Prediction of optimal drilling parameters in machining of AA6061 using TOPSIS

A Project report submitted in partial fulfillment of the requirement for the award of the degree of

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IN

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LIST OF CONTENTS

ABSTRACT

This book presents in-depth and comprehensive approach for optimizing the machining parameters in milling of wrought alloy AA6061 using a MCDM/MADM method called TOPSIS. The present work is carried out in three phases - phase-I the orthogonal array L18 design is prepared using Minitab software by considering various milling parameters such as drill type, point angle, speed and feed. In the phase-II, milling operations are performed on the work piece using a carbide end mill cutter as per Taguchi design and the responses such as material removal rate (MRR) and Surface roughness (Ra) are measured. In the phase-III, the experimental response data are analyzed using TOPSIS method. The TOPSIS results are used for finding the optimal combination of cutting parameters which maximizes the material removal rate and minimizes the surface roughness at a time.

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

v	Cutting speed, rpm
f	Feed rate, mm/min
D	Depth of cut, mm
VMRR	Volume of Material Removal Rate, cm^3/min
R_a	Arithmetic Surface Roughness Average, µm
CNC	Computerized Numerical Control
DOE	Design of Experiments
OA	Orthogonal Array
S/N	Signal to Noise Ratio
ANOVA	Analysis of Variance
DF	Degree of Freedom
SS	Sum of Squares
MS	Mean Square
F	Variance Ratio
P	Probability of Significance
S	Variance
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution

r_{ij}	Normalized Decision Matrix
V_{ij}	Weighted Normalized Matrix
PIS	Positive Ideal Solution
NIS	Negative Ideal Solution
S_i^+	Separation Distance from PIS
S_i^-	Separation Distance from NIS
C_i^+	Relative Closeness Coefficient

CHAPTER-1

INTRODUCTION

1.1 Introduction

Drilling is one of the most complex machining processes. The chief characteristic that distinguishes it from other machining operations is the combined cutting and extrusion of metal at the chisel edge in the center of the drill. The high-thrust force caused by the feeding motion first extrudes metal under the chisel edge. Then it tends to shear under the action of a negative rake angle tool.

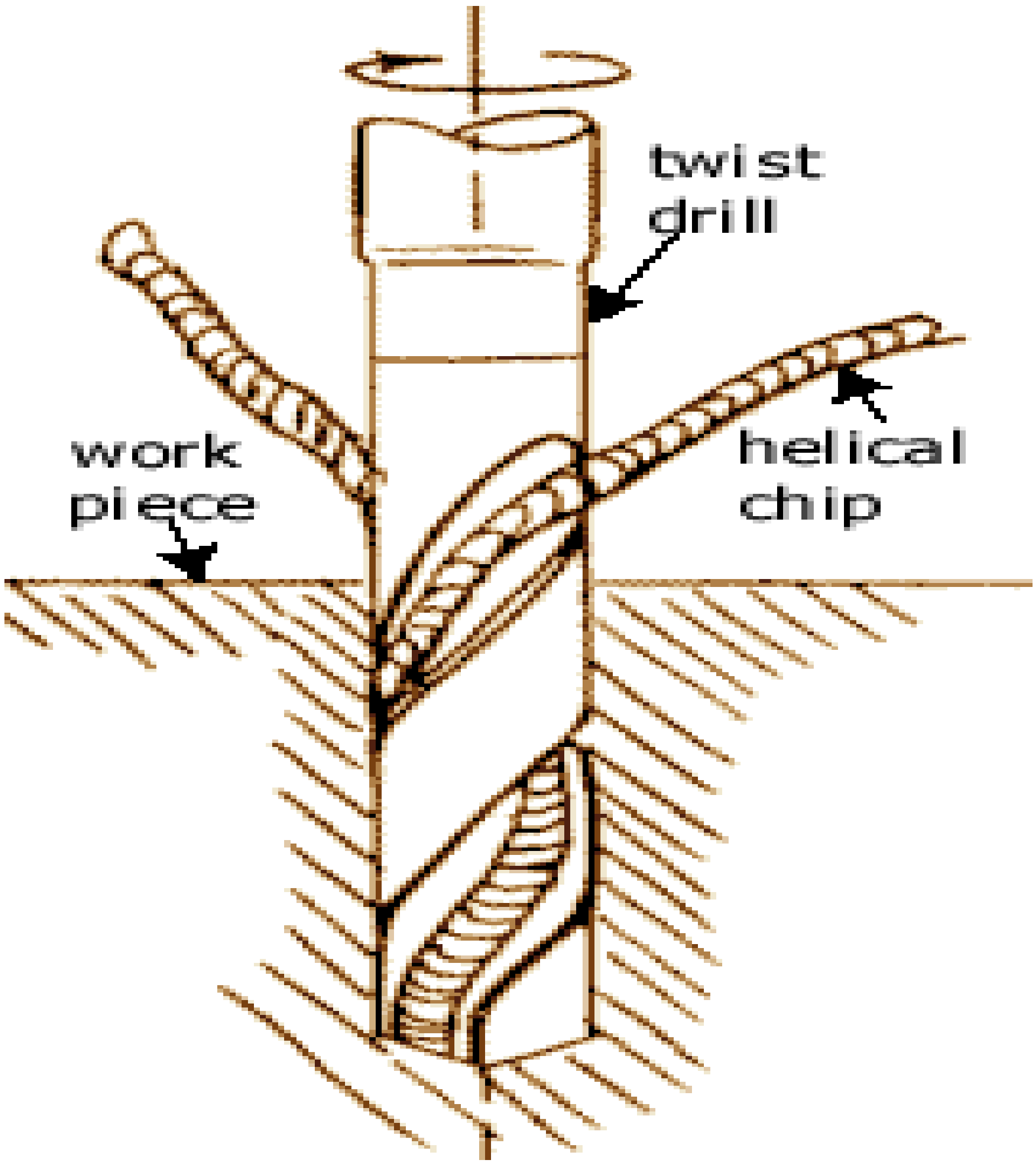


Figure 1.1 Drilling Operation

The cutting action along the lips of the drill is not unlike that in other machining processes. Because of variable rake angle and inclination, however, there are differences in the cutting action at various radii on the cutting edges. This is complicated by the constraint of the whole chip on the chip flow at any single point along the lip. Still, the metal-removing action is true cutting, and the problems of variable geometry and constraint are present. Because it is such a small portion of the total drilling operation, though, it is not a distinguishing characteristic of the process.

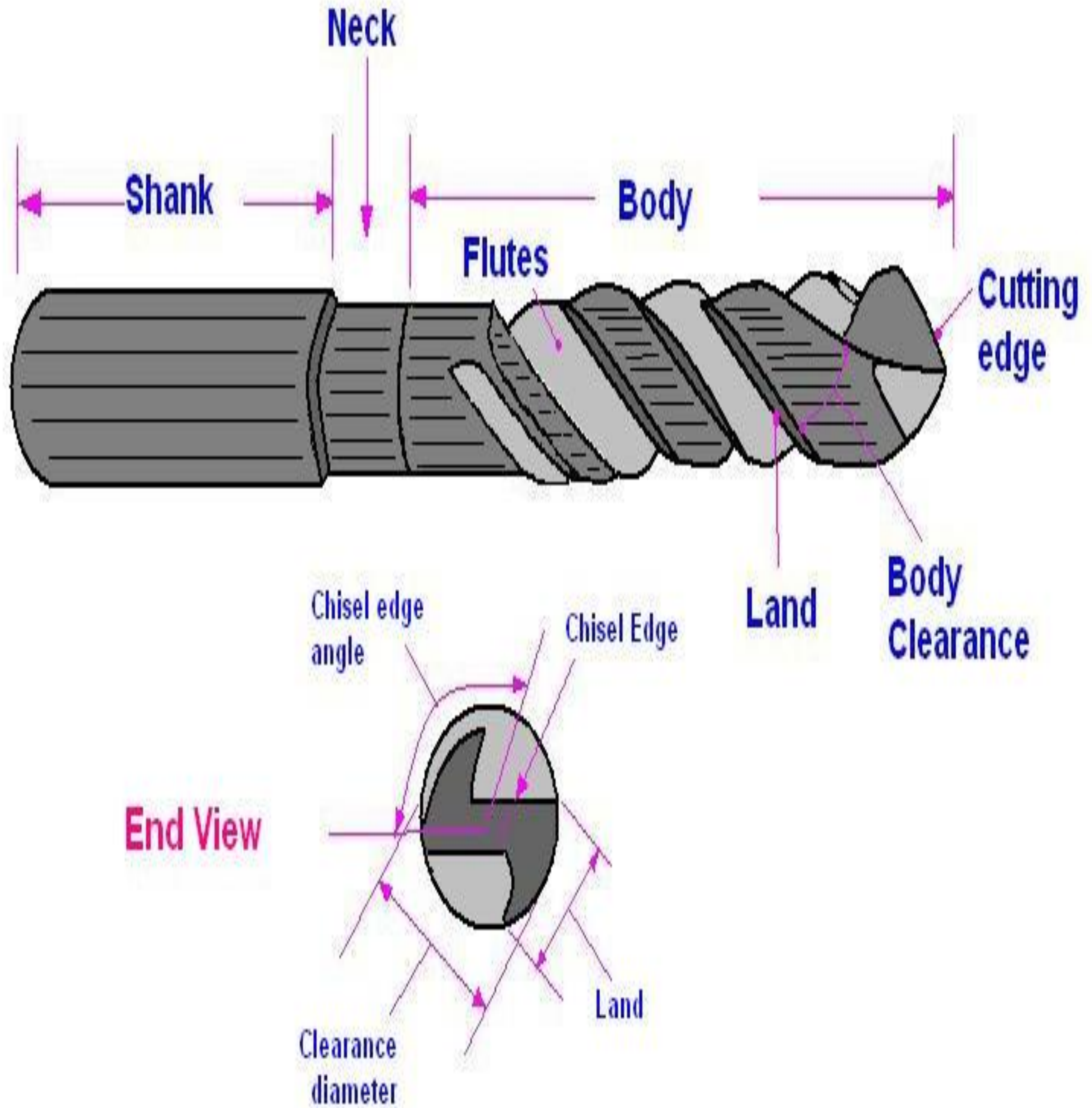
The machine settings used in drilling reveal some important features of this hole-producing operation. Depth of cut, a fundamental dimension in other cutting processes, corresponds most closely to the drill radius. The un-deformed chip width is equivalent to the length of the drill lip, which depends on the point angle as well as the drill size. For a given set-up, the un-deformed chip width is constant in drilling. The feed dimension specified for drilling is the feed per revolution of the spindle. A more fundamental quantity is the feed per lip. For the common two-flute drill, it is half the feed per revolution. The un-deformed chip thickness differs from the feed per lip depending on the point angle.

The spindle speed is constant for any one operation, while the cutting speed varies all along the cutting edge. Cutting speed is normally computed for the outside diameter. At the center of the chisel edge the cutting speed is zero; at any point on the lip it is proportional to the radius of that point. This variation in cutting speed along the cutting edges is an important characteristic of drilling. Once the drill engages the work piece, the contact is continuous until the drill breaks through the bottom of the part or is withdrawn from the hole. In this respect, drilling resembles turning and is unlike milling.

