A SIMPLE METHOD OF SYNTESIS OF CARBON NANO TUBES (CNT) ON HIGH SPEED STEEL DRILLING TOOL AND EVALUATION OF PERFORMANCE WHILE MACHINING

A THESIS SUBMITTED IN FULFILMENT OF
THE REQUIREMENT FOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

IN

PRODUCTION ENGINEERING

BY

LALIT MOHAN VERMA

(ROLL NO- 2K12/PRD/10)

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CANDIDATE'S DECLERATION

I hereby certify that the work which is being presented in this thesis entitled, "**A SIMPLE METHOD OF SYNTHESIS OF CARBON NANO TUBES (CNT) ON HIGH SPEED STEEL DRILLING TOOL AND EVALUATION OF PERFORMANCE WHILE MACHINING**" in partial fulfillment of the requirements for the award of **Master of Technology Degree** in **Production Engineering** at **Delhi Technological University**, **Delhi** is an authentic work carried out by me under the supervision of Mrs Navriti Gupta in Mechanical, Production, Industrial and Automobile Engineering department.

The matter embodied in this report has not submitted to any other university/institute for award of any degree.

(Lalit Mohan Verma)

This is to certify that above statement made by the candidate is correct to best of my knowledge.

Mrs.Navriti Gupta

Date:

ACKNOWLEDGEMENT

While bringing out this thesis to its final form, I came across a number of people whose contributions in various ways helped my field of research and they deserve special thanks. It is a pleasure to convey my gratitude to all of them.

First and foremost, I would like to express my deep sense of gratitude and indebtedness to my supervisor Mrs.Navriti Gupta for his invaluable encouragement, suggestions, motivation and support from an early stage of this research and providing me extraordinary experiences throughout the work. I also thanks for their support in my project research. Above all, their priceless and meticulous supervision at each and every phase of work inspired me in innumerable ways.

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Lalit Mohan Verma

(2K12/PRD/10)

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ABSTRACT

Crbon Nano Tube(CNT) based drilling HSS(18 4 1) tool is a coated tool with more hardness when used with drilling process it can work for longer periods of time without less tool wear and capable of machining different work materials. During machining Carbon Nano Tube(CNT) plays an important role with high hardness which act as a protecting shield on HSS drill tool surface against wear. Chemical vapor deposition method is used for synthesis of CNT on this tool. The gases used for this method is acetylene and argon which is very has less cost also this coating have less cost due to this advantage this can be commercially used for drilling. Three parameter Force, Torque and tool wear is analyze with different depth of cut on radial drilling machine while machining with ductile material. Experiment shows that force and torque produced while drilling is very less results less power consumption and heat generated while drilling on radial drilling machine.

Chapter 1

INTRODUCTION

Finishing of a part improves its aesthetics and functional performance i.e. the fine finished parts and required machine tool have better dimensional controls, required hardness and thus more life. In the recent times, there are requirements of effective machine tool with close dimensional controls along with capable of machining complex shape of job. For such requirements CNT (Carbon Nano Tubes) based cutting tool plays an important role in machining of work materials.
CNT cutting tool based drilling is improved tool life with less tool wear and less power consumption which required more in conventional drilling process.

1.1 CONVENTIONAL MANUFACTURING PROCESSES

From the last many years different traditional manufacturing processes have been invented and successfully implemented into production. The conventional manufacturing processes which are being used these days mainly uses cutting tools with different tool holding machines like drilling, milling, reaming etc. In present requirements of suitable cutting tool is a primary need of industry. and past and present manufacturing activities can be conveniently projected into the domain of future requirements. According to him three outstanding needs of future manufacturing technology are:

- Higher productivity
- Higher accuracy consistent with the increasing demand for better tolerances.
- Controlled power consumption.

Among various mechanical conventional processes, Drilling with CNT based coated cutting tool needs lesser power consumption and less tools wear along with machining different work materials.

1.1.1 Drilling process

Drilling is manly used for producing holes in different work materials and use of drilling tool in this process plays an important role for machining job.

1.2 BASIC PRINCIPLE OF DRILLING

The drilling machine or drill process is one of the most common & useful machine employed in industry for producing forming & finishing holes in work piece the unit essentially consist of a spindle which turns the tool(called drill) which can be advanced in the work piece either automatically or by hand. A work table which holds the work piece rigidly in position. The rotating age of the drill exerts a large force on the work piece and the hole is generated. The removal of metal in the drill operation is by shearing**.**

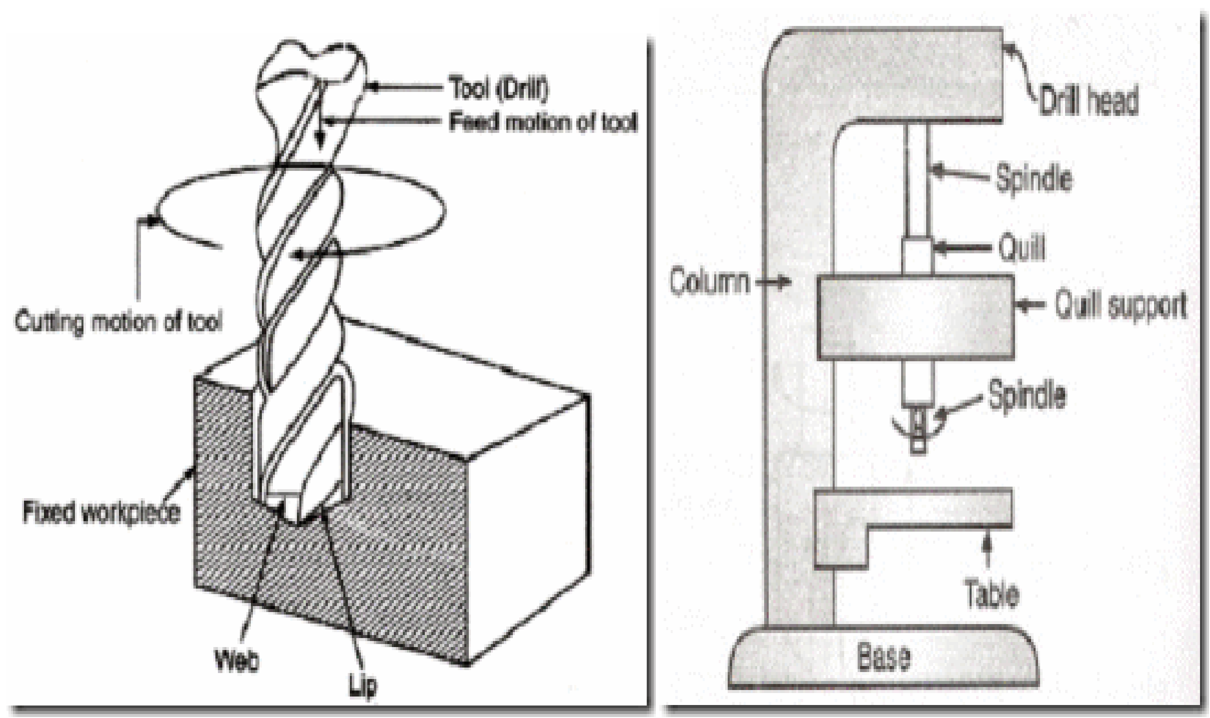

Fig.1: Basic principle of drilling[1]

1.3 CLASSIFICATION OF DRILLING MACHINES

On the basis of working and configuration, drilling machine is classified major categories one of important is tool sensitive drilling machine, pillar drilling machine, column drilling machine, radial drilling machine normally radial drilling machine is used for commercial application.

1.3.1 Tool sensitive drilling machine

These small capacity (≤ 0.5 kW) upright (vertical) single spindle drilling machines are mounted (bolted) on rigid table and manually operated using usually small size (φ≤ 10 mm) drills. Fig. 2. Typically shows one such machine.

Fig.2: Tool sensing drilling machine[38]

1.3.2 Pillar drilling machine

These drilling machines, usually called pillar drills, are quite similar to the table top drilling machines but of little larger size and higher capacity (0.55 ~ 1.1 kW) and are grouted on the floor (foundation). Here also, the drill-feed and the work table movement are done manually. Typically shows a pillar drill. These low cost drilling machines have tall tubular columns and are generally used for small jobs and light drilling.

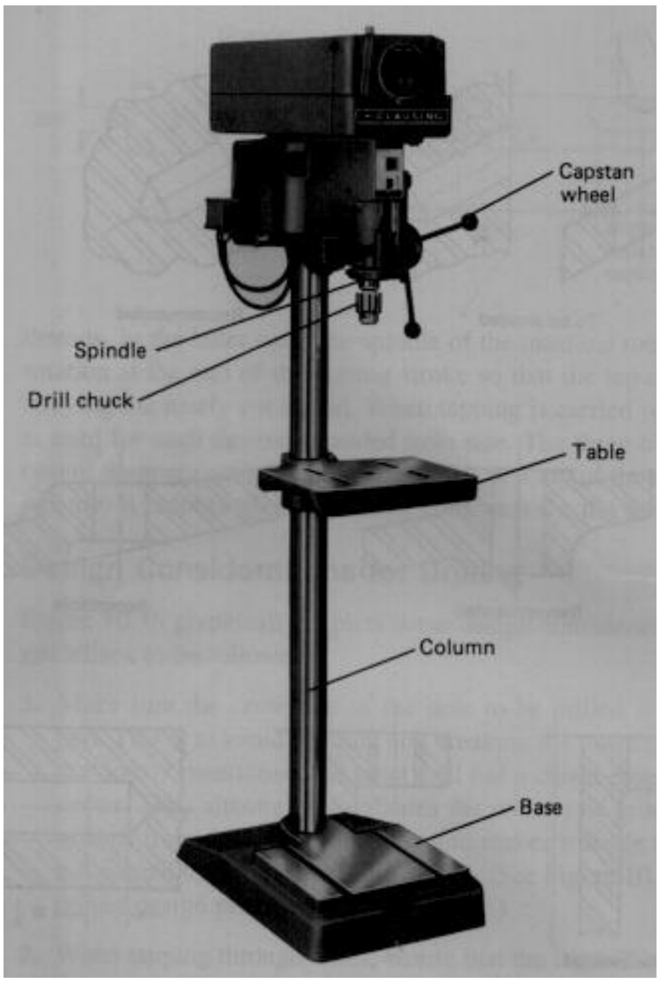

Fig.3: Pillar drilling machine[38]

1.3.3 Column drilling machine

These box shaped column type drilling machines as shown in Fig. 4.2.3 are much more strong, rigid and powerful than the pillar drills. In column drills the feed gear box enables automatic and power feed of the rotating drill at different feed rates as desired. Blanks of various size and shape are rigidly clamped on the bed or table or in the vice fitted on that. Such drilling machines are most widely used and over wide range (light to heavy) work.

Fig.4: Column drilling machine[38]

1.3.4 Radial drilling machine

This usually large drilling machine possesses a radial arm which along with the drilling head can swing and move vertically up and down as can be seen in Fig. 4.2.4. The radial, vertical and swing movement of the drilling head enables locating the drill spindle at any point within a very large space required by large and odd shaped jobs. There are some more versatile radial drilling machines where the drill spindle can be additionally swiveled and / or tilted.

