

WAFER FAB CYCLE TIME MANAGEMENT USING MES DATA

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ABSTRACT:

A critical factor for most wafer fab managers is maintaining acceptable cycle times. In the highly variable environment of a wafer fab, this is no small task. Batch processing, tool dedication, unreliable equipment, setups, rework, and hot lots all conspire to drive cycle times upward. To combat these factors, we propose a methodology for cycle time management based on extracting real-time data from the manufacturing execution system (MES). We use the MES data to identify problems on the shop floor, and then draw on our experience in cycle time management to recommend improvement strategies. We first review the cycle time management information that can be derived from lot move data alone. Next, we highlight other improvement areas for which additional MES data must be collected. Finally, we indicate the point at which users must turn to simulation to perform further what-if analysis.

INTRODUCTION

A critical factor for wafer fab managers is maintaining acceptable cycle times. Long cycle times are associated with high inventory cost, poor line yield, and lost opportunity. Sales are sometimes lost by those fabs that cannot offer the lowest cycle times. Planning for acceptable cycle times costs money, too. Fabs are generally run at only 85% to 90% of their maximum capacity, leaving a 10-15% cushion to guard against the high cycle time caused by variability. By reducing this variability, a factory can often increase the actual throughput rate at which it operates, yet achieve the same average cycle time. Increasing throughput with the same equipment set (if the additional products can be sold) translates into a direct improvement of the bottom line.

In the highly variable environment of a wafer fab, reducing cycle times is no small task. Many factors conspire to drive cycle times upward,

including batch processing, tool dedication, unreliable equipment, setups, rework, and hot lots. While many of these factors cannot be eliminated, their cumulative effect can often be improved. This paper presents a systematic process for improving fab cycle times through the use of data extracted from the factory manufacturing execution system (MES).

METHODOLOGY

The first step towards reducing cycle times without purchasing capital equipment is educating personnel to understand the effects of variability. The next step is identifying problem areas in the fab by looking at actual MES data. This data should be made prominently available for employee review and motivation. Next, operating practices must be modified, and the impact of the changes on cycle times verified. In some cases, simulation must be used for longer-term analysis.

Educate Personnel

Most fab workers have an intuitive understanding of the relationship between utilization and cycle time. They know that as the loading on a tool increases, they can expect the cycle time to increase, and that they need to pay particular attention to highly loaded tools to mitigate their harmful effect on cycle time. However, it has been our experience that the effects of variability on cycle time are sometimes counter-intuitive, leading factory people into behavior patterns that are not beneficial with regard to cycle time.

For example, a common practice is to work to increase the mean time between maintenance events for a piece of equipment. While this is certainly helpful if the time spent performing the maintenance events remains constant, or decreases, the effect is less clear if the maintenance time is increased. For the same total percentage of time spent doing preventive maintenance (PM), longer PM events introduce more variability into the factory than do shorter, more frequent PMs. Similarly, operators are

sometimes charged with running equipment to maximize batch sizes, so that capacity is not “wasted” by running non-full batches. Large batch sizes, however, have a negative effect on cycle time, because they introduce WIP bubbles into the line. For batch tools that are not highly loaded, forcing full batches is generally a poor policy.

We have found that education, including concrete, numerical examples and graphs, can be very helpful in minimizing behaviors that adversely affect cycle time (Fowler and Robinson 1995). A sample graph is shown in Figure 1. In a cycle-time-constrained environment, having operators who intuitively understand the effects of variability on cycle time can be a huge benefit.

