FabTime Cycle Time Management Newsletter

Volume 4, No. 11 December 2003

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 current version (5.6) include the ability to quickly generate lot history charts from anywhere in the software, and the ability to autoplay charts in slide show view.

Editor: Jennifer Robinson

Contributors: Daren Dance (WWK); Jimmy Giles (STMicroelectronics); Roger Winkles (Microchip Technology); Dan Siems (Philips Semiconductor); Norbie Lavigne

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Welcome

Welcome to Volume 4, Number 11 of the FabTime Cycle Time Management Newsletter. In this issue, we are pleased to include an announcement about TDK's maintenance contract renewal and upgrade of our FabTime web-based digital dashboard software. Subscriber discussion topics for this month include two responses to last month's article about tool standby and productive time reporting. New topics include incorporating setup in equipment utilization calculations, understanding the cycle time effects of automated material handling and robotic systems, and understanding cycle time and "under-utilization" in fabs. This month also kicks off a new newsletter section: Cycle Time in the News. We welcome your contributions.

This month's main article was inspired by the last discussion topic listed above. Dan Siems sent us his observations about what happens to cycle time in a real fab when start rate goes down. Although cycle time normally decreases when utilization decreases, Dan found that in practice, fabs sometimes see cycle time increase when start rate goes down. He attributed this increase to "a cost-down policy where equipment is turned off or operators are sent home during times of under-utilization." We thought that this made sense, given that the amount of tool redundancy is a known driver of cycle time. We did a series of fab model simulation experiments in which available capacity was adjusted downward as start rate decreased. The results showed that cycle time tended to be higher for smaller fabs (as expected), with non-linear increases where more one-of-a-kind tools are present. We think that this is worth discussing, since it adds an important caveat to the fact that cycle time generally deceases when utilization decreases in a fab.

We wish you a wonderful holiday season, and a happy and prosperous New Year! Thanks for reading!—Jennifer

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Community News/Announcements

TDK HDD Head Wafer Fab Upgrades to Version 5.6 of FabTime Software, Renews Maintenance Contract

Menlo Park, CA. November 24, 2003 – FabTime Inc. today announced that TDK's HDD head wafer fab in Saku, Japan has upgraded to Version 5.6 of FabTime's cycle time management software, and renewed its maintenance contract for the next year. FabTime's software is also installed at TDK's subsidiary, Headway Technologies, in Milpitas, CA.

Version 5.6 is a significant software upgrade for TDK. The new functionality includes the ability to share individual home pages with other users, new A20/ A80 charts for equipment availability analysis, the FabTime bulletin board – users with bulletin board permissions can create messages for the login page, home pages, or specific users' home pages – and support for WIP transaction reversals.

"We are pleased with FabTime's support, and their responsiveness to our requests for the software," said Hideki Mori, Senior Manager of wafer production group, Head Products Division. "We believe that the shared home page tabs in this version will be particularly useful for TDK."

"TDK's suggestions and their attention to detail have helped us to continuously improve the functionality of the software, and to increase its applicability for Japanese customers," said Frank Chance, President of FabTime. "We look forward to supporting TDK during the coming year."

FabTime is a web-based digital dashboard designed for wafer fabs. In real-time, it provides managers and supervisors a comprehensive view of fab performance. More information 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.

Call for Papers – Applied Cost Modeling

Daren Dance submitted the following announcement: "WWK is resuming the publication of the e-zine Applied Cost Modeling and we are looking for new (or slightly used - see note) articles focusing on any area related to cost of manufacturing or business processes. Thus, in addition to cost articles, we are interested in articles related to:

- Productivity
- Quality and reliability
- Overall equipment efficiency
- Maintenance
- Materials usage
- Components
- Cycle time
- AMHS, etc.

Note: Slightly used articles – we also reprint previously published material directly related to manufacturing cost and productivity if we can get reprint permission from the original author and publishers. Most of the time getting reprint permission is not a problem.

