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SIMULATION ISSUES IN ELECTRONICS MANUFACTURING

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ABSTRACT

This paper attempts to bring into focus some of the more difficult modeling issues that relate to electronics manufacturing. It also provides some direction derived from the authors own experiences.

1 INTRODUCTION

Say the word "electronics" and what do you think of? Computers, televisions, consumer electronics, and perhaps semiconductors. In the latest edition of The Electronic Business 200, Electronic Business had 16 different types of electronics companies. They included groups like software, medical, communications, government, peripherals, and computer-based systems. Well over 2 million people are employed by companies that produce electronics that are sold as end products. There are companies that we would not consider electronics companies that, in fact, are quite large electronics companies. Ford is the twenty-second largest electronics company in the U.S. With electronics sales of $3.25 billion, electronics makes up 3.3% of Ford's sales. Boeing is the thirty-second largest electronics company in the U.S. Its $2.6 billion in sales was 9.4% of the company's sales. There are other such companies including No. 6 GM Hughes Electronics, No. 15 Rockwell International, No. 17 Eastman Kodak, and the list goes on. These sales numbers do not include the captive electronics manufacturers throughout the country. Ford, GM and Chrysler all have captive electronics manufacturing operations that produce electronics for the automotive assembly plants. If you work in the U.S. with a major U.S. manufacturing firm, it is likely that somewhere along your manufacturing chain, your company is producing electronics.

We decided to do this paper because of our experiences in electronics manufacturing simulation and electronics manufacturing. There have been the successes and failures that you would expect. There have also been the refinements, redefinitions, and rewrites of models that are common on simulation projects. Based on that experience, we simply want to provide people some insight when developing electronics manufacturing simulations.

2 ELECTRONICS MANUFACTURING

Electronics manufacturing can be broken down into three basic categories: Assembly (automated and manual), test/repair, and pack. There are many combinations of these three basic processes, depending on the industry. Simulation issues regarding electronics manufacturing can be discussed in this electronics manufacturing structure.

What makes electronics manufacturing different from other industries where you have assembly, test, and pack? We have discovered that there are two differences that greatly contribute to the issues in simulation.

First, test dominates the manufacturing process. You would be hard pressed to find a manufacturing process of a quality electronics manufacturing company where test was not the dominate portion of the total process time. Also, due to the nature of the product, test results are highly variable. Failures can occur at any time during the test and the cause may not be traceable to a particular component or process in the system. Due to that uncertainty, repair times are also highly variable, since most of the repair time is spent isolating and debugging the problem instead of correcting the problem.

Second, one could argue that electronics are some of the most complex products to assemble. From Class 1 cleanrooms for semiconductors to placement of millions of chips on circuit cards to the electro-mechanical world of systems assembly, electronics is a highly complex manufacturing environment.

3 SIMULATION ISSUES

3.1 Automated Assembly

As the technology is more advanced, such as semiconductors, or the number of operations is high, such as PCA Assembly, automation plays a major role in manufacturing. Although it would seem that automated assembly would be less effected by variability, we have found the opposite to be true.

In PCA assembly, most automated placement machine rates vary depending on the type of component being placed. Without sufficient detail to comprehend different part type mix on a given machine, a generalized placement rate per part may be very inaccurate. Further, these different part types each have unique "failure" rates, i.e., each part is fed from a feeder, these feeders on occasion run out of parts, jam or otherwise misfeed. Each feeder type can have significantly different failure characteristics (MTBF) and repair distributions (MTTR). These factors can and do significantly effect cycle rates, model flow and throughput. Generalization of the average MTBF and MTTR may not comprehend these differences and can result in large errors. An excellent source of data are data collection system files, including those that may reside directly on the machine, that record transaction data. If those files contain the correct information, it is possible to determine MTBF, MTTR and perhaps an overall runtime distribution. If that data cannot be obtained, a generalization of the overall runtime distribution using gamma or beta distributions tends to work best.

