CHAPTER-1
INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

Liberalization and globalization in the competitive market, present market demands high quality of product with minimum cost. During manufacturing of product major cost is associated with machining operations. Optimization of the machining conditions can reduce the unit production cost. Hence, production cost can be minimized through optimization of machining condition and proper setting of various parameters during machining. The production cost may be enhanced due to rapid tool wear and frequent changes of cutting tool. The production cost can also be reduced by reducing the lead time and proper selection of machine tools, tool geometry, cutting conditions such as velocity, feed rate, depth of cut and as well as through proper selection of cutting tool material and operations involved. This variable governs the economics of machining operations. Therefore, there is a vital need to correlate the technological factors involved in the machining process for analyzing the economics of the process and product in practice.

However, with the rapid technological acceptance of hard alloy steel in industrial application, the machining of E0300 and En31 alloy steel has been of urgent importance for modern die and shaft manufacturing industries. As E0300, En-31 alloy steels have high value of hardness and stiffness, the selection of proper cutting tool materials and machining process for effective machining of E0300, En-31 alloy steels has really been very difficult. The major problems encountered during traditional machining of E0300, En-31 alloy steels are rapid tool failure, severe abrasive wear, flank wear of cutting tool, formation of flank build up layer on the cutting tool edge, poor surface finished etc.

Although some research on traditional and non-traditional machining of hard alloy steel have been carried out by the previous researchers but still a lot of applied research on traditional machining process are required as to explore the successful utilization of the process parameters for effective machining of E0300, En-31 alloy steels. To explore the successful utilization of the traditional machining process
experimental investigation on machinability of hard alloy steel during turning is needed to be carried out considering some major machining factors such as various tools, tooling system, cutting forces, built-up edge, chip formation, temperature generated during cutting, tool wear and surface finish criteria etc. for searching out the effective machining conditions with cost effective machining process for achieving the criterial objective fulfillment.

Keeping in view, the present research investigations have been carried out on traditional machining i.e. turning operation using different graded tools, special tooling system e.g. self-propelled rotary circular tooling during turning of E0300, En31 alloy steels. Special fixture has been designed, fabricated and utilized for measurement of the circular tool flank wear during experimental investigations. According to the machining requirements, the experimental investigations have been carried out in a pre planned way keeping the objective of the present research. Analysis of the influence of turning parameters on the various pre determined machining performance and optimization of machining parameters for different performance criteria are carried out.

The variables affecting the economics of machining operations are numerous and include machine tool capacity, required work piece geometry, cutting conditions such as speed, feed, depth of cut, environment etc. The proper selection of cutting conditions involves technological and the operational criteria, which are really very difficult to choose and achieve require economics in actual practice. Hence, there is a vital need to correlate the technological factors involved in the cutting process to achieve the desire economics.

The present research investigation will describes a procedure to obtain the machining conditions for turning operation considering minimum production cost as the objective function. The optimal values of machining condition for single point cutting operations are to be determined based on the objective function using dynamic programming technique. The optimal values of machining conditions are also to be determined for cost evolution considering the following criteria such as actual machining time, setup time, tool life, tool changing time etc. The mathematical models are to be developed considering krononberg’s data used for standard turning.
operation. The optimal mathematical models will be verified with the experimental results and the effect of the various constraints on the objective functions will be analyzed through various graphical representations. The developed optimality condition will affect the economics of machining conditions. The graphical representations of cost versus machining conditions will also help to understand and analyze the effect of various input constraints at the optimum point and their significant influences on production cost. The research investigations will propose an effective methodology in advance for proper setting of machining parameters in practice, which may improve the economics of unit production.

1.2 MACHINABILITY: AN OVERVIEW

1.2.1 DEFINITION AND CONCEPT

Machinability is a much-maligned term, which has many different meanings but generally refers to the easy with which a metal can be machined to an acceptable surface finish. The machinability can be defined on the basis of the material properties, tool life, cutting speed as well as on the basis of the quality of surface finish, dimensional stability with easy removal of chips. When material is a key factor the machinability is defined by the ease of difficulty with which the metal can be machined. When tool life is the key factor, the machinability is defined by the relative cutting speed for a given tool life of the tool for cutting some material, compared to the standard material cut with the same tool material. When cutting speed is the key factor, the machinability is defined by the measurement of the maximum cutting speed at which a tool can provide satisfactory performance for a specified term under specified conditions.

However, machinability is not a work material property but rather a property of the machining system, which is affected by the work material, tool material, machine tool, part, fixture, cutting fluid and cutting conditions. Therefore, the term machinability is often used for comparison or ranking purpose for example, a list of material choices for a given part machining that may be ranked from most to least machinable. In this case the primary consideration is usually the overall machining
cost, which depends most strongly on the tool life and other machining criteria that can be achieved under the assured production conditions.

1.2.2 AIM AND OBJECTIVE OF MACHINABILITY

The main objective of the machining industries and the people concerned with machining science and technologies are

(a) Effectiveness, efficiency and economy through improvement in product variety and product quality by best utilization of resources.

(b) Development of new process, technique and cutting tool materials and tool geometry and as well as development of highly rigid versatile, automatic and precision control machining systems to meet the growing demands for higher productivity and quality and to maintain the parity of globalization.

(c) Achieving goal with optimal cost and as well as minimum harm to the environment and social life etc. for surviving in the liberalization and competitive market.

