FabTime Cycle Time Management Newsletter

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Information

Mission: To discuss issues relating to proactive wafer fab cycle time management.

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Welcome

Welcome to Volume 4, Number 3 of the FabTime Cycle Time Management Newsletter. In this issue, we are pleased to announce the completed installation of our FabTime cycle time management software at TDK's HDD Head Wafer Fab in Saku, Japan. We are very happy to add TDK to our list of customers! We also have an announcement about the semiconductor track at the Winter Simulation Conference. Subscriber discussion topics for this month include responses to our article about quantifying availability variability and to last month's subscriber question about train schedule batch policies, as well as a new question about estimating company-wide savings from cycle time reduction.

This month's main article is about cycle time entitlement. In this newsletter, we have talked a lot about managing and improving cycle times, and about the various metrics for reviewing historical cycle times and benchmarking cycle time performance. But what people who work in fabs really need to know is: what is a good cycle time for our fab, under our current constraints? And where should we focus our cycle time improvement efforts? Cycle time entitlement is our answer to these questions. More formally, cycle time entitlement is the best achievable cycle time for a fab given short-term realities related to tool utilization, staffing, and downtime characteristics. In this article we define cycle time entitlement, and discuss ways of estimating it, ways of using it, and associated data issues.

Thanks for reading!—Jennifer

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Community News/Announcements

FabTime Completes Installation of Cycle Time Management Software at TDK HDD Head Wafer Fab

Menlo Park, CA. March 5th, 2003 - FabTime Inc. today announced the completed installation of their FabTime cycle time management software at TDK's HDD head wafer fab in Saku, Japan. FabTime's software is also installed at TDK's subsidiary, Headway Technologies, in Milpitas California.

FabTime is designed to give wafer fab managers and their staff the information that they need, in real-time, to run their fabs effectively. FabTime extracts operational data from the fab manufacturing execution system (MES) every five minutes, and processes this data into a SQL Server data warehouse. Users can then access a comprehensive system of cycle time-related charts and alerts via a web browser from anywhere within the corporate Intranet. More information about FabTime's software is available at www.fabtime.com/software.htm.

About TDK

TDK Corporation (NYSE: TDK) is a leading global electronics company based in Japan. It was established in 1935 to commercialize "ferrite", a key material in electronics and magnetics. TDK's current product line includes ferrite materials, electronic components and semiconductors, wireless computer networking products, magnetic heads for hard disk drives (HDD), digital recording hardware and advanced digital recording media.

Winter Simulation Conference - Semiconductor Track

The following announcement was submitted by Chad DeJong (Intel): "The Winter Simulation Conference 2003 will be held Dec 7-10 in New Orleans, LA with the theme "Driving Innovation". I am organizing the Semiconductor track this year, and would very much appreciate all your inputs and participation. If interested, please email me directly about potential topics and starting the papers at chad.d.dejong@intel.com. Deadline is April 1, 2003. Also, please forward this announcement to all others who may be interested. The website and the call for papers are at www.wintersim.org. Thanks!"

FabTime welcomes the opportunity to publish community news and announcements. Simply send them to Jennifer.-Robinson@FabTime.com.

Subscriber Discussion Forum

Quantifying Availability Variability

Peter Gaboury (STMicroelectronics) wrote in response to last month's main article: "Thank you for the reference. I think we failed to mention a key point about A80 versus the fab loading commitment.

A80 is an excellent "WARNING" measurement for forecasting glass bottlenecks. We see in many instances where we have loaded machines at ~ 85 - 90% and everything looks ok, but we forget we are fixing our loading based on an average availability. Taking a closer look at A80 and A20, we identify tools "virtually" loaded above 100% (I say virtually loaded because A80 is only a statistical and not dynamic measurement) and we can then plan our Continuous improvement activity around these tools.

Interestingly enough, A80 is also an excellent justification to have photo as your bottleneck. We see from many practical measurements that photo is the least variable toolset in the fab (often spreads <5%). This is why even in fabs showing high loading in photo, they don't feel the pain like other zones (notably etch where it is a roll of the dice if the machine will be up after a wet clean).

So I would add to your recommendations to take the historical data and also compare against your loading commitment."

John Fowler (ASU) wrote in response to last month's main article on A80 and A20: "It seems to me that if one is going to collect A20 and A80, one might as well also calculate the variance (std. dev.) of the (daily or shiftly) availability. One could also build control charts on these much as we have R (range) and s (std. Dev.) charts."

