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INTRODUCTION

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CHAPTER-1

1.1 Introduction

In the metal working industry work piece of different shapes, dimensions and different materials are worked. Produced/Manufactured undergoing many changes due to the unending needs of the customers for qualitative, reliable and sophisticated parts and products in the modern and technological world. To meet such requirements on one hand and global market on other hand, manufactures around the world are striving for lower price solutions in order to maintain their competitiveness on machined components and manufactured goods. Thus the manufacturing of goods involves the machining of components with the cutting tool set loaded on the machine tools. Thus the Production/Manufacturing of any part depends on the effective working of the cutting tool and thus leading to meet the production schedules and cost effectiveness. To meet such demands in Production/Manufacturing, the technology has been playing enormous role in advancing the metal working industry and creating opportunities in the reduction of cost and improvement quality.

To achieve the above the selection of suitable material, cutting tool and combination plays greater role in Production/Manufacturing parts. Further, the selection of material with required hardness is a basic requirement. After the selection of appropriate cutting tool for the work material, the next step is the selection of manufacturing or production process. The lathe involved in turning is considered to be
the first and fundamental operation for metal removal with the usage of single point cutting tool.

1.2 Manufacturing system

The manufacturing system can be defined as: systems in which raw materials are processed from one form into another, known as product, gaining a higher or added value in the process and thus creating wealth in the form of a profit.

Figure 1.1: Input / output relationships in Manufacturing System, ASM [11]

Figure 1.1 shows the input/output relationships in manufacturing system. The products are classified as consumer products or producer products. The producer products which are manufactured for the other organizations to use in the manufacture of their products.
1.3 METAL CUTTING

Metal cutting process can be viewed as consisting of independent (input) variables and dependent process variables leading to output performance characteristics. The engineer or machine tool operator has direct control over the input variables and can specify or select them when setting up the machining process. Several input and output variables and relationships associated with metal cutting operation are shown in figure 1.2.

![Figure-1.2: Input / output relationships in metal cutting, ASM [11]](image)

1.3.1 Independent Input Variables

(a) Workpiece Material:

The metallurgy and chemistry of the work piece can either be specified or is already known. Quite often, a material is selected for a particular application chiefly because of its use. Cast iron and Aluminium, for example, are known to machine easily. Other metals, such as stainless steel or Titanium are difficult to machine. They often
require large cutting forces and result in poor surface finishes, thus leading for short cutting tool life, yet the metals are selected to meet other functional design criteria.

(b) Starting geometry:

The size and shape of the workpiece may be dictated by production process (such as casting forging, forming etc.) or may be selected from standard machining stock(for example, bar stock for screw machines). Usually such variables directly influence the machine process or processes that are selected, as well as the depth of cut.

(c) Specific Machining Processes:

The selection of machining processes required to convert the raw material into a finished part and then a product is produced based on the geometry of the part (size and shape) with the required finishing, tolerances and the quantity of the product. Machining process can be grouped into three broad categories such as traditional chip formation process, abrasive machining processes and non traditional machining processes.

(d) Chip Formation Processes:

The basic chip formation processes are turning, shaping, milling, and drilling, sawing, broaching and abrasive machining. The principles of operations associated with each of these processes differ from one another.
(e) Tool Materials:

The common cutting tool materials currently in use of production machining operations are High-Speed Steel (HSS), Carbides, Coated tool. Cubic Boron Nitride (CBN), Ceramics and Diamonds are also being widely used for difficult applications. HSS tool is used for general purpose tools, when cutting speeds are more modest. Carbide and Ceramic tools are available in a wide variety of grades and geometries used for cutting speeds are high. For better wear resistance at faster cutting speeds harder tool materials are more appropriate.

(f) Cutting Parameters:

Selection of cutting parameters such as speed, feed and depth of cut are most important for any machining operation. The machining conditions influence all the dependent variables leading to the amount of material to be removed, surface roughness and tool materials and the machining process or processes.

1.3.2 Dependent Variables.

Dependent variables are chosen by the process based on the prior selection of the input or independent variables. The important dependent variables are the cutting force, power, the size and properties of finished product, surface finish tool wear and tool failure.

