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DEVELOPMENT OF RULES FOR METHOD SELECTION FOR THE SURFACES OF MACHINING CYLINDRICAL PART TO FACILITATE COMPUTER AIDED PROCESS PLANNING (CAPP) FOR JOBBING TYPE MANUFACTURING INDUSTRIES

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ABSTRACT

This paper presents an attempt made to develop clear rules/ideas for the development of fundamental base required for **generative CAPP** for **method selection** for machining of cylindrical parts. The new ideas of analysis and breaking the present concept, **method selection** decisions into its basic elements introduced is used for development of CAPP. For all the element of method selection**,** the rules are developed for machining of cylindrical part. The processing decision rules for (i) locating surface (ii) holding or clamping surface, (iii) selection of work-holding methods and (vi) confirmation/correctness of job set up are presented in the paper.

The paper highlights the developed and integrated rules specifically for machining of cylindrical part based on (i) technological requirements (finish part database) of the components, (ii) input of raw material either in bar type or single piece and (iii) the initial and final condition during processing of the component. The effectiveness of proposed rules is confirmed with an example.

The developed rules and integrated domain knowledge is useful for development of CAPP for jobbing industries is engaged in producing cylindrical parts.

KEYWORDS: CAPP, Cutting Operation, Process Planning, Locating Surface, Holding Surface, Work-Holding Methods

INTRODUCTION

Process planning is defined by society of manufacturing engineers as the ‘systematic determination of the method by which a product is to be manufactured economically. It is the bridge which connects the engineering department to the shop floor includes all of the steps required to convert design specification into detailed manufacturing instruction The functions of process planning are same irrespective of type of industries. The process planning decisions may vary from industry to industry and person to person. Kurian and Gary (1996) analyzed the time spent by a process planner during manual process planning. It is broken down in various categories viz technical decision making (15%), data look-up and calculation (40%), text and document preparation (45%), etc. It reveal that 85% of a process planner time is spent doing non- decisional and often repetitive activities. This non-decisional time spent by process planner can be reduced certain extent by development of CAPP. An attempt has made in recent years to make use of computer for developing an expert system to generate process plan to the given components. In a survey of Birajdar and Pawar (2013) it was observed that, CAPP was not implemented effectively in Indian industries. It is revealed from the Indian industries that almost all the company process plans are prepared by manual approach i.e. manual process planning (MPP). But all the companies felt the importance and need of CAPP. But no one successfully attempted to develop CAPP in jobbing industries. In other countries some of the variant CAPP as well generative CAPP approaches available and commercially reported. It is hardly seen in Indian manufacturing industries.

Cutting operation is an important component of process planning whether it is manual process planning (MPP) or computer aided process planning (CAPP). Presently, MPP function in jobbing industry carried out by the experience process planner based upon his or her experience. Therefore, to realize the benefits of CAPP in Indian industries scenario there is a significant need for comprehensive CAPP system. Till date number of expert systems like AUTOCAP, TOJICAP, OPEX, OP-PLAN etc has developed. However, all system are developed, based on assumed sequences of operations (user interactive) or based on heuristic rules. Therefore, the developed expert system is not worth for the industrial users. Besides this, all present systems are user interactive based. Here, user has to decide the operations and their sequences based on his or her experience to produce process plan. Hence, again it is manual type of process planning. It only saves certain amount of time of the process planner because of computers. In a survey of Kenneth Crow (1992) of twenty two large and small companies found out various benefits of CAPP in tangible and intangible benefits. The tangible benefits are 58% decline in process planning time, 12% saving in tooling, 10% saving in direct labor etc. Intangible benefits like reduced lead time, process plan consistency, plans to use improved technology etc. Therefore, to realize benefits of CAPP in manufacturing industries and to overcome limitation of the present method of manual process planning (MPP), there is a significant need for CAPP system.

An expert systems developed by using various logics and programming languages. To do effective use of logic and languages, it is important to justify logic by conformation and not by judgments. Because of non availability of CAPP, it is decided to undertake research study to decide logic for method selection to facilitate generative CAPP for jobbing industries. The next section presents literature review on cutting operation sequencing for rotating parts made on lathe.

