

To Design and Manufacture Complex Shapes through CAD/CAM Integration on CNC Lathe Machine

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Abstract—The advancement of modern technology has brought enormous changes in manufacturing technology. Development of whole new generation of manufacturing equipment, such as automatic guided vehicles, computer numerical control machines has escalated degree of quality and can produce parts which maximize accuracy. NX is one of the leading integrated solutions for CAD/CAM/CAE software developed by Siemens PLM Software. It provides various CAD solutions for the design of complex mechanical products in reduced period of time. NX for manufacturing provides a complete solution set for part manufacturing - from CAM to CNC controller. This work aims to focus on the linkage of CAD-CAM system in order to manufacture complete set of chess. Complex shapes are designed in the CAD software (NX9.0) and subsequently, part programs for respective shapes are generated by estimating necessary parameters like depth of cut, tool parameters, feed, and speed etc. to the software. The part programs thus produced are the simulated in the NX software and then in the MAXTURN+ lathe machine. Altogether five shapes are designed and manufactured on CNC lathe machine. This work is a step towards bridging the gap between design and manufacturing, one of the ultimate goals for concurrent engineering and computer integrated manufacturing.

1. INTRODUCTION

CNC lathe machining is a specific form of computer numerical controlled (CNC) machining. The various machine processes which can be carried out are facing, turning, drilling, boring, threading etc. In conventional lathe, all the operations are manual. Changing tool, moving the tool post, adjusting feed, depth of cut etc. was controlled manually. In CNC lathe, all these operations can be programmed and saved it in the machine. One can machine as many parts as you want. An operator has to load the work piece and start machining process. The machining work is performed based on your program automatically. Advanced machines require CAM programming for optimal performance due to the incredibly complex geometries involved in the machining process.

Computer-aided design (CAD) is regarded as the application of computer and graphics software to aid or enhance the product design from conceptualization to documentation.

Computer-aided manufacturing (CAM) is defined as the effective use of computer technology in manufacturing planning and control. CAM is most closely associated with functions in manufacturing engineering such as process and production planning, machining, scheduling, management, quality control, and numerical part programming [1]. The basic features of CAD/CAM system can be summarized as: geometric modelling/CAD Interface, tool motion definition, data processing, and post processing and data transmission. The bridge between design and manufacture is regarded as process planning. The size, shape, tolerances and finishes of the part all affect process plans. The process planning task involves many activities, like selection of machining operations, cutting tools, and cutting parameters, ordering of operations, and calculation of setup and fixtures. All the activities are closely related and dependent on each other.

This paper explains the designing of the all the chess shapes on the NX software possible to develop on 2-axis CNC lathe machine. Further, the part programming of all shapes are generated on the same software by providing estimates of the required parameters prior to machining process. The machining parameters involve type of tool being used, coordinate system in which tool is working, depth of cut, spindle speed, etc. Once part programs are obtained, machining is carried out MAXTURN+ lathe machine one by one. The material used is aluminium. The paper is organized as follows: Section 2 presents the brief literature review. Section 3 and 4 gives description of the CNC machine and NX 9.0 software. Section 5 underlines the designing and manufacturing methodology. Finally, Section 6 presents the conclusion.

2. LITERATURE REVIEW

With the recent trends in industries, manufacturers are forced to implement more competitive manufacturing strategies. These may involve higher production rate, maximizing the profits as well as customer satisfaction. CNC machines provide incredible surface finish and better tool life in a

reduced time period. These machines such as 3-axis and 5 axis lathe machines are capable to give shapes to turbines with geometrical complexities [11]. CNC machines can machine different metals as well as ceramics, obtaining smooth surface machines [4]. The ceramics such as Corain which are used to replicate the lighter materials and enhance other properties can be easily machined on CNC machines [6].

Now-a-days, user of CAD/CAM develop NC programs to cut the object in required on the CNC machines. One such example is an integrated CAD/CAM system which is designed for milling operations to help designers to solve machining problems at the design stage [7]. Another engineer M.S.D. de Bartoli studied the influence of CAE/CAM/CAD system during compressor design. The CAD/CAM also play an important role in designing developing and manufacturing of new products especially for agile Manufacturing environment[9]. Intervention of the operator is completely or partially removed in the research. The selection of machining parameters is also an important aspect for manufacturing purposes. This is regarded as process planning. Process Planning is the process of determining detailed operation instructions to transform the engineering design to a final part [5]. Integration of CAD/CAM software substantially increase production and reduce lead time [2].

