Problems in Improving Production Rate in Turning Operation

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Abstract

Machining has become indispensable to the modern industry. It is used directly or indirectly in the manufacture of almost all the goods and services being created all over the world. It is the basis of everything manufactured such as sewing machines, papers, drug, computers, cars etc. wherever metal is used in any manmade object, one can be sure that it must have reached its final stage through processing with machine tools. Even the parts made from plastics require metal dies made by machining processes.

Turning is one such machining process used to reduce the diameter of the parts having circular outer profile. 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 term productivity, in general, simply refers to the ratio of rate of output and the rate of input. It is the desire of any manufacturing industry that the machines they are using to convert certain raw material into finished product have higher productivity. The present paper pays attention towards the major barriers in improving the productivity of the component when it is subjected to turning operation on simple lathe machine.

Keywords: Machining, turning operation, productivity, lathe machine etc.

1. Introduction to Turning

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece 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 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 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 workpiece (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.)

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.

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

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grooved work piece. 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. Requirement of the turning process

The basic elements of all the machining operations including turning are given as below:

- Work piece
- Tool
- Chip
- Relative motion between the tool and the work

These elements are shown in the following fig, which represents the cutting action of the tool in two directional or orthogonal cutting. For providing the cutting action, a relative motion between the tool and the work piece is necessary. This relative motion can be provided by either keeping the work piece stationary or moving the tool or by keeping the tool stationary and moving the work piece or by moving both in relation to each other.

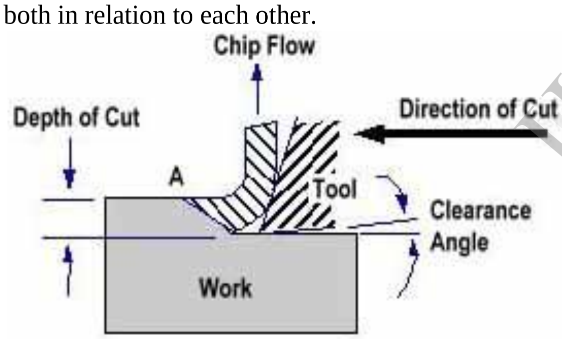

Fig. 1 Chip Formation in turning

The work piece provides the parent metal, from which the unwanted metal is removed by the cutting action of the tool to obtain the predetermined shape and size of the component. The chemical component and the physical properties of the metal of the work piece have a significant effect on the machining/turning operation. Similarly, the tool material and the geometry of the tool are equally responsible for the successful machining/turning operation. The type and the geometry of the chip formed are greatly affected by the metal of the work piece, geometry of cutting tool and the method of cutting, etc. Chemical composition and the rate of flow of cutting fluid also provide considerable influence over the turning operation.

3. Lathe machine

A lathe is a machine tool used principally for shaping pieces of metal, wood, or other materials by causing the work piece to be held and rotated by the lathe while a tool bit is advanced into the work causing the cutting action. Lathes can be divided into three types for easy identification: engine lathe, turret lathe, and special purpose lathes. Some smaller ones are bench mounted and semi-portable. The larger lathes are floor mounted and may require special transportation if they must be moved. Field and maintenance shops generally use a lathe that can be adapted to many operations and that is not too large to be moved from one work site to another. The engine lathe is ideally suited for this purpose. A trained operator can accomplish more machining jobs with the engine lathe than with any other machine tool. Turret lathes and special purpose lathes are usually used in production or job shops for mass production or specialized parts, while basic engine lathes are usually used for any type of lathe work. Mainly used in production for multitask work.

