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Investigation of Hardness and Coating Properties for Different Single Point Cutting Tools to Enhance Tool Life

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ABSTRACT: In this project work by considering six different Alloys namely SS316, SS304, SS410, SS440C, HSS, Ti-6Al-4V, and machining is done all these six different alloys. These are placed in Furnace and applying heat treatment process namely Normalizing, Annealing, Tempering and Hardening. Maintaining the different temperatures for different heat treatment process for six different Alloys. After this process by using Rockwell Hardness machine the hardness Value for Six different Alloys are taken. It is found that HSS, Ti-6Al have very good Hardness value compare to other alloy materials. The plasma spray coatings are carried out by using different powder particles on these tools to increase the tool hardness life and comparisons made on these tools. From the experimental results it is found that HSS and Ti-6Al very good hardness and coating properties compared to other tools. Keywords: SS316, SS304, SS410, SS440C, HSS, Ti-6Al-4V, Heat treatment process, Hardness value, Plasma spray coating.

I. INTRODUCTION

This chapter explains about cutting tool, Classification of cutting tool along with an cutting life and requirements of an cutting life.

1.1 Cutting tool: is defined as eliminate or withdraw material from the component by using lathe machine. Removal of material on the work piece is done by using single point cutting tool.

Types of cutting tool: - Single/Multi point cutting tools. Rotary cutting tools, taps and dies, milling cutters etc

Cutting edge:-The sharp edge of cutting tool is called cutting edge. The cutting edge measured by using a tactile instrument.

1.1.1 The silent appearance cutting edge are:

- Cutting edge angles or free angle and rake angle.
- Magnitude of the chamfers

1.1.2 Basic properties of cutting tools:

Hot Hardness, Toughness, Wear Resistance, Chemical Stability or Inertness
Shock Resistance and Low Friction.

1.1 .3 Designation and Features of tools: -

The following shows the Designation and Features of tools:

- ASA system (American Standards Association)
- ORS or ISO Old System (Orthogonal Rake System)
- NRS or ISO New System (Normal Rake System)
- MRS (Maximum Rake System)

The following shows are the resources of cutting tool
Ceramics, Cubic Boron Nitride (CBN), High Speed Steel (HSS), Tungsten carbide, Diamond.

1.1.4 Categorization of cutting tool:- The cutting tools are classified based on cutting edges and cutting action at a time. Single point cutting tool example turning tool**,** Double point cutting tool example drill bit**,** Multi-point cutting tool**.** Milling cutter.

1.1.5 Breakdown of cutting tools:-

Due to extreme forces and impacts, Due to exhaustive stresses and thermal properties, Due to erosion of the cutting edges of tool.

1.1.6 The following are the procedure of cutting tool wear:

Mechanical wear, Thermo chemical wear, Chemical wear, galvanic wear

1.1.7 The following are the Measurement of tool wear:-

Using optical microscope fitted with micrometer, Using scanning electron microscope
Talysurf, Grooving and indentation method etc.,

Tool wear:-is take place due to regular usage or operation of tool in machinery.

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Abrasive Wear: - Due to mechanical abrasion is take place from the workpiece to cutting edge of the tool.

Fig 1. Abrasive Wear

Thermal Cracking: During continuous operation take place in the lathe or any machine, heat or temperature generated and it reflect the tool failure is called Thermal cracking.

Fig 2.Thermal cracking

Fracture:- Due to continuous operation or usage of tool the sudden breakage of tool take place is called Fracture**.**

Fig 4. Fracture

1.1.8. Prevention of Tool wear:-

Suggestion from Shop MT staff: The following coating should be done to improve the tool life and reduces tool wear namely CVD (chemical vapour deposition) technology and PVD (physical vapour deposition)

1.2 Introduction to the Problem Identification

Now a day's the single point cutting tool wear and its strength decreases during the different operations are carried out with the working of lathe machine.

The single point cutting tools fails due to various reasons and it is summarized as follows:

(a) Due to extreme forces and impacts.
(b) Due to exhaustive stresses and thermal properties
(c) Due to erosion of the cutting edges of tool
(d) Dimensional deviation beyond tolerance
(e) Rapid worsening of surface finish
(f) Adverse chip formation
(g) Mechanical wear
(h) Thermochemical wears etc.

II. LITERATURE SURVEY

2.1 Introduction:

In this section introduction to Cutting tools and its scope, historical background for Cutting tools are discussed. Exhaustive literature survey has been done on the basis of parameters strength, coating, corrosion and wear.

