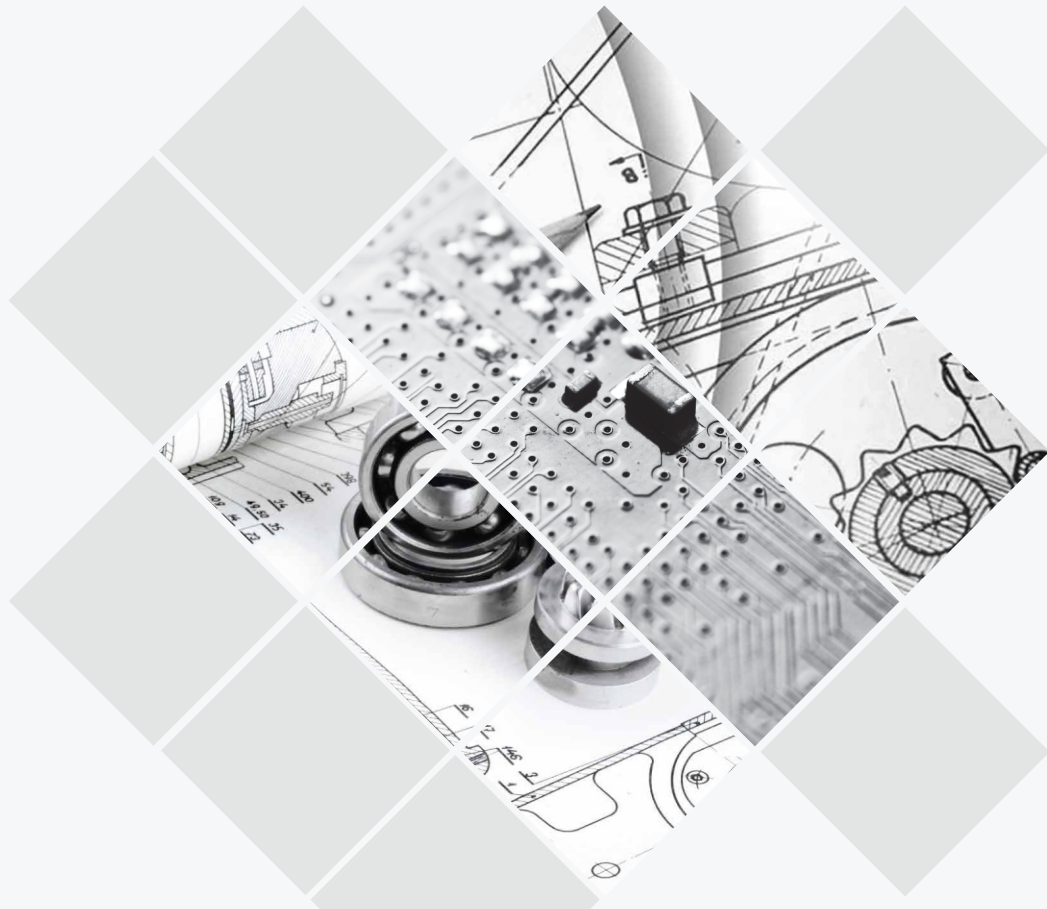


Automation of CNC Program Generation

In a typical product manufacturing industry, there is a long lead time involved starting from the manufacturing plant layout, machine setup, product machining in CNC (Computer Numeric Controlled) machines, inspecting the manufactured parts in CMM (Co-ordinate Measuring Machine), etc.