Fig.5: Radial drilling machine[38]

1.4 .DRILLING TOOL

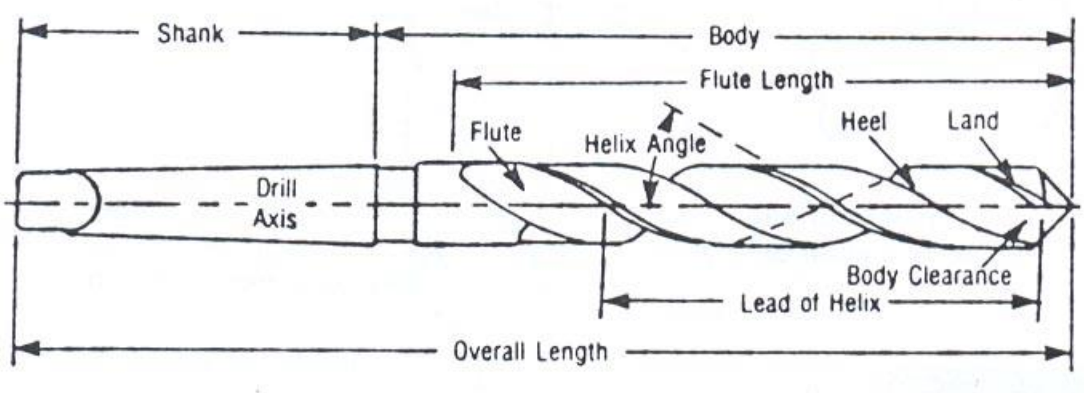

Fig.6: Drilling tool nomenclature[20]

A drill is a tool fitted with a cutting tool attachment or driving tool attachment, usually a drill bit or driver bit, used for boring holes in various materials or fastening various materials together with the use of fasteners. The attachment is gripped by a chuck at one end of the drill and rotated while pressed against the target material. The tip, and sometimes edges, of the cutting tool does the work of cutting into the target material. This may be slicing off thin shavings (twist drills or auger bits), grinding off small particles (oil drilling), crushing and removing pieces of the workpiece (SDS masonry drill), countersinking, counter boring, or other operations.

Fig.7: Different types of drilling **b**its[38]

1.5 CARBON NANO TUBE(CNT)

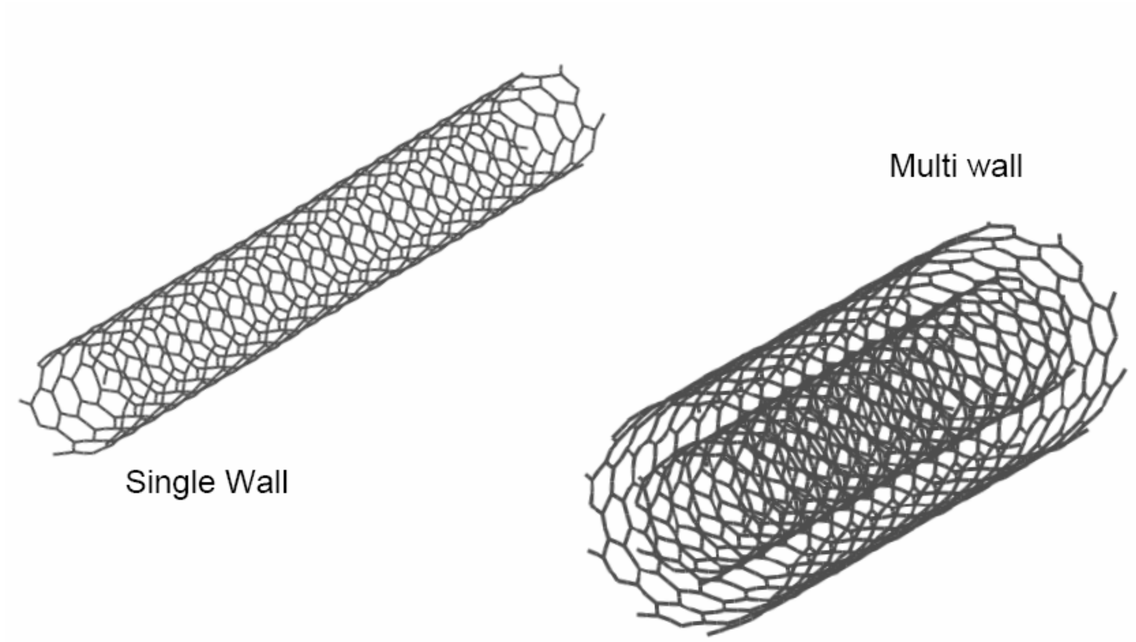

Fig.8: types of carbon Nano Tube(CNT) images[18]

Single and multiwall carbon nanotubes, hypothetically one can visualize the formation of single wall carbon nanotube through rolling single graphene sheet into a cylinder. For multiwall nanotubes bi-layer graphene sheet will be the starting material. A single wall carbon nanotube is technically defined as a cylinder made up of rolled up sheet of graphene as described artistically in Fig. 1.1. However, rolling up graphene is not the actually way a nanotube forms; its actual synthesis process is explained in chapter 2. The diameter of carbon nanotubes typically vary from 0.7-3 nm. Due to such small diameters, nanotubes become quasi one dimensional. They can posses a single shell or multiple shells, as depicted in Fig 1.4. Tubes with single shell are called single wall carbon nanotubes (SWNT) while once with more than one shell are multiwall carbon nanotubes (MWNT). The length of nanotubes can be up to centimeters, giving them an astonishing length/diameter ratio of 10^7.

Carbon nanotubes (CNT) were first discovered in the black soot product from a CVD process [2, 7]. Since then, their synthesis techniques have evolved considerably. The last 10 years have seen tremendous research in both nanotube synthesis[8] and their potential use in electronic circuits[9], composites, thin films[10], etc. Electronic properties of nanotubes have attracted their use as metallic wires and as semiconducting channels in field effect transistors. Processes have been developed to separate semiconducting from metallic nanotube through solution based techniques. However CVD growth of specific chirality nanotube is still not possible. On the industrial front, carbon nanotubes have found use in making composites and gas sensors. This stems from their extraordinary mechanical properties and high surface area.

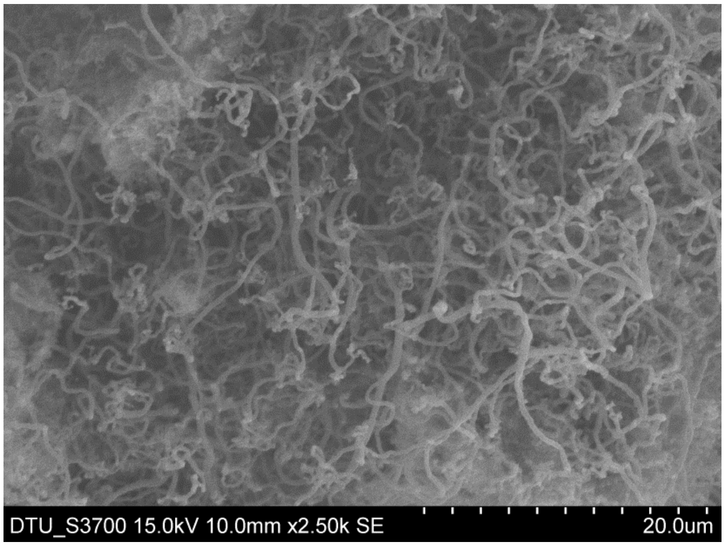

Fig.9: SEM(Scanning Electron Microscopic) image of Carbon Nano Tube

Chapter 2

DRILLING TOOLS AND COATINGS

2.1 INTRODUCTION

Drilling tool is widely used in all drilling machine with various cutting tool material in this chapter we will explain different drilling tool and coatings.

2.2 DRILL GEOMETRY

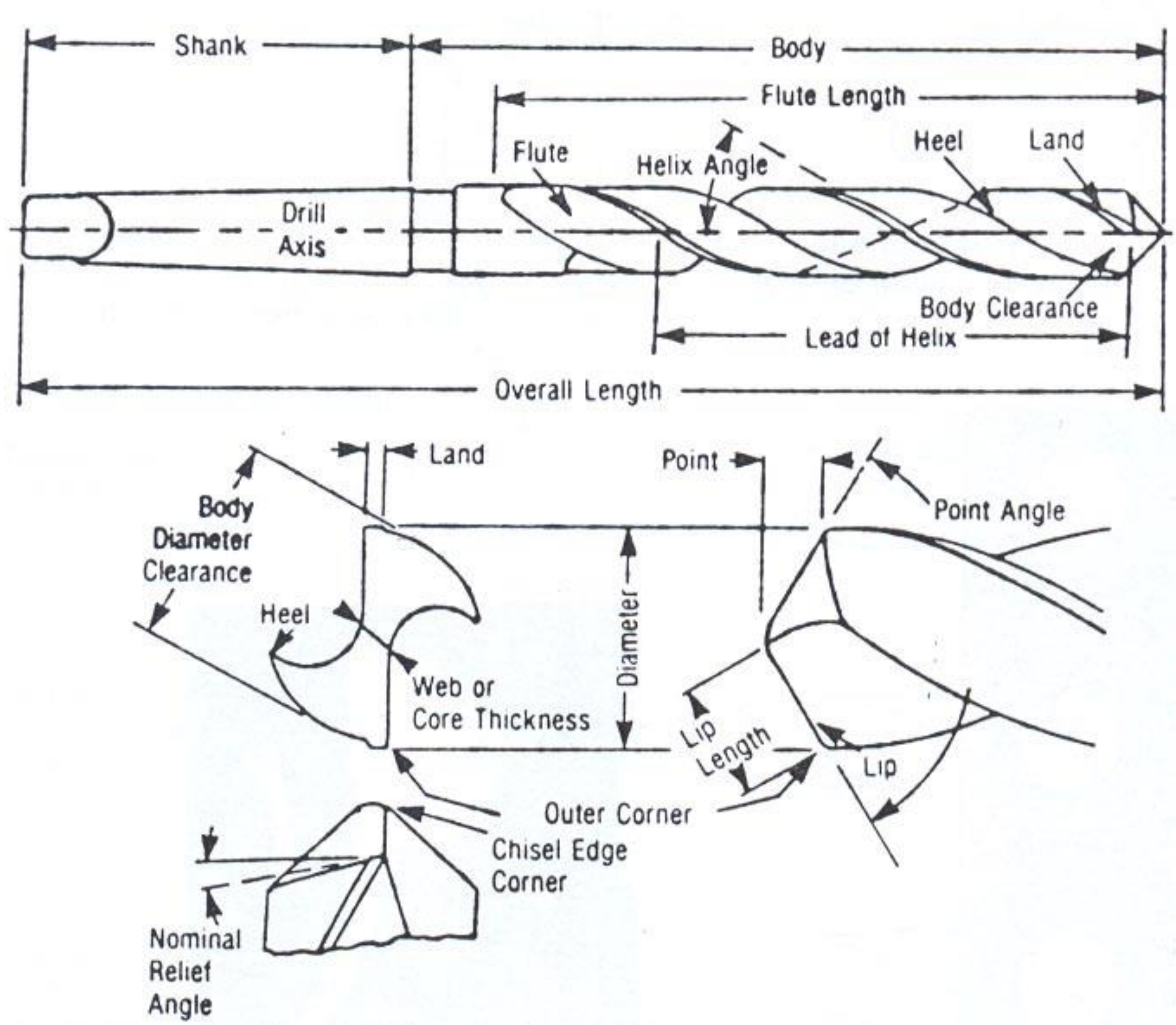

Fig.10: Drilling tool geometry[20]

2.2.1 Helix angle

The helix angle of the drill influences the temperate rise during drilling. The helix angle of a drill bit varies with the drill diameter; larger angles are used for larger diameter drills. The 18°optimum range for the helix angle has been reported as 24–36° [12].

2.2.2Point angle

The angle formed at the tip of the bit, is determined by the material the bit will be operating in. Harder materials require a larger point angle, and softer materials require a sharper angle. The correct point angle for the hardness of the material controls wandering, chatter, hole shape, wear rate, and other characteristics

2.2.3 Lip angle

It determines the amount of support provided to the cutting edge. A greater lip angle will cause the bit to cut more aggressively under the same amount of point pressure as a bit with a smaller lip angle. Both conditions can cause binding, wear, and eventual catastrophic failure of the tool. The proper amount of lip clearance is determined by the point angle.