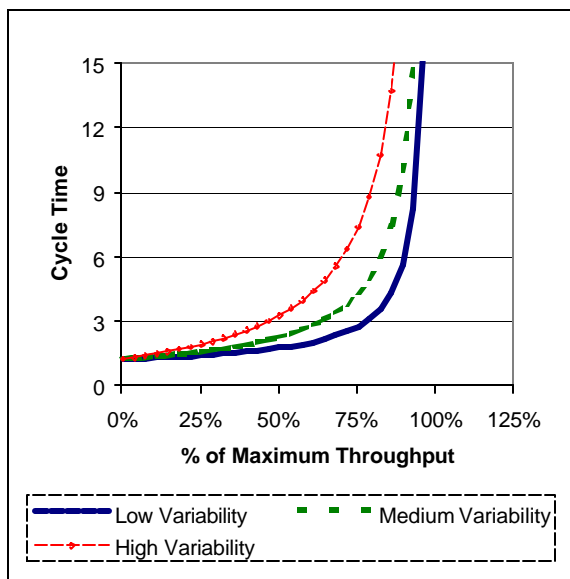


Figure 1. Impact of Factory Loading and Variability on Average Cycle Time

Identify Problems

To improve cycle times in the factory, it is necessary to understand which tool groups and operations are causing problems. Long-range planning models (capacity analysis or simulation models) can often highlight tools that are likely to be problems in the future. However, because the environment of a wafer fab changes so constantly, this information is not always relevant. And, the real fab is always going to have factors that the modeler cannot include in his model, or chooses not to include. It is more useful to know which tools are causing problems on the shop floor today, and which tools have been causing problems in the recent past. Then changes can be made that address these known problems.

Using Move Out Data Alone. Lot move out data is among the most reliable data to be found in the MES. When an operator reports completion of processing on a lot, he or she is reporting a straightforward, positive event. The importance of maintaining accurate knowledge of lot locations is clear, and there is no confusion over whether this lot “really” finished or not (as there might be in recording downtime events).

In addition to being relatively accurate, move out data, when successfully stored and processed, can yield considerable information about the state of the factory. For example, measuring the time between move out events gives us the total cycle time that a particular lot spends at each operation. Measuring the time between move out of the start operation and move out of the ship operation gives us total shipped lot cycle time. By making an assumption that when a lot moves out of one operation, it moves in to the queue at the next operation, we can also use move data to calculate WIP. Since we know where each lot is at any point in time, we can scan across the lots at any specific point in time to find out how many are at each operation or tool group. We can also derive the current time in queue for each of the lots, and sum values to get the total accumulated cycle time at the operation (or tool group). The latter can be a more useful metric than simple WIP levels, since it takes into account operations that only have a few lots waiting, but at which the waiting lots have spent a long time. We can use information derived from lot move out data to answer questions such as:

- What effect did specific equipment downtime events have on WIP and cycle time?
- How many units per day did a particular tool group process in each of the last seven days? How did this compare with the goal for the tool group?
- Over the past month, what was the maximum WIP at a particular tool group? Did that WIP build quickly or gradually?
- Given the average cycle time by operation for recently exited lots of this product type, when can we expect this lot to complete processing?
- Where in the factory are cycle time and WIP building up right now?

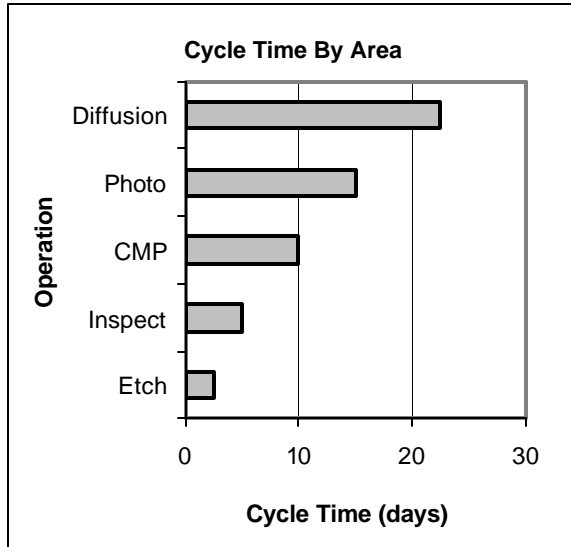


Figure 2. Total accumulated cycle time by area.

- Over the past month, what has been the distribution of cycle time for different product types?
- For a particular lot, which tool groups, areas or operations contributed the most to overall lot cycle time?