LITERATURE REVIEW OF CUTTING OPERATION FOR CYLINDRICAL COMPONENTS

Several researchers have attempted to do the research in CAPP and have identified areas that need further research. David et al. (1991) discussed that CAPP have distinctly evolved in the literature as variant approach and generative approach. Variant approach follows the principle that similar part requires similar plans. Generative approach utilizes decision logic, mathematical formulas, manufacturing rules and geometric data to determine the process required to convert the raw material into a finished part. The cutting operation has been automated by various researchers using various approaches such as mathematical models, decision trees, decision tables, production rules, expert system, heuristic and artificial neural network (ANN), Genetic Algorithm, Geometric programming, quadratic programming etc. The detail literature review of research carried out by various researchers on the cutting operations is presented below.

Hinduja et al. (1989) developed a system to determine automatically work holding methods, number of setups, clamping position on the blank and component considering only the length and diameter of the part without considering tolerances. The system also determines the chucking styles. However for the effective analysis it is essential to consider the technological requirement placed on part such as size tolerances, geometrical tolerances, machine capability, accessories capacity etc. Kim et al. [1994] developed a computer aided process planning system interfaced with CAD for turning operation. The system performs process planning function such as process and operation selection, machine tool selection and setup planning. However, for effective implementation of CAPP, is to necessary to carry out detail mathematical analysis.

The researchers Huang and Hong (1996), Zhang (1996), Huang et al. (1997) and Huang (1998) proved importance of job set up planning to bridge gap between CAD and CAM. The work focused on job setup planning by considering tolerance and aimed to decide setup formation, datum selection and datum sequencing. The setup planning task carried by using graph theory, set theory etc. The work carried without considering work-holding devices, selection of type of blank, position checking of datum selection, set up of machine etc. Bai et al. (2000) created feasible machining datum using genetic algorithms. It considered the tolerances and machine capacity in constructing tolerance chart. Rico et al. (2000) developed logic to determined clamping surface considering the work-holding specification and geometrical shape of the part. However, the authors not discussed all the issues related to job set up planning may be beyond the scope of the paper.

Arieh et al. (2003) presented process-planning problem described as a generalized traveling salesman problem (GTSP). One of the important characteristics of this research is the tolerance relationship is converted into tolerance factor. Huang and. Xu (2003) presented an integrated job set-up planning methodology which integrated the solution of various sub-problems. However, researchers still not addressed issue of work-holding methods, position checking and chucking styles. Valino et al. (2007) developed a methodology for set-up planning consists of coding of surfaces, grouping of features, datum selection etc. However the some of the decisions are not analyzed quantitatively such as selection of work-holding methods. Sanka et al. (2011) developed an integrated and intelligent CAPP methodology for symmetrical parts to automate selection of operations, operation sequencing and setup planning based on ANN. The authors suggests that if the feature having a range of diameter D, range of tolerance and range of surface roughness, the suggested sequence of sequence of operation is rough turn or rough turn-semi finish turn or rough turn-semi finish turn-finish turn and so on. But the sequence (rough turn or rough turn-semi finish turn or rough turn-semi finish turn-finish turn) is definitely depend upon the type of features, amount of material removed, cutting parameters and technological requirements of parts.

Kayacan et al. (1996) .had developed an optimized process sequence system for rotational part for optimizing number of tool changes and minimum tool travelling time by RIL method. One of the important limitations of this work is that it is assumed that each feature is considered as a single operation. Cho et al. (1991) developed an integrated process planning and monitoring system for turning operation with interface for simple turned part without considering technological requirement of part which is the limitation of this work.

However there is no clear indication how the selection of cutting parameters, process sequence are generated. Zhang, and Gao (1984) have focused on generation of process sheet using TOJICA with user interface. All the decisions based upon the judgment of process planner. Kim and Cho (1994) developed a CAD interfaced process planning system for selection of process, machines tool selection, tool selection etc by user through interactive mode. The selection of process carried out by mapping the machining operation and features. However there is no proper quantitative analysis for these functions and stated that further research is needed for practical applications.

Gupta et al. (2011) developed integrated model for sequencing of operations, machine and tool selection and machining parameter selection to minimise the processing cost. However authors are assumed that the rate of feed and cutting speed remains constant which is the severe limitation of the work. Chung and Peng (2003) used web based environments to select the tools and machines based upon the sequence of operation for simple rotating part. However it is not developed any sequencing rule to decide the sequences of surfaces.