G-codes and Step NC are two ways by which codes are generated. A program from C++ language can also be used to generate NC codes from the extracted data of the part model[10].

3. MACHINE DESCRIPTION

The machine used for machining purpose on lathe is MAXTURN + manufactured by MTAB, India. The MAXTURN+ is a numerically controlled machine tool used for machining parts in every industrial field, featuring high speed, high accuracy and high productivity. It performs turning, boring, reaming, roughing and chamfering operations using CNC programming and Siemens Controller Operation. The machine gives operator freedom to give various shapes to the blank by generating G-M code programs in the machine. It allows simulating the programs written before machining to state conformity with the design. Machining of a work piece by NC program requires a coordinate system to be applied to the machine tool. Each plane is assigned a letter and is referred to as an axis i.e. X-axis and Z-axis. The Z-axis is always parallel to the main spindle of the machine. The x-axis is parallel to the work holding surface.

4. SOFTWARE DESCRIPTION

The software used for CAD and CAM purposes in this work is NX 9.0 software. NX is one of the world's most advanced and tightly integrated CAD/CAM/CAE product development solutions. The designing (CAD) and manufacturing (CAM) process using this software can be divided into 5 segments:

Sketching

To create a new model, we need to choose the plane and create a sketch and then extrude, revolve or sweep the sketch as required to create solids. Many complex shapes that are otherwise very difficult to model using *primitives* or other *form features* can easily be drawn by sketching. To generate the part program we first need to develop a virtual machining environment [3].

Setting Machining Environment

As soon as the **Manufacturing** environment is opened, we will notice many changes in the main screen such as new icons that are displayed, shown in Fig. 1.

The first step in order to generate part program is to establish "Machine Coordinate System". To initiate, click on "Create Geometry" icon. This section helps in setting the MCS as required.



Fig. 1: Manufacturing Toolbar

Tool Selection

Another important decision to make is to select the right shape and size of the tool to use. For defining the tools go to CREATE TOOL, it will pop up a window asking the type of tool we want to use.

Creating Operation and Parameter Setting

Create Operation window pop up. There are many different subtypes under turning like rough turn, finish turn, facing centerline tapping, grooving etc. On clicking "OK", another pop up comes on to the screen to enquire about depth of cut, cutting and non-cutting parameters, speed and feed.

Post Processing

For generating the part program of the required operation, select the POST PROCESS tab shown in Fig. 1. Select the machine of own purpose and enter a location for the file. This will create the post-processed file for the desired machine in G-M codes.

5. DESIGN AND MANUFACTURING

The components are first designed on CAD, followed by CAM which will include generation of part programming.

Finally, these will be manufactured on the CNC lathe machine.

- **Pawn:**

In the first model we select to design simplest design of chess. To draw the model of the chosen part the sketch module is used in which XZ plane is used to draw the sketch of the part. In given model, the diameter is of 25mm and net height of 50mm. The modules used for designing are line, point, arc, extrude, rotate etc.

The method to design and generate part programming for all the shapes is generalized. The difference is the size and shape of the components. The procedure followed to do so is explained for "Pawn". The rest can be developed similarly.

As the model of the part is completed, now the G-M codes are supposed to be generated using the CAM software. As soon as we get into the manufacturing module of the NX software some icons are changed. Now in manufacturing module, tool is defined which will be used for cutting. For this part turning tool is used for machining.

Also, we need to mention blank geometry and its dimensions from which required shape will be obtained. For this, CREATE GEOMETRY tab selected and required variables such as blank geometry and part geometry. FINISH TURN operation is performed using the tool that is defined previously. The name of the operation is specified as "FINISH TURN-OD". Further the parameters related to finish turn are specified. One such parameter is step over, which is used to mention number of passes in which required job would be developed from blank work piece. In this case, the number of passes are 25 and depth of cut is 0.425 mm. Further, cutting parameters, non-cutting parameters, feed and speed are mentioned as per requirement. Cutting feed rate is maintained in the range of 0.1-0.45 mm/rev. These parameters are variable for shapes manufactured but in optimally chosen. As all these parameters are defined in the finish turn window the GENERATE option is selected which will show the slices of the part in the depth of cut defined which can be seen in the Fig. shown below.