1.2 Drill Nomenclature

The most important type of drill is the twist drill. The important nomenclature listed below.

Drill: A drill is an end-cutting tool for producing holes. It has one or more cutting edges, and flutes to allow fluids to enter and chips to be ejected. The drill is composed of a shank, body and point.



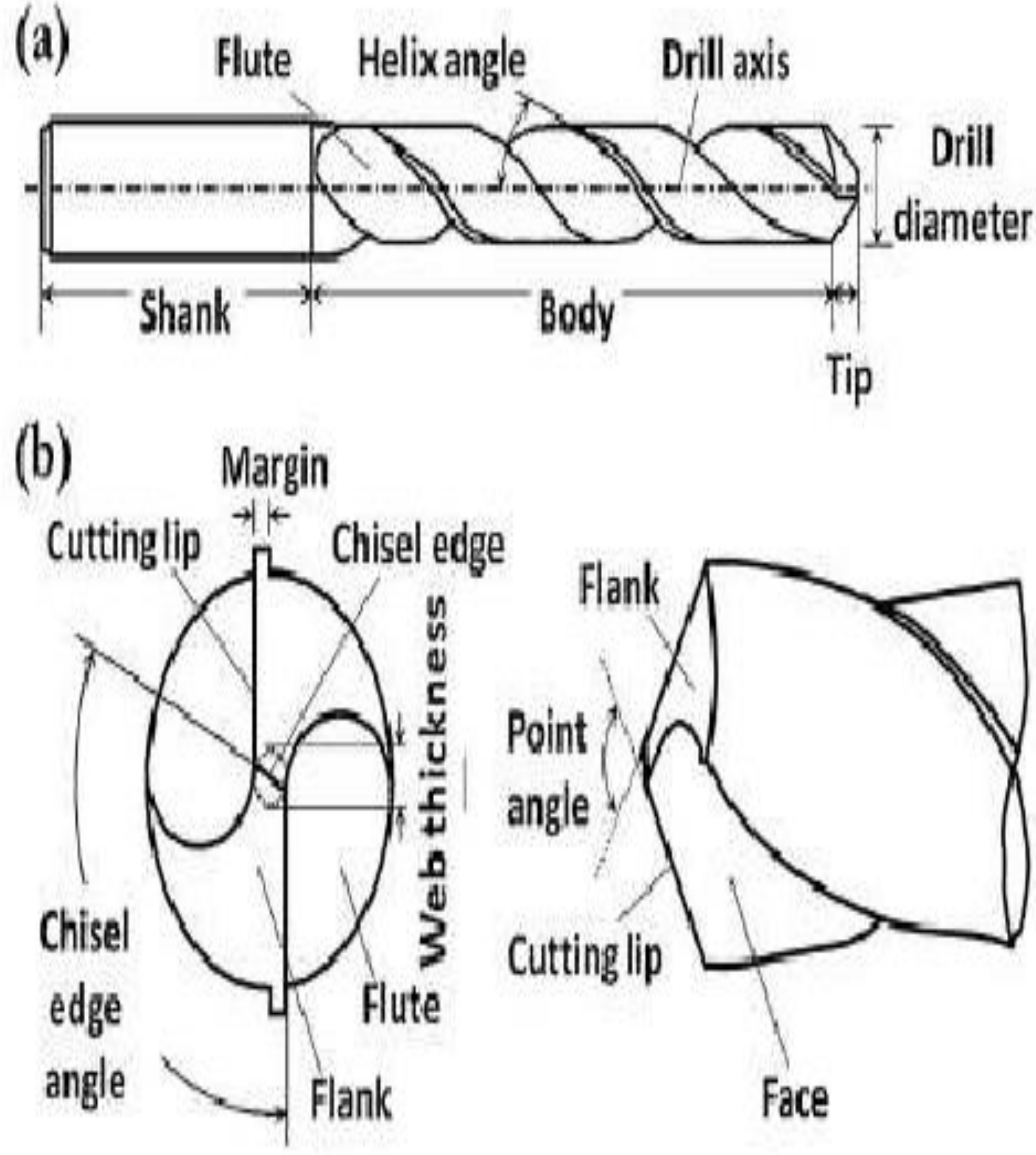


Figure 1.2 Twist Drill and Parts

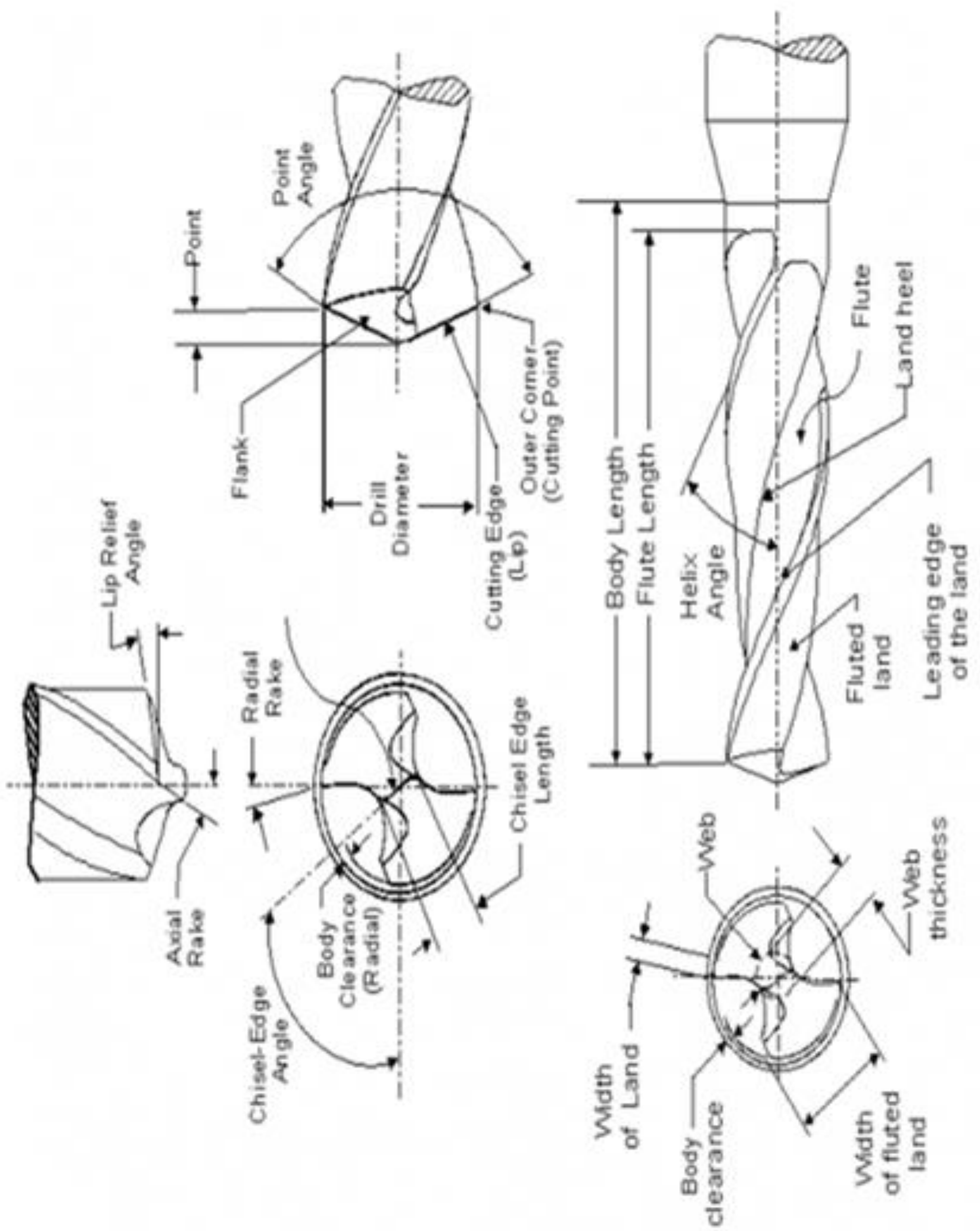


Figure 1.3 Nomenclature of Twist Drill

Shank: The shank is the part of the drill that is held and driven. It may be straight or tapered.

Tang: The tang is a flattened portion at the end of the shank that fits into a driving slot of the drill holder on the spindle of the machine.

Body: The body of the drill extends from the shank to the point, and contains the flutes. During sharpening, it is the body of the drill that is partially ground away.

Point: The point is the cutting end of the drill.

Flutes: Flutes are grooves that are cut or formed in the body of the drill to allow fluids to reach the point and chips to reach the work piece surface. Although straight flutes are used in some cases, they are normally helical.

Land: The land is the remainder of the outside of the drill body after the flutes are cut. The land is cut back somewhat from the outside drill diameter to provide clearance.

Margin: The margin is a short portion of the land not cut away for clearance. It preserves the full drill diameter.

Web: The web is the central portion of the drill body that connects the lands.

Chisel edge: The edge ground on the tool point along the web is called the chisel edge. It connects the cutting lips.

Lips: The lips are the primary cutting edges of the drill. They extend from the chisel point to the periphery of the drill.

Axis: The axis of the drill is the centerline of the tool. It runs through the web and is perpendicular to the diameter.

Neck: Some drills are made with a relieved portion between the body and the shank. This is called the drill neck. In addition to these terms that define the various parts of the drill, there are a number of terms that apply to the dimensions of the drill, including the important drill angles. Among these terms are:

Length: Along with its outside diameter, the axial length of a drill is listed when the drill size is given. In addition, shank length, flute length and neck length are often used.

Body diameter clearance: The height of the step from the margin to the land is called the body diameter clearance.

Web thickness: The web thickness is the smallest dimension across the web. It is measured at the point unless otherwise noted. Web thickness will often increase in going up the body away from the point, and it may have to be ground down during sharpening to reduce the size of the chisel edge. This process is called "web thinning."

Helix angle: The angle that the leading edge of the land makes with the drill axis is called the helix angle. Drills with various helix angles are available for different operational requirements.

Point angle: The included angle between the drill lips is called the point angle. It is varied for different work piece materials.

Lip relief angle: Corresponding to the usual relief angles found on other tools is the lip relief angle. It is measured at the periphery.

Chisel edge angle: The chisel edge angle is the angle between the lip and the chisel edge, as seen from the end of the drill.

1.3 Classes of Drills

There are different classes of drills for different types of operations. Work piece materials may also influence the class of drill used, but it usually determines the point geometry rather than the general type of drill best suited for the job. The twist drill is the most important class. Within the general class of twist drills there are a number of drill types made for different kinds of operations.

