TUTORIAL ON

STANDARDS FOR DIGITAL MANUFACTURING

October 21st, 2015, Pier 5 Hotel, Baltimore, Maryland

Machine tools have been controlled using digital codes since the invention of paper tape. You must have seen examples – if not see Figure 1. They are used for every type of manufacturing. Digital manufacturing is about replacing these codes with 3D models. There are several good reasons. One is that models are easier to share because they are not specific to one system. A second is that cloud services can be developed to optimize models. A third and compelling reason is that laboratory tests have shown models make manufacturing 15% more efficient. Here an analogy with driving a car is helpful.

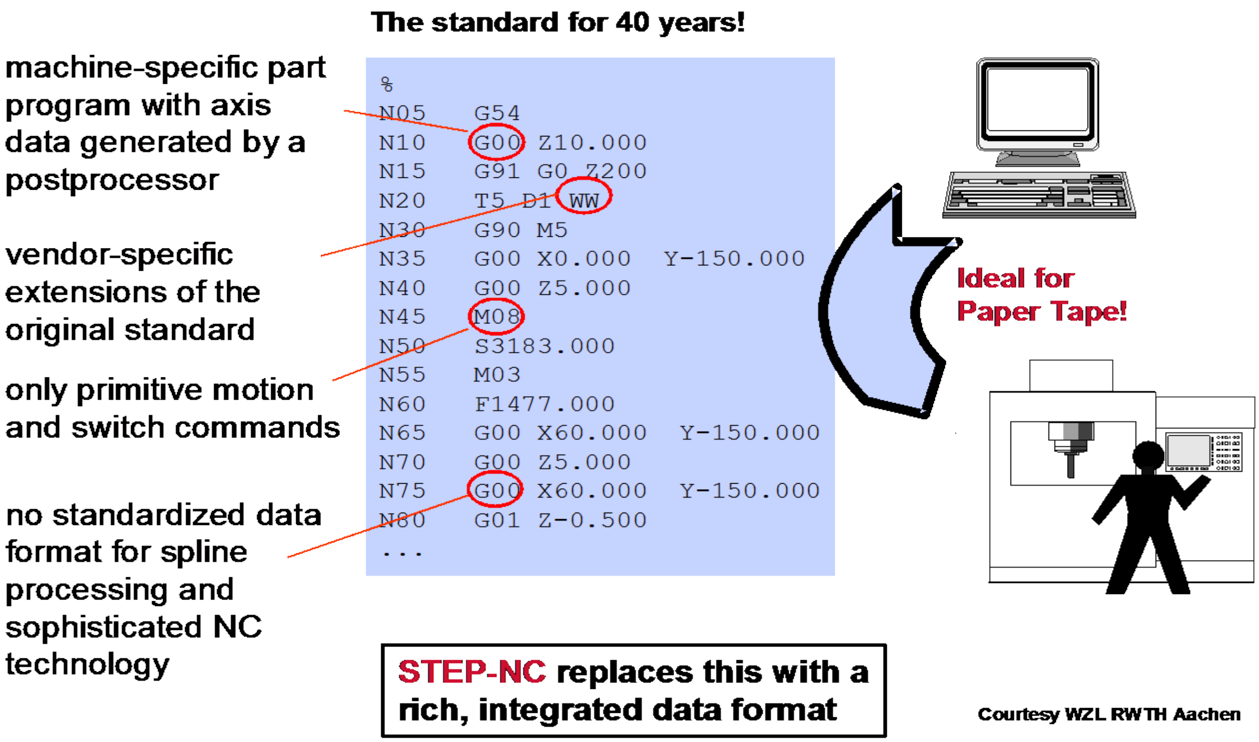

Figure 1 some limitations of machining from codes

Consider a trip from New York to Washington. If the schedule is tight you put the pedal to the metal. If there is time you save gas and reduce wear by driving as gently as possible. Now suppose I ask you to do this with your eyes closed. No worries. We are going to give you very detailed instructions, like the following:

- **Drive for 2 minutes 16 seconds at 69.1 mph**
- **Turn left by 35 degrees and slow down to 55.4 mph**
- **Etc. and enjoy! We never make mistakes!**

Figure 2 contains some humorous examples of what might happen. Like the left cartoon, you are going to miss opportunities. Like the middle cartoon, there are going to be some near misses. Like the right cartoon, all the careful planning is for naught if it does not cover all the contingencies such as a stopped driver. The bottom line is that once you have a plan that works, you are not going risk making changes, which is why machine tools are very rarely adjusted to go faster or slower.

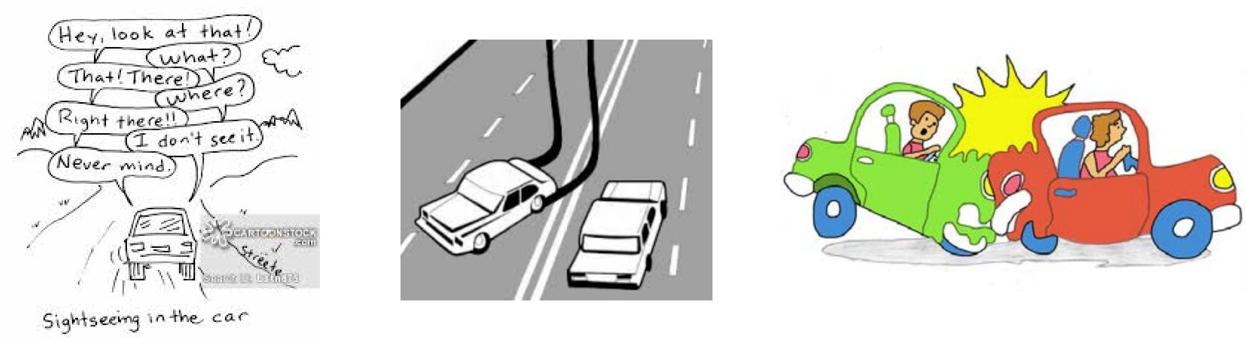

Figure 2 dangers of the road

Models make manufacturing more flexible. If the machining plan is about to start cutting metal then a change in forces can be anticipated. If you are going to cut more deeply then slow down to balance the forces. If you are hogging material, then do not worry so much about the corners. If you are finishing then keep the machining smooth.

Figure 3 shows a machining model example. As shown on the top left, the geometry of the part with its tolerances is very important. Without this you cannot know what you are making. If you do not know what you are making, and what the design requirements are in the form of surface finishes, tolerances and dimensions, then you cannot make any adjustments on the machine.

The top right shows other models. You should have models of the cutters and fixtures so that you can model where they will be located during the machining, and if you are going to be slowing down or speeding up, then you need to know their performance limits, and the current cutter wear.

The bottom left shows how the process can be modeled. A lot has happened in Computer Science since Gcodes were invented. A digital manufacturing standard can organize a process into workplans and workingsteps. The process data can be associated to the workingsteps so that a single instance can be edited instead of the many places in a Gcode file. Also, the workplans can be organized to allow for multiple consecutive steps, multiple alternate steps and multiple concurrent steps.