(a) Cutting Force and Power

Cutting force in general during the machining of a work piece or job material at a specified speed, feed and depth of cut, with a
specified lubricant, cutting tool material, and geometry, remains constant. A change in any of the variables alters the forces, but the changes are indirect and the concerned production engineer does not specify the forces, only the parameters generate those forces. Forces are important since the influence of the deflections in the tools, the work pieces, and the work holders, which in turn affect the final part. Forces also play a role in chatter and vibration phenomena common in machining. Obviously, equipment for a manufacturing operation, including the machine tool, cutting tool and work holding devices.

(b) Surface Finish:

The final finish on a machined part surface is a function of a tool geometry, tool material, work piece material, machining process, speed, feed, depth of cut and cutting fluid (if any). Surface finish is also related to the process variability. Rough surfaces have more variables than smooth surfaces. Often it is necessary to specify multiple cuts, that is roughing and finishing cuts, to achieve the desired surface finish, or it may be necessary to specify multiple processes, such as in turning with cylindrical grinding, in order to obtain the desired finish.

(c) Tool Wear and Tool Failure:

The plastic deformation and friction inherent in machining generate considerable heat, which raises the temperature of the tool and lowers its wear resistance. As the tool wears, it undergoes changes in both geometry and size. A dull cutting edge and change in geometry can result in increased cutting forces that in turn increase
deflections in the work piece and may create a chatter condition. The increased force also causes increased heat generation in the operation, which accelerates the wear rate. The selection slow speeds results in less heat and lower wear rate, but decreases the production rate because the metal removal rate is decreased. Alternatively, the feed or depth of cut can be increased to maintain the metal removal rate while reducing the speed.

1.3.3 Relation between Input Variables and Process Behaviours

The manufacturing engineer should have good knowledge of the relationship between input material and process behaviour. Machining is a unique plastic deformation process in which it is constrained only by the cutting tool and operates at very large strains and very high strains rates. The tremendous variety in the input variables results in almost infinite number of different machining combinations which are dependent on the job material, cutting tool material, the speed, feed, depth of cut, etc.

(a) Experiments:

Machining experiments are expensive, time consuming and difficult to carry out. Tool life experiments, for example, are quite commonly done, yet tool life data for most work piece/tool material combinations are not available. Even one laboratory data have been published; the results are not necessarily transferable to particular machine tools and cutting tools on the shop floor. Tool life equations are empirically developed from turning experiments in which all input variable except cutting velocity are kept constant. The experimental
arrangement may limit the mode of tool failure to wear. Such results are of little value on the shop floor, where tools can cut and do fail from causes other than wear.

1.4 SURFACE FINISH

Surface finish and tolerance are among the most critical quality measures in finished products. Making surface quality parts become one of the most competitive dimensions in today's manufacturing industry. Roughness of the machined surface is an important quality measure in metal cutting. It is important to monitor and control surface roughness over time during the machining operation. Chou and Evans [116], Chou and Evans [117] and Sista et al. [113].

1.4.1 Surface topography

The general characteristics of a surface are discussed in the following.

**Surface**: The surface of an object is the boundary which separates that object from another substance. Its shape and extent are usually defined by a drawing or descriptive specifications.

**Profile**: (Primary texture): On surfaces produced by machining and abrasive operations, the irregularities produced by the cutting action of the tool edges and abrasive grains and by the feed of the machine tool are roughness. Roughness may be considered as being superposed on a wavy surface.

**Waviness**: (Secondary structure): The surface irregularities which are of greater spacing than the roughness and may result from machine and work deflections, vibrations, etc
**Flaws:** Irregularities which occur at one place or at relatively infrequent intervals in the surface, e.g., a scratch, ridge, hole, crack, etc.

**Lay:** The direction of predominant surface pattern.

A typical surface is shown in Figure-1.3 and the identification of the macro-geometrical errors based on $l/h$ ratio is shown in Figure-1.4. When, $(l_1/h_1) > 1000$, the deviation is macro geometrical denoting out-of-round-ness, taper or barrel form.

When $500 > (l_2/h_2) \geq 150$ the deviations denote waviness.

When $(l_3/h_3) \leq 50$, micro-geometrical deviations are the characteristic of surface roughness.

![Figure-1.3: A typical surface highly magnified](Bhattacharya, (125))

![Figure - 1.4: Macro geometrical errors](Bhattacharya, (125))
1.4.2 Importance Of Surface Roughness

The quality of surface plays a important role, a good-quality machined surface significantly improves the fatigue strength, corrosion resistance. Hence, surface roughness also affects several functional attributes of parts, such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, coating, or resistance fatigue, [Sahin and Motorcu; (127)], [Subramanyam et al. (83)].