Please submit any articles for Applied Cost Modeling directly to daren.dance@wwk.com. Past issues of Applied Cost Modeling are posted on our website at www.wwk.com."

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

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FabTime User Tip of the Month

Operation Queue Time Alert

FabTime version 5.6.1 includes a new alert that we wish to bring to your attention. The operation queue time alert warns you of lots that have exceeded a specified queue time limit.

For example, you can use this alert to watch for lots that are about to exceed time-constrained process limits. Suppose that operation 2250 is a clean, and wafers must start operation 2300 within 12 hours of completion at 2250. FabTime can warn you of any lots that exceed 8 hours of queue time at 2300, giving you time to address the problem before the wafers time out and must be reprocessed at 2250. From the FabTime Alerts page, select "operation 2300" from the "Alert Object" drop-down list, choose "Opn Queue" from the "Alert Variable" drop-down list, set the comparison to ">=" and the alert value to "8". Use the "Sleep After" Alert field to tell FabTime how long to sleep after each triggering of this alert (e.g. 2 or 3 hours).

Each time FabTime receives new data from the MES, it will check the lots in queue at operation 2300. If any of these lots exceeds 8 hours of queue time, the alert will fire and FabTime will send an alert that identifies both the maximum queue time and the individual lots that have exceeded the trigger queue time. The alert will be similar to the following:

"Subject: FabTime Alert: Operation 2300

Operation 2300 Opn Queue = 10.5 hour(s) >= trigger of 8 hour(s). Lots AB272: 10.5 hours, AB331: 9 hours, AB502: 8.5 hours."

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

Tool Standby and Productive Time Reporting (Responses to Issue 4.10)

Jimmy Giles (STMicroelectronics) wrote: "I wholeheartedly agree that accurate tool status logging is critical in correctly focusing improvement programs on tools that contribute the highest lost time per lot; however, I have a natural aversion to adding any non-value-added steps to Operator processing (assuming manual entry of tool status). This is particularly true when it is a "global" addition of a non-value-added step. The best solution is, of course, to have automated systems to track and change tool statuses. If this is not an option, perhaps the best option would be to identify tools with equipment utilization rates above a certain threshold (i.e. >85% EUR), and implement real-time tool status updates on these critical tool-sets (as they are not only the tools that require the highest utilizations, but they are also the tool-sets where improvement programs should be focused). Also, if you must add the manual status updates, every attempt should be made to make this (or other non-value-added step additions) as painless as possible to the Operator. For example, if bar code scan guns/readers are in use at the site, attaching barcodes of commonly used commands/functions onto fab PC monitors so that an Operator can scan the desired command/function with the scan gun and the MES system is updated/changed without manual keystrokes will help minimize non-productive time spent by Operators at the PC."

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Another subscriber wrote: "Thought I would send some thoughts on "standby" logging. As you correctly say, the logging of "no operator" is very difficult as there usually needs to be an operator to log this. However the differentiation between "No Operator" and "No WIP" is, I think, crucial. My fab has been developing an IS fix for this. Most of our tools now use a PC as a station controller for the front end of the tools. All information, batch selection, DLIS etc is controlled from here. The station controller can take a signal from the tool to tell if it is running or is not running, plus it interfaces with the MES to understand if WIP is available. When the MES senses that the tool is idle AND there is WIP available it logs the tool state to "No Operator", as clearly the tool is up and wip is available. I hope this is of some help."

Setup and Equipment Utilization

Roger Winkles of Microchip Technology asked: "In regards to your definition of Utilization, where does setup fit into the equation? This is mostly for the Probe Area, where 80+ setups can occur in a single day. I think this time needs to be accounted for in some manner."