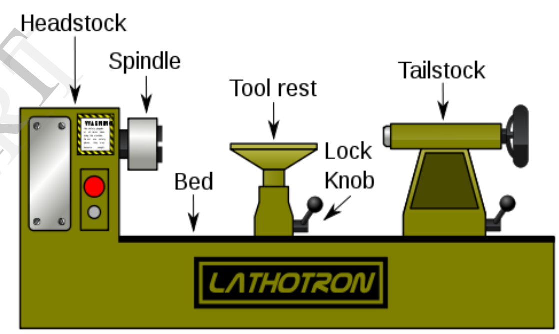

Fig. 2 Typical Lathe machine

3.1 Work-holding methods

- Chuck: Chucks are a very common work holding devices. There are many types, some for round and square stock, and other for irregular shapes. Chuck may of three jaws (Universal) or having four jaws (Individual).
- Collet: Primarily used for small round work pieces.

4. Parts of Lathe machine

A lathe may or may not have legs which sits on the floor and elevates the lathe bed to a working height. Some lathes are small and sit on a workbench or table, and do not have a stand.

Almost all lathes have a bed, which is (almost always) a horizontal beam (although CNC lathes commonly have an inclined or vertical beam for a bed

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to ensure that swarf, or chips, falls free of the bed). Woodturning lathes specialized for turning large bowls often have no bed or tail stock, merely a free-standing headstock and a cantilevered tool rest.

At one end of the bed (almost always the left, as the operator faces the lathe) is a headstock. The headstock contains high-precision spinning bearings. Rotating within the bearings is a horizontal axle, with an axis parallel to the bed, called the spindle. Spindles are often hollow, and have exterior threads and/or an interior Morse taper on the "inboard" (i.e., facing to the right / towards the bed) by which work-holding accessories may be mounted to the spindle. Spindles may also have exterior threads and/or an interior taper at their "outboard" (i.e., facing away from the bed) end, and/or may have a hand-wheel or other accessory mechanism on their outboard end. Spindles are powered, and impart motion to the work piece.

The spindle is driven, either by foot power from a treadle and flywheel or by a belt or gear drive to a power source. In most modern lathes this power source is an integral electric motor, often either in the headstock, to the left of the headstock, or beneath the headstock, concealed in the stand.

In addition to the spindle and its bearings, the headstock often contains parts to convert the motor speed into various spindle speeds. Various types of speed-changing mechanism achieve this, from a cone pulley or step pulley, to a cone pulley with back gear (which is essentially a low range, similar in net effect to the two-speed rear of a truck), to an entire gear train similar to that of a manual-shift auto transmission. Some motors have electronic rheostat-type speed controls, which obviates cone pulleys or gears.

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The counterpoint to the headstock is the tailstock, sometimes referred to as the loose head, as it can be positioned at any convenient point on the bed, by undoing a locking nut, sliding it to the required area, and then re-locking it. The tail-stock contains a barrel which does not rotate, but can slide in and out parallel to the axis of the bed, and directly in line with the headstock spindle. The barrel is hollow, and usually contains a taper to facilitate the gripping of various type of tooling. Its most common uses are to hold a hardened steel center, which is used to support long thin shafts while turning, or to hold drill bits for drilling axial holes in the work piece. Many other uses are possible.

Metalworking lathes have a carriage (comprising a saddle and apron) topped with a cross-slide, which is a flat piece that sits crosswise on the bed, and can be cranked at right angles to the bed. Sitting atop the cross slide is usually another slide called a compound rest, which provides 2 additional axes of motion, rotary and linear. Atop that sits a tool-post, which holds a cutting tool which removes material from the work piece. There may or may not be a lead screw, which moves the cross-slide along the bed.

Woodturning and metal spinning lathes do not have cross-slides, but rather have banjos, which are flat pieces that sit crosswise on the bed. The position of a banjo can be adjusted by hand; no gearing is involved. Ascending vertically from the banjo is a tool-post, at the top of which is a horizontal tool rest. In woodturning, hand tools are braced against the tool rest and levered into the workpiece. In metal spinning, the further pin ascends vertically from the tool rest, and serves as a fulcrum against which tools may be levered into the work piece.