[1] Daniel H. Herring et.al [2006]: They investigated that titanium nitride (TiN), is commonly in order to obtain superficial endurance and for aesthetic purposes on tool and also found In case of Low temperature stress relief in the 325°F (160°C) to 775°F (415°C) variety will decrease residue stress for SS grade steel.

[2] Yahya Işık et.al [2010]: They investigated that TiAlN single-layered PVD sheathed tools indicates that higher hardness when compare to CVD coated tools, and also machining cost per part using TiAlN CVD is very high compared to TiAlN PVD.

[3] R A MAHDAVINEJAD et.al [2011]: They investigated that AISI 304 stainless steel have cutting speed of 175 m/min and feed rate of 0.2 mm/rev found that excellent turning qualities.

[4] Fritz Klocke et.al [2011]: They investigated that in machining HS 6-5-3 PM resulted in a significantly decreased feed force and enhanced tool life and also In machining HS 4-2-4 PM the feed force increased more sharply with advanced cutting speeds while tool life was tripled in regard to HS 6-5-3 PM.

[5] Turgay Kıvak et.al **[2013]:** They investigated that CVD TiCN/Al2O3-coated carbide tool inserts shows the improve achievement than PVD TiAlN-coated carbide inserts.

[6] A. Z. Sultana et.al [2015]: They investigated that Austenitic stainless steel AISI 316L the work piece material. As the cutting speed strengthens on AISI 316L the surface roughness AISI 316L reduces (1.09 μm).

[7] Dr. Zeyad D. Kadhim et.al [2016]: They investigated that The tensile strength and hardness values of medium carbon steel AISI 1039 increased after quenching with raise the temperature of heat treatment.

[8] Husain Mehdi et.al [2017]: They investigated that the soft zone results in hardness drop near interface of SA 508 Gr3 while hard zone increases the hardness.

[9] H. Sutara, et.al [2018]: They investigated that plasma sprayed coatings like pure red mud, composited with varying weight % (10, 20 and 50) of fly ash on mild steel and found that Reinforcement of fly ash leads to form stronger bond strength with mild steel.

[10] Abhishek Anand et.al [2019]: They investigated that Dry cutting technique is used in hard turning for hardened steels which results the process to be reasonable and also eco-friendly.

III. SCOPE AND OBJECTIVES OF THE PROJECT WORK

Now a day, Due to various reason cutting tools fails and tool wear takes place, in this context to enhance the life of the cutting tool the various Heat Treatment process and coating on different single point cutting tool is carried out. And it leads to investigations of single point cutting tools material which is having low density and good Hardness properties, to withstand Wear properties, chemical, and mechanical properties.

3.1 Objectives of the Project

The main objective is to simultaneously enhance the strength and ductility of the SS316, SS304, SS410, SS440C, HSS and Ti-6A -4V alloys by heat treatment. Therefore to improve the strength Heat Treatment process is performed. And also the Coating on these specimens carried to enhance the wear properties.

IV. SELECTION OF MATERIALS AND METHODOLOGY

In this chapter the SS316, SS304, SS410, SS440C, HSS and Ti-6Al-4V six different alloy materials are selected to conduct the heat treatment process to get the hardness value, to improve the Wear properties, hardness and strength on these specimens Plasma spray coating carried out and comparison of these alloys with Hardness properties are carried out.

4.1 Selection of materials: In this section, six different alloys i.e. cutting toolsare selected namely SS316, SS304, SS410, SS440C, HSS and Ti-6Al-4V selected and discussed.

4.1.1 Cutting tool materials: - SS316, SS304, SS410, SS440C, HSS and Ti-6Al- 4V utilized in the present work and from literature survey mechanical, chemical and physical properties are collected and discussed.

4.1.1.1 STAINLESS STEEL - GRADE 440C: The Chemically Combination of stainless steel - grade 440C is explained in the table as follows

Table.4.1 shows the Combination of stainless steel - grade 440c

Composition:-

Element	C	Mn	Si	Cr	P	S	Mo
Weight %	0.95-1.20	1.00	1.00	16.0-18.0	0.04	0.03	0.75

4.1.1.2. SS316 (ASTM A240/A240M Grade 316):

The Chemical Combination of stainless steel- Grade SS316 is explained in the Table 4.2 as follows

Table.4.2 Shows the Combination of stainless steel - grade SS316

Chemical Composition:-

Element	C	Mn	Si	Cr	P	Ni	S	Mo
Weight %	0.08	2.00	1.00	16.0-18.0	0.045	10.0-14.0	0.03	2.0-3.0

4.1.1.3 TITANIUM ALLOY (Ti- 6Al- 4V):

Ti-6Al-4V is also called as titanium alloy. Ti-6Al-4V or Ti 6-4 or grade 5, The Chemical Combination of Ti-6Al-4V is explained in the table as follows

