Computer Aided Process Planning of a Ginning Machine Component

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ABSTRACT:
CAPP system plays a key role to integrate design and manufacturing or assembly systems properly considering available resources and design constraints. The main objective of the present study is the development of a process planning methodology with the help of CAD and CAM systems by automatically generating CNC codes with CAD geometry as the primary input and reducing the Machining time by varying certain machining parameters. In the process of product design and manufacturing, the role of process planning becoming increasingly important for improvements in product performance and quality and for reduction in time. Computer Aided Process Planning (CAPP) has been recognized as playing a key role and used as a bridge to link CAD with CAM systems. Computer-aided design (CAD) uses computer systems to assist in the creation, modification, analysis, or optimization of a design. Computer-aided manufacturing (CAM) uses computer systems to plan, manage, and control the operations of a manufacturing plant.

Keywords: CAD, CAM, CAPP, Machining time.

I. INTRODUCTION

Process planning translates design information into the process steps and instructions to efficiently and effectively manufacture products. As the design process is supported by many computer-aided tools, computer-aided process planning (CAPP) has evolved to simplify and improve process planning and achieve more effective use of manufacturing resources. Conventional manufacturing using Computer Numerically Controlled (CNC) machines from design inputs requires significant effort and time. Instead, by using CAM software with inputs like (CAD) drawing, machinable features, setup directions, tools, toolpath generation and machining parameters selection, we can generate CNC code automatically. This is, indeed, one privilege of using Computers in production process that is saving time and reducing production cost. As the machining time reduces, the production cost also reduces. Basically, Process planning is a result of engineering planning activities which prepare a list of processes needed to convert a raw material of a machine part as a starting point into a finished part. The aim the of process planning is to convert design specification into manufacturing instructions and to make products within the function and quality specification at the lowest costs.

Sanjay Joshi [1] presented a study showing automatic generation of CNC codes with the help of CAM software in order to improve CAPP. Conventional manufacturing using Computer Numerically Controlled (CNC) machines from design inputs requires significant effort and time. Manufacturers have to understand and interpret Computer Aided Design (CAD) drawing inputs, map these to machinable features, determine setup directions, select appropriate tools and machining parameters. This data is fed to Computer Aided Manufacturing (CAM) systems for generation of CNC code. With increase in global competition in manufacturing, there is a need to automate this process to reduce the lead time, improve quality, productivity and product development life cycles. In this regard, Computer Aided Process Planning (CAPP) was introduced as a bridge between CAD and CAM systems that were developed independently. CAPP refers to activities done either automatically or with minimum human intervention to convert component designs into manufacturing instructions that describe how components are to be produced. A large segment of the current literature is devoted to feature recognition which is vital in automated integration of CAD and CAPP systems. To build an effective system for automation of CAD and CAM, setup analysis and operation sequencing problems must also be addressed. Setup analysis identifies features to be machined in each setup and locates the datum for each setup. To realize true automation of process planning systems, feature recognition, setup analysis, tool path generation and tool selection must all be addressed simultaneously. The purpose of this study is the development of an approach towards achieving this for machining profiles.

For this purpose a feature recognition model is developed where machining features are determined using machined and non-machined faces of part drawings.
Golam Kabir [2] explains the design process supported by many computer-aided tools, computer-aided process planning (CAPP) has evolved to simplify and improve process planning and achieve more effective use of manufacturing resources. Process planning encompasses the activities and functions to prepare a detailed set of plans and instructions to produce a part. The planning begins with engineering drawings, specifications, parts or material lists and a forecast of demand.

Manual process planning is based on a manufacturing engineer's experience and knowledge of production facilities, equipment, their capabilities, processes, and tooling. In some companies, process plans are manually classified and stored in workbooks. The manual approach is also considered a poor use of engineering skills because of the high clerical content in most of its functions. Computer aided process planning is done in this study by generating G-CODE for CNC machine for rotational parts. The paper provides a rigorous basis for the understanding of process planning of rotational parts and the development of effective and efficient Computer-Aided Process Planning systems.

