FabTime Cycle Time Management Newsletter

Volume 12, No. 6 December 2011

Information

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

Publisher: FabTime Inc. FabTime sells cycle time management software for wafer fab managers. New features in the software this month include modified OEE loss calculations (to make them easier to interpret for analysis), and the ability to display average instead of starting WIP on moves charts.

Editor: Jennifer Robinson

Contributors: Bob Kotcher (Simitar Consulting); Adar Kalir (Intel)

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Welcome

Welcome to Volume 12, Number 6 of the FabTime Cycle Time Management Newsletter! We hope that the holiday season finds you all well. In this issue, we have an announcement about a change to our Tip of the Month email list (a separate subscription from the newsletter, for customers). Our FabTime Tip of the Month is about identifying top causes of equipment downtime. In our subscriber discussion forum we have two responses to last month's question from Amrusha Varadarajan about capacity planning for cascading tools.

In our main article this month, we focus on metrics for fab variability. This article was inspired by informal discussions with several people at the November Fab Owner's Association meeting in Austin, Texas. These discussions encouraged us to consider whether we are providing the best toolkit that we can in FabTime in terms of fab variability metrics. We review the sources of variability in fabs, and our current approach for tracking fab variability, and propose a brief variability sources snapshot report. We seek our subscribers' feedback regarding other metrics that should be added to this fab variability toolkit.

Wishing you a joyful holiday season, and a productive 2012 – Jennifer, Frank & the FabTime Team

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Community News/Announcements

New Signup Form and Plans for FabTime Tip of the Month Email List

We always include a Tip of the Month in each newsletter for our software customers. These tips are short, nuts-and-bolts articles with a "how-to" focus. They are generally inspired by either questions from customers ("How do I do x?") or new features that require a bit of extra explanation. In addition to being posted in the newsletter, the tips are sent out to customers who request them as short, html-based emails. Some of our customers subscribe only to the tips, while others read about the tips in the newsletters, and don't subscribe to those separately. Some subscribe to both.

In 2012, we're planning to expand the Tips email list a bit. In addition to sending out the "how-to" based tips of the month (which will still also be included in the newsletter), we plan to use the Tips list to foster knowledge-sharing among our customers. Subscribers to the Tips list will be able to post questions to the customer community ("Does anyone have experience in using FabTime for XYZ?" etc.). We will moderate and post responses on this customer-only mailing list. (Though we may also take general ideas from the discussions, and include them in the newsletter as future Tips of the Month.)

What this means is that if you are a FabTime software customer who only subscribes to the newsletter, you may want to also subscribe to the separate Tip of the Month list. To make that as easy as possible, we've created a new signup form here. You can also email newsletter@FabTime.com with "Subscribe Tips" in your message subject, if that's easier for you. Please include your full name and tell us which FabTime site you work at.

