magazine and dispense area. Second, the dispense operation needs to be optimized to finish the dispensing requirements in the least amount of time.

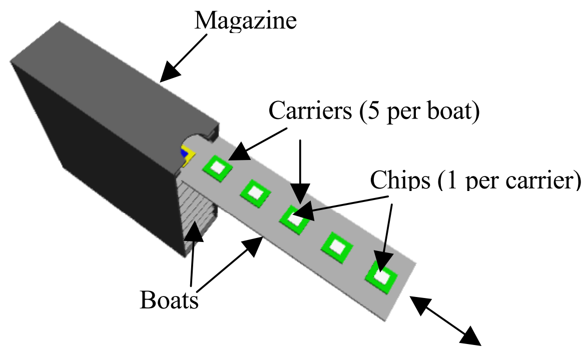

Figure 1: Product Component Terminology

New dispensing technologies and product requirements have paved the way for development of a new tool design. Using simulation, various configurations and options have been studied. Simulation has proven to be a quick and cost-effective method for making intelligent decisions relating to new equipment designs.

Simulation provides many key benefits to tool designers. For example, prototype simulation models can be built much quicker and at less cost than actual prototype equipment. This can greatly reduce the time required to get the final product to market. In addition, simulation models can expose less efficient configurations and options early in the tool design phase, so they can be eliminated from design consideration early on. Equipment designers can then focus their efforts on configurations and options that simulation has shown to have a positive impact on throughput. By focusing only on those options that were proven through simulation, equipment designers can streamline the development process, reduce development costs, and help ensure the integrity of the final design.

2 EQUIPMENT SIMULATION MODEL

Simulation has been used as a marketing and engineering tool for years in the semiconductor equipment industry with varying degrees of success. A successful simulation model contains three key attributes:

1. **The model must be fast and easy to use.** This includes the capability of quickly and easily setting up case scenarios and interpreting the results.
2. **The model must be accurate**. For a simulation model to be of any worth, it needs to accurately reflect the reality it is designed to simulate.
3. **The model must be flexible.** The model must allow for periodic changes and updates due to the iterative process of modifying the design, running the scenario, and analyzing the results.

Flexibility can be built into the initial model design if the correct simulation software is chosen. A flexible model design will allow the model to be run using any possible configuration or option within the bounds of the design concept. This, in turn, results in quick analysis and experimentation with the simulator.

In the Cookson study, a flexible simulation model was constructed to address all possible configurations and options within the bounds of the new tool concept. The simulation model was driven by several data input files contained within an Excel workbook and read into the simulation model at the beginning of the run. These data files were used to define the system configuration, options, and component speeds for the given scenario. These data files are discussed in the sections that follow.

2.1 Configuration File

The Configuration input file specifies the dispenser configuration and product dispense requirements. Input from this file includes:

- Visual measurement and sense times
- Dispense weight (per shot) and overall capacity
- Changeover, calibration, and maintenance requirements for each dispense head
- Number of dispense passes required per product, and time requirements for each pass including wait times in between passes
- Pre-heat and post-heat timers.

2.2 Options File

The options.txt input file specifies the various options being considered for implementation in the real tool. The simulation results were used to validate each option and support decisions about implementation into the final tool design. Input from this file includes:

- Product information such as magazines per elevator, boats per magazine, carriers per boat, chips per carrier, and so forth
- Product loading and unloading sequence options
- Dispense unit processing options
- Dispense unit dependency options
- Number of magazine elevators
- Boat dimensions.

2.3 Speeds Input File

The speeds input file specifies hardware speeds. Every possible move of the system equipment was defined and assigned a variable move time. Input from this file includes:

- Elevator speeds and index times
- Pallet shuttle times
- Gantry move times including clamp and unclamp
- Dispenser head move times.

3 EQUIPMENT DESCRIPTION

The dispensing equipment is made up of several components. Each component may or may not be used, depending on the design configuration. Two main design configurations were established for this study.

