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Effect of Chemical Composition on Tool Life of a Hybrid Nano (WC & TIC) Insert Turning Insert for A Cast Iron Component Machining

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ABSTRACT

This work focuses on improving the tool life by changing the ratio of material composition used in the manufacturing of tool insert. The composition of the tungsten carbide materiel is used to enhance the Properties of the tool insert; This is used for turning operation in the machining of cast iron in automobile applications. The three different compositions is analysed for enhancing tool insert and to improve the tool life. Three different samples of tool insert are considered with varying composition of WC&TIC. These are manufactured by powder metallurgy for particle sizes less than 20 microns. A comparative study of the failure modes caused by change in mechanical and physical properties of the insert with varying compositions were studied. The experimental and simulation analysis of the proposed microstructure composition of three samples were investigated. Results from the investigations suggest that the varied composition (sample B) tends to enhance tool life for the proposed material composition and tool deformation is well contained for more number of jobs than the conventional material composition of the existing tool insert. The simulation was carried out using ANSYS V12 to estimate the tool life of each sample considering cast iron as the machined component. The temperature at the tool and work-piece interface, the cutting forces and surface structure of the machined component were carefully considered and the results are compared to the existing coated carbide insert.

1. INTRODUCTION

1.1 General

Liberalization and globalization in the competitive market, present market demands high quality of product with minimum cost. During manufacturing of product major cost is associated with machining operations. Optimization of the machining conditions can reduce the unit production cost. Hence, production cost can be minimized through optimization of machining condition and proper setting of various parameters during machining. The production cost may be enhanced due to rapid tool wear and frequent changes of cutting tool. The production cost can also be reduced by reducing the lead time and proper selection of machine tools, tool geometry, cutting conditions such as velocity, feed rate, depth of cut and as well as through proper selection of cutting tool material and operations involved. This variable governs the economics of machining operations. Therefore, there is a vital need to correlate the technological factors involved in the machining process for analyzing the economics of the process and product in practice. However, with the rapid technological acceptance of hard alloy steel in industrial application, the machining of cast iron has been of urgent importance for modem hub and disc brake automobile manufacturing industries. As cast iron have high value of hardness and low stiffness, the selection of proper cutting tool materials and machining process for effective machining of cast iron, grey cast iron has really been very difficult. The major problems encountered during traditional machining of cast iron are rapid tool failure, severe abrasive wear, flank wear of cutting tool, formation of flank build up layer on the cutting tool edge, poor surface finished etc. Although some research on traditional and non-traditional machining of hard alloy steel have been carried out by the previous researchers but still a lot of applied research on traditional machining process are required as to explore the successful utilization of the process parameters for effective machining of cast iron. To explore the successful utilization of the traditional machining process experimental investigation on machinability of cast iron during turning is needed to be carried out considering some major machining factors such as various tools.

1.2 MACHINABILITY: AN OVERVIEW

Machinability is a much-maligned term, which has many different meanings but generally refers to the easy with which a metal can be machined to an acceptable surface finish. The machinability can be defined on the basis of the material properties, tool life, cutting speed as well as on the basis of the quality of surface finish, dimensional stability with easy removal of chips. When material is a key factor the machinability is defined by the easy of difficulty with which the metal can be machined. When tool life is the key factor.

Properties of cast iron;

Cast iron is a ferrous alloy which has more than 2% carbon in it. Though it can have any percentage of carbon between 2% to 6.67%, but practically it is in between 2% to 4% only. There is a basic difference between cast iron and steel. Steel contains less than 1% carbon and cast iron contains more than 2% carbon. Cast iron has got its name due to its excellent casting qualities. Other alloying elements which are generally used in cast iron are

Manganese: Increases resistance to wear and abrasions

Chromium: Increases hardenability, wear resistance, corrosion and oxidation resistance

Nickle: Increases tensile strength

Tungsten: It increases hot hardness and hot strength **Molybdenum**: Increases hardenability

Vanadium: Increases hardenability and hot hardness **Silicon**: Increases hardenability and electrical resistivity **Aluminum**: Works as deoxidizer in steel

Titanium: Works as deoxidizer in steel

Table 1: Types of cast iron

Range of compositions for typical unalloyed cast irons
Values in percent (%)

Type of Iron	Carbon	Silicon	Manganese	Sulfur	Phosphorus
Gray	2.5 - 4.0	1.0 - 3.0	0.2 - 1.0	0.02 - 0.25	0.02 - 1.0
Ductile	3.0 - 4.0	1.8 - 2.8	0.1 - 1.0	0.01 - 0.03	0.01 - 0.1
Compacted Graphite	2.5 - 4.0	1.0 - 3.0	0.2 - 1.0	0.01 - 0.03	0.01 - 0.1
Malleable (Cast White)	2.0 - 2.9	0.9 - 1.9	0.15 - 1.2	0.02 - 0.2	0.02 - 0.2
White	1.8 - 3.6	0.5 - 1.9	0.25 - 0.8	0.06 - 0.2	0.06 - 0.2

In above table you can find the composition of different types of cast iron. There are four basic types of cast iron (not taking Compacted Graphite, since its composition is almost same as Gray cast iron)

White cast iron.

1.3 CHALLENGES IN MACHINING CAST IRON

Cast iron alloy are distinguished by their suitable applicative nature due to their good combination of high chemical properties. These properties are dependent and influenced by quantity and nature of their alloying elements. They are also dependent on the heat treatment used. The major challenges while machining are expressed in high adhesion affinity up to high cutting speed ranges, high thermal loads as well as in a hardening of the material. Further the high toughness leads to an unpropitious chip breakage and increased burr formation. In turning cast iron, burr formation is of great importance because it influence not only the quality and handling of work piece but also the tool wear.

Importance of the Cutting Tool Geometry for cast iron machining

The lack of information on cutting tool geometry and its influence on the outcomes of machining operation can be explained as follows. Many great findings on the tool geometry were published a long time ago when CNC grinding machines capable of reproducing any kind of tool geometry were not available and computers to calculate parameters of such geometry were not common; it was therefore extremely difficult to reproduce proper tool geometries using manual machine.

