INTRODUCTION TO MACHINING

Machining also regarded as metal cutting is a process required to create a part by removing unwanted material from a workpiece in the form of chips. Of all manufacturing processes, machining is the most important because it is either used as a clean-up process after an initial manufacturing operation, and due to its ability to produce high precision works involving tight tolerances and high-quality finishes. A typical machining process is depicted in figure 1.

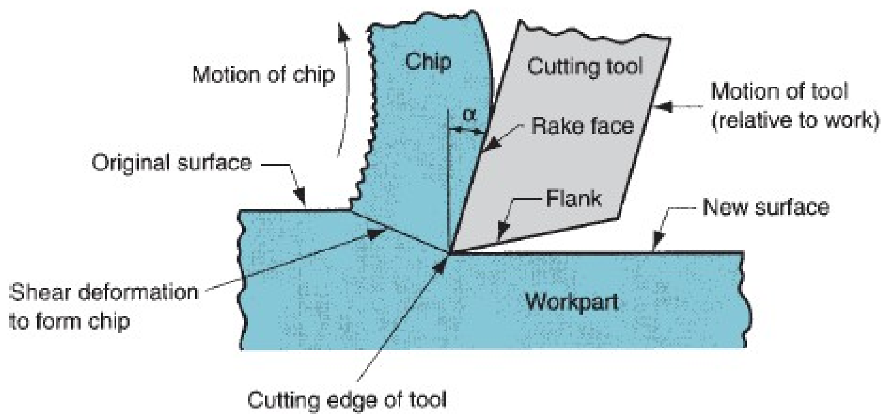

Figure 1 Basic machining process

In the study of machining, there are several considerations regarded as inputs which affect the quality of the part to be produced. The input considerations are categorised into;

- Machine tool selection: Lathe, milling machine, grinding machine
- Workpiece parameters: Material type, hardness and purity
- Cutting parameters: Depth of cut, feed, speed
- Cutting tool parameters: Tool geometry, material hardness and coating

Depending on the operation to be carried out, there are 6 basic machining processes. These processes are **turning, milling, drilling, grinding, broaching and planing**. To perform the machining operation required to produce a part, a machine tool is used. A machine tool is a power-driven tool required to conduct a given machining operation. A machine tool works in several ways.

- Provides the necessary power required for the cutting operation.
- Constrains the workpiece to enable proper and accurate cutting.
- Input the necessary cutting parameters based on design considerations.
- House the cutting tool that performs the actual chip production process.

The basic machine tools used in machining are summarised in table 1.

Table 1 Machine tools summary

S/No	Machine tool	Operation
1	Lathe	This machine tool removes material from a workpiece by rotating the workpiece at a high rotational speed while a stationery cutting tool shaves into it to create the required part. The end result of parts machined using the lathe are usually cylindrically shaped. Operations that can be carried out using the lathe include boring, knurling, drilling and threading.
2	Milling machine	This machine tool works to remove material by feeding the secured workpiece into a rotating multi-edged cutting tool.
3	Grinding machine	This machine tool removes materials by putting the workpiece in contact with a rotating abrasive wheel referred to as a grinding wheel. The most common materials used in the production of grinding wheels are silicon carbide and aluminium oxide.
4	Broaching machine	A broaching machine produces chips by moving the cutting tool referred to as the broach against the workpiece.
5	Drill press	The drill press or drilling machine performs drilling operations by using a twist drill or drill bit to cut holes into a workpiece.
6	Planer	This is a reciprocating type of machine tool in which the ram moves the cutting tool backwards and forwards in a straight line. It is primarily used to produce flat surfaces.

Cutting conditions in turning

In turning operations, there are two major machining processes based on the position of the edge of the cutting tool relative to the workpiece. These machining processes are illustrated in figure 2.

- Orthogonal cutting: Also regarded as 2-dimensional metal cutting, the cutting tool is perpendicular to the workpiece. In orthogonal cutting, no force exists in the direction perpendicular to the relative motion between the workpiece and the cutting tool. The cutting forces exerted on the workpiece during this type of cutting are cutting force and radial force.
- Oblique cutting: This type of cutting is also referred to as 3-dimenstional cutting. Here, the cutting edge is set at an angle during the metal cutting process. The cutting tool in this case is set at an oblique angle in the direction of the tool’s motion. In this process of metal cutting, the 3 components of force (cutting force, radial force and feed force) are acting on the workpiece.