3.1 Configuration 1

Configuration 1, as shown in Figure 2, uses one magazine elevator and requires a pallet loader to load and unload boats onto two indexing pallets.

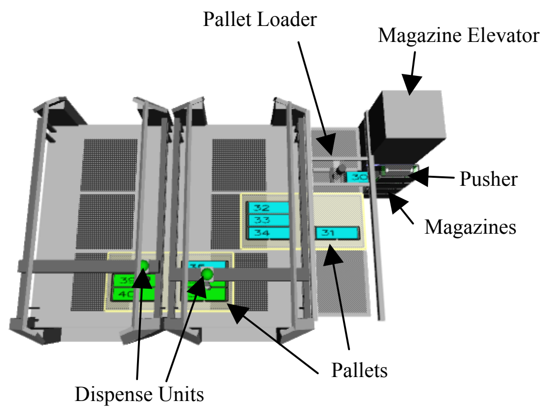

Figure 2: Equipment Components for Configuration 1

Magazines are loaded into the magazine elevator by an operator. The elevator indexes to the slot height of the next boat that is to be removed. The pusher then pushes the boat out of the magazine and into the gripper of the pallet loader. The pallet loader then moves and places the boat to a position on the pallet.

Each pallet has a left and right side. Each side holds a variable number of boats (three boats per side are shown in Figure 2). Once both sides of the pallet have been loaded, the pallet indexes into the processing position (beneath the dispense units). At this location, the left dispense unit processes product on the left side of the pallet and the right dispense unit processes product on the right side. The dispense units can work in their front or rear quadrants. The goal of this configuration is to keep the dispense heads working in one area (front or rear), while the pallet associated with the other area is being unloaded and reloaded. This configuration defines the "High Volume Batch" design.

3.2 Configuration 2

Configuration 2, shown in Figure 3, uses four magazine elevators and eliminates the pallet loader and indexing pallets. Instead, a bi-directional conveyor system is used to index boats between the magazine and dispense area.

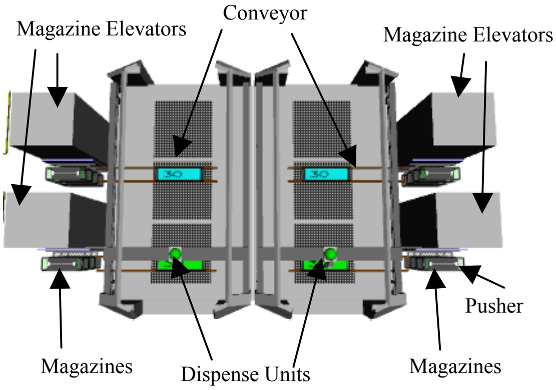

Figure 3: Equipment Components for Configuration 2

Magazines are loaded into the magazine elevator by an operator. The elevator indexes to the slot height of the next boat that is to be removed. The pusher then pushes the boat out of the magazine, and onto the indexing conveyor. The indexing conveyor then transports the boat to the respective dispensing area.

Conveyor sections are bi-directional and are also used to index a processed boat from the dispense area back into the magazine slot. With this configuration, only one boat at a time can occupy the respective dispense quadrant.

The dispense units are used to process the carriers in the boat. Each dispense unit carries a camera (used for visual and measurement work), and a dispensing unit (used for dispense and overfill). Each dispense unit can work in either the front or back areas of its respective side. Figure 3 shows both dispense units working in the front.

4 PROCESSING REQUIREMENTS

Magazines are loaded into the magazine elevator by an operator. The magazine remains loaded until all of the carriers inside have been routed to the dispense area and processed. When a boat is removed from the magazine, it is either placed on the pallet (configuration 1) or indexed into the dispense location (configuration 2). At this point, the preheat timer starts. Each boat must be pre-heated before any dispensing can occur.

Once the boat is in the dispense area, the dispense unit can begin work. The camera is used to check carrier coordinates, Z sense, and other measurement work. Once the fiducials have been checked and the carriers are preheated, the first pass of the dispensing can begin. If there is more than one dispense pass required, the subsequent pass cannot begin until a specified wait time has elapsed from the previous pass.