A very acute point angle has more web surface area presented to the work at any one time, requiring an aggressive lip angle, where a flat bit is extremely sensitive to small changes in lip angle due to the small surface area supporting the cutting edges.

The best geometry to use depends upon the properties of the material being drilled. The following table lists geometries recommended for some commonly drilled materials[3]

Workpiece material	Point angle	Helix angle	Lip relief angle
Aluminum	90 to 135	32 to 48	12 to 26
Brass	90 to 118	0 to 20	12 to 2
Cast iron	90 to 118	24 to 32	7 to 20
Mild steel	118 to 135	24 to 32	7 to 24
Stainless steel	118 to 135	24 to 32	7 to 24
Plastics	60 to 90	0 to 20	12 to 26

Fig.11: Drill lip angles for different material [20]

2.2.4 Drill sharpness

Blunt drill bits are reported to produce more thermal damage [6, 11, 27, 29]. A worn tool causes greater maximum temperature elevation and longer duration of temperature elevation. In the case of reaming, worn reamers has been shown to produce higher temperatures of about 10°C higher than sharper reamers [19].

2.3 DRILL MATERIALS

Many different materials are used for or on drill bits, depending on the required application. Many hard materials, such as carbides, are much more brittle than steel, and are far more subject to breaking, particularly if the drill is not held at a very constant angle to the workpiece; e.g., when hand-held.

2.3.1 Steels

Low carbon steel bits are inexpensive, but do not hold an edge well and require frequent sharpening. They are used only for drilling wood; even working with hardwoods rather than softwoods can noticeably shorten their lifespan.

high carbon steel are more durable than low-carbon steel bits due to the properties conferred by hardening and tempering the material. If they are overheated (e.g., by frictional heating while drilling) they lose their temper, resulting in a soft cutting edge. These bits can be used on wood or metal.

High speed steel (HSS) is a form of tool steel; HSS bits are hard, and much more resistant to heat than high carbon steel. They can be used to drill metal, hardwood, and most other materials at greater cutting speeds than carbon steel bits, and have largely replaced carbon steels. High speed steels are alloys that gain their properties from either tungsten or molybdenum, often with a combination of the two. They belong to the Fe–C–X multi-component alloy system where X represents chromium, tungsten, molybdenum, vanadium, or cobalt. Generally, the X component is present in excess of 7%, along with more than 0.60% carbon. The alloying element percentages do not alone bestow the hardness-retaining properties; they also require appropriate high-temperature heat treatment to become true HSS.

In the unified numbering system (UNS), tungsten-type grades (e.g. T1, T15) are assigned numbers in the T120xx series, while molybdenum (e.g. M2, M48) and intermediate types are T113xx. ASTM standards recognize 7 tungsten types and 17 molybdenum types.[7] The addition of about 10% of tungsten and molybdenum in total maximizes efficiently the hardness and toughness of high speed steels and maintains those properties at the high temperatures generated when cutting metals. In general the basic composition of T1 HSS is 18% W, 4% Cr, 1% V, 0.7%C and rest Fe. Such HSS tool could machine (turn) mild steel at speed only up to 20~30 m/min (which was quite substantial in those days

A sample of alloying compositions of common high speed steel grades (by %wt)

Grade	C[8]	Cr	Mo	W	V	Co	Mn	Si
T1	0.65–0.80	4.00	-	18	1	-	0.1–0.4	0.2–0.4
M2	0.95	4	5	6.0	2.0	-	-	-
M7	1.00	4	8.75	1.75	2.0	-	-	-
M36	0.94	4	5	6.0	2.0	8.0	-	-
M42	1.10	3.75	9.5	1.5	1.15	8.0	-	-
Note that impurity limits are not included								

Fig.12: Types of HSS drilling tool materials [22]

- M2 is molybdenum based high-speed steel in tungsten–molybdenum series. The carbides in it are small and evenly distributed. It has high wear resistance. After heat treatment, its hardness is the same as T1, but its bending strength can reach 4700 MPa, and its toughness and thermo-plasticity are higher than T1 by 50%. It is usually used to manufacture a variety of tools, such as drill bits, taps and reamers. Its decarburization sensitivity is a little bit high.[9]
- M36 is similar to M2, but with 8% cobalt added. The addition of cobalt increases heat resistance. M36 is also known as HSSE or HSS-E.
- M42 is a molybdenum-series high-speed steel alloy with an additional 8% cobalt. It is widely used in metal manufacturing because of its superior red-hardness as compared to more conventional high-speed steels, allowing for shorter cycle times in production environments due to higher cutting speeds or from the increase in time between tool changes. M42 is also less prone to chipping when used for interrupted cuts and costs less when compared to the same tool made of carbide. Tools made from cobalt-bearing high speed steels can often be identified by the letters HSS-Co.

Cobalt steel alloys are variations on high speed steel which contain more cobalt. They hold their hardness at much higher temperatures, and are used to drill stainless steel and other hard materials. The main disadvantage of cobalt steels is that they are more brittle than standard HSS.

2.3.2 Others

Tungsten carbide and other carbides are extremely hard, and can drill virtually all materials while holding an edge longer than other bits. The material is expensive and much more brittle than steels; consequently they are mainly used for drill bit tips, small pieces of hard material fixed or brazed onto the tip of a bit made of less hard metal. However, it is becoming common in job shops to use solid carbide bits. In very small sizes it is difficult to fit carbide tips; in some industries, most notably PCB manufacturing, requiring many holes with diameters less than 1 mm, carbide bits are used.

Polycrystalline diamond (PCD) is among the hardest of all tool materials and is therefore extremely resistant to wear. It consists of a layer of diamond particles, typically about 0.5 mm (0.020 in) thick, bonded as a sintered mass to a tungsten carbide support. Bits are fabricated using this material by either brazing small segments to the tip of the tool to form the cutting edges, or by sintering PCD into a vein in the tungsten carbide "nib". The nib can later be brazed to a carbide shaft; it can then be ground to complex geometries that would otherwise cause braze failure in the smaller "segments". PCD bits are typically used in the automotive, aerospace, and other industries to drill abrasive aluminum alloys, carbon fiber reinforced plastics, and other abrasive materials, and in applications where machine downtime to replace or sharpen worn bits is exceptionally costly.

2.4TYPES OF COATING

To increase the life of high-speed steel, tools are sometimes coated. One such coating is TiN (titanium nitride). Most coatings generally increase a tool's hardness and/or lubricity. A coating allows the cutting edge of a tool to cleanly pass through the material without having the material gall (stick) to it. The coating also helps to decrease the temperature associated with the cutting process and increase the life of the tool.

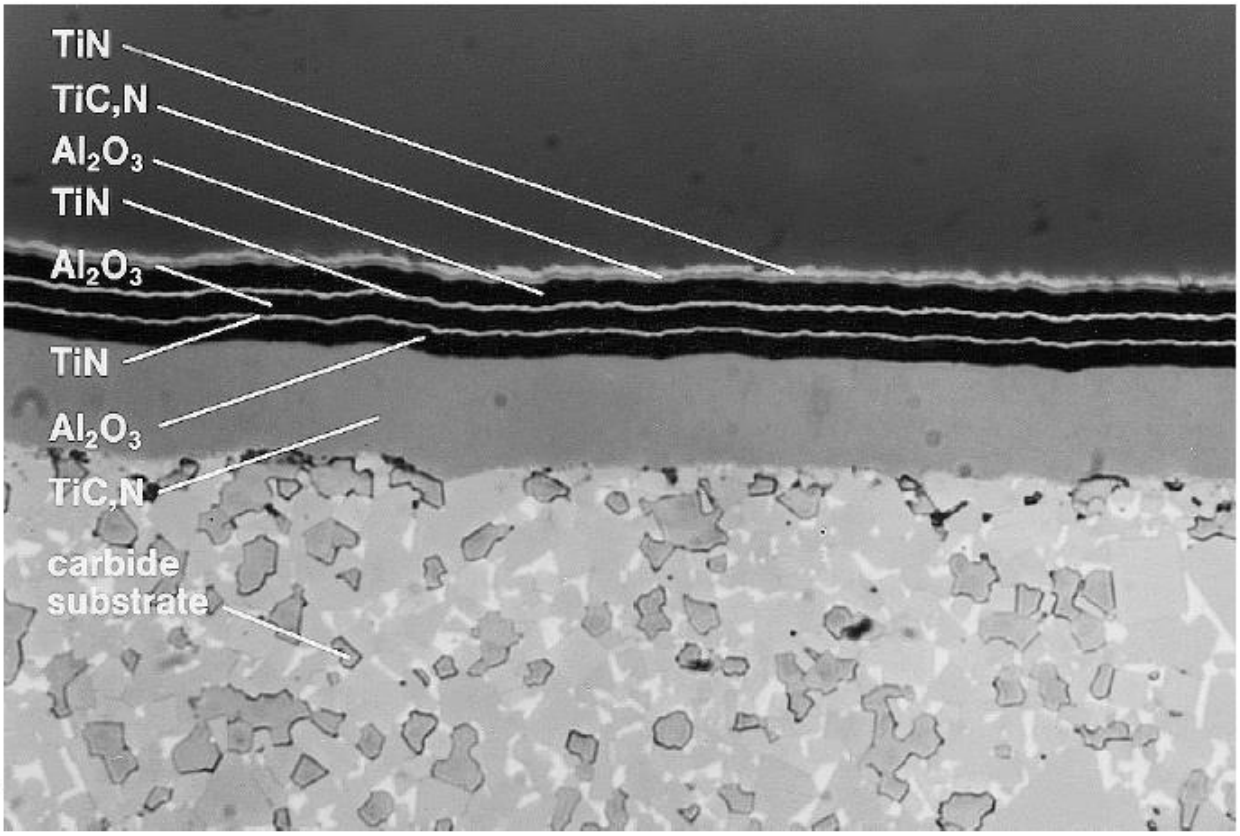

Fig.13: Different types of tool coatings[1]

2.5 COATING MATERIALS

Black oxide is an inexpensive black coating. A black oxide coating provides heat resistance and lubricity, as well as corrosion resistance. Coating increases the life of high-speed steel bits.

Titanium nitride **(TiN)** is a very hard ceramic material that can be used to coat a high-speed steel bit (usually a twist bit), extending the cutting life by three or more times. However, when the bit is sharpened the new edge will not have the benefits of the coating.

Titanium aluminum nitride **(TiAlN)** is a similar coating that can extend tool life five or more times.

Titanium carbon nitride (TiCN) is another coating also superior to TiN.

Diamond **powder** is used as an abrasive, most often for cutting tile, stone, and other very hard materials. Large amounts of heat are generated by friction, and diamond coated bits often have to be water cooled to prevent damage to the bit or the workpiece.

Zirconium nitride has been used as a drill bit coating for some tools under the Craftsman brand name.

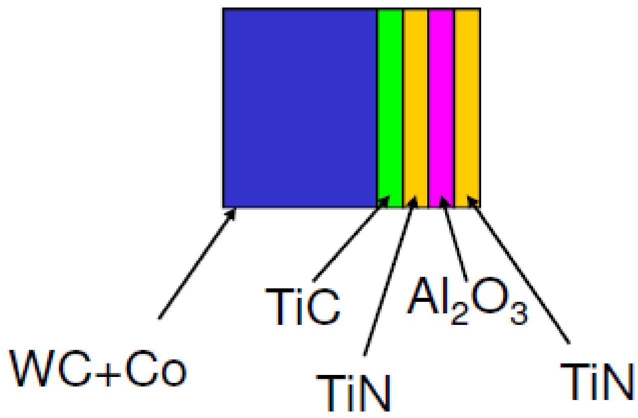

Fig.14: Different tungsten coatings[24]

2.6 CARBON NANO TUBES (CNT) COATING

The new coating materials with carbon nanotube (CNT) molecularly attached with HSS drilling tool that comparises iron,carbon,trungusten,chromium and vanadium is used as a thin layer of carbon based tubes that cover entire tool as a protecting shield this layer is harder which helps in reducing tool wear while drilling.