Another aspect of automated assembly that adds to the variability of the process is changeover or setup time. The primary difficulties encountered have been infrequency of occurrence and variability of each occurrence. The infrequency might suggest that this is not a critical parameter until the time required to complete the changeover is reviewed. Typical changeovers can take several hours. Most setups are heavily manual and numerous factors and interactions occur during a changeover. These interactions and actions do not occur with the same frequency or cycle from occurrence to occurrence. We would suggest trying to understand some of the elements that comprise a changeover, especially if it consumes more than 5% of the total equipment availability. Changeover of this magnitude should be a major concern to manufacturing management and detailed modeling could bring to light ways to significantly reduce the changeover time.

3.2 Test/Rework

In the introduction, we mentioned that test dominates the manufacturing process. While that is true, failures, repairing those failures, and routing those failures through the system cause the most problems when it comes to accurately modeling electronics manufacturing. Let us first consider the distribution of a unit if the unit passes the test. If a unit passes the test, that distribution is as close to constant as you can get in the real world. The only exception we have seen to that are newer adaptive tests that we have seen in some manufacturing arenas. Although these tests can have a highly variable cycle time for units that pass the test, the test engineer that wrote the program can usually explain the conditions under which the test adapts. This information should allow you to generate either a discrete probabilistic or conditional distribution for the cycle time of the adaptive test.

Determining the distribution if the unit fails the test can be very difficult. The correct modeling is crucial to the correct modeling of the overall system. Let me describe a situation that we modeled in the area of electronics assembly. The primary test in the system ran continuously for 22 hours. The average failure time for the first pass through the test was approximately 10% of that, or 2.2 hours. Over 50% of the failures occurred during the first hour. After a test failed, it could be immediately removed from the test fixture and reworked. Failure probabilities by product could range from as low as 60% to as high as 99%. To paraphrase a friend, all of this information is variable based depending on the number of tests, complexity of the product, the day of the week, and the phase of the moon. In some manufacturing simulations, this type of data has been aggregated and generalized so to simplify the modeling process. Since test/repair is so dominate, both in cycle time and in system complexity, we would discourage simplifying too much. There is some hope, however. Generally, we have found that the failure time distribution does tend to be exponentially distributed, or at least can be fit with a truncated exponential distribution. We will deal with the routing complexity later in the paper.

Another issue arises in the test/repair cycle when the test equipment often does not depend on human intervention. You have the complexity of two different working calendars, one for the test and the control system, and one for the remainder of the factory. Although it will take some additional code to model two different calendars, we would caution against trying to simplify to the model down to one calendar. Many issues arise when you have multiple calendars that cannot be generalized. For example, queues build when the test equipment is running and the people are not there to continue processing or repair failures. We called this condition the "Monday

Rush" because well over half, and possibly all of units in test where ready to be processed on Monday morning. This effects the sizing and utilization of the test area, control of downstream operations, and burden on the material handling system. To understand the magnitude of the possible problem, modeling showed that the queue built over the weekend was not worked down until Wednesday or Thursday of that week.

3.3 Material Handling/Control Systems

After modeling electronics applications from semiconductors to assembly and in industries as varied as automobiles, fighter jets, and computers, we have determined that a modeler should model the material handling and control systems in detail, and possibly grueling detail. The only exception to this would be if you are certain that you have captured the material handling cycle time accurately, the control system logic is incredibly straight-forward (such as first in, first out), and that you are absolutely certain that the material handling system will never be a bottleneck in the system.

In order to show the significance of accurately modeling the material handling systems, let us relate a true story. We were designing a new factory and also developing the model for it. There was one area in the material handling system that was tightly controlled as far as what number of units could be enroute from the queuing area to the equipment (see figure 1). The initial modeling approach was to queue units on the incoming conveyor, determine if the unit could be released, release the unit for a given delay time based on which machine it was going to, and then place it into that machine's queue. Outgoing units determined if there was room in the destination queue, if there was it was delayed for the time to get from the machine to the outgoing control point. This was done because we did not think that the traffic between the two control points would be significant. After presenting the initial results of that model, our supervisor asked us to model that piece of the material handling system in more detail. That part of the material handling system ended up being a transient bottleneck of the system. During the high traffic times like the "Monday Rush", the outgoing traffic was so dense that incoming traffic ended up being bottlenecked in the system.

