FabTime Cycle Time Management Newsletter

Volume 16, No. 6 November/December 2015

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 development for FabTime include modification of tool availability charts to ignore factory shutdown, new core procedure to copy selected columns from an Excel data set into a local table, and new Elapsed Cycle Time Contribution Pareto Charts.

Editor: Jennifer Robinson

Keywords: OEE, Metrics and Goals, Cluster Tools

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Welcome

Welcome to Volume 16, Number 6 of the FabTime Cycle Time Management Newsletter! We hope that the holiday season is treating you all well, and that those who celebrate it had a Happy Thanksgiving last week. In this issue we have a quick announcement about recent and upcoming Fab Owners Association events, as well as an announcement about our latest software release. Our software tip of the month is about understanding the different types of cycle time reported in the software. We have no subscriber discussion this month. But we continue to offer this forum for discussing fab management topics, if anyone has questions to ask or information to share.

In our main article this month we discuss some computational issues that have arisen as we have worked with several of our customers to implement cluster tool OEE. We share our approaches to dealing with these very nuts-and-bolts issues, and hope that this article will be useful to those of you working on cluster tool OEE.

Wishing you all a joyful holiday season, and a productive 2016! – Jennifer, Frank, and the FabTime Team

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Community News/Announcements

Fab Owners Association Participation Update

FabTime's Jennifer Robinson and Frank Chance attended the most recent Fab Owners Association meeting, held at Microchip Technologies in Gresham, Oregon in late October. We were pleased to learn that Novati-Technologies, a new device maker member of the FOA, will be hosting the May FOA meeting at their site in Austin, Texas. M/A-COM has also recently joined the FOA as a device maker member. We are glad to see this useful organization continuing to grow.

Meanwhile, Jennifer and Frank plan to attend the FOA's fourth annual Collaborative Forum in Redwood City in February. More details can be found here. We hope to see some of you there!

FabTime Releases Patch 107

FabTime is pleased to announce the formal release of Patch 107, already in place at many of our customer sites. Highlights in this release include:

1. Support for site-specific tool-state transaction attributes, e.g. Downtime Owner.
2. OEE for multi-path cluster tools.
3. Improved performance for sites with tens of thousands of defined goals that are ramped on a regular schedule.
4. Dispatch lists generated by a real-time short-interval scheduler.
5. Usability enhancements for JavaScript charts:
   a. Axis gridline support.
   b. Increased color choices for stacked charts.
   c. Improved performance.

We are also making rapid progress with Patch 108, with several customer sites previewing new functionality on their test servers. Features already included in Patch 108 include:

1. Support for automated uploads of Excel datasets, e.g. for goal and UPH maintenance. Local FabTime administrators can maintain this configuration data in Excel, and then upload it to FabTime in a secure fashion, with change-tracking.
2. Usability enhancements requested by FabTime user group:
   a. Excel export formatting.
   b. Managing home page tabs.
3. Improved performance for Charts menu.
4. Usability enhancements for JavaScript charts:
   a. Improved formatting and abbreviations for y-axis labels.
   b. Control over data value labeling.

Please contact your internal FabTime administrator to ask about your site's status in implementing these patches.

FabTime welcomes the opportunity to publish community announcements, including conference notices and calls for papers. Send them to newsletter@FabTime.com.