Mr. Deepak Pawar [3] uses CAPP for developing Die/Mold. The Die itself needs a well-defined process while being transformed from a stock of material or while it is being assembled with the help of standard components. Process planning is responsible for the conversion of design data to work instructions through the specification of the process parameters to be used as well as those machines capable of performing these processes in order to convert the piece part from its initial state to final form. In general, it is found that the Die (or a Mold) goes through a series of processes which are generally recommended and sequenced at random depending on the availability of the material, machine or the resource. This poses a problem for sequential and timely processing of the Die/Mold coupled with quality issues.

Most of the machining operations are Computerized control including Wire-cut, EDM, VMC machining followed by CMM inspection and so on which has a huge influence over the cost of the Die. As a result, the overall cost of the Die is high. The point to consider here is that even the Die itself needs a well-defined process while being transformed from a stock of material or while it is being assembled with the help of standard components. The varied elements of a die ranging from the standard Die set, the die-block, the punch plate with the punch holder, compression springs and the other elements necessary for assembling the die calls for a make-or-buy decision. While standard parts are preferred to be bought out, the components to be manufactured in-house necessitates an elaborate 'Process Plan' for yielding the most economic die with the prescribed specs for quality.

Shivkumar Biradar [4] in his paper discussed about the method of combining the virtual prototype with design by analysis techniques. Final outcome of the report is to provide quality products, good accuracy by creating the prototype model. The main intention of virtual prototype for customized product development is to provide multidisciplinary design. This design helps in utilization and capture of information generated during the design phase, and the simultaneous generation, at design time, of manufacturing, materials, costing, and scheduling data, together with visual evaluation of customer perception on target products, hence supporting the implementation of engineering. The range of CATIA V5’s capabilities allows for its application in a wide variety of industries, from aerospace, automotive, industrial machinery, electrical, electronics, shipbuilding, plant design, and consumer goods, to jewellery and clothing. CATIA V5 is the only solution that covers the complete product development process, from product concept specifications through to product-in-service, in a fully integrated manner. Mastercam, founded in Massachusetts in 1983 CNC Software, Inc. is one of the oldest developers of PC-based computer-aided design / computer-aided manufacturing (CAD/CAM) software. They are one of the first to
introduce CAD/CAM software designed for both machinists and engineers. CNC Software’s main product, started as a 2D CAM system with CAD tools that let machinists design virtual parts on a computer screen and also guided computer numerical controlled (CNC) machine tools in the manufacture of parts. Since then, Mastercam has grown into the most widely used CAD/CAM package in the world. The steps that are as follows:

![Flow of processes](image)

**Fig.3 Flow of processes**

Mastercam is a three-dimensional geometry creation engine along with features to aid in tool path generation and verification. It allows tool path planning and NC code generation for a given part. This part can either be modeled in MasterCAM or imported from other CAD packages. It’s comprehensive set of predefined toolpaths—including contour, drill, pocketing, face, peel mill, engraving, surface high speed, advanced multiaxis, and many more enable machinists to cut parts efficiently and accurately. It can automatically calculate the feed, spindle speed, material removal rate according to the tool or material of the product.

Ashok Krishna [5] the article presents a study in which an attempt has been made to figure out the optimal arrival parameters to reduce the cost of manufacturing submersible pumps. This article uses Taguchi method for optimization of process parameters to yield least manufacturing cost. The Taguchi method is a powerful tool for the design of high quality systems and is a well-established technique that provides a systematic and efficient methodology for process optimization. Taguchi approach to design of experiments is simple to adopt and apply for users with limited knowledge of statistics, hence obtained wide popularity in the engineering and scientific field. The need for optimization includes financial impact of this study. In order to study the combined effect of associated factors affecting the manufacturing cost of pump, all those factors with the selected levels in each are to be involved when formulating design of experiments. The analysis was performed for “Smaller the Better” type since minimizing manufacturing cost was the final goal. Parameters such as cost and time were measured accurately using detailed process study. The same process was observed repeatedly to validate same time of operation. Cost parameters were enquired. Parameters such as worker wages were noted down accurately. Machining cost was calculated by a detailed process study and shown in table below.