Figure 1.4 Types of Drills

Figure 1.5 Drills Based on Helix Angle

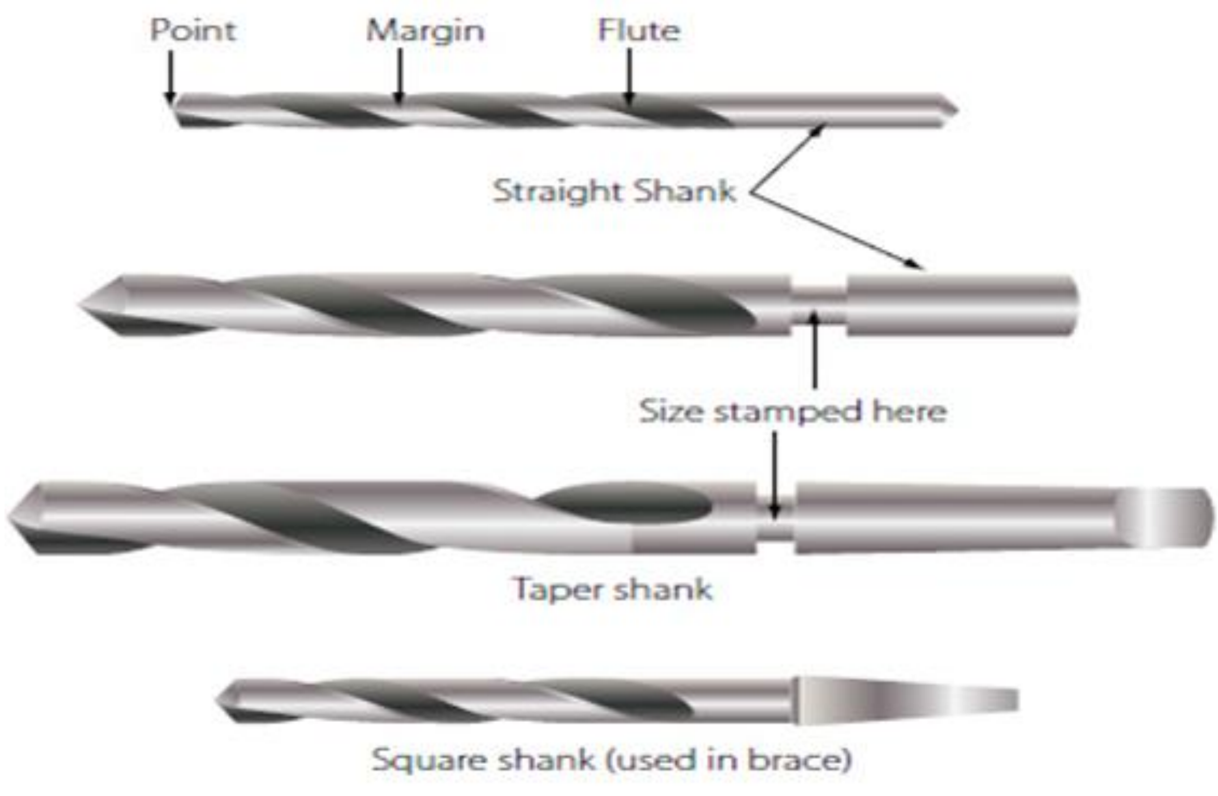


Figure 1.6 Drills Based on Shank Type

High helix drills: This drill has a high helix angle, which improves cutting efficiency but weakens the drill body. It is used for cutting softer metals and other low strength materials.

Low helix drills: A lower than normal helix angle is sometimes useful to prevent the tool from "running ahead" or "grabbing" when drilling brass and similar materials.

Heavy-duty drills: Drills subject to severe stresses can be made stronger by such methods as increasing the web thickness.

Left hand drills: Standard twist drills can be made as left hand tools. These are used in multiple drill heads where the head design is simplified by allowing the spindle to rotate in different directions.

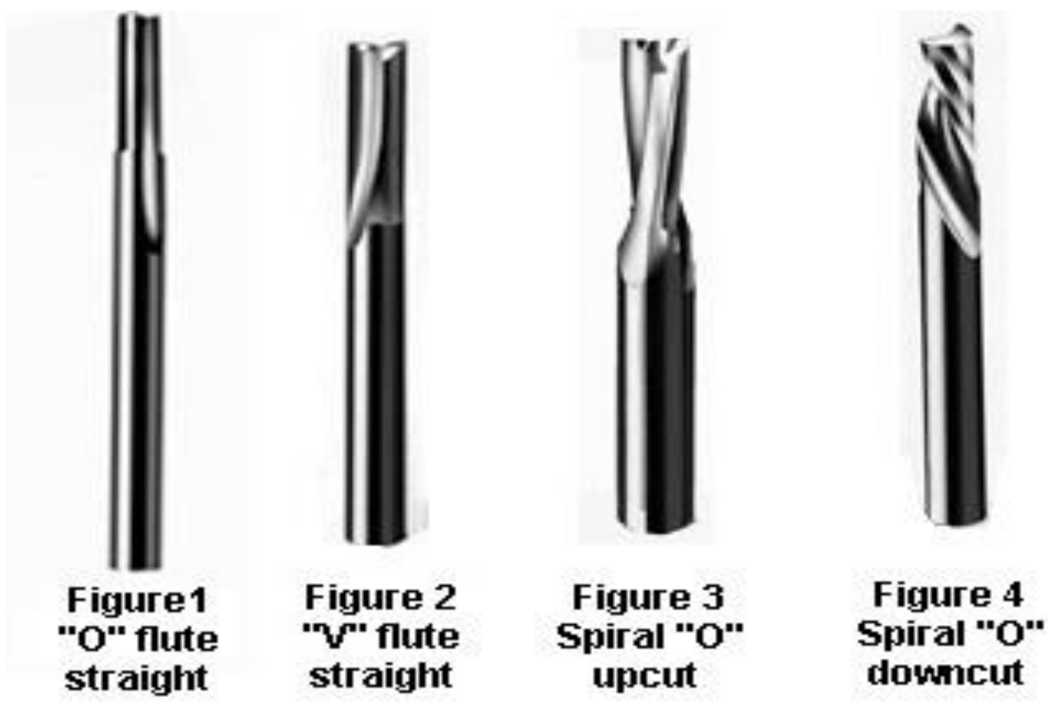


Figure 1.7 drills Based on Flutes

Straight flute drills: Straight flute drills are an extreme case of low helix drills. They are used for drilling brass and sheet metal.

Crankshaft drills: Drills that are especially designed for crankshaft work have been found to be useful for machining deep holes in tough materials. They have a heavy web and helix angle that is somewhat higher than normal.

Extension drills: The extension drill has a long, tempered shank to allow drilling in surfaces that are normally inaccessible.

Extra-length drills: For deep holes, the standard long drill may not suffice, and a longer bodied drill is required.

Step drill: Two or more diameters may be ground on a twist drill to produce a hole with stepped diameters.

Subland drill: The subland or multi-cut drill does the same job as the step drill. It has separate lands running the full body length for each diameter, whereas the step drill uses one land. A subland drill looks like two drills twisted together.

Solid carbide drills: For drilling small holes in light alloys and nonmetallic materials, solid carbide rods may be ground to standard drill geometry. Light cuts without shock must be taken because carbide is quite brittle.

Carbide-tipped drills: Carbide tips may be used on twist drills to make the edges more wear resistant at higher speeds. Carbide-tipped drills are widely used for hard, abrasive non-metallic materials such as masonry.

Oil hole drills: Small holes through the lands, or small tubes in slots milled in the lands, can be used to force oil under pressure to the tool point. These drills are especially useful for drilling deep holes in tough materials.

Flat drills: Flat bars may be ground with a conventional drill point at the end. This gives very large chip spaces, but no helix. Their major application is for drilling railroad track.

Figure 1.8 Straight, 2 Flute and 3 Flute Drills

Three- and four-fluted drills: There are drills with three or four flutes that resemble standard twist drills except that they have no chisel edge. They are used for enlarging holes that have been previously drilled or punched. These drills are used because they give better productivity, accuracy and surface finish than a standard drill would provide on the same job.

Drill and countersink: A combination drill and countersink is a useful tool for machining "center holes" on bars to be turned or ground between centers. The end of this tool resembles a standard drill. The countersink starts a short distance back on the body.

Figure 1.9 Countersink Drills

1.4 Drilling Operations

Several operations are related to drilling. In the following list, most of the operations follow drilling except for centering and spot facing, which precede drilling. A hole must be made first by drilling and then the hole is modified by one of the other operations. Some of these operations are illustrated below.

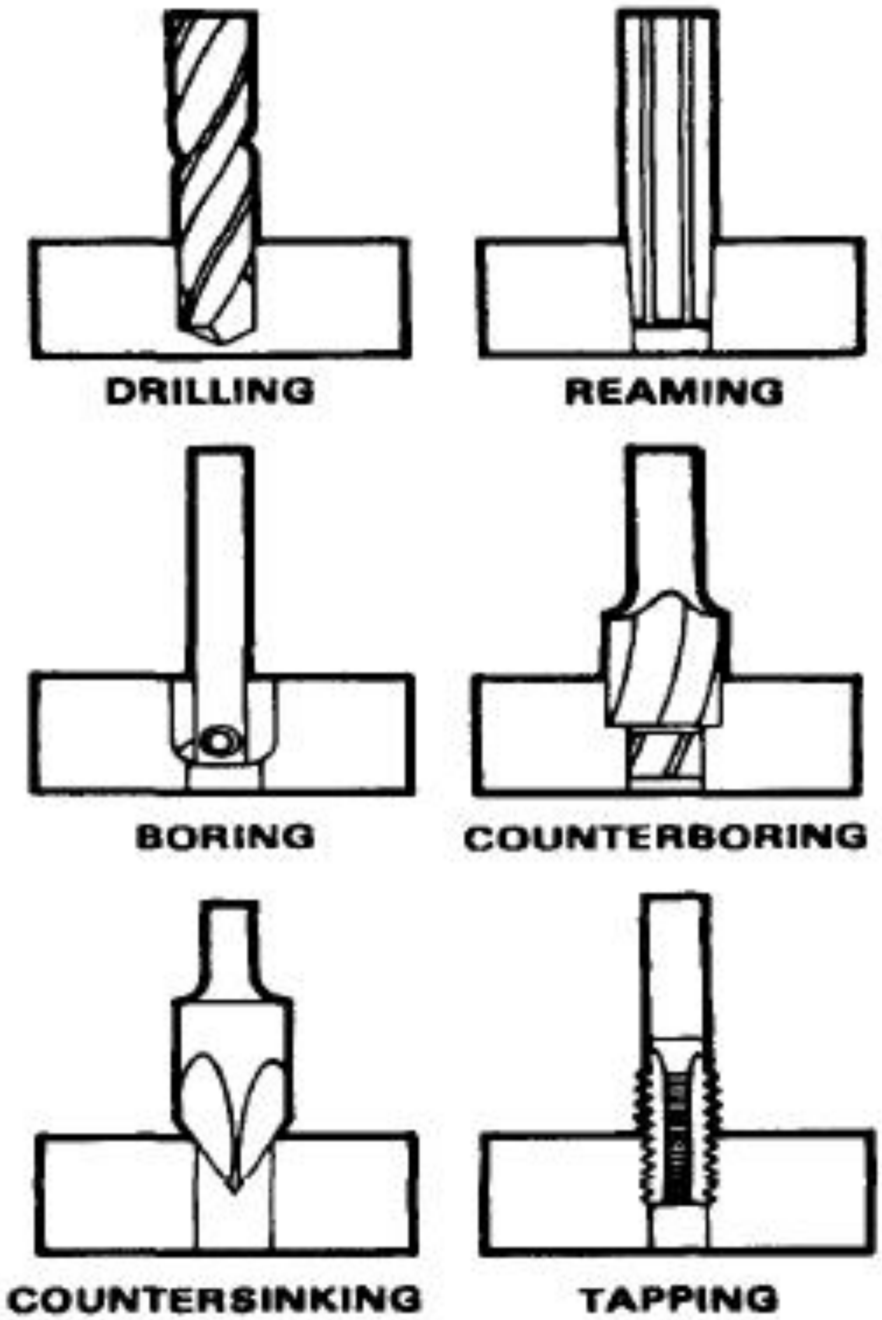


Figure 1.10 Drilling Operations

Reaming: A reamer is used to enlarge a previously drilled hole, to provide a higher tolerance and to improve the surface finish of the hole.