However the authors not considered the position checking of datum surfaces in each set up. The datum which is defined is not accessible by chuck. Fernandes and Raja (2000) developed an incorporated tool selection system in five steps: alternative tooling, compatibility, logic elimination, determination of tooling parameters and database search based upon the sequences of surfaces.

However it is not developed any sequencing rule to decide the sequences of surfaces. Mendes et al. (2003)

developed a mixed integer linear programming model for part mix, tool allocation and process plan selection in CNC machining centers. Halvei and Weill (1995), Johnson (1962) and Rao (2000) presented various issues related to process planning.

Gaps in Literature

Considering all these research contributions made by various researchers in developing CAPP and discussion with experts, it noticed that there are gaps in research work which are summarize as follows.

- Each of prior research work addresses only whole cutting operation. Therefore, **splitting the** cutting operation into various elements yet to be done.
- The expert system developed till today based on assumed sequences of operations. Expert system which can decide cutting operation by giving job data as input yet to be developed. However, to decide cutting operation no expert system reported.
- Despite lot of research on CAPP, research yet to success to provide a solution of process plan.
- Today's research incomplete and yet to define correctly meaning of cutting operations. At present meaning of method selection is not clearly states the elements which includes job set up, machine set up, tool set up, relative motion of job and tool and confirmation of set up.
- For elements locating surface, clamping surface, work holding methods and confirmation of set up, rules for processing decision are yet to be developed.
- The researcher's contribution towards to implement of CAPP and to create awareness of CAPP and its benefit is limited.

Considering **present status of deciding "method for operation" (**literature gaps), research work is undertaken. In first step, **"method for operation"** broken down in elements. For job setup, work has undertaken to develop rules and logic. The rules and logic helps development of CAPP for jobbing industries engaged in producing cylindrical parts. The following paragraph presented inputs needed for cutting operations with assumptions followed by development of rules particularly for cylindrical parts.

INPUTS TO THE METHOD SELECTION

To develop CAPP, various databases needed. For deciding "**method selection**", inputs required are (i) Finish part database (CAD model) (ii) input of raw material as bar type or in single piece (iii) Initial condition and condition of the component during processing. It is assumed that database is available and relevant.

Assumptions

The following assumptions are made for development of rules for machining cylindrical job.

- The developed rules are only for cylindrical part and turning on a single machine.
- Only one surface is to be done at a time i.e. combine operations are not considered.
- The machining is to be done by using single point turning tool.
- The raw material and its size selected by designer considering material allowance.

- The machine tool, cutting tools and accessories and attachments selected.

METHODOLOGY USED FOR DEVELOPING THE RULES/LOGIC FOR METHOD SELECTION

The proposed methodology shows a systematic procedure for all elements of **method selection** of cylindrical part made on lathe. The steps in research methodology adopted are (i) Break-up of existing method selection (ii) Identification of various activities in each element iii) Development of rules for each element and (iv) An illustrative example to confirm the proposed rules. These proposed steps are explained in detail in next section.

Break-up of Existing Method Selection

The idea of work study has applied for breaking **method selection** in elements. The following element has identified.

- Job set up for locating surface.
- Job set up for holding surface
- Job set up for work holding methods
- Confirmation of job set up

Identification of Various Activities/Tasks in Method Selection

By studying various research papers and discussion with various experts from academician and industry experts (process planner), various activities identified shown in table 1.

Table 1: Elements in Method Selection

Method Selection	Elements in Method Selection	
Job set up	(i)	Selection of locating surface
	(ii)	Selection of holding surface
	(iii)	Selection of work-holding methods
	(iv)	Confirmation of set up

To develop fundamental base for generative CAPP, it is necessary to develop rules for all elements listed in table 1. It is not only sufficient development of logics but it is also essential to integrate rules.