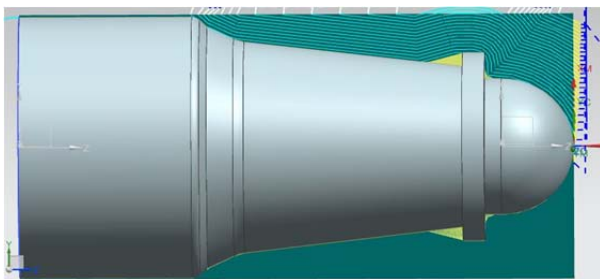


Fig. 2: Simulated image of Pawn (CAM)

In the post processing window, the machine LATHE_2_AXIS_TURRET_REF is selected and the units are

changed to METRIC/PART. It will use metric units to generate the part program. This will generate the part program.

Now this part program has to be executed on the MTAB CNC LATHE MACHINE. The blank is mounted on the table. The blank, mounted on 3 jaw chuck is having diameter of 25.4 and length of 90 mm. Before executing the program the origin has to be defined. Once operation has been performed on the machine, the excess portion used to hold work piece is chopped off and facing operation is performed.

The total numbers of pawn generated are eight. Once a single pawn is obtained after computer aided design and manufacturing and machining, rest of the seven are also generated with same part programming. Thus, all shapes produced by machining are similar to each other as well as with respect to the designed shape.

- **Rook**

This model is drawn by following similar steps as used in drawing pawn. In this model, the diameter is of 25mm and net height of 58mm.

The CAD/CAM modules used in modelling as well as virtual manufacturing are similar to step followed in "PAWN". Tool is defined for cutting, blank geometry is mentioned and its dimensions. Finish turn is the operation selected. In this window the parameters related to finish turn are specified. In this case, total number of passes as 15 and depth of cut is 0.530 mm. The cutting feed rate is maintained as 0.5 mm/rev.

In the post processing window the machine is selected and the units are changed to METRIC/PART. It will use metric units to generate the part program. This will generate the part program.

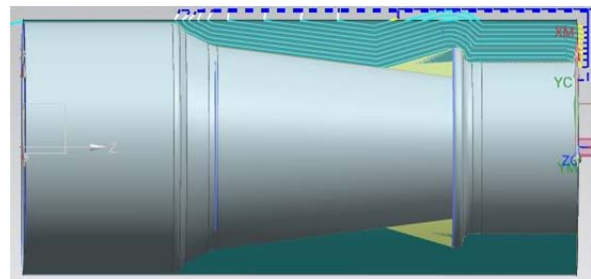


Fig. 3: Simulated image of Rook (CAM)

Now this part program has to be executed on the MTAB CNC LATHE MACHINE. 2 pieces of rook were manufactured.

- **Bishop**

The designed bishop has diameter base of 25mm and height as 65mm. The number of passes for the bishop is 25 and depth of cut is 0.429 mm. The cutting feed rate is maintained in the range of 0.10-0.6mm/rev. Followed by it, part programs are generated with numeric in program in mm. The part program

is executed on the MTAB CNC LATHE MACHINE. The blank have diameter of 25.4 and length of 100 mm. Two pieces of rook were manufactured.

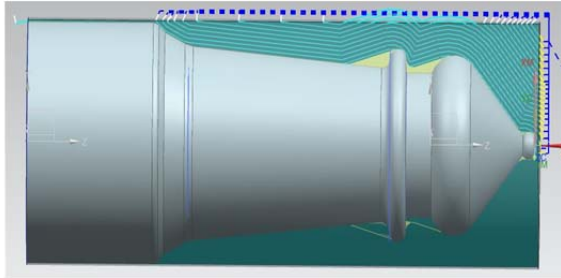


Fig. 5: Simulated image of Bishop (CAM)

- **Queen**

The diameter of base is 25mm and height is 78mm. G-M codes are generated using the CAM software by switching to manufacturing module of software from designing module. The number of passes for the queen is 20 and depth of cut is 0.539 mm. The cutting feed rate is maintained in the range of 0.012-0.5 mm/rev while machining to develop a queen.