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Table.4.3 Shows the Combination of Ti-6Al-4V

Composition:

Element	Weight %
Al	6
V	4

4.1.1.4 STAINLESS STEEL - GRADE -SS304:

Grade 304 is the standard "18/8" stainless; The Chemical Combination of SS304 is explained in the table as follows

Table.4.4a Shows the Composition of SS304

Composition:-

Element	C	Si	Mn	P	S	Ni	Cr	Fe
Weight %	0.08	1.00	2.00	0.04	0.03	8.00-10.50	18.00-20.00	Balance

4.1.1.5. STAINLESS STEEL - GRADE -SS410:

SS410 Grade 410is the basic martenstic SS, The Chemical Combination of SS410 is explained in the table as follows.

Table.4.4b Shows the Combination of -SS410

Composition:-

Element	C	Mn	Si	P	S	Cr	Mo	Ni	N
Weight %	0.15	1.00	1.00	0.04	0.030	11.5 - 13.5	-	0.75	-

4.1.1.6, HIGH SPEED STEEL - GRADE HSS:

It is also called HSS or HS or High speed steel. The Chemical Combination of HSS is explained in the table as follows.

Table.4.4c Shows the Composition of HSS

Element	C	Mn	Si	Cr	Ni	Mo	W	V	Cu	P	S
Weight %	.78-1.05	.15-.40	.20-.45	3.75-4.50	.3	4.50-5.50	5.50-6.75	1.75-2.20	.25	.03	.03

4. 2 METHODOLOGY:

In this work, the SS440C, SS316, Titanium alloy (Ti-6Al-4V) (G5) ,SS304, SS410, HSS material are taken or purchased and heat treatment process carried out to know the hardness properties and by using milling machine machining is done to the round bars to prepare the single point cutting tools after this by using plasma spray method the coating is carried out to improve the hardness property of the tools.

4.2.1 HEAT TREATMENT:- Heat treatment is a combination of heating and cooling process conducted on a metal or alloy in the solid state to get a particular microstructure and desired attributes. The different processes are Annealing, Normalizing, Hardening and Tempering.

4.2.2 CUTTING TOOL MANUFACTURING:

For selected materials, milling process was carried out to obtain standard tool dimensions. SS316, SS304, SS410, SS440C, HSS and Ti-6A - 4V chosen as standard dimensions,. Few of the materials purchased were in circular cross-section, so milling process was necessary.

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Fig 5 SS440C raw material Fig 6 Ti-6Al-4V raw material

4.2.3 MILLING PROCESS:

Milling is the machining of a material with removal process; It is used to produce flat surface, slots, pockets, angle surfaces and even three dimensional surface contours on material or specimen.

Fig 7. Milled Component

4.2.4 SURFACE GRINDING:

Surface grinding is used to produce a smooth finish on flat surfaces of a specimen. Making a face of it flat or smooth.

4.2.5 TOOL AND CUTTER GRINDER:

A tool and cutter grinder is used to sharpen milling cutters and tool bits and also performs grinding operations like surface, cylindrical, etc., The tool nomenclature with angles specified is given below. The tool nomenclature is the same for all the different materials; this is employed to obtain a more consistent reading.

4.3 TOOL

The figure12 below represents standard cutting tool nomenclature.

Table.4.5.shows the TOOL SIGNATURE: 7-14-6-6-18-16-3

Tool Signature	Dimensions	Abbreviation
7	Back Rake Angle	BR
14	Side Rake Angle	SR
6	End Relief Angle	ER
6	Side Relief Angle	SRF
18	End Cutting-Edge Angle	ECEA
16	Side Cutting-edge angle	SCEA
¾	Nose radius	NR