Development of Rules/Logic for Method Selection

The numbers of decisions are made for processing the work piece. The decisions are made mainly to meet the accuracy of the part and at the same time to minimize the processing time. Therefore, the various rules have developed considering the objectives of each function or decisions, available methods for each function and literature review (gaps in literature). In this research paper, for the following functions/decisions, rules have been developed for machining surfaces of cylindrical part which helps the development of CAPP. To meet part requirements, rules have been developed and integrated for each activity shown in table 1 presented as follows.

Rules/Logic for Selection of Locating Surface

To develop a rule for locating surface, it is necessary to know the objectives, available methods and gaps in literature are presented below.

Objectives of Selection of Locating Surface

The various objectives for selection of locating surface are:

- Consistent positioning of work pieces to maintain part print tolerances.
- To control length of work piece/to minimize overhang length of part.
- To minimize the skill required to load and unload the work piece.
- To minimize deflection of the work piece despite number of variables.

To achieve all these objectives it is necessary to determine those areas/surface best qualified for **locating** the work piece.

Available Methods of Locating Surface

The methods to select locating surface in the industries based on trial and error method based on his or her experience. The selection of locating surface varies person to person even for the same part. The methods available for locating surfaces are placing the locator either at tailstock or headstock spindle or inserting in the work holding device/fixture.

Literature Review

The various researches developed logic for locating surface using different approaches such as graphical approach, set theory, genetic algorithms etc. However, these developed logic not considered the input of raw material, status of raw material at each stage of the processing, and accessibility of the locating surface by work-holding devices.

Rules for Locating Surface

Considering the objectives, available methods and literature review (gaps in literature), the rules has been developed. The following factors considered during the development of rules to select a locating surface to achieve the objectives and to overcome the limitation of existing research work so far. The various factors considered are:

- The input of raw material. The raw material used may be either bar type or in single pieces.
- Condition of the work pieces at the initial state and condition during processing.
- Tolerance relationship between the surfaces.
- Diameter of blank and part.
- Single or multi step components mainly in second set up.

Raw Material in Bar Type

When raw material is in **bar type**, the rules for each set up for length and diameter location presented as follows.

For First Set up

The condition of the part is always in first condition of the material.

- **Length Location**: Place the locator (centres) in the tailstock. Therefore, the **locating surface** is on the end face of blank. With this, the objectives of control overall length of work piece will be achieved. Also the loading and unloading time of the work piece and skill required will be minimized. After the surfaces are machined, parting operation performed to part the work piece from the blank.

- **Diameter Location**: The chuck itself acts as a locator for diameter. The jaws of chuck moved up and down to locate the work piece for diameter location despite the variation in stock diameter by the previous process.

For Second Set up

The initial condition of the material is changed due to machining in first setup. On the machined side of the part, there may be single step or multistep exists on the part. This must be considered in developing rules.

- **Length Location**: For single step on the work piece, place the locator in the work holding device to control the finish length of work piece. Hence the locating surface is the finished end surface machined in the first set up.

In multistep components, if more than one plane surface available, the procedure for selection of locating surface is as follows:

Step 1: List or record all possible/feasible locating surfaces accessible by work-holding devices.

Step 2: Select locating surfaces among the feasible surface listed in step 1 based on **tolerance relationship**

Among the locating surface accessible by the work-holding devices, the priority assigned to the tolerance relationship. If there is any tolerance relationship between the surfaces; such surface will be selected as the locating surfaces. If there is more than one tolerance relationship exists, the priority assigned to the smallest tolerance. If all tolerances are same, priority must be given to the surfaces which minimize overhang length of part. If there is no tolerance relationship, select the surface which minimizes the overhang length of part.

- **Diameter Location**: Same as in first step.

Raw Material in Single Piece

If the raw material used in pieces, the location depend on the diameter of blank. The blank diameter may be more than machine spindle bore diameter or less than machine spindle bore diameter.

For First Set up

Case 1: If the blank diameter less than machine spindle bore diameter,

In this case, place the locator in the work holding device to minimize overhang length of part. Therefore, the locating surface is the left hand surface of the blank.

Case 2: If the blank diameter is more than machine spindle bore diameter

In this case the locating surface is on the face of the chuck. However if the reverse oriented jaws is used, the locating surface is on the surfaces of step length of jaws. In both the cases the left hand side surface of the blank is the locating surface.

For Second Set up

- **Length Location**: Follow the rules developed in section 4.3.1.5 in second set up.

