CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Manufacturing is the backbone of any modern industrialized economy. Among various manufacturing processes, material removal is one of the oldest and most indispensable processes for shaping components. Machining process, with its intrinsic versatility and associated precision, machine tools capable of being driven by computers, has been responsible for the recent industrial advancements. The main objective of any machining process is to produce a part of required size and shape, with specific quality. The growth of a manufacturing-based economy largely depends on the development of various machining operations. The driving force behind this development is the ability to make parts with high quality and precision, both faster and at lower cost. In view of its economic importance, complexity of the process, and to develop new cutting equipment, techniques, or processes, researchers have continuously expressed their desire in understanding the principles of cutting mechanisms.

Generally, materials are machined in Computer Numerical Control (CNC) machines to get good surface finish, dimensional accuracy, and complex geometrical shape. In machining, considerable amount of material is removed from the raw material in the form of chips to get the desired size and shape. This method of metal removal is a more expensive process when compared to other manufacturing processes such as forging, casting, etc. Due
to high capital and machining costs of the CNC machines, there is a need to operate the machines as effectively as possible in order to get the required pay back. Effective machining mainly depends on proper selection of cutting parameters. The machining variables are selected properly by using optimization techniques.

1.2 CUTTING TOOL MATERIALS USED FOR MACHINING

During cutting, the tool is exposed to thermal and mechanical stresses. It is of great interest for the industry to decrease the machining time while the new materials are designed with more emphasis on mechanical properties. This tendency places even more pressure on the tool manufacturers to produce tools with high wear resistance, toughness and hardness even at high temperatures.

Two categories of carbide tool materials are available for commercial machining applications, straight and mixed grade carbides. The usual composition of the straight grade carbides is 6 wt.% Co and 94 wt.% Tungsten Carbide (WC) with the cobalt composition ranging from 5 to 12 wt.%. The mixed grade carbides have Titanium Carbide (TiC), Tantalum Carbide (TaC) or Niobium Carbide (NbC) and other rare-earth elements added to the base composition of the straight grade. Titanium carbide is harder than tungsten carbide and its inclusion improves the wear resistance of the carbide tools.

The usual composition is about 5 - 25 wt. %. An increased composition of titanium carbide increases the hot hardness of the tool, thus preventing plastic deformation of the cutting edge, at higher speeds conditions. Heavy interrupted and roughing operations require high cobalt (Co) content and medium coarse grain tungsten carbide to withstand the shock. For finishing applications, lower cobalt content is required as hardness
is important. The ISO-designated M grade carbide is the preferred tool material for machining aero engine alloys. It has a cobalt content in the range of 6 – 9 wt.%, TiC (4 - 8 wt.%) and NbC (5 – 10 wt.%) with hardness between 1450 and 1650 HV.

1.3 NEED FOR OPTIMIZATION

Machine tool manufacturers suggest a range of cutting parameters for various machining processes – the minimum and maximum values. In actual practice, exact values – the optimum cutting parameters, are required in order to prepare the process plan and part program.

Optimization can be defined as the process of finding the variables that give the maximum or minimum value of the functions. The objective function, variables, and constraints are the three basic ingredients of optimization problems. It is the act of obtaining the best result under given circumstances. In any engineering system, engineers have taken many technological and executive decisions at several stages. The most important goal of the decision is either to minimize the effort required or maximize the desired benefit. Accurate and reliable models of a machining process can compensate for the inability to completely understand and adequately describe the process mechanism. Modeling of mathematical equations and optimization of machining parameters are of great concern in manufacturing environments. The economical production of components plays a key role in the competitive market. The optimal values are determined even before the raw material is put into production. Many researchers have employed various optimization techniques for solving machining processes. It is observed that, these techniques have not fulfilled the need of the customers.

It has long been recognized that cutting conditions such as feed rate, cutting speed and depth-of-cut in machining operations should be
selected to optimize the economics of machining operations as assembled by productivity, total manufacturing cost per component or some other suitable criteria (Gilbert 1950).

Optimization of cutting parameters is an important activity for operating machine tools, particularly CNC machine tools. With the use of sophisticated and high cost machines, coupled with high labour costs, optimum machining parameters are essential for producing the parts economically. It is essential to systematically investigate the process or product variables that influence the product quality. After identifying the influencing variables, one can achieve improvement in order to enhance the product's manufacturability, reliability, quality, and field performance. Machine tool manufacturers suggest cutting parameters for various machining processes in limits of minimum and maximum values.

1.4 RESEARCH SCOPE

The machine tool industry has made exponential growth in its manufacturing capabilities in the last decade, yet machine tools are not utilized to their full potential. This limitation is due to the failure in running the machine tools at their optimum operating conditions. The problem of arriving at the optimum levels of the cutting parameters has attracted the attention of the researchers and practicing engineers for a very long time.