FabTime User Tip of the Month

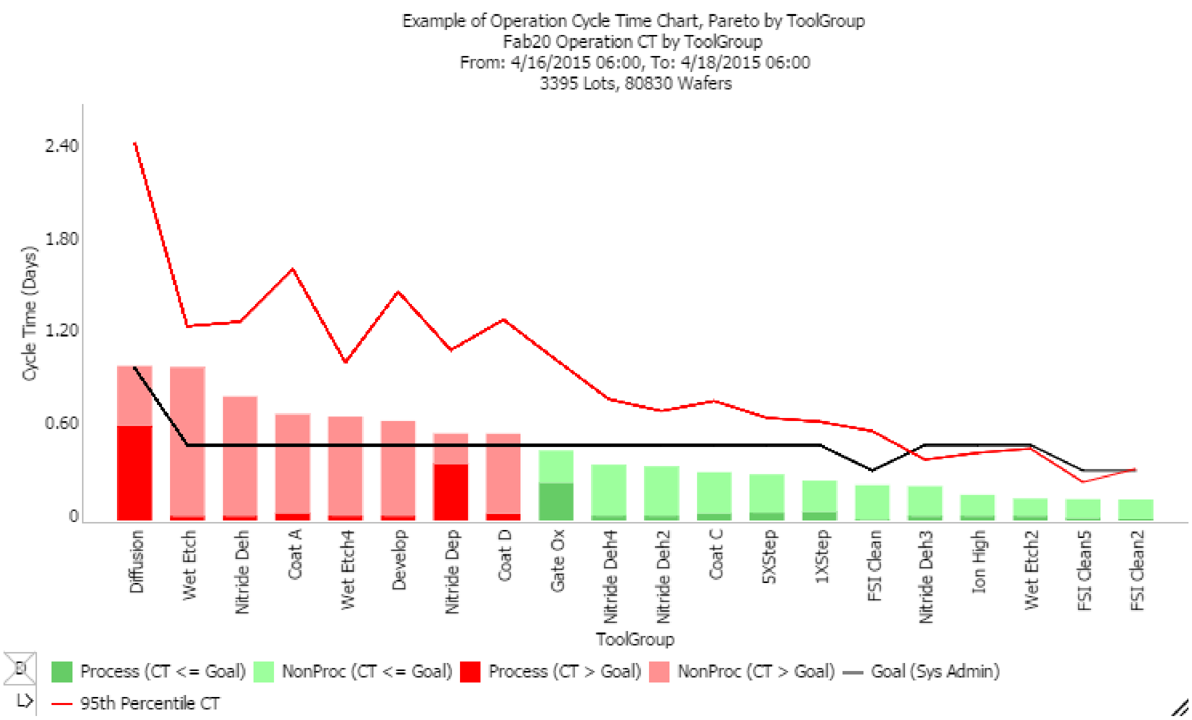
Understand the Different Cycle Time Charts in FabTime

A new user of FabTime recently requested a quick clarification regarding the different types of cycle time charts available in FabTime. We thought this would make a useful tip for others.

Operation Cycle Time: The Operation Cycle Time charts show time per visit, or per move, averaged across all applicable lots. The time per visit is the time from when the lot moved out of the previous operation until it moved out of the current operation. Charts display process time (begin run to end run) and non-process time (queue time, transport time, hold time, post-process time, etc.). Use the Operation Cycle Time Pareto, sliced by Tool or ToolGroup, to see which tools have recently been cycle time bottlenecks. Tools that have a small amount of process time and a large amount of non-process time offer opportunities for cycle time improvement. An example is shown below. The second through fifth ToolGroups shown all have significant queue time per visit.

Summed Operation Cycle Time: Summed Operation Cycle Time indicates overall cycle time conditions based on current operation-level cycle times. Operation-level cycle times are estimated and then summed to provide an overall cycle time estimate. This chart is most useful when filtered for a particular process flow, as it then gives an estimate of the overall cycle time for that flow. Charts display Actual Summed Operation Cycle Time and Fill In Summed Operation Cycle Time, where actual is based on move completions, and fill in is based on planned cycle time values across the remainder of a flow.