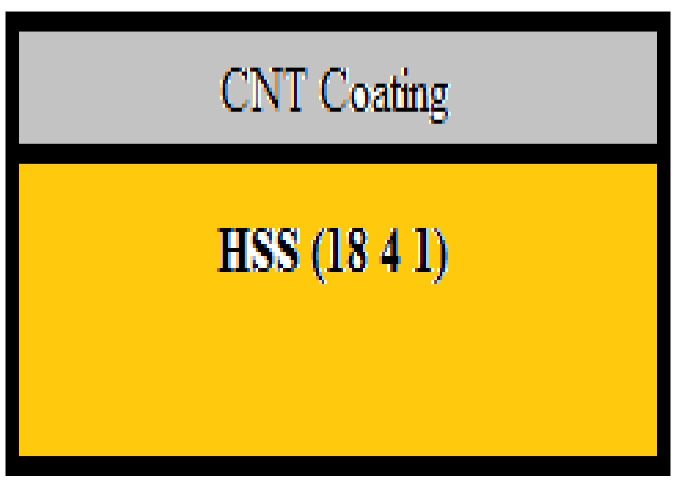

Fig.15: CNT coating on HSS material

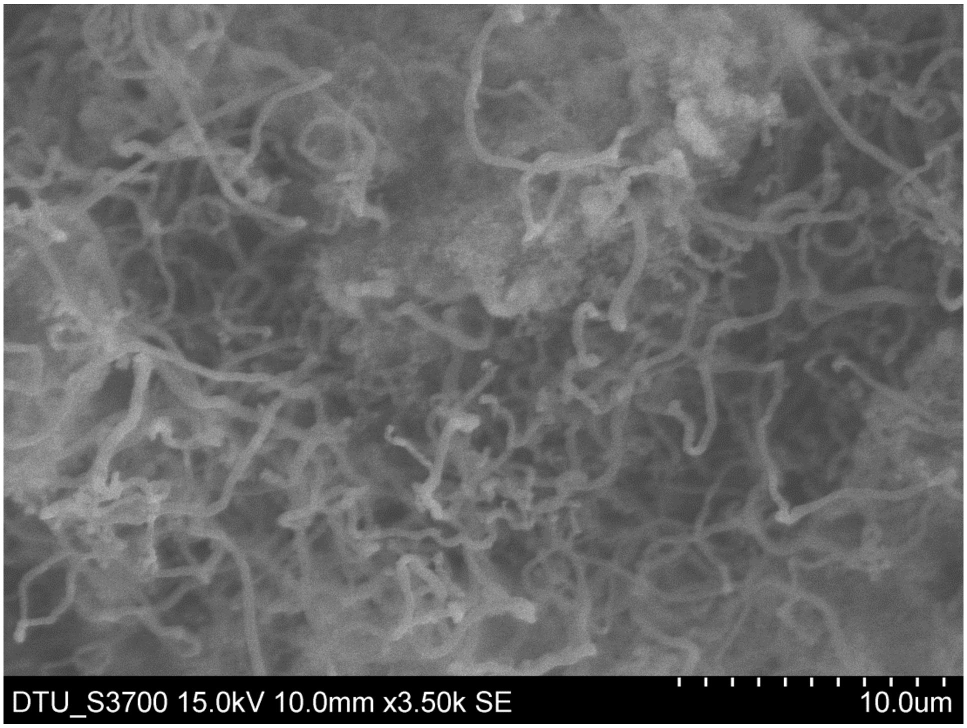

Fig.16: SEM image ifcarbon nano tubes

2.7 CNT COATED DRILLING TOOL

Fig.17: Carbon Nano Tube coated HSS tool

Chapter 3

LITERATURE REVIEW AND PROBLEM IDENTIFICATION

Drilling is a purely mechanical process. Different types of drilling machines are used with HSS drilling tool. Crbon Nano Tube(CNT) based drilling HSS(18 4 1) tool is a coated tool with more hardness when used with drilling process it can work for longer periods of time without less tool wear and capable of machining different work materials. During machining Carbon Nano Tube(CNT) plays an important role with high hardness which act as a protecting shield on HSS drill tool surface against wear[4]. Chemical vapor deposition method is used for synthesis of CNT on this tool. The gases used for this method is acetylene and argon which is very has less cost also this coating have less cost due to this advantage this can be commercially used for drilling. Three parameter Force, Torque and tool wear is analyzed with different depth of cut on radial drilling machine while machining with ductile material[5]. Experiment shows that force and torque produced while drilling is very less results less power consumption and heat generated while drilling on radial drilling.

3.1 EFFECT OF AFM PROCESS PARAMETERS

Thrust force and torque while drilling with CNT based tool depends on the following: (1) Speed (2) Feed (3) Depth of cut (4) Type of tool coating (5)Tool wear (6) coolant used (7) Drill point angle (8) Drill helix angle (9) Drill diameter

A lot of work has been done to study the effects of important drilling process parameters. Some of the works have been reported as under:

3.1.1 Drilling speed

Drilling speed effects the drilling operation research shows as drilling speed increases heat also increases[7] resulting more power consumption but some reported that it depends on work material with ductile material heat generated is less compare to brittle[10].

3.1.2 Feed

Increasing feed increases material removal rate but more feed can damage tool produced more tool wear and surface roughness[10]. In some research it is found that feed effects more in brittle material and less effect while machining ductile materials because they locally manage stress concentration [13].

3.1.3 Depth of cut

Depth of cut is a very important parameter in drilling because it does not effect material removal rate but force and torque effects increasing feed increases force while torque is also increases in brittle material[14].ductile material produces more uniform torque then brittle[15].

3.1.4 Tool coating

These are dominant process parameters controlling the amount of wear which is heat and tool material coating with TiN produces less tool[15] wear while coating with TiAlN produces more abrasion resistance[16] other coatings will produce less tool wear.

3.1.5 Tool wear

Tool wear is protacted with coating HSS tool will wear out at 600 degree centigrade[2] temperature but carbides and ceramics tool has more temperature capacity and able to bear temperature around 3000 degree centigrade[4].

3.1.6 Coolant used

soluable oil produces more cooling and lubrication[16] compare to others oil while working with ductile material. but in case of brittle material dry compressed ai[4]r can be used for machining**.**

3.1.7 Drill point angle

The angle formed at the tip of the bit, is determined by the material the bit will be operating in. Harder materials require a larger point angle[10], and softer materials require a sharper angle[7]. The correct point angle for the hardness of the material controls wandering, chatter, hole shape, wear rate, and other characteristics

3.1.8 Drill Helix angle

The helix angle of the drill influences the temperate rise during drilling. The helix angle of a drill bit varies with the drill diameter; larger angles are used for larger diameter drills. The 18°optimum range for the helix angle has been reported as 24–36° [12].

.

3.1.9 Drill diameter

Force and torque increases with increase in drill diameter. This is because ore heat is generated while using drill of larger diameter.

3.2 OBJECTIVES OF CNT BASED COATED TOOL

Conventional machining process has limitations that tool wear is more with more power consumption but CNT coated HSS drilling tool produces less tool wear and less power consumption the following is other objective of CNT coated tool.

- Development CNT coating set up and optimal parameters.
- Development of CNT on HSS(18 4 1) drilling tool.
- Experimental Study of the effect of various process parameters on the performance characteristics and to optimize the CNT coating on HSS drilling tool.
- Study of tool wear with and with coating using SEM(Ecanning Electron Microscopy).

Chapter 4

EXPERIMENTAL INSTRUMENTS AND THEIR SPECIFICATIONS

Experimental instruments are used for performing experiment in the following content we will explain experimental instrument used for drilling.

4.1 RADIAL DRILLING MACHINE

Radial drilling machine is used for drilling with coated and non coated tool with ductile work material, following is the figure of radial drilling machine that is used in laboratory for our experiment.

Fig.18: Radial drilling machine

4.1.1 DRILLING MACHINE SPECIFICATION

Table 1: Tool sensitive Drilling machine specification

MACHINE TOOL IS A SENSATIVE DRILLING MACHINE	
Work material	Mild steel
Work size	Diameter: 38mm
	Length:68mm
Cutting tool	High speed steel drilling(HSS)
Cutting tool material	Carbon: .7%
	Tungsten: 18%
	Chromium: 4%
	Vanadium: 1%
Working tool geometry	Diameter: 6mm
	Flute length:75mm
	Overall length: 117mm
	Tip angle: 118°
	Helix angle: 20°
Process parameters	Cutting velocity: 580rpm
	Feed rate: .2mm/rev
	Depth of drilled blind hole-5,10,1520mm
Tool condition	Non cryogenically treated
Measuring instrument	Drill tool dynamometer for measuring thrust force in kg and torque in kg-cm.
	Scanning electron microscope(SEM)

4.2 DRILING TOOL DYNAMOMETER

Fig.19: Drill tool dynamometer

4.2.1 Drill tool dynamometer specification

Table2: Drill tool dynamometer specification

Sensing unit	It consists of mild steel cylinder with strain gauges mounted on it. The unit accurately senses axial thrust and torque independently.
Bridge balancing unit(panel)	It consists of power supply unit, balancing pots for initial zero.
Strain gauges	Quantity-8 Resistance-350Ω Gauge factor-2+-1
Test piece	Diameter-38mm Length-68mm Material-mild steel
Balance pot (tare)	Ten turn helical potentiometer for balancing channel 1&2.

4.3 WORKPIECE MATERIAL AND DIAMENSIONS

Fig.20: Workpiece for drilling

Work diameter is 38mm and length is 68mm.The machining workpiece is made of ductile material.

