FabTime Cycle Time Management Newsletter

Volume 10, No. 9 December 2009

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 customizable alert text and detailed reporting of ancestor lot cycle time.

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Welcome

Welcome to Volume 10, Number 9 of the FabTime Cycle Time Management Newsletter! We hope that you're all enjoying the holiday season, and we have a relatively short issue for you to close out the year. Our FabTime user tip of the month is about reporting open lot cycle times. We have one community announcement, about ISS Europe 2010. We also have a new subscriber discussion topic (well, something that we haven't discussed in several years): operator productivity metrics.

In our main article this month, we return to something that we think is important for cycle time improvement efforts, but that we haven't discussed in detail since Volume 1 of the newsletter: cycle time improvement at non-bottleneck tools. It's well-known that in order to increase overall capacity in a fab, it's necessary to focus on the bottleneck (or bottlenecks, in most cases). However, when seeking to improve cycle time, it's possible to make improvements at tools that aren't capacity bottlenecks, and see improvement in overall cycle times. In this article, we explore the impact of improvement at non-bottleneck tools in a reentrant environment, and then offer concrete suggestions for deciding where to begin, and taking action. We welcome your feedback.

We wish you all a joyful holiday season, and a productive 2010—Jennifer and Frank

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Community News/Announcements

Industry Strategy Symposium (ISS) Europe 2010: Dublin, Ireland: February 7-9

Here is the event announcement from Semi for ISS Europe:

"ISS Europe will address three main topics: Critical Mass, Technology Leadership, and Environmental Sustainability. In addition you'll hear about new opportunities for the European micro- and nano-electronics industry.

Critical Mass

The European electronics market is typically strong in innovation, but this position is threatened if the critical mass of skills in engineering, manufacturing and applications are not retained and developed. You'll hear discussions on strategies to maintain and expand these core capabilities within the European microelectronics industry.

Technology Leadership

Electronics is the foundation of consumer and industrial applications worldwide; this opens up an enormous amount of commercial opportunities for Europe. This session will address ideas on how to identify new market segments and develop solutions to improve manufacturing technology.

Sustainability

Sustainability, in the general sense for manufacturing, is the maintenance of a balance at any stage of the product lifecycle—from production of raw materials through manufacture, use and disposal of the final product. This balance must be respected and improved economically, globally and physically. You'll hear discussions on the interconnection between manufacturing, the economy, and the environment.

At ISS Europe 2010,we'll look at these and other critical issues—providing the market data, technology insights, industry-leading speakers and networking opportunities that are critical to making effective decisions.

Join us at ISS Europe 2010, where the focus is "Building on Sustainability" in the global marketplace." You can find the complete agenda, plus registration information, at http://www.semi.org/-eu/eventstradeshows/p035572.

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

View Open Lot Cycle Time for Lots

A long-time user of FabTime recently asked a question that we thought other people might also find relevant. The question was: "how do I display the open lot cycle time for engineering lots, while excluding time that was spent at operation ABCD?" Here is our answer. To see the open lot cycle time for individual lots (time since each lot was released into the fab) you can use the WIP Lot List chart (under WIP charts). The trick is that you need to set the “Age:” drop-down (near the bottom of the main set of filters to the left of the chart) to “Factory”. Then the “Age” displayed on the y-axis for each lot will be the total time since the lot was released into the fab.

To look at the average age across all lots (= average open lot cycle time), you can use the WIP Trend or WIP Pareto chart, and again, set the “Age” drop-down to be “Factory”. The data that you want will be the value of the red line, against the right-hand axis (Average Inventory Age). You can change the units for that axis using the “U/M” dropdown (weeks, days, hours or minutes).

On any of these charts, you can use the “-Opn:” filter (the one with the minus sign in front of it) to exclude any time that lots spent at a particular operation, or use the “-Own:” filter to exclude any time that lots spent with a particular owner code. With the minus filters, you don’t need the ~ exclusion filter. Just type the “ABCD” in the -Opn filter (without the quotes) to tell FabTime “show me the total cycle time for all lots, except subtract out any time that the lots spent at operation ABCD”. Note that using these minus filters is different from using an exclusion filter (~) on the “Own” or “Opn” filters. That would just exclude lots that currently have a particular owner code or are at a particular operation. The minus filters look back over the whole history of the lot, and exclude ANY time that a lot had that owner code or operation value.