FabTime Response:

You're absolutely right that our definition of utilization doesn't explicitly talk about setup time. According to the SEMI E-10 specification (which we use as a basis for the equipment states in our software and training), setup is counted as part of scheduled downtime. In practice, you might break it out separately from other scheduled downtime, but it would still be separated out prior to our calculation of utilization (Productive / (Productive + Standby)). The reasoning here is that it's how much standby time you have relative to the time that the tool actually spends processing wafers that really drives cycle time. If you can reduce setups, you can increase standby time, even for the same amount of productive time, which is in turn good for cycle time. Therefore, setup reduction will tend to be good for cycle time.

Cycle Time Effects of Automated Material Handling and Robotic Systems

Another subscriber wrote: "I'm interested in knowing if any fabs have analyzed the effects of automated material handling systems and robotic systems on TPT and/or cycle time. I recently heard about a company who learned that several of their automated robotic loaders were actually negatively impacting TPT and they subsequently removed or reconfigured them.

In the drive to become ever more automated, I fear we may often build inefficiencies into our production systems. And in our world, sacrificing TPT for quality is unacceptable; we need both."

Please send responses to Jennifer.Robinson@FabTime.com, and they will be included in the next issue (with or without your name included, as you prefer).

Cycle Time and Under-Utilization in Real Fabs

Dan Siems of Philips Semiconductor wrote: "I've been pondering the Operational Characteristic curve — the u/(1-u) relationship — and what you wrote in the last FabTime Newsletter. You said:

"While this exact approximation for cycle time is only accurate in certain cases (one-of-a-kind tools, medium variability in arrival and process times, independence), the general behavior (cycle time increases as standby time decreases) holds in most circumstances."

I buy into the curve — I know the theory — I even teach it ..... but when I look at the actual performance data I find that there is another POLICY in place that over-rides the PHYSICS. I looked at some actual fab data that showed that when utilization

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drops — most likely because starts have gone down — that CTx does not drop — instead CTx GOES UP. This is a clue that another policy is overriding the physics — such as a cost-down policy where equipment is turned off or operators are sent home during times of under-utilization. Of course this changes the actual utilization numbers, but if you look at the start rate numbers, you see cycle time going up as starts go down. This is shown in the figure below.

Put another way — if you left all the equipment up and on and qualed and in great shape and if you kept a full staff all the time — even in times of under-loading — then your cycle time would go down and follow the general operating curve — until the extreme case when you had very little work and it all ran at close to 1X cycle time. I have only seen one fab do this before cost concerns forced their hand and they started turning equipment off.

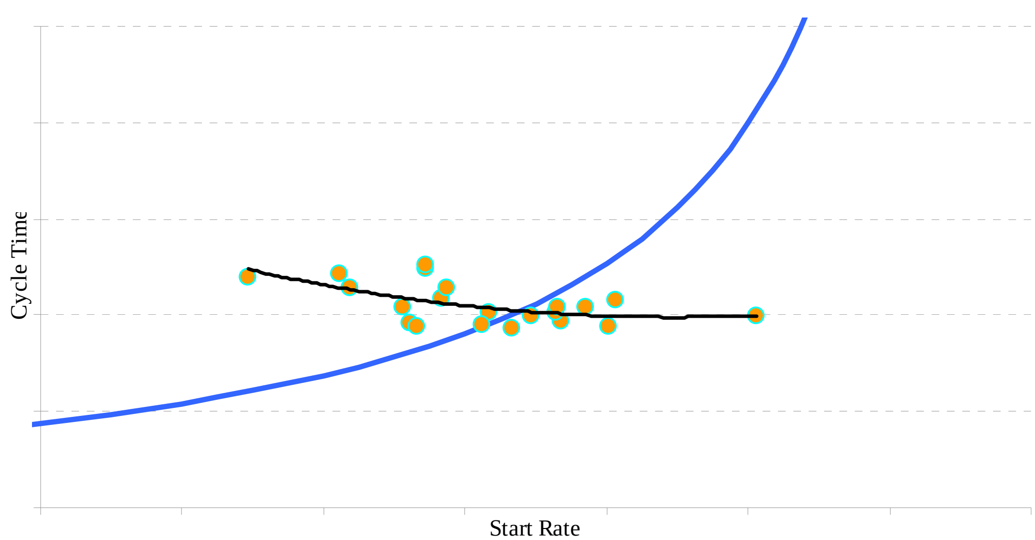
Instead, each fab has its own "asymptote of practicality". This is a curve that's something of a mirror image of the operating curve (it slopes up towards lower utilization values). Once certain low utilization thresholds are crossed, fabs take capacity off line (people, equipment, processes) to save money and CT goes up instead of down. What do you think about this?"