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1. INTRODUCTION

In a typical product manufacturing industry, there is a long lead time involved starting from the manufacturing plant layout, machine setup, product machining in CNC (Computer Numeric Controlled) machines, inspecting the manufactured parts in CMM (Co-ordinate Measuring Machine), etc. There are many factors which contribute to this. Some of them are:

- Product family change in the shop floor resulting in the complete revamp of the layout
- Need for advanced CNC machines to meet the demanding needs of the market with tight manufacturing tolerances & higher precision
- Custom post processors to match the controller of the CNC machines
- Compliance to safety regulations
- Due to the need for faster introduction of a manufactured product to the market, there has been a continuous thrust to significantly reduce lead time by making underneath process efficient & effective and developing smarter systems & tools. One such area where lots of progress has been made & impacted is the automation of the CNC program generation in the CAM (Computer Aided Manufacturing) system. This technical paper particularly talks about the need for this process automation where huge amount of time is spent in:
 - o Setting up the environment
 - o Defining the kinematics
 - o Defining the tool parameters & operations
 - o Custom building the post processor
 - o Generating the CNC program that matches the controller of the machine on the shop floor

CNC program generation is a combination of 2

major elements.

- 1) CNC tool path generation in a CAM system
- 2) Post processor which is custom built depending on the CNC machine's kinematics & controller type

The tool path generation is both component specific & operation specific which is essential to manufacture any component that undergoes CNC machining.

The traditional process is as follows:

- 1) Build the geometry of the final machined part & the Blank /Raw material or the In-process work part (IPW) in any CAD software
- 2) Bring the CAD geometry inside the CAM environment using Unigraphics NX, CATIA, TurboSoft, etc.
- 3) Create the tool for each operation
- 4) Define the operations
- 5) Define the cutting & non-cutting moves
- 6) Generate the tool path
- 7) Verify it using Unigraphics NX simulation

In case of a configuration change to the component, steps 3 to 6 have to be started from the scratch, which is a time consuming activity. Based on the complexity of the component & the number of operations, this will multiply.

2. PROBLEM STATEMENT

In the present manufacturing industry, Lead time is a major challenge for most of the OEMs and most of it comes from design to manufacturing of a product. Nevertheless to say, heavy infrastructure investment is also needed based on the product line. The conventional machines are already replaced by CNC machines in many OEMs to meet the expected market demand. However, there is still scope for further

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improvement in terms of Design & Manufacturing integrations, automated CNC tool path generation, automated post processor customization, automated NC code generation, etc which will cut down the product launch time tremendously.

3. PROPOSED SOLUTION

Defining the CNC machining tool path is a time consuming process which needs a good amount of manufacturing domain expertise. Though this process cannot be fully automated, due to the machining operations being a function of the component to be manufactured, however the automation is feasible to manufacture a family of parts like a family of turbine blades, rotors, etc.

By automating the process embedded with design rules, the cycle time will be reduced by more than 70%.

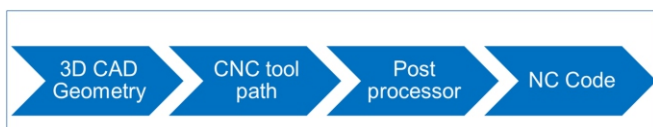


Figure 1 Process flow from CAD geometry to NC code generation

The **Post processor development** cycle time can be considerably brought down by the use of modular libraries of functions which are controller generic or could be for a family of controllers.

4. CNC TOOL PATH AUTOMATION IN UNIGRAPHICS NX:

The tool path generation process in Unigraphics NX is a time consuming process which is dependent on the complexity of the component & the number of Roughing & Finishing operations involved. There are a few techniques that can be used to automate this process.

4.1. Automated tool path generation using FBM (Feature Based Machining)

Features in Unigraphics NX are considered as building blocks of geometry. Teaching Unigraphics NX to recognize non-standard features & reusing it to identify the feature will create identical operations & tool paths for a repetitive family of parts. This will significantly bring down the cycle time as well as facilitate in standardizing the process. The manufacturing rules like tool selection can be embedded to the geometry using Machine Knowledge Editor, which is the rule engine.

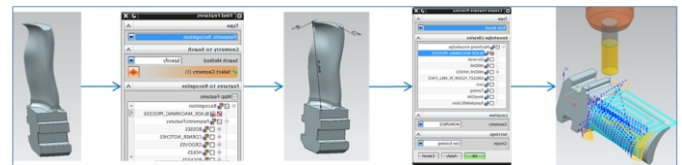


Figure 2 Feature Based Machining process

4.2. Automated tool path generation using CAM templates

Developing pre-built templates for a combination of operations & reusing them to different geometrical shapes will also bring down the cycle time. CAM templates are powerful as they are not geometry centric and are operation specific. So, a cavity milling operation done on a compressor wheel's DoveTail slot can be reused on a seal slot of a packing casing.