Development of Rules for Selection of Clamping (Holding) Surface

To hold the work piece in the work holding device a cylindrical surface is required. The selected clamping surface must be suitable for clamping.

Objectives of Selection of Clamping/Holding Surface

The objectives of selection of correct clamping surfaces are:-

- Holding the desired position of work piece against clamping and tool forces.
- Restricting deflection of the work piece due to tool and holding forces.
- The work piece does not become marred or permanently distorted due to the holding force.
- To provide maximum rigidity.
- To minimize loading and unloading time of part.

Available Methods for Selecting Holding Surface

Similar to locating surface, to select holding surface in the industries determined by trial and error method based on his or her (process planner) experience.

Literature Review

Rico et al. developed logic to decide clamping surface considering the work-holding specification and geometric shape of the part by developing heuristic rules. The other researchers also developed logic for selecting holding surface using different approaches such as graphical approach, set theory, genetic algorithms etc. However, these developed logic not considered the input of raw material (bar type or single piece), status of raw material, accessibility of the locating surface etc while defining holding surface.

Rules for Holding Surface

Considering the objectives, available methods and literature review (gaps in literature), the rules has been developed. The following factors considered during the development of rules to select a locating surface to achieve the objectives and to overcome the limitation of existing research work so far. The various factors considered are:

- The input of raw material. The raw material used may be either bar type or in single pieces.
- Condition of the work pieces at the initial state and condition during processing.
- Tolerance relationship between the surfaces.
- Variation in diameter of the work piece during processing.
- Single or multi step components mainly for second set up.
- Number of set ups.
- Extent of damage to the **holding surface**.

First Set up

For first set up, the holding surfaces is always on the blank surface. Therefore, the **holding surface** diameter is on the blank diameter i.e. $\mathbf{D_{blank}}$. This is applicable either raw material used in bar type or in single pieces.

For Second Set up

For second set up all factors must considered. If it is only one holding surface available to hold the job, define that surface is a holding surface. If there are more than one holding surface exists, the procedure for selection of holding surface is as follows:-

Step 1: List or record all possible/feasible holding/clamping surfaces accessible by work-holding devices.

Step 2: Select clamping surfaces among the feasible surface listed in step 1 based on:

- **Tolerance Relationship**

Among the holding surfaces accessible by the work-holding devices, the priority assigned to the tolerance related surfaces. If there is any tolerance relationship between the surfaces; such surface will be selected as the holding surfaces. If there is more than one tolerance relationship exists, the priority assigned to the smallest tolerance. If the tolerances same, priority given to the surfaces which minimizes overhang of part. Also, if there is no tolerance relationship, select the surface which minimizes the overhang part.

- **Maximum Diameter**

If there is no **tolerance relationship between the surfaces (Geometric tolerance),** while selecting the holding surface, **the priority** must be assigned to the maximum diameter. The reason is to provide maximum rigidity to the part.

- **Damage to the Surface**

The last but least criterion is the extent of damage to the holding surface. The care must be taken while selection and clamping the surface.

Development of Rules for Selection of Work-Holding Methods

To select work-holding methods for machining process is one of the most important tasks in planning a job. Presently the task of work-holding methods performed manually. It requires extensive experience. Due to this large amount of time will be spent on to decide work holding configuration. Therefore here the attempt is made to develop rules for work-holding method which saves a large amount of time spent on determination work-holding method**.**

Objectives

It is very well known that the main purpose of work-holding methods is to:

- Provide stability/rigidity to the work piece during machining and
- Maintain accuracy/quality of the machining.
- To minimize the total processing time by maximizing the cutting parameter.

Available Methods

The available work-holding methods are-

- Chuck only (CO) method
- Chuck and Centre (CC) method
- Between centre (BC) method.

Literature Review

According to Hinduja et al. (1989) analyzed the effect of L/D ratio to determine work-holding methods.