FabTime Response:

We think that it's very interesting. You're saying that (for this fab, at least, where you have data) cycle time doesn't go down as volume goes down, because of operational policies that require turning off equipment, etc. Of course, it's not really that the physics doesn't hold - as you noted, you would need to re-calculate the utilization based on equipment closures, staffing, etc. And when you look at it that way, it's not so surprising that the cycle time goes up at those lower "utilization" points. That's because you're likely bumping into the other thing that really drives cycle time, which is tool redundancy. What fabs seem to be doing, in times of lower demand, is scaling back and acting like smaller factories. And smaller factories have higher cycle times, as a rule. We do like the "asymptote of practicality" idea. It shows clearly that it doesn't really matter that fabs can get great cycle times at 30% utilization, because business demands will rarely really let them run that way.

We think that Dan's point may be relevant to other subscribers, and we have chosen to explore this topic in more detail in this month's main article.

Fab Cycle Time vs. Start Rate - Asymptote of Practicality



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Cycle Time and Factory Size

Introduction

Everyone knows that for a given fab, as start rates increase (as they seem to be doing for many fabs) cycle time is likely to also increase. What's less obvious is the behavior that Dan Siems pointed out in the subscriber discussion item above: sometimes when start rates decrease, cycle time increases.

This wouldn't normally happen if there were no other changes in the fab. Utilization would go down, for tools and operators, and cycle time would almost surely go down. However, that's not a realistic case. What really happens in many fabs is that when start rates go down, tools are turned off and staffing is reduced. The net result from this is that the bottleneck utilization of the fab may stay the same, or even increase. So, no cycle time payoff from the decreased start rate.

What also happens is that the number of tools per tool group decreases, sometimes to the point of having one-of-a-kind tools in operation. This lack of tool redundancy is a key driver of cycle time (currently ranked third on FabTime's cycle time problems survey, after downtime and bottleneck utilization), and is the primary subject of this article.

Tool Redundancy and Cycle Time

If you look at what drives cycle time at the tool level, there are three primary levers: utilization, variability, and level of tool redundancy. (Yes, downtime is a significant cycle time driver, but this happens through downtime's impact on utilization and variability, as discussed back in Issue 4.04.) Utilization and variability are directly (if non-linearly) correlated with cycle time. As they increase, cycle time increases.

Redundancy drives cycle time in the opposite direction. When you have no redundancy (a one-of-a-kind tool, no backup), you can expect high cycle times. As you add redundancy (larger tool groups, more backup), cycle time tends to go down. Usually there is a large drop in cycle time when you go from a one-of-a-kind tool to having two tools per group, with smaller decreases as tool groups get larger. We discussed this in the context of dedication decisions back in Issue 3.3 (How Much Does Tool Dedication Inflate Cycle Time?) and also way back in Issue 1.8 (Understanding the Impact of Single-Path Tools). In this issue, we look at redundancy in the context of factory size.

The reason that lack of redundancy drives up cycle time has to do with variability (this wouldn't be true in a perfect, no variability system, if one existed). The fewer tools you have, the more likely individual lots are to be affected by variability due to downtime, batching, setups, etc. For an intuitive example, consider a one-lane (per direction) road. If you're driving on a one-lane road, even if the overall traffic is light, you can easily be delayed by a single slow truck. On a two-lane (per direction) road, even if the overall number of cars is higher, you're much less likely to be delayed by the slow truck, because you can use the other lane to pass. Hence your cycle time per trip will be lower.