Elapsed Cycle Time: The Elapsed Cycle Time charts show the elapsed time for all lots that passed between a specified From Step and a specified To Step over the time period of the chart. This gives an indication of how long it takes lots to traverse some portion of their process flow, and can be helpful in estimating when future lots may arrive (taking into account more dynamic data about recent conditions than the Forecast charts). It is



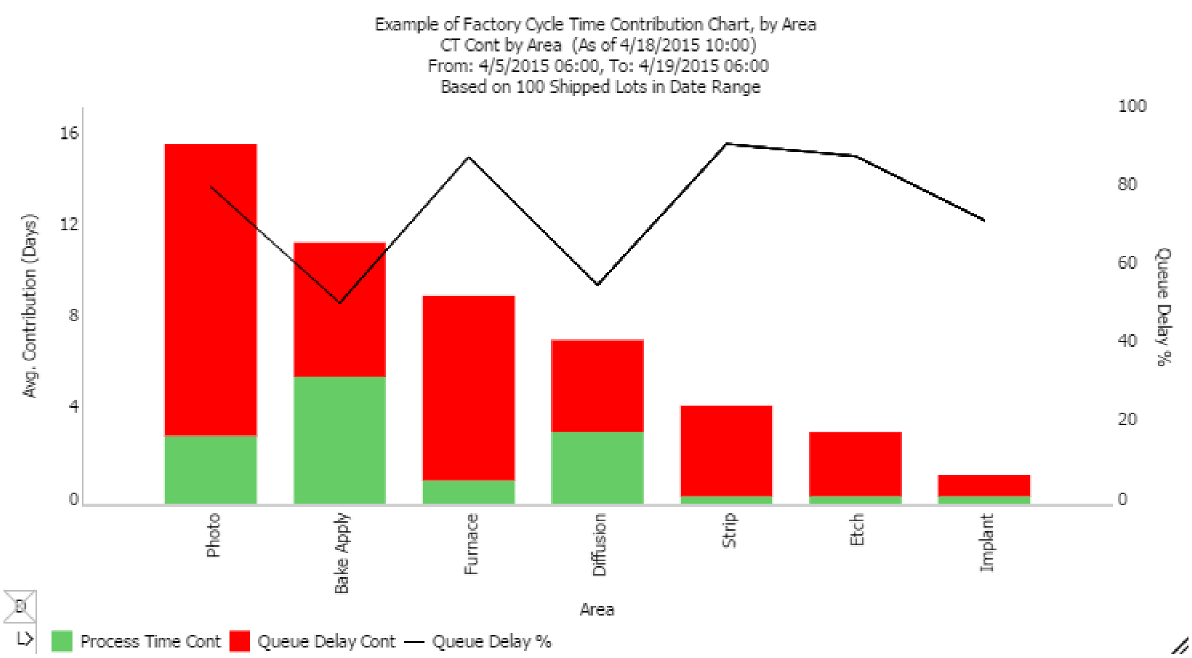
possible on the Elapsed Cycle Time charts to subtract out time that lots had a particular owner, were at a particular operation, or had a particular hold code.

Factory Cycle Time: The Factory Cycle Time charts include data only for shipped lots. Factory cycle time for a lot is the elapsed time from the lot's start to the lot's shipment, unless the subtract owner "-Own:" or subtract operation "-Opn:" controls are specified. In that case, factory cycle time excludes any time spent in owner codes or operations matching these controls. If your MES -> FabTime data link indicates parent/child relationships, FabTime will follow the list of ancestors, if any, for a shipped lot back to the original started lot. If FabTime is unable to trace all the way back to the original started lot, it reports any missing time as "ancestor cycle time". Factory Cycle time data is available in trend, pareto and histogram formats.

Factory Cycle Time Contribution: The Factory Cycle Time Contribution Pareto chart also applies to shipped lots. For each lot that shipped during the time period designated on the chart, FabTime computes the total time that the lot spent in different areas, toolgroups, tools, etc. Use this chart when you want to look at the relative contribution to cycle time of a lot attribute that changes over time. E.g., as shown below, as lots move through different areas in the factory, they accumulate cycle time in areas Etch, Photo, Strip, etc. These areas apply to all (or nearly all) lots. When sliced by area, this chart shows the relative contribution of each area to shipped lots, e.g. the average time spent by each lot in Etch, Photo, Strip, etc.

