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Machining

Ask An Expert: Georgia Tech Professor on the Future of Machining

Julie Sullivan and Don Sears | Feb 22, 2018

Dr. Thomas Kurfess, a machining expert and researcher at Georgia Tech, has developed algorithms that dramatically boost the production of 5-axis machines with automatic toolpath generation. Here, we sit down with Kurfess to discuss the industry's most recent advancements and where machining is headed.

Single-dimension machining was a fairly straightforward process several decades ago, only requiring a decision about the travel, feeds and speeds needed. The capabilities of today's CNC equipment are a bit more advanced. With 5-axis machining, manufacturers can move a cutting tool along five different axes simultaneously––which allows them to create highly intricate parts and designs.

And the innovation is only starting to expand, finds ***Dr. Thomas Kurfess***, a professor and the HUSCO/Ramirez Distinguished Chair in Fluid Power and Motion Control at the Georgia Institute of Technology. His work focuses on the design and development of advanced manufacturing systems targeting complex product production and optimization.

He has researched algorithms for 5-axis machines that allow for automatic toolpath generation––a capability that can dramatically boost productivity by reducing the amount of user interaction and preparation time for toolpaths. Kurfess has also worked on research that spotlights the inadequacies of quantifying tool wear in advanced tool geometries—and he's officially worked for the White House. From 2012 to 2013, he served as the assistant director for advanced manufacturing at the Office of Science and Technology Policy working under President Obama.

We sit down with Kurfess to discuss the current state of multiaxis machining––and where the future is headed.

You've done research around automatic toolpath generation for 5-axis machines. Could you give us your take on the challenges of the past, present and the future?

KURFESS: I grew up in a small machine shop; back in the day it was NC, or numerical control. Fast-forward into the future, and we are now in the era of 5-axis machining. While 2- or 3-axis milling is relatively straightforward, with 5-axis, things are swinging around at different angles and it can sometimes be hard to program. And in all honesty, we haven't necessarily improved our programming capabilities from the 1980s on the machine, and we still have a very complex task requiring a highly trained programmer with a significant amount of experience. This is in stark contrast to 3D printing––which is perceived as simply a matter of downloading a file and printing. My students often asked, “Why don’t we just 3D print the part?” But when you go into a real plant that has millions of dollars of machine tools, you are going to make use of those machine tools because they are there and cannot be easily or cheaply replaced. So industry still has some distance to go. Furthermore, additive manufacturing typically makes plastic parts. You can make structures out of metal, but there are limitations. One of our enabling technologies for advanced machine tool programming is the graphical processing unit, or GPU.

Could you go into a bit more detail about GPUs?

KURFESS: If you buy a computer with a graphics board, it’ll have a GPU. While gaming is the primary market, we use that capability to generate our 5-axis machining trajectories … The GPU is like a little super computer and gives us gaming-like interfaces for programming, taking a significant cognitive load off the human programmer. With supercomputing capabilities of the GPU, we can look at all of the different prospects out there and a wide variety of scenarios even the expert programmer wouldn’t have the time to consider. G-code has gotten us far, but it’s limiting and this technology is going to rapidly move us well beyond anything that we see today.

Where do you see the future of multiaxis machining and machining in general heading?

KURFESS: I predict a few things in particular. First, we will move toward making machine tools easier to program. Second, while many people say we will be fully automated, I don’t necessarily believe that. There’s a great dishwasher analogy someone brought up to me. In my lifetime, I don’t believe you’ll ever see your dishwasher unload automatically because there’s expertise and complexity that goes into loading and unloading. The same thing goes for machines––we need to make the machines easier to use by helping the programmer make choices such as which tool to use, and what orientations to program in full 5-axis continuous modes. Finally, I see a move toward more graphical user interfaces similar to what you would experience on a gaming system. Those interfaces can help make you more productive, and let’s face it, the current workforce, like my kids, are very adept at using those gaming interfaces.

> **"It's about lifelong learning. If you haven't learned anything in 30 years, you'll get cut. Keeping skills up to date is critical to stay relevant."**
> Dr. Thomas Kurfess
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Are there aspects of these machines that are being underutilized today? What is your advice for getting the most out of these machines?

KURFESS: It’s a matter of utilizing higher-end machines to their fullest––and the big issue there is training. We work closely with nearby community colleges and technical colleges, and it’s difficult and expensive for them to provide training at the associate level for these complicated machine tools. Having a $500,000 machine tool in a teaching laboratory is fairly cost prohibitive, but the training is critical, especially with multiaxis machining. It is also difficult for companies to train individuals, as once someone becomes good at it, keeping them around is difficult. Simply put, they’re in high demand.

You have done research to develop algorithms that would benefit automatic toolpath generation. Tell us about that *research* and the challenges you were trying to overcome there. What was the outcome? Where do you see automatic toolpath generation today, and where do you think it is heading?

KURFESS: In regard to toolpath generation, instead of pixels, we work in voxels. It’s a 3D pixel where we take a design and voxelize it. We do digital volumetric processing, which is a natural format for the

GPU. We take out part design that is in a CAD model and voxelize it so we can process it on the GPU. This approach lends itself well to machining parts and to hybrid machines, which combine additive on machine tools (additive and subtractive manufacturing). Companies are beginning to use voxels more and more with higher-end problems. Slowly but surely, voxels are working their way down to a variety of products. At Georgia Tech, our second-year design build course, we had students designing turned parts with voxel-based tools using cloud-based high performance computing platforms and they loved it. The systems that they use are orders of magnitude faster than anything out there; so, they are getting feedback in real time as to whether their part is producible on the lathe with the currently installed tooling package, while they are in the process of drawing the part.