Fab Model Example

We did a series of simulation experiments on a fab model in which we explored this behavior. The model that we used was originally based on an actual fab, but has been extensively modified over the past few years. We use it for illustration, though the exact results from any specific fab will of course vary. We started out with a 6000 wafer start per week fab, with a suggested maximum capacity loading of 85% on each tool group (capacity was planned with a 15% buffer for all tool groups). Operators were also modeled, but had a maximum loading of 65%. There were no one-of-a-

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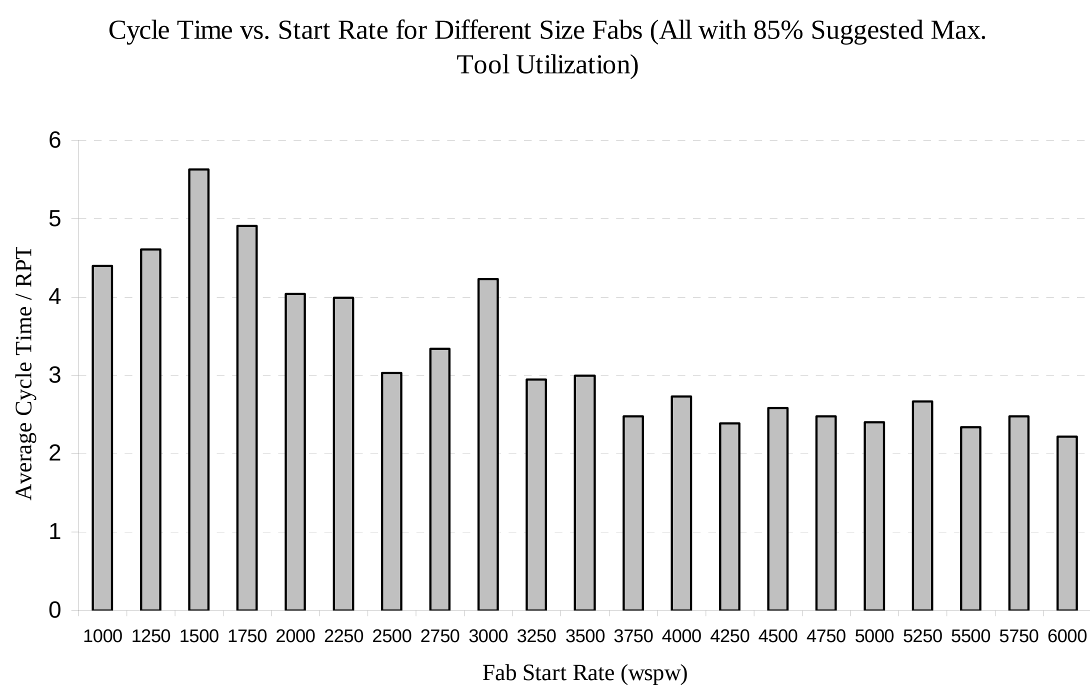
kind tools in this toolset. We simulated this model for two years, and came out with an average cycle time x-factor (cycle time / raw process time) of 2.2.

We then did a series of other runs in which we kept successively ratcheting back the starts by 250 wafers per week, down to a minimum of 1000 wafer starts per week (21 total experiment points). All else being equal, we would have seen cycle time decrease dramatically for the 1000 wafer starts per week (wspw) case. However, we also turned off tools for each run, so that we maintained our suggested capacity loading of 85%. So, for example, if at 6000 wspw we needed 4 implant tools, and had a resulting utilization of just below 85%, the 3000 wspw case would only use 2 implant tools. In this case, the 2 implant tools would still each be loaded to just below 85%. The cycle time through the implant tool group would likely be higher for the 3000 wafer start per week case, because of the decrease in redundancy.

