Experimental Investigation of Machining Time in Turning Mild Steel Component using Multi Tool Turning Method

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Abstract— The basic endeavor in any production process is to produce an acceptable component at the minimum possible cost. In order to achieve this objective in metal cutting or metal machining, many attempts have been made in several different ways; such as optimizing the tool life in order to minimize the production cost, maximizing the production rate to reduce the production cost, etc. but no single effort has been found fully successful because of the numbers of complexities involved in the process. For example, if cutting speed is reduced in order to enhance the tool life, the metal removal rate is also reduced and therefore, the production cost increased. A similar effect is observed if the efforts have been made to increase tool life by reducing the feed rate and depth of cut. Against this, if the effort is made to increase the production rate or to reduce the machining time by substantially increasing the cutting speed, feed and depth of cut, the tool life shortens and therefore, tooling cost increases and so the total production cost is also increased. A balance is therefore required to be stuck and a reasonable cutting speed determined, corresponding to which an economical tool life will be ensured and an economical production will result. The present study introduces one such method of improving the production rate in turning operation.

Key words: Machining Time, Production Rate, Cutting Speed, Feed, Depth of Cut

I. INTRODUCTION

Machining is a form of subtractive manufacturing in which a sharp cutting tool is used to physically remove material to achieve a desired geometry. Most of the engineering components such as gears, bolts, screws, nuts need dimensional and form accuracy for serving their purpose, which cannot be obtained through casting or deformation process like forging, rolling, etc. Following figure schematically illustrates the basic principle of Turning.

A wide variety of machining processes are available today that can broadly be classified in three main categories:

1) Conventional machining processes that are used for all kinds of bulk material removal operations.
2) Grinding processes that are primarily employed to obtain a desired surface finish.
3) Non-conventional or advanced machining processes that are used for special kind of material removal operations.

As per the name suggests, non-conventional machining processes do not follow the principle of relative hardness as conventional machining, where the tool material must be harder than the work material for proper removal of material. The processes that remove material by melting, evaporation, chemical and/or electrochemical action etc. are generally referred as non conventional machining processes. Electro-discharge machining, electrochemical machining, laser and electron beam machining are some of the common examples of non-conventional machining processes.

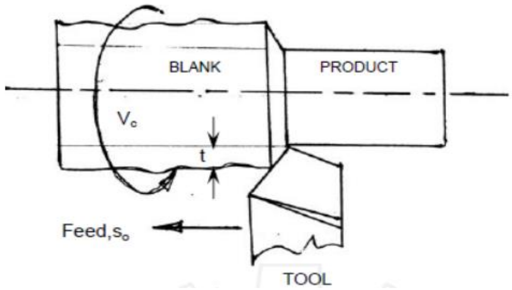

Fig. 1: Principle of Turning

The advantages of machining process are manifold. Some of these broad merits of machining processes are listed below.

- The machining processes can produce a wide variety of dimensions with fine form accuracy.
- Almost all kind of engineering materials and plastics can be machined,
- The machining processes can be easily automated to achieve an excellent productivity
- The role of the process parameters and their control to obtain a desired part with good dimensional accuracy are well established in most of the machining processes.

Turning is a machining process in which a cutting tool, typically a non-rotary tool bit, describes a helical tool path by moving more or less linearly while the work piece rotates. The tool's axes of movement may be literally a straight line, or they may be along some set of curves or angles, but they are essentially linear (in the non-mathematical sense). Usually the term "turning" is reserved for the generation of external surfaces by this cutting action, whereas this same essential cutting action when applied to internal surfaces (that is, holes, of one kind or another) is called "boring". Thus the phrase "turning and boring" categorizes the larger family of (essentially similar) processes. The cutting of faces on the work piece (that is, surfaces perpendicular to its rotating axis), whether with a turning or boring tool, is called "facing", and may be lumped into either category as a subset.

II. LITERATURE SURVEY

Meenu Sahu, "Optimization of Cutting Parameters on Tool Wear, Work piece Surface Temperature and Material Removal Rate in Turning of AISI D2 Steel" International Journal of Advanced Mechanical Engineering. ISSN 2250-3234 Volume 4, Number 3 (2014), pp. 291-298. After the study has been made the authors reach to the following conclusion- The results showed that depth of cut and cutting speed are the most important parameter influencing the tool wear. The minimum tool wear was found at cutting speed of 150 m/min, depth of cut of 0.5 mm and feed of 0.25 mm/rev. Similarly low w/p surface temperature was obtained at cutting speed of 150 m/min, depth of cut of 0.5 mm and feed of 0.25 mm/rev. Whereas, at cutting speed of 250 m/min, depth of cut 1.00 mm and feed of 0.25 mm/rev, the maximum MRR was obtained.