You have also worked on *research* about quantifying tool wear in complex geometries. Tell us about that research and what you discovered.

KURFESS: We are doing quite a bit of work in this area, but let me tell you about our biggest win: We were doing machining of a very advanced nickel-based superalloy that was terrible to machine. It was hard to achieve our target geometry, but we also were concerned about not damaging the grain structure of the part. As you're machining, you can do thermal damage to the surface (cracking, subsurface damage, etc.). That arises from heat-related issues, as heat causes the most damage. In this instance, we were given new ceramic inserts to try and they gave us speeds that were crazy high––so much so that we had to go to our machine tool partner and ask if we could swap our machine tool out. We needed a much higher speed spindle. Because we were using ceramics, we needed to avoid using coolant so as to not induce thermal shock in the inserts and shatter them. Despite the speed, it worked without coolant incredibly well. In fact, we were able to machine so fast that we beat the heat transfer rate––that means that the heat could not get into the part. So after you were done machining you'd feel the part and it was cool. This helped to minimize the subsurface damage. We eliminated thermal damage to the part, ran at significantly higher material removal rates, and did not have chips loaded with coolant, making them much easier to recycle.

What are your thoughts on the manufacturing skills gap? How do you view it and how do you think it can be improved? What measures should manufacturers of all sizes take to help find the talent they will need for the future?

KURFESS: The skills gap is real. Kids nowadays are not into programming G-code like we were 20 or 30 years ago. Of course, our more advanced video game was Pong, and we punched paper tape! Our next-generation workforce is more graphically oriented and possesses a different skill set. So moving toward more graphical interfaces helps to really engage this next generation. Many people feel that to be a machinist or an engineer you have to be a super math genius. The reality is you don't need to be a genius … you have to be good and like it. Additionally, I serve as the president of SME and I see how the next-generation training products for operations such as ***Tooling U-SME*** are really engaging next generation and current generation workforce in terms of technical training and development. The approaches that are being employed are state-of-the-art, engaging and very effective. Furthermore, this training is starting to become targeted and personalized. We are moving into the realm where the machine will know if you are properly trained and will recommend training to you to improve the way you run and utilize the machine. Furthermore, we are not far off from a 3-axis machine recommending that you be trained and promoted to a 5-axis machine based on your performance on the 3-axis machine.

What role do you believe manufacturers need to play in helping to shrink the skills gap?

KURFESS: It's about lifelong learning. You have to have a culture change such that both the workforce and employers understand that continuous and lifelong training are the way to a more profitable operation and a long, secure, and successful career. You have to get everyone in the mode that ongoing training is a good thing. Let's be realistic, if you haven't learned anything in 30 years, you will be a technological dinosaur, and we know what happened to the dinosaurs! Keeping skills up to date is critical to stay relevant.

Your background also shows you spent time working in the automotive sector. Can you tell us about that, the work you did and where you see that industry today––and for the future?

KURFESS: I was at Georgia Tech from 1994 to 2005. In 2005 I started the academic and research program at the Clemson University – International Center for Automotive Research. In general, producing simple parts with 2 and 3-axis machining was relatively straightforward. However, when it came to 5-axis parts, we were really making a difference. Again, the higher end and more complex work was where the highly trained individuals really shined, and where they made great salaries!

Are there any other specific vertical industry innovations that you keep your eye on closely? What manufacturing innovations do you see having the ability to cross over and make an impact today and in the near future? What should manufacturers really be paying attention to?

KURFESS: When I was President Obama's technical point for advanced manufacturing in the Office of Science and Technology Policy, I gained a great perspective on things. Across both parties, manufacturing is critical. I was testifying to a subcommittee a few weeks ago where we highlighted the importance of the internet of things for manufacturers. We are seeing machines extracting a great deal of information about the product and the process. This helps to not only make a much better product and an efficient process, but to improve job opportunities and the competitiveness of our modern workforce. Every representative on that subcommittee understood this and was supportive of advancing this type of technology and capability.

In terms of automation, do you believe that advances in technology could actually help bridge the skills gap with less workers required?

KURFESS: With increased automation, we will need less people at a higher skill set. Once employees are doing high-end axis programming, companies will get it. They'll realize that these machines are better and they'll buy more of them––and ultimately need more people. Granted, we will still need human beings at the center of the work, as people will be doing all the programming. Whether for the workforce in general or for individuals, it's a matter of lifelong learning and understanding these machines will take someone to the next level of capability. So the lower-skill jobs will go away, but we will see a significant expansion in higher-skill jobs that have much higher pay rates!

Finally, let's discuss high-performance machining for a moment. Are there any new, innovative developments in that area?

KURFESS: It's all about the controller. Ease of use, connectivity … getting all the info together––that's the future. It beats the pants off that '80s CNC controller that still looks like my first PC!

Has your shop adopted 5-axis machining? What challenges do you face––and would you be open to programming machines with automatic toolpath generators? Let us know in the comment section below.