Train Schedule Batch Policy

Pres White (UVA) wrote in response to last month's "Train Scheduling" question: "Don't know if this helps, but I'm just completing a simulation study in another context (manufacture of spacer grids for nuclear fuel assemblies) with some pretty complicated rules about how to build legitimate batches for various processes based on metal type, grid type, and how far along grids are in a particular sequence. Besides the obvious problem of wanting to move partial batches along "when appropriate" to reduce WIP, the two-year-plus-some dispatch schedule does not contain volumes of grids that are even multiples of batch counts. The simulation won't terminate unless there is some mechanism for flushing partial batches.

After considerable inquiry, we learned that the actual rules for releasing partial batches are not codified and left largely to the discretion of the production workers, with different operators adopting different strategies. The best we could find out is that partial batches are released (1) "when they've been there too long", and/or (2) "when there aren't enough grids upstream in the process, or it will take too long for these to get to the batch point, to make a complete batch".

We've implemented rule 1 by releasing one partial batch by the clock, late every shift, but when there is still time in the shift to complete the partial batch before the end of the shift. I guess this is like the train schedule and it assumes ignorance of the upstream WIP composition and looks only at the clock. We've implemented rule 2 by maintaining an array of counts of grid orders by batch type as these orders are released to the floor. Partial batches are released when the tool becomes available and the upstream count is below some quantity. This quantity can be based on the number of grids in the potential partial batch, if so desired. The simulation logic becomes pretty convoluted, but it works.

Experience with the model suggests that, in the end, how partial batches are formed doesn't make any difference in overall throughput, since there is enough capacity on the corresponding tools to prevent these from becoming long-term bottlenecks. Partial batching does help to keep all grids moving, however, and evens out cycle times. And (happily) these rules admit a graceful termination of the simulation replications, so we don't look too stupid. In retrospect, I guess this means the operators are doing it right! I might add the nuclear fuel assembly simulation has been a glowing success.

Estimating Company-Wide Savings from Cycle Time Reduction

James Ignizio of Intel submitted the following: "I have a question about the value of reduced Factory Cycle Time. You have a spreadsheet on your site that may be used to estimate this value. However, I wonder if it is appropriate in all cases. For example, if you can decrease the Factory Cycle Time from, say, 70 days to 50 days, this would seem to have an impact on the entire firm, rather than just a single factory. Specifically, this reduction might mean that, instead of having to build four 300mm fabs, we may only need to build three --- for a savings of 2 to 3 billion dollars. Such a savings -- if they are actually achievable -- would not seem to be captured by the Fab Time spreadsheet.

At this time we are evaluating a method designated CONWIP/IGNITE for the reduction of Factory Cycle Times via rigorous simulations of a 300mm HVM fab. In all evaluations, we routinely reduce Factory Cycle Time by 25% or more compared to standard WIP management methods. This is accomplished via a system that should be straightforward to implement in fabs (see the following URL for details: http://www.future-fab.com/documents.asp?d_ID=1658), and which has already been successfully implemented in other factories (i.e., non-semiconductor factories). What we need now is a way to compute the savings achieved, company-wide, of the introduction of the technique. If you or your readers have any suggestions, please let me know.

References:

- Hopp and Spearman, FACTORY PHYSICS, *McGraw-Hill*, 2001.
- Ignizio, J.P. "The Implementation of CONWIP in Semiconductor Fabrication Facilities," *Future Fab International*, February 2003.
- Ignizio, J.P. "Integrating, Cost, Effectiveness, and Stability," *Acquisition Review Quarterly*, Vol. 5, No. 1, Winter 1998, pp. 51-60."

FabTime Response:

Our spreadsheet was designed to quantify the dollar impact of cycle time reduction in a single existing fab. Naturally I agree that if cycle time reduction leads you to need to build fewer factories, there can be a big cost saving. However, I think you have to take capacity requirements into account, too. Most companies plan for their fabs to be 85% loaded - even if you could operate at a higher loading (because of improved cycle time), you would still only be able to squeeze another 5-10% out of that fab. So it would seem relatively rare that cycle time improvement would actually save you building a fab, unless you're planning with a pretty big capacity buffer to start with. I think that the biggest dollar impact from cycle time reduction comes from the revenue side.

At any rate, these types of questions are a bit outside of FabTime's current scope, but I will be happy to post your question in the next newsletter. Perhaps some other subscribers will have something to add.