Therefore for high productivity, quality and overall economy require improvements in various machinability criteria such as

(i) Reduction of tool wear rate.

(ii) Improvement of surface finish.

(iii) Reduction of cutting force.

(iv) Reduction of cutting temperature.

(v) Favorable chip formation.

(vi) Reductions of build up layer and build up edges during machining.

1.2.3 FACTORS AFFECTING THE MACHINABILITY

The following factors affecting the machinability are given below:

(i) Cutting mechanism

(ii) Cutting force

(iii) Cutting too wear

(iv) Surface finish

(v) Chip formation

(vi) Cutting temperature

(vii) Cutting conditions
1.2.3.1 TOOL WEAR MECHANISM

Under usual cutting conditions, when the form stability of the cutting edge has been achieved, wear due to interaction between the chip and the tool and between the work and the tool are the main processes by which a cutting tool fails. After the tool has been used for sometime, wear land will appear at the flank of the tool below the cutting edge. The wear will also appear on the tool face forming a cavity known as crater wear. Wear can be described as total loss of weight or mass of the sliding pairs accompanying friction. The basic mechanism of wear that can be insisted for formation of wear between sharp cutting tool edge and work-piece surface due to

(i) abrasion and adhesion,
(ii) diffusion,
(iii) localized galvanic action e.g. oxidation,
(iv) surface cracks,
(v) Chemical decomposition effect etc.

**Adhesive Wear**

Adhesive or attritional wear occurs when small particles of the tool adhere or weld to the chip due to friction and high pressure, and are removed from the cutting tool edge. It occurs primarily on the rake face of the cutting tool and formation of crater wear. It is occurred when machining is done at low cutting speed. It is not significant at high cutting speed. However, significant adhesive wear may accompany Built-up Edge (BUE) formation, since the BUE is also caused by adhesion and can result in chipping of the cutting tool edge.
**Abrasive Wear**

Abrasive wear occurs when hard particles abrade and remove material from the tool. It may from a chemical reaction between the chip and cutting fluid. Abrasion occurs primarily on the flank surface of the tool. It is an important cause for flank wear, which controls tool life, especially at low cutting speed. The volume of material worn out due to the abrasive wear can be explained by the product of the three things (e.g. wear co-efficient, cutting force normal to the sliding interface and distance slide in a given time) divided by hardness of the cutting tool material.

**Diffusion Wear**

In diffusion wear, a constituent of the tool material diffuses into a solid solution with the chip material. It weakens the tool surface and results in formation of crater on the rake face of the tool. Severe cratering ultimately failure the cutting tool by breakage. The diffusion wear rate depends primarily on the solubility of the tool material with the work material. It depends on the contact time between the tool and chip at elevated temperature. This wear also depends on the chemical compatibility of the tool and work-piece. The cutting speed at which the form of wear becomes significant depends on the tool-chip interface temperature and the melting temperature of the chip. When metal is in sliding contact during cutting, the temperature at their interface is high, condition may arises to diffuse the harder metal cutting tool atom into the softer matrix i.e. work-piece, thereby increasing the work-piece hardness and abrasiveness. Hence, hard metal atom sheared off and carried away with the chips and with the coolant, may basic mechanism of diffusion wear.

**Chemical Wear**

Chemical wear is caused by chemical reaction between the tool and the work-piece or cutting fluid, produces both flank and crater wear. Chemical wear may be result from reactions with additives in the cutting fluid. Additives, in fact, are used to reduce adhesive wear by controlling the chemical wear. Localized chemical reactions may occur that weaken the tool edge by dissolution of the bond between the binder and the hard constituents.
Oxidation Wear

Oxidation occurs when constituents of the tool especially the binder react with atmospheric oxygen. It most usually occurs near the free surface the tool where the hot portion of the tool in and around the tool chip contact region is exposed to the atmosphere. Oxidation often results in severe notch formation and cutting tool edge is typically discolored in the region near the notch. Oxidation does not occur with aluminium oxide based ceramic tools.

1.2.3.2 SURFACE INTEGRITY

The irregularities produced on the surface by the cutting action of tool edges and by the feed of the machine tool during machining are roughness. Surface integrity may be considered as relatively fine-spaced surface irregularities being superposed on wavy surfaces. The surface integrity is the sum of all the elements that describes all the conditions existing on or at the surface of a work piece. Surface topography is describes the roughness, lay or texture of the outermost layer of the work-piece i.e. machined surface.

Therefore several factors influencing surface quality in machining operation such as:

(i) The machining parameters e.g. cutting speed, feed rate, depth of cut etc.
(ii) The geometry of cutting tool
(iii) The chip formation and removal.
(iv) The application of cutting fluid.
(v) The machine tool rigidity and bearing accuracies etc.