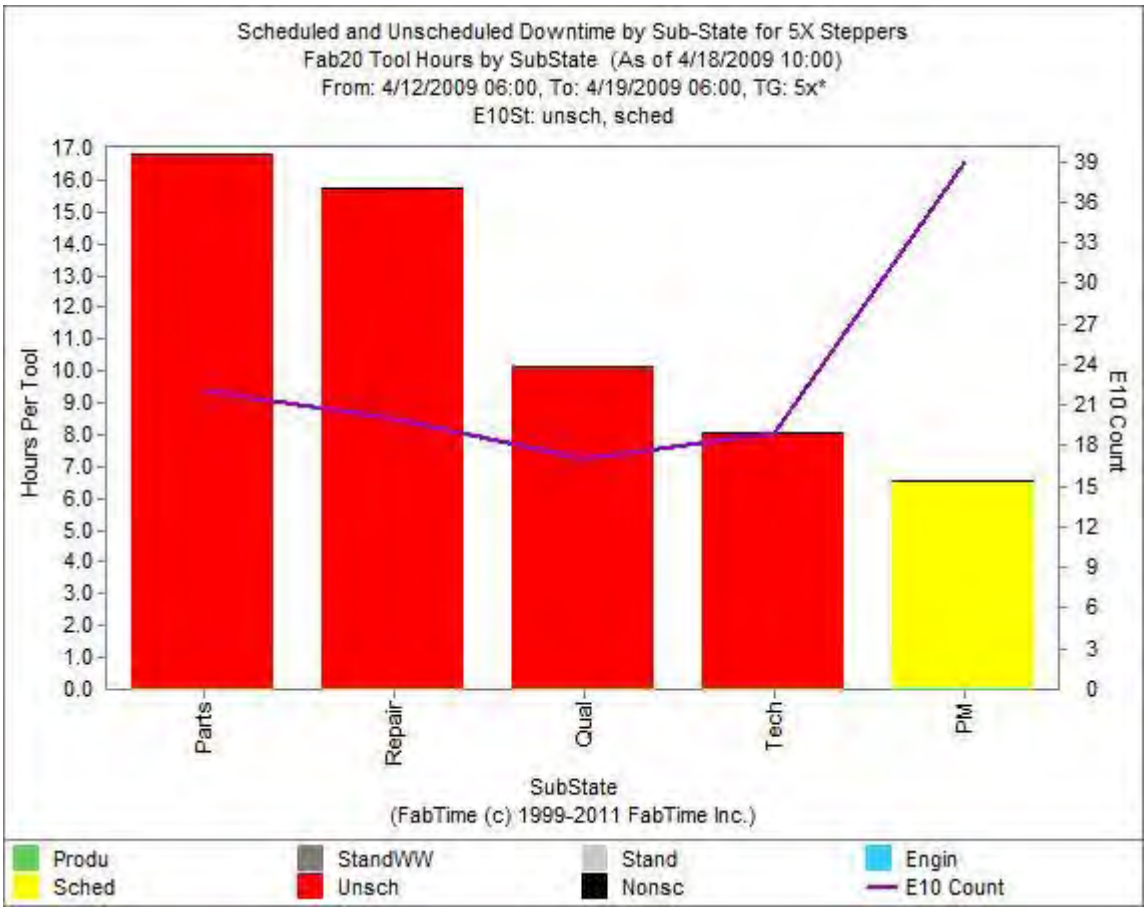
Our goal is to make this FabTime Tip of the Month list a more useful resource for our customers. If you use FabTime at all, we strongly encourage you to sign up for the Tips list. These brief messages will be sent no more frequently than once a month, and we are positive that you will find them useful. Please consider asking your colleagues to sign up, too.

FabTime welcomes the opportunity to publish community announcements. Send them to newsletter@FabTime.com.

FabTime User Tip of the Month

Identify the Top Causes of Equipment Downtime

A customer recently asked us about how to use FabTime to identify the top causes of equipment downtime. We suggested a two-step process. First, use the Tool Available % Pareto Chart, sliced by tool (or tool group), and sorted in ascending order of availability, to see which tools have the worst availability. You'll want to change the time period on the chart to be at least a week long, and you may need to filter to remove inactive tools. Or, you may want to filter by area, to reduce the number of tools included on each chart.



Then, for each of the active tools (or tool groups) with the worst availability, use the Tool Hours Pareto chart, sliced by sub-state, and filtered for that tool (or set of tools). This chart then shows the average number of hours spent in each sub-state per tool, over the time period of the chart. An example is shown above.

You'll generally want to make the time period for this chart at least a week, also. Optionally, you can enter "Unsch" and/or "Sched" in the E10St: field to only see the unscheduled and/or scheduled downtime categories. The sub-states are the equipment states that your operators and maintenance techs enter into your MES. These sub-states are mapped into the industry standard SEMI E10 tool states for many FabTime charts. But looking at the original sub-states entered into the MES can give you quite a bit of information about what's really going on with the tools.

You can also drill down further to look at the individual transactions that were entered into the MES (with any comments attached to those transactions, if available at your site).

If you have any questions about this feature, or any questions about the software, just use the Feedback form inside FabTime. Subscribe to the separate Tip of the Month email list (with additional discussion for customers only) here. Thanks!