- Chuck only (CO) method: When $L/D \leq 2$
- Between centre (BC) method: When $L/D \geq 4$
- Chuck and centre (CC): When L/D ratio is between 2 and 4

According to Geoffrey Boothroyed (1983) the determination of work-holding method is as follows:

- Chuck only (CO) method: if $L/D \leq 0.5$
- Between centre (BC) method: if $L/D \geq 3$
- Chuck and centre (CC): if $0.5 \leq L/D \leq 3$

Rules for Selection of Work Holding Methods

From the practical point of views the rules suggested by the various authors are not correct. For example, if length of job is 60 mm and diameter is 20 mm, then L/D ratio=3. According to rules stated by different researchers, select the work-holding method may be chuck and centre or between centre methods. But for length of 60mm, it is impossible to support the centre because of distance/ or pace between the face of chuck and tailstock centre when rested against the cross slide. It means the carriage cannot move in this space/distance for machining. Therefore, chuck and centre or between centre methods is not suitable. Considering the research contribution, objectives, available methods and literature review (gaps in literature), the following rules has developed.

Chuck Only (CO) Method

Use chuck only method, if the distance between face of the jaw and tailstock centers is less than or equal to the length of job. To measure distance, it is ensured that tailstock is rested against the cross slide.

Chuck and Centre (CC) Method

If the projected length of job form face of the jaw is greater than distance between face of the jaw and tailstock centers when the tailstock is in fully backward position. Using CC method it is possible to select the maximum condition of cutting parameters. Therefore, the total processing time will minimize.

Between Centre (BC) Method

If using chuck and centre (CC) method not satisfied the accuracy of part, then use between centre (BC) methods.

Confirmation of Job Set up

Before actual start of machining it is necessary to confirm all set ups. The procedure for confirmation of job set up presented as follows.

- Size of blank in terms of diameter and length.
- Check work piece located at defined position and held at defined work-holding surface.
- Centering stock/alignment of job with axis of machine with a dial indicator for diameter as well face.

- Chucking force. Insure that work held rigidly in work-holding devices and also verify that excessive clamping force may damage to machined surface.
- Gripping length. Length of contact between jaw and part should not be less than 5 mm.

AN ILLUSTRATIVE EXAMPLE

An illustrative example used to show the effectiveness of the proposed methodology shown in figure 1. The figure shows all the technological requirements of parts. It includes such as size tolerances, geometric tolerances and surface roughness. The figure also shows the different surfaces such as plane, cylindrical and chamfers surfaces. Before applying the developed rules, it is necessary to convert the part drawing into CAPP drawing. It is assumed (specified by the designer), the size of blank considering the machining allowance=ϕ160 x 160mm. As the size is more than the machine bore diameter, Therefore, using raw material is in pieces. To decide the elements of method selection, the steps are presented below. It means applying rules presented in section 4 for single pieces are applied for the illustrated example.

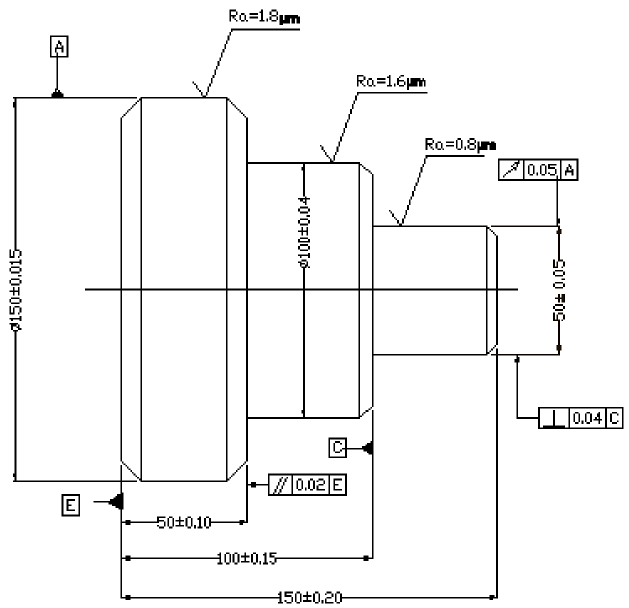


Figure 1: Cylindrical Component

Step 1: Priority of the Side Machined

As the blank is in pieces, the part must be machined in two set up. Next, decide which side to be machined first. This is decided based on tolerance relationship and rigidity calculations. When RHS machining performed first, the stiffness value is 0.6 x 10^6 N/mm. Similarly when machining LHS first, the stiffness values is 1.25 x 10^6N/mm. Therefore, the left side machining carried out first. Also based on tolerance relationship, linear dimensions are controlled with reference to surface f1. Therefore, the left side of part processed first.