After the last pass has been dispensed onto the carrier, a post-heat timer is started. The boat cannot be placed back into the magazine until this post-heat time has elapsed. With configuration 1, the pallet will not index back into the load/unload position until all boats on the pallet have completed processing. With configuration 2, the boat will not index back into the magazine until the post-heat time has elapsed.

5 SIMULATION SCENARIOS

Initial simulation scenarios were setup and run to determine optimal tool configuration and options given known dispensing requirements. Table 1 outlines the initial scenario matrix.

In Table 1, the Configuration Used column indicates which configuration, previously defined in sections 3.1 and 3.2, was used.

The Pre-Heat and Post-Heat columns show the respective timers that were used in each scenario, as explained in section 4.0.

The Dispense Setup column indicates the dispense requirements needed for the respective scenario. Information for the dispense profiles is located in Table 2 and represents known requirements.

Table 1: Scenario Matrix

Scenario	Config Used	Preheat	Post-heat	Disp. Setup	Unit Dependency	Loading Option
1	Config 1	30	30	DP1	Coupled	Batch
2	Config 2	30	30	DP1	Coupled	NA
3	Config 1	30	30	DP1	Uncoupled	Batch
4	Config 2	30	30	DP1	Uncoupled	NA
5	Config 1	30	30	DP1	Coupled	ALT
6	Config 1	30	30	DP1	Uncoupled	ALT
7	Config 1	130	80	DP2	Coupled	Batch
8	Config 2	130	80	DP2	Coupled	NA
9	Config 1	130	80	DP2	Uncoupled	Batch
10	Config 2	130	80	DP2	Uncoupled	NA
11	Config 1	130	80	DP2	Coupled	ALT
12	Config 1	130	80	DP2	Uncoupled	ALT

Table 2: Dispense Profiles

Disp. Setup	Pass 1 Time	Wait 1 Time	Pass 2 Time	Wait 2 Time	Pass 3 Time	Wait 3 Time	Pass 4 Time
DP1	2.0	40.0	3.0	0	0	0	0
DP2	1.7	20.0	1.5	50.0	2.0	90.0	2.0

The Unit Dependency column is used to specify how the dispense units are configured. This value will be either "Coupled" or "Uncoupled." When the dispense units are "Coupled," both dispense heads must move along the Y-axis (front to back) at the same time. Dispense units can move independent of one another if the option is set to "Uncoupled."

The Loading Option is used only with configuration 1 and will be set to either "Batch" or "ALT." If Batch is used, the pallet will be loaded one quadrant at a time (left side then right side). If ALT is used, the pallet will load one boat to the left side, then one boat to the right side, and continue alternating until both quadrants are full. This option allows the pre-heat timers to be staggered between the left and right side, eliminating the need for the right dispense head to wait for the pre-heat time to elapse after the left dispense head has started.

This loading option also applies to unloading. If Batch is used, the pallet will be unloaded one quadrant at a time (right side then left side). If ALT is used, the pallet will unload one from the right, then one from the left, until all of the boats on the pallet have been unloaded.

6 RESULTS

The simulation scenarios were run using the simulator. The simulation model, which provides real-time 3-D graphical animation, was used to verify that each scenario ran the configuration and options correctly. Also, since there was no measurable variation in the input process times or equipment speeds, only one run per scenario was made.

The simulation response used to measure system performance is throughput. Throughput is measured in carriers per hour. This measurement tracks the number of carriers that have been processed over time. A carrier is not considered complete until the magazine in which it resides has been unloaded. The simulation results are shown in Table 3.