1) ***Chip control***

The tool geometry defines the direction of chip flow. This direction is important to control chip breakage and evacuation.

2) ***Productivity of machining***

The cutting feed per revolution is considered the major resource in increasing productivity. This feed can be significantly increased by adjusting the tool cutting edge angle. For example, the most common use of this feature is found in milling, where increasing the lead angle to 45° allows the feed rate to be increased 1.4-fold. As such, a wiper insert is introduced to reduce the feed marks left on the machined surface due to the increased feed.

3) ***Tool life*** *The*

geometry of the cutting tool directly affects tool life as this geometry defines the magnitude and direction of the cutting force and its components, the sliding velocity at the tool–chip interface, the distribution of the thermal energy released in machining, the temperature distribution in the cutting wedge etc.

4) ***The direction and magnitude of the cutting force and thus its components***.

Four components of the cutting tool geometry, namely, the rake angle, the tool cutting edge angle, the tool minor cutting edge angle and the inclination angle, define the magnitudes of the orthogonal components of the cutting force.

5) ***Quality (surface integrity and machining residual stress) of machining***.

The correlation between tool geometry and the theoretical topography of the machined surface is common knowledge. The influence of the cutting geometry on the machining residual stress is easily realized if one recalls that this geometry defines to a great extent the state of stress in the deformation zone, i.e., around the tool.

Basic Terms and Definitions

The geometry and nomenclature of cutting tools, even single-point cutting tools, are surprisingly complicated subjects [1–4]. It is difficult, for example, to determine the appropriate planes in which the various angles of a single-point cutting tool should be measured; it is especially difficult to determine the slope of the tool face. The simplest cutting operation is one in which a straight-edged.

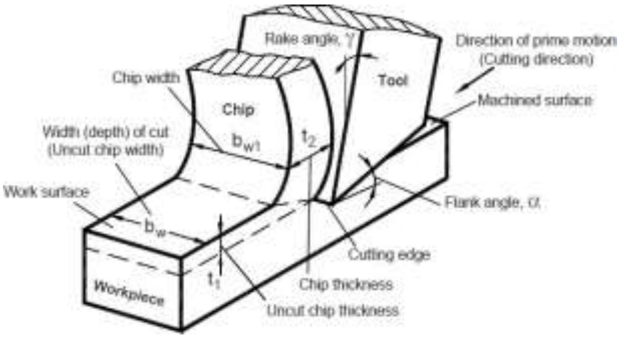

Figure 1.1. Terminology in orthogonal cutting

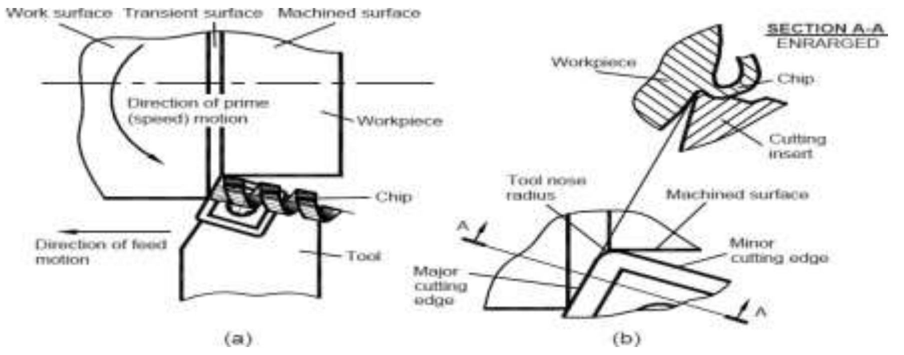

Figure 1.2. Turning terminology

2. HARD TURNING

2.1 INTRODUCTION

Hard turning is defined as the process of single point cutting of part pieces that have hardness values over 45 RC. Typically, however, hard turned part pieces will be found to lie within the range of 58-68 RC. The approach to machining hardened alloys depends on the degree of hardness and its depth (if case hardened). The hard turning process is similar enough to conventional soft turning that the introduction of this process into the normal factory environment can happen with relatively small operational changes when the proper elements have been addressed. The range of applications for hard turning can vary widely, where at one end of the process spectrum hard turning serves as a grinding replacement process, it can also be quite effective for pre-grind preparation processes. The attractiveness of the process lies in the performance numbers. A properly configured hard turning cell would typically demonstrate the following:

- Surface finishes of 0.002 mm

- Roundness values of 0.00023 mm
- Size control ranges of 0.004mm
- Production rates of 5- 7 over comparable grinding operations

2.2 HARD TURNING

Hard turning can certainly be considered for most pre-grind applications, which is followed by an abbreviated grinding cycle. In some cases, the hard turned surface may complete the operation and will completely eliminate the grinding cycle altogether. If one were to list the current applications of hard turning, it would certainly be a voluminous document. On a daily basis, parts are being hard turned in the following industry segments: automotive, bearing, marine, punch and die, mould, hydraulics and pneumatics, machine tool and aerospace. While these industries are representatives, this list is certainly not conclusive and new applications and industry segments are constantly being added.

2.3 HARD TURNING AND PROCESS PARAMETERS

Singh and Rao, (2007) said Hard turning is a process, workpieces, with hardness ranging from 50 to 70 HRC and are machined at low depths by using cutting tools of high hardness and wear resistance. Chavoshi and Tajdari(2010) also defined that the hard turning is a process in which workpieces with minimum hardness value of 45 HRC are machined by using suitable inserts. Machining of hard steel using advanced tool materials, such as cubic boron nitride and mixed ceramic, has more advantages than grinding or polishing, such as short cycle time, process flexibility, compatible surface roughness, higher material removal rate and less environment problems without the use of cutting fluid

2.4 MODELLING HARD TURNING PROCESS AND SURFACE ROUGHNESS

Lin & Chang (1998) established a surface topography simulation model to simulate the surface finish profile which was generated after a turning operation with known vibration characteristics. The model incorporated the effects of tool geometry, cutting parameters and the relative motion between the cutting tool and the workpiece on the surface finish profile, which was decomposed‖ into three directions, namely, the radial, tangential and axial direction. The vibration frequency ratio (FR), which was defined as the ratio of vibration frequency (in Hz) over spindle rotational speed (in rps), was thought to influence the period of the surface waviness along the axial direction. It was also found that the effects of the radial direction vibrations on the surface roughness measures were much more significant than those of either the tangential direction vibrations or the axial direction vibrations as would be expected.