Tapping: A tap is used to provide internal threads on a previously drilled hole.

Counter boring: Counter boring produces a larger step in a hole to allow a bolt head to be seated below the part surface.

Counter sinking: Countersinking is similar to counter boring except that the step is angular to allow flat-head screws to be seated below the surface.

Centering: Center drilling is used for accurately locating a hole to be drilled afterwards.

Spot facing: Spot facing is used to provide a flat-machined surface on a part.

Operating Conditions: The varying conditions, under which drills are used, make it difficult to give set rules for speeds and feeds. Drill manufacturers and a variety of reference texts provide recommendations for proper speeds and feeds for drilling a variety of materials.

Drilling speed: Cutting speed may be referred to as the rate that a point on a circumference of a drill will travel in I minute. It is expressed in surface feet per minute (SFPM). Cutting speed is one of the most important factors that determine the life of a drill. If the cutting speed is too slow, the drill might chip or break. A cutting speed that is too fast rapidly dulls the cutting lips. Cutting speeds depend on the following seven variables:

- The type of material being drilled. (The harder the material, the slower the cutting speed.)
- The cutting tool material and diameter. (The harder the cutting tool material, the faster it can machine the material. The larger the drill, the slower the drill must revolve.)
- The types and use of cutting fluids allow an increase in cutting speed.
- The rigidity of the drill press.
- The rigidity of the drill. (The shorter the drill, the better.)
- The rigidity of the work set-up.
- The quality of the hole to be drilled.

Drilling Feed: Once the cutting speed has been selected for a particular workpiece material and condition, the appropriate feed rate must be established. Drilling feedrates are selected to maximize productivity while maintaining chip control. Feed in drilling operations is expressed in inches per revolution, or IPR, which is the distance the drill moves in inches for each revolution of the drill. The feed may also be expressed as the distance traveled by the drill in a single minute, or IPM (inches per minute), which is the product of the RPM and IPR of the drill. It can be calculated as follows: IPM = IPR x RPM.

The selection of drilling speed (SFPM) and drilling feed (IPR) for various materials to be machined often starts with recommendations in the form of application tables from manufacturers or by consulting reference books.

1.5 Cutting Tool Material Selection: M2 High Speed Steel (HSS) is the standard Rota broach cutting tool material. M2 has the broadest application range and is the most economical tool material. It can be used on ferrous and non-ferrous materials and is generally recommended for cutting materials up to 275 BHN. M2 can be applied to harder materials, but tool life is dramatically decreased. TiN-coated M2 HSS Rota broach drills are for higher speeds, more endurance, harder materials or freer cutting action to reduce power consumption. The TiN coating reduces friction and operates at cooler temperatures while presenting a harder cutting edge surface. TiN-coated tools are recommended for applications on materials to 325 BHN. Carbide cutting tool materials are also available as a special option on Rota broach drills. Carbide offers certain advantages over high-speed steel. Applications are limited and need to be discussed with a manufacturer's representative.

Figure 1.11 HSS Drill Bits

CHAPTER 2

LITERATURE REVIEW

Literature Review

Godfrey C. Onwubolu. et.al. (2006) [1] correlates the interactions of drilling parameters such as speed, feed rate and drill diameter & their effects on axial force and torque acting on the cutting tool through a mathematical model by means of response surface methodology with Sheet metal (Aluminium alloy bar) as work piece material. It was found that, Drill axial force increases as drill size increases for a given speed and decreases as spindle speed increases for a given diameter. Also drill axial force increases as feed rate increases for a given diameter, while the drill torque varies non-linearly with all the control parameters.

C.C. Tsao. et.al. (2008) [2] predicts and evaluates the thrust force and surface roughness in drilling of composite material using candle stick drill & by considering the drilling parameters - feed rate, spindle speed and drill diameter. The approach is based on Taguchi method and the artificial neural network. Feed rate and the drill diameter are found to be the most significant factors affecting the thrust force, while the feed rate and spindle speed are seen to have the largest contribution to the surface roughness. It was found that Radial basis function network (RBFN) seems to be more effective than multi-variable regression analysis.

S Jayabal and U Natarajan (2010) [3] investigated the influence of point angle, spindle speed and feed rate on thrust force and torque using HSS twist drills during the machining of GFR composites. A mathematical model was developed to correlate the interactions of drilling parameters and their effect on thrust force and torque. The optimum value of the cutting parameters was also determined to get minimum value of the thrust force and torque. It is found that 90° point angle gives better results compared to 104° and 118° point angles.

Murthy B.R.N. et.al. (2012) [4] stated the effect of process parameters i.e. spindle speed, feed, drill diameter, point angle & material thickness on thrust force and torque generated during drilling of Glass Fibre Reinforced Polymer (GFRP) composite material through integration of Taguchi method and Response Surface Methodology & by using solid carbide drill bit. It was found that, Thrust force is significantly influenced by spindle speed, and they are inversely proportional. Higher the drill diameter, larger will be the thrust force and cutting torque required. `Both thrust force and cutting torque increase with the increase in feed rate and material thickness.

S. Madhavan. et.al. (2012) [5] reports the effect of drilling parameters - Speed, Feed rate, drill type on thrust force during drilling of holes in Carbon Fibre Reinforced Plastic composite laminate using HSS, Solid Carbide (K20) and Poly Crystalline Diamond insert drills. Experiments were conducted by using Taguchi design of experiments and a model is developed to correlate the drilling parameters with thrust force using Response surface Methodology (RSM). Thrust force recorded for HSS drill was high when compared to Carbide and there is tremendous increase in thrust force values for PCD. The thrust force generally increases as the speed increases but decreases further in the case of Carbide and PCD tool. Medium cutting speed and feed rate provides optimum thrust forces irrespective of the drills used.

Yogendra Tyagi. et.al. (2012) [6] states the impact process parameters- Spindle speed, Feed rate and Depth of cut on Surface Roughness and Material Removal Rate for CNC drilling machine operation by using high speed steel Tool and by applying Taguchi methodology. It was observed that, as spindle speed increases there is increase in the MRR and the surface roughness initially decreases with increase in spindle speed while after some process there is increase in surface roughness. As there is increase in the feed rate there is decrease in both the MRR and the surface roughness. Initially there is decrease in MRR & the surface roughness with increase in depth of cut and after some process, there is increase in MRR and surface roughness with increase depth of cut.

P.Venkataramaiah. et.al. (2012) [7] focused on development of a neural network model to predict the multi-responses and to study the influence of drilling parameters- cutting speeds, feed rates, type of drill tool, cutting fluids on output parameters- Torque, cutting force, surface roughness, material removal rate and power for determining the optimum input parameters combination using Taguchi method. It was found that, Surface finish and torque are mostly affected by types of drill tools. Cutting force is mostly affected by cutting environment. Material removal rate is mostly affected by feed rate, with increase in feed rate there is decrease in MMR and Power is mostly affected by cutting speed.

N. Keerthi et.al. (2013) [8] states the impact process parameters- Spindle speed, feed rates, type of drill tool, cutting environment on performance parameters- material removal rate, surface roughness, Torque, cutting force, & power during the drilling of En 8 steel. In the present work, Taguchi method is combined with ANN for effective data representation in wide range with low experimental cost, to predict responses in drilling of En 8. From ANOVA it was observed that torque and surface roughness is mostly affected by feed and cutting force, material removal rate & power is mostly affected by spindle speed.

M.A. Amrana. et.al. (2013) [9] investigates the effects of drilling parameters such as spindle speed, feed rate and drill diameter on the surface roughness and surface texture of drilled hole by applying RSM. From One factor plot analysis found that the most significant parameter was spindle speed followed by drill diameter and feed rate and from experimental observations it was found that, surface roughness decreased when increasing the spindle speed, feed rate and drill diameter. There were interactions between all the parameter of spindle speed, feed rate and drill diameter in drilling process under investigation.

Indumathi V. et.al. (2014) [10] presents optimization of machining parameters- Spindle speed, Feed rate & Cone radius ratio for thermo – mechanical form drilling of Aluminium sheet (AA1100) with tungsten carbide tool using desirability function analysis (DFA). The spindle speed (Percentage contribution, P = 27.59%) is the more significant machining parameter for affecting the multiple performance characteristics form drilling process. High spindle speed, high feed rate and high cone ratio – optimum machining condition are obtained.

Kapil Kumar Goyal. et.al. (2014) [11] presents the optimization of cutting parameters - Spindle speed, Feed rate, and Slurry concentration in order to improve the surface finish of stainless steel SS304 in the abrasive assisted drilling RSM has been adopted for planning of experiments and ANOVA has been used to find the contribution of process parameters and the interaction among them. It was observed that the surface roughness of drilled surface significantly improves through the use of abrasive particles. The speed and feed significantly affects the surface roughness of SS304 in comparison to the slurry concentration and an overall improvement of 10.81% was observed in surface finish by using the abrasive slurry instead of only coolant.

A.Navanth,T Karthikeya, Sharma 2014 [12] have concluded that In this study, drilling of Al2014 alloy is carried out with the input drilling parameters considered as spindle speed, point angle and feed rate, and the response obtained are hole diameter and hole surface roughness at the entry and exit of the hole .The drilling parameters are optimized with respect to multiple performances in order to achieve a good quality of holes in drilling of Al 2014 alloy. Optimization of the parameters was carried out using Taguchi method. It was identified that a spindle speed of 300 rpm, point angle & Helix angle of 1300/200 and a feed rate of 0.15 mm/rev is the optimal combination of drilling parameters that produced a high value of S/N ratios of Hole roughness. And also identified that a spindle speed of 200 rpm, point angle & Helix angle of 900/150 and a feed rate of 0.36 mm/rev is the optimal combination of drilling parameters that produced a high value of s/n ratios of Hole Diameter

Reddy Sreenivasulu (2014) [13] focused on optimization of surface roughness in drilling of Al 6061 using Taguchi design method and artificial neural network method. Cutting speed, feed rate, drill diameter, clearance angle and point angle were taken as cutting parameters and HSS twist drill bit as a tool. L27 orthogonal array, ANOVA, S/N ratio was employed to study the effects of the control factors. ANOVA analysis showed cutting speed, feed rate, drill diameter, clearance angle and point angle all were significant on surface roughness. The paper shows Optimal settings for roughness are speed 800 rpm, feed rate .3 mm/rev , drill dia 10 mm, point angle 1180, clearance angle 40.