4.3.1 DRILL BIT MATERIAL AND SPECIFICATION

Table3: Drill bit specification

Cutting tool material	Carbon: .7%
	Tungsten: 18%
	Chromium: 4%
	Vanadium: 1%
Cutting tool geometry	Diameter: 6mm
	Flute length:75mm
	Overall length: 117mm
	Tip angle: 118°
	Helix angle: 20°

Chapter 5

METHOD OF DEVELOPMENT OF CNT ON HIGH SPEED STEEL (HSS) DRILLING TOOL

5.1 HSS DRILL BIT COMPONENTS

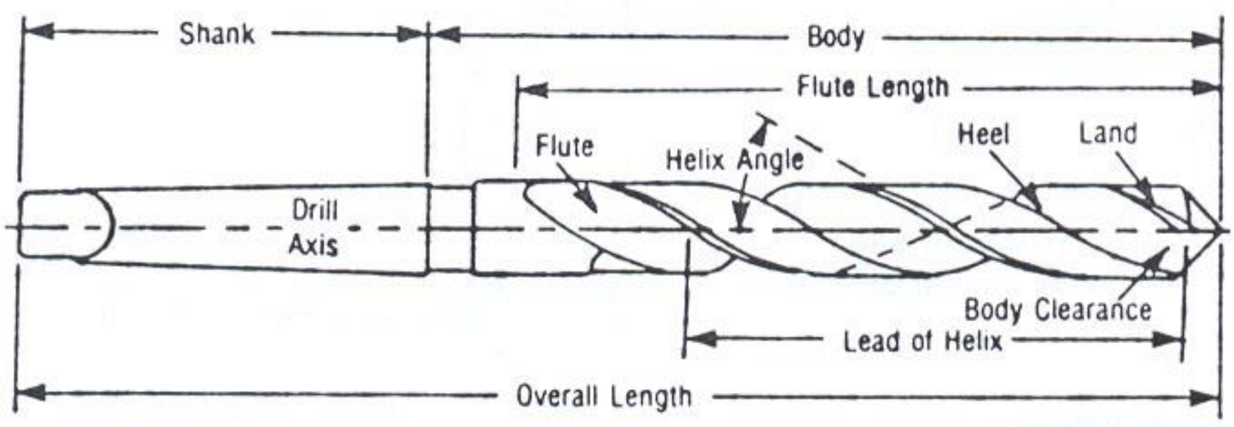

Fig.21: HSS drilling tool

5.2 CARBON NANO TUBE

A Carbon Nano tube is a tube-shaped material, made of carbon, having a diameter measuring on the nanometer scale. A nanometer is one-billionth of a meter, or about one ten-thousandth of the thickness of a human hair. The graphite layer appears somewhat like a rolled-up chicken wire with a continuous unbroken hexagonal mesh and carbon molecules at the apexes of the hexagons. Carbon Nanotubes have many structures, differing in length, thickness, and in the type of helicity and number of layers. Although they are formed from essentially the same graphite sheet, their electrical characteristics differ depending on these variations, acting either as metals or as semiconductors[22]. As a group, Carbon Nanotubes typically have diameters ranging from <1 nm up to 50 nm. Their lengths are typically several microns, but recent advancements have made the nanotubes much longer, and measured in centimeters. The carbon network of the shells is closely related to the honeycomb arrangement of the carbon atoms in the graphite sheets. The amazing mechanical and electronic properties of the nanotubes stem in their quasi-one-dimensional (1D) structure and the graphite-like arrangement of the carbon atoms in the shells. Thus, the nanotubes have high Young's modulus and tensile strength, which makes them preferable for composite materials with improved mechanical properties.

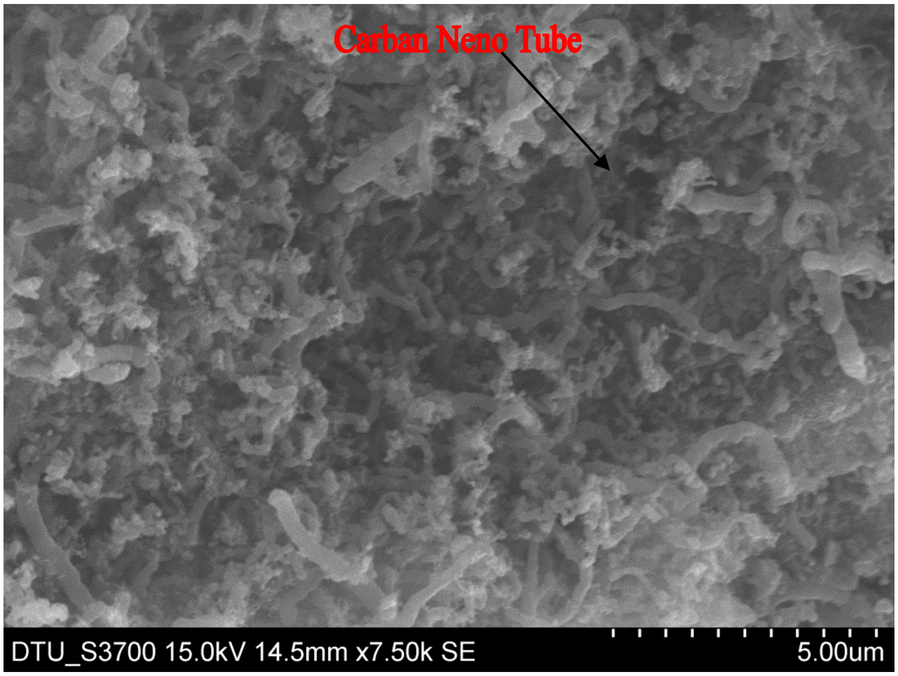

Fig.22: SEM(Scanning Electron Microscopic) image of Carbon Nano Tube image

5.3 METHOD OF FORMATION OF CNT

5.3.1 Introduction

The first experimental evidence of Carbon nanotubes (CNTs) came in 1991[1] in the form of multi wall nanotubes (MWNT). This prompted a sudden increase in nanotube synthesis research. In 1993, the first experimental evidence of single wall nanotube tubes (SWNT) came [2, 3]. Since then, the synthesis methods for CNTs have been developed tremendously. This chapter explains the basics of CNT growth as well as describes several unique CNT growth processes developed throughout this study[22].

Production methods for carbon nanotubes (CNTs) can be broadly divided into two categories: chemical and physical depending upon the process used to extract atomic carbon from the carbon carrying precursor. Chemical methods rely upon the extraction of carbon solely through catalytic decomposition of precursors on the transition metal nanoparticles, whereas physical methods also use high energy sources, such as plasma or laser ablation to extract the atomic carbon[32].

Traditionally, physical methods give bulk quantities of CNTs which could then be treated chemically to remove any carbon soot or nanoparticles present in the mixture[4]. These two approaches can further be characterized according to the use of other important aspects of the synthesis process, such as type of precursor and transition metal nanoparticles used. In spite of being thoroughly investigated for the last 10 years, CNT growth process has remained somewhat controversial[25]. Although the exact dynamics of the growth is not yet clear, consensus has been reached on a hypothesis which works pretty well. It is so far been understood that the nanotubes grow from the over saturation of the transition metal nanoparticles with carbon atoms.

The over-saturation of nanoparticles with carbon atoms results in the production of different type of molecular carbon species, like graphitic carbon, carbon filaments, multiwall carbon nanotubes, single wall carbon nanotubes and most recently, graphene. Selecting the right conditions to grow any of these materials (especially, nanotube and graphene) has remained a trial and error approach. This has resulted in a plethora of CNT growth papers, each having a specifically tuned recipe for growth, which is very difficult to reproduce in any other system or setup.

The holy grail of controlling the growth has focused the synthesis effort more towards chemical vapor deposition (CVD) process where the yield of tube growth is not that high and it can finely be controlled through the use of catalyst nanoparticles placed on a silicon chip. The next few sections will detail CVD process and advancements.

5.3.2 Chemical Vapor Deposition (CVD)

CVD process consists of placing catalyst nanoparticles in a quartz tube inside furnace which is then heated to the desired growth temperature approximately 750 degree calicoes. Carbon carrier gases with a inert gas are then flown through the quartz tube for a predetermined time(approximately 10 minuts). After the growth the furnace is cooled down and the wafer is inspected for the resultant nanotube growth. This technique was first used in 2001 [5] to grow single wall carbon nanotubes on flat silicon substrates. The process gained popularity due to its ability to grow well separated, long single wall carbon nanotubes with less defect density and amorphous carbon content, compare to processes that utilize physical route such as plasma.

Due to its wide acceptance in research community, several groups have focused on optimizing the CVD process [5-9].

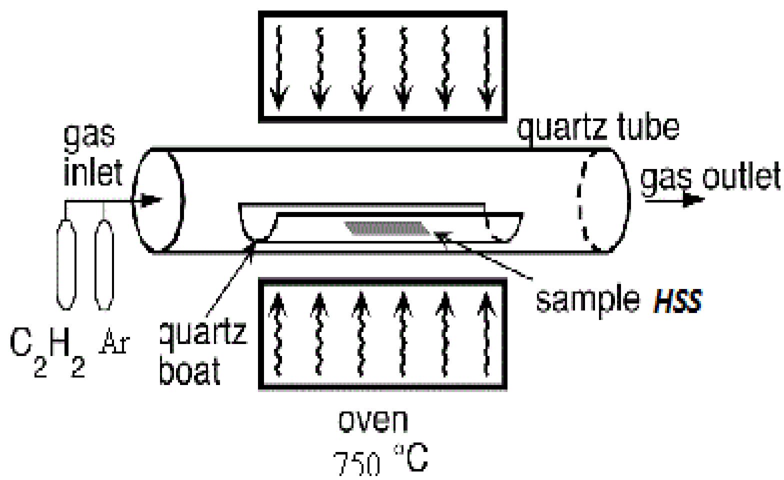

Fig. 23:CVD(Chemical Vapour Deposition) method furnace

5.4 PROCESS AND FORMATION OF CNT ON HSS DRILLING TOOL

5.4.1 Apparatus and furnace used

In the making of Carbon Nano Tubes main apparatus used were oven, tube, beaker, cylinders of argon and acetylene gas in this process acetylene gas is used as a source of carbon and argon gas is used as a carrier gas.

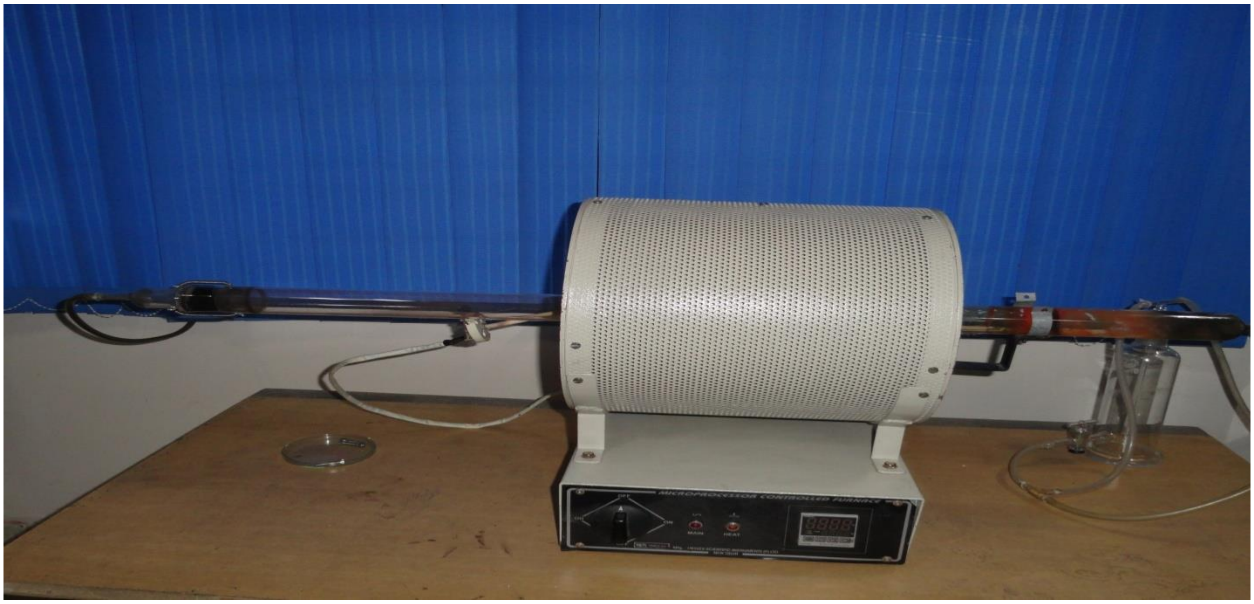

Fig.24: CNT synthesis furnace

5.4.2 Optimal Process parameters while synthesis of carbon nano tubes

Table4: Process parameters of CNT formation

Optimal Process parameters of CNT formation	
Tool material	High speed steel(18-4-1)
Carrier gas	Argon gas
Carbon Precursor	Acetylene gas
Carrier gas flow rate	200sccm
Carbon Precursor flow rate	100sccm
CNT formation time	10 minutes
Catalyst nano particle	Iron

5.4.3 Process of CNT synthesis

Synthesis of CNT on HSS drilling tool use chemical vapor deposition method Initially HSS tool is placed on the quartz boat which is placed inside the furnace then from room temperature around 25°C we flow the argon gas with 200sccm till the furnace achieve temperature 750°C. After this temperature acetylene gas is flowing with 100sccm for 10 minutes along with continuous flow of argon gas with 200sccm. Then wait for some time till furnace cools to room temperature in this way CNT will deposited on HSS drilling tool.