Cemented Carbides tools;

The basic ingredient of most cemented carbides is tungsten carbide which is extremely hard. To allow machining at higher cutting speeds (and increased production rates), carbide tools were developed in the 1930s, Kalpakjain and Steven et al [37].

2.5 Tool-life Modelling Methodologies and Approaches

The major machining variables that affect tool-life performance are (Armarego and Brown, 1969):

- Cutting conditions,
- tool geometry,
- tool material,
- work material, and
- Cutting fluid.

Initial efforts in developing an empirical tool-life equation is attributed to Frederick

W. Taylor, who, based on large experimental observations, proposed a tool-life prediction equation in 1907 (Taylor, 1907). He found the cutting speed to be the most influential factor in determining the tool-life. He observed that high as well as low cutting speeds were undesirable, since the former led to frequent tool replacement, while the latter gave less productivity. This inspired him to develop a relationship between tool-life and cutting speed, described as,

$VT n= Ct$

where,

T = Tool-life (min)

V = Cutting speed (sfpm)

Ct = Empirical constant equal to the cutting speed for one minute of tool-life

N = Empirical constant determined from the slope of log V Vs. log T

This equation can be represented by a straight line when plotted on logarithmic coordinates, as shown in Figure 6.1. From this, n is found from the slope and Ct is the intercept on the velocity axis when the tool-life is one minute.

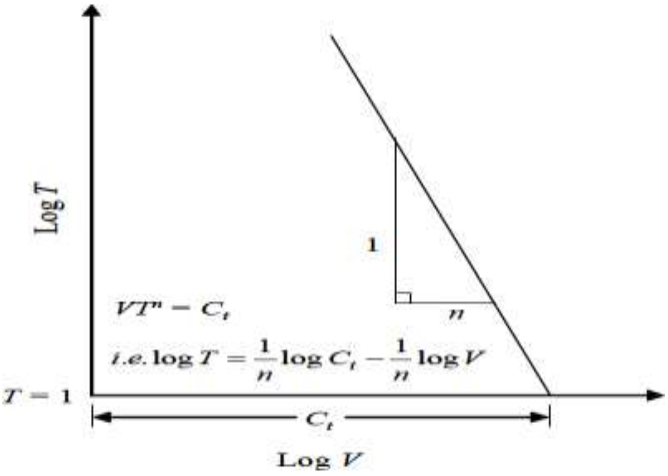

Figure 2.1: Graphical Representation of Taylor's Tool-life Equation (Armarego and Brown, 1969).

Based on Taylor's research, a large domain of specific knowledge has been acquired and many tool-wear/tool-life equations have been developed through analytical modeling and experimental observations. A variation of Taylor's tool-life equation is written as (Boothroyd and Knight, 1989; Schey, 2000),

$$\left(\frac{V}{V_R}\right) = \left(\frac{T_R}{T}\right)^n$$

where,

T = Tool-life (min)

TR = Reference tool-life (min)

V = Cutting speed (rpm)

VR= Reference cutting speed for tool-life TR = 1 min

C, n = Empirical constants

An extended version of Taylor equation is usually considered a good approximation

to predict tool-life T (Cook, 1973). It is expressed in terms of cutting speed V, feed f

and depth-of-cut d, with empirical constants C, n, m, and l as (Da et al., 1998),

$$T = \frac{K}{V^{1/n} f^{1/n_1} d^{1/n_2}}$$

It has been suggested from experimental work and temperature analysis that the tool

-life is directly related to the tool's temperature. The relationship between the tool-life and temperature is suggested by several researchers (Mills and Redford, 1983; Oxley, 1989; Arsecularatne, 2002), as:

$\theta Tn= C \quad (4.7)$

Where,

θ = Tool temperature

C, n = Empirical constants

Colding (1959) used a dimensional analysis to suggest a tool-life relationship in which he considered tool-life to be a direct function of temperature. Furthermore, he included the concept of equivalent chip thickness (ECT). His variation of tool-life equation is represented as,

$$y = K - \frac{(x-H)^2}{4M} - (N_0 - Lx)z$$

where,

x = Equivalent chip thickness (ECT)

$y = \ln V z \quad = \ln T$

K, H, M, N0 and L are empirically determined; feed, depth-of-cut, lead angle and nose radius are integrated into a single parameter ECT. Efforts to include the geometry parameters into the basic Taylor equation (Equation 4.4) resulted into the following equation (Venkatesh, 1986),

$$T = CV^n f^m d^p r^q s^t i^{-u} j^{-x}$$

The above equation is highly empirical, requiring excessive tool-life tests to deterine the constants – C, n, m, p, q, t, u and x.

A number of investigators have also shown a relationship between the work material hardness and the tool-life. It is an extended version of Taylor's equation, including the cutting speed and the material hardness, and is represented as (Wang and Wysk, 1986; Hoffman, 1984),

$$V = \frac{C}{T^m f^y d^x (BHN/200)^n}$$

where, the constants – C, m, y, x and n are determined experimentally. All the tool-life equations discussed above are developed for flat-faced carbide tools and they rely on empiricism. The tool-life prediction equation developed for a grooved tool incorporates the influence of chip-flow and coating effect on tool-life (Jawahir et al., 1995). In this work, the Taylor tool-life equation was modified by adding variables for the chip-groove effect and the coating effect factors.

$$W_g = \frac{km}{f^{n_1} d^{n_2}} \qquad T = T_R W_g \left(\frac{V_R}{V}\right)^{W_C \frac{1}{n}}$$

T = Tool-life (min)

TR = Reference tool-life (min)

V = Cutting speed (sfpm)

VR= Reference cutting speed for tool-life TR = 1 min

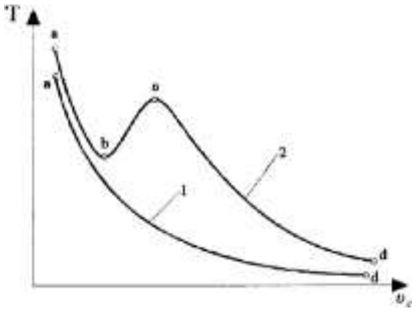

Figure 2.1: Comparison of Taylor Tool-life Curve and the Dromedary Tool-life Curve (Mamalis et al., 2005).

$$\frac{dW_c}{dt} = D_c e^{-E_C / K_C T_f}$$

Wc= Mass loss due to chemical wear

dt= Time

Tf= Tool flank temperature

Dc, Ecand Kcconstants.