The inherent surface roughness is dependent on feed and geometry of the cutting tool. During turning using a single point radius-turning tool the maximum peak-to-valley height of surface roughness $R_t$ is described by the relation given below [72]:

$$R_t = \frac{f^2}{8r} \times 1000$$

- - - Eqn. 1.1
And the average surface roughness height $R_a$ can be described through the relation as listed below:

$$R_a = \frac{0.032 \ f^2}{8 \ r} \times 1000$$  --- Eqn. 1.2

Where, $f = \text{feed, mm/rev.}$

$r = \text{nose radius, mm}$

There are various parameters required for functional assessment of surface texture such as total depth, leveling depth or depth of smoothness, CLA value, RMS or root mean square value etc. The total depth is the peak to valley depth which is perceived by looking at and touching the surface and is generally influenced by scratch and tool marks. Leveling depth is the distance between the mean line and upper surface line. The CLA value is center line average value and is defined according to BS-1134 as ‘the arithmetical average value of the departure of the whole of the profile both above and below its center line throughout the prescribed meter cut off in a plane substantially normal to the surface. The RMS or root mean square value is defined as the geometrical average value of the departure of the whole of the profile both above and below the centre line throughout the prescribed meter cut off in a plane substantially normal to the surface. It is known as $R_d$ value. Based on the mean line average method, ISO has recommended a standard (ISO-TC-57-1958) where CLA value $R_a$ of M-System has been chosen. In ISO recommendation three values are (i) $R_a$, (ii) $R_t$ and (iii) $R_z$.

### 1.2.3.3 CHIP FORMATION

The excess material removes from the blank i.e. work specimen during machining in the form of chips. The formation of chips involves a shearing of the work material in the region of a plane extending from the tool edge to the position where the upper surface of the chip leaves the work surface. However, the nature of the chip forming process is extremely variable, the exact mechanism of chip formation depending upon the metallurgical aspects of tool work pair, the sharpness of the tool and geometry of the cutting tool. When very ductile materials are machined at very low speed and with the help of smaller rake angles of the cutting tools, a crack runs in front of the tool.
and actual shear takes places farther changes the shape of the chips. Soft material having relatively high friction at the tool face is susceptible to the continuous type of chip formation when cut at low cutting speed. However, chips will become thinner consuming relatively less cutting energy. The factors involved for study of chip formation are depth of cut to feed ratio, cutting speed, inclination angle, depth of cut, action of cutting fluid etc. Chips can be classified based on the final shape and the most commonly known ISO based chip form classifications are

(i) Ribon Chip
(ii) Tubular Chips
(iii) Cork Screw Chips
(iv) Helical Chips
(v) Spiral Chips
(vi) Arc Chips
(vii) Elemental Chips
(viii) Needle Chips.

1.2.3.4 TEMPERATURE

Temperature generated at the too chip interface during metal cutting is influenced on the machinability criteria e.g. increase the rate of tool wear, reduction of tool life etc. Therefore, it is important to understand the factors, which influence the generation of temperature and heat, flow and distribution of heat in the tool and work material at the cutting edge. From past literature review it is understood that the cutting temperature increases with increase of cutting speed, feed rate and depth of cut. The cutting temperature can be reduced by

(i) reducing the principal cutting edge angle,
(ii) increasing the nose radius
(iii) proper selection of rake angle
(iv) proper selection and application of cutting fluid etc.
1.3 LITERATURE REVIEW

Uptil now ample research and investigation have been done in different parts of the world on machinability of different materials mainly in respect of chip morphology, cutting forces, cutting temperature, chip tool interaction dimensional accuracy, surface integrity, cutting tool wear and tool life with and without using cutting fluid. Environmental pollution arises out of conventional cutting fluid applications has been a serious concern of the modern machining industries. Brief reviews of some of the interesting and important contribution in the area closely related to the machinability study are presented in this section in alphabetic order.

Abele E. et al. [1] studied on the characteristics of the cutting tool body deformation and cutting edge offset. In this study, authors analyzed the tool body enlargement and cutting edge displacement due to elastic and plastic deformation during metal cutting.

Aggarwal Aman et al. [2] reviewed the literature on optimization of machining parameters in turning processes. In this paper, authors reviewed various conventional techniques employed for optimization of machining conditions included geometric programming, geometric plus linear programming, goal programming, sequential unconstrained minimization technique, dynamic programming etc.

Andreasen J. L. et al. [3] studied on the carbon steel during dry turning using standard throw away carbide tip. The inserts used for the experiment were triangular and provided with various chip braking shapes.

Anselmo Eduardo Diniz et al. [4] investigated on ABNT1045 steel during turning using different cutting tools with and without use of coolant. Author concluded that the wet turning is expected to be better for longer tool life but dry turning could not be used with large depth of cut.

Armarego E. J. A. et al. [5] presented multi constraint optimization analyses and computer aided strategies for selecting the optimal feeds and speeds in single pass rough turning operations with modern coated chip breaker tool on CNC lathe. Authors also investigated on the economics of machining performance.
Arrazola P. J. et al. [6] studied on 3D-FEM based numerical modelling of precision hard turning to investigate the effects of chamfered edge geometry on tool forces, temperatures and stresses during machining of AISI 52100 steel using low-grade PCBN inserts. In this study, authors focused on cutting forces, temperatures and tool stresses developed during machining with feed rate and cutting speed were constant.

Arrazola P. J. et al. [7] studied micro-scale temperature fields in the cutting of two AISI 4140 steels with different machinability ratings. For this, they constructed a custom infrared microscope and used it to investigate the behaviour of the certain critical regions of the thermal field. Authors measured the micro scale temperature at the thermal field and concluded that it will help to select proper tool materials for further improvement of machinability.

Astakhov V. P. et al. [8] studied on the chip formation mechanism to classify the chip structure during turning. Author established that the study provides a clear idea to the tool designer for designing the better chip breaker which can capable of breaking the chip with minimum energy consumptions.

Astakhov Viktor P. et al. [9] studied the effect of a cutting speed on the flank wear of carbide P10 insert during turning of AISI 52100 steel. Author concluded that tool wear is minimum at optimum cutting speed.