Subscriber Discussion Forum

Cascading Tools

Bob Kotcher from **Simitar Consulting** wrote in response to Amrusha Varadarajan's question about cascading tools in the last issue. Bob said:

"Yes, one should definitely account for cascading in capacity modeling, since it can have a big effect on capacity and also vary considerably from tool to tool. Using historical cascading levels is better than nothing, but a more accurate way to do this is with a discrete-event simulation model. Though considerable resources are required to build a fab-wide simulation model, building one of a particular tool is comparatively simple and fast. I suggest using historical arrival data to set up the inflow of product into the model (mean time between arrivals, product mix, and statistical distribution). For future scenarios, modify this to reflect forecast changes in volume and mix. Run the simulations and determine an appropriate cascading number for the future. You can also do sensitivity analyses to see if this cascading number will change much if volume or mix is much different from forecast.

A side benefit of this is that the modeler often stumbles across sources of throughput loss within the tool, which can be corrected. For example, I've come across tools where one of the loadlocks had never even been activated, or wafers were being routed within the tool in a far-from-optimum fashion. This is more common than you think, given that the engineers who set up tools and recipes usually have an R&D bent and are focused on just making the process work, as opposed to maximizing throughput."

Adar Kalir from **Intel** also wrote in response to Amrusha's question:

"The way we handle cascading in capacity modeling at Intel is by differentiating run-rates on a cascading tool for first lot, mid-lot, and nth-lot. The nth-lot cascade represents the asymptotic value for the run-rate when a sufficiently large number of lots are cascaded.

Mid-lots represent the fact that occasionally, lots would overlap in a cascading manner but not a full cascade (i.e. next lot arrived to the tool/operation after it could have started cascading at the earliest; so it cascades only partially.) Once we have the run-rates for first lot, mid-lot, and nth-lot, we either use a simulation or historical data, to determine the run-rate for a planned mix of these lots."

FabTime Response: We appreciate this feedback from Bob and Adar, in an area where we don't have direct personal experience.

FabTime welcomes the opportunity to publish subscriber discussion questions and responses. Simply send your contributions to Jennifer.Robinson@FabTime.com.

Variability Metrics for Fabs

By Jennifer Robinson

Introduction

Last month, when I was at the Fab Owners Association meeting in Austin, Texas, a couple of different current and prospective FabTime software customers spoke to me about metrics for capturing fab variability. Here at FabTime, we have been preaching variability reduction as a means of reducing cycle time for coming up on 13 years now. We teach an entire class on this subject. And, of course, our primary source of revenue is our web-based dashboard for fab performance improvement.

We have lots of charts in FabTime that can help to identify different types of variability: arrival variability, downtime variability, cycle time variability, shipment variability, etc. And yet, these people, who have seen and/or used FabTime, were saying (and I'm paraphrasing here): "Yes, you have variability metrics, but we think that you can do better." As we are always looking for ways to improve, we took this suggestion to heart, and decided to put some thought into this question.

So we decided that we would start by opening this question up to you, our subscriber community. We'd like to ask you, in this relatively informal article, what you think are the best metrics for capturing variability in a fab. Although this discussion clearly benefits us (if we end up with new ideas for charts that should be included in FabTime, and hence come up with new ways to help our customers to improve their cycle times), we believe that anyone, at any fab, could also benefit from new ideas about ways to understand and monitor fab variability.

Background

The reason that we'd like to better understand the sources of variability in fabs is that variability directly influences cycle time. Moreover, variability reduction tends to be the least expensive way of reducing cycle time (compared with buying tools, adding people, or reducing throughput). This has been discussed in various FabTime newsletter issues, including 4.01, 4.02, 4.05, and 6.05.