Step 2: Prepare CAPP Drawing

The necessity and the coding of surfaces presented in the earlier paper. Using the same procedure, CAD drawing converted into CAPP drawing. The modified diagram referred as CAPP drawing which is shown in figure 2. It consist of faces f1-f2-f3-f4, cylinder d1-d2-d3, chamfers C1 (f1), C2 (f2), C3 (f3), C4 (f4) with linear and geometrical tolerances.

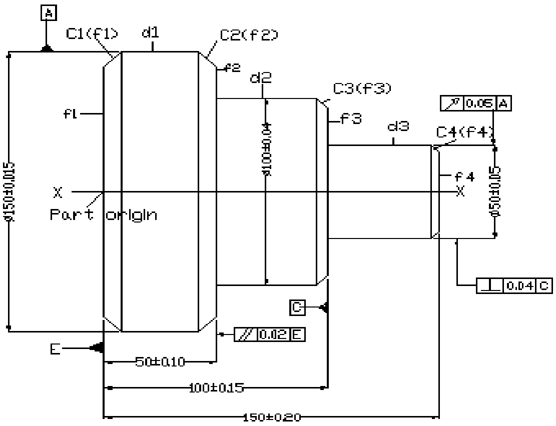


Figure 2: CAPP Drawing

Step 3: Selection of Locating Surface

Considering the assumptions, the selection of locating surface for each set up is determined as follows.

First Set up

Applying the rules developed in section 4.3.1.4 for length location, when the input of raw material in pieces, the possible locating surface are =f2, f3 and f4. The surface f2, f3 and f4 do not exist on stock. Hence these surfaces are rejected. Therefore, locating surface is on the left end face of blank.

Second Set up

The possible locating surface = f1. The surface is accessible by the work-holding device. Therefore, locating surface = f1.

Step 4: Selection of Holding Surface

First Set up

The possible clamping surfaces are = d2 and d3.The surface d2 and d3 not exists on the part. Hence, these surfaces are rejected. Therefore, clamping surface is on blank surface having clamping surface diameter, $D_{clamp}=D_{blank}=\phi 160$mm.

Second Set up

Listing the clamping surface = d1. The surface is accessible by the work-holding device. Therefore, clamping surface=d1. Hence, clamping surface diameter, $D_{clamp}=\phi 150$mm. The summary of calculation is shown in table 2.

Table 2: Selection of Clamping and Locating Surface

Set up	Selection of							
	Clamping Surfaces				Locating Surface			
	List of Clamping Surfaces	Surface Exist on the Part	Accessible by the Jaws	Final Selection	List of Locating Surfaces	Surface Exist on the Part	Accessible by the Jaws	Final Selection
First set up	d2	No	--	--	f2	--	--	--
	d3	No	--	**--**	f3	--	--	--
				D_{blank}	f4	--	--	**--**
								End face of blank
Second set up	d1	Yes	d1	**d1**	f1	Yes	f1	**f1**