Nisha Tamta, R S Jadoun (2015) [14] analyzed the effect of spindle speed, feed rate, drilling depth on drilling Aluminium alloy 6082 with the help of CNC machine. Taguchi L9 orthogonal array was used to perform the experiment. Signal to noise ratio (S/N), analysis of variance (ANOVA) were used to analyze the effects drilling parameters on surface roughness. For analyzing statistical software MINITAB-15 has been used. It has been found that spindle speed 3000 rpm, feed rate 15 mm/min, drilling depth 9 mm were the optimum value. According to the paper drilling depth was the most significant factor for surface roughness followed by spindle speed.

Vishwajeet N. Rane, Ajinkya P.Edlabadkar, et al. (2015) [15] focused in optimizing drilling parameters such as cutting speed, feed and point angle for resharpened HSS twist drill bit on hardened boron steel using Taguchi method. L16 orthogonal array has been used to perform the experiment in a double spindle drilling machine. Analysis of variance was employed to find out effects of control factors on surface roughness. It was found that point angle was the main significant factor for tool wear and feed rate for surface roughness.

Taking the above literature as reference, we formulated our project methodology. We have considered TOPSIS method followed by TaGuChi analysis in MINITAB-18 software to arrive at our optimal solution.

CHAPTER 3

METHODOLOGY

Methodology

3.1 TOPSIS Method

In a general sense, it is the aspiration of human being to make "calculated" decision in a position of multiple selections. In scientific terms, it is the intention to develop analytical and numerical methods that take into account multiple alternatives with multiple criteria. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is one of the numerical methods of the multi-criteria decision making. This is a broadly applicable method with a simple mathematical model. Furthermore, relying on computer support, it is very suitable practical method.

3.1.1 Description of the Problem

Given m options (alternatives) A_i, each of which depends on n parameters (criteria) x_j whose values are expressed with positive real numbers x_{ij}. The best option should be selected.

3.1.2 Mathematical Model of the Problem

Initially, the parameter values x_{ij} should be balanced according to the procedure of normalization. Suppose that a_{ij} are the normalized parameter values. Then each option A_i is expressed as the point A_i $(a_{i1}, \ldots\ldots a_{in}) \in R^n$. Selecting the most optimal value $a_j^* \epsilon$ $\{a_{1j}, \ldots\ldots a_{mj}\}$ for every parameter x_j, we determine the positive ideal solution $A^* =$ $(a_1^*, \ldots\ldots\ a_n^*)$. The opposite is the negative ideal solution $A^0 = (a_1^0, \ldots\ldots\ a_n^0)$.. The positive and negative ideal solution are also denoted by A^+ and A^-. The decision on the order of options is made respecting the order of numbers.

$$D_i^* = \frac{d(A_i, A^0)}{d(A_i, A^*) + d(A_i, A^0)} = \frac{1}{\frac{d(A_i, A^*)}{d(A_i, A^0)} + 1}$$

The option A_{i1} is the best solution if max $\{D_1^*, D_2^*, \ldots\ldots D_m^*\} = D_{i1}^*$ and the option A_{i2} is the worst solution if min $\{D_1^*, D_2^*, \ldots\ldots D_m^*\} = D_{i2}^*$. The other options are between these two extremes. The maximum distance $D^* = max_{i=1,\ldots\ldots,m} D_i^*$ is usually called TOPSIS metric.

3.1.3 Geometrical Representation of the Problem

Figure 3.1 shows the initial arrangement of alternatives in TOPSIS method for n =2. Parameter $x_1 = x_1^*$ has a monotonically increasing preference, and parameter $x_2 = x_2^0$ has a monotonically decreasing preference. The positive A^* and negative A^0 ideal solution are located at diagonally opposite positions. The best solution is the alternative A_7.

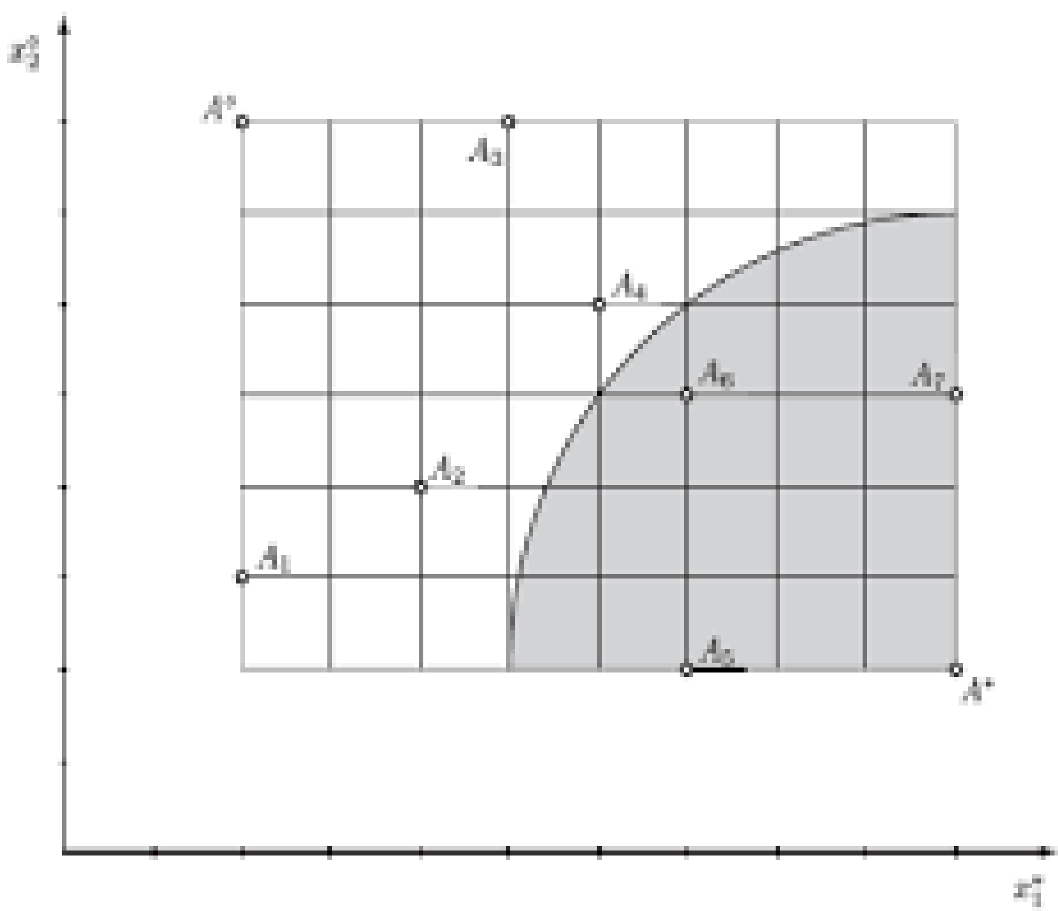


Figure 3.1 Geometrical Representation of TOPSIS Method

TOPSIS is a compensatory method. These kinds of methods allow the compromise between different criteria, where a bad result in one criterion can be compensated by a good result in another criterion. An assumption of TOPSIS method is that each criterion has either a monotonically increasing or decreasing preference. Due to the possibility of criteria modeling, compensatory methods, certainly including TOPSIS, are widely used in various sectors of multi-criteria decision making.

3.1.4 Computational Procedure For TOPSIS Method

We examine m alternatives $A_1,\dots\dots A_m$. Each alternative A_i respects n criteria $x_1,\dots\dots x_n$ which are expressed with positive numbers x_{ij} . The criteria $x_1,\dots\dots x_k$ are benefit (monotonically increasing preference), and criteria $x_{k+1},\dots\dots,x_n$ are non-benefit (monotonically decreasing preference). Weights w_j of the criteria x_j are given so that $\sum_{j=1}^{n} w_j = 1$. it is necessary to select the most optimal alternative.

Initial Table and Decision Matrix

For better visibility, the given alternatives, criteria and its weights are placed in the table 3.1.

Table 3.1 Initial Table for TOPSIS Method

Criteria	x_1 cr.1	x_2 cr.2	….. …..	x_n cr.n
Weights	w_1	w_2	…..	w_n
A_1	x_{11}	x_{12}	…….	x_{1n}
A_2	x_{21}	x_{22}	…….	x_{2n}
. . .	. . .	. . .	. . .	. . .

A_m	x_{m1}	x_{m2}	……	x_{mn}

The given numbers x_{ij} and their matrix must be balanced, since the numbers x_{ij} present values of different criteria with different measuring units. One must also take into account the given weights w_j of the criteria x_j. first the measuring numbers x_{ij} of the criteria x_j are replaced with the normalized or relative numbers.

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

$$\mathrm{rij} = \frac{\mathrm{x_{ij}}}{\sqrt{\sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{x_{ij}}^2}}$$

belonging to the open interval (0,1). Then, according to the share w_jx_j of the criteria x_j, the normalized number r_{ij} are replaced with the weighted normalized numbers.

$$a_{ij} = w_j r_{ij} = w_j \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

Belonging to (0,1). The further data processing uses the weighted normalized decision matrix.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

If all weights w_j are mutually equal, in which case $w_j = 1/n$, the numbers r_{ij} can be applied in the matrix A as the numbers a_{ij}.

Working Table

The weighted normalized decision matrix A and all the data that will be calculated, we try to write in one table 3.2.

Table 3.2 Working Table for TOPSIS Method

Criteria	x_1^* cr. 1	x_2^* cr. 2	… …	x^*_k cr. k	x^0_{k+1} cr. k+1	… …	x^0_n cr. n	d^* dips	d^0 dins	D^* topm
A_1	a_{11}	a_{12}	…	a_{1k}	a_{1k+1}	…	a_{1n}	d_1^*	d_1^0	D_1^*
A_2	a_{21}	a_{22}	…	a_{2k}	a_{2k+1}	…	a_{2n}	d_2^*	d_2^0	D_2^*
⋮	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋮	⋮
A_m	a_{m1}	a_{m2}	…	a_{mk}	a_{mk+1}	…	a_{mn}	d_m^*	d_m^0	D_m^*
A^*	a_1^*	a_2^*	…	a^*_k	a^*_{k+1}	…	a^*_n	A^*	A^0	d^*-d^0
A^0	a_1^0	a_2^0	…	a^0_k	a^0_{k+1}	…	a^0_n			

The coordinates a_j^* of the positive ideal solution $A^* = (a_1^*, a_2^* \ldots . a_n^*)$ are chosen using the formula

$$a_j^* = \begin{cases} min a_{ij} \; for \; j = 1, \ldots . k \\ max a_{ij} \; \; for \; j = k+1, \ldots \ldots n. \end{cases}$$

If some alternative A_{io} is equal to A^*, then it obvious that the alternative A_{io} is the best solution. If it is not, then we continue the procedure.

