Optimized Machining of A PRU Base Plate by Developing A Virtual Machine Tool Kit

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Abstract This paper presents about the optimized machining of a PRU (Pyro - Relay - Unit) base plate component by developing virtual machine tool kit for a DMG 5 AXIS CNC milling machine. PRU base plate is a missile component that is used for target identification using image processing technology. This work includes the development of a virtual machine tool kit and PRU base plate component for which tool path is generated using Uni-Graphics NX-8 CAD/CAM software. It involves a detail study on various objectives like the optimization of machine tool elements and interaction between the machine tool, controller, and cutting process disturbances, control of the feed drives, cutting conditions and machine tool structure is presented by taking PRU Base plate as a case study. In this paper, influence of above mentioned parameters on the production time and cost of the machining have been evaluated with practical data.

Keywords virtual machining, virtual prototyping, virtual manufacturing, virtual simulation

I. INTRODUCTION

In the context of modern, fast and global manufacturing world, the technology and automation is considered to be a big boon for the fast, rapid and cost effective product development. The goal of present manufacturing technology is to produce even the first part correctly in a shortest time and most cost effective way as the product complexities are increasing day by day and the competitive product life cycle times are reduced, the realization and testing of physical prototypes became major aspects for the successful and economically advantageous production of modern machine tools. The trends which accounts for such technological developments include CAD, CAM, CAE (Design Optimization), Digital manufacturing and PLM (Product Lifecycle Management). Presently, the machine tool builders can no longer afford the time- and cost-intensive manufacturing and testing of physical prototypes to detect weak spots and optimize the design. Instead, the design processes of modern machine tools employ “virtual prototyping” technology to reduce the cost and time of hardware testing and iterative improvements of the physical machines.

Virtual machine tool kit

Siemens virtual machine tool kit is just like replica of the real machine tool that is available at any time for programmer training, pre-machining setup preparation and also provides pre-monitoring facility to the operator. It enables the user to visualize the machining processes and tool paths and simulates the machine movements based on the generated CNC code.

Problem statement

Generally many of the manufacturing industries follow traditional manufacturing process i.e. complex parts and high end application components are manufactured with the help of physical prototypes in order to achieve precision and accuracy which leads to time and money wastage. In this types of process, first a physical prototype is constructed and then tested in order to evaluate the performance of the machine tool. Without any way to evaluate its performance in advance, the initial prototype was highly unlikely to meet the desired expectations. Keeping this

in view, higher number of products are manufactured by developing virtual machine tool kit in which engineering simulation software is used to predict the performance prior to constructing physical prototypes.

In any cam software only tool will be displayed some times tool holders, but it cannot display complete machine. For instance the tool path executed by NC program sometimes cannot machine the component as per customers requirement because it is for generic machine and not for its corresponding machine, so this program may cause collisions between various parts of the machine tool while operation is going on which can only be detected during real time manufacturing. Due to this, company has to bear enormous loss in replacing all the damaged material for further processing. With the help of virtual machine tool kit, this issue can be eliminated by detecting the errors in the initial stages before it is sent to the shop floor so that the component is produced within stipulated time.

Overall view of the project

The process involved in this project is comprised of various steps i.e. a) development of a virtual machine tool kit for a DMG (Deckel- Maho - Gildemeister) 5 axis CNC milling Machine b)generation of a PRU base plate component and c) virtual simulation of the machining process to evaluate production and cost . Each and every step involved in this project have been discussed in detail for reader's understanding as shown below

A) Developing a Virtual Machine Tool Kit for a DMG 5axis CNC milling machine
DMG which is leading manufacturer of its lathe and milling machines has 5 axis in which 3 are linear axis namely x-guide, y-Guide and z-work table and 2 are rotary axis namely b-spindle and c-table.

Steps involved in developing a virtual machine tool kit are
1)3D model and assembly of the machine tool
Virtual machine tool kit for the above machine is developed with the help of UG-NX 8.0 which is a software suit of Siemens PLM software solutions. First the parts of the machine tool are modeled using NX 8.0 CAD module and are assembled according to real machine configuration as shown below

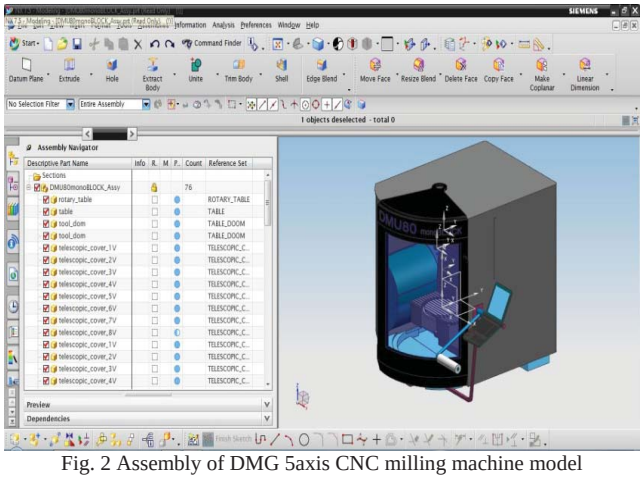


Fig. 2 Assembly of DMG 5axis CNC milling machine model

2**)** *Establishing ISV (integrated simulation and verification) scenario setup for the virtual machine tool kit*