Coming soon: Elapsed Cycle Time Contribution Pareto Chart. This chart (not yet released) displays elapsed cycle time contributions between any two specified starting and ending move transactions. This chart is similar to the Factory Cycle Time Contribution Chart, but the Factory Cycle Time Contribution Chart looks only at Start to Ship time. For example, you can use the Elapsed Cycle Time Contribution Pareto Chart to analyze time spent in various Segments, Areas, or Owners between the move out of operation 1000 and the move out of operation 5000.

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



Subscriber Discussion Forum

FabTime welcomes the opportunity to publish subscriber discussion questions and responses. Simply send your contributions to Jennifer.Robinson@FabTime.com. There are no subscriber discussion topics in this issue.

Implementing OEE for Cluster Tools

Introduction

Over the past year, FabTime has worked, with the help of our customers, to implement OEE (overall equipment efficiency) calculations for cluster tools in our product. We have followed the SEMI E79-0814 Specification for Definition and Measurement of Equipment Productivity, as approved in May of 2014. This document contains a considerable amount of detail, including numeric examples, which we found extremely helpful. However, as we got into the nitty-gritty of implementing these calculations, we ran into several issues regarding cluster tool data as stored in the manufacturing execution system. We believe that these issues (for example, a lack of stored data on productive vs. standby time within process modules) are likely common to many fabs, whether or not they use FabTime for reporting, and so we have chosen to share our experiences and solutions in this article.

Background: OEE for Multi-Path Cluster Tools (MPCTs)

In theory, calculating cluster tool OEE is straightforward. We will start with a simple example that looks at calculations related to production time, rate efficiency, and OEE. Suppose you have a multi-path cluster tool (MPCT, in the language of E79) that is composed of three process modules (chambers), PM1, PM2, and PM3.

Here is the data by module (all times in hours):

Total Time: PM1 = 24, PM2 = 24, PM3 = 24

Production Time: PM1 = 6, PM2 = 8, PM3 = 14

Theoretical Production Time for Actual Units (the production time that was theoretically required to complete the units processed): PM1 = 5, PM2 = 7, PM3 = 13

Theoretical Production Time for Effective Units (adjusting for equipment-assignable quality losses): PM1 = 5, PM2 = 7, PM3 = 11

Next, we aggregate this process module data.

Total Time = 24 + 24 + 24 = 72 hours

Production Time = 6 + 8 + 14 = 28 hours (Production time for an MPCT is the sum of the SEMI E10 Production Times of all process modules.)

Theoretical Production Time for Actual Units = 5 + 7 + 13 = 25 hours (For MPCTs, Theoretical Production Time is the sum of the Theoretical Production Times for all process modules.)

Theoretical Production Time for Effective Units = 5 + 7 + 11 = 23 hours

Now, let's compute the OEE and Rate Efficiency Metrics (leaving out other OEE-related calculations for simplicity).

Rate Efficiency = (Theoretical Production Time for Actual Units) / (Production Time) = 25 hours / 28 hours = 89.3%

OEE = (Theoretical Production Time for Effective Units) / (Total Time) = 23 hours / 72 hours = 31.9%

Note that these calculations required only values related to the process modules (vs. the MPCT as a whole).

Two Computational Issues in Practice

These calculations seem straightforward enough. However, as we set out to estimate OEE for cluster tools in our customers' fabs, we ran into two issues. First of all, a number of sites do not have easy access to the exact sequence of chambers used when a lot runs through an MPCT (nor the Theoretical UPH rate for each of the possible combinations). Without this chamber information, we cannot compute Theoretical Production Time (for actual or effective units). Second, a number of our sites do not have easy access to productive and standby time for process modules. Only the availability-related transactions are tracked and reported to the MES by module. Without the module-level productive and standby time, it is not possible to compute "Production Time" as above. Unless we can solve these two problems, we cannot even compute Rate Efficiency, let alone OEE.