Step 5: Selection of Work-Holding Methods

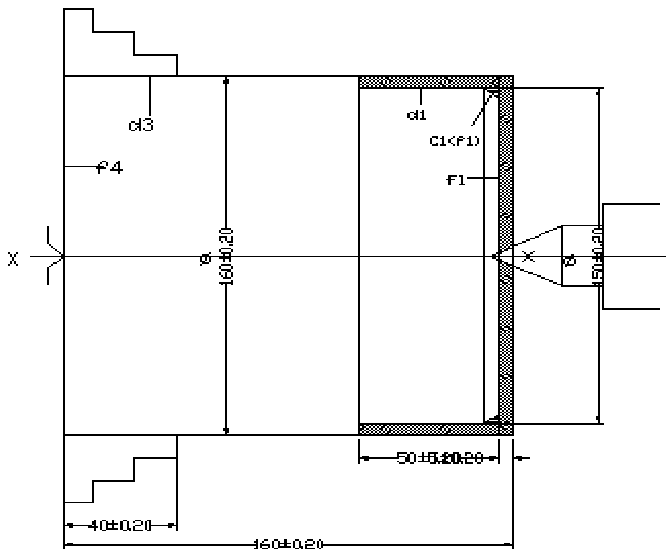
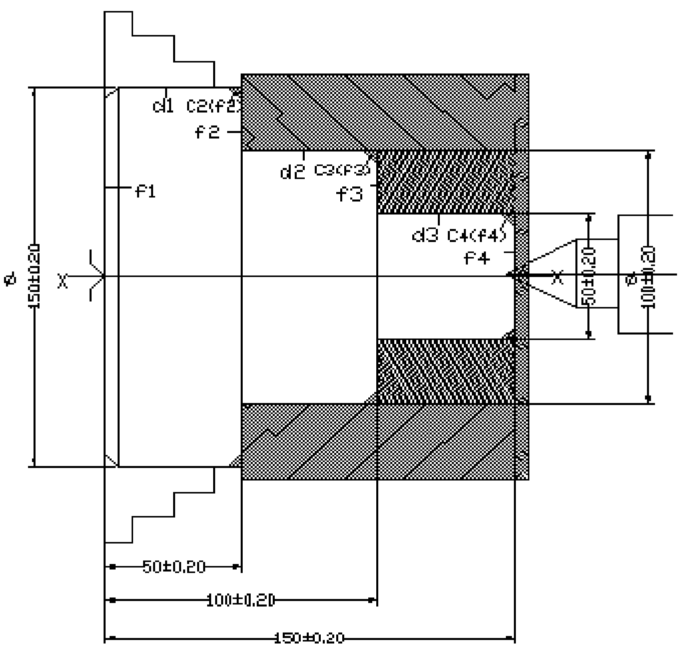
The length of job is more than the space between face of the jaw and tailstock centre when it is rested against the cross slide. Therefore, chuck and centre (CC) method selected in both the set up.

Step 6: Confirm the Job is Set up on the Machine as Per Calculation/Results

RESULTS

A process sheet is prepared to give the details of calculation shown in table 3. The process sheet shows the position of locating surface, holding surface and work holding method. This table is in suitable format showing the information necessary for the machinist for executing or machining job.

Table 3: Generated Method Selection for Illustrated Example

Process Sheet	
First Set up **Type Blank:** Cylinder **Clamping Surface:** d3 (on blank) **Locating Surface:** Left end face of blank.(f_4) **Work-Holding Method:** Chuck and centre (CC) method **Sequence of Surface:** f1, d1 and C1 (f1).	
Second Set up **Clamping Surface:**d1 **Locating Surface:** f_1 **Work-Holding Method:** Chuck and centre (CC) method **Sequence of Surface:** f4, d2, d3, f1f2, f1f3, f1f4, d3d1, d3f3, C2 (f2), C3 (f3) and C4 (f4).	

CONCLUSIONS

The emphasis in this paper given to the **"method selection"** at micro level on the basis of developed rules. The following conclusions are drawn from this study.

The **method selection** broken in elements

- Job set up for locating surface.
- Job set up for holding surface.
- Job set up for work holding methods.
- Confirmation of job set up.

To identify the different surfaces of component it is necessary to modify the CAD model into CAPP drawing which is the first step in the development of generative CAPP.

The developed rules and integrated domain knowledge base confirmed with an example.

The following rules/logics developed to integrate method selection of cylindrical parts:-

Rules for selection of locating surface for length and diameter dimension in each set up.

Rules for selection of holding surface for length and diameter dimension in each set up.

Rules for selection of work holding methods.

Rules for confirmation of set up.

Despite lot of research on CAPP, the software's are not available in the market like CAD and CAM software

SCPOE FOR FUTURE WORK

It is also important to note that it is essential to create awareness among the process planner. There must be Industry Institution Interaction at regular interval to understand the development in the technology and share the information to each other so that the development of the future need can be correctly envisaged or planned.

The following points may be considered in future research work and work is under progress except last point.

- Other surfaces will be incorporated in the logic.
- Integrate other functions/decisions of the process planning with current logic.
- The rules developed in this study are to be used for development of logic and tested by development of computer program and using hypothetical data or case study.
- The methodology adopted here is to be extended to other machining process.

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