ISV allows the programmer to verify the tool paths and machine motion with the help of digital simulation during the programming session. It helps to detect the errors in tool path generated at the initial stages of machining before the component is sent to shop floor for real time manufacturing.

Pre-requisites required to build the scenario are

a) Kinematic model of the machine tool

Providing kinematics to the machine tool is one of the most important pre-requisite on which the whole virtual machine simulation relies upon. Kinematics are provided by defining those parts of the machine tool that are going to take part in machining and also coordinate system and axis limits are also specified so that, the kinematic component moves with respect to that coordinate system and within those limits. In this project kinematics is given to all the axis of the machine tool i.e. x-guide, y-guide, z-work table, b- spindle, and c- rotary table.

b) Building a directory for the machine tool.

Generally every machine tool is stored at separate locations in NX software so that it will be easy to retrieve whenever required. All the information related to the machine tool like type of controller, post-processed files and its graphics data is stored in a directory under the name of the machine tool

c) Adding machine to machine database

NX has a central database file which contains data about different types of installed machines but it does not contain data about DMG milling machine. As a result machine cannot be retrieved from the library. In order to have multiple setup scenarios including work part and tooling it is to add the machine to the current machine database

B) Generation of PRU (Pyro-Relay-Unit) base plate

Till now the requirements for developing the virtual kit have been described briefly and now the PRU base plate is generated which is to be manufactured by the virtual tool kit. First a 3D model of the PRU base plate component is generated using CAD module of UG-NX 8.0 software. In order to simulate virtual machine, the component must have a tool path generated which is obtained by performing various operations on the component from the NX CAM module. NX has got many CAM session configurations along with different CAM setups. The operations that are performed on PRU base plate are face milling area, planar milling, spot drilling and drilling. By specifying proper tool parameters and operation settings to the above manufacturing processes, the final component generated is as follows

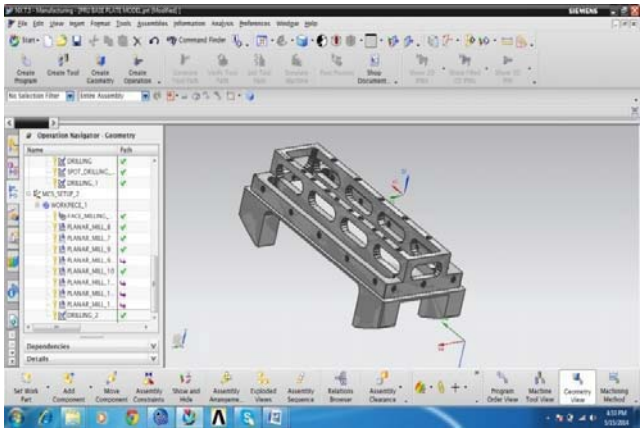


Fig 3. CAM model of PRU base plate

C) Virtual machine simulation: In order to simulate virtual machine, first it has to be retrieved from the machine tool library and the tool paths generated after creating the operations are inspected visually in order to check how the simulation is taking place. For acquiring virtual simulation the DMG machine tool is retrieved from the machine tool library which contains list of machines and the tool paths generated after creating the operations are inspected visually in order to check how the simulation is taking place. NX CAM has the ability to detect any collision violation between different components of the machine tool that were found during simulation and verification of the component.

When PRU base plate is manufactured on CNC machine without virtual simulation the component is directly machined on the CNC machine with trial and error method by stopping the machine at each and every stage of the operation. The production time and cost obtained for manufacturing one component at speed and feed of 1200 rpm and 250 rpm is obtained as follows

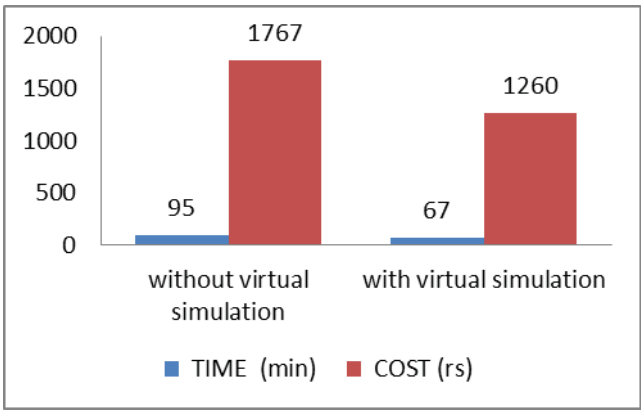
Table 1 Manufacturing time and cost obtained without virtual simulation (VMS)