Cycle Time Entitlement

Introduction

At FabTime, we talk a lot about managing and improving cycle times. There are various metrics for reviewing historical cycle time numbers, and for benchmarking cycle time performance between fabs (shipped lot cycle time, cycle time x-factors, days per mask layer, etc.). But what people who work in fabs really need to know is:

- What is a good cycle time for our fab, under our current constraints?

and

- Where should we focus our cycle time improvement efforts?

Answering these questions led us to the notion of cycle time entitlement. Cycle time entitlement is the best achievable cycle time given short-term realities (e.g. downtime characteristics, staffing, and utilization). Cycle time entitlement is calculated at the operation level, and can then be rolled up to the route-level, to obtain best-case achievable cycle times.

Note that "achievable" is key to this definition. For example, you might have an operation that is performed on the bottle-neck tool in the fab, and has a theoretical cycle time (process time) of one hour. However, because the bottleneck is highly loaded, a reasonable expectation for the cycle time per visit might be six times theoretical, or six hours per visit. Operations performed on non-bottleneck tools will generally have lower entitlements.

Cycle time entitlement can be a useful guide for improvement efforts. If you know what the cycle time entitlement is for each operation, you can focus on operations (and the associated tools) that have actual cycle times much higher than their entitlements. Cycle time entitlement also provides a useful guide for setting cycle time goals. Cycle time goals often include a buffer on top of entitlement, to account for extra components such as transport times or holds.

Estimating Entitlement

All of these factors influence cycle time entitlement:

- Hot lots
- Number of qualified tools (single-path operations in particular lead to higher entitlements)
- Variability in arrivals due to upstream batch tools or transport batching, among other factors
- Variability in process times (e.g. from processing different operations on the same tool)
- Tool availability (including frequency, duration, and variability of downtime and PM events)
- Tool utilization
- Staffing levels
- Batching characteristics at the tool

Operation-level entitlement depends on all of the above factors. So, how do you estimate cycle time entitlement? The two primary methods are mathematical models and simulation models. Mathematical models (queueing models) are frequently convenient because they have straightfor-ward calculations, and can be coded into spreadsheets. The drawback to mathemati-cal models is that they cannot capture all of the necessary details, and hence may not be accurate enough. Simulation mod-els, on the other hand, can capture as much detail as you like, but they take much longer to build and debug and maintain. They also tend to have a re-stricted set of users (industrial engineers).

Both types of methods require access to up-to-date information, particularly concerning tool qualification matrices and arrival process variability coefficients.

FabTime Tools for Estimating Entitlement

FabTime has been developing spreadsheet tools in this area for several years. We want tools that capture enough of the complexity to be relevant for wafer fabs, while still being easy to use and maintain. We currently have two tools in this area. The first is our operating curve spreadsheet (or characteristic curve generator). This spreadsheet tool generates a response curve of cycle time vs. utilization for up to three scenarios. This tool was described back in newsletter Issue 2.7, and is available for download from FabTime's website, at www.FabTime.com/charcurve.shtml. The operating curve spreadsheet is useful for getting a general idea of the behavior of the operating curve for a tool group, under different scenarios. An extended version that includes the impact of hot lots is used as part of FabTime's cycle time management course.

Our second tool is an entitlement calculator spreadsheet for estimating the cycle time entitlement for a route (process flow). It has a row for each operation in the route. Users enter the process time, percentage of hot lots, and the number of qualified tools for each operation, as well as average downtime, utilization, and variability characteristics for the qualified tools. Using the same assumptions that are in the operating curve generator, the entitlement calculator estimates the expected average cycle time for each operation, and rolls up the operations to give a route-level cycle time entitlement estimate. These entitlement numbers are only approximations, of course. The entitlement calculator does not directly take into account staffing levels or batching (though transfer batching is implicitly accounted for, as it drives up arrival process variability). However, it does give a good idea of which operations can be expected to have high cycle times. The entitlement calculator spreadsheet is currently only available to companies that purchase our 2-day cycle time management course or our cycle time management consulting services. Contact us for more details.

Using Entitlement

Assuming that you have a way of estimating cycle time entitlement, be it using spreadsheet models or simulation models, the next question is, how do you use entitlement data? We believe that entitlement data is crucial in two areas. The first is capacity planning. Cycle time entitlement should be a component of the capacity planning process, so that fabs are designed with an understanding of what cycle time can be expected. This is currently done implicitly by most fabs. For example, you try not to plan for one-of-a-kind tools because you know that one-of-a-kind tools tend to have unacceptably high cycle times (where "unacceptable" is not explicitly defined). Incorporating entitlement into your capacity planning process allows you to plan more explicitly for target cycle times, at both the tool and factory level. This approach also gives you a better sense for what cycle time goals will be achievable for the fab, based on the equipment set and product mix.