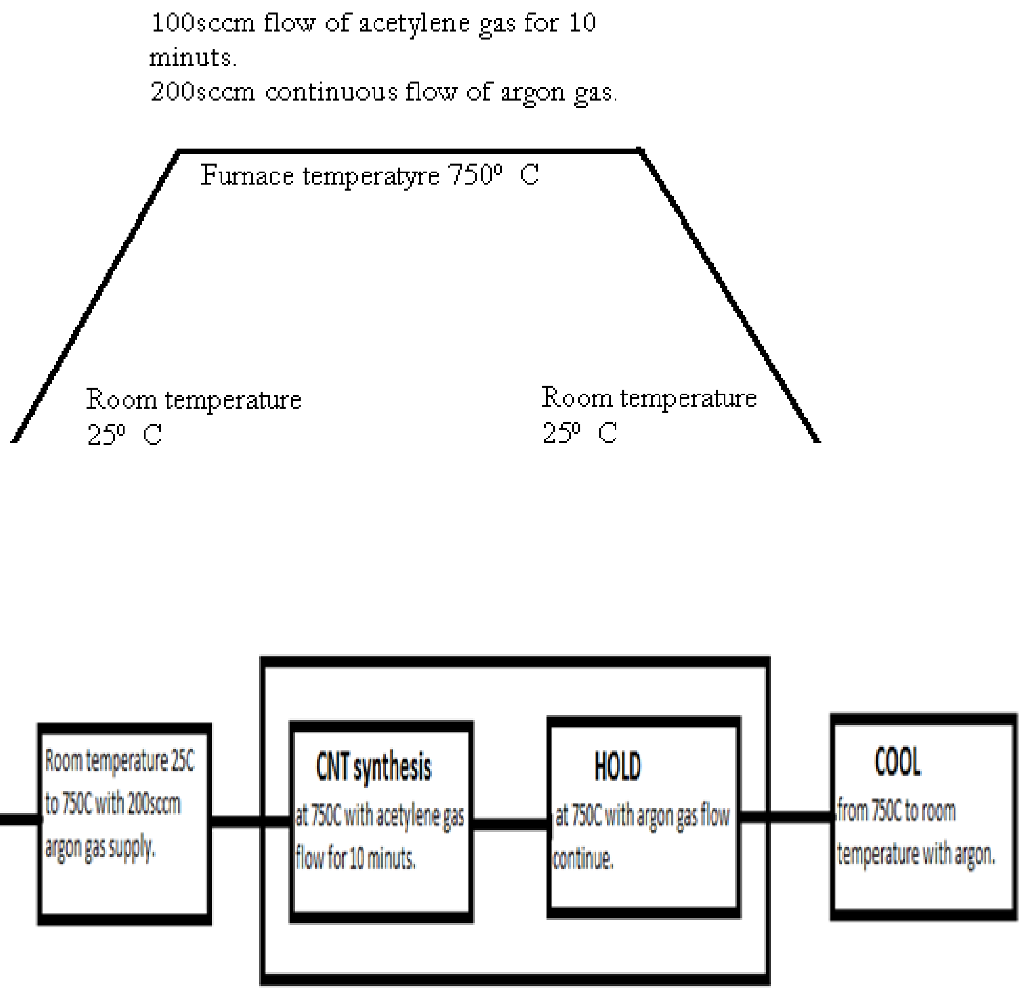

Fig.25: Process of CNT formation

The growth of carbon nano tubes is depends mainly up on flow rates of argon and acetylene gases along with flow time of acetylene gas. A lot of experiments have been done to optimize the CNT formation on HSS. The following is the brief description of all process.

5.5 SCANNING ELECTRON MICROSCOPY (SEM) IMAGES OF CARBON NANO TUBE GROW ON HSS TOOL

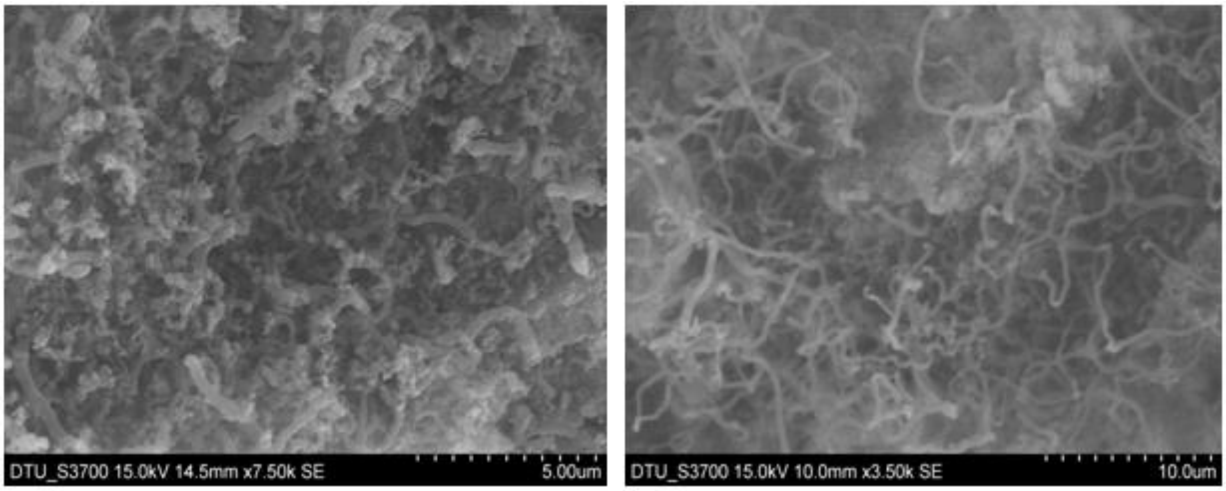

Fig.26: SEM(Scanning Electron Microscope Image of CNT grow on HSS tool

5.6 EFFECT OF USING CARBON NANO TUBE WITH HSS DRILLING TOOL ALONGWITH MACHINING ON RADIAL DRILLING MACHINE

The major limitation of using HSS drilling tool is more wear of tool. So to reduce this limitation, carbon Nano Tubes is used with HSS drilling tool because it is harder and act as a protecting shielding layer on drilling surface.

Chapter 6

PROCESS PARAMETER SELECTION AND EXPERIMENTATION

Drilling with HSS tool needs special attention of operator for accurate results of force and torque but with CNT coated tool also need controlled condition of process parameters and tool sensitive drilling machine.

6.1 SELECTION OF WORKPIECE

The length to diameter (L/D) of the workpiece was decided on the basis of the tool sensing radial drilling machine which is 1.79. The material selected for the workpiece is mils steel. The workpiece was taken out from setup and cleaned with acetone before the subsequent measurement[28].

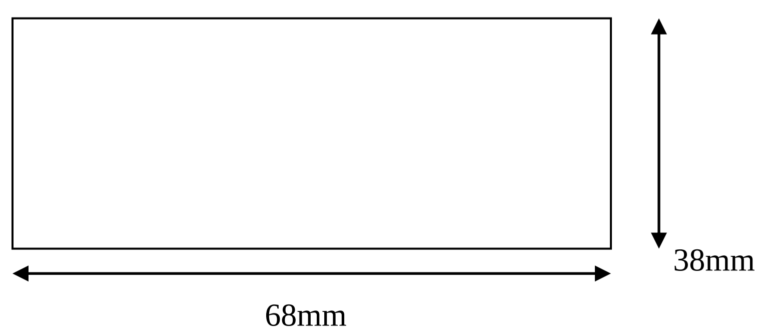

Fig.27: Drilling workpiece diamension

6.2 SELECTION OF PROCESS PARAMETER IN DRILLING

Table5: Process parameters of drilling

S. No.	Process Parameter	Range	Unit
1	Drilling force	227-171	Kg
2	Drilling torque	.3-.7	Kg-cm
3	Speed	580	Rpm
4	Feed	.2	mm/rev
5	Depth of cut	5-20	Mm
6	Drill diameter	6	Mm
7	Drill coating		CNT
8	Cutting fluid		Soluble oil

6.2.1 Parameters Influencing the Drilling Force

Cutting speed does not have a significant influence on the axial dill force [1]. But, higher drill speeds require higher pressure force or axial drill force. In some studies it has been reported that as speed is increased the drilling time decreases and the force increases [1, 2]. While it has been recommend to use low drill speeds while applying larger axial force [33].

The feed rate is directly proportional to drill force. As the feed rate per tooth increases the axial force increases [1, 34].

As the drill tip angle is reduced the drilling force is reduced [1]. An optimum rake angle aids cutting, decreases deformation of material cut by the tool, improves chip flow and reduces specific cutting energy. Increasing the positive rake angle decreases the principal cutting force for orthopedic drills and increases their cutting efficiency [35].

6.2.2 Force Temperature Correlation

Force is shown to be an important factor affecting the magnitude and duration of cortical temperature elevations as compared to drill rotation speed [8, 9]. There has been little agreement regarding the influence of force in increasing the maximum temperature. Some researchers have reported it to be directly proportional [9, 36]. While some reported that higher drilling forces cause lower average temperature and shorter durations of temperature elevation [8, 9, 37].

6.2.3 Material Removal Rate (MRR)

Material removal signifies the amount of material removed from the specimen in a specified number of experiments with change cutting condition. Material removal is calculated from the formula[31].

$$MRR = \frac{\Pi}{4} * d^2 * f * N \text{ mm}^3/\text{min}$$

Where,

d= drill diameter (mm)

f= feed rate (mm/rev)

N= no of rev. (rpm)

6.3 RESPONSE CHARACTERISTICS

The effect of these process parameters were studied on the following response characteristics of drilling process.

1. Thrust force(Kg)
2. Cutting torque(Kg-cm)
3. Tool wear (experimental investigation)

6.4 SCHEME OF EXPERIMENTS

The experiment were designed to measure force along with torque for different depth of cut drilling on radial drilling machine with and without CNT coating HHS drilling tool the following is the table on which all these experiment parameter are designed.

Table 6: Process Parameters of drilling and their values at different levels

SNo.	Process Parameters	Unit	Level 1	Level 2	Level 3	Level4
1	Speed	Rpm	580	580	580	580
2	Feed	mm/rev	.2	.2	.2	.2
3	Depth of cut	Mm	5	10	15	20

6.5 EXPERIMENTATION

The three process parameters depth of cut, ,CNT coated HSS drilling tool, non CNT coated HSS drilling tool with same feed and speed were selected as in table . The process parameters were varied according to the values as shown in table 5.2. Experiments were conducted according to the test condition on the radial drilling machine in the following sequence.

- First, with CNT coated HSS drilling tool with same speed and feed with varying depth of cut and then measuring force and torque along with and tool wear.
- Second, with non CNT HSS drilling tool with same speed and feed with varying depth of cut and then measuring force and torque along with tool wear.

6.6 VALUES OF FORCE AND TORQUE

Following readings is experiment of drilling which is performed on tool sensitive radial drilling machine.