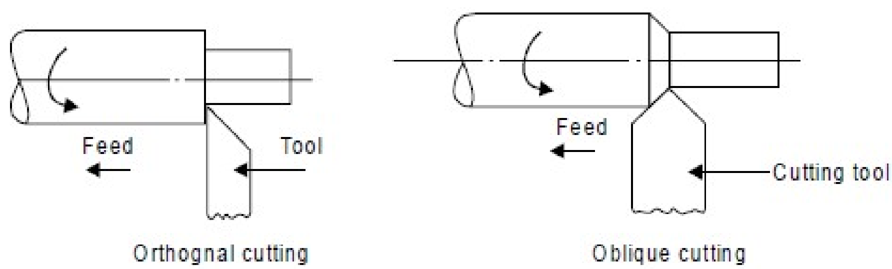

Figure 2 Orthogonal and oblique cutting processes.

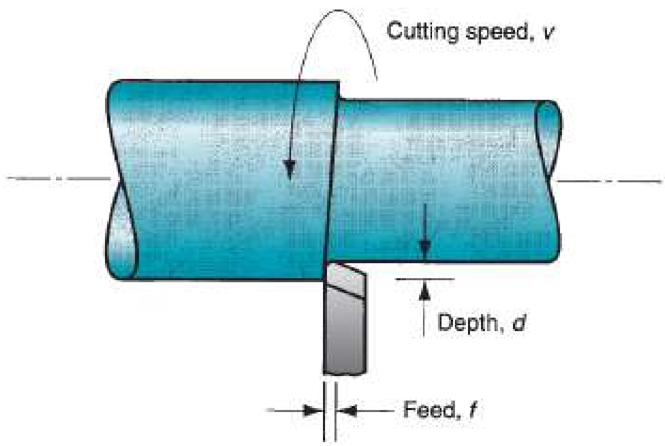

Figure 3 Illustration of cutting parameters

The cutting speed (V_s) is the velocity of the cutting tool relative to the workpiece. This is the primary cutting motion. The feed (f) is the distance the cutting tool moves in one revolution of the spindle. The depth of cut (d) is the distance the cutting tool is plunged into the workpiece for every cut. These cutting parameters are shown in figure 3.

The cutting speed (m/min) is given as

$$V_s = \frac{\pi D_1 N_s}{1000}$$

Where D_1 is the initial diameter (m).

Where D_2 is the final diameter (m).

The depth of cut (m) d is given as

$$d = \frac{D_1 - D_2}{2}$$

Machining time (mins) is the time required to cut the entire length of the part. This is designated as T_m.

$$T_m = \frac{L_m}{f \times N_s}$$

Where L_m is the machined length.

Material removal rate (MRR) simply put is the amount of material removed from the workpiece per unit time

Mathematically, MRR (mm^3/min) is given as

$$MRR \approx V_s f d$$

However, for most machining operations, the MRR can be obtained using the expression

$$MRR = \frac{Vol\ of\ cut}{T_m}$$

Cutting tools

A cutting tool has one or more sharp cutting edges used for the material removal operation during machining. Usually, the cutting tool is made out of a material harder than the workpiece. Connected to the cutting edge are 2 surface, **rake face** which directs the flow of the newly formed chip and **flank of the tool** which provided clearance between the tool and the newly generated work surface. Every single cutting tool edge is rounded. This rounded edge referred to as the nose absorbs and distributed shock during impact loading in machining. It also offers a small amount of rubbing between the flank surface and the machined surface which improves the surface finish. Cutting tools are generally categorized based on the complexity of its geometry. Based on this categorization, cutting tools can either be,

- Single point: This category of cutting tools have only one cutting edge. Operations that utilize single point cutting tools include turning and planing.
- Multi-cutting-edge tool: These cutting tools have more than one cutting edge. This category of cutting tools removes material by rotating the cutting tool relative the workpiece.

Cutting tool materials

For a material to be suitable for use as a cutting tool, it must possess 3 main characteristics. These are;

- Toughness: This is the capacity of a material to absorb energy without failure. It is usually characterized by a combination of strength and ductility of a material.
- Hot hardness: This is the ability of a cutting tool to retain its hardness at elevated temperatures.
- Wear resistance: The cutting tool must possess high resistance to all forms of wear. In addition to hardness, other criteria including tool surface finish, tool chemistry and work material affects the wear resistance of the cutting tool.

Examples of cutting tool materials include; high carbon steel, cast cobalt alloy, cemented carbide, cermet, cubic boron nitride, natural diamond and polycrystalline diamond.

Cutting tool failure

- Fracture failure: This mode of failure occurs when the cutting force at the tool point becomes excessive resulting in a catastrophic failure.
- Temperature failure: This takes place when the cutting temperature as a result of friction between the cutting tool and workpiece is too high for the cutting tool material. This results in the softening of the tool point leading to plastic deformation and loss of cutting edge for the cutting tool.
- Gradual wear. This failure mode occurs due to extended use of the cutting tool. Gradual wear of the cutting edge leads to the loss of tool shape and reduction in cutting efficiency. Gradual tool wear could be brought about by certain mechanism including abrasion, adhesion, diffusion, oxidation and fatigue.