Calculating Theoretical Production Time

What we did in FabTime was add a new method of specifying UPH (Units per Hour) data so that it could handle both cluster tools and non-cluster tools. For cluster tools (MPCTs), the UPH data includes which chambers are used for each possible way the recipe can be run. Together with WIP transactions, we are able to use this UPH data to estimate Theoretical Production Time for process modules (chambers).

Let's delve into the details of this a bit. Suppose we have two identically configured process modules, PM1 and PM2, and a recipe that could run on PM1, PM2, or both. The method of running the tool determines the Theoretical Production Time. Therefore, in addition to the recipe (e.g. Zeus), we need to know the "production recipe", which is the list of chambers used in the actual processing. We also need to know the UPH. There might be three production recipes "Zeus.PM1" (run only in PM1), "Zeus.PM2" (run only in PM2), and "Zeus.PM1.PM2" (run in both chambers). Each of these might have different UPH values, e.g. 25 wafers per hour for Zeus.PM1 and for Zeus.PM2, but 40 wafers per hour for Zeus.PM1.PM2 (if it is faster to run on both chambers at once).

Now when a move is recorded, if we know the recipe and the production recipe, then we can compute the Theoretical Production Hours for Actual Units (adjusting later for Effective Units as required) for each of the chambers involved.

If we have a 25 wafer lot and the WIP history tells us that it was run using production recipe Zeus.PM1, then the Theoretical Production Time for that lot is (wafer quantity) / (wafers per hour) = 25 wafers / 25 wafers per hour = 1 hour. Similarly, the Theoretical Production Time for production recipe Zeus.PM2 is also 1 hour.

For that same 25 wafer lot, the Theoretical Production Time through Zeus.PM1.PM2 is calculated as a sum across each chamber:

PM1: 25 wafers / 40 wafers per hour = 0.625 hours

PM2: 25 wafers / 40 wafers per hour = 0.625 hours

Theoretical Production Time = 1.25 hours

Note that running the wafers using both PM1 and PM2 results in a shorter cycle time than running on a single chamber (0.625 hours vs 1 hour) but more Theoretical Production Time (1.25 hours versus 1 hour). This situation arises when the multi-chamber UPH is less than twice the single-chamber UPH. In this example, running on a single chamber gives us 25 wafers per hour, but running on two chambers gives us slightly less than twice that speed. Whether or not it is a good idea to use both chambers depends on what else can run at the same time.

This example only hints at the complexity hiding in cluster tools. In some cases that we've seen, a dual-chamber cluster tool may serve as a backup for recipe Zeus (to be run on PM1), but while Zeus is running on PM1, PM2 is forced idle and cannot be used for other recipes, so the tool effectively loses half its capacity for the time while it is processing Zeus.

Due to this complexity, it is best to retain a certain degree of modesty when computing cluster tool OEE. It is a useful performance metric, but there are many factors behind the final number that influence its accuracy.

Calculating Actual Production Time

To calculate Production Time, we use the UPH data described above, in combination with the WIP transactions sent to the MES, to infer the productive vs. idle status of each chamber. From this inferred status, we are able to estimate the Production Time for each process module.

In practice, in some tool-tracking systems, operators log process modules up and down, but there is no split of up time into production time vs. standby time. In FabTime, we use the production recipe information at the time of the BeginRun transaction as input for our auto-productive/standby logic, to determine if there are wafers in each production chamber. From that information we are able to generate automatic productive (or standby) transactions when the chambers are busy or idle. We do make a simplifying assumption that each process module relevant for this production recipe is busy from the time of BeginRun until EndRun. This might not be the case, when wafers move sequentially through multiple chambers, but without transactions reporting chamber-level productive vs. standby, we were unable to see any other way of approximating process module productive time.

Special Case: When the Mainframe is Down

The situation can arise for MPCTs in which the mainframe or handler is down, but one or more process modules are up. The E79 specification implicitly treats this situation as an Operational Loss, because it uses the process module availability data, which says that the process modules are up, but not being run. Our customers indicated that they would prefer to see this situation recorded as an Availability Loss, rather than an Operational Loss, because the downtime of the mainframe is incapacitating the tool. We made adjustments to handle this situation in FabTime.