Table 7: Cutting condition while working on radial drilling machine

Cutting conditions	
Speed	580 rpm
Feed	0.2mm/rev
Depth of cut(DOC)	5,10,15,20mm

6.6.1 Values of force and torque for CNT coated tool

Table 8: Torce and Torque values of machining with CNT coated HSS drilling tool

CNT coated HSS drilling tool			
FORCE(Kg)	Torque(kg-cm)	Depth of cut(mm)	Material removal rate(mm³/min)
171	.5	20	3278.16
172	.4	20	3278.16
187	.3	20	3278.16
207	.3	20	3278.16
215	.4	20	3278.16
205	.5	20	3278.16
206	.4	20	3278.16
212	.5	20	3278.16
220	.4	20	3278.16
215	.3	20	3278.16
197	.3	20	3278.16
181	.4	15	3278.16
178	.5	10	3278.16
190	.4	5	3278.16

6.6.1 Values of force and torque for CNT coated tool

Table9: Force and Torque values of machining with non CNT coated HSS drilling tool

Non coated HSS drilling tool			
FORCE(Kg)	Torque(kg-cm)	Depth of cut (mm)	Material removal rate (mm^3/min)
173	.6	20	3278.16
216	.6	20	3278.16
198	.6	20	3278.16
206	.4	20	3278.16
198	.4	20	3278.16
189	.5	20	3278.16
191	.4	20	3278.16
209	.4	20	3278.16
227	.4	20	3278.16
218	.5	20	3278.16
211	.5	20	3278.16
208	.6	15	3278.16
190	.7	10	3278.16
172	.4	5	3278.16

6.7 ELECTRON MICROSCOPY (SEM) OF TOOL WEAR

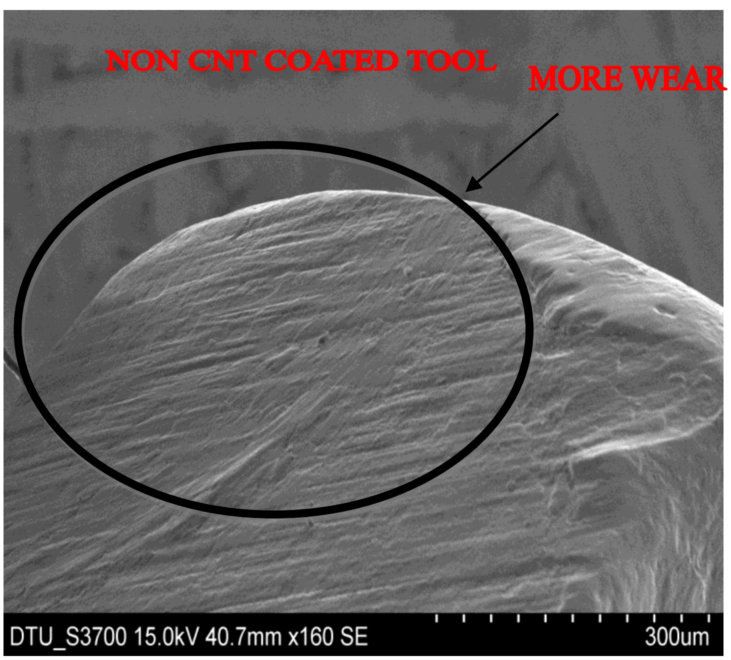

Fig.28: SEM(Scanning Electron Microscope) image of Tool wear of non CNT coated tool

Based on the experiment that is performed on radial drilling machine we observe the tool wear in case of CNT coated and non coated HSS drilling tool that is used with ductile work material.

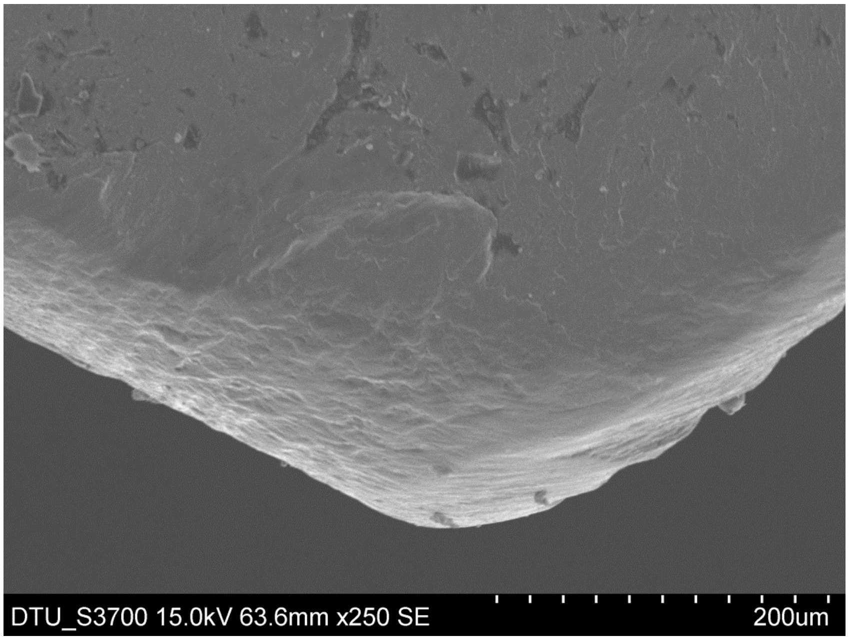

Fig.29:SEM(Scanning Electron Microscope) image of Tool wear of CNT coated tool

Chapter 7

ANALYSIS AND DISCUSSION OF RESULT

The chapter contains the analysis and discussion of experimental results.

7.1 ANALYSIS AND DISCUSSION OF RESULTS

The different experiment that is conducted on radial drilling machine measures the effect of different process parameter on force and torque that is used while drilling on ductile workpiece. In this way different force torque readings are measured with different depth of cut and various graph are drown between them but while performing this experiment tool wear is also considered with help of scanning electron microscopy (SEM).

