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Effect of Coolant and Tool Nose on Material Removal Rate on Conventional Lathe Machine

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***Abstract*: Material removal rate (MRR) is a great challenging field for engineering because it affect the quality and cost of final product. There are many problems comes to origin during material removal process on the conventional lathe machine. In spite of perfect skill and knowledge of operation, we fail to remove material at high accuracy. This paper investigates the effect of different cutting parameter(s) on the Material removal rate. The work piece materials of Mild steel were machined on conventional lathe machine and find the difference between actual and theoretical value. Then we analyze the problems by PDCA method and select two basic parameters "Tool nose and cutting fluid". After removal of selected problem, the work pieces of same specification were machined on lathe machine and find the result. It was observed that the error of removing material rate decreased up to 42%. We conclude that "Tool nose" increases the cutting forces and "Cutting fluid" increases the thermal stress in the material and hence removal rare increases.**

***Keywords*: Cutting speed, Spindle speed, Feed, Depth of cut, Cutting fluid, Tool nose, MRR (Material Removal Rate).**

1. Introduction

Reduction in length of the work piece to produce flat surface is called facing operation. A lathe can be used to create a flat face & smooth very accurately perpendicular to the axis direction of a cylindrical part. A single-point turning tool moves radically with constant speed, along the end of the work piece, removing a thin layer of material to provide a smooth flat surface. The depth of the face is typically very small. It may be machined in a single pass or may be reached by machining at a smaller axial depth of cut and making multiple passes [1]. Facing operation is widely used in workshop practice for applications carried out in conventional machine tools machining centers and related manufacturing systems. Facing operation is done on a lathe and it is used primarily to produce flat surface end of cylindrical parts.

The quality of tool plays a major role to improve surface accuracy, feed force, to reduce main cutting force, and to reduce machining zone temperatures (chip-tool interface temperature) in facing operations. The material of tool and cutting angle (nose) are important factors to determine MRR (Material removal rate). Cutting fluids are generally used in machining process to reduce wear and friction. It improves the life span of tool and surface finish. It also used to reduce the cutting forces and energy consumption. The heat generated during friction of tool and moving part is also absorbed by the coolant. It also washes away the chips, and to protect the machined surfaces from environmental corrosion. So, the selection of tool, its cutting angle and coolant are the key factors for the MRR (Material Removal Rate) and quality of operation.

There are various cutting tools and machine tools are used in metal cutting. The cutting tools for facing can generally be divided into two groups: cemented carbides and high-speed steels. High speed steel (HSS) cutting tools can be subdivided into three groups according to their manufacture: single, brazed and index able inserts. Cutting tool geometry, chip geometry, cutting speed, cutting tool and work piece material, cutting speed and cutting fluid are the main factors affecting the metal cutting process. Tool geometry is the most important factor affecting metal cutting process and material removal rate. It is determined by rake angle, side clearance angle, side cutting edge angle and back rake angle. Tool geometry is an important factor having influence on cutting forces and tool life. The proper selection of cutting parameters as well as the length of tool holder extending from its post is essential. The improper selection of cutting parameters leads to rapid tool wear, breakage and plastic deformation. This increases machine tool idle time due to the changing of damaged cutting tools and causes some other problems such as poor surface quality. This will lead to increase the overall cost [1].

2. Parameters Affecting MRR (Material Removal Rate)

The three primary factors in any basic facing operation are speed, feed, and depth of cut. There are also other factors such as types of material and type of tool have a large influence on material removal rate but these three are the ones the operator can change by adjusting the controls, right at the machine [2].

A. Speed

Speed always refers to the spindle and the work piece but in lathe machine tool is in stationary position and job is in rotation position. Whenever, it is stated in revolutions per minute (rpm) it tells their rotating speed. The important feature for a particular facing operation is the surface speed, or the speed at which the work piece material is moving past the cutting tool. It is simply the product of the rotating speed times the

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circumference of the work piece before the cut is started. The speed of the work piece is expressed in meter per minute (m/min). The different diameter of work piece will have a different cutting speed, even though the rotating speed remains the same.

$$V=\pi DN/1000$$

Here, V is the cutting speed in turning, D is the initial diameter of the work piece in mm, and N is the spindle speed in RPM [2].

B. Feed

Feed always refers to the cutting tool. It is the rate at which the tool advances along its cutting path. The feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev.

$$F=fN \text{ mm min}^{-1}$$

Here, F is the feed in mm per minute, f is the feed rate in mm/rev and N is the spindle speed in RPM.