There are two possible solutions to this issue:

We can report that the chambers are down whenever the mainframe is down. Some of our sites are able to do this using state rules. However, this does not seem to us to be a great solution, because it involves reporting chambers as down when they are not really down (leading to inaccurate downtime statistics for the chambers). This does ensure that any downtime of the mainframe shows up in OEE as an Availability Loss, however.

Another approach is to alter the OEE calculations slightly so that availability is downgraded by the mainframe downtime when the process modules are up. We experimented with many solutions along this path before a customer suggested using a chamber state called "standby waiting for associated tool" (this customer's MES reports a chamber in this state when the chamber is up but the mainframe is down). So in FabTime now, we have a flag at the substate level (the tool state recorded into the customer MES) to indicate, "If the tool is in this substate, treat this as an Availability Loss for OEE". In this way, time in a non-downtime state (e.g. standby waiting for associated tool) can be subtracted from overall Availability. At the MPCT level, then, we see an OEE Availability Loss when the mainframe is down but the chambers are all up.

Conclusions

Estimating OEE for cluster tools has long been a challenge for wafer fabs, due to the complexity of these tools. The SEMI committee responsible for the E79 specification made great strides towards detailing and clarifying these calculations in the 2014 revision of the specification.

As we have worked with some of our customers to implement cluster tool OEE in FabTime, however, we have run across a few implementation issues. These issues would likely not be a problem for the most highly automated fabs. However, for fabs running older manufacturing execution systems, particularly custom systems, some data limitations can arise. In this article, we have described our approach to handling production recipe-specific UPH data, as well as the lack of productive vs. standby transactions for individual chambers. We've also briefly discussed an approach for treating mainframe downtime, when the chambers are available, as an Availability Loss.

These are very pragmatic, nuts-and-bolts issues. We hope that others who are working on cluster tool OEE will find this discussion useful. We would be happy to share more details with anyone who has questions.

Questions for FabTime Subscribers

Do you report OEE for cluster tools? Do you do anything special to handle the issue of the mainframe being down when there are chambers up? Does your MES store detailed UPH data by all of the possible production recipes within a cluster tool?

Acknowledgement

FabTime is grateful to our customers for their help with the cluster tool OEE project, particularly Carsten Wiemann and the rest of the project team from Elmos Semiconductor.

Subscriber List

Total number of subscribers: 2792.

Top 20 subscribing companies:

- Infineon Technologies (146)
- Intel Corporation (140)
- Micron Technology, Inc. (139)
- Maxim Integrated Products, Inc. (125)
- ON Semiconductor (109)
- GLOBALFOUNDRIES (100)
- Fairchild Semiconductor (76)
- Carsem M Sdn Bhd (71)
- Texas Instruments (65)
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- Skyworks Solutions, Inc. (49)
- Seagate Technology (46)
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- NXP Semiconductors (34)
- Cypress Semiconductor (32)

Top 4 subscribing universities:

- Ecole des Mines de Saint-Etienne (EMSE) (18)
- Arizona State University (8)
- Nanyang Technological University (7)
- Virginia Tech (7)

New companies and universities this month:

- Laser Components DG Inc.
- Lionbridge
- Tesla Motors

Sampler Set of Other Subscribing Companies and Universities:

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- Colibrys (1)
- Dell Computer (3)
- dpiX (1)
- Gadir Solar (1)
- GNE Corp. (1)
- HEC Paris (1)
- Infinera (5)
- Innovative Global Services & Solutions (IGSS) (4)
- iSky Factory Automation (1)
- Lexmark International, Inc. (1)
- MSEI/Biotronik (1)
- Phillips Service Industries (1)
- Polar Semiconductor (24)
- Power Integrations Inc. (1)
- Powerex, Inc. (1)
- Suss MicroOptics (1)
- Tokyo Electron Ltd. (2)
- Ubisense (1)
- University of Malaysia (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.

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Headway Technologies

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