U. D. Gulhane, "Investigation of turning process to improve Productivity (mrr) for better surface finish of Al-7075-T6 using DOE" International Journal of Design and Manufacturing Technology (IJDMT), ISSN 0976 – 6995(Print), ISSN 0976 – 7002(Online) Volume 4, Issue 1, Jan-Apr, 2013. From the current study it can be concluded that the Feed has a greater influence on the Surface Roughness followed by Speed. Depth of Cut had least influence on Surface Roughness. And that the cutting speed has a greater influence on the Surface MRR followed by feed rate. Depth of Cut had least influence on MRR. Also he has given the optimum combination of the cutting parameters speed, feed and depth cut as Cutting speed (15.102 m/min), feed rate (0.3207 mm/rev.) and depth of cut (0.5 mm) are cutting parameters for higher MRR with better surface finish.

S. K. Deepak, "Cutting Speed and Feed Rate Optimization for Minimizing Production Time of Turning Process" International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.5, Sep-Oct. 2012 pp-3398-3401ISSN: 2249-6645. In this research paper, the cutting speed and feed rate were modeled for the minimum production time of a turning operation. The maximum cutting speed, the maximum feed rate, maximum power available and the surface roughness was taken as constraints. The results of the model show that the proposed method provides a systematic and efficient method to obtain the minimum production time for turning. This approach helps in quick analysis of the optimal region which will yield a small production time rather than focusing too much on a particular point of optimization.

Wassila Bouzid, "Cutting parameter optimization to minimize Production time in high speed turning" Journal of Material Processing Technology 161 (2005) 388-395.

The proposed method needs empirical models for tool life, cutting force and roughness. The principle of cutting parameter optimization consists in:

– A calculation of the optimal value of cutting speed Vco.
– A calculation of the maximum cutting speed Vc max (Eq. 26) in relation of the constraint of machine power.
– A calculation of the allowed cutting speed Vca (Eq. 29) in relation of the maximum spindle speed.
– A determination of the used value of cutting speed Vcu (Vco, Vca or Vc max) in relation to the two constraints.
– A calculation of the used value of feed fu in relation to the roughness and the speed Vcu.

The developed model of machining time per piece shows that an optimal value of cutting speed may be calculated for each value of roughness and for each insert. For carbide inserts, the used cutting speed is fixed to the optimum value and the feed calculated in relation to the roughness. For ceramic inserts, the optimal value of cutting speed is equal to 7463 m/min. *V*c max takes high values because the cutting forces are small. So *V*cu was limited only by the allowed spindle speed *V*ca. For insert C, it will be interesting to use NC machine having a high values of maximum spindle speed.

B. Y. Lee, "Cutting parameter selection for maximizing production rate or minimizing the production cost in multistage turning operations" Journal of Material Processing Technology in 6th Feb, 1999

In this work, optimal selection of cutting parameters considering the economics of multistage turning operations has been reported. Polynomial networks have been used to construct the machining model for multistage turning operations. The sequential quadratic programming method is then applied to the networks for searching optimal cutting parameters with maximizing the production rate or minimizing production cost. Practical examples in multistage turning operations are presented to illustrate the approach proposed by this study.

III. NEED OF MULTI TOOL TURNING:

As we have seen that it is the desire of every machining industry to have the rate of production as high as possible in order to acquire high profit by reducing the production cost per component. But one cannot just go on increasing the cutting speed, feed rate and /or depth of cut to achieve high production rate because of the reasons mentioned above.

In order to increase the material removal rate (MRR) the cutting speed should be as high as possible, so in order to improve the rate of production one will just increase the cutting speed keeping all the remaining parameters constant. But the major problem in the increasing the cutting speed is that at higher cutting speed the life of the tool may reduce as the tool gets overheated during the operation. So the cutting speed should be selected in order to enhance the rate of production at the same time with optimum tool life of the tool.

Also in order to increase the material removal rate (MRR) the feed should be as high as possible, so in order to improve the rate of production one will just increase the feed keeping all the remaining parameters constant. But the major problem in the increasing the feed is that at higher feed rate the life of the tool may reduce as the tool gets overheated during the operation. So the feed rate should be selected in order to enhance the rate of production at the same time with optimum tool life of the tool.

The same effect can be seen if we increase the depth of cut, if we want to increase the rate of production, we should increase the depth of cut in the turning operation but the major problem in increasing the depth of cut is that it affects adversely on the surface finish and the life of the tool. This means it is inversely proportional to the surface finish and tool life. So in order to maintain the surface finish and tool life better we cannot increase the depth of cut above certain extent.

Generally conventional turning involves one single point cutting tool (SPCT) which moves linear to the work piece (feed motion) and the work piece is having a rotational motion as it is fixed in the spindle of the lathe machine.