A graph showing the cycle time x-factor for each start rate is shown below. This data shows average cycle time x-factor increasing slightly as factory size decreases, but staying basically around 2.5X until the factory size is reduced below 3500 wspw. Below 3500 wspw, the cycle time tends to increase (to a maximum of 5.6X), but shows significant peaks and valleys at individual start rates. This peak/valley behavior has to do with granularity of the individual tool groups at each start rate. When we plan capacity (number of tools) such that each tool group has a maximum loading of 85%, what we end up with is perhaps one or two tool groups at 85%, and the other tool groups at lower utilizations. For smaller factories, these other tool groups, and even the bottlenecks, sometimes end up at much lower utilizations than 85%.

Individual Tool Group Example

In the above example, we'll look at the Wet Etch tool group in detail. Each Wet Etch tool can process a maximum of 1389 wafers per week (after accounting for downtime). For the 1000 wspw fab, after accounting for number of visits, product mix, and scrap, we find that the Wet Etch toolgroup needs to be able to process 699 wafers per week. This means that we can get by with a single Wet Etch tool, and that



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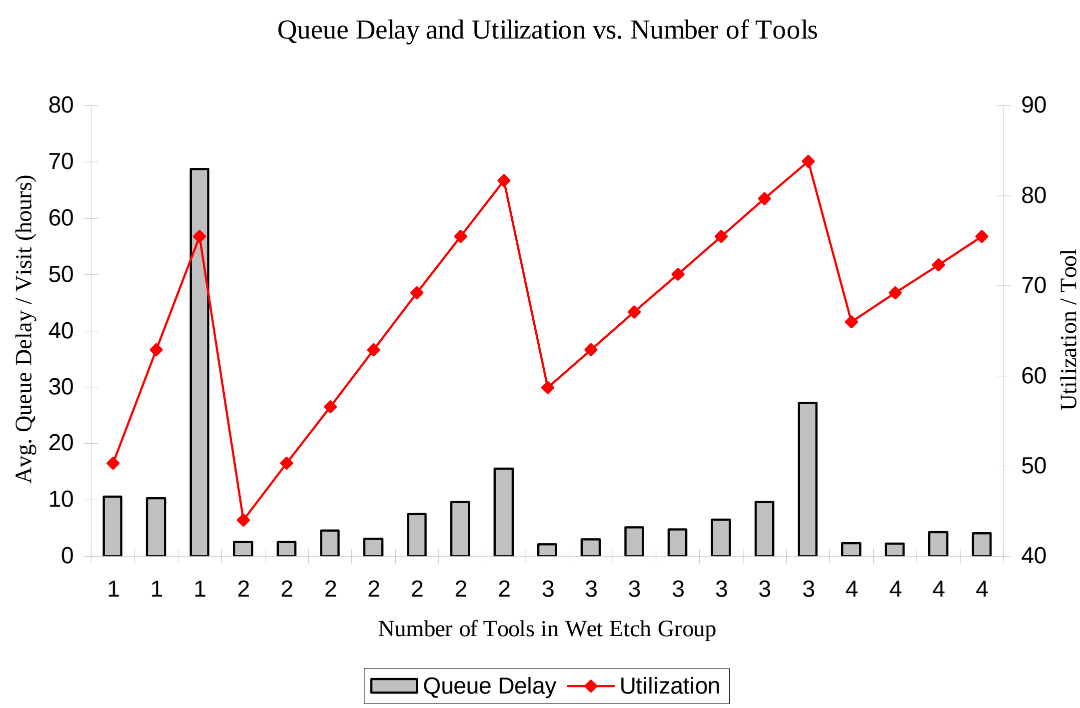
tool will have a utilization of 50.3% (698/1389). As we increase the start rate into the factory, the required process time on the Wet Etch tool group increases, but we can continue to get by with a single tool up to the 1500 wspw factory. For this case, the Wet Etch tool needs to be able to process 1048.2 wafers per week, and ends up loaded to 75.5% of capacity (which is less than the target of 85%). Once starts increase a bit more, to 1750 wspw, we have to turn on a second tool, and the utilization drops back to 44% for each tool in the tool group. Not surprisingly, the cycle time through this tool group increases as the loading increases, and then drops back when the second tool is added. The complete set of data points for the Wet Etch group is shown below.