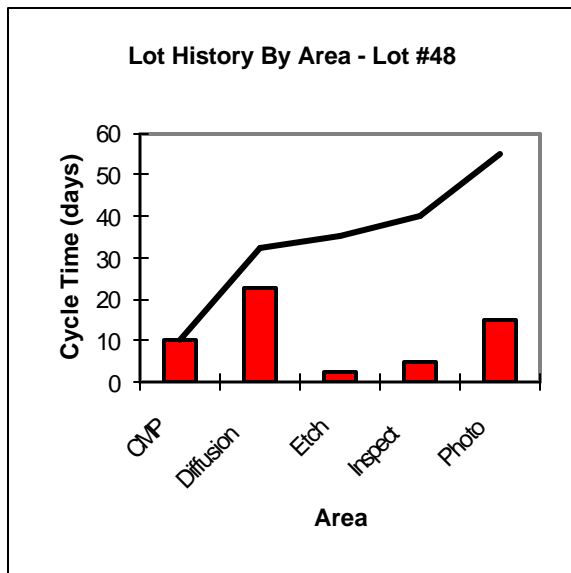


Figure 3. Cycle time spent in each area for Lot #48.

- How many visits (including rework visits) did a particular lot make to a certain tool group?
- For a particular area or operation, what is the accumulated cycle time of lots currently in queue?

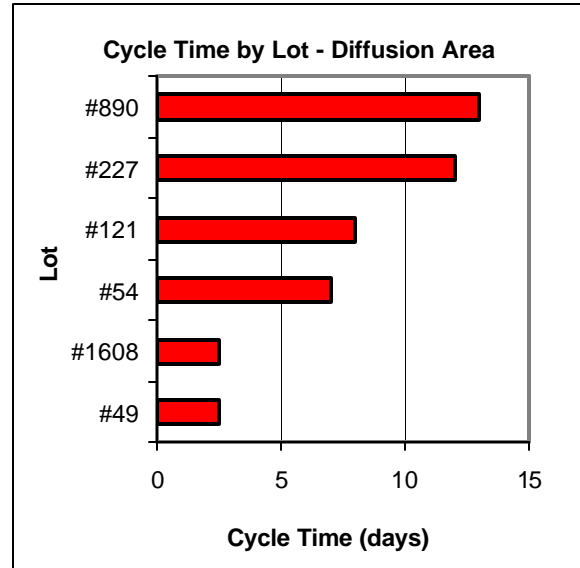


Figure 4. Current accumulated cycle time by lot for lots in the diffusion area.

Using Additional MES Data. By looking at other types of data from the MES, we can extract even more information about manufacturing performance. For example, the addition of equipment status events such as SEMI E-10 states allows us to answer questions like:

- Which tools are down right now?
- When was this particular tool down over the past month?
- What happened to the WIP and cycle time at the tool group when this tool was down?
- Given the current factory tool and WIP status, what machines are likely to be overloaded today?
- What is the OEE of this tool?

The addition of the start processing event to the data extract allows us to divide cycle time into queue time versus processing time. This information lets us focus on the right problems. For example, if lots spend a long time at a particular tool group, but the time consists mainly of processing time, we know that the only way to improve the cycle time is by making some sort of process change. On the other hand, if the cycle time is mainly queue time, then we probably want to look at dispatch rules or equipment failure events.

Change Operating Practices

Taken together, the various types of MES-generated information can give factory managers a good idea of where to focus improvement efforts. A

number of case studies have been conducted that suggest the types of improvements that are likely to pay off on the shop floor. Examples in which modifications were actually implemented on the shop floor include Demeester and Tang (1996), Domaschke *et. al.* (1998), Fowler *et. al.* (1997), Neve *et. al.* (1987) and Peikert *et. al.* (1998). Some specific suggestions to investigate, drawn from these papers as well as our own consulting experience, include:

- Eliminate large minimum batch size requirements for all but very highly loaded tools.
- Cross-train equipment maintenance personnel, to reduce long delays waiting for the right repair person.
- Reduce tool dedication.
- Cross-train regular operators to handle more types of equipment, and to balance schedules.
- Change preventive maintenance schedules to minimize variability.
- Modify setup avoidance policies to ensure that low-volume products are not excessively delayed.
- Reduce transfer lot batch sizes.
- Modify lot release policies to smooth flow through the early steps of the process (lower variability).
- Explore process changes to eliminate operations that can only be done on a single piece of equipment (eliminate unnecessary dedication).
- Explore batching rules, to make sure that all lots that can be batched together are batched together (eliminate unnecessary waiting for form batches)
- Check batching and setup assumptions for rework wafers. The entire parent lot is usually delayed whenever the rework wafers are waiting for processing. Also make sure all operations within the rework loop are necessary.