If you have any questions about this feature (or any other software-related issues), just use the Feedback form in the software.

Subscriber Discussion Forum

Operator Productivity for 200mm vs. 300 mm Fabs

Bruce Fan of SMIC wrote to ask us about operator productivity values. He said:

“MA productivity is a filter that we use to check our Manufacturing Assistants’ (MA) loading. And we can track manpower loading in the fab. We define it by:

Stage productivity = daily stage move/(daily total manpower number* working hours of every operator)

So productivity is the stage move number of every operator working hour. We can know the operator’s loading based on the productivity data. But we do not know what is reasonable data for a fab, and what is criteria other fabs use for this metric. We’re also concerned with how to evaluate performance between 200mm and 300mm. We need do our recruiting plan based on the forecasted productivity, so it’s very crucial to have references, then we can do our recruiting plan. We recognize that it may be different in different fab due to automation status. Our specific questions are:

a) What is reasonable operator productivity number for 200mm and 300mm fabs. And how do other people define it? Does anyone know of reference papers about this?

b) Is there a defined proportion between 300mm productivity and 200m operator productivity? 2.25? or 1.4? or 1.2?"

FabTime Response: We have not seen publicly reported numbers lately for operator productivity (though we know that some fabs are using such numbers internally). We talked about this in the newsletter back in Volume 4 (2003), and we did publish some numbers on wafer moves per operator vs. fab loading in Issues 4.01 and 4.06. However, there was not data at that time for 200 mm vs. 300 mm, and automation levels tended to be different then. Thus, we thought that it was a good time to re-open this topic for your input. We welcome any discussion or data that any subscribers would care to share (and we are happy to share results with attribution or anonymously, as you prefer).

FabTime welcomes the opportunity to publish subscriber discussion questions and responses on issues related to semiconductor manufacturing performance. If you have a contribution, please send it to Jennifer.Robinson@FabTime.com.

Improving Factory Cycle Time through Improvements at Non-Bottleneck Tools

Introduction

In honor of FabTime's 10-year anniversary (and the upcoming 10-year anniversary of the launch of the newsletter), we're going to be taking a retrospective look at some of our early articles and providing updated information where it's available. In our seventh newsletter issue (published in October of 2000), we published an article about the benefits of focusing on cycle time improvement at tools that aren't necessarily bottlenecks. In this article, we revisit and expand upon this topic. One of the nice things about cycle time improvement, as compared with capacity expansion projects, is that you can improve cycle time anywhere in the fab.

Way back in issue 1.04 we talked about the theory of constraints, and the importance of locating and focusing on the bottleneck. The capacity of a fab is, of course, limited by the capacity of the bottleneck. As Eli Goldratt said: "An hour lost at the bottleneck is an hour lost for the entire system." If you want to improve throughput for your fab, you need to start with the bottleneck (or, more commonly, bottlenecks), and work from there. However, this is not true when you're trying to reduce cycle time. We believe that you can reduce overall cycle time by reducing cycle time at virtually any tool group in the factory.

The notion that you can improve overall cycle times by reducing cycle time at the bottleneck is obvious. And in fact, the bottleneck is a good place to start cycle time improvement efforts, since you probably have a large queue there, and lots of waiting time. The purpose of this article, however, is to point out that you can ALSO reduce cycle time by making changes at non-bottleneck tools. This is far less obvious. With throughput, it doesn't matter if you process at a higher rate at non-bottleneck tools, because things get held up at the bottleneck anyway. Sometimes this happens with cycle time, too. But not always. We'll divide the discussion below into three cases: tools located after the bottleneck in the process flow, tools located before the bottleneck, and tools located between visits to the bottleneck.

Tools Located After the Bottleneck

Cycle time improvements that take place at tools after the bottleneck in a process flow have a direct impact on overall cycle time. For example, suppose that you have a very simple production line, with two operations in series. The first operation takes place on Tool B (the bottleneck), and takes two hours per lot, on average (including any queue time). The second operation takes place on Tool C, and takes one hour per lot. The total average cycle time is three hours:

Start → Tool B (2 hours) → Tool C (1 hour) → Ship (Total Cycle Time = 3 hours)

If we now make improvements to Tool C such that the average cycle time is only 30 minutes, making no changes to Tool B, then the total average cycle time decreases to 2.5 hours:

Start → Tool B (2 hours) → Tool C (0.5 hours) → Ship (Total Cycle Time = 2.5 hours)

→ Reducing Tool C's cycle time by 30 minutes directly reduces total cycle time by 30 minutes.