The coordinates a_j^0 of the negative ideal solution $A^0 = (a_1^0, a_2^0 \ldots . a_n^0)$ are chosen using the formula

$$a_j^0 = \begin{cases} min a_{ij} \; for \; j = 1, \ldots . k \\ max a_{ij} \; \; for \; j = k+1, \ldots \ldots n. \end{cases}$$

The numbers d_i^* of the column $d^* = (d_1^* d_2^* \ldots d_m^*)^T$ are the distances from the points A_i to the point A_0, which is calculated by the formula

$$d_i^* = d(A_i, A^*) = \sqrt{\sum_{j=1}^{n} \left(a_{ij} - a_j^*\right)^2}$$

The numbers d_i^0 of the column $d^0 = (d_1^0 d_2^0 \ldots d_m^0)^T$ are the distances from the points A_i to the point A_0, which is calculated by the formula

$$d_i^0 = d(A_i, A^0) = \sqrt{\sum_{j=1}^{n} \left(a_{ij} - a_j^0\right)^2}$$

The numbers D_i^* of the column $D^* = (D_1^* D_2^* \ldots\ldots D_m^*)^T$ are the relative distances of the points A_i respecting the points A^* and A^0, which is expressed by the formula

$$D_i^* = \frac{d_i^0}{d_i^* + d_i^0} = \frac{d(A_i, A^0)}{d(A_i, A^*) + d(A_i, A^0)}$$

If max $\{D_1^*, D_2^* \ldots\ldots, D_m^*\} = D_{i1}^*$, then we accept the alternative A_{i1} as the best solution. If min $\{D_1^*, D_2^* \ldots\ldots, D_m^*\} = D_{i2}^*$, then we accept the alternative A_{i2} as the worst solution.

3.2 Proposed Methodology

TOPSIS decision making method is a technique introduced by Yoon and Hwang. It is a worldwide accepted approach to finding the best alternative that is closest to the ideal solution. The basic principle in this method is that chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS). In TOPSIS method of decision making problems, first step is to determine the weights using an entropy approach.

Step 1: Determination of weights using entropy approach

The entropy approach includes in four steps they are,

i. Formation of a decision matrix (D)
ii. Formation of Normalized decision matrix ($\bar{Y}_{ij}$)
iii. Calculation of output entropy ($\acute{\varepsilon}_j$)

iv. Calculation of the weight (W_j)

(i). Formation of a decision matrix (D)

In a decision matrix, the rows are assigned to available alternatives and the columns are assigned to characteristics. The general decision matrix can be shown as

$$D = \begin{matrix} A_1 \\ A_i \\ A_m \end{matrix} \begin{bmatrix} Y_{11} & Y_{12} & .. & Y_{1j} & Y_{1n} \\ Y_{i1} & Y_{i2} & .. & Y_{ij} & .. \\ Y_{m1} & Y_{m2} & .. & Y_{mj} & Y_{mn} \end{bmatrix}$$

Where, A_i (i = 1,2,3........m) signifies the potential alternatives, Y_j (J = 1,2,3........n) signifies the attributes and Y_{ij} is the performance of A_i with respect to characteristic Y_j.

(ii). Formation of Normalized decision matrix ($\overline{Y}_{ij}$)

$$\overline{Y}_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{m} Y_{ij}} \quad (1 \leq i \leq m,\ 1 \leq j \leq n)$$

(iii). Calculation of output entropy ($\acute{\varepsilon}_j$)

$$\acute{\varepsilon}_j = \frac{-1}{\ln(m)} \sum_{i=1}^{m} \overline{Y}_{ij} \ln \overline{Y}_{ij}$$

(iv). Calculation of the weight (W_j)

$$W_j = \frac{1 - \acute{\varepsilon}_j}{\sum_{i=1}^{m}(1 - \acute{\varepsilon}_j)}$$

Where, $\sum_{i=1}^{m} W_j = 1$ and (1- $\acute{\varepsilon}_j$) is called uncertainty.

Step2. Determination of the Normalized decision making matrix (r_{ij})

Normalize the decision matrix of r_{ij} can be determined by using

$$rij = \frac{Y_{ij}}{\sqrt{\sum_{i=1}^{n} {Y_{ij}}^2}}$$

Where, r_{ij} represents the normalized performance of A_i with respect to characteristic Y_j.

Step3. Construction of a weighted normalized decision matrix (V_{ij})

$$V_{ij} = W_j \, r_{ij}$$

Where, W_j represents the relative weight of the J^{th} criteria.

Step4. Determination of Positive ideal solution (PIS) and Negative ideal solutions (NIS)

$$\text{Positive ideal solution}, A^+ = \{(\max_i V_{ij} \mid j \, \varepsilon \, J), (\dot{\min} V_{ij} \mid j \, \varepsilon \, \dot{J}) \; i = 1,2 \ldots .m)\}$$

$$= \{v_1^+, \; v_2^+, \ldots . . v_j^+, \ldots \ldots v_n^+\}$$

$$\text{Negative ideal solution}, A^- = \{(\min_i V_{ij} \mid j \, \varepsilon \, J), (\dot{\max} V_{ij} \mid j \, \varepsilon \, \dot{J}) i = 1,2, \ldots \ldots \ldots . m\}$$

$$= \{v_1^-, \; v_2^-, \ldots \ldots v_j^-, \ldots \ldots v_n^-\}$$

J = 1, 2, 3........n, associated with the beneficial attributes.

J = 1, 2, 3...n, associated with non-beneficial adverse attributes.

Step5. Determination of the separation values from the PIS and NIS

The separation of each alternative from PIS is given by

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_i^+ - v_{ij}\right)^2};\ \text{Where, } i = 1, 2 \ldots m.$$

The separation of each alternative from NIS is given by

$$S_i^- = \sqrt{\sum_{j=1}^{n}\left(v_j^- - v_{ij}\right)^2};\ \text{Where, } i = 1, 2 \ldots m.$$

Step6. Determination of the relative closeness to the ideal solutions and corresponding Signal to noise (S/N) ratios

Relative closeness coefficient, $C_i^+ = \frac{S_i^-}{S_i^+ + S_i^-}$;

Where i = 1,2......m

The larger the C_i^+value, the better the performance of the alternatives. The corresponding S/N ratios of C_i^+ were calculated from Taguchi's Larger-the-Better characteristic.

Step7. Rank the alternatives in descending order of C_i^+.

CHAPTER 4

EXPERIMENTAL DETAILS

Experimental Details

This chapter presents the details of work piece (chemical and mechanical properties), drill bits, CNC drilling machine specifications, cutting process parameters and their levels, orthogonal array (L18) design and the setup conditions in measurement of surface roughness values for the machined components etc.

4.1. Work Material and Drills

In the present work the drills are made on a plate of aluminium alloy 6061 having 25mm thickness shown in the figure 4.1 using carbide twisted drills (10 mm size with 4 flutes) shown in the figure 4.2. Aluminium alloy 6061 is a medium strength alloy with excellent corrosion resistance. The addition of a large amount of manganese controls the grain structure which in turn results in a stronger alloy. Al 6061 is typically used for

- Due to light weight and corrosion resistance and mechanical toughness, these are used in making of high pressure gas cylinders
- Due to high machinability, these can be used in machine components
- Due to light weight, these are used in air crafts building

Figure 4.1 AA6061 Plate

Figure 4.2 Drill Tools

4.2 Chemical Composition and Mechanical Properties of AA6082

6061 aluminium alloy is an alloy in the wrought aluminium-magnesiuum-silicon alloy. The chemical composition and some of the mechanical properties of AA6061 are given in the tables 4.1 and 4.2.

Table 4.1 Chemical Composition of AA6061

Aluminium (Al)	95-98%
Silicon (Si)	0.4-0.8%
Iron (Fe)	0.7%

Manganese (Mn)	0.15%
Magnesium (Mg)	0.8-1.2%
Chromium (Cr)	0.04-0.35%
Zinc (Zn)	0.25%
Tin (St)	0.15%

Table 4.2 Mechanical Properties of AA6061

Young's modulus	68.9 GPa
Maximum tensile strength	124-290 MPa
Poisson ratio	0.33

4.3 CNC Machine Specifications used for Drilling

In the present work the experiments were conducted on CNC drilling machine and the specifications of the machine were tabulated in table 4.3.

Table 4.3 CNC Machine Specification

PARAMETERS	DETAILS
Clamping area	450mm x 900 mm
No/Width/CD of T-slots	5/18mm/80mm
Maximum Safe load on Table	600kg
Distance from table to Spindle face	100-600(300-800)
Traverse	

X-axis	600mm
Y-axis	450mm
Z-axis	500mm
Axis Drive	
Feed rates	1-10000mm/min
Rapid Traverse X/Y/Z	36m/min
Spindle	
Power	5.5/7.5kw
Speed	6000rpm
Taper	BT45
Auto Tool Changer	
No of tools	20
Maximum Tool diameter with Adj pocket full/empty	75/140
Maximum Tool length	250mm
Maximum Tool weight	8kg
Tool change time(tool to tool)	2.5sec
Accuracy	
Positioning	±0.005mm
Repeatability	±0.003mm

4.4 Selection of Process Parameters and Their Levels

The methodology of taguchi for four factors with mixed levels is used for the implementation of the experiments. The degree of freedom required for the study is 10 and taguchi's L18 OA is used to define the sixteen experiments. The experiments were conducted on a CNC drilling machine (maximum spindle speed of 6000 rpm and 5.5/7.5 Kw drive motor) as shown in the figure 4.3. The selected process parameters with their levels and L18 OA are given in the tables 4.4 and 4.5.

Table 4.4 Process Parameters with Their Levels

Parameter	Unit	1	2	3
Drill type	-	HSS	HSS-COBALT	-
Point angles	Degrees	90	102	118
Feed	mm/min	100	200	300
Speed	rpm	500	1000	1500

Figure 4.3 CNC Machine used for Machining

Table 4.5 L18 Orthogonal Array

Sl.no	DRILL TYPE	POINT ANGLE	FEED	SPEED
1	HSS	90	100	500
2	HSS	90	200	1000
3	HSS	90	300	1500
4	HSS	102	100	500
5	HSS	102	200	1000
6	HSS	102	300	1500
7	HSS	118	100	1000
8	HSS	118	200	1500
9	HSS	118	300	500
10	HSS-COBALT	90	100	1500
11	HSS-COBALT	90	200	500
12	HSS-COBALT	90	300	1000
13	HSS-COBALT	102	100	1000
14	HSS-COBALT	102	200	1500
15	HSS-COBALT	102	300	500
16	HSS-COBALT	118	100	1500
17	HSS-COBALT	118	200	500
18	HSS-COBALT	118	300	1000

4.5 Measurement of Surface Roughness after Machining

After conducting the experiments the machined surface was measured at three different positions using roughness measuring instrument SJ-210 as shown in the figure 4.4 and the average surface roughness (R_a) values is recorded in microns.