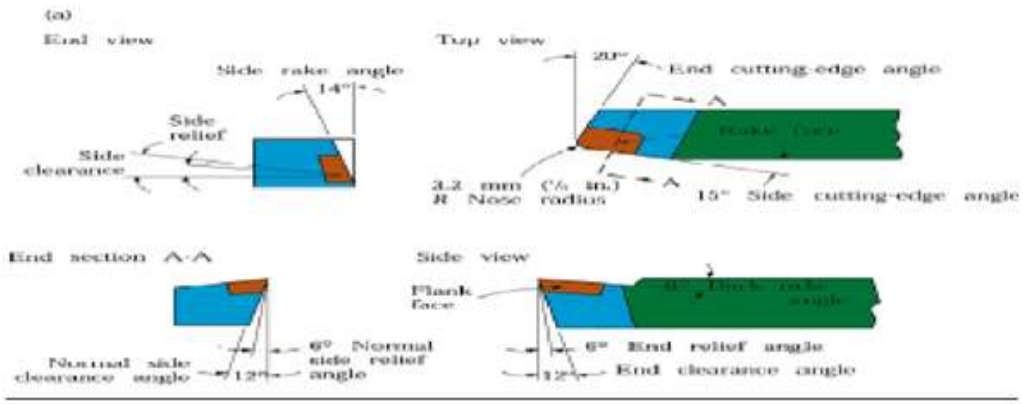

Fig.8. Tool Nomenclature

4.4 FINISHED TOOLS:

The figures below represents the final cutting tools obtained after going through all the above mentioned machining processes.

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Fig. 9 Finished cutting tools

4.5 TYPES OF COATING AND COATING CHARACTERISTICS

4.5.1 Different Types of Coatings

Titanium nitride (TiN):- It is used in PVD coating that enhances hardness; this coating works great with HSS tooling.

Titanium carbo-nitride (TiCN):-It gives more hardness and good surface lubricity used for HSS cutting tools.

Titanium aluminum nitride (TiAlN):-This coating is used for carbide tooling.

Chromium nitride (CrN):-. This coating is used for HSS or carbide cutting.

Diamond:- This coating is used for hard milling, tapping and drilling on Metal Matrix Composites (MMC), high silicon aluminum.

V. EXPERIMENTATION

5.1. Heat Treatment process Heat treatment is a combination of heating and cooling process conducted on a metal or alloy in the solid state to get a particular microstructure and desired attributes.

5.1.1 Various stages of a heat treatment process:

1. Heating the metal or the alloy to the specific temperature.
2. To increase resistance to wear, abrasion and corrosion.
3. To increase Hardness of specimens

5.1.2 Specimen types used for Heat treatment process:

1) SS316 2) SS304 3) SS410 4) SS440C 5) Ti-6Al-4V 6) HSS Materials

5.1.3 Types of Heat treatment carried out for specimens:

1. Annealing 2. Normalizing 3. Hardening 4. Tempering

5.1.4 Description of Various Heat treatment processes:

Annealing:

In order to conduct the annealing process of heat treatment the specimens of various compositions were heated above the recrystallisation temperature i.e., 950^0c and were held at the same temperature for nearly about 20 min. After the holding period is completed the specimens were cooled to the room temperature at a very cooling rate. Furnace was switched off and the specimens were left inside the furnace itself for cooling which almost took 24hrs to cool to room temperature.

5.1.5 Normalizing:

In order to conduct normalizing process of heat treatment the specimens were heated above the recrystallisation temperature to nearly 950^0c and the specimens were held at this same temperature for about 30 min. After holding the specimens at this temperature they were taken out of furnace to cool them. The method of cooling used in normalizing is air quenching.

5.1.6 Hardening:

Hardening: For hardening process of heat treatment the specimens were placed inside the furnace and heated to a temperature of 950^0c and held at this temperature for about 30 min. After holding period is completed the specimens were taken out of the furnace and water quenched to cool to room temperature.

5.1.7 Tempering:

It is a process of heat treatment carried after hardening process is completed to reduce the hardness of hardened specimens and followed by air/furnace cooling. The specimens after hardening were again placed inside the furnace and heated below the recrystallisation temperature i.e., for 650^0 c and held at this temperature for about 30 min. After holding the specimens were taken out of the furnace to follow air quenching.

5.2 HARDNESS TEST:-

After heat treatment the hardness properties found out by using Rockwell hardness testing machine. Rockwell hardness testing is used to measure the hardness of polymer and metallic materials. In present experimental work Rockwell, hardness was measured on round specimens or tool samples as per ASTM standards ASTM D785. For each of the sample, five readings or trials considered and average hardness value of all the samples Fig. 10 Hardness test
was taken and tabulated in the table. The Rockwell and Brinell Hardness Numbers are related by the following expression $R_C=88(BHN)^{0.162}-192$.

5.3 COATING:- Coating is carried out on six different tools by using plasma spray.

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5.3.1 Different Coating Techniques used to coat on cutting tool

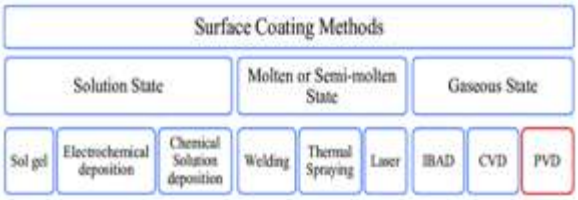