In a more complex environment, with reentrant flow, you still see this improvement for operations that take place after all visits to the bottleneck. To expand the example above, suppose that lots go through a process flow that looks like this:

Start → Tool B (2 hours) → Tool C (1 hour) → Tool B (2 hours) → Tool C (1 hour) → Ship (Total Cycle Time = 6 hours)

Suppose now that we make improvements to Tool C such that the average cycle time per visit is 30 minutes.

Start → Tool B (2 hours) → Tool C (0.5 hours) → Tool B (2 to 2.5 hours) → Tool C (0.5 hours) → Ship (Total Cycle Time = 5 to 5.5 hours)

With no other changes, lots will get to their second visit at Tool B 30 minutes earlier than they would have previously. They might have to wait an extra 30 minutes before getting through Tool B on this visit, canceling out the savings from that first visit to Tool C (more on this in a later section). However, on the second visit to Tool C, the 30 minute savings is still a keeper, and the overall cycle time is reduced by at least 30 minutes, from six hours to 5.5 hours.

→ Reducing Tool C's cycle time by 30 minutes per layer may only reduce total cycle time by 30 minutes, but may reduce cycle time by a full hour.

Tools Located Before the Bottleneck

Cycle time improvements at operations that take place before any visits to the bottleneck can reduce cycle time by reducing the lead time that you use to allow lots to get to the bottleneck. For example, suppose we have another production line in which lots first go to Tool A for one hour, and then go to Tool B (the bottleneck) for two hours. If we follow a theory of constraints methodology, and release lots into the system according to the rate at which the bottleneck can handle them, then we release lots an hour before we would like them to be in queue for Tool B, and we have a total cycle time of three hours:

Start → Tool A (1 hour) → Tool B (2 hours) → Ship (Total Cycle Time = 3 hours)

If, however, we make improvements to Tool A that reduce the average cycle time to 30 minutes, then we can actually wait an extra 30 minutes before releasing lots into the system (in order to keep things the same at the bottleneck). Thus we can reduce the average cycle time to 2.5 hours by releasing lots 30 minutes later relative to when they will be needed at the bottleneck:

Start (one-time delay of 0.5 hours) → Tool A (0.5 hours) → Tool B (2 hours) → Ship (Total Cycle Time = 2.5 hours)

→ Reducing Tool A's cycle time by 30 minutes, and delaying additional starts for 30 minutes, directly reduces total cycle time by 30 minutes. As above, should there be later visits to Tool A, these improvements may also result in additional overall cycle time improvement, though the picture, as discussed in the next section, is a bit more complex.

Tools Located Between Visits to the Bottleneck

Because of the reentrant flow in most fabs, the situations described above only represent a portion of the operations in a wafer fab. Many operations take place after one visit to the bottleneck and before another visit, like the first visit to Tool C in the B – C – B – C example described above. The impact of cycle time reduction at such operations is less clear. In many cases, these changes improve overall cycle time by smoothing the flow of WIP to subsequent bottleneck operations. This is especially true if the bottleneck is sometimes starved, because the change will mean that lots sit in queue in front of the bottleneck, rather than being at a non-bottleneck. This can lead to significant improvements in overall cycle time. In other cases, the lots simply end up spending the time saved at Tool C sitting in queue at Tool B. However, we don't believe that this will ever make the total cycle time through Tool B and Tool C worse, because the total arrival rate to Tool B remains the same, and the variability of arrivals should always be decreased by improvements at Tool C.

We would also like to add that predicting the exact impact of an improvement to Tool C, even in this very simple case, is non-trivial. Try constructing a sample event-by-event timeline, and you'll see what we mean very quickly. Now magnify this by 600 or more steps, to represent the situation in a real wafer fab. However, what we believe is that if improvements at Tool C might make things much better, and won't make things worse, there's good reason to go ahead with an improvement program for the non-bottleneck Tool C, in addition to any that might already be in place for the bottleneck Tool B. Note that this is a good use of simulation, to test out the potential impact of cycle time improvements at non-bottleneck tools.