We know that the root causes of variability in fabs are things like:

- Equipment downtime (increases process time variability, especially unscheduled downtime)
- Product mix (running different recipes on the same tool)
- Reentrant flow (which also leads to running different recipes on the same tool)
- Batch processing (which creates significant arrival variability downstream)
- Transport batching (ditto)
- Scrap (which leads to variation in lot size, and thus process time)
- Rework (small size lots going through tools unexpectedly)
- Time constraints between process steps (unexpected additional processing needed when constraint is violated)
- Split lots (which also leads to variation in lot sizes)
- Operators (for example, when there is no one there to unload the tool)
- Dispatch (we reorder the lots according to the dispatch rule, which can add variation)
- Lot release into the fab (lots are released in batches and start rates can change from week to week)
- Hot lots (increase dispatch variability, sometimes have smaller lot sizes, and sometimes lead to held tools for hand carry lots)

- Setups (these look like process time variability for a lot that's ready to go, but has to wait for setup)

Some of these are controllable by the people in the fab, and some of them are not. When we're talking here about variability metrics, it's not so much that we need to know exactly what impact, say, product mix has on overall fab variability (though this might be useful in discussions with management). It's more that we need to know where the variability is in the fab, and how it's affecting cycle time. Then we'll know what we might be able to change to improve cycle time (and possibly yield and throughput). Some possible metrics for looking at this are described below.

Coefficient of Variation:

The classic metric for quantifying variability is coefficient of variation. Coefficient of variation is a statistical measure that can be calculated for any set of values as Standard Deviation / Average. Standard deviation is a measurement of how widely the values are dispersed from the average. Normalizing standard deviation by dividing by average results in a dimensionless number, Coefficient of Variation (CV), that can be used in queueing models to estimate cycle time. A higher CV indicates more variability (particularly when the CV is greater than 1).

Per-visit cycle times through any tool group are a function of (among other things):

- CV of time between arrivals to the tool group (how evenly spaced are the arrivals to each tool?);
- CV of process times (how consistent are the process times, from lot to lot, at each tool); and
- CV of repair times (when the tool is down, is the length of the downtime predictable or unpredictable?).

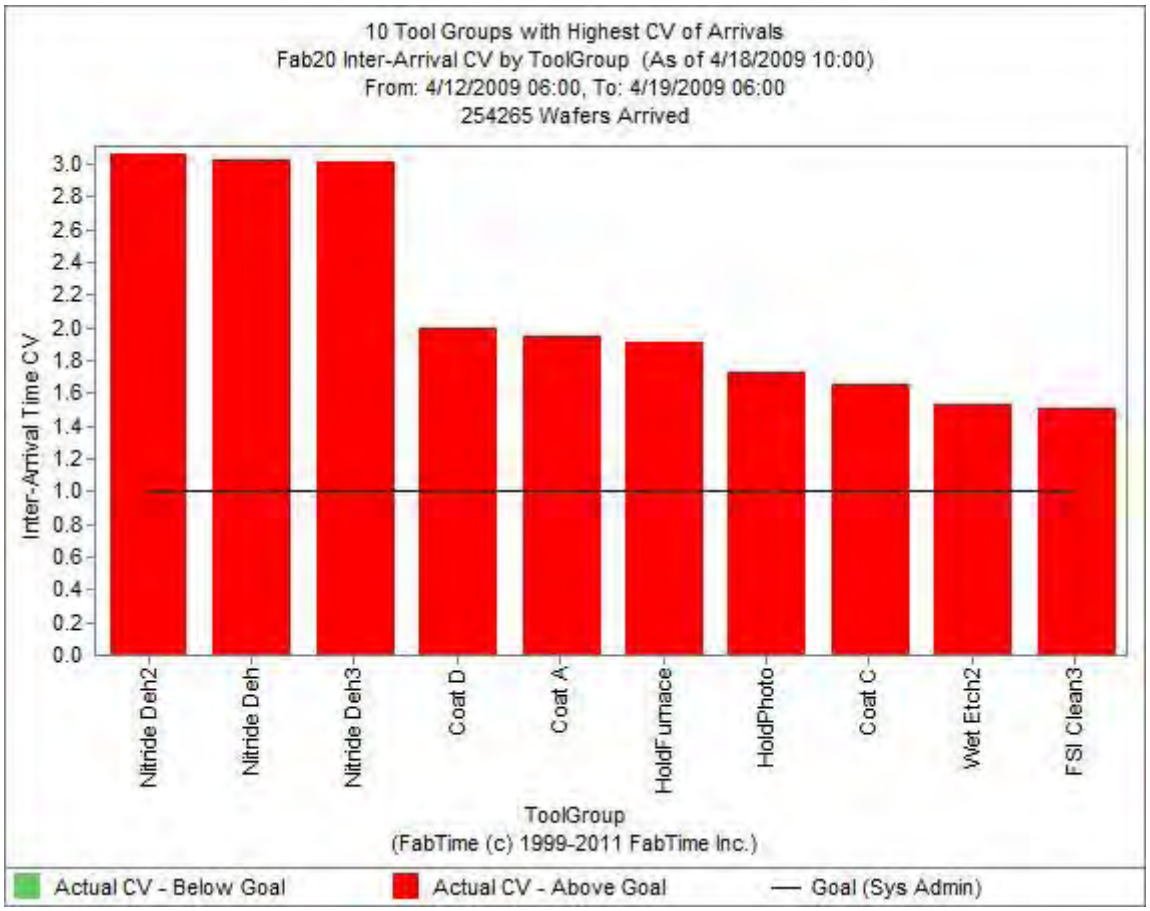
In FabTime, we calculate CV of arrivals (to any tool group, area, or operation), as well as the CV of both scheduled and unscheduled downtime duration for each tool. An example of a chart showing the 10 tool groups with the highest CV of arrivals over a week is shown at the top of the next page.