5. Choosing a Cutting Tool

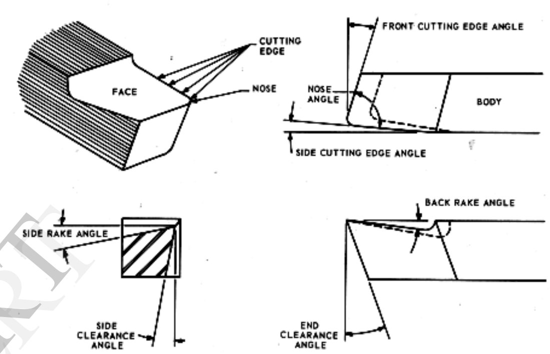

Fig.3 Cutting Tool Terminology

The figure above shows a typical cutting tool and the terminology used to describe it. The actual geometry varies with the type of work to be done. The standard cutting tool shapes are shown below.

- 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.

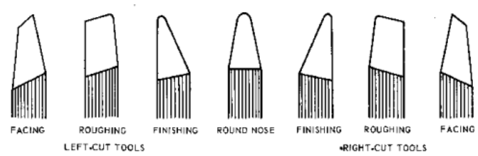

Fig. 4 Standard Cutting Tools

6. Cutting Speed, Feed and Depth of Cut

Cutting speed of a cutting tool can be defined as the rate at which its cutting edge passes over the surface of the work piece in unit time. It is normally expresses in terms surface speed in meters per minute.

It is a very important aspect in machining since it considerably effect the tool life and efficiency of machining. Selection of a proper cutting speed has to be made judiciously. If it is too high, the tool gets overheated and its cutting edge may fail, needing regrinding. If it is too low, too much time is consumed in machining and full cutting capacities of the tool and the machine are not utilized, which results in lowering the productivity and increasing the production cost.

Feed of the cutting tool can be defined as the distance it travels along or into the work piece for each pass of its point through a particular position in unit time. For example in turning operation on lathe it is equal to the advancement of the tool corresponding to each revolution of the work piece. The cutting speed and the feed of a cutting tool is largely influenced by the following factors.

- Material being machined.
- Material of the cutting tool.
- Geometry of the cutting tool.
- Required degree of surface finish.
- Rigidity of the machine tool.
- Type of coolant being used.

Depth of cut: it is an indicative of the penetration of the cutting edge of the tool into the work piece material in each pass, measured perpendicular to the machined surface, i.e. it determines the thickness of the metal layer removed by the cutting tool in one pass.

Table.1

Cutting speeds for various materials using a plain high speed steel cutter		
Material type	**Meters per min (MPM)**	**Surface feet per min (SFM)**
Steel (tough)	15–18	50–60
Mild steel	30–38	100–125
Cast iron (medium)	18–24	60–80
Alloy steels (1320–9262)	20-37	65–120
Carbon steels (C1008-C1095)	21-40	70–130
Free cutting steels (B1111-B1113 & C1108-C1213)	35-69	115–225
Stainless steels (300 & 400 series)	23-40	75–130
Bronzes	24–45	80–150
Leaded steel (Leadloy 12L14)	91	300
Aluminium	75–105	250–350
Brass	90-210	300-700 (Max. spindle speed)

7. 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

8. Machinability

Machinability of a material gives the idea of the ease with which it can be machined.the parameters generally influencing the machinability of the material are:

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

Since this property of the material depends on the various variable factors, it is not possible to evaluate

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the same in terms of precise numerical value, but as a relative quantity. The criteria determining the same is as follows:

- Tool life: the longer the tool life it enables at a given cutting speed the better is the Machinability.
- Surface finish: it is also directly proportional i.e. the better the surface finish the higher is the Machinability.
- Power consumption: lower power consumption per unit of metal removed indicates better Machinability.
- Cutting forces: the lesser the amount of cutting force required for the removal of a certain volume of the metal or the higher the volume of metal removed under the standard cutting forces the higher is the Machinability.