What are the tradeoffs in this approach to modeling material handling systems? The benefits include using the simulation to debug high level control system logic, getting a true picture of transient traffic problems in the system, and understanding perhaps the most complex portion of the manufacturing system. You pay for these benefits with time, both model development time and simulation run time. The next time you want to model the material handling system in some higher level than suggested here, just be sure you can deal with a manufacturing manager that says, "I thought you told me that the testers were the bottleneck!"

4 CONCLUSION

We have come up with a couple of recommendations when it comes to simulation modeling of electronics manufacturing. These recommendations can also be applied to other types of manufacturing simulation. First, do your homework. There is still no substitute for good data collection and analysis, spending time on the manufacturing floor, asking questions, and performing basic industrial engineering to understand the process dynamics. If you are to gain the respect of the manufacturing and industrial engineers that live with the manufacturing system you are modeling, you must be able to enhance their understanding of their system by what you do.

Second, do not let an inexperienced modeler, or a modeler with no sense of electronics manufacturing dynamics, perform large-scale simulation work for you or your company. Over and over again, we have seen intelligent, energetic, but inexperienced simulation engineers, possibly with a master's thesis under their belt, come into industry and fail. Be patient with them and let them do smaller models and force them to spend time on the manufacturing floor to learn about the manufacturing as well. Forcing inexperienced people to take on major simulation tasks may be the main reason we have so few simulation people in corporate America with more than 5 years simulation experience.

Many people will not understand what the simulation engineer does for a living. With that in mind, we would like to leave you with Clarke's Third Law which reads, "Any sufficiently advanced technology is indistinguishable from magic."

REFERENCES

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AUTHOR BIOGRAPHIES

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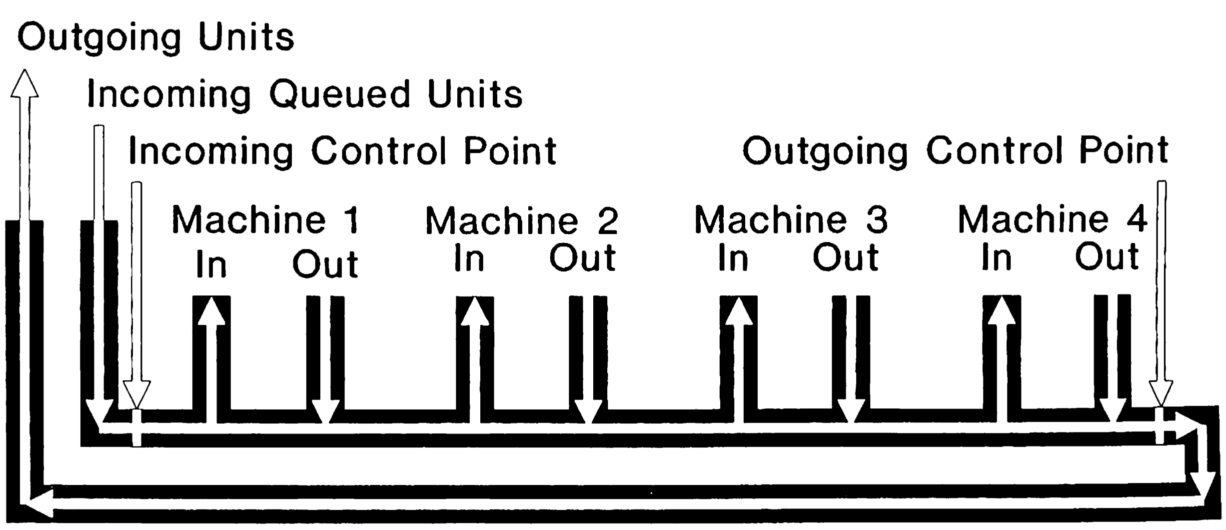

Figure 1