This article emphasizes the application and compatibility of Taguchi technique in the field of manufacturing simulations. This work creates a platform for research in the field of optimization of manufacturing process using software simulations and Taguchi method. The main advantage is that the research can be performed without actually affecting routine production using software simulations and also time saving was achieved by performing experiments only for selected trials using Taguchi method.

### II. EVALUATION OF ENERGY

S. Anderberg [6] is his paper investigated the role of process planning as enabler for cost efficient and environmentally benign CNC machining. Specific energy is used as the principal indicator of energy efficient machining and different method to calculate and estimate the specific energy. Specific energy can be described as the energy that must be fed to the machine to remove the material.

\[
\text{Specific Energy} = \frac{\text{Machine Power}}{\text{Material Removal Rate}}
\]

The study gave the result that the most efficient machining was found towards higher MRR. Decisions made during process planning to a large extent dictates the production outcomes such as lead times, quality levels, capability, energy used and environmental impact of goods production. If production output can be increased by optimized machining parameters, cost and energy saving can be concurrently follow.

### III. OBJECTIVE

The main objective of this paper is to improve the existing process plan by:

- Improving existing manufacturing process plan with the help of CAD and CAM systems.
- Simulation of an operation in CAM software, taking CAD geometry as input,
- Optimization of machining parameters to reduce machining time and increase material removal rate.
- Reducing material handling time and cost by changing the sequence of operation.
- Hence, reducing the total manufacturing time and cost per workpiece.

The material of the Clutch used in Ginning Machine is EN8 which is an Unalloyed Medium Carbon Steel having following Mechanical and Chemical properties.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Yield Stress $\times10^6\text{Pa}$</th>
<th>Tensile Stress, MPa</th>
<th>Elongation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalised</td>
<td>280</td>
<td>550</td>
<td>16</td>
</tr>
<tr>
<td>Cold Drawn (thin)</td>
<td>530</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>
TABLE 2 CHEMICAL PROPERTIES

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.35</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>Mn</td>
<td>0.60</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Si</td>
<td>0.05</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.015</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.015</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Mo</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Following are the machining parameters need to study while performing an operation during manufacturing [7]:

1) Spindle Speed (rpm): It is the rotational speed of the spindle of the machine.
2) Feed rate (mm/min): It is the velocity at which the tool is fed to the workpiece.
3) Cutting speed (m/min): The speed at which material is removed by the tool from the workpiece is called cutting speed.
4) Depth of cut (mm): The perpendicular distance measured from the machined surface to the uncut surface of the workpiece.
5) Material Removal Rate (m³/min): It is the volume of the material removed from the surface per unit time.
6) Machining Time (min): It is Ratio of machined length to feed given to the machine. These machining parameters plays an important role to find out the machining time required for each operation.

By varying any of these parameters, material removal rate and machining time can be optimized for any operation.

IV. METHODOLOGY

The major aim and objectives in machining industries generally are:
- Reduction of total manufacturing time,
- Increase in MRR, i.e., productivity,
- Reduction in machining cost without sacrificing product quality,
- Increase in profit or profit rate, i.e., profitability.

Depending on the type of operation, different formulas are used to evaluate the machining time, material removal rate, cutting speed and other required parameters.

Accordingly, as per the requirement, we can modify and optimize the process plan having minimum machining time. The best product dimensions and the minimization of time and cost of production has become a measure of concern.

It can be observed that, in a process plan, by changing the sequence of operations used in manufacturing, we can reduce material handling time. Material handling means providing the right amount of the right material, in the right condition, at the right place, at the right time, in the right position and for the right cost, by using the right method. The cost of material handling contributes significantly to the total cost of manufacturing. Planning for machining sequence can be considered as one of the most important functions of manufacturing process planning.