The term **machinability** refers to the ease with which a metal can be machined to an acceptable surface finish. Materials with good machinability require little power to cut, can be cut quickly, easily obtain a good finish, and do not wear the tooling much; such materials are said to be **free machining**. The factors that typically improve a material's performance often degrade its machinability. Therefore, to manufacture components economically, engineers are challenged to find ways to improve machinability without harming performance.

Machinability can be difficult to predict because machining has so many variables. Two sets of factors are the condition of work materials and the physical properties of work materials.

The condition of the work material includes eight factors: microstructure, grain size, heat treatment, chemical composition, fabrication, hardness, yield strength, and tensile strength.

Physical properties are those of the individual material groups, such as the modulus of elasticity, thermal conductivity, thermal expansion, and work hardening.

Other important factors are operating conditions, cutting tool material and geometry, and the machining process parameters.

9. 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

9.1 Effect of Cutting speed on rate of production:

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 following fig reveals the effect of cutting speed on tool life.

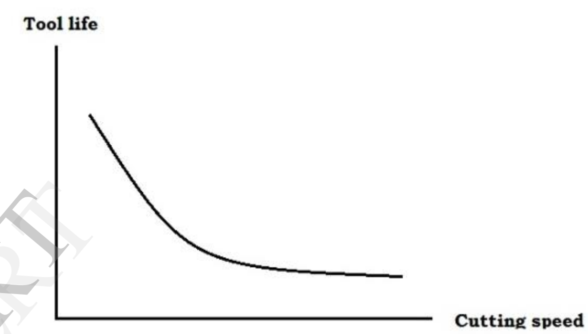

Fig. 5 Relationship between cutting speed and tool life

9.2 Effect of feed on rate of production:

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 following fig reveals the effect of feed on tool life.

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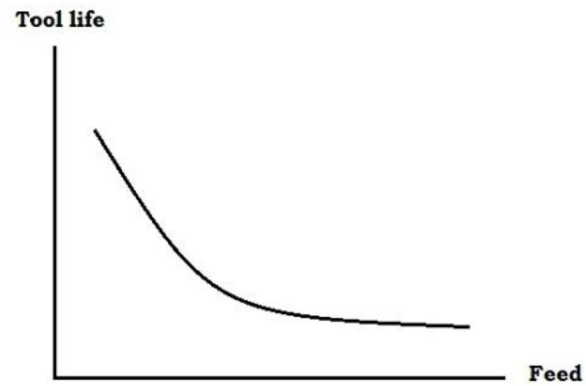

Fig. 6 Relationship between feed and tool life

9.3 Effect of depth of cut on rate of production:

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 following fig reveals the effect of depth of cut on power consumption

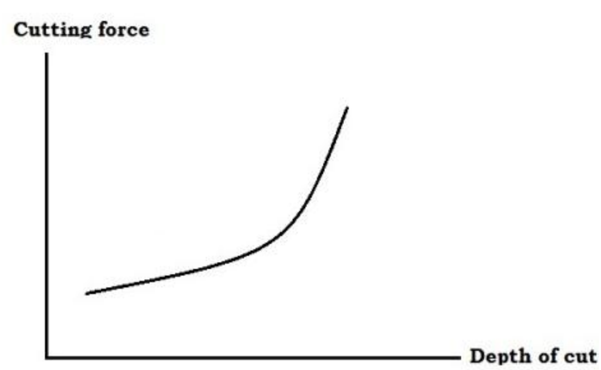

Fig. 7 Relationship between depth of cut and cutting force

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.

10. Conclusion

We have seen that in order to increase the production rate one has to give up with the quality of the surface being machined, the effective tool life of the cutting tool and ultimately, the cost of production. Every metal working industry is facing the problem of improving the production rate without sacrificing these parameters. The present paper reveals the facts about why one cannot increase the cutting parameters of the turning process in order to achieve the higher rate of production. Further there may some another methods which ensures improving of the production rate without affecting the above said factors i.e. tool life, surface finish and cost of production. Such methods should be ideal one for the mass production industry where there is a large number of quantities being machines with little or no variations at all.

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