Methods to Improve Production Rate in Turning Operation

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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 metal removal rate 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 relationship between various costs associated with production is shown in fig given below. The present study focuses on such methods of improving the production rate in turning operation.

Keywords: production process; metal machining; production rate; cutting speed; feed; depth of cut.

1. INTRODUCTION TO TURNING

Turning is the removal of metal from the outer diameter of a rotating cylindrical workpiece. Turning is used to reduce the diameter of the workpiece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the workpiece will be turned so that adjacent sections have different diameters.

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 workpiece 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 nonmathematical 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.

Turning can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using an automated lathe which does not. Today the most common type of such automation is computer numerical control, better known as CNC. (CNC is also commonly used with many other types of machining besides turning.). The fig below shows the mechanics of chip formation in machining operation.

When turning, a piece of relatively rigid material (such as wood, metal, plastic, or stone) is rotated and a cutting tool is traversed along 1, 2, or 3 axes of motion to produce precise diameters and depths. Turning can be either on the outside of the cylinder or on the inside (also known as boring) to produce tubular components to various geometries. Although now quite rare, early lathes could even be used to produce complex geometric figures, even the platonic solids; although since the advent of CNC it has become unusual to use non-computerized tool-path control for this purpose.

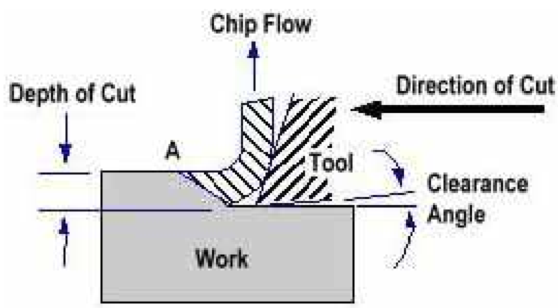

Fig 1. Basics of Chip Formation

The turning processes are typically carried out on a lathe, considered to be the oldest machine tools, and can be of four different types such as straight turning, taper turning, profiling or external grooving. Those types of turning processes can produce various shapes of materials such as straight, conical, curved, or grooved workpiece. In general, turning uses simple single-point cutting tools. Each group of work piece materials has an optimum set of tools angles which have been developed through the years.

The bits of waste metal from turning operations are known as chips (North America), or swarf (Britain). In some areas they may be known as turnings.

2. RATE OF PRODUCTION

The term rate of production refers to the no of components machines per unit time. It is the ratio of the components being machined to the time required for the machining of those components. It is desirable in every industry that this rate of production should be as high as possible. There are number of factors on which this rate is influenced. Some of them are as follows:

- Cutting speed
- Feed
- Depth of cut

2.1 *Cutting speed*: It is one of the major factor on which the rate of production depends. 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.

2.2 *Feed*: It is also major factor on which the rate of production depends. 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.

2.3 *Depth of cut*: In order to improve the material removal rate, the depth of cut should be as high as possible i.e. the depth of cut is directly proportional to the material removal rate so as the rate of production. So 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.

This gives rise to obtaining the optimum speed, feed and depth of cut in order to improve the production rate in turning operation.

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 metal removal rate 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.

3. FACTORS AFFECTING THE RATE OF PRODUCTION

There are several factors which affect the production rate of any machining operation. Some of them are directly affecting the production rate like, cutting speed, feed rate and depth of cut, while other may influence the rate of production indirectly like, presence or absence of cutting fluid, nature of work to be performed, nature of machine tool on which work is to be performed. In order to consider the effect of each parameter one should have detailed knowledge about all these parameters affecting the production rate.

3.1 *Cutting speed, feed and depth of cut:*

The cutting speed of a cutting tool may be defined as the speed at which the cutting edge passes over the material. Cutting speed is ordinarily expressed in meter per minute, often referred to as surface speed in meter per minute.

The feed of a cutting tool is the distance the tool advances into or along the work piece each time the tool point passes a certain position in its travel over the surface. In the case of turning on the lathe, the feed is the distance that the tool advances in one revolution of the work piece. On a shaper, the feed is the distance the work is moved relative to the tool for each cutting stroke. For single point tools, feed is specified in millimeters per revolution, millimeters per stroke, etc. It also may be expressed as millimeters per tooth for milling cutters and broaches.

Since so many factors must be given considerations, it is difficult to state definitely what the speed and feed foe a given material should be. In general the speed and feed are determined by the following factors.

- Kind of material being cut.
- Kind of material and life of the tool.
- Shape and dimensions of the cutting elements.
- Size of chip cross section.
- Type of finish desired.
- Rigidity of the machine tool.
- Type of coolant used.