Tool wear becomes additional parameter affecting surface quality of finished parts. Hard turning is a fine finishing process and the surface roughness obtained in hard turning processes depends on various factors and the related data like cutting conditions, cutting tool material and its geometry, cutting fluid, rigidity of the machine tool and type of work material, [Shatla et al (111)].

To get ideal surface roughness selection of proper cutting tool and cutting conditions are most important, [Bernandos Vosniakos, (123)] The various methodologies are classified into theories based on machining theory, experimental investigation, designed experiments in modelling and application in CIM were reported by, [Oxley et al, (112)].

1.4.3 Factors affecting surface quality

The surface roughness is mainly a result of various controllable or processes parameters. The fishbone diagram with factors that influence on surface roughness is shown in figure 1.5.
Figure 1.5: Fishbone diagram with factors influencing on surface roughness [Bajic et al, (120)]

The major factors influencing the surface quality in machining operations are reported by Bhattacharya [125] are as follows.

1. The cutting variables: cutting speed, feed, and depth of cut.
2. Work piece and tool material combination, and their mechanical properties
3. Quality and type of the machine tool used.
4. Auxiliary tooling, and lubricant used and
5. Vibrations between the work piece, machine tool and cutting tool.

1.4.4 Assessment of the Surface

The basic assessment of the surface systems as given in Bhattacharya, [125] are briefly discussed in the following.

(i) Peak-to-valley measures,  (ii) Mean, line measures (M-system),

(iii) Crest line measures and (iv) Envelope method (E-system, Von Weingraber).

The definitions of the different roughness values are based on the mean line. Some of these are given below:

(i) Total depth R: It is the peak-to-valley value and is perceived by looking at and touching the surface and generally the depth is called Rauhtiefe.

(ii) Levelling depth or depth of smoothness (Rp) is the distance between mean line Lm and upper surface line Lu. The parameter is often necessary for assessing the frictional quality of a surface. The complimentary depth, Rm, (in German: mittlereRauhtiefe) denotes distance between the mean line and bottom surface line.

(iii) CLA or centre-line-average value is defined according to BS-1134 as the arithmetical average (AA) value of the departure of the whole of the profile both above and below its centre line throughout the prescribed meter cut-off in a plane substantially normal to the surface. Magnified cross section of a typical machined surface is shown in figure-1.6

![Figure 1.6: Illustration of surface roughness, [Sharma, (110)]](image-url)
The following factors influence the formation of surface roughness in the turning process. The tool wear influences the surface roughness of the work piece. Surface roughness is the main parameters to establish the moment to change the tool in finish operation. [Bonifacio and Diniz, (119)]. Mechanical detachment large fragments of tool, wear occurs by using carbide tools and it causes the surface roughness to increase significantly. [Dearnley, (122)].

Flank wear along with crater wear influence change in surface roughness and tool life. [DeGarmo, et al., (38); Ravindra, et al., (100)]. The relationship between surface roughness and flank wear studied by Sundaram and Lambert, [115]. The relationships between Rmax, Ra and Vb with cutting length, [Petropoulos, (124)] and between tool wear and surface roughness by Bonifacio and Diniz [119]. Shown in Figure -1.6. The surface finish obtained during the usage of TiN coated carbides and Al2O3 coated carbide tools as compared to uncoated carbides showed that TiN coated carbides had good surface finish followed by Al2O3 coated carbides and finally uncoated carbides, [Noordin, et al., (114)]. Shown in Figures-1.7 and 1.8.
Figure 1.7: Surface roughness vs. cutting length for different speeds [Bonifacio & Diniz, (119)]

Figure 1.8: Surface roughness vs. cutting speed [Noordin et al., (114)]
1.5 MOTIVATION AND SCOPE OF THE PRESENT WORK

For hard turning most of the researchers carried out with different types of cutting tools for cutting AISI 4340 work material.

The present work is carried focused on considering PVD and CVD cutting tools for AISI 4340 work material.

The work is focused on Optimization of cutting parameters like speed, feed, and depth of cut for the above said material.

This chapter deals with manufacturing system and the dependent variables of metal cutting. The quality of the surface roughness plays an important role in machining. For surface roughness, two independent factors effect during machining. They are irregularities in cutting operation, geometry of the tool and feed rate. Also, the factors affecting surface quality is discussed with fishbone diagram. The next chapter deals with the literature review of the metal cutting and objectives are drawn for the present study.