Set Up Milling &Drilling Operations	Time Required In Mins.	MACHINING COST PER HOUR	MACHINING COST/Piece
Milling	75	RS.1200/HR	₹ 1500
Drilling	20	RS.800/HR	₹ 267
TOTAL	95		₹ 1767

But when the component is manufactured with the aid of virtual simulation there is no time waste for trial and error operations on machine and time consumption was very less because every operation is virtually verified and modifications if required are done in the software itself. The production time and cost obtained for manufacturing one component at speed and feed of 2300 rpm and 300 rpm is obtained as follows

Table 1 Manufacturing time and cost obtained with virtual simulation (VMS)

Set Up Milling&drilling operations	Time required in mins	Machining Cost	Machining Cost/Piece
Milling	55	RS.1200/HR	₹ 1100
Drilling	12	RS.800/HR	₹ 160
TOTAL	67		₹ 1260



Graph 1. Cost and time mitigation with and without virtual simulation

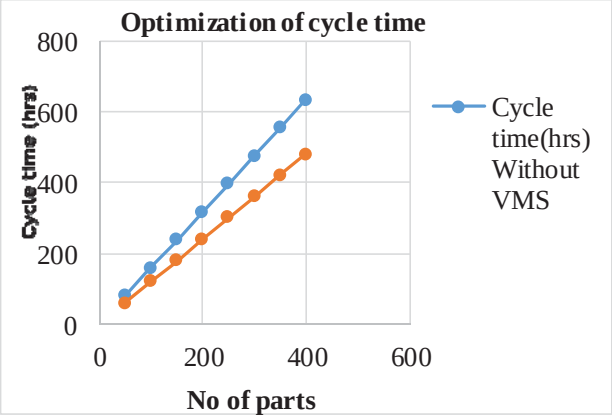
Optimization of cycle time

Generally in traditional manufacturing processes, shop floor testing, code editing and setup checking is often done in a hurry since activities are related to the machine. Whereas in virtual machine, simulating with respect to machine specific g-code, post-processed NC code, cycle times, including tool change can be calculated more accurately. New

operations can be validated and optimized without the risk or wasting time on the real machine. It provides more time to make sure that the program and setup are optimized for maximum performance and productivity.

Table 3. Cycle time obtained with and without VMS

No. of parts	Cycle time(hour) without VMS	Cycle time(hour) with VMS
50	79	60
100	158	120
150	237	180
200	316	240
250	395	300
300	475	360
350	554	420
400	633	480



Graph 2 Optimization of cycle time with and without VMS

Elimination of non-productive time

Generally in most CNC machines the first component is run in block mode i.e. the part is verified and inspected at each and every stage which decreases machine utilization and thereby increasing non-productive time. The below table and graph represents the total time taken to manufacture PRU base plate component with and without virtual machine system.

Table 4. Machine utilization time obtained with and without virtual simulation

Single Part Manufacturing Time	Machine utilization time without virtual simulation	Machine utilization time with virtual simulation
Total time	95	67
Machine cutting time	68	63
Machine idle time	27	4

II. CONCLUSION

From the above results obtained in manufacturing of a PRU base plate it is observed that use of virtual machine tool kit reduced the production cost and time up to 29.4% and also optimized cycle time up to 24.21 %.

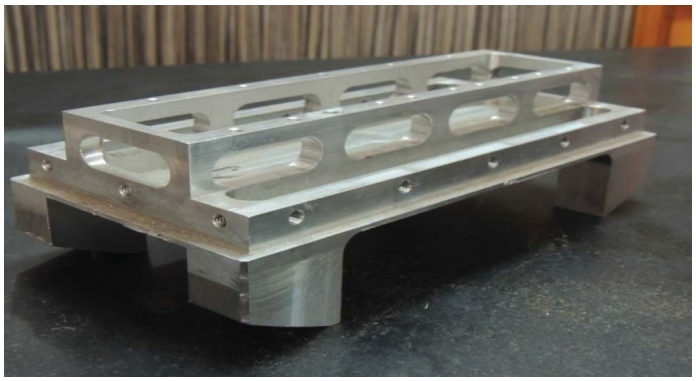


Fig 4 Final manufactured product of pyro relay base plate unit

Using virtual simulation in manufacturing field will automatically increase machine utilization as there is no need to stop machine for any modification of NC program or to check operation status because everything is verified in the virtual simulation itself.

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