Display Current and Historical Performance Data Prominently

Industrial studies of the early 20th century found that productivity increases as a result of attention received by the workers. This phenomenon is believed to be due at least in part to the fact that work is a group activity, and employees strive for a sense of belonging (Hopp and Spearman 1996). This insight is known as the Hawthorne effect (named after the Western Electric Hawthorne plant in which the studies were conducted). In recognition of the Hawthorne effect, we recommend prominently displaying the current and historical performance data extracted from the MES. Performance relative to

specific goals should be included, as should methods for comparing performance across different parts of the organization.

Verify Results

An important step in any improvement project is to verify whether or not the change has the desired effect. One benefit of making changes based on real-time data (as compared with long-range simulation models) is that in a short time window, the factory is subject to relatively small amounts of change. This allows management to actually look at factory output after the change is made, and assess factory performance on a relatively level playing field. By contrast, when we suggest improvements based on analysis of simulation models, it is usually harder to know whether or not the improvements have the desired effect. Even when using real-time data, we advise caution in comparing results, because the fab environment is so dynamic (For example, if start rates go down, cycle times will likely go down, regardless of what else you do). However, it is important to try to close the loop, and give feedback to the people involved in the improvement effort. This helps them to stay motivated, and interested in making additional improvements.

Simulate Longer-Term Alternatives

Certain types of cycle-time management questions still lend themselves to simulation, rather than to real-time data analysis. For example, simulation can and should be used to estimate the relative effect of more global changes such as modifying dispatch rules, lot release policies, or lot priorities. Our recommendation, when working to reduce current cycle times, is to use simulation to evaluate ideas for changes, and then take those changes that look the most promising and make them on the shop floor. Simulation is also useful in evaluating capital equipment purchases to make sure they will yield acceptable cycle times in the future (Grewal *et. al.* 1998).

CONCLUSIONS AND RECOMMENDATIONS

In summary, our suggested methodology for cycle time management using MES data is as follows:

1. Educate fab personnel about the relationship between cycle time and variability, and the primary contributors to variability in the fab.

2. Identify problem areas on the shop floor through analysis of actual fab data.
3. Make specific operational changes to reduce variability in the identified problem area. These will vary by site. Some information can be derived from basic move data, while other information requires collection of additional MES data.
4. Display performance data prominently so as to maximize the Hawthorne effect.
5. Check progress using actual cycle-time data, and return to step 2, as needed.
6. Use simulation to perform more detailed what-if analysis for longer-term or more globally applied changes.

The methodology recommended in this paper generally does not require adding capital equipment. While increasing capacity is a well-known method for reducing overall cycle times, capital equipment procurement typically involves long lead times. In the rapidly changing environment of a wafer fab, equipment purchases are not usually a viable method for reducing CURRENT cycle times (though planning for sufficient slack capacity will help FUTURE cycle times). Instead, this methodology focuses on making simple operational changes immediately, and using real-time reporting to track progress and make necessary adjustments.

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BIOGRAPHIES

Dr. Jennifer Robinson is co-founder and chief operating officer of FabTime Inc., a provider of wafer fab cycle time management software and services. Previously, she worked as an independent consultant in semiconductor manufacturing. Her clients in that industry have included SEMATECH, Digital Equipment Corporation, Seagate Technology, and Siemens AG. Dr. Robinson holds a B.S. (1989) degree in civil engineering from Duke University, an M.S. (1992) degree in Operations Research from the University of Texas at Austin, and a Ph.D. degree in Industrial Engineering from the University of Massachusetts at Amherst (1998). Her research interests center on factory productivity measurement and improvement.

Dr. Frank Chance is co-founder and president of FabTime Inc. Dr. Chance is a software development specialist with extensive domain expertise in semiconductor wafer fabs. His experience in software development for manufacturing dates to 1983; since 1991 he has been fascinated by the complexities and challenges of wafer fab operations. Prior to the founding of FabTime, he developed Factory Explorer®, an integrated capacity, cost, and simulation analysis tool distributed by Wright Williams & Kelly. Dr. Chance holds MS (1991) and Ph.D. (1993) degrees in Operations Research from Cornell University. He has taught at Cornell University and at the University of California, Berkeley.