6.1 Configuration Results

The initial results show that configuration 1 achieves a higher throughput than configuration 2 for the two common dispense setups that were studied. Figure 4 illustrates the throughput difference for each configuration on similar runs. Careful examination of the simulation runs shows why configuration 1 provides higher throughput than configuration 2. Since configuration 1 is a "Batch" method of loading the dispense area, it is less affected by the pre-heat

Table 3: Throughput Results

Scenario	Config Used	Pre-Heat	Post-Heat	Disp. Setup	Unit Dependncy	Load Option	THRUPUT Carriers/Hr
1	Config 1	30	30	DP1	Coupled	Batch	958.5
2	Config 2	30	30	DP1	Coupled	NA	631.5
3	Config 1	30	30	DP1	Uncoupled	Batch	958.5
4	Config 2	30	30	DP1	Uncoupled	NA	631.5
5	Config 1	30	30	DP1	Coupled	ALT	686.2
6	Config 1	30	30	DP1	Uncoupled	ALT	686.2
7	Config 1	130	80	DP2	Coupled	Batch	840
8	Config 2	130	80	DP2	Coupled	NA	609
9	Config 1	130	80	DP2	Uncoupled	Batch	840
10	Config 2	130	80	DP2	Uncoupled	NA	609
11	Config 1	130	80	DP2	Coupled	ALT	840
12	Config 1	130	80	DP2	Uncoupled	ALT	840

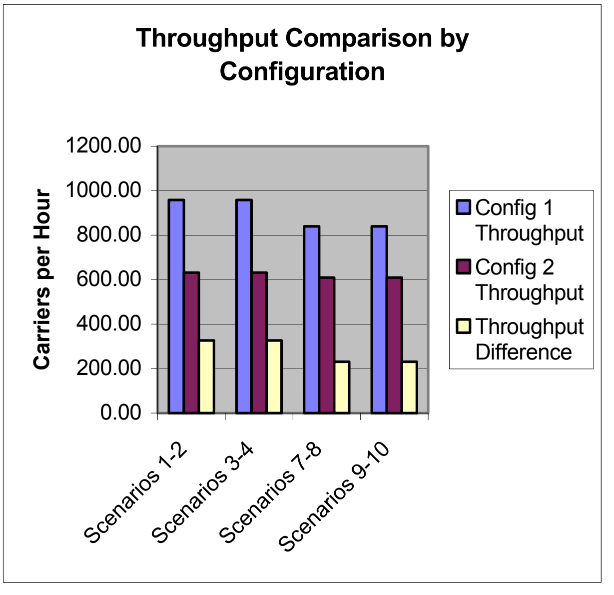

Figure 4: Throughput Comparison by Configuration

timer, the post-heat timer, and the wait times between-passes. With a batch of boats waiting to be processed, the dispense unit is more insulated from the effects of the timers. This was proven by making additional simulation runs with scenario 1 and scenario 2. In these runs, the wait time (time between passes) was set to 0 and the preheat and post-heat times were gradually increased. Figure 5 illustrates the effects of pre-heat and post-heat timers on throughput for the two configurations and supports the claim that configuration 1 is less affected by the timers than configuration 2.

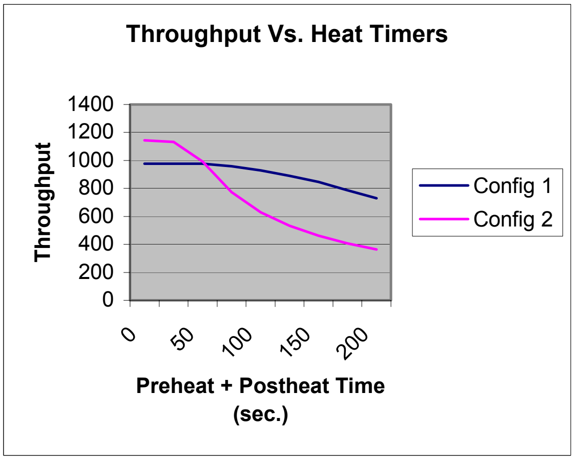

Figure 5: Effects of Heat Timers on Throughput

6.2 Unit Dependency Results

Simulation results show that there is no design benefit to uncoupling the two dispense units. When comparing like scenarios, in which only the Unit Dependency is altered, all comparisons achieve the same throughput.