How Do You Improve Cycle Time at Non-Bottleneck Tools?

If we've convinced you that cycle time improvement programs at non-bottleneck tools makes sense, a logical question to ask is: what specifically should you do? Of course there are many possible answers. We've drawn the list below from published studies, as well as from our own experience. (This list is reprinted from our paper "Wafer Fab Cycle Time Management Using MES Data," which you can download from [http://www.fabtime-.com/abs_MASM00.shtml](http://www.fabtime.com/abs_MASM00.shtml). Many of these recommendations are also discussed in more detail in Issue 6.10.)

- 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.
- Explore process changes to alleviate single-pass operations, e.g. operations that can only be performed on a single piece of equipment.
- Explore batching rules, to make sure that all lots that can be batched together are batched together (eliminate unnecessary waiting to 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.

Perhaps some of your have other suggestions to add – we would like to hear them, and we're sure that our other readers would, too.

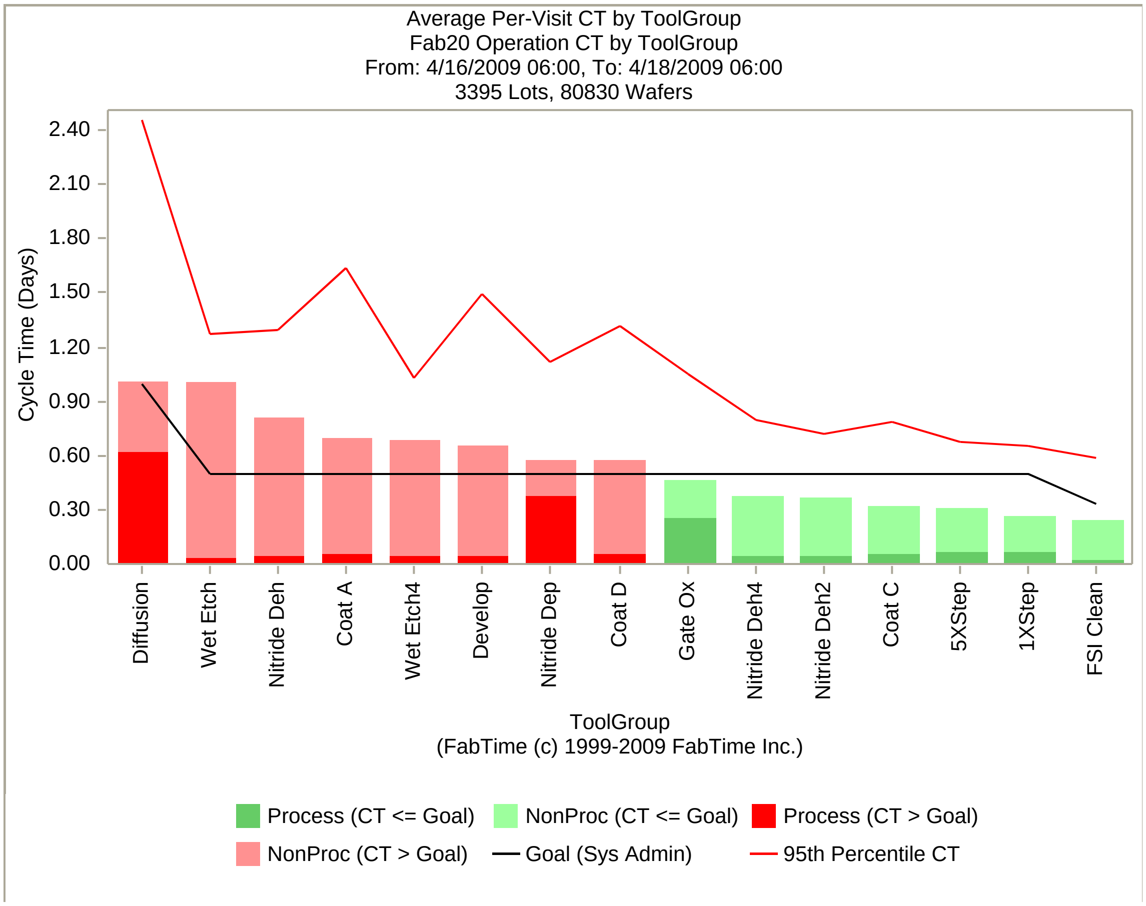
Which Non-Bottleneck Tools Should You Focus on First?