The second area in which cycle time entitlement can be useful in is in identifying areas for improvement. If you estimate the entitlement for each operation, and compare that with recent actual data from the fab, you can identify steps where the actual cycle time is higher than it should be. These are promising areas for cycle time improvement. This process will be most relevant if the entitlements estimates are obtained using actual recent data, rather than planning data. Which begs the question: where do you get the necessary data for estimating operation-level entitlements? And which data is most critical?

Data Issues in Estimating Cycle Time Entitlement

In our experience, the largest drivers of cycle time are usually utilization and number of qualified tools. We believe that when comparing to actual cycle times, it's important to look at actual historical move data to identify the set of tools that have been used to do a particular operation. The reason for this (as opposed to just taking the tool qualification matrix) is that operator preferences and/or communication problems can result in fewer tools being used for a particular operation than planned. The resulting utilization on the tools may then be higher than expected. If you are finding that actual cycle times are much higher than expected for an operation, checking the actual set of qualified tools is a good first step.

The other large driver of cycle time, as we have discussed many times in past newsletter issues, is variability. We have observed that arrival variability to individual tools in the fab can be much higher than people expect, and can vary significantly across the fab. Similarly, process times, which are often treated as constant in simulation models, may in actuality be much more variable. Both of these types of variability will tend to drive up cycle time, and it is worth extracting data from the manufacturing execution system to measure them. In our FabTime cycle time management software we currently report the coefficient of variation of inter-arrival times by tool (or combination of tools) and by operation. We don't currently calculate process time variability. However, users can export a list of lot moves to Excel, and then use Excel functions to calculate the coefficient of variation of the sequence of process times, which is a lower bound on the process time variability.

The final, critical component to obtaining realistic cycle time entitlement estimates is to understand the downtime characteristics of the set of tools that performs each operation. We believe that you should go beyond measuring mean time between failure and mean time to repair, and also measure the variability of the downtime durations. This is another metric that we have recently included in our software - it is reasonably straightforward to calculate for the set of detailed SEMI E10 tool state transactions.

If you estimate cycle time entitlement using simulation, you may also wish to consider including some level of operator modeling, to account for the additional level of resource contention when lots wait for both an operator and a tool. We don't recommend spending a lot of time collecting data on this. However, it may be worth measuring the percentage of time that tools spend idle, while there is WIP in front of the tools. This gives you an idea of which tools may be influenced by operator constraints. Also, if you are using simulation, you will need to obtain some understanding of how the batching logic works at batch tools. MES reports can probably give you average batch size information, but more detailed investigation may be required to understand the logic that is used for batching lots together.

Summary

Cycle time entitlement is the best achievable cycle time given short-term realities (e.g. downtime characteristics, staffing, and utilization). It is calculated at the operation level, and can then be rolled up to the route-level, to obtain best-case achievable cycle times. Fabs can estimate cycle time entitlement using simulation models or spreadsheet tools. In either case, accurate data is needed to make the entitlement estimates realistic, particularly data related to tool qualification, tool utilization, arrival and process time variability, and tool downtime characteristics. Cycle time entitlement can be a sub-set of a fab's capacity planning process, so that the fab can plan for cycle time goals that match the realities of the equipment set. On an ongoing basis, entitlement can also be highly useful in identifying areas in which to focus cycle time improvement efforts.

Recommendations

If you are interested in learning more about cycle time entitlement, we cover this topic in our 2-day cycle time management course. In the course, we describe how various factors influence cycle time entitlement, and we have a detailed exercise showing how entitlement can be integrated into the capacity planning process. More information about the course can be requested from http://www.fabtime.com/ctmcourse.shtml. For details on the queueing theory behind entitlement calculations, an excellent reference is Factory Physics (see our review at www.fabtime.com/physics.shtml).

Closing Questions for FabTime Subscribers

Is cycle time entitlement a new idea for you? Does your fab have a system for estimating what the actual cycle time will be by tool or by operation? If so, do you use simulation or spreadsheet models or some other method? Do you have any publications to share on this topic?

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Winbond Electronics Corporation (1)
Wright Williams & Kelly (5)
Xerox Brazil (1)
X-FAB Texas, Inc. (3)
Yonsei University (1)
Zetek PLC (1)
ZMC International Pte Ltd (2)
Unlisted Companies (16)

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