Turning is one of the most common of metal cutting operations. In turning, a work-piece is rotated about its axis as single-point cutting tools are fed into it, shearing away unwanted material and creating the desired part. Turning can occur on both external and internal surfaces to produce an axially-symmetrical contoured part. Parts ranging from pocket watch components to large diameter marine propeller shafts can be turned on a lathe. The capacity of a lathe is expressed in two dimensions. The maximum part diameter, or "swing," and the maximum part length, or "distance between centers." The general-purpose engine lathe is the most basic turning machine tool. As with all lathes, the two basic requirements for turning are a means of holding the work while it rotates and a means of holding cutting tools and moving them to the work. The work may be held on one or by both its ends. Holding the work by one end involves gripping the work in one of several types of chucks or collets. Chucks are mounted on the spindle nose of the lathe, while collets usually seat in the spindle. The spindle is mounted in the lathe's "headstock," which contains the motor and gear train that makes rotation possible.

In modern industry the goal is to manufacture low cost, high quality products in short time. So in order to full fill the above mentioned goal, one has to focus on such a method which will enhance the production rate by minimizing the machining time and at the same time will not affect the quality of the work finished. The purpose can be solved or we have tried to solve the above by introducing the additional tool post into the lathe machine which will consist of another single point cutting tool. We will try to analyze the effect of using this type of additional tool posts on the overall performance of the machine. i.e. on machining time, tool life and surface finish etc.

IV. CONCEPT OF MULTI TOOL TURNING:

The concept of multi tool turning is to use two single point cutting tools rather than one for turning the same shaft.

The second tool should be mounted on the additional tool post. The additional tool post is fitted on the same carriage, and mounted on the same lead screw as the first one. It is noted here that to mount the second tool post on the same lead screw is the most important step in the process. The following figure refers the schematic representation of the two tools working simultaneously on the single work piece.

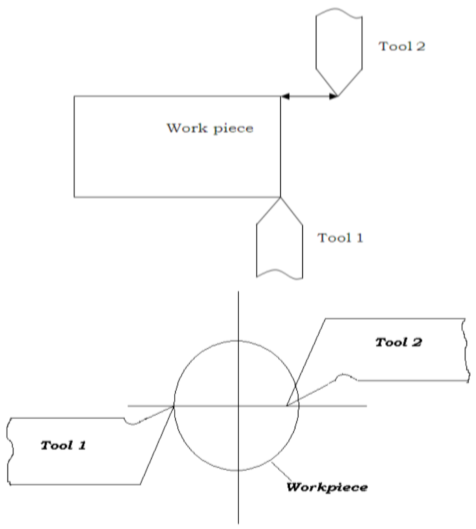

Fig. 2: Schematic representation of multi tool turning

The working model of the lathe machine after introduction of the additional tool post is shown in the following figure.

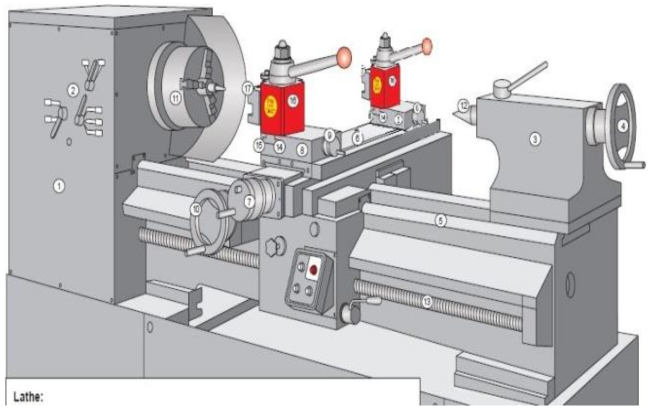

Fig. 3: Working model of the lathe machine.

V. EXPERIMENTAL SET UP

The experimental setup for such turning operation is described in the following figure. It consists of two single point cutting tool mounted on the two tool posts which are located in front of one another. For the simplicity of understanding we call the first single point cutting tool as tool A and the second single point cutting tool as tool B. The first tool that is tool A is fixed in the tool post in conventional manner while the second tool that is tool B is fixed in the second tool post which is mounted on the same carriage but in opposite direction of the first tool post. Both the tool posts are attached or slides over the same lead screw with the help of single handle.

The arrangement is made in such a way that when we rotate the handle, both the tool post along with the tools comes close to each other with the same distance. The center of the tool post is not at the center of the job but a little offset is given to the tool posts. The arrangement is made in such a way that when we give depth of cut of say 2mm to tool A, the tool B automatically provides the depth of cut of 4mm on the other side of the first tool post. Also both these tools are situated at some distance from each other if seen from top, which means tool B starts its operating only after the tool A travels some distance on the work piece or after sufficient interval of time.