6.3 Load and Unload Option Results

Simulation results show that the alternate (ALT) loading and unloading method has a negative impact on throughput for dispense profile DP1, and no effect on the DP2 dispense profile. The initial idea behind alternate loading and unloading was to even out the timer starting values between both of the pallet. For example, using batch loading, the left side of the pallet is loaded completely before the right side is loaded. Therefore, all boats on the left side of the pallet are eligible for dispense prior to any boat on the right side (because their preheat times elapse sooner). This may force the right dispense head to wait until well after the left dispense head has started. Alternate loading would lessen the time gap between sides. With smaller timer values (as with DP1), this benefit is more than offset by the negative impact of the additional pallet moves required for alternate loading and unloading. Figure 6 illustrates the throughput difference.

6.4 Other Results

The simulation model has been used to quickly answer many other types of questions. For example, an operator has a certain time window in which a completed magazine needs to be exchanged before throughput is affected. Scenarios have been run to graph the point at which the operator response time starts impacting throughput as shown in Figure 7.

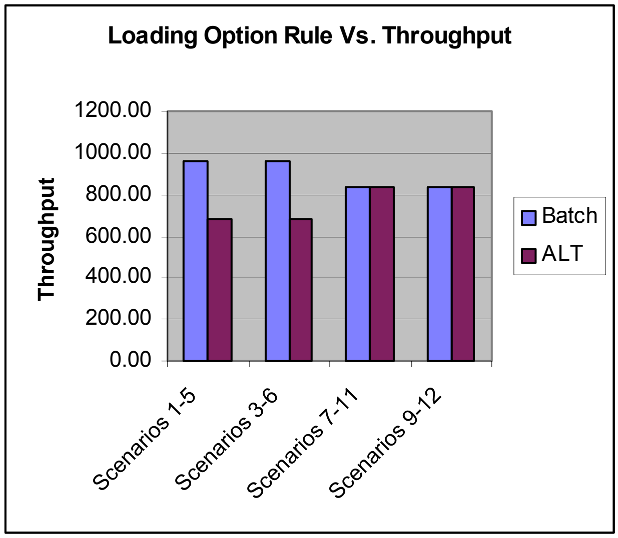

Figure 6: Effects of Loading and Unloading Options Rule

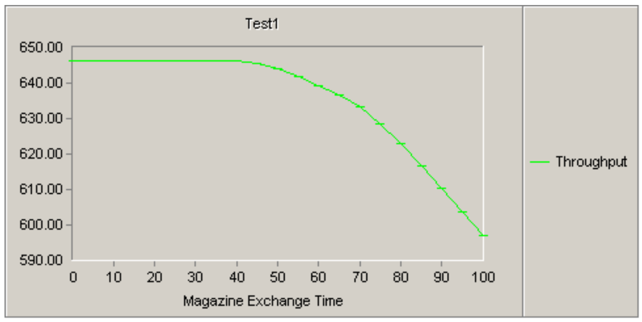

Figure 7: Effects of Operator Exchange Time

7 CONCLUSIONS

The increasing complexity and versatility of semiconductor equipment has enhanced the need for simulation. The initial investment of time and resources for constructing a flexible simulator of the equipment design concept is minimal when weighed against the benefits it provides.

In the Cookson study, the simulator accurately identified the options and configuration that would have a positive effect on tool performance. It was also used to fine tune other areas. For example, the simulator was used to determine that, for most common dispense profiles, adding a second magazine elevator to configuration 1 offers only a slight benefit. Also, the simulator was used to determine that there is no benefit to having individual preheat timers on each boat and that one timer for the quadrant is sufficient. This alone saved weeks of software development work.

Using simulation at Cookson Electronics provided several benefits. Simulation helped build consensus among the design team. It helped answer many difficult and complex questions, enabling designers to focus on impact areas. It resulted in reduced time to market, and a more competitive design at a lower production cost than originally anticipated.

ACKNOWLEDGMENTS

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