While we do feel that cycle time improvement anywhere in the fab can translate to improvement in overall cycle time, it of course makes sense to look first at toolgroups that have a high ratio of total cycle time to process time (a high operation-level x-factor). A useful chart for this is one that reports average cycle time per visit, across all operations, by toolgroup, for some relatively short-term time window, broken into process time vs. non-process time (a bucket including queue time, hold time, transfer time, etc.). An example is shown at the top of the next page. The more queue time and other non-value-added time, especially relative to process time, the more opportunity there is for improvements at this toolgroup to have a significant overall difference in cycle time. For example, the second through sixth tool groups, from the left, on the chart all show considerable opportunity to make improvements to reduce overall cycle time. This type of analysis was discussed in more detail back in Issue 6.09.

It can also be useful to look for non-bottleneck tools that directly feed the bottleneck. Any improvements that smooth flow to the bottleneck are likely to be of high benefit. This is especially true for batch tools that feed the bottleneck, since batch tools tend to have high-variability output processes.

Conclusions

Our point is very simple: actions that you take to improve cycle time at non-bottleneck tools generally will improve overall product cycle times. For operations located before the first visit to the bottleneck, or after the last visit to the bottleneck, the cycle time reduction leads to an essentially direct reduction in the overall cycle time. For intermediate operations the situation is less clear, but we believe that improvements here can sometimes improve cycle time dramatically, and in the worst case, will not make cycle time any worse. If you focus your efforts strictly on bottleneck tools, then, you miss out on many opportunities for improvement.



Closing Questions for FabTime Subscribers

When looking for cycle time improvement opportunities, do you look primarily at capacity bottlenecks, or do you look for any toolgroups that are contributing to cycle time? Have you had success stories from improvements at particular types of non-bottleneck tools (such as batch tools, or tools with reliability issues)?

Further Reading

■ J. Bonal, C. Ortega, L. Rios, S. Aparicio, M. Fernandez, M. Rosendo, A. Sanchez, and S. Malvar, "Overall Fab Efficiency," *Proceedings of the 1996 IEEE/SEMI Advanced Semiconductor Manufacturing Conference*, 49-52, 1996. This paper discusses which non-bottleneck tools should be the focus of OEE improvement efforts.

■ C. W. Craighead, J. W. Patterson, and L. D. Fredendall, "Protective Capacity Positioning: Impact on Manufacturing Cell Performance," *European Journal of Operational Research*, Vol. 134, No. 2, 425-438, 2001. This study looked at placement of extra protective capacity at non-bottleneck tools. They found that placement didn't have much impact on average cycle time, but did affect how often bottlenecks tended to shift.

■ J. Robinson and F. Chance, "Estimating and Using Operation Cycle Times," *FabTime Newsletter*, Volume 6, No. 9, 2005. Email newsletter@FabTime.com if you would like to request a copy of this issue.

■ J. Robinson and F. Chance, "Operational Recommendations for Wafer Fab Cycle Time Improvement," *FabTime Newsletter*, Volume 6, No. 10, 2005. Email newsletter@FabTime.com if you would like to request a copy of this issue.

Subscriber List

Total number of subscribers: 2742, from 460 companies and universities.

Top 20 subscribing companies:

- Maxim Integrated Products, Inc. (191)
- Intel Corporation (147)
- Chartered Semiconductor Mfg (87)
- Micron Technology, Inc. (81)
- Western Digital Corporation (76)
- X-FAB Inc. (69)
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- STMicroelectronics (45)
- Infineon Technologies (44)
- Cypress Semiconductor (38)
- Seagate Technology (37)
- ATMEL (33)
- NXP Semiconductors (31)

Top 3 subscribing universities:

- Virginia Tech (11)
- Arizona State University (8)
- Ben Gurion Univ. of the Negev (8)

New companies and universities this month:

- Deloitte Consulting
- Innovo Strategy, Inc.
- Lantiq GmbH
- Luminus Devices
- Preston Lane Consulting

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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