3.2 *Machinability*

The ease with which a given material may be worked with a cutting tool is machinability. It depends on:

- Chemical composition of the material of work piece.
- Micro structure
- Mechanical properties.
- Physical properties.
- Cutting conditions.

In evaluating the machinability the following criteria may be considered.

- Tool life between grinds.
- Value of cutting forces.
- Quality of surface finish.
- Form and size of chips.
- Temperature of the cutting.
- Rate of cutting under the standard force.
- Rate of metal removal.

The main factors to be choosen for judging the machinability depends on the type of operation and the production requirements. Some factors that are used to predict and calculate machinability are tensile strength, Brinell hardness and shear angle. The shear angle of given material may be calculated by comparing chip thickness before removal and chip thickness after removal. Let the chip thickness before removal is ‘a’ and that of after removal is ‘b’. The shear angle is found by the formula-

Tan $\beta = \cos\gamma/1-\sin\gamma$.

3.3 *Machinability index:*

Machinability is a term indicating how the work material responds to the cutting process. In the most general case good machinability means that material is cut with good surface finish, long tool life, low force and power requirements, and low cost.

A closer definition of machinability requires that some quantitative judgments be made. Several possibilities are available, but in practice so called machinability index is often quoted. The machinability index KM is defined by

$$KM = V60/V60R$$

Where V60 is the cutting speed for the target material that ensures tool life of 60 min, V60R is the same for the reference material. Reference materials are selected for each group of work materials (ferrous and non-ferrous) among the most popular and widely used brands.

If KM > 1, the machinability of the target material is better that this of the reference material, and vice versa. Note that this system can be misleading because the index is different for different machining processes.

3.4 *Tool life*:

Tool life can be defined as the time interval for which the tool works satisfactorily between two successive grindings. Thus, it can be basically conceived as functional life of the tool. The tool is subjected to wear continuously while it is operating. Obviously, after some time, when the tool wear is increased considerably, the tool losses its ability to cut efficiently and must be reground. If not it will totally fail. The life can be effectively used as the basis to evaluate the performance of the tool material, access machinability of the work piece material and know the cutting condition. Following are the factors affecting the tool life of the cutting tool.

- Cutting speed
- Feed and depth of cut
- Tool geometry
- Tool material
- Work material
- Nature of cutting
- Rigidity of the machine tool
- Use of cutting fluid

4. METHODS OF IMPROVING THE RATE OF PRODUCTION:

4.1 *By increasing the cutting speed:*

It is one of the major factor on which the rate of production depends. 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.

The effect of increasing the cutting speed on the tool life will be revealed from the fig. below:

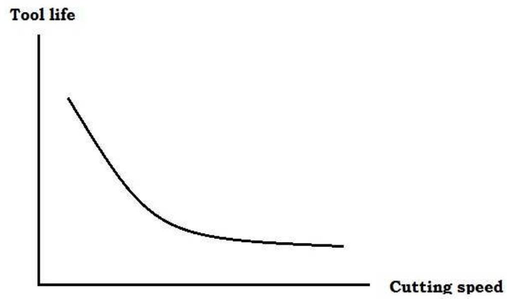

Fig.2 Relationship between cutting speed and tool life

It is observed in the above fig that cutting speed should not be increased beyond a certain limit in order to achieve good tool life which in turn results in reduction of tooling cost and ultimately the production cost.

4.2 ***By increasing the feed rate:***

It is also major factor on which the rate of production depends. 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 effect of increasing the feed on the tool life will be revealed from the fig. below:

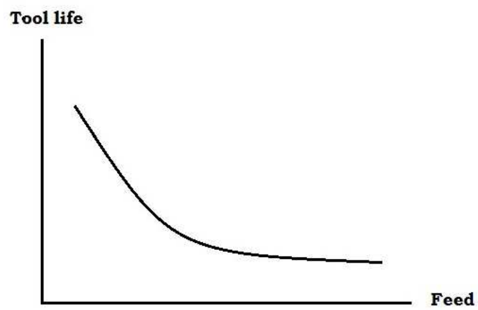

Fig. 3 Relationship between feed and tool life

It is observed in the above fig that cutting speed should not be increased beyond a certain limit in order to achieve good tool life which in turn results in reduction of tooling cost and ultimately the production cost.

4.3 By increasing the depth of cut

In order to improve the material removal rate, the depth of cut should be as high as possible i.e. the depth of cut is directly proportional to the material removal rate so as the rate of production. So 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.

It is observed in the above fig that depth of cut should not be increased beyond a certain limit in order to reduce the cutting force required to cut the metal and to achieve good tool life which in turn results in reduction of tooling cost and ultimately the production cost.

