**CHAPTER TWO**

**LITERATURE REVIEW**

**2.1. Introduction**

It has long been recognized that conditions during cutting, such as feed rate, cutting speed and depth of cut,should be selected to optimize the economics of machining operations. Turning of composite materialsubstantially different from metallic materials due to its mechanical properties. The turning of this material maygenerate delaminating of work piece. The objective of this research is to study the effect of cutting speed, feed,depth of cut, machining time on metal removal rate, specific energy, surface roughness, volume fraction andflank wear. Taylor showed that an optimum or economic cutting speed exists which could maximize materialremoval rate. Considerable efforts are still in progress on the use of hand book based conservative cutting conditions and cutting tool selection at the process planning level. The need for selecting and implementingoptimal machining conditions and most suitable cutting tool has been felt over the last few decades. DespiteTaylor’s early work on establishing optimum cutting speeds in machining, progress has been slow since all theprocess parameters need to be optimized. Furthermore, for realistic solutions, the many constraints met inpractice, such as low machine tool power, torque, force limits and component surface roughness must be overcome**[7].**

**2.2. Review of Conventional Optimization Techniques**

Traditionally, the selection of cutting conditions for metal cutting is left to the machine operator. In such cases,the experience of the operator plays a major role, but even for a skilled operator it is very difficult to attain the optimum values each time. Machining parameters in turning process are cutting speed, feed rate and depth ofcut. The setting of these parameters determines the quality characteristics of turned parts. Following thepioneering work of Taylor (1907) and his famous tool life equation, different analytical and experimental **[8].**

approaches for the optimization of machining parameters have been investigated. Gilbert (1950) studied theoptimization of machining parameters in turning with respect to maximum production rate and minimumproduction cost as criteria. Armargosa& Brown (1969) investigated unconstrained machine-parameteroptimization using differential calculus. Brewer&Rued (1963) carried out simplified optimum analysis fornon-ferrous materials. For cast iron (CI) and steels, they employed the criterion of reducing the machining costto a minimum. A number of monograms were worked out to facilitate the practical determination of the mosteconomic machining conditions. They pointed out that the more difficult- to-machine materials have a restrictedrange of parameters over which machining can be carried out and thus any attempt at optimizing their costs areartificial. Brewer (1966) suggested the use of Lagrangian multipliers for optimization of the constrainedproblem of unit cost, with cutting power as the main constraint. Walvekar & Lambert (1970) discussed the useof geometric programming to selection of machining variables. They optimized cutting speed and feed rate toyield minimum production cost. Petropoulos (1973) investigated optimal selection of machining rate variables,viz. cutting speed and feed rate, by geometric programming. Santarem (1978) applied a goal-programmingtechnique in metal cutting for selecting levels of machining parameters in a fine operation on AISI 4140 steelusing cemented tungsten carbide tools. Elmer& Kromodiharajo (1981) developed a multi-step mathematicalOptimization of machining techniques 701 model to solve a constrained multi-pass machining problem. Theyconcluded that in some cases with certain constant total depths of cut, multi-pass machining was moreeconomical than single-pass machining, if depth of cut for each pass was properly allocated. They used highspeed steel (HSS) cutting tools to machine carbon steel. Hinduja *et al* (1985) described a procedure to calculatethe optimum cutting conditions for machining operations with minimum cost or maximum production rate as theobjective function. For a given combination of tool and work material, the search for the optimum was confinedto a feed rate versus depth-of-cut plane defined by the chip-breaking constraint. Some of the other constraints

considered include power available, work holding, surface finish and dimensional accuracy. Tsai (1986) studiedthe relationship between the multi-pass machining and single-pass machining. He presented the concept of abreak-even point, i.e. there is always a point, a certain value of depth of cut, at which single-pass and doublepassmachining are equally effective. When the depth of cut drops below the break-even point, the single-passis more economical than the double-pass, and when the depth of cut rises above this break-even point, double passis better. Carbide tools are used to machine the carbon steel work material. Gopalakrishnan & Khayyal(1991) described the design and development of an analytical tool for the selection of machine parameters indrilling. Geometric programming was used as the basic methodology to *determine values for feed rate and*cutting speed that minimize the total cost of machining SAE 1045 steel with cemented carbide tools of ISO P-10grade. Surface finish and machine power were taken as the constraints while optimizing cutting speed and feed