It is noted here that for accomplishing the metal cutting, tool B must be placed in the inverted direction in the tool post. So the tool post for the second tool B is situated lower than that of tool post for the tool A in order to achieve the centers of both tools in one plane. The following table states the specifications of the lathe machine which has been used for the above experiment.

Lathe machine specifications:

SN	Specification	Values
1	Height of the centers	165 mm
2	Swing over bed	320 mm
3	Length of bed	1370 mm
4	Range of speed	40 to 950 rpm
5	Motor capacity	1400 rpm, 415v, 3 phase
6	Chuck diameter	75 mm

Table 1: Lathe Machine Specifications

Fig. 4: Multi Tool Turning Setup

This method of turning by single two tools simultaneously would serve the purpose of improving the production rate more profitably than the other three methods discussed earlier. The method does not affect the tool life of the single point cutting tool rather the conditions which given optimum values of cutting speed, feed and depth of cut is selected and instead of turning the component using one single point cutting tool , it is done by using both the tools simultaneously.

The shortcomings of this type of turning are generally associated with the cost of toolings. So it may be proposed that this type of turning setup should be employed if the industry is having mass production with large number of component to be produced without variation in the design.

The concept of multi tool turning method on lathe machine may be considered as a rigorous solution in increasing production rate and improved surface finish while maintaining cutting forces or power at reasonable levels if the arrangement for lathe machine can be properly designed. Multi tool turning method not only increases production rate but also increases tool life in case of volume of metal removal. In order to make arrangement in conventional lathe machine in order to perform multi tool turning on it, the major changes takes place in case of lead screw and compound rest on which we have to mount another tool post. In order to turn conventional lathe machine into multi tool turning lathe machine following parts have to be modified.

VI. EXPERIMENTATION

To perform the experiment following data is selected in order to obtain the best results. The data i.e. cutting speed, depth of cut and the feed rate are selected based on the cutting tool and work piece material, and the work piece material is selected as per the availability. With the above modifications in the existing lathe machine, experimentation is carried out by considering the following machining parameters. For finding out the machining time, we will used the optimized cutting parameters which are ideally suited to give the longer tool life when machining a free machining steel with the HSS cutting tool. The machining parameters are taken as follows:

Tool geometry of HSS tool used:

Back rake angle = 10°, Side rake angle = 7°, End relief angle = 7°, Side relief angle = 7°, End cutting edge angle = 15°, Side cutting edge angle = 15°, and Nose radius = 0.5 mm.

Work piece material = Mild steel
Spindle speed, N = 750 rpm
Feed, f = 0.3 mm/rev
Depth of cut, t = 0.5mm
Length of the job, L = 100mm
Tool overruns and approach, O and A = 15mm
Total length of cut, Lc = L + O + A = 115mm
Initial diameter of work, Di = 30mm
Final diameter, Df = 22mm
Cutting speed (velocity), V = DiL / 1000
V = 70.66m/min ≈ 71m/min

VII. RESULT AND DISCUSSION

Calculations for machining time in Multi tool turning:
Initial diameter of work, Di = 30mm
Final diameter, Df = 22mm
Cutting speed (velocity), V = DiL / 1000
V = 70.66m/min ≈ 71m/min
No. of passes required, n = (Di – Df) / 2t
n = (30 – 22) / 2×1.0 (0.5 mm for each tool)
n = 4
Total machining time, T = Ti + Tc /TL+ Tc × TCT
Where, Ti = Idle time per piece
Tc = Actual cutting time per piece
TL = Tool life
TCT = Average tool changing time per piece
Length of the work piece, L = 100mm
Overrun and Approach, O and A = 35mm
Total length, Lc = 135mm (L + O + A)

From the above formulae, we have calculated the time required to complete each pass in Multi tool turning as follows:

SN	Diameter prior to cut (mm)	Diameter after cut (mm)	Time required to cut in seconds	No of passes
1	30	28	36.00	1
2	28	26	33.60	2
3	26	24	31.20	3
4	24	22	28.80	4
Time required for cutting			129.6	

Table 2: Readings of multi tool turning

VIII. CONCLUSION

As we are using two single point cutting tools rather than one for the machining of the given component, the number of passes required for completing the components or to convert the raw material into the finished component will be reduced to nearly half than that of the conventional turning, hence the machining time for turning the given component will be near to half as compared to the conventional turning.

Multi tool turning method play significant role to improve production rate of turning operation. From the result and discussion it can be concluded that Multi tool turning method can give the approximately double production rate than Conventional turning method as number of pass required for multi tool turning method is exactly half than conventional turning method.

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