We do not currently calculate CV of process times. The reason for this is that the proper value to include in a queueing model is not so much the CV of the actual process times, but rather, the CV of the "Effective Process Times", where Effective Process Times take into account variability due to things like setups and downtime. Calculation of Effective Process Times is computationally challenging, because the Effective Process Time for the lot at the front of the queue changes if another lot arrives with a higher priority, before that lot can be processed. Calculating the CV of the sequence of actual process times would provide a lower bound on the process time variability, but not the whole story. [Perhaps, however, we should calculate it anyway, since it does provide at least relative information. We'll poll our customers, and see what they think about this relative to other possible enhancements.]

Recently, customers from two of our FabTime sites have asked us to also provide the CV of tool availability in FabTime. That is, looking at the sequence of availability observations by tool by time period, how variable is that? We do currently use this availability data as the basis for our A20/A80 availability variability charts, but we have not, up until now, also calculated the CV of the availability. This is now on our development list, and we think that it will be a nice addition to FabTime.

A20 and A80

The A20/A80 metric, which we introduced back in issue 4.01, looks at the set of availability values by time period for



a toolset (e.g. availability by tool by day, across a week). However, instead of calculating a CV of that sequence, this metric looks at percentiles. A80 is the best availability reached within 80% of the periods in a set of periods, while A20 is the best availability reached (or exceeded) in at least 20% of the periods. The result is a tangible number, which we can compare across tools. We can say, of all the tool groups in the fab this week, these 5 tools had the worst A80 value. However, although this metric still takes variability of the availability into account, it's still more a statement about the availability itself than the impact that the availability has on fab variability.

Distributions and Control Charts

Moving out of the realm of quantifiable metrics (where we come up with a single number, which we can sort by tool), there are a variety of distribution and control chart-based metrics. Examples include:

- Histogram of shipped lot cycle times, filtered by major device type. The spread of these histograms is an indication of how variable each device type is, and an indicator of which are the most difficult to manufacture.

- Dynamic X-Factor (see issues 4.08 and 5.03). This chart is used to record total WIP divided by WIP running on tools each hour. Viewed over time, it looks like a control chart, and gives a visual impression of WIP variation.

- 95th percentile of per-visit cycle times. Here, in addition to looking at average cycle time per visit through a tool group, we can also look at the 95th (or 98th) percentile line. Places where the 95th percentile line is highest are the places with the most per-visit variability.

These metrics provide a nice visual snapshot of the variability, and let us compare across, say, device types to visually determine which is the most variable. But they are harder to use in a variability snapshot sort of way, where we're looking for our top sources of variability.

Variability Snapshot

We do think that one could build a nice little fab variability snapshot based on Paretos of the CV values defined above. Something like:

1. Top 10 tools (or tool groups) in terms of arrival CV over the past week (as shown on the previous page).
2. Top 10 tools (or tool groups) in terms of process time CV over the past week.
3. Top 10 tools (or tool groups) in terms of CV of availability over the past week (or month).
4. Top 10 tools (or tool groups) in terms of CV of unscheduled downtime duration over the past week (or month).