rate for a given depth of cut. Agapiou (1992) formulated single-pass and multi-pass machining operations.Production cost and total time were taken as objectives and a weighting factor was assigned to prioritize the twoobjectives in the objective function. He optimized the number of passes, depth of cut, cutting speed and feed ratein his model, through a multi-stage solution process called dynamic programming. Several physical constraintswere considered and applied in his model. In his solution methodology, every cutting pass is independent of theprevious pass; hence the optimality for each pass is not reached simultaneously. Prasad *et al* (1997) reported the development of an optimization module for determining process parameters for operations as part of a PC-based

generative CAPP system. The work piece materials considered in their study include steels, cast iron, aluminum, copper and brass. HSS and carbide tool materials are considered in this study. The minimization of production

time is taken as the basis for formulating the objective function. The constraints considered in this work include power, surface finish, tolerance, and work piece rigidity, range of cutting speed, maximum and minimum depths

of cut and total depth of cut. Improved mathematical models are formulated by modifying the tolerance andwork piece rigidity constraints for multi-pass turning operations.

**2.3. Optimization techniques**

The latest techniques for optimization include fuzzy logic, scatter search technique, ant colony technique, genetic algorithm, and Taguchi technique and response surface methodology.

**2.3.1. Fuzzy logic**

Fuzzy logic has great capability to capture human commonsense reasoning, decision-making and other aspects of human cognition. Kosko (1997) shows that it overcomes the limitations of classic logical systems, whichimpose inherent restrictions on representation of imprecise concepts. Vagueness in the coefficients and constraints may be naturally modeled by fuzzy logic. Modeling by fuzzy logic opens up a new way to optimize cutting conditions and also tool selection.

**2.3.2 Genetic algorithm (GA )**

These are the algorithms based on mechanics of natural selection and natural genetics, which are more robustand more likely to locate global optimum**.** It is because of this feature that GA goes through solution space

starting from a group of points and not from a single point. The cutting conditions are encoded as genes bybinary encoding to apply GA in optimization of machining parameters. A set of genes is combined together toform chromosomes, used to perform the basic mechanisms in GA, such as crossover and mutation. Crossover isthe operation to exchange some part of two chromosomes to generate new offspring, which is important whenexploring the whole search space rapidly. Mutation is applied after crossover to provide a small randomness tothe new chromosomes. To evaluate each individual or chromosome, the encoded cutting conditions are decodedfrom the chromosomes and are used to predict machining performance measures. Fitness or objective function isa function needed in the optimization process and selection of next generation in genetic algorithm. Optimumresults of cutting conditions are obtained by comparison of values of objective functions among all individualsafter a number of iterations. Besides weighting factors and constraints, suitable parameters of GA are required tooperate efficiently. GA optimization methodology is based on machining performance predictions modelsdeveloped from a comprehensive system of theoretical analysis, experimental database and numerical methods.The GA parameters along with relevant objective functions and set of machining performance constraints areimposed on GA optimization methodology to provide optimum cutting conditions.

**2.3.2.1 Implementation of GA**

First of all, the variables are encoded as *n*-bit binary numbers assigned in a row as chromosome strings. To implement constraints in GA, penalties are given to individuals out of constraint. If an individual is out ofconstraint, its fitness will be assigned as zero. Because individuals are selected to mate according to fitness

value, zero fitness individuals will not become parents. Thus most individuals in the next generation are ensuredin feasible regions bounded by constraints. The GA is initialized by randomly selecting individuals in the fullrange of variables. Individuals are selected to be parents of the next generation according to their fitness value.The larger the fitness value, the greater their possibility of being selected as parents. Wang& Jawahir (2004)

have used this technique for optimization of milling machine parameters. Kuo & Yen (2002) have used acontrol of a computernumerical control machine tool.

**2.3. 3Scatter search technique (SS)**

This technique originates from strategies for combining decision rules and surrogate constraints. SS iscompletely generalized and problem-independent since it has no restrictive assumptions about objectivefunction, parameter set and constraint set. It can be easily modified to optimize machining operation undervarious economic criteria and numerous practical constraints. It can obtain near-optimal solutions within

reasonable execution time on PC. Potentially, it can be extended as an on-line quality control strategy foroptimizing machining parameters based on signals from sensors. Chen & Chen (2003) have done extensivework on this technique.