Several major milestones have been achieved over the years, in the development of tool life equations for machining processes. Cutting speed has been identified as the primary parameter affecting the tool-life, followed by feed and depth- of-cut.

3.RESEARCH METHODOLOGY

3.1BACKGROUND

Purpose of Research;

The increasing performance of machining tool inserts has presented casting producers with an opportunity to greatly increase productivity while reducing machining costs. Cemented-carbide and mixed oxide ceramic inserts are capable of machining at much higher cutting speeds than traditional tool steels while maintaining much longer tool lifetimes. New tool designs can be produced with superior hardness, fracture toughness, and high-temperature wear characteristics, much to the satisfaction of the foundry machinist.

- **Methodology**

This work presents a study on the enhancement of tool life by altering the ratio of different materials in the tungsten carbide tool insert namely carbon, cobalt, Molybdenum, chromium and tungsten. Three samples with different compositions are selected. Based on analysis of various studies and simulative observations we arrive at the below mentioned table (3) for different composition of tungsten carbide tool insert [5][6][7]. The existing material composition is tabulated along with the composition of material chosen for this work. The variation of the materials such as tungsten carbide, titanium carbid, tungsten are taken in the ratio that it has enhanced physical properties compared to the existing system(Table 1). The cause of different types of tool wear that result in reduction of tool life are abrasive wear, corrosion, fracturing, thermal deformation, thermal cracking, cratering and galling.

4 DEVELOPMENT OF TUNGSTEN CARBIDE INSERTS FOR CAST IRON MACHINING

4.1General

The achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and to increase the performance of the product with reduced environmental impact are the main and effective challenges of modern metal cutting and machining industries. Traditionally, cast irons are machined by turning process due to their high strength and wear resistance properties but turning operations are time consuming and limited to the range of geometries to be produced.

4.2 Details view of existing tungsten carbide inserts

The definition of a ceramic material is the marriage of a metal to a nonmetal, for example silicon (metal) carbide (carbon, nonmetal), aluminum (metal) oxide (oxygen, non-metal), or silicon nitride. A cermet is a composite material composed of ceramic (cer) and metallic (met) materials. It is the addition of the metallic binder, i.e. cobalt or nickel that makes the cemented carbide (WC- Co) a cermet and differentiates it from truly brittle materials, that is, the ceramic family of materials.

- **Specification of tungsten carbide (CNMG1204044P)**

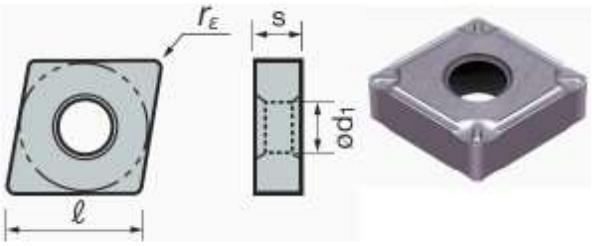

Fig 4.1: tungsten carbide

Table 4. 1: Insert Specification

ISO Catalogue No.	**l**	**re**	**s**	**d1**
	Mm	Mm	mm	mm
CNMG1204044P	12.90	0.4	4.76	4.76

i. **Properties of tungsten carbide**

Table 4.2: Properties of tungsten carbide

Property	**Tungsten carbide (CNMG1204044P)**
Hardness (HRA)	93.5
Density (g/cm^3)	14.82
Average tranverse rupture strength (Psi)	530000
Young’s modulus (GPa)	5.98
Compressive yield strength(MPa)	143
Tensile yield strength (MPa)	370
Poisson ratio	0.25

ii. Microstructure and material composition

Toughness is determined by the amount of energy a material can absorb before it fractures and can be obtained from a stress-strain curve. Strength can also be obtained through similar means but it is the measure of bending tension required to cause fractures in the material. The microstructure of the material plays a vital role in determining the toughness and strength of the tungsten carbide insert [104]. These parameters determine the deformation and breaking of the insert due to the applied load and friction. The material composition plays an equally important role in determining the physical and mechanical properties of the tungsten carbide tool insert. The contents of different elements in different ratios tend to affect different properties in the tool insert. The density, hardness, ductility, tensile strength can be varied by varying the composition of material used in metal alloys [105] 2012.

iii. Machinability aspects of tungsten carbide cutting tool

The prime target of machining is that its every operation ought to be completed in productive, powerful and monetary way by removing workpiece material at high rate alongside lower utilization of power, tool wear, surface roughness and lower generation of temperature. Henceforth the term machinability can be portrayed as the simplicity with which a workpiece can be machined. However, again the term simplicity is subjective and relative. In machining this can be quantitatively evaluated by measuring parameters like

1. Cutting force
2. Tool wear
3. Temperature
4. Vibration
5. Power consumption

b. Proposed tool design and fabrication by powder metallurgy

Table (3) for different composition of tungsten carbide tool insert [5][6][7]. The existing material composition is tabulated along with the composition of material chosen for this work. The variation of the materials such as carbon, Molybdenum, chromium, cobalt and tungsten are taken in the ratio that it has

4.3.1 Introduction of powder metallurgy

Literature confirms that tungsten reinforced into the soft cobalt, chromium, molybdenium and carbon hybridmatrix with various compositionfinds application in wear resistance or abrasion resistance without any major compensation of electrical conductivity and equivalent to the tungsten carbide composites.