C. Depth of Cut

Depth of cut is practically self-explanatory. The thickness of the layer being removed (in a single pass) from the work piece or the distance from the uncut surface of the work to the cut surface is known as "Depth of cut". It is expressed in mm. During the facing operation the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work [2].

$$\text{Depth of cut}=D\text{-}d/2$$

Here, D and d represent initial and final diameter (in mm) of the job respectively.

3. Selection of Machining Component

A. Selection of Cutting Tool

Cutting tool geometry varies with the type of work to be done. Facing tools are ground to provide clearance with a center. Roughing tools have a small side relief angle to leave more material to support the cutting edge during deep cuts. Finishing tools have a more rounded nose to provide a finer finish. Round nose tools are for lighter turning. They have no back or side rake to permit cutting in either direction Left hand cutting tools are designed to cut best when traveling from left to right. Aluminum is cut best by specially shaped cutting tools (not shown) that are used with the cutting edge slightly above center to reduce chatter.

B. Selection of Cutting Fluid

The cutting fluids applied in machining processes basically have three characteristics. These are:

- Cooling effect
- Lubrication effect
- Taking away formed chip from the cutting zone i.e., washing of work piece & tool.

The cooling effect of cutting fluids is the most important parameter. It is necessary to decrease the effects of temperature on cutting tool and machined work piece. Therefore, a longer tool life will be obtained due to less tool wear. The dimensional accuracy of machined work piece will be also improved. The lubrication effect will cause easy chip flow on the rake face of cutting tool because of low friction coefficient. This would also result in the increased by the chips. The influence of lubrication would cause less built-up edge when machining some materials such as aluminum and its alloys. As a result, low surface roughness would be observed by using cutting fluids in machining processes. The effect of the formed chip on the machined surface would be eliminated causing poor surface finish. So, it is also necessary to take the formed chip away quickly from cutting tool and machined work piece surface [3].

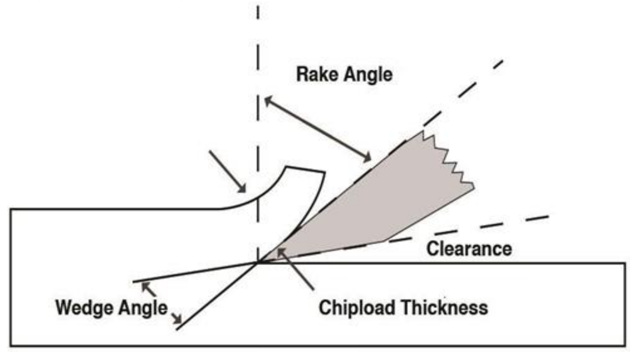

Fig. 1. Various angles of cutting tool

C. Characteristic of Vegetable based Cutting Fluid

Table 1
Basic properties of cutting fluid

Metal Cutting Fluid **	pH (Emulsion 8%)	Density (g/ml)	Viscosity	Flash Point (°C)	Refractive Index
CSCF-I	8.7	0.97	71	218	1.475
SCF-I	9.1	0.98	74	199	1.474
SCF-II	9	0.975	75	170	1.475
CVCF	9.32	0.96	85	205	1.476
CMCF	9.4	0.906	29	175	1.482

*CSCF-I: Crude sunflower cutting fluid; SCF-I: sunflower cutting fluid; SCF-II: sunflower cutting fluid (a mixture of two surfactants); CVCF: Commercial vegetable cutting fluid; CMCF: Commercial mineral cutting fluid [4].

4. Research Methodology

A. Facing Operation

A center hole is drilled deeper for better support during facing operation. Generally, a right-cut facing tool with 580-point angle is used which gives a slight clearance between the center point end the work face.

It is important to ensure that during facing operation, the cutting tool point is not damaged by running it in to the center point. For the first or roughing cut, set the cutter bit, and begin the cut as close as possible to the axis of the work piece, feeding the bit outward, away from the axis. Remove only enough metal to square the end over its entire surface. If the piece must be faced to a specific length, take two or more roughing cuts in the same manner, leaving a small amount of metal to be removed for the finishing cut. For the finishing cut, readjust the bit so that the cutting edge is set nearly flat against the work piece surface, removing only a light, thin chip. The finishing can be taken in either direction, from the axis outward as in the roughing cut, or from the circumference of the work piece inward toward the axis. In facing, care is needed to see that the bit does not contact the tailstock center. Then we'll check the length of the work piece by a vernier caliper and we analyzed that how much the length is reduced against the expected to reduce.