**2.3.4 Taguchi technique**

Gnocchi Taguchi is a Japanese engineer who has been active in the improvement of Japan’s industrial productsand processes since the late 1940s. He has developed both the philosophy and methodology for process orproduct quality improvement that depends heavily on statistical concepts and tools, especially statisticallydesigned experiments. Many Japanese firms have achieved great success by applying his methods. Wu (1982)has reported that thousands of engineers have performed tens of thousands of experiments based on histeachings. Sullivan (1987) reports that Taguchi has received some of Japan’s most prestigious awards for qualityachievement, including the Deming prize. In 1986, Taguchi received the most prestigious prize from theInternational Technology Institute – The Willard F. Rockwell Medal for Excellence in Technology. Taguchi’s

major contribution has involved combining engineering and statistical methods to achieve rapid improvementsin cost and quality by optimizing product design and manufacturing processes. Barker (1990) reported that since1983, after Taguchi’s association with the top companies and institutes in USA (AT & T Bell Laboratories,Xerox, Lawrence Institute of Technology (LIT), Ford Motor Company etc.), his methods have been called aradical approach to quality, experimental design and engineering. Sullivan (1987) reported that the term“Taguchi methods” (TM) refers to the parameter design, tolerance design, quality loss function, on-line qualitycontrol, design of experiments using orthogonal arrays, and methodology applied to evaluate measuringsystems. Pignatiello (1988) identifies two separate aspects of the Taguchi methods: the strategy of Taguchi andthe tactics of Taguchi. Taguchi tactics refer to the collection of specific methods and techniques used by GenichiTaguchi, and Taguchi strategy is the conceptual framework or structure for planning a product or process designexperiment. Ryan (1988) and Benton (1991) reported that Taguchi addresses design and engineering (off-line)as well as manufacturing (on-line) quality. This fundamentally differentiates TM from statistical process control(SPC), which is purely an on-line quality control method. Taguchi’s ideas can be distilled into two fundamentalconcepts:

(1) Quality losses must be defined as deviations from targets, not conformance to arbitrary specifications(Benton 1991).

(2) Achieving high system-quality levels economically requires quality to be designed into the product.Quality is designed, not manufactured, into the product ( Daetz 1987; Taguchi 1989).Lin *et al* (1990) stated that Taguchi methods represent a new philosophy. Quality is measured by the deviation

of a functional characteristic from its target value. Noises (uncontrolled variables) can cause such deviationsresulting in loss of quality. Taguchi methods seek to remove the effect of noises. Taguchi (1989) described thatquality engineering encompasses all stages of product/process development: system design, parameter design,and tolerance design. Byrne & Taguchi (1987), however, pointed out that the key element for achieving highquality and low cost is parameter design. Through parameter design, levels of product and process factors aredetermined, such that the product’s functional characteristics are optimized and the effect of noise factors isminimized. Kackar & Shoemaker (1986) observed that parameter design reduces performance variation byreducing the influence of the sources of variation rather than by controlling them, it is thus a very cost-effectivetechnique for improving engineering design**[9]**

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**2.3.5 Response surface methodology (RSM)**

Experimentation and making inferences are the twin features of general scientific methodology. Statistics as ascientific discipline is mainly designed to achieve these objectives. Planning of experiments is particularly very

useful in deriving clear and accurate conclusions from the experimental observations, on the basis of whichmaking inferences has three mainaspects. First, it establishes methods for drawing inferences from observations when these are not exact but

subject to variation, because inferences are not exact but probabilistic in nature. Second, it specifies methods forcollection of data appropriately, so that assumptions for the application of appropriate statistical methods to

them are satisfied. Lastly, techniques for proper interpretation of results are devised. The advantages of designof experiments as reported by Adler *et al* (1975) and Johnston (1964) are as follows :

 Numbers of trials are reduced.

 Optimum values of parameters can be determined.

 Assessment of experimental error can be made.

 Qualitative estimation of parameters can be made.

Inference regarding the effect of parameters on the characteristics of the process can be made. Cochran & Cox(1962) quoted Box and Wilson as having proposed response surface methodology for the optimization of

experiments. Box & Hunter (1957) have proposed that the scheme based on central composite rotatable designfits the second-order response surfaces very accurately.