Therefore, the modified Process Plan from existing Process plan with the sequence of operations and machines used for each operation would be:

TABLE 3 MODIFIED PROCESS PLAN

<table>
<thead>
<tr>
<th>OP.SEQ.</th>
<th>MACHINE NAME</th>
<th>OPERATION DETAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CNC (1st Set up)</td>
<td>Rough Turning</td>
</tr>
<tr>
<td>2</td>
<td>Radial Drilling Machine</td>
<td>Centre Marking</td>
</tr>
<tr>
<td>3</td>
<td>CNC (2nd Setup)</td>
<td>OD Turning</td>
</tr>
<tr>
<td>4</td>
<td>CNC (3rd Setup)</td>
<td>OD Turning, Drilling and Boring</td>
</tr>
<tr>
<td>5</td>
<td>Horizontal Milling Machine</td>
<td>Slot Milling</td>
</tr>
<tr>
<td>6</td>
<td>Radial Drilling Machine &amp; RASCOMAT</td>
<td>Drilling, Reaming and Tapping</td>
</tr>
<tr>
<td>7</td>
<td>Hardening</td>
<td>N/A</td>
</tr>
<tr>
<td>8</td>
<td>Cylindrical Grinder</td>
<td>OD Grinding</td>
</tr>
<tr>
<td>9</td>
<td>Cylindrical Grinder</td>
<td>ID Grinding</td>
</tr>
</tbody>
</table>
For any manufacturing industry, main aim is to produce a good quality product in less time as per the requirement. Hence, it becomes necessary to reduce the machining time required to perform these operations with increasing material removal rate. In previous process plan, Drilling and Tapping operation was performed on Radial drilling machine before Slot milling operation and then Reaming was done on slot-milled component again on Radial drilling machine. But according to the locations of the machines, we can save the material handling time by changing the sequence of the operations performed. Hence, the Drilling, Tapping and Reaming operations are performed together on radial drilling machine. So, we can also reduce the number of operations required to manufacture the component.

In the manufacturing Industry, a Programming Expert, with his knowledge and experience, feeds the Code program to the CNC machines. On the other hand, if we use a CAM software for generating the CNC codes, it becomes less time consuming. This automatically generates a program that can be directly fed to the CNC machines. Depending on the type of microcontrollers of CNC machine, convenient type and version of CAM software can be used. In this paper, Simulation of an operation is to be performed on a CAM software to virtually observe the machining, before directly performing it on CNC machine. If needed, necessary modifications can be performed to improve the performance of the machining operation.

Machining time optimization in CNC programming plays an important role in manufacturing process planning and scheduling. It is one of the most important deciding factors for cost estimation.

With the help of these literature survey and considering the Slot milling operation performed on Horizontal milling machine, we can observe that most effected parameters to cutting condition are cutting speed, feed rate and depth of cut and they are easily controlled while machining. Hence, for this operation, the Material removal rate and Machining time are calculated according to the following formulas:

\[
\text{Material removal rate} = \frac{a_p \times a_e \times D_c}{1000} \quad \text{&} \quad \text{Machining time} = \frac{\text{Machined Length}}{\text{Feed}}
\]

Calculations for Slot Milling:

Diameter of cutter, \(D_c = 150\) mm,
Axial depth of cut, \(a_p =13.5\) mm,
Radial depth of cut, \(a_e = 29\) mm,

So, these machining parameters can be calculated by putting the values accordingly.

**Table 4 Evaluations Of The Machining Parameters**

<table>
<thead>
<tr>
<th>FEED (MM/MIN.)</th>
<th>SPINDLE SPEED (RPM)</th>
<th>MATERIAL REMOVAL RATE (MM³/MIN)</th>
<th>MACHINING TIME MIN(SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>250</td>
<td>39.15</td>
<td>0.79 (47.4)</td>
</tr>
<tr>
<td>120</td>
<td>300</td>
<td>46.98</td>
<td>0.66 (39.9)</td>
</tr>
</tbody>
</table>

From the above calculation it is clear that the feed rate and spindle speed are inversely proportional in that given table.
Table, we can observe that by increasing the Feed given to the machine, machining time is reduced and material rate is increased. The Feed is changed considering the specifications of the material of milling cutter, workpiece and milling machine.