This data tells us a few things. First, if we look within each set of points with the same number of tools, we can see that yes, cycle time increases with utilization, and this increase is non-linear. The highest utilization points have markedly higher cycle times than the lower utilization points.

Next, if we look within each set of points that have the same utilization, we can see the effect of redundancy on cycle time. For example, there are four points that have utilization of 75.5% (start rates of 1500, 3000, 4500, and 6000). For the 1500 wspw fab, there's only one Wet Etch tool, and the average queue delay per visit through this tool is 68.7 hours (nearly 3 days!). Because there are about 10 visits to this tool, this really drives up the overall cycle time for this fab (overall CT/RPT = 5.6). For the 3000 wspw fab there are two tools, and the average cycle time per visit is only 9.6 hours. With 3 tools (at 4500 wspw), the average cycle time per visit is 6.5 hours, and with 4 tools (6000 wspw), the average cycle time per visit is only 4.1 hours. Remember, these four examples all have the same utilization – the difference in queue delay is largely due to redundancy.

So, what we see is that high utilizations on one-of-a-kind tools result in particularly high cycle times. As we add redundancy, we can operate at higher utilizations without paying as much of a cycle time penalty. This effect does taper off quickly. We see a much bigger benefit in going



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from 1 to 2 tools than in going from 3 to 4, for example. But it's why, as a general rule, smaller fabs will tend towards higher cycle times than larger fabs.

Implications

Many fabs turn off tools (and/or reduce operators) when start rates decrease. And this makes sense for a number of reasons. However, unless you do this very carefully, you will likely see increased cycle times, due to the decreased redundancy in individual tool groups. The penalty will be highest if you go to one-of-a-kind tools, especially if those tools end up heavily loaded.

Summary

We know that when utilization decreases, cycle time usually decreases. Therefore, we tend to expect that when starts go down in a fab, cycle time will also go down. It's like a silver lining. "We're not making as much as we could be, but at least we can get great cycle times." However, in practice this cycle time improvement may not be attainable, if capacity is taken offline during slower periods. When this happens, individual tool groups will be smaller, and will tend to have higher average cycle times (particularly one-of-a-kind tool groups). The good news is that as you ramp starts back up, and increase the number of tools online per tool group, cycle time may actually go down, as long as the resulting utilization of the individual tool groups doesn't grow too high. Once all of your equipment is online, if utilization continues to grow then you will likely see cycle time rising as well.

Closing Questions for FabTime Subscribers

Have you seen this type of behavior in your fab? Did cycle times decrease for a while during the downturn, and then start to go up, as tools and/or operators were taken offline? What do you expect to see as starts ramp back up?

Further Reading

■ J. Robinson and F. Chance, "How Much Does Tool Dedication Inflate Cycle Time?" *FabTime Cycle Time Management Newsletter*, Volume 1, Number 8, 2000. The abstract, and a link to purchase the issue from FabTime's Amazon zShop, is available at www.fabtime.com/news_abs3.shtml.

■ J. Robinson and F. Chance, "Understanding the Impact of Single-Path Tools," *FabTime Cycle Time Management Newsletter*, Volume 1, Number 8, 2000. The abstract, and a link to purchase the issue from FabTime's Amazon zShop, is available at www.fabtime.com/news_abs1.shtml.

Acknowledgements

This newsletter topic was inspired by email discussions with Dan Siems, of Philips Semiconductor (see Dan's comments in the subscriber discussion forum above).

The simulation runs described in this article were made using the Factory Explorer® capacity analysis and simulation tool, distributed by Wright Williams & Kelly (www.wwk.com).