Referring to Figure 3, 1 CAM template can handle the varying topology of a dovetail slot, if it can be manufactured by the same CNC operation like Planar milling or Cavity milling.

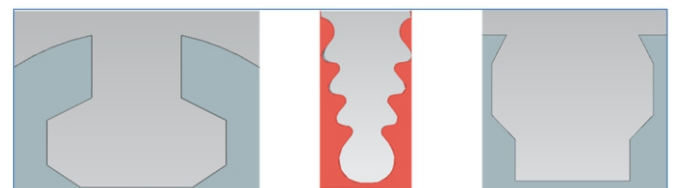
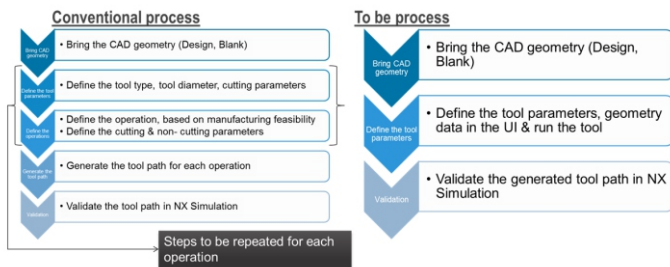


Figure 3 DoveTail slot configurations on a Compressor wheel

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4.3. Automated tool path generation using Unigraphics NX open API (Application Program Interface)

With limited user inputs, CNC tool path can be generated by the click of a button with the help of UNIGRAPHICS NX open programming to auto define the tool path on any geometry. The user has to make sure that the CNC operation suits the geometry. The standard Unigraphics NX dialogues can be customized to display only the entries which the user wants to modify on a case by case basis. Figure 4 illustrates a typical process flow to run an utility developed which can identify the geometry & create the tool path based on the critical user inputs.

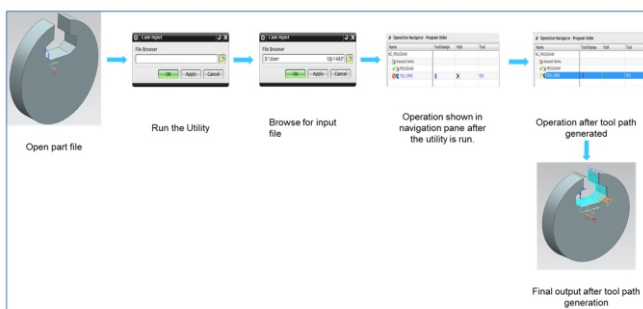


Figure 4 Process flow to generate the CNC tool Path at Run Time

4.4. Automated tool path generation using Manufacturing User Defined Features (MUDF)

UNIGRAPHICS NX has a cool feature called User Defined Feature which can be customized based on the specific needs. User Defined Feature can be a combination of features which appear as a collector with intelligent decision making algorithms & embedded design rules. With the added tool path to the feature definition,

Manufacturing UDFs become more powerful for automating the tool path for a family of parts that follow a similar tool path strategy. This technique is more useful when the features or parts are more repetitive in nature with minor design variants. This especially benefits in developing the CNC tool path for parts which can be classified into families.