Azizur Rahman M. et al. [10] studied on the micro turning of brass, aluminum alloy and stainless steel with PCD and cermets inserts. The effect of depth of cut, feed rate and spindle speed on cutting forces as well as chip formation were also studied. Author concluded that DOC is the most influential cutting parameter in micromachining.

Baker Marin et al. [11] developed a finite element model for a two-dimensional orthogonal metal-cutting and used the developed model to study the influence of the cutting speed on the cutting force and the chip formation. Authors concluded that the cutting force decreased with decreased in cutting speed. At higher cutting speeds, segmented chips are produced.
Bil Halil et al. [12] studied on various simulation models of orthogonal cutting process. Authors measured the cutting and thrust forces, chip thickness and determined the shear plane angle from the measured chip thickness.

Blais Carl et al. [13] studied on the optimization of machining parameters. Author presented new approaches to improve the P/M machinability. Author suggested that the presence of MnS in P/M part improve the machinability. Authors also concluded that the presence of MnS particles minimizes seizure effect during chip formation and there by reducing cutting forces during turning.

Budak E. et al. [14] presented a thermo mechanical dual district model for cutting process. Authors concluded that the simulation of the machining processes can be done by analytical methods, which are much faster than numerical solutions.

Cakir M. C. et al. [15] studied on the variable affecting the economics of machining operations, which are numerous and include machine tool capacity, required work piece geometry, cutting conditions of velocity, feed rate, depth of cut and many others. Authors concluded that the effects of constraints on the objective function can be evaluated by graphical representation and by developed software.

Calamaz Madalina et al. [16] developed a model for 2D numerical simulation of serrated chip formation during machining of Ti-6Al-4V titanium alloy. One of the main characteristics of titanium alloys is to produce segmented chips for a wide range of cutting speeds and feeds. Authors pointed out some difference in cutting forces and highlighted the reason for disparity between numerical and experimental cutting forces.

Casto S. Lo. et al. [17] studied on the ceramic cutting tool materials wear mechanisms during cutting nickel based alloys. In this work, the performance of some commercial ceramic inserts during cutting AISI 310 steels are investigated and compared to those of the carbide based tool. Authors concluded that the most important wear mechanism in the ceramic inserts is related to the segmented edges of the chip that abrade a notch at the end of cut zone. Alumina zirconium inserts are very sensitive to this kind of wear but alumina with SiC whiskers tool exhibit slightly better performance.
Chen M. C. et al. [18] studied the extensive attention regarding optimization of machining conditions for turning cylindrical stocks into continuous finished profiles. Authors developed a machining model and claimed that the developed model is usefulness for turning of cylindrical work-piece on CNC machine.

Childs T. H. C. et al. [19] studied on surface finishes during turning and facing by round nosed tools. Author concluded that the minimum roughness can be achieved by cemented carbide but also with single crystal diamond round nosed tools.

Chiou Richard Y. et al. [20] investigated the progressive wear of cutting tools and occurrence of chatter vibration often pose limiting factors on the achievable productivity in machining process. This research presented a dynamic model of cutting RMS acoustic emission (AE) signal to evaluate the cutting tool flank wear. Authors concluded that RMSAE is quiet sensitive to the dynamic incremental changes in the friction and wear mechanism during machining.

Cho J. R. et al. [21] used FEA software and studied on the optimum material composition design for thermal stress reduction in Functionally Graded Material (FGM) lathe tool bit. Authors concluded that the thermal stress concentration that has been occurred near the tip-shank interface in traditional lathe bits could be significantly relaxed if the material composition distribution in the graded region is appropriately tailored.

Choudhury I. A. et al. [22] carried out a series of turning tests on Inconel 718 using coated and uncoated carbide tools. Author described the effects of cutting variables (speed, feed and depth of cut) on cutting forces and tool life. Author concluded that an uncoated carbide tool gives better results as compared to that of the coated too.s.

Choudhury S. K. et al. [23] studied on the flank wear of HSS tool during turning of C45 carbon steel. Author developed the mathematical models considering tool wear as a function of force ratio, cutting speed, feed, and depth of cut.

Chung Shin Chang [24] proposed force model to study the stability of the single point cutting tool during turning of stainless steel. Author validated the developed
force model with the experimental data and concluded that the model is closely correlated with the theoretical values.

Chungchoo C. et al. [25] studied on cutting tool flank and crater wears during CNC turning of AISI 1045 steel. Kennametal K420 cutting tool was used for experimental investigation. Author concluded that in oblique cutting with flat face tool, the geometry of the tool chip contact area depends on cutting speed, feed and rake angle.

David W. Smthey et al. [26] studied on the region of a worn cutting tool where plastic flow of the work piece materials occurs. Authors concluded that the increase of cutting force depends on the cutting tool flank wear. Increment of cutting force is the function of the flank wear width and nature of the wear.

Dhar N. R. et al. [27] presented the work with explained the effects of cryogenic cooling on chips and cutting forces during turning of AISI 1040 and AISI 4320 steels. Authors concluded that cryogenic cooling can be reduced the cutting forces during turning. Authors also concluded that the favourable chips can be formed during turning with cryogenic cooling.

Diniz Anselmo Eduardo et al. [28] investigated the cutting conditions during finish turning of 1045 steel for better tool life. Author concluded that the dry cutting requires less power and produces better surface finish than wet cutting.