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Cycle Time in the News

This month we are kicking off a new section of the newsletter, in which we highlight news stories related to cycle time management, with emphasis on how cycle time can impact the bottom line.

Norbie Lavigne (former IBM-Burlington plant manager, and current member of FabTime's Advisory Board) brought to our attention the following article, from the October 13th issue of Forbes Magazine.

"Back on the Chain Gang: These guys slashed $3 billion in costs by overhauling the massive supply chains of IBM. Can they do it for you?", Daniel Lyons, Forbes Magazine, 10.13.03. Available at www.forbes.com/free_forbes/2003/1013/114.html. Part of the savings described in the article involve inventory management techniques, which are closely tied to cycle time.

Subscriber List

Total number of subscribers: 1412, from 367 companies and universities. 28 consultants.

Top 10 subscribing companies:

- Intel Corporation (69)
- Motorola Corporation (57)
- Infineon Technologies (44)
- Philips (44)
- STMicroelectronics (44)
- Seagate Technology (42)
- Micron Technology, Inc. (39)
- Texas Instruments (36)
- Advanced Micro Devices (35)
- Agere Systems (32)

Top 3 subscribing universities:

- Arizona State University (12)
- Virginia Tech (7)
- University of California – Berkeley (6)

New companies and universities this month:

- Hindalco Industries Ltd.
- Nano Venture International (NVI)
- Prince Donut
- Storm Manufacturing Consultants
- Tsinghua University
- Unitive, Inc.

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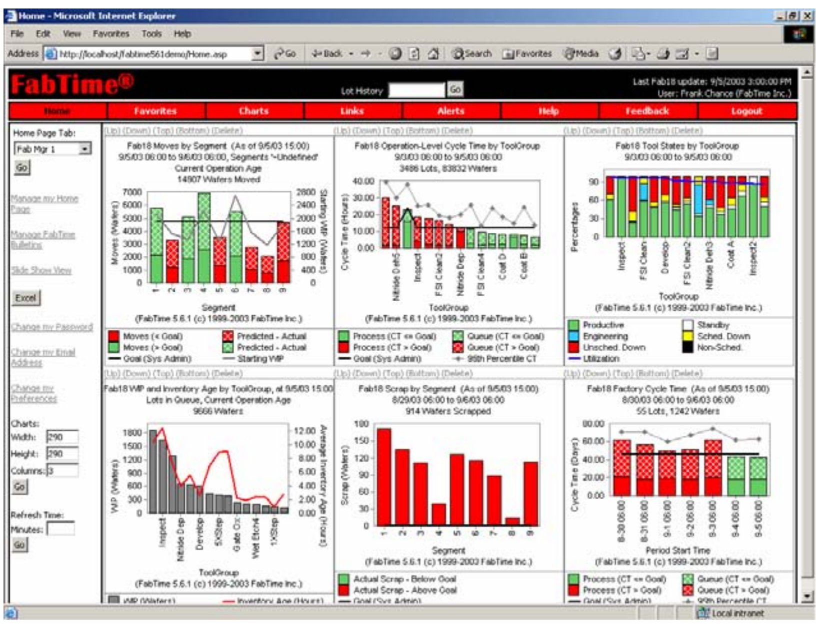
Do you have the best possible information?

- 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?

FabTime is a digital dashboard for your fab. In real-time, it provides a comprehensive view of fab performance data – everything you need for proactive management of cycle time. FabTime is designed for hands-on use by managers and supervisors, unlike traditional reporting tools, which were designed for programmers.

A Web-Based Digital Dashboard

"I use FabTime every day, and so do the supervisors who report to me. The data that I need is right on my home page where I need it when I come in every morning."
Jim Wright
Production Manager
Headway Technologies



FabTime Benefits

- Cut production cycle times by 10%, hot lot cycle times by 20%.
- Focus improvement efforts on the tools that inflate cycle time.
- Improve supervisor productivity – cut reporting time by 50%.

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