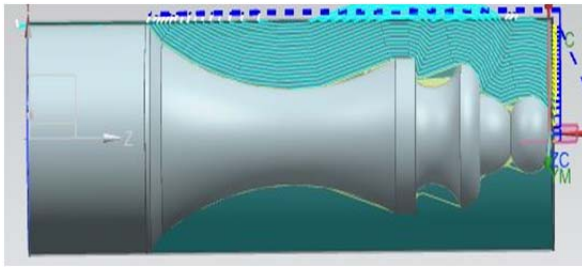


Fig. 6: Simulated image of Queen (CAM)

The abstract of part programming for queen is written below:

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N0010 G94 G90 G20
N0020 G50 X0.0 Z0.0
N0030 T00 H00 M06
N0040 G94 G00 Z10.0
N0050 X23.4846 Z1.66
N0060 Z1.2451
N0070 G97 S0 M04
N0080 G95 G01 X24.0248 Z.4921 F.7
N0090 G03 X25.37 Z-5.1336 CR=12.415
N0100 X25.4 Z-5.1728 CR=12.006
N0110 G01 X26.5010 Z-4.5924 F1.0
N0120 G94 G00 X13.86
N0130 Z1.66

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N0140 X22.504
N0150 Z1.2491
N0160 G95 G01 X23.0654 Z.5 F.7
N0170 G03 X24.3712 Z-5.3065 CR=11.967
N0180 X25.4 Z-5.8008 CR=11.559
N0190 G01 X24.5436 Z-5.2414 F1.0
N0200 G94 G00 X27.0858 Z-5.065
N0210 Z1.66
N0220 X21.523

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- **King**

This piece is the tallest of all in the chess set. The modules used are line, point and arc, which are later either extruded. The diameter of base of king is 25mm and total height is 90mm.

Here, total number of passes are 25 and depth of cut is 0.423mm. The cutting feed rate is maintained in the range of 0.012-0.4mm/rev. The obtained part program in fed into the CNC lathe machine. The simulated shape on software is shown in Fig. 7.

6. CONCLUSION

The products in this study are simple design and manufacturing of chess pieces. The case study started from part design to all the down-stream activities related to manufacture of the part. All the parts are designed on a 3D CAD/CAM system. The software used for designing is NX9.0. This work is to make an interface between CAD and CAM system and integrate the two systems.

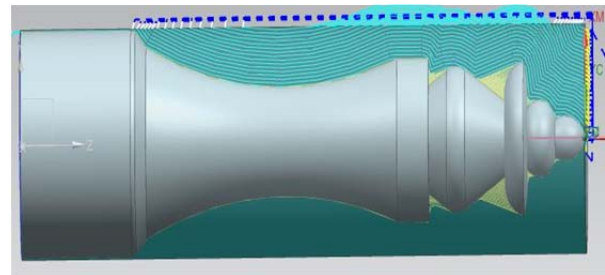


Fig. 7: Simulated image of King (CAM)

Process planning for NC code generation is also carried out with NX9.0 software. NX software provided solutions to problems in a fast, flexible efficient way along with less time consumption. The NC codes thus developed through the software are executed on the MAXTURN+ machine resulting in the manufacturing of the required products.

Different components required for developing CAD and CAM systems have been identified and various problems that arose in the development of these systems have been dealt with,

leading to an adequate basis for integration of CAD and CAM technologies. Proper process planning such as selection of machining operations (e.g. finish turning), estimating available cutting tools and cutting parameters, and ordering of operations helped to complete assigned designing to finished product in an effective manner. The system developed allows direct manufacturing of complex parts by just designing them in the CAD software.

All fourteen shapes obtained after machining are close to the designed shapes. The presence of slight inaccuracy in shapes proves the inability to fully conform virtual machining environment to the real machining environment but they do not affect in achieving the objective. The eight pawns are similar in shape and size, thus proving better dimensional accuracy and similarity among all. All the shapes designed and manufactured are of intricate shape and prepared in reduced time period. Thus, manufactured shapes are shown in Fig. 8.

It thus integrates different areas of design and manufacturing, giving each area an appreciation of its role in the design process. It has been proven that use of this system results in considerable improvements in machining efficiency, time and cost.



Fig. 8: Developed Shapes

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