Dragos, A. Gindy et al. [29] studied the process monitoring to assess the work piece surface quality in machining. Author made an attempted to correlate the quality of the machined surface after broaching and the output signal obtained from the multiple sensors. Author suggested that the vibration signals were found sensitive to detect the chatter marks.

ElTobgy M. S. et al. [30] studied the finite element modelling of erosive wear. Author state that the material damage caused by the attack of particles entrained in a fluid system impacting a surface at high speed is called ‘erosion’. In this research work, an elasto plastic finite element (FE) model is presented to simulate the erosion process in 3D configuration.
Ezugwu E. O. et al. [31] evaluated the performance of different graded CBN tools during turning of Ti 6Al-4V alloy at high cutting speed e.g. 250 m/min with use of different coolant. Author concluded that the machining of Ti 6Al-4V alloy with different graded CBN tools gave lower performance, in terms of tool life compared to uncoated carbide tool.

Ezugwu E. O. et al. [32] presented the test results during turning of titanium alloy by self propelled rotary tool. Authors concluded that the circular insert exhibited superior wear resistance as compared to conventional rhomboid shaped carbides tool.

Fang Ning [33] studied the kinematics characterization of chip lateral curl. Author recognized two pattern of chips namely up and side curl. Author concluded that the lateral curl is perpendicular to the rotating axis of the chip of up and side curl.

Grzesik W. et al. [34] compared two variants of the FEM simulation model of orthogonal cutting process of AISI 1045 carbon steel with uncoated and multilayer-coated carbide tools. Authors concluded that the FEM package can be applied for understanding the generated temperature distribution and heat flux intensity during orthogonal cutting.

Gu Jie, et al. [35] studied the flank wear of face milling inserts during cutting of 4140 preheat treated steel. The flank wears of uncoated C5 carbide insert as well as TiN , TiAIN and ZrN coated inserts was evaluated and ranked. Authors conclude that the TiN and TiAIN coatings provided significant improvement in tool life.

Huang Yong et al. [36] studied for modeling of cutting forces during hard turning. Author concluded that the measurement of cutting forces in hard turning is important for thermal modeling, estimation of tool life, chatter prediction, and tool condition monitoring purposes. The forces generated during turning are the linear summation of forces due to chip formation and forces due to flank wear.

Hui Y. V. et al. [37] studied the optimal machining conditions based on costs of quality and tool maintenance in turning. Author developed a time dynamic economic model for single pass turning.
Husnu Dirikolu M. et al. [38] studied on various available machining models and found some shortfall in modelling and reasons for these shortfall in machining. Author concluded that the approaches considered for modelling, mesh and boundary conditions, the flow stress of the work piece material and the frictional properties at the interface between chip and cutting tool are essential for good modelling.

Jackson M. J. et al. [39] experimentally investigated on the variety of coated tool during machining of M42 tool steel. Authors concluded that TiAlCrYN coated WC-Co cutting tools perform better than uncoated cutting tools.

Jurkovic J. et al. [40] suggested a reliable direct measuring procedure for measuring different tool wear parameters. Authors employed modern image processing techniques and machine vision systems for direct wear measurement, and concluded that these are flexible, economical, high spatial resolution and good accuracy for detection of tool wear.

Kadirgama K. et al. [41] conducted experiments to determine the temperature distribution on cutting tool when machining HASTELLOY C-22HS with carbide coated cutting tool. Response Surface Method (RSM) used to minimize the number of experiments and to develop first order temperature model. Finite element analysis (FEA) was used to verification of the temperature distribution on cutting tool. They found that feed rate has the most dominant parameter on the temperature, followed by the axial depth and cutting speed. The results from FEA were compared with the experimental values.

Karpat Yigit et al. [42] studied on tool edge geometry during machining and explained that the combined cutting conditions highly affect the performance of high speed cutting. They utilized an analytical slip-line field model to study the cutting mechanics and friction at the tool-chip and tool–work piece interfaces in the presence of the dead metal zone in machining with negative rake PCBN tools.

Kaye J. E. et al. [43] developed a mathematical model for on line prediction of tool wear during turning using the surface response methodology. Authors conducted different tests with varying the combination of cutting speed, feed rate, depth of cut and material hardness for development of mathematical model and to predict the flank wear.
Kevin Y. et al. [44] investigated the performance of CBN tool during interrupted turning of hardened M50 steel. Author suggested that the higher hardness and fracture toughness of CBN-H result in greater resistance to mechanical wear that becomes more dominant in interrupted cutting. Author concluded that tool wear decreases with decrease in grain sizes of CBN cutting tools material.

Kishawy H. A. et al. [45] presented a performance assessment of rotary tool during machining of hardened steel. The investigation includes an analysis of chip morphology and modes of tool wear. The effect of cutting tool geometry and type of cutting tool material on the tool self propelled motion are also investigated. Authors concluded that the self propelled coated carbide tools showed superior wear resistance.

Kishawy H. A. et al. [46] described the results of the applications of different coolants during high speed milling of A356-aluminium alloy. The work investigated the effect of tool floods coolant, dry cutting and minimum quantity of lubricant (MQL) technologies on tool wear, surface roughness, and cutting forces. Author concluded that the main wear mechanism encountered are abrasive at the tool tip region and the adhesive wear on the flank and rake face of the tool tip.

Kopac J. et al. [47] presented a reviewed result from available published work of some recently used cutting tool materials and coatings in machining. Authors concluded that Tool life is depending on certain technological parameters such as cutting tool material, tool materials etc.