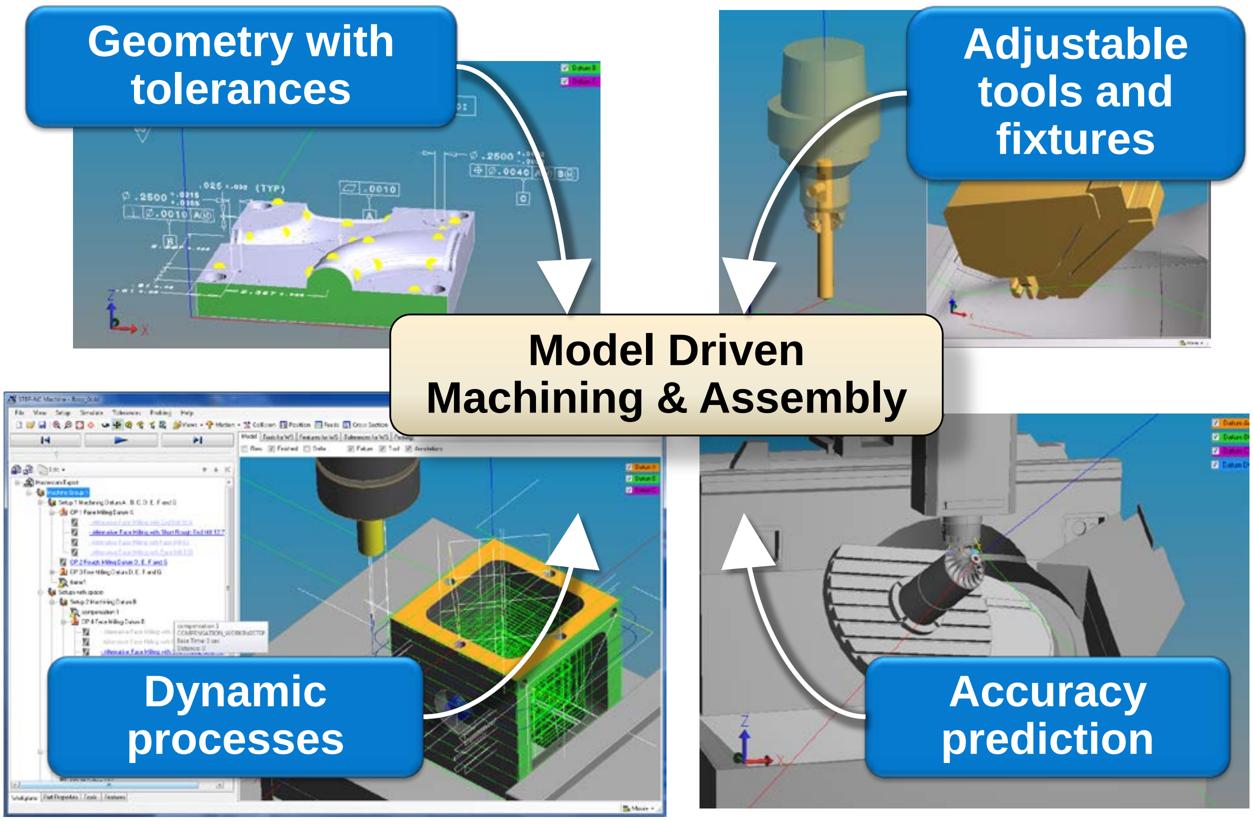

Figure 3 machining from models

Finally, the bottom right of Figure 3 shows why a model of the machine tool should also be included in the digital manufacturing data. With this model the kinematics of its components can be included in the calculations. This further reduces the chances of collisions and if the kinematics contains accuracy data then it further enhances the quality of the result.

With all this data you can simulate the manufacturing process. You have seen such simulations, only from Gcodes. What we are talking about is putting a system like Vericut or one of the many others in charge, running it on the control, and having it generate any internal codes just in time from the models. And just like a driver with his eyes open, the simulator will be able to take advantage of the conditions to run more quickly, save tool wear, avoid collisions and enhance quality.

How do we know all this? Well there has been ten years of testing by an international team. The team has built a new simulator that can be used to run controls from models called STEP-NC Machine®. Using STEP-NC Machine, it has shown that machining can be made more efficient by substituting better tooling. It has shown how CNC machining and CMM measurement can be integrated. And it has tested all kinds of machine configurations on all kinds of parts. See the following URL:

http://www.steptools.com/library/stepnc/demos.html

So what's the problem? Ten years is a long time. There have been several issues. First there was the difficulty of deciding how to add tolerances to geometry data. This took a long time. Agreement had to be reached between the big engineering users and the CAD vendors. Everyone had to be assured that the new models would have all the necessary capabilities, for now, and into the future.