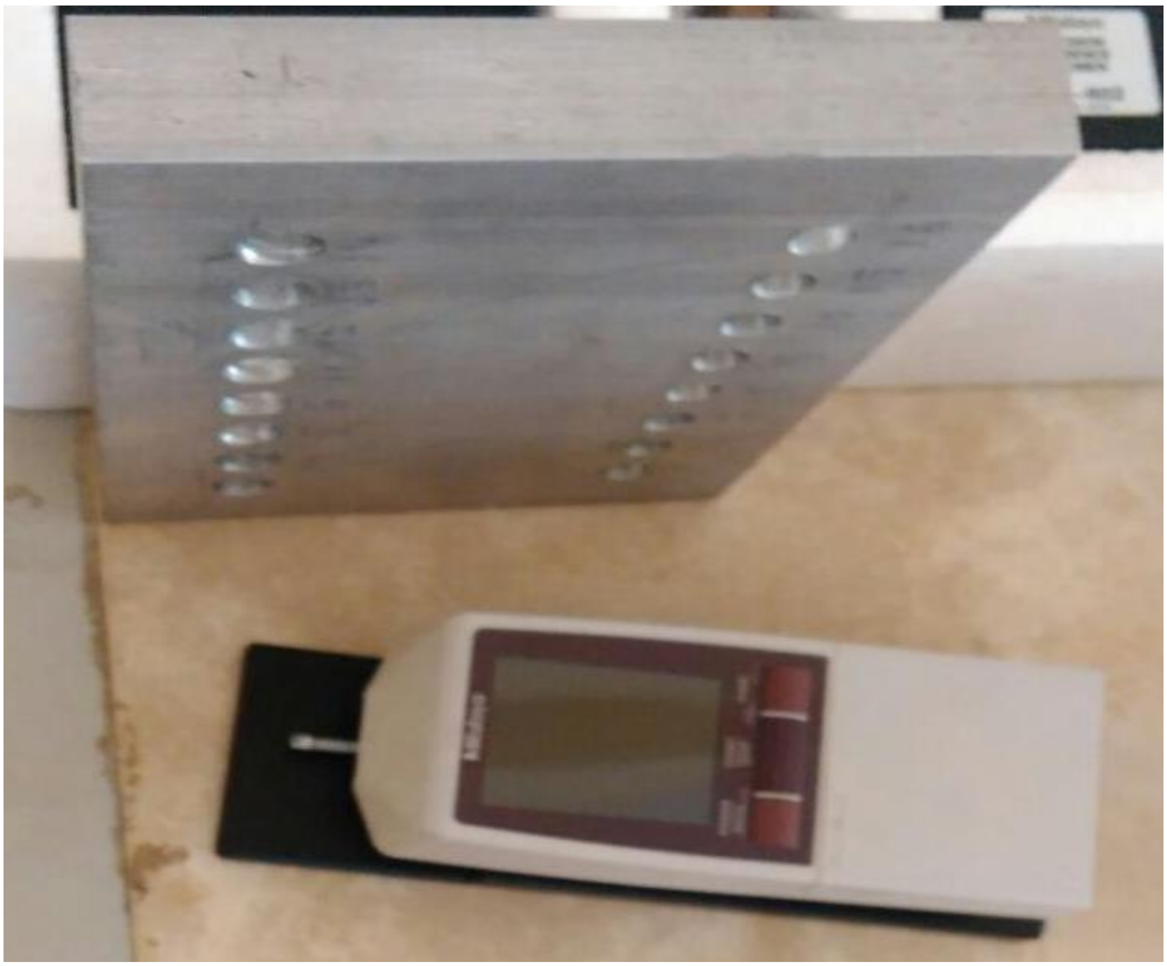


Figure 4.4 SJ-210 Surface Tester

CHAPTER 5

RESULTS & DISCUSSIONS

Results and Discussions

After machining of AA6061 work pieces the performance characteristics of Dimensiona deviation (DD), Burr, Material Removal Rate (MRR) and Surface Roughness characteristics (R_a) are measured for the analysis. The experimental results are shown in the table 5.1 and they represent the decision matrix for the alternatives. The decision matrix contains four columns for the four performance characteristics namely Dimensional deviation, material removal rate, arithmetic average roughness and burr and eighteen rows representing the alternatives for the experiments.

$$\mathrm{MRR} = \frac{\text{Volume of material removed perhole}}{\text{machining time per hole}}$$

$$\text{volume of material removed per hole} = \frac{\pi D^2 t}{4}$$

Where D- diameter of the hole

t- thickness of the plate

Table 5.1 Experimental Results

Sl.no	DD	MRR	Burr height	Ra
1	0.04	52.92	0.1	1.948
2	0	97.56	0.14	1.384
3	0.06	140.75	0.16	2.040
4	0.025	65.99	0.08	1.225
5	0.19	116.61	0.4	0.988
6	0.07	126.88	0.6	2.356
7	0.105	104.71	0.44	2.066
8	0.025	114.65	0.86	1.242

9	0.085	146.39	0.38	1.712
10	0.12	60.11	1.58	1.129
11	0.125	94.68	0.84	1.987
12	0.13	148.04	0.94	0.692
13	0.03	73.61	0.98	1.982
14	0.12	109.92	0.72	1.476
15	0.11	141.51	1.86	0.898
16	0.02	64.85	1.98	1.006
17	0.015	116.61	1.12	1.304
18	0.095	146.94	1.42	4.868

5.1 Entropy Results

The decision matrix values are first normalized using the equations given in step 1 of proposed methodology and the corresponding values obtained are shown in the table 5.2. The output entropy values and the weights for the individual responses are calculated from the normalized values and the results are shown in the table 5.3.

Calculation of normalised values:

From the methodology step 1 (ii), formula to calculate normalised values is

$$\overline{Y_{ij}} = \frac{Y_{ij}}{\sum_{i=1}^{m} Y_{ij}}$$

Using this formula, each and every value corresponding to each experiment and each parameter is normalised and the readings are tabulated as shown below.

Note: Y_{ij} denotes each and every value of the decision matrix

m- denotes the number of experiments done (18 in our case).

Table 5.2 Normalized Values of the Responses

Sl.no	DD	MRR	Ra	Burr
1	0.029	0.0275	0.0642	0.00684
2	0.01	0.05	0.0456	0.00958
3	0.043	0.0732	0.0673	0.0109
4	0.018	0.034	0.0404	0.00547
5	0.139	0.0606	0.0326	0.0273
6	0.051	0.0659	0.0777	0.041
7	0.077	0.0544	0.0681	0.0301
8	0.018	0.0596	0.0409	0.0589
9	0.622	0.0761	0.0564	0.026
10	0.087	0.0312	0.0369	0.1082
11	0.091	0.0492	0.0655	0.0575
12	0.095	0.0769	0.0228	0.0643
13	0.021	0.0382	0.0654	0.0671
14	0.087	0.0571	0.0487	0.0493
15	0.08	0.0735	0.0296	0.1273
16	0.014	0.0337	0.0331	0.1356
17	0.01	0.0606	0.043	0.0767
18	0.069	0.0764	0.16	0.0972

Calculation of output entropy ε_j:

Using the normalised values, output entropy values are calculated using the relation from the methodology step 1 (iii)

$$\varepsilon_j = \frac{-\sum_{i=1}^{m} \overline{Y_{ij}} \cdot \ln \overline{Y}_{ij}}{\ln(m)}$$

Calculation of weights W_j :

Using the entropy values, weights are calculated using the relation from the methodology step 1 (iv)

$$W_j = \frac{(1-\varepsilon_j)}{\sum_{i=1}^{m}(1-\varepsilon_j)}$$

The calculated output entropy values and the weightage of each parameter is tabulated as shown below.

Table 5.3 Output Entropy and the Weights of the Responses

	DD	MRR	Ra	Burr
Ɛ	0.96079	0.9824	0.958	0.8247
Wij	0.143045	0.064208	0.153223	0.639524

5.2 TOPSIS Results

In TOPSIS the first step is to normalize the experimental results by using the equation given in the step 2 of proposed methodology and the obtained results are shown in the table 5.4. The Normalized values (r_{ij}) of the responses were now turned into weighted normalized (V_{ij}) values by using the equation given in the step 3 of proposed methodology and obtained results are shown in the table 5.5.

Normalised decision matrix (r_{ij}):

Normalised decision matrix is calculated using the relation from the Methodology step 2.

$$r_{ij} = \frac{Y_{ij}}{\sqrt{\sum_{i=1}^{n} Y_{ij}^2}}$$

Where n denotes the number of different parameters under consideration (4 in our case).

Table 5.4 Normalized Values of Responses (r_{ij})

Sl.no	DD	MRR	Ra	Burr
1	0.103357	0.112031	0.240391	0.023653
2	0.025839	0.206533	0.170791	0.033114
3	0.155035	0.297966	0.251745	0.037845
4	0.064598	0.1397	0.15117	0.018922
5	0.490943	0.246862	0.121923	0.094612
6	0.180874	0.268603	0.29074	0.141917
7	0.271311	0.22167	0.254953	0.104073
8	0.064598	0.242713	0.153268	0.203415
9	0.219633	0.309906	0.211268	0.089881
10	0.31007	0.127252	0.139323	0.373716
11	0.322989	0.200436	0.245204	0.198684
12	0.335909	0.313399	0.085396	0.222337
13	0.077517	0.155831	0.244587	0.231798
14	0.31007	0.232699	0.182145	0.170301
15	0.28423	0.299575	0.110817	0.439944

16	0.051678	0.137287	0.124145	0.468327
17	0.038759	0.246862	0.160919	0.264912
18	0.245472	0.31107	0.600732	0.335871

Weighted normalised values of the responses:

weighted normalised values of the responses is calculated using the relation from step-3.

$$V_{ij} = W_j . r_{ij}$$

Where W_j represents weights of each parameter and r_{ij} represents normalised value corresponding to that particular experiment.

The values of V_{ij} are tabulated in the tabular for below.

Table 5.5 Weighted Normalized Values Of The Responses (V_{ij})

Sl.no	DD	MRR	Ra	Burr
1	0.014785	0.004715	0.024143	0.009915
2	0.003696	0.008693	0.017153	0.013881
3	0.022177	0.012541	0.025283	0.015864
4	0.00924	0.00588	0.015182	0.007932
5	0.070227	0.01039	0.012245	0.039659
6	0.025873	0.011306	0.029199	0.059489
7	0.03881	0.00933	0.025605	0.043625
8	0.00924	0.010216	0.015393	0.085267
9	0.031417	0.013044	0.021218	0.037676

10	0.044354	0.005356	0.013992	0.156654
11	0.046202	0.008436	0.024626	0.083284
12	0.04805	0.013191	0.008576	0.093199
13	0.011088	0.006559	0.024564	0.097165
14	0.044354	0.009794	0.018293	0.071387
15	0.040658	0.012609	0.011129	0.184416
16	0.007392	0.005778	0.012468	0.196313
17	0.005544	0.01039	0.016161	0.111046
18	0.035113	0.013093	0.060331	0.14079

From the weighted normalized (V_{ij}) values of the responses the ideal and negative ideal solutions are chosen based on the equations given in the step 4 of the proposed methodology and the chosen values are given in the table 5.6.

Table 5.6 Positive ideal solution & Negative Ideal Solution Values

DD	MRR	Ra	Burr
0.003696	0.01309	0.011129	0.0079
0.070227	0.004715	0.060331	0.1963

The separation values of each alternative from the Positive Ideal Solution (PIS) and Negative Ideal Solutions (NIS) of the responses are determined using the equations given in the step 5 of the proposed methodology the corresponding values are shown in the table 5.7. Finally, the Relative Closeness (C_i^+) values are obtained from the equation given in step 6 of the proposed methodology and the ranking given for the alternatives from the Signal-to-Noise ratios (S/N) are shown in table 5.8.