Note that 1 and 2 will probably see enough data in a week to generate reasonably solid values (with the possible exception of large batch tools). For 3 and 4, fewer observations will be available each day. For example, if we are looking at availability by day for a single tool across a week, we'll only have 7 observations, which is not enough to meaningfully calculate CV. We generally want at least 30 observations. So, 3 and 4, unless they are calculated for a group of like tools, may need to be measured over a longer time period.

Conclusions

FabTime has always focused on variability reduction as a way to reduce fab cycle times, and we include a number of variability-related metrics in our web-based dashboard software. However, we are always looking to improve, and we wonder whether there might be additional metrics that we are missing. Inspired by our customers, and our friends from the Fab Owners Association, we've also been thinking about additional ways to frame variability metrics, to make them more useful in driving day-to-day improvement efforts.

We believe that the list above provides a good start for a fab variability sources snapshot, while the other charts mentioned earlier in the article add additional nuance and understanding. We still wonder, though, if there are other metrics that we might be missing, or other ways to look at fab variability that would be even more useful. We welcome your feedback and discussion on this topic.

Closing Questions for FabTime Subscribers

What do you think are the best metrics to use to monitor and improve fab variability (and hence improve cycle time)? If you were creating a fab variability snapshot report, what would be in it?

Further Reading

- J. Robinson and F. Chance, "Quantifying Wafer Fab Variability," *FabTime Newsletter*, Vol. 4, No. 1, 2003.
- J. Robinson and F. Chance, "Quantifying Availability Variability," *FabTime Newsletter*, Vol. 4, No. 2, 2003.
- J. Robinson and F. Chance, "Arrival Variability and Cycle Time," *FabTime Newsletter*, Vol. 4, No. 5, 2003.
- J. Robinson and F. Chance, "Dynamic X-Factor," *FabTime Newsletter*, Vol. 4, No. 8, 2003.
- J. Robinson and F. Chance, "Dynamic X-Factor Revisited," *FabTime Newsletter,* Vol. 5, No. 3, 2004.

Subscriber List

Total number of subscribers: 2723, from 477 companies and universities.

Top 20 subscribing companies:

- Maxim Integrated Products, Inc. (152)
- Intel Corporation (145)
- Micron Technology, Inc. (107)
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- Nanyang Technological University (7)
- Virginia Tech (7)

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- Keystone Strategy
- Mattson Technology
- MiaSole
- Semiconductor Laboratory
- Soraa Inc.
- Universtia Degli Studi di Padova

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- Era7 Information Technologies (1)
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- CAMDesigns (1)
- Front Line Performance (1)
- IM Flash Technologies (12)
- Lexmark International, Inc. (1)
- Lilliputian Systems (1)
- Molnlycke Health Care (1)
- Nikon Precision (1)
- Phillips Service Industries (1)
- Photronics Ltd. (1)
- SMIC (14)
- Telefilter GmbH (1)
- ZettaCore (1)

Note: Inclusion in the subscriber profile for this newsletter indicates an interest, on the part of individual subscribers, in cycle time management. It does not imply any endorsement of FabTime or its products by any individual or his or her company.

There is no charge to subscribe and receive the current issue of the newsletter each month. Past issues of the newsletter are currently only available to customers of FabTime's web-based digital dashboard software or cycle time management course.

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Cycle Time and Line Yield Improvement Manager
Spansion Fab 25

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Turn fab MES data into information and save time and money

- Are your supervisors swamped with daily reports, but lacking real-time information?
- Is it difficult to link equipment performance to cycle time?
- Does each new cycle time analysis require IT resources?

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Jim Wright
Production Manager
Headway Technologies

FabTime Benefits

- Cut cycle times by up to by 20%.
- Focus improvement efforts on the tools that inflate cycle time.
- Improve supervisor productivity – cut reporting time by 50%.
- Improve IT productivity – eliminate need for custom reports.