Kwon Yongjin et al. [48] proposed a simulated model to predict the tool wear index during turning of 4340 steel using uncoated tungsten carbide tools. Author concluded that the tool wear index can help to measure the wear conditions more accurately and comprehensively.

Lee B. Y. et al. [49] reported the use of computer vision techniques to inspect the machined surface roughness during turning operations.
Lee J. H. et al. [50] studied to monitor the flank wear considering the cutting force as an input signal. Author concluded that the force signal ratio is the best input variable for tool wear monitoring. It was also concluded that the statistical and sensitivity analysis depend on three factors, namely cutting speed, depth of cut, and workpiece material factor.

Lian et al. [51] developed a self-organizing fuzzy controller (SOFC) for constant cutting force control and to control performance of the turning system. Authors concluded that the SOFC has a better control performance in constant cutting force control over traditional fuzzy controller (TFC).

Lim C. Y. H. et al. [52] investigated the wear of coated cemented carbide inserts during dry turning of hot rolled medium carbon steel workpiece. Author concluded that TiC coatings on carbide tool could increase the wear resistance during cutting.

Lo H. W. et al. [53] developed a “broad brush” towards the selection of the geometry of general purpose cutting tools for maximum tool life. The large numbers of independent tool angles involved are combined into two independent non-dimensional factors. The first is the mechanical stress intensity factor and the second is the cooling factor which accounts for the ability of the tool wedge to dissipate cutting heat. A semi empirical method is then used to integrate the two factors into one single variable which is shown to correlate well with experimental tool life magnitudes in turning and drilling. The modification has enabled an improvement of drill corner life of the order of 400%.

Luke H. et al. [54] studied the effect of tool chip contact length on orthogonal turning performance. Author concluded that the contact length of the tool/chip interface on a natural tool grows as the depth of cut increases. It is further noted that the larger the shear angle, the shorter the shear length and less the shear force, since the shear stress is constant.

Luo X. et al. [55] performed experimental investigation to investigate the intrinsic relationship between tool flank wear and operational conditions in metal cutting processes using carbide cutting inserts. A new flank wear rate model, which combines
cutting mechanics simulation and an empirical model, was developed by the authors to predict tool flank wear land width. Authors concluded that the cutting speed has a more significant effect on tool life as compared to feed rate.

Maan Aabid Tawfiq et al. [56] studied the effect of edge preparation of the cutting tool in orthogonal cutting considering the following variables: stress distributions at the tool rake face, cutting forces and tool-chip contact length. Authors concluded that the optimum edge radius recommended is 0.01 mm for minimum tangential cutting and feed force.

Manna A, Bhattacharyya B. [57] studied on the different tooling system during turning of AL/SiC MMC for optimal selection of tool and tooling system for effective machining of the above MMC. The influence of cutting time and length of machining on the tool wear and the influence of cutting speed, feed, depth of cut, inclination angle of tool holder on the surface finish was established for each of the tooling systems. Author suggested that self propelled rotary circular tooling exhibit superior wear resistance, extended tool life.

Manna A. et al. [58] studied on machinability of Al/SiC MMC. The influence of machining parameters e.g. cutting speed, feed and depth of cut on the cutting force and surface finish criteria were investigated during the experimentation. The BUE and chip formation at different sets of experiments were examined though SEM micrographs. Author concluded that flank wear rate is high at low cutting speed due to the generation of high cutting force and formation of BUE during machining of Al/SiC-MMC.

Manna A. et al. [59] experimental investigated the influence of cutting conditions on surface finish during turning of AL/SiC-MMC. In this study, author used the Taguchi method based experiment design to optimize the cutting parameters for effective turning of AL/SiC-MMC by rhombic insert.

Matsushima K. et al. [60] examined the worn out condition of cutting tool by TV camera during changing of each cutting tool. In this study, author used the pattern recognition technique and the morphology of tool failure was classified.
Mohamed N. A. et al. [61] used commercially available finite element ABAQUS software for analyzing and predicting the induced residual stresses during machining. Author claimed that this approach reduced the analyzed time.

Molinari, A. et al. [62] studied on the chip formation during turning and developed analytical models to predict the cutting forces, global chip flow direction and the temperature distribution at the rake face which affects strongly the tool wear.

Gunay Mustafa et al. [63] investigated the effect of tool rake angle on the main cutting force. Experimental results were compared with empirical formula developed by kienzle. It was concluded that the main cutting force increases with increase in negative rake angle and decreases with increase in positive rake angle.

Mustafizur Rahman et al. [64] reviewed of the research worked on the machining of titanium alloys and analyzed the drawback of the research with the following conclusions (i) The high chemical reactivity of titanium alloys with low modulus of elasticity and low thermal conductivity of the CBN and PCD tools cause the tool wear (ii) The chip produce by CBN tool have not shown any diffusion of the tool materials.

Özel T. et al. [65] investigated on the tool wear and cutting force generated during turning of AISI 4340 steel by variable micro-geometry PcBN inserts. Authors concluded that the variable micro-geometry tool reduced the heat generation along the cutting tool edge and hence reduce plastic deformation.

Ozler L. et al. [66] studied on the hot machining of austenitic manganese steel to predict the tool life in hot machining. They developed mathematical model for tool life utilizing factorial regression method. Author concluded that at room temperature, the tool life in hot machining of austenitic manganese steel was longer. As the cutting speed was increased, the tool life was decreased.