Table 4.3: Chemical composition of tungsten carbide (our sample) in weight percent

Sample	**Titanium carbide (%) (C)**	**Tungsten (%) (W)**	**Particle size (µm)**	**Morphology**
A	5	95	<2	random

The cause of different types of tool wear that result in reduction of tool life are abrasive wear, corrosion, fracturing, thermal deformation, thermal cracking, cratering and galling. The three samples are then subjected to experimental analysis to determine the ratio on material that yields in reduction of the various factors that reduce tool life. The experimental analysis include

1. Hardness test
2. Compressive test
3. Corrosion test

4. Microscopic analysis

i. POWDER CHARACTERIZATION

The particle size and distributions of the milled powder composites were described through the SEM.

4.3.3 Ball Milling

Figure 4.8 shows the image of ball mill. The W-Co-Mo-C-Cr-Ni composites powders were mixed on weight percentage basis and the individual powders were pulverized and mixed in a high energy ball mill (planetary mono mill, rapid fab3d engg solution, chennai) with tungsten carbide vials using10mmdiameter tungsten carbide balls. The ball to charge weight ratio was 20:1. Milling was done at 300 rpm in wet medium in the presence of toluene to prevent oxidation.

Figure 4.2. Ball mill

Scanning Electron Microscope;

SEM is a powerful tool for examining and interpreting microstructures of materials and is widely used in the field of material science. The principle of SEM is based on the interaction of an incident electron beam and the solid specimen. SEM(Hitachi, Model S-3000H) images were used for the evaluation of particles after mixing. The SEM microstructure of W and Co-Mo-C-Cr-Ni composites studied in this research is shown in Figure 4.9.SEM was used for evaluation of particles before and after mixing and is shown in Figure 4.9 (a-d). Figure 4.9(a) shows the SEM image of the received metal particle and has a structure of a cluster of tiny particles like small flattened flake particles. Figure 4.9(b) shows the image of the W powders; it is in the form of hexagonal and rhombus structure. Figure 4.9(c) shows the SEM image of the sample. A powder composite particles after mixing. Figure 4.9(d) shows the SEM image of the sample B and Figure 4.9(e) corresponding to the sample C composite powder composite.

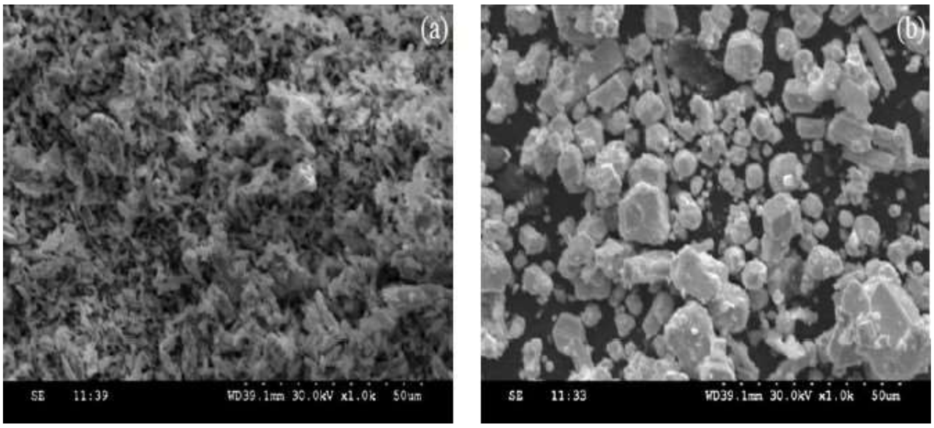

Figure 4.3. SEM micrograph after ball milling of various composite powders (a) WC (b) TIC

4.3.4 PREPARATION OF SAMPLES

Compaction;

Cylindrical compacts of 20mm diameter were prepared using a compaction die as shown in Figure 4.10. The compacts were prepared using ball milled various sample powders. The required powders were compacted by using suitable punch and die set assembly on UTM having 1 MN capacityas .Compacting pressure was applied gradually and it was 1.2 GPafor all the specimens. Graphite was used to lubricate the punch, die and the butt. While preparing the compacts, the initial density of 85%was maintained by accurately controlling the mass and observing the compacting pressure employed.

Metal powder Industries Federation standard (MPFI: 35) was used for the compaction of powders. The prepared compacted samples are shown in Figure 4.12.

Figure4.4;preparedcompasamples.

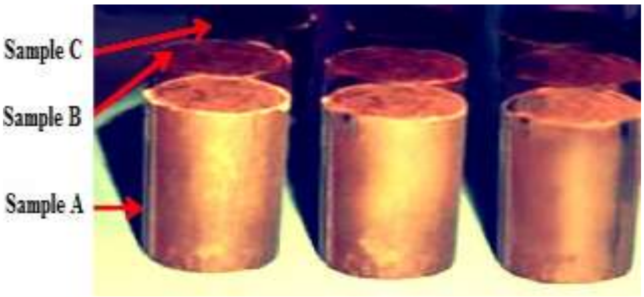

Fig 4.5: The prepared compacted samples

Sintering

After the compaction, the compacts were immediately taken out from the die set assembly and loaded into the sintering furnace (supplied by M/S. B.S. Pyromatic India (P) Ltd) for sintering. Figure 4.13 shows the schematic diagram of sintering furnace. To prevent oxidization, the green compacts were initially covered with inert argon atmosphere in the furnace. The sintering was carried out in an inert gas circulated electric muffle furnace at various sintering temperature of 750°C, 800°C, 850°C respectively for a holding period of one hour. As soon as the sintering schedule was over, the preforms were cooled inside the furnace itself to the room temperature and shown in Figure 4.14. If the sintering temperature is 750°C, the centre part of the composite was in powder form and 850°C the formation of minor cracks along the specimen wall was noticed. So it was carried out in between 750 and 850°C. After the completion of sintering, the preforms were cleaned by using a fine wire brush.