Machinery’s Handbook [7] gives the recommended range of cutting speed, feed and spindle speeds for required material. So, accordingly these parameters are varied within the specified range.

B. R. Borkar [8] in his paper describes an efficient algorithm for automatic machining in milling and drilling operations. Machining time optimization helps in reducing the Total manufacturing time and cost. CNC machining time optimization methods can be classified into four categories:

1. Optimization based on material removal rates
2. Optimization based on NC program
3. Optimization based on NC program and machine characteristics
4. Artificial intelligence based Optimization methods.

The proposed study consists of three levels, namely data preparation level, data level and data calculation level. Data preparation level has the function of preparing data for machining time estimation, preparing geometry-process information and NC program information. Geometry-process information is generated through process planning which is rule-based. Machining process template is used for process sequence, required machine tool and cutting tool. At the same time, cutting parameters database is used for cutting parameters decision. The geometry information is transferred by feature reorganization. NC program is generated based on feature-based auto-programming. The proposed approach considers the influence to cutting speed and it is integrated with NC programming and machine tool information. Since the cutting speed can be predicted more precisely, the machining time can be estimated more accurately.

Victor Songmene [9], in his journal concluded that slot milling burr can be controlled by varying Feed per tooth and Depth of cut. This paper presents the effects of cutting parameters on friction angle and the correlation between friction between milling side burr thickness during slot milling. The effects of numerous process parameters on milling burrs were reported using experimental studies and analytical modelling approaches. Smaller burr thickness is resulted with increased friction angle. Consequently, smaller primary exit bottom burr size is which in fact reduces the necessity of secondary deburring operations.

![Fig. 5 Data Automation in required for process planning](image1)

![Fig. 6 Slot-milled parts with (a) large burr formation, (b) burr formation with tiny scales resulted.](image2)
The author concluded that following are the principal factors governing milling burr formation:

1. Machined part (geometry, dimension, etc.);
2. Cutting parameters (cutting speed, feed rate, etc);
3. Cutting tool (material, shape, geometry, rake angle, etc.);
4. Machine tool (rotational speed, dynamic strength, etc.);
5. Manufacturing strategy (tool path, coolant, lubrication);

The problems associated with the burr are that they cause misalignment between adjacent parts and also reduction of fatigue life. The other problems are like danger to operator with the sharp edges of burrs, poor part aesthetics etc. The burr formation is dependent on many process parameters. The elimination of burr in any machining process is quite difficult. However, the proper selection of different process parameters can minimize the burr formation.

Catalogue for Kyocera insert [10] suggested that Compressed air should be used to move all chips out of the work area, and feed rates must be appropriate for the material.

M. Groover [11], in his book, explains the importance of CAD/CAM system. With the help of these system, it becomes easy to examine various activities and functions that must be accomplished in the design and manufacture of a product. In this paper, a CAD model of the Machine part is modelled and for purpose of virtual machining, using CAM software, various inputs are given like material of the workpiece, type of tool, material of the tool, toolpath direction, position of the tool, etc. CAM software is features to aid in tool path generation and verification. It allows the tool path planning and NC code generation for a given part. Hence, we can confirm and optimize various types of machining operations before directly feeding to CNC machines.

V. CONCLUSIONS
This paper concludes that with the use of advanced CAD/CAM technologies, we can improve the Process plan used in manufacturing industry. The output of the planning includes the specification of machine and tooling to be used, the sequence of operations, machining parameters, and time estimates. CAD and CAM systems plays very important role in order to obtain an efficient process plan for manufacturing a machine component. With the help of CAM software, less machining time for manufacturing is obtained and less human interference is possible. The operation sequence and total number of operations in process plan can be changed to reduce the material handling time and cost. This result in reducing Total manufacturing time and cost required to manufacture a better finished part from raw material.

REFERENCES