Then we'll apply fishbone diagram to overcome or reduce the defects arises in the cutting of work piece and minimize the error. Then by this so many defects arises for the cause of error in the length of job, then we choose one defect and study about that defect and analyze it. Our defect is tool nose that is basically selection of tool dimension problem. By PDCA we solve the problem. Then we repeat the facing operation and analyze how much improvement is there in the error reading.

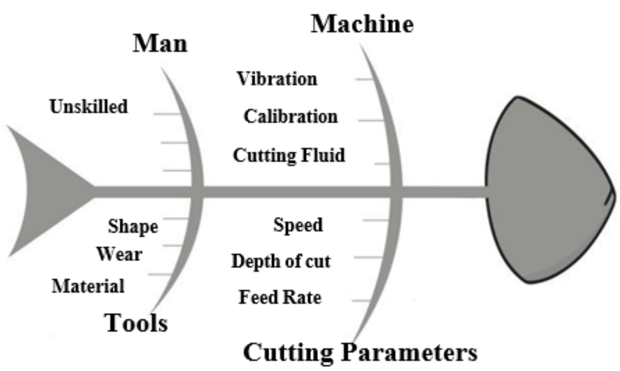

Fig. 2. Fishbone diagram analysis

B. *Process Flow Chart of Facing Operation*

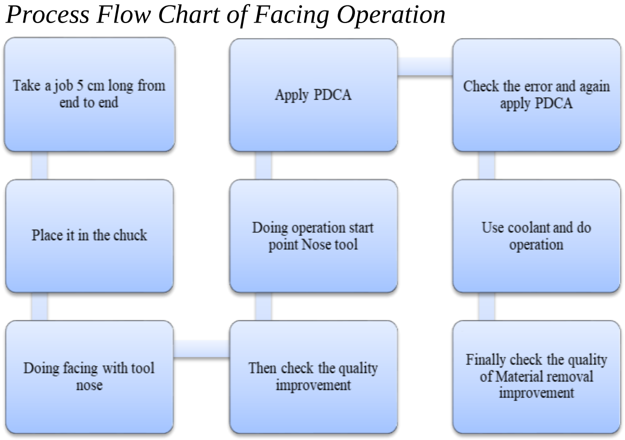

Fig. 3. Flow chart of operation

5. Result

A. *Operation-1 (Tool having nose at cutting point)*

- Feed: 0.5 mm
- Size of the job: 50 mm

Total material to be remove (Theory) = 5 mm
Total material to be remove (Practical) =8.9 mm
Percentage error = 78%

Table 2
Operation-1

S. No.	Initial Length (mm)	After one pass Length (mm)	Difference (mm)
1	50	49	1
2	49	48.3	0.7
3	48.3	47.5	0.8
4	47.5	46.5	1
5	46.5	45.1	0.9
6	45.1	44.3	0.8
7	44.3	43.7	0.6
8	43.7	42.8	0.9
9	42.8	42.1	0.7
10	42.1	41.1	1

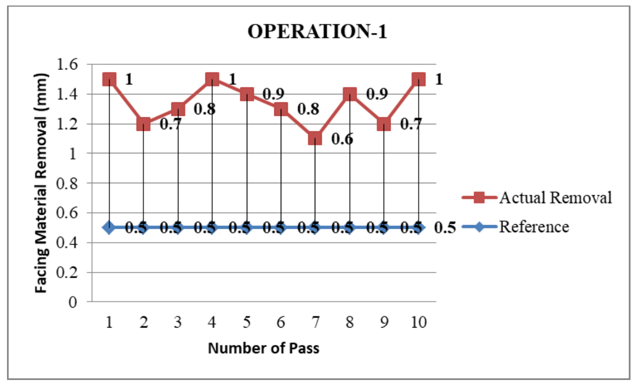

Fig. 4. Variation of material removal in Operation-1

B. *Operation-2 (Tool having sharp cutting point-without nose)*

- Feed: 0.5 mm
- Size of the job: 50 mm

Table 3
Operation-2

S. No.	Initial Length (mm)	After one pass Length (mm)	Difference (mm)
1	50	49.2	0.8
2	49.2	48.5	0.7
3	48.5	47.8	0.7
4	47.8	47.3	0.5
5	47.3	46.4	0.9
6	46.4	45.8	0.6
7	45.8	45.1	0.7
8	45.1	44.3	0.8
9	44.3	43.7	0.6
10	43.7	43.1	0.6