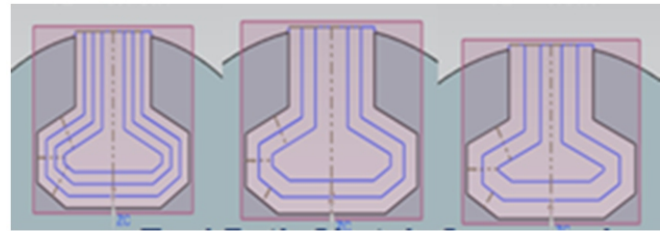


Figure 5 User defined feature of the dove tail slot & the tool path

5. POST PROCESSOR DEVELOPMENT AUTOMATION

The CNC tool path generated out from a CAM software cannot be fed to a CNC machine as the machine understands only G & M codes and not the graphical tool path. The post processor is a sandwich layer between the CAM toolpath & the CNC machine. It generates the NC codes from the CAM tool path which are more dependent on CNC controller & machine Kinematics. This makes the post processor always custom built, based on the above said parameters. However, to speed up the development time for configuring a post processor, building modular, reusable & scalable libraries can be configured. Using this concept, the Wheel need not be reinvented every time Building a library of post processor functions and plugging them to the post will tremendously cut down the development time. Even though, this is a challenging piece of work, it will be powerful when the libraries are more modular in nature. At QuEST, we developed some frameworks which help in speeding up the development time for building a custom post processor.

Some of the widely used CNC controllers in the manufacturing industry are listed below:

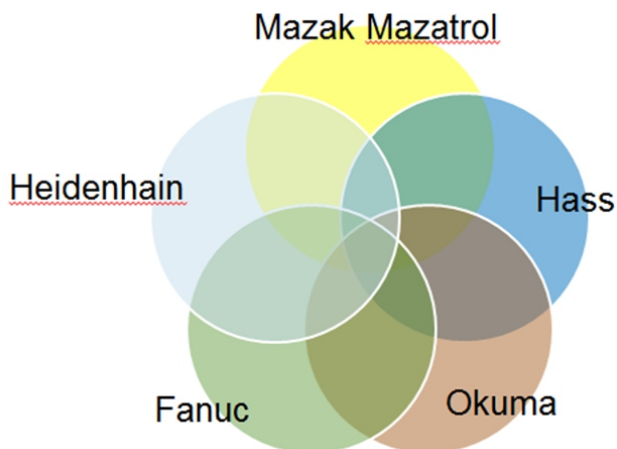


Figure 6 CNC Controllers widely used in the Industry

Creating Libraries of modular functions based on the machine kinematics & family of controllers will lead to significant cycle time reduction in developing the post processors.

6. CONCLUSION

With the emerging trends of Digital manufacturing and Factory automation, it is essential to automate the CNC, CMM tool path generation time. Along with the power of cycle time reduction in developing custom Post processors, it helps in product optimization with proven manufacturing techniques, minimizing the producibility issues.

Following are the steps to automate the cycle of CNC code generation from the CAM system.

- 1) Categorize the parts based on the topology & manufacturing operations as Part families
- 2) Automate the fixture design process to hold the component using CAD automation techniques like building Master modelling templates
- 3) Embed the PMI entities (Product Manufacturing Information, in case of UNIGRAPHICS NX CAD data) as a downstream to the Part family parts
- 4) Use the best suited CNC tool path automation technique namely FBM, CAM

templates, MUDF, etc. Sometimes, it might need a hybrid approach by mixing & matching 2 or more of these techniques for various features of the component

- 5) Automate the CAM simulation process to ensure that the tool path doesn't have Gouges & Excess
- 6) Develop modular Post processor libraries based on CNC controller families. This will be plugged in to develop the custom post based on the machine Kinematics & Controllers
- 7) Generate the NC code using the tool path & the custom post processor
- 8) Validate the NC code using Vericut simulation to ensure there is no collision of the tool with the machine & the fixtures.

7. AUTHOR'S PROFILE



Vijay is the Service Line leader of the Knowledge Based Engineering sub-service at QuEST. He is an expert in Master modelling developments, Model Based Definition, Physics Based Analysis automation, Manufacturing process automation & System integration activities. He has a professional experience of 15 years with a sound domain knowledge of turbo machines & aircraft engines.

Vijay holds a Bachelor's degree in Mechanical Engineering from the Institution of Engineers, India & also a Diploma in Advanced Mechanical CADD. He is involved in exploring technology advancements in the CAD, CAM & CAE domains & implementing them to provide faster solutions to customer needs.



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