Penalva M. L. et al. [67] studied on CBN tool wear during turning of hardened steels. Author concluded that roughness profile could helpful to estimate the tool wear.

Petropolous Georgios et al. [68] studied on the longitudinally and faced turned surface generated during turning of Ck60 steel over a wide range of feed and cutting
speed. The correlations of each parameter considered were examined with the machining condition and statistical regression models with varying correlation coefficient were developed.

Piotr Nieslony et. al. [69] compared between two variants of the FEM simulation model of orthogonal cutting process for C45 carbon steel with multilayer-coated tools. He found that Temperature distribution patterns have some visible physical analogies to the reduced von Mises stresses and tool-chip contact behaviour. The differences in thermal behaviours of uncoated and coated tools, especially those related to the intensity and fluctuation of the heat fluxes in the seizure region can be clarified in terms of quartiles.

Poulachon et al. [70] studied on the chip morphology during hard turning using constitutive models and material property data. Micro hardness tests performed on these quick stop test samples show the effect of cutting temperature. Author stated that the greater understanding of applied machinability is gained through this precise study of work material, physical properties and its behaviour.

Qiang et al. [71] studied on finite difference analysis for calculating the deformations of multi diameter work piece during turning. Author also studied on deflection of work-piece during turning in order to achieve required accuracy of work piece diameter. Authors concluded that the work piece deflection is very sensitive to the clamping methods.

Rao R. Venkata et al. [72] presented a methodology to evaluate the machinability of work materials for a given machining operation using digraph and matrix methods. A universal machinability index is proposed that evaluates and ranks work materials for a given machining operation. The index is obtained from a universal machinability junction, obtained from the universal machinability attributes diagraph. The proposed method also helps in selecting the best work tool combination for a given machining operation.
Schnffer C. et al. [73] studied to develop a monitoring system for hard turning by using dynamic artificial intelligence (AI) technique. Authors concluded that AI could be utilizing to monitor crater and flank wear during hard turning.

Schulz H. et al. [74] studied the material aspects of chip formation in HSC machining. Investigation in the past shown, that chip formation changes by increasing cutting speed, because most of the experimental work has been carried out in the original material stage.

Sert H. et al. [75] studied on the surface roughness and dimensional deviations when machining of AISI 5140 steel with PVD-TiAN, CVD-TiN coated and uncoated cermet cutting tools. Authors concluded that surface roughness and dimensional deviation related by machining time for all cutting speed and tool life depended on surface roughness is to be achieved.

Shane Y. Hong et al. [76] reviewed the temperature affects T-6Al-4V properties and compare different cryogenic cooling strategies. Based on the findings, a new economical cryogenic cooling approach is proposed. Authors concluded that the combination of the two micro nozzles provides most effective cooling during machining in cryogenic environment and enhance improve the tool life.

Shaw Milton C. et al. [77] described the generation and transport of micro cracks across the shear plane. Authors also describe the important role of the compressive stress that plays on the shear plane. Since the shear stress and shear strain in metal cutting is unusually high, discontinuous micro cracks usually form on the shear plane is relatively low, micro cracks grow into gross cracks giving rise to discontinuous chip formation.

Sheikh Ahmad J. Y. et al. [78] studied the wear characteristics of the cutting tools during machining of particleboard by several graded cemented tungsten carbide tools on high speed lathe and their wear characteristics were determined. Authors found that wear occurs predominantly on the clearance face of the tool. Authors concluded that the amount of wear generally decreased with the increase in hardness, decrease in grain size and decrease in binder content of the cutting tool material.
Shet Chandrakanth et al. [79] conducted the experiment in which frictional interaction along the tool-chip interface is modeled with a modified coulomb friction law and chip separation is based on a critical stress criterion. Authors demonstrated that it is possible to carry out sophisticated finite element simulation of metal cutting processes using advanced general purpose commercial codes. Further they also concluded that friction along the tool-chip interface strongly affects the distribution of thermo mechanical fields.

Stevenson Robin et al. [80] studied the measurement of parasitic forces during orthogonal cutting. According to authors not all the forces measured during a cutting operation contribute to chip formation. Some fraction of the forces is parasitic forces which affect adversely on the machining performance.

Stockton D. et al. [81] examined the use of artificial neural network (ANN) in the development of cost model. In this work accuracy of model developed using the best and worst ANN structural elements have been compared with the use of regression analysis. Author used the Taguchi approach to represent an efficient method for determining appropriate ANN structures.

Suresh P. V. S. et al. [82] studied on the genetic algorithm approach for optimization of surface roughness model. This approach was used for prediction of optimal machining conditions for good surface finish and dimensional accuracy.

Sutter G. et al. [83] studied on the chip geometries during high speed machining for improving the orthogonal cutting conditions. Large ranges of cutting velocities were used for identify the proper tool geometry. Authors measured the root chip geometry and studied the geometrical characteristics of chips for better machining.

Takeyama Hidehiko et al. [84] studied the machining of hard ceramics with sintered diamond tools. Author studied the possibilities of cutting extremely hard aluminium oxide ceramics (1650 Hv) with sintered diamond tools and also to expand the possibilities by analysing the tool wear behaviour.
Tandon Puneet et al. [85] established a new three dimensional standard to specify single point cutting tool geometry. Author model a single point cutting tool in terms of biparametric surface patches. Six new angles called grinding angles, conventional tool nomenclature and setting or swivel angles for grinding are established.