Figure 4.6. Sintering furnace setup

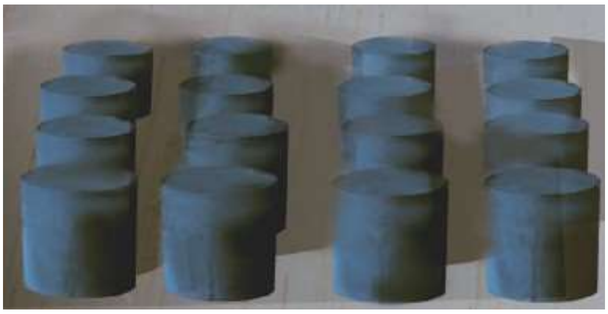

Figure 4.7. Sintered specimens

4.3.5 Machining (WCEDM)

In order to reduce the pore size and also to increase the relative density, the sintered preforms were machined by the wire cut EDM die set assembly. During this process, the preforms were cutted to 0.1mmby using brass wire. The diameter of the specimens was reduced into diamond shaped different steps to achieve the preform density of 92% from 85% for micron level composite and the nano level the density increased from87% to 94%. During the WCEDM the shape was reduced by 12.9mm length diamond shape. Further, the sample of the preforms was polished and grinding from 2mm edge radius into 0.4 mm by grinding operation. The grinded preforms were polished using 600 grit silicon carbide papers.

Figure 4.8.Exploded view of Wire cut EDM set up

Fig 4.9: Machining finished final model of work piece

5. EXPERIMENTAL WORK

a. INTRODUCTION

In this chapter, a detailed illustration and experimental work is conducted to enhance the understanding of the dominating process factors in macro scale machining. The selection factors for machine tools, work piece materials, and cutting tool materials are presented in this chapter. The detailed specification of machine tools, cutting tools and work piece materials, experimental setup with measurement devices used in this work are given. The experiments are performed by investigators in practically all fields of inquiry, usually to discover something about a particular process or system. Moreover formally said that experiment is a test or series of tests in which to solve, purposeful changes are made to the input variables of a process or system so that one can observe or identify the reasons for changes that may be observed in the output responses. In this work, to carry out the mathematical model and develop the predicted values by using different methods and techniques and then compare and analyze, the actual experimental values should be available based on the experimental work.

b. NEED FOR A SINGLE TOOL

Investigations are done to use single tool to machine the grey cast iron rod. The available cutting tool materials are high speed steel, cemented carbide, ceramics, coated tools, cubic boron nitride and diamond. The selection of cutting tools depends on the work material, surface integrity, specified tolerance and productivity. Cutting speed of a tool with varying cutting tool materials can be understood from the Figure

5.1 (Venkatesh V.C et al 1982). The high cost diamond tool can be justified by the associated quality issue of component and productivity.

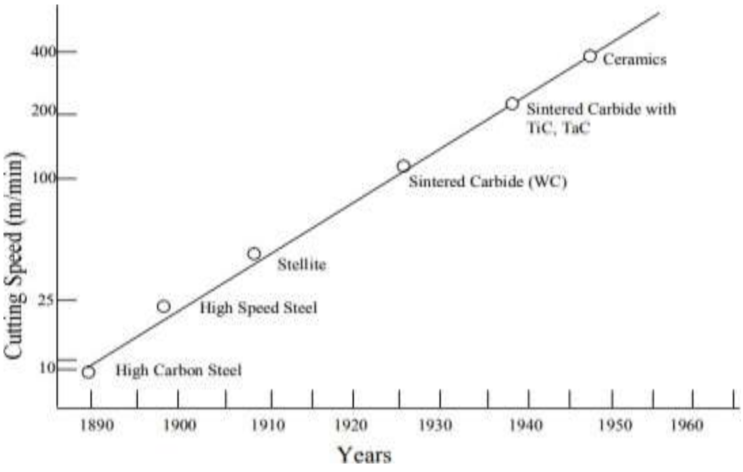

Figure 5.1 Development of tool material

To machine the grey cast parts, Diamond (PCD) tool is recommended. Carbide tools are often used for machining the cast iron part of the disc and rod. Hence, to machine the rod type materials, four different kinds of tools are employed. However, this leads to a frequent change of tool and machining parameters. This results in reduction of productivity. Time study was initiated to observe the total time required for machining a rod.

5.3 WORK PIECE

Grey Cast Iron is made by remelting pig iron. It is an alloy of Carbon and Iron. Small amounts of Silicon, Phosphorus, Manganese and Sulfur are also present in it. The reasons behind its popularity are: ability to make complex structures and low cost. In addition, the excellent properties of Grey Cast Iron have made it one of the most widely used alloys. Its properties are as follows: high compressive strength

i. High Compressive Strength

This strength is defined by the endurance of any metal or alloy to withstand its compressive forces. Grey Cast Iron has a high compressive strength and that’s why, it is widely used in posts and columns of buildings. In addition, their compressive strength can be as high as that of some Mild Steels.

Tensile strength

There are different varieties of Grey Cast Iron and their tensile strength varies accordingly. Some varieties show the tensile strength of 5 tons per square inch, some show 19, but on an average their strength is 7 tons per square inch. However, addition of vanadium can increase the strength of Grey Cast Iron.

ii. Resistance to deformation

Grey Cast Iron is highly resistant to deformation and provides a rigid frame. However, if there is some construction related problem, then even Grey Cast Iron made structure can breakdown.

iii. Low melting point

Grey Cast Iron has low melting point – 1140 ºC to 1200 ºC.

iv. Resistance to oxidation

Grey Cast Iron is highly resistant to rust, which is formed by the reaction of oxygen and Iron. It is a perfect solution to avoid the problem of corrosion.

v. Uses of Grey Cast Iron:

Class 300 Grey Iron: Can be used in producing heavy-duty machine tools, bed,

b. CUTTING TOOL MATERIALS

i. Selection of PCD Inserts

The selection of appropriate tool material is vital for process efficiency and depends on the accuracy and surface finish required. When hardness exceeds 45 HRC, PCD inserts become the best choice because they can be run at the lathe‘s highest spindle speed. Available with one cutting edge or as a multiple insert, it is also the most expensive option. Insert geometry is important, said Andrews. ―Most PCD inserts have a small, negative hone placed on the edge to provide strength for this operation. The angle and size of hone can be modified for different operations, like interrupted cutting. Within each type, hundreds of different grades are available from various tool material, cutting insert, and tool manufacturers. Therefore, the selection of appropriate tool material grade is one of the most important tasks in hard turning in terms of obtaining efficient and stable machining process

ii. PCD Grade

PCD tools may be used either in the form of small solid tips or as a 0.5 to 1 mm thick layer of polycrystalline boron nitride sintered onto a carbide substrate under pressure. In the PCD layer provides very high wear resistance and cutting edge strength. Poly crystallite nitride is the standard choice for machining alloy and cast iron with a hardness of 40 RC or higher. Typical cutting speeds is 30 -310 m/min. The performance of the PCD tools depends on the PCD content, grain size, bonding material, and microstructure. In general, PCD tools can be classified into two types.