Determination of separation of values from PIS and NIS :

Separation of values from PIS and NIS is calculated using the formula in step-5

$$S_i^+ = \sqrt{\sum_{j=1}^{n}(v_i^+ - v_{ij})^2} \qquad S_i^- = \sqrt{\sum_{j=1}^{n}(v_i^- - v_{ij})^2}$$

Table 5.7 Separation Distances of the Responses from Positive ideal solution & Negative Ideal Solution

Sl.No	Si+	Si-
1	0.019146	0.197795
2	0.009561	0.198956
3	0.024609	0.190147
4	0.00996	0.203081
5	0.073781	0.163954
6	0.059017	0.1473
7	0.052278	0.159762
8	0.077736	0.134526
9	0.041915	0.168128
10	0.154431	0.066249
11	0.087712	0.120989
12	0.096176	0.117779
13	0.090808	0.120863
14	0.075801	0.134409
15	0.180345	0.05915
16	0.188596	0.078995
17	0.103321	0.115911

18	0.145148	0.066215

Relative closeness values (C_i^+):

Relative closeness values are calculated using the relation, step-6 of the methodology

$$C_i^+ = \frac{S_i^-}{S_i^+ + S_i^-}$$

Table 5.8 Relative Closeness Values (C_i^+)

Sl.No	Ci+
1	0.911747
2	0.954147
3	0.88541
4	0.95325
5	0.689651
6	0.713951
7	0.753453
8	0.633773
9	0.800444
10	0.300203
11	0.579724
12	0.550486
13	0.570993
14	0.639403
15	0.246978
16	0.295208

17	0.528714
18	0.313278

For finding the optimal conditions of process parameters Taguchi's Higher-the-Better characteristic is used and the obtained results are shown in the table 5.9. From the Mean values of Signal-to-Noise ratios of process parameters the main effect plot was drawn and shown in the figure 5.1. The main effect plot showing that drill type is the main affecting parameter on the multi response with the changes in levels and followed by point angle, speed and feed respectively. The optimal combination of the process parameters to achieve higher relative closeness (Ci+) value is found at drill type HSS, speed of 500 rpm, feed rate of 200 mm/min, point angle at 90 degrees and drill size of 10 mm.

Table 5.9 Response Table for Signal-to-Noise Ratios

Level	DRILL TYPE	POINT ANGLE	FEED	SPEED
1	0.8106	0.6970	0.6308	0.6701
2	0.4472	0.6357	0.6709	0.6387
3	-	0.5541	0.5851	0.5780
Delta	0.3634	0.1428	0.0858	0.0922
Rank	1	2	4	3

Table 5.10 Optimal Combination of Process Parameters

Process Parameter	rank	Value
Drill type	1	HSS
Drill point angle	2	90°
speed	3	500 RPM
feed	4	200 mm/min

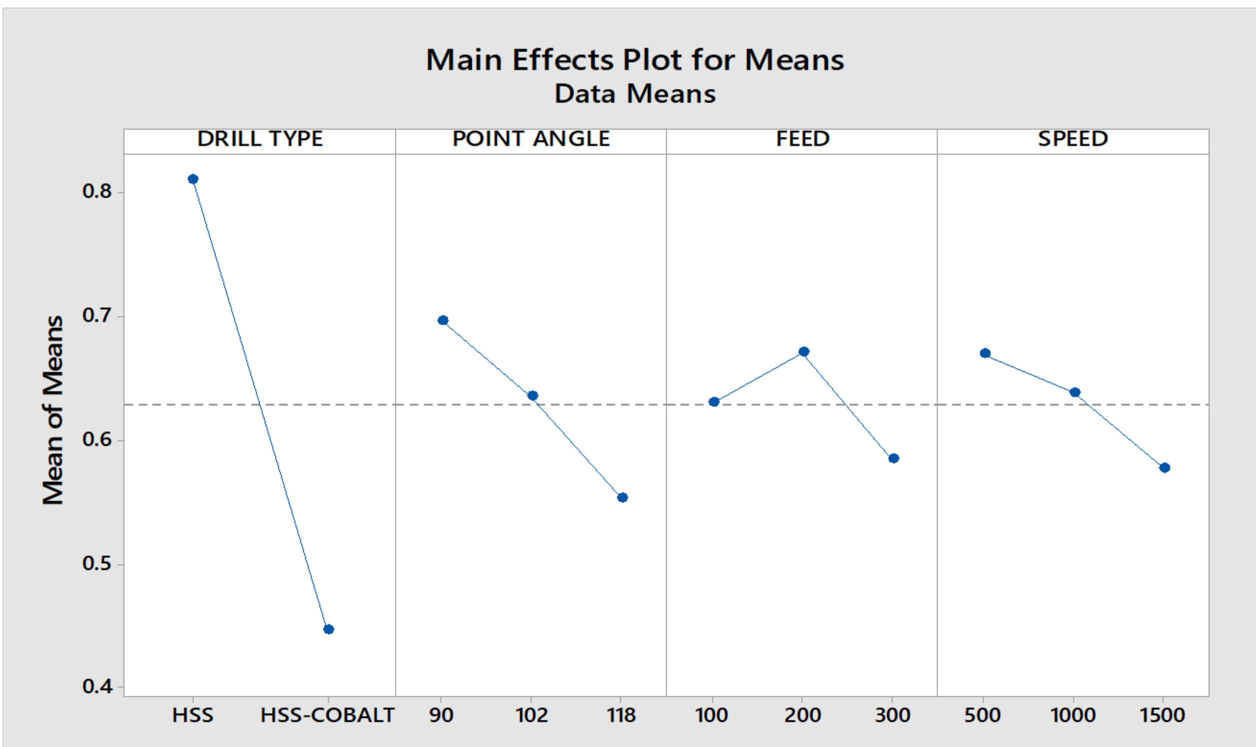


Figure 5.1. Main Effect Plot for S/N Ratios of C_i^+

5.3 ANOVA Results

Analysis of variance is employed at 95% of confidence level (P<0.05) for finding the significance of the process parameters on the multiple response. From the ANOVA results given in the table 5.11, it is observed that drill type is highest influencing factor followed by point angle, speed and feed. The residual plots are drawn for checking the normality and the constant variance assumptions of ANOVA. From the figure 5.3, it is noticed that the residuals are following the normality as all the errors are lie nearer to the straight line. Similarly, the residuals are not showing any regular pattern in versus fits and order plots hence satisfying the constant variance.

Table 5.11 ANOVA Results of C_i^+

Source	DF	Adj SS	Adj MS	F-Value	P-value
DRILL TYPE	1	0.59435	0.59435	30.45	0.000
POINT ANGLE	2	0.06159	0.03080	1.58	0.254
FEED	2	0.02212	0.01106	0.57	0.585
SPEED	2	0.02633	0.01316	0.67	0.531
Error	10	0.19522	0.01952		
Total	17	0.89962			

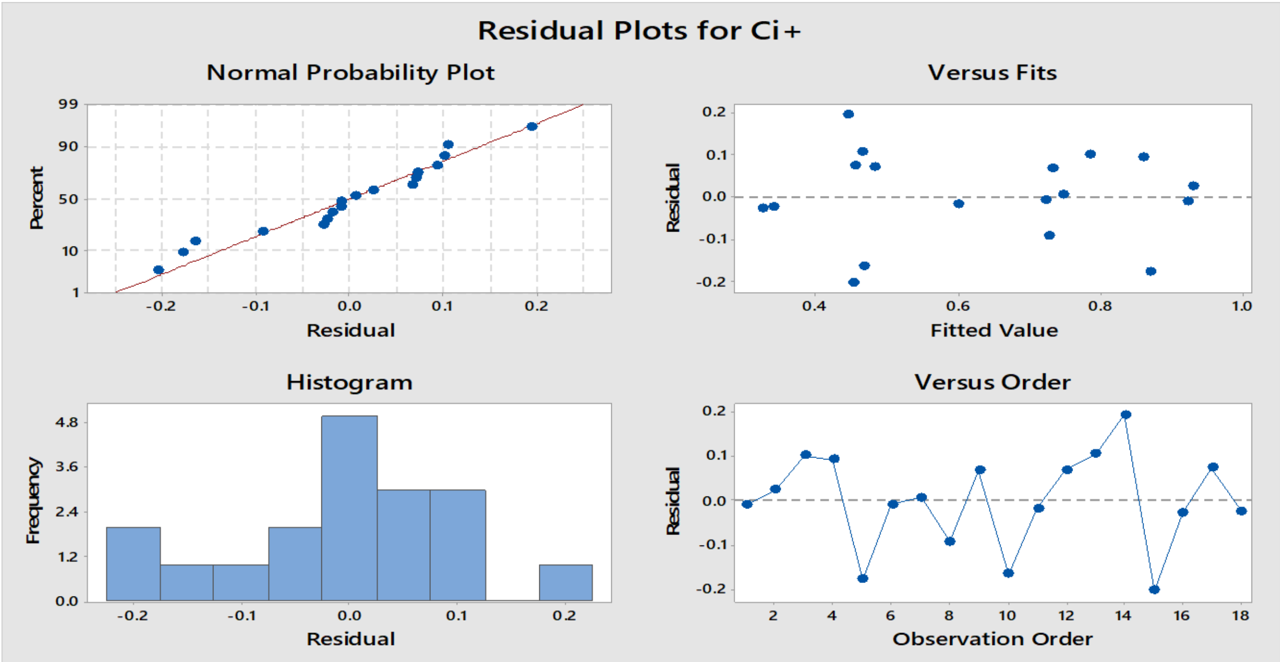


Figure 5.2 Residual Plots for C_i^+

CONCLUSIONS

Conclusions

- The experiment was conducted by taking a AA6061 plate with dimensions 250mm×150mm×25mm. The input parameters considered are Drill type, drill point angle, speed and feed.
- Drill bits of two different materials HSS and HSS-cobalt are taken for our experimentation purpose. Three different point angles, speeds and feed rates are considered for the same.
- Using Taguchi L18 orthogonal array, 18 holes were drilled using a CNC machine in dry conditions. Time taken to drill each hole is noted.
- Using the above noted times, different output parameters like Dimensional Deviation (DD), Material removal rate (MRR), surface roughness (R_a) and Burr height are calculated.
- Then these parameters are optimized using TOPSIS method and Taguchi optimization technique and the final plots are obtained using MINITAB-18 software.
- The following conclusions are drawn from this study:
    - The optimal combination of process parameters to achieve higher relative closeness (C_i^+) value is found at drill type HSS, speed of 500rpm, feed rate of 200mm/min, and point angle of 90°.
    - ANOVA results concluded that Drill type has the highest influence on the multiple responses, followed by point angle, speed and feed rate.
    - The residuals are following the normality and constant varience as they lie nearer to the straight line and do not represent any regular pattern.
    - The proposed method of entropy combined with TOPSIS can be applied to all industrial sectors for solving multi objective optimization problems effectively.

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