The literature survey reveals (discussed in chapter 2) that most of the researchers have varied the cutting parameters like cutting speed, feed rate and depth of cut, to machine different work materials with different cutting tools. In CNC machining ‘off-line’ optimization of cutting parameters is possible, which when implemented will avoid catastrophic failures during actual machining. The recent developments in ‘Virtual Machining’ have enabled this very much. However, very little or no research has been
conducted to vary the feed rate gradually along a cut so that the ill effects of sudden acceleration can be avoided.

1.5 PROGRESSIVE FEED RATE

In CNC part programs a single feed rate is chosen for any cut-segment i.e. a constant feed rate is applied. The part program is executed by the controller. The controller executes one block at a time. So there is a time delay between executions of two successive blocks. This leads to a stop-go fashion of machining. Due to this, at the start of every cut-segment, the tool starts from a stationary position i.e. a feed rate of zero mm/min and accelerates to the programmed feed rate instantly. This leads to sudden increase in the cutting force, spindle deflection, poor surface finish and accelerated tool wear.

An existing solution for the above problem is ‘Adaptive Control System’ which is also called as ‘Online Optimization’ technique. With the help of sensors the cutting parameters are changed dynamically thereby maintaining a constant cutting force. But the cost of adaptive control system is very high and cannot be installed in all CNC machines.

In order to have an off-line optimization technique, which will also be cost effective, a progressive feed rate concept is introduced. The feed rate is increased gradually from a low value to the programmed feed rate through a certain distance in steps. Beyond this distance the feed rate will be constant for the rest of the cut. This eliminates the sudden acceleration and thereby reduces the ill effects like high cutting forces etc. The progressive feed rate concept can be incorporated in the part program itself.
1.6 OBJECTIVES

The primary objective of the present work is to investigate the effect of increasing the feed rate gradually i.e., progressively, along a cut-segment, on the output characteristics such as surface roughness, tool wear and cutting forces. Exhaustive review of literature on optimization of process parameters revealed that the application of Taguchi techniques for single objective; Grey relational analysis for multi-response optimization were widely used. Therefore, it is attempted through this research work to evaluate the above said optimization methods for achieving the objective of selecting the appropriate process parameters for machining AISI 1045 steel.

The cutting speed of the tool, feed rate and the depth of cut are the significant parameters which have effect on the output characteristics. In order to achieve the above mentioned primary objective, the following sub-objectives are formed:

- To do machining with the existing ‘constant feed rate’ method and the proposed ‘progressive feed rate method’
- To measure the surface roughness, tool flank wear and the cutting forces
- To compare the output characteristics between the existing constant feed rate method and the proposed progressive feed rate method
- To investigate the effect of progressive feed rate on surface roughness, tool flank wear and cutting force
- To create a regression mathematical model from the experimental data, using RSM technique, which can be used
to predict the output parameters for the given set of input parameters

- To use ANOVA technique to validate the regression model
- To find the most influential input parameter on the output parameter using ANOVA
- To model the machining process using Artificial Neural Network (ANN) to ensure the validity of the RSM model and also to predict the output characteristics for the given input parameters
- To use Grey Relational Analysis (GRA) to perform multi-objective optimization as there are multiple input and multiple output parameters
- To perform experiments with various cutting inserts like PVD, CVD and Uncoated carbide inserts to compare their performances.

1.7 ORGANIZATION OF THE THESIS

Chapter 1, entitled ‘Introduction’, gives a brief introduction to the background and motivation for the study. The material chosen for the investigation is AISI 1045. The need for efficient machining is brought out in this chapter. Optimization of various machining parameters is discussed. The scope and objectives of the research are listed. The outline of the thesis is presented in this chapter.

Chapter 2, entitled ‘Literature Survey’, reviews the literature on the work done by various researchers in optimizing the machining parameters to obtain better output characteristics. Literature pertaining to the application of Taguchi method for conducting experiments is surveyed. Regression
modeling and ANN modeling are discussed. Multi-response optimization using Grey Relational Analysis (GRA) has also been discussed.

**Chapter 3**, entitled ‘Experimental Investigation’ describes the experimental procedure for machining AISI 1045 steel. It describes the new concept of ‘Progressive Feed Rate’ method. The experimental setup needed for conducting the machining experiments, instruments needed to measure the surface roughness, tool flank wear and cutting force has been given in detail. Experiments were conducted for the existing and the proposed method.

**Chapter 4**, entitled ‘Modeling’, details the procedure to create a regression mathematical model from the experimental data to predict the output characteristics for the given input. ANOVA was performed to check the validity of the generated mathematical model. Modeling using Artificial Neural Network (ANN) has been done to compare it with the regression model.

**Chapter 5**, entitled ‘Optimization’ explains the importance of multi-response optimization, as there are multiple input and multiple output characteristics. The concept of Grey Relational Analysis (GRA) and the procedure to optimize the machining parameters using GRA have been explained in detail.

**Chapter 6**, entitled ‘Results and Discussion’, compares the results obtained from both the existing constant feed rate method and the proposed progressive feed rate method to check for the improvement in surface roughness, tool wear and cutting force.

**Chapter 7**, entitled ‘Conclusion’, presents the summary of the thesis, findings, limitations, and the scope for future research in this area.