iii. Cutting Inserts DimensionThe cutting insert used is PCD coating, removable type of square form with eight cutting edges and having ISO designation of CNMG1204044P. The edge preparation provided on the 20°×0.2mm chamfer with honing. The cutting insert was clamped on the tool holder (make: Sandvikcoromat, model: PSBNR2525 with the geometry of the active part characterized by the following angles: $\chi = 75^\circ$, $\alpha = -5^\circ$, $\gamma = -5^\circ$; $\lambda = -5^\circ$

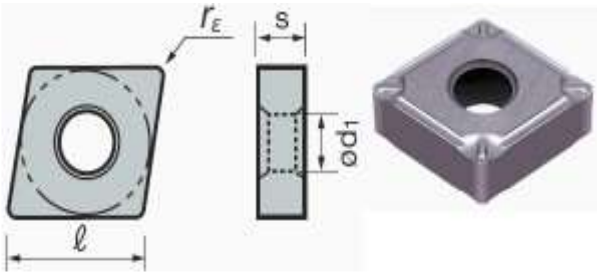

Figure 5.1: Insert Geometry

Table 5.2: Insert Specification

ISO Catalogue No.	L	re	s	d1
	mm	Mm	mm	Mm
CNMG1204044P	12.9	0.4	4.7	4.7

5.5 Tool Holder

The tool holder used for the experiment is PSBNR2525M12. Its photograph and specification is given below in Figure 4.7.

Figure 5.2 Tool Holder (PSBNR2525M12)

c. EXPERIMENTAL SETUP

The collection of the experimental setup and the investigation conducted as well as lathe, cutting force measurement setup instrument, surface roughness measurement instrument, tool micros scope and scanning electron microscope (SEM) equipmentare shown in Figure 4.11-4.12 respectively. A lathe, KIROLOSKAR (India) make is used for hard turning Cast iron. Which specification is present in forth coming section 5.2. A Kistler three components piezo-electric dynamometer, made by Kistler Corporation, Model 9257B is used to record cutting forces evolved during hard turning. The arrangement of dynamometer is listed in Table 5.4. Sufficient care was taken to prevent the damage of lathe, while machining due to the chips produced during machining in the form of ringlets.

- **Machine Tool**

The experimental tasks were conducted on Kiroloskar lathe. The Hard turning technique is preferred to be performing under dry environment condition. Cast iron was apprehended in between head stock and tail stock to rigid explicit control of work piece to avoid surplus beat cause because of the span of the work piece. Table4.7 shows the specification of machine tools. Figure 4.8 shows the lathe machine tool (Kiroloskar Model).

Figure 5.3. Lathe Machine Tool (Kiroloskar Model)

5.6.2 Cutting setup

The response parameters of hard turning operation are the investigate attention that is receiving overstated during hard turning operation. They are cutting force ,surface roughness, and tool wear .The cutting force and surface roughness are measured during hard turning process is carryout and the tool wear is measured after the hard turning operation is achieved. The work piece material is Grey cast iron. The length of the shaft is 265mm each cutting length is 130 mm and bar diameter 30 mm. Hard turning were carried out 9 cuts on each sides.

5.6.3 Cutting Force Measurement

A Dynamometer was used to measure the cutting forces. The cutting forces were measured according to the three major directions are axial, radial and tangential axis respectively. Such as axial force, Fx, performed downward on the tool tip. This force supplies the power necessary for the cutting operation. The second one is the radial force, Fy, in radial direction and has a propensity to thrust the tool away from the work piece. Subsequently the tangential force, Fz, acts in the longitudinal direction. This is also known as feed force, for the reason that which is in feed direction. Once the trials are over, the data is stored in the excel sheets.

5.7 The influence of machining parameters on tool flank wear and surface texture.

Tool flank wear seems to be an inverse function of cutting speed. The tool flank wear seems to reduce with cutting speed to the fact that, thermal conductivity of cast iron is less. The tool seems to perform very well at higher cutting speeds. This can be owed to the fact that lower cutting speeds provide longer surface contact. The tool flank wear experiments were conducted at dry conditions on lathe machine.

5.8 TOOL LIFE EVALUATION BY FINITE ELEMENT ANALYSIS

5.8.1 Introduction

FEA is important as the computation time and cost are related to the number of elements chosen. Number of elements to be chosen for idealization is related to the accuracy desired, size of elements and the number of degree of freedom involved. Although an increase in the number of elements generally mean more accurate results, there will be a certain number of elements beyond which the accuracy cannot be improved by any significant amount, since the use of large number of elements involve large number of degrees of freedom.

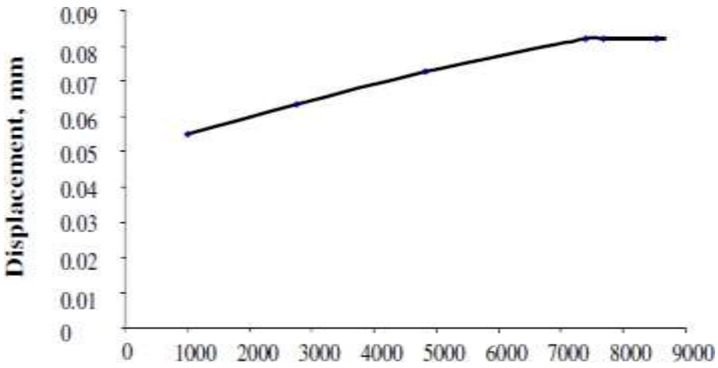

Figure 5.4 Element convergence of solid tool

i. **Modelling**

Accurate model development is an essential step for effective simulation and the model is developed as per the mentioned dimensions and the material properties are obtained from the above experimental findings. The analysis is carried out using ANSYS V12 and the properties for the materials are obtained through experimental data or engineering standard data. The simulative environment is obtained from the Taguchi L9 orthogonal array which was constructed by factoring in the various factors pertaining to tool wear. The properties of the three samples vary and hence the simulation has to be done in Sample A, Sample B and Sample C separately. The 3D model required for the simulation was realized using CATIA.