Tansel I. N. et. al. [86] studied on the aluminum silicon carbide during turning in CNC machine using carbide tools. Back propagation type neural network was used for the estimation of tool wear. Author concluded that the cutting force variations increased.

Tarang Y. S. et al. [87] proposed an automatic fuzzy rule base generation method to control nonlinear and time varying turning processes with constant cutting forces based on this study, the optimum fuzzy rule base for the control of turning processes can be self organised without the need for experienced manufacturing engineers. A fuzzy logic controller based on these fuzzy rules can adjust feed rate on line to achieve an optimal production rate in turning operations.

Tonshoff C. H. K. et al. [88] studied the cutting of hardened steel and presented an overview of the mechanism of chip removal in hard cutting and the thermo mechanical influence of the work area is presented. Furthermore several models of chip removal in hard turning are introduced and discussed summarising the metallurgical fundamentals and giving an overview on stress and temperature distribution in the work.

Toropov A. et al. [89] represented an experimental study of the burr formation mechanism in feed direction using CNC turning machine tool. Author considered the influence of tool angles and work piece angles as well as other cutting conditions.

Troy D. Maruscih et al. [90] studied the simulation and analysis of chip breakage in turning processes. Many approaches such as empirical, mechanistic analytical and numerical have been proposed by the author. Author presented and a validated finite element based machining model and employed to calculate chip geometry, chip breakage, cutting forces and effects in work hardened work piece surface layers.
Vijay Sekar K. S. et al. [91] evaluated the effect of three different flow stress models on the finite element simulation of the orthogonal cutting process on AISI 1045 steel. The predicted finite element (FE) results for cutting force and shear strain were compared against the experimental values. Authors concluded that the FE results showed a marked closeness to the experimental values with a minimum deviation of 1% to 11%.

Wilson G. F. et al. [92] presented the result obtained from machining of tungsten carbide-cobalt alloys by polycrystalline diamond tools. Authors concluded that it is commercially feasible to machine hard die material with diamond tools. The chips produced are examined with a scanning electron microscope. In this work authors made an attempt to analyze the mechanism of chip formation.

Xie J. Q. et al. [93] studied for developing the FEA modelling and simulation of shear localized chip formation in metal cutting. Authors also compared the materials behaviours and chip formations during machining of different work piece materials.

Yen Yung-Chang et al. [94] developed a methodology to predict the tool wear evolution and tool life in orthogonal cutting using FEM simulations. They concluded that location of the maximum wear rate is on the tool rake face and is nearly coincident with that of the maximum cutting temperature.

Zghal B. et al. [96] presented the dynamic response of the system tool work piece during turning operation by taking into account the regenerative effect. A new model based on finite element method was developed to establish the dynamic equation of the system. The simulation shows the variation of the cutting forces around the static equilibrium and the effect of the vibratory behaviour on the profile of the work piece during the raising operation.
1.4 OBJECTIVE OF THE PRESENT RESEARCH INVESTIGATION

1. To identify the influence of cutting speed, feed and depth of cut on flank wear and surface finish during turning of E0300 alloy steel and En-31 steels. Turning experiments are to be performed using different inserts with and without use of coolant.

2. To identify the influence of special tooling systems e.g. rotary circular tooling system, fixed square tooling system on machinability of E0300 alloy steel and En-31 steels through the analysis of machinability factors e.g. flank wear, surface finish, prediction of tool life and setting of inclination angle i.e. angle of obliquity etc. during turning operation using different uncoated and coated carbide tools with and without use of coolant.

3. To study and compare the utility of specially designed tool and tooling system in the machining of E0300 alloy steel, En-31 steels for achieving optimal machining criteria yield of the conventional machining process during turning operation.

4. To predict the tool life and analyze the influence of the continuous length of machining and time of continuous machining on the flank wear. Considering maximum 0.3 mm flank wear width is the life span of the tool.

5. On line monitoring of the turning condition by using VCD camera.

6. To study the wear out condition of the cutting tool inserts through scanning electron microscope (SEM) micrographs, for tool geometry analysis and suggestive measures for machining.

7. To study the detail machinability criteria of E0300 alloy steel and En-31 steels during turning through the analysis of temperature generated and chip formation phenomenon etc. through SEM micrographs and micro-photos for searching out the facts, which will influence the machining performance.

8. To determine the effect of cutting variables on the machinability criteria and compare the performance of different coated and uncoated inserts and tooling system will be used for conducting the experimentations.

9. To carry out in-depth experimental investigation during turning machining of hard alloy steel for achieving better surface finish using Taguchi design methodology. The test results have to be analyzed for investigating the influence of various predominant machining parameters e.g. cutting speed,
feed, and depth of cut and interactions of these parameters on the surface roughness criteria i.e. $R_a$ and $R_t$ during machining of E0300 alloy steel and En-31 steels.

10. To carry out machining using CNC and to measure and analyze the selective machinibility criteria.

11. To develop mathematical models based on regression analysis for correlating the influence of the various machining parameters on the surface roughness criteria, $R_a$ and $R_t$; cutting forces, tool wear during turning using coated and uncoated carbide tools.

12. To judge the applicability of the Taguchi method based robust design analysis in the optimization of surface roughness criteria during tradition machining of E0300 alloy steel and En-31 steels through confirmation test by comparing the test results on the basis of developed models with the standard theoretical models.

13. To determine the optimal values of various machining conditions using experimental design.

14. To perform the cost optimization using dynamic programming techniques.

15. Validity test.