7.2 EFFECT ON FORCE WITH CNT COATED TOOL

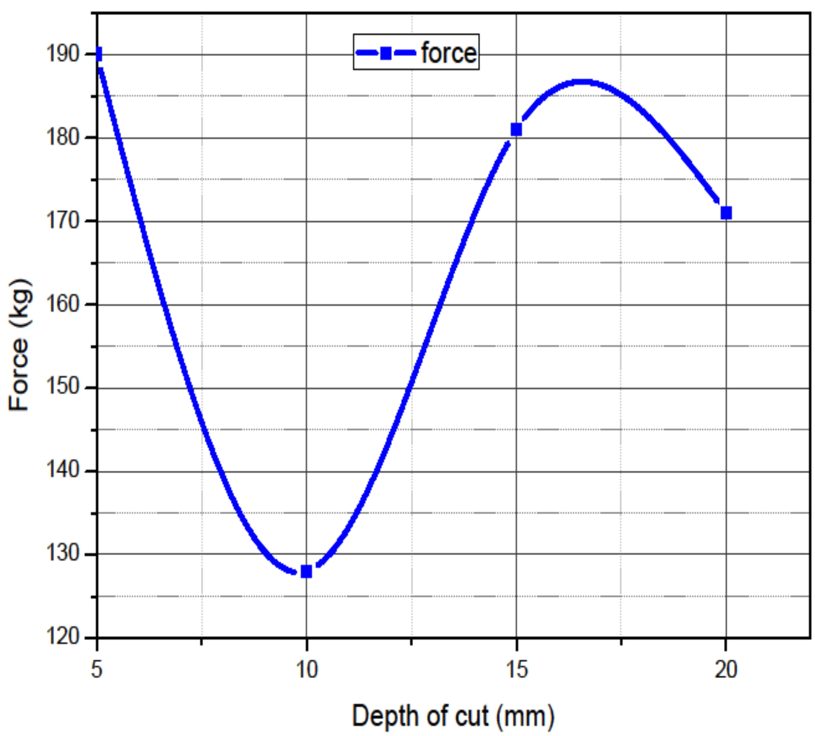

Fig.30: Effect of force with depth of cut with CNT coated tool

7.3 EFFECT ON TORQUE WITH CNT COATED TOOL

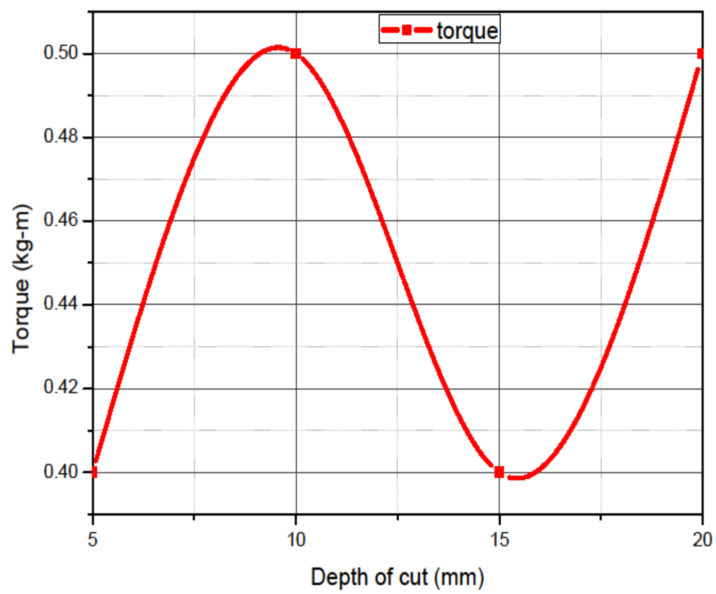

Fig.31: Effect of torque with depth of cut with CNT coated tool

7.4 EFFECT ON FORCE WITH NON CNT COATED TOOL

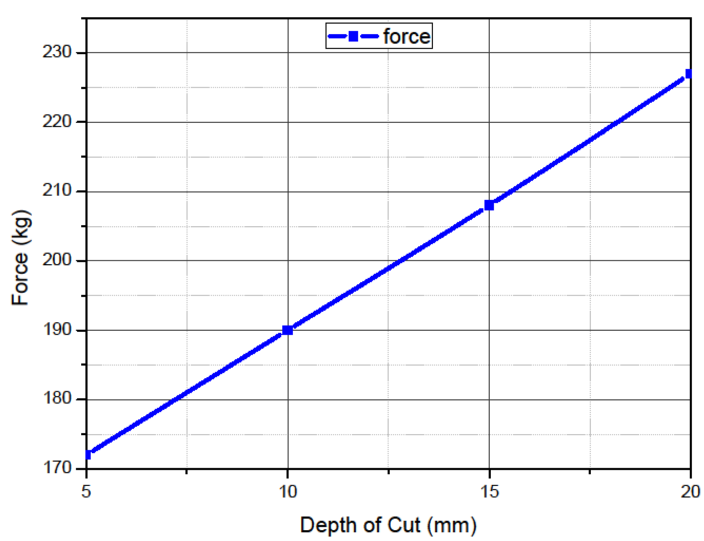

Fig.32: Effect of force with depth of cut with non CNT coated tool

7.5 EFFECT ON TORQUE WITH NON CNT COATED TOOL

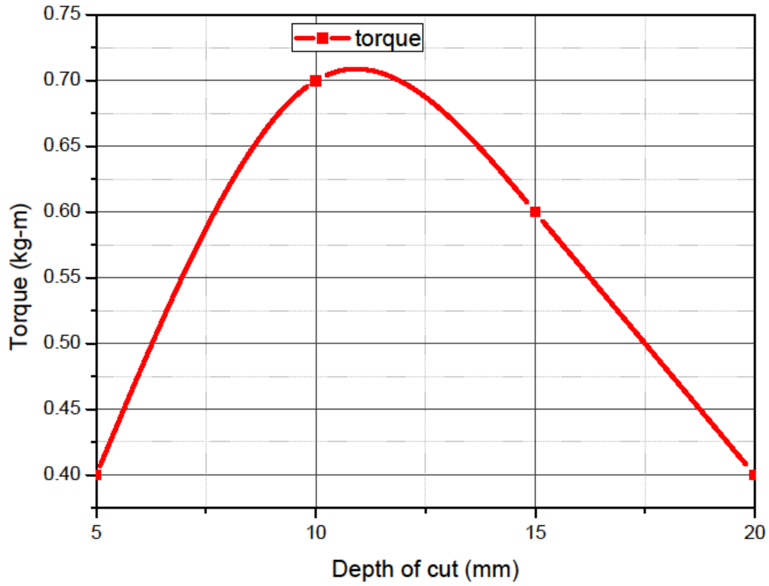

Fig.33: Effect of torque with depth of cut with non CNT coated tool

7.6 FORCE Vs DEPTH OF CUT

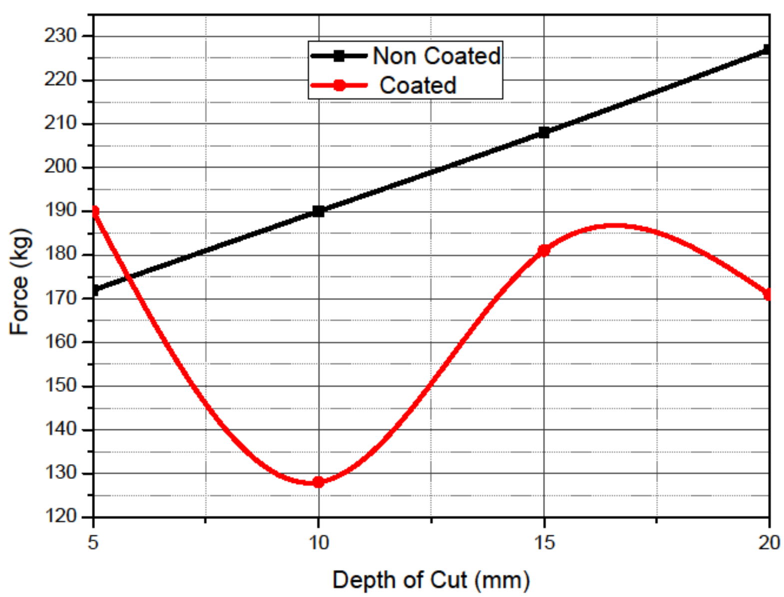

Fig.34: Effect of force with depth of cut for both tool

7.7 TORQUE Vs DEPTH OF CUT

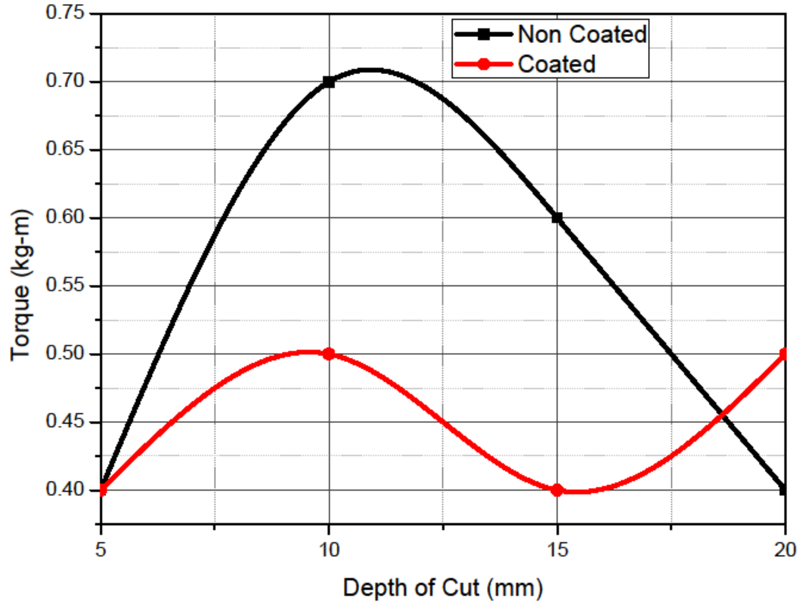

Fig.35: Effect of torque with depth of cut for both tool

7.8 SCANNING ELECTRON IMAGES (SEM) OF CNT COATED AND NON COATED HSS DRILLING TOOL

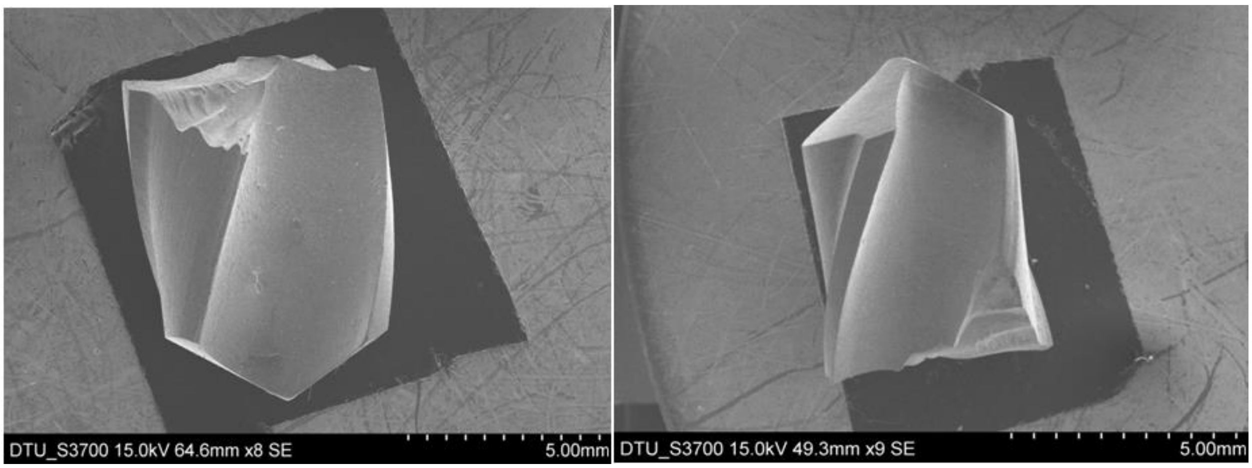

Fig.36: SEM(Scanning Electron Images) of coated and non coated HSS drilling tool

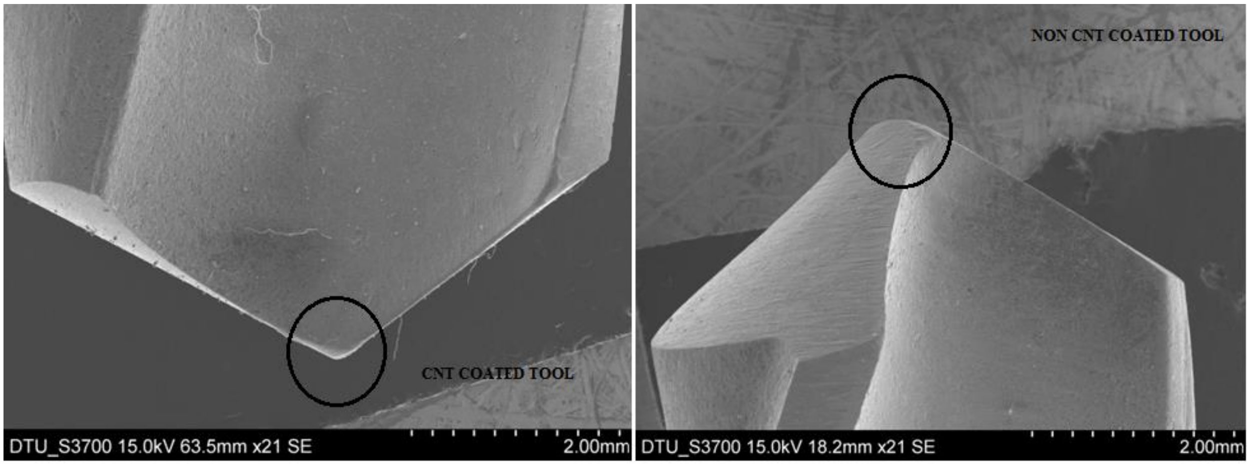

Fig.37: SEM(Scanning Electron Images) of coated and non coated HSS drilling tool after machining on ductile material.

7.9 EFFECT ON TOOL WEAR WITH AND WITHOUT COATING AFTER MACHINING

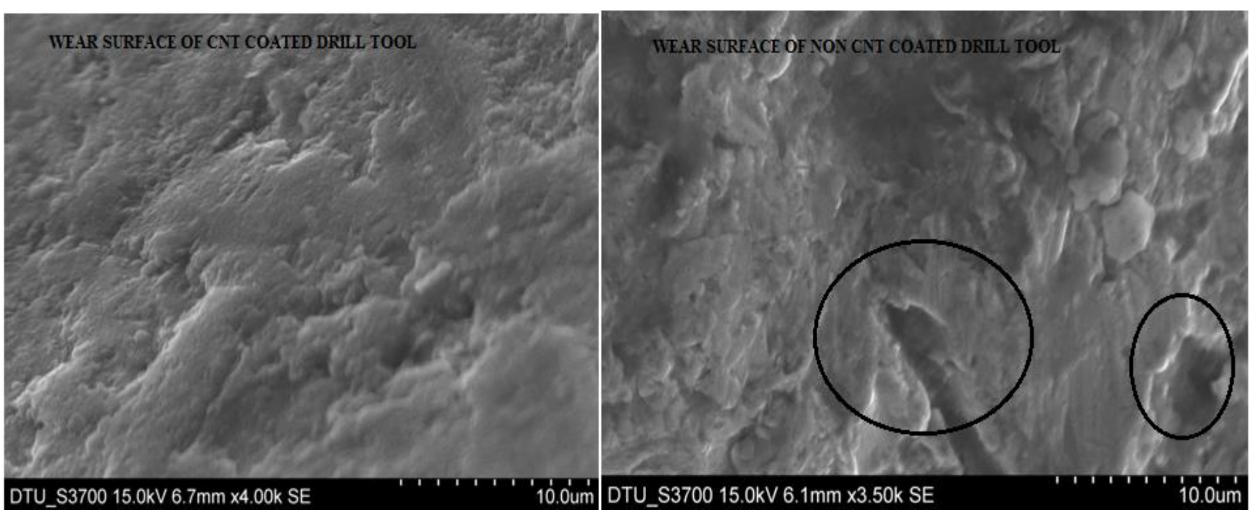

Fig.38: SEM(Scanning Electron Images) of tool wear of coated and non coated HSS drilling tool after machining on ductile material.

Chapter 8

CONCLUSION AND SCOPE FOR FUTURE WORK

There is a possibility of improvement in the process of drilling by using the CNT coated drilling tool because it is harder than the conventional abrasives. According to this study, it is clearly defined that after using CNT along with High Speed Steel drilling tool force required for drilling reduces which lead to reduce in power consumption. It is also clearly defined that CNT based coating required controlled condition of temperature otherwise it will oxidize. The important conclusion from this research work is provided in the next subsection.

8.1 CONCLUSIONS

- The study of CNT based drilling on radial drilling machine with ductile work material was done successfully.
- The effects of using CNT were properly analyzed.
- It was seen that force first decreases and then increases with depth of cut in case of CNT coated drilling tool.
- T he amount of torque first increases and then decreases with CNT coated tool.
- As the temperature reduces CNT will stabilize.
- It was obtained from the experiment that tool wear is less in case of CNT based coated tool as compare to non CNT coated tool.
- As force required is less in case of CNT based tool this leads to less heat generation which consumes less power.

8.2 SCOPE FOR FUTURE WORK

- This process can be improved with tool sensitive dynamometer which good response characteristic.
- The life of the tool increases due toeless tool wear with CNT based coated tool.
- The set up can be optimized for many other process parameters like different shapes of work materials, different drill bit diameter, versatile work materials.
- Higher order Orthogonal Array (OA) can be considered to incorporate all the possible interactions of the process parameter.

Chapter 9

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