The effect of increasing the depth of cut on the cutting force will be revealed from the fig. below:

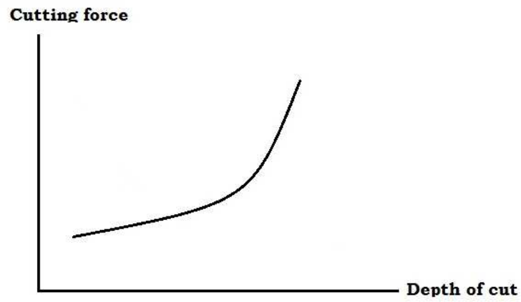

Fig. 4 Relationship between depth of cut and cutting force

4.4 ***By using more than one tool simultaneously:***

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. Turning is the most common method for cutting and especially for the finishing machined parts. Furthermore, in order to produce any product with desired quality by machining, cutting parameters should be selected properly. In turning process parameters such as cutting tool geometry and materials, the depth of cut, feed rates, cutting speeds as well as the use of cutting fluids will impact the material removal rates and the machining qualities like the surface roughness, the roundness of circular and dimensional deviations of the product. Surface roughness of cutting process has been studied intensively, mostly through experiments.

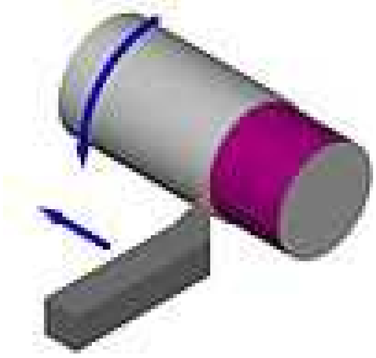

Fig. 5 Turning Operation

Conventionally turning is done by holding a work piece rigidly in the work holding device called chuck which is attached to the spindle of the lathe machine. The spindle rotates about the axis which is perpendicular to the spindle. The tool which is generally single point cutting tool is fixed onto the tool post which is free to move linearly in the direction parallel and perpendicular (in facing operation) to the direction of the axis of rotation of the spindle. As the tool material is harder than the work piece material, when the relative motion between the tool and the work piece occurs, the material shears along the shear plane. Thus some material is removed in the form of chip from the work piece leading to the formation of the desired part. The fig below shows the conventional setup for the turning operation.

Fig. 6 Conventional Turning Setup

5. EXPERIMENTAL SETUP:

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 arrangement is shown in the figure.

Fig. 7 Multi Tool Turning Setup

This method of turning by sing 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.

6. ADVANTAGES OF THE MULTI TOOL TURNING APPROACH:

1. By using two single point cutting tools rather than one, machining (turning in this case) time will be reduced considerably.
2. For similar volume of metal removal, tool life of the tools used in multi tool turning is more as compared to the tool life of the tool in single tool turning.
3. To obtain good quality of finished surface, the depth of cut should be minimum. It is possible to reduce the depth of cut in multi tool turning to obtain high surface finish without affecting the metal removal rate
4. The amount of cutting force or power consumption is also reduced because the depth of cut is decided in accordance with the standard specifications.

7. TENTATIVE SHORTCOMINGS OF THE MULTI TOOL TURNING APPROACH:

1. Cost associated with the toolings is increased.
2. The new attachment used to accommodate the second tool will carry high cost.
3. The technique should be used for mass production where the quantity of production is very high with little or no variation. This compensates the high initial cost of the attachment.
4. As both the tools are somewhat offset to each other, finishing the turning operation is not possible in single pass using both the tools.
5. To operate the tools having such type of attachment requires skilled labor.

So it is suggested that this technology should be used in the industries where there is a large number of components to be turned at lowest possible cost.

8. CONCLUSION

The basic objective 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 metal removal rate 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

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. The present paper focus the possibility of employing one more single point cutting tool in the operation and then checking its effect on overall productivity of the component.

REFERENCES

[1] A textbook of *"Workshop technology"* by B. S. Raghuwanshi, Dhanpat rai and co publications.
[2] A textbook of *"Workshop technology Vol. II"* by Hajra Chaudhary and, Dhanpat Rai and co publications.
[3] A textbook of *"Fundamentals of metal cutting"* by B. L. Juneja,
[4] A textbook of *"Workshop technology part II"* by W. A. J. Chapman, The English Language book society and Edward Arnold publications.
[5] A textbook of *"Metal cutting Theory and Practice"* by A. Bhattacharya, New Central Book Agency Ltd. publications.
[6] http://www.me.nchu.edu.tw/CIM/courses/Manufacturing Processes/Ch21-MetalCuttingTheory-Wiley.pdf
[7] http://www.universe.bits-pilani.ac.in/uploads/4 metal cutting.pdf