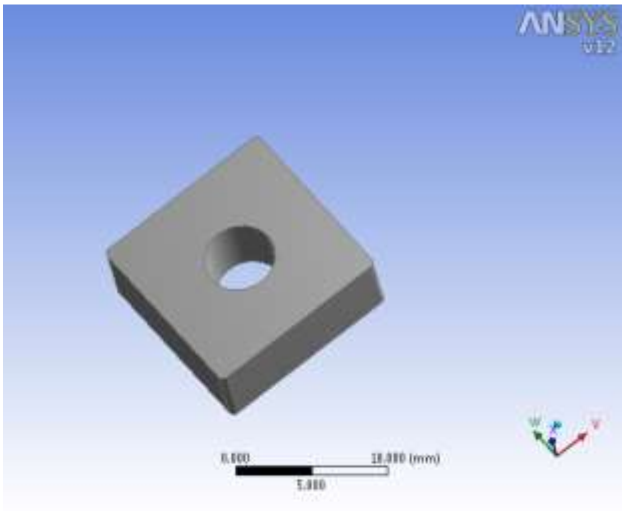

Figure 5.5 .Model developed by ANSYS

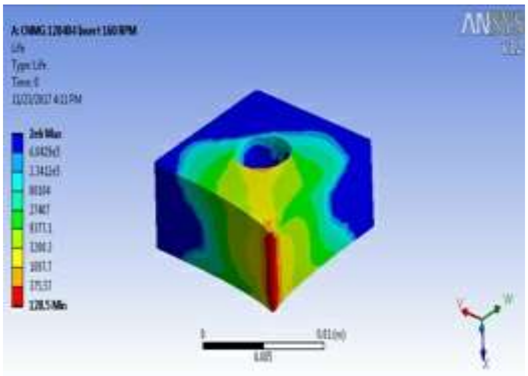

Figure 5.6. Tool Life of sample C insert at 250rpm

5.8. Material Selection:

The three samples with variable composition are used:

1. Sample A (WC) Insert
2. Sample B (WC) Insert
3. Sample C (WC) Insert

6. RESULTS AND DISCUSSION

a. Effect of Cutting Parameter on Tool Life by FEA Analysis

Table 5.19 illustrates the tool life details. The same aspects are considered for the detailed investigation of the tool life enhancement of different inserts with different process parameters and forces with respect to the cast iron cylindrical rod machining operations.

b. Effect of Cutting Speed on Tool Life

The tool life for Sample B and Sample C is shown to be high when compared with the existing coated tool insert. It is to be noted that the existing insert is a coated one, whereas the Samples B and C are uncoated materials. The two samples seem to provide enhanced tool life due to the varied chemical composition that has increased chromium and TI content. Sample B has a tool life of around 137 minutes

which is nearly 7% more than the existing coated tool insert.

- Samples B and C are able to outlast the existing coated carbide tool insert, with sample B lasting almost 7% more than the existing coated insert.
- Tool wear, insert and surface structure of the machine parts are optimal using varied composition samples and they prove to be more effective than the existing insert.

This work has conducted various trials to study the life of the tool using finite element analysis. Here different composition of material was considered and used for cast iron machining operations. Using the ANSYS analysis array it was possible to process many variable parameters and arrive at a comprehensive conclusion.

- Samples B and C were able to outlast the existing coated tool insert. With sample B lasting almost 7% more than the existing coated insert.
- Tool wear, temperature and surface structure of the machine part were optimal using varied composition samples and prove to be more effective than the existing Insert.
- The results were achieved for uncoated tool insert. Future scope of this work could extend to optimized coatings of the proposed samples, which would improve the tool life by a huge margin and improve productivity. Samples B and C were able to outlast the existing coated tool insert. With sample B lasting almost 7% more than the existing coated insert.
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REFERENCE;

1. Microstructure of Nanocrystalline Wc Powders And Wc-Co Hard Alloys A.S. Kurlov, A. Leenaers, S. Van Den Berghe, M. Scibetta And A.A. Rempel 2011
2. Machining Optimization of Nano Coated Tool Insert in Hard Turning using Taguchi Method Ranjit Babu, Sonachalam. M April 2014
3. Micromechanics and Microstructure of WC Hard Metals Karyn Muir
4. Microstructural Aspects of the Strength and Hardness of Cemented Tungsten J.Gurland 1969
5. Electrical Resistivity and Mechanical Properties of Tungsten Carbide Reinforced Copper Alloy Composites B.M.Girish1,*, Basawaraj B. R.1, B.M.Satish1, D.R.Somashekar2 2012
6. Variation of Mechanical Properties of Wc-Co Alloys with Microstructure A. Haerian 1986. Mechanical Properties Of Nano crystalline Cemented Tungsten Carbide Z. ZakFangXuWang,TaegongRyuKyu, SupHwangH.Y.Sohn March 2009
7. Modes of failure of cemented tungsten carbide tool bits (WC/Co): A study of wear parts Prvan KumarKatiyar Prince KumarSinghaRityujSinghbA. lavaKumar January 2016
8. Study of milling effect on particle size and mechanical properties of WC-Co composite A. Fazili, L. Nikzad, M. Razavi spring 2017
9. Effect of Cobalt Powder Morphology on the Properties of WC–Co Hard Alloys by A. S. Kurlova and A. A. Rempela,b February 6, 2013
10. Microstructure and Mechanical Properties of WC-Co Reinforced With NbC Wilson Acchara*, Cordt Zollfrank, Peter Greil .March 21, 2004
11. Fracture And Fatigue Behavior Of Cemented Carbides: 3-D Fib Tomography Of Crack-Microstructure Interactions Jose María Tarragó, Emilio Jiménez- Piqué, Miquel.