Second there was a processing problem. Until recently the computer in a control was very small. Perhaps, smaller than the one in most smart phones. This is ironic because when Gcodes were first invented the machine tool was the second biggest computer in the enterprise. Fifty years later, and the only reason why a control computer is updated, is because it needs a bigger CPU to meet the minimum requirements of the operating system.

Model based control requires real time simulation which in turn requires a powerful computer. Fortunately all the multi-media support required for modern applications means that even the smallest computers are now getting powerful. Controls are available that include up to four co-processors, and 16 gigabytes of memory, which is sufficient for most real time simulations.

This leaves us with one problem - developing a standard for the digital manufacturing data. The ten years of testing was performed using a very large model, but it was not large enough. It included the best available definitions, for all the different kinds of features and operations, used for milling and turning. But, for each type of property it only picked one definition, and in practice there are many possible definitions with each being optimal for a different situation.

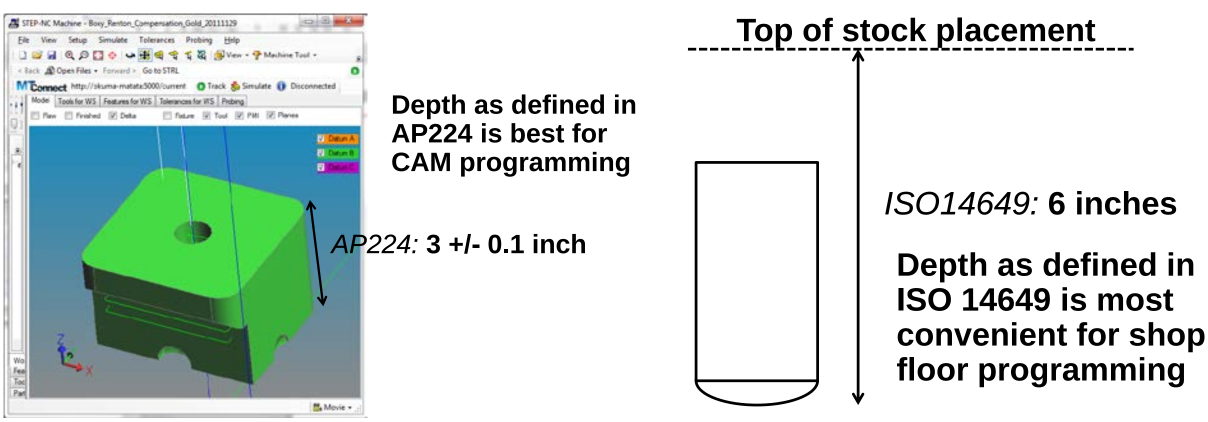

Figure 4 Two standards for feature depth

For example, Figure 4 shows two ways to measure the depth of a feature – one from the top and one from the bottom. From the mathematical perspective measuring from the bottom is best. It is a more stable location if the machining changes. However, if you are a machinist then you probably want to measure from the top because that is where you placed the part.

The Digital Manufacturing Day in Baltimore on October 21st will present a new ISO solution. Instead of including the best definition for each concept, the new solution will allow a definition to be shown in the geometry, associated with a design requirement, and referenced to an external standard. Figure 4 gives an illustration. Each dimension is prefixed with the name of its source definition.

So please come and join us at the Digital Manufacturing day on October 21st. Digital manufacturing can be applied to all the different kinds of control. Anything that uses Gcodes can be replaced by the models that generated those codes. This includes precision machining, composite tape layup, robotics and 3D printing. Figure 5 shows more of the testing and below you will find the URL required for registration.

Figure 5 Digital Manufacturing demonstrations at IMTS 2014

Attendees can register for the workshop at

http://www.eccma.org/2015tc184sc4/index.php