Total material to be remove (Theory) = 5 mm
Total material to be remove (Practical) = 6.9x mm
Percentage error = 38%

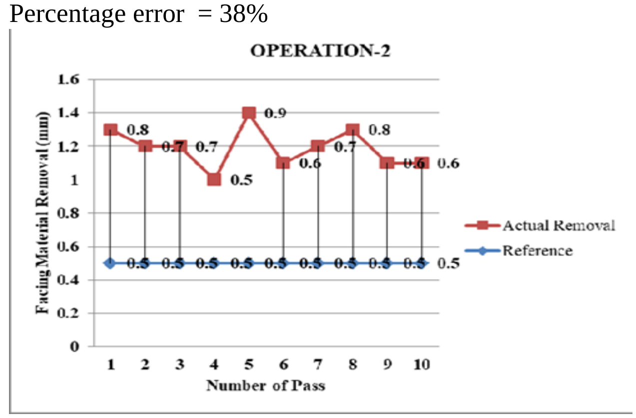

Fig. 5. Variation of material removal in Operation-2

C. Operation-3(Tool having sharp cutting point-without nose)

- Feed: 0.5 mm
- Size of the Job: 50 mm

Table 4
Operation-3

S. No.	Initial Length (mm)	After one pass Length (mm)	Difference (mm)
1	50	49.5	0.5
2	49.5	48.9	0.6
3	48.9	48.1	0.8
4	48.1	47.4	0.7
5	47.4	46.6	0.8
6	46.6	46.1	0.5
7	46.1	45.4	0.7
8	45.4	44.8	0.6
9	44.8	44.3	0.5
10	44.3	43.7	0.6

Total material to be remove (Theory) = 5 mm
Total material to be remove (Practical) = 6.9x mm
Percentage error = 26 %

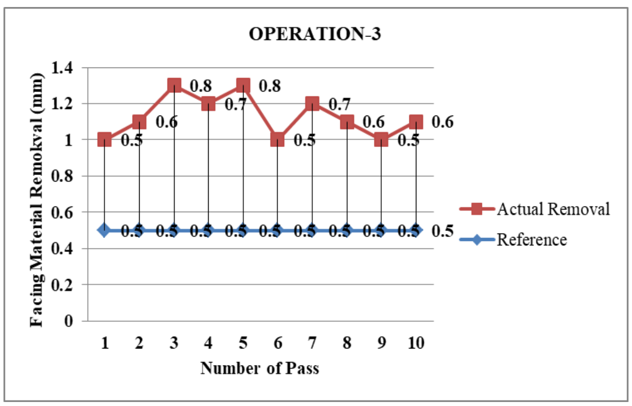

Fig. 6. Variation of material removal in Operation-3

The comparison between operation-1, 2 & 3 is given below. The first operation was done with nose on the cutting tool. Second operation is done without nose of the cutting tool & the third operation was done with sharp edge and using appropriate cutting fluid.

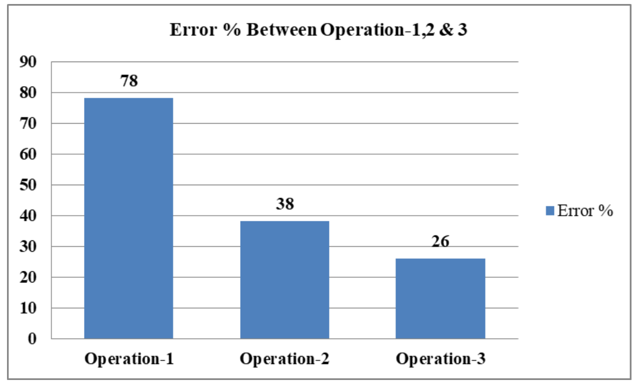

Fig. 7. Errors % between Operation-1, 2 & 3

6. Conclusion

A lathe machine is a heavy duty and high-powered tools largely used in engineering. There are different kinds of lathes used in engineering depending on what the job is, such as mechanical engineering. The selection of tool dimension and proper cutting fluid provides better quality of operation. The tool having nose radius provides excess radial forces. The excess forces cause the removal of thick chips. As result material removal is more as required. Cutting fluid reduces the thermal stress, wear in tool, and formation of continuous chips. We concluded that by applying fish bone diagram and PDCA error can be define. In second operation, after defining errors, we use the tool having sharp cutting nose instead of tool having nose radius. In third operation, we provide proper coolant. So, from the operation 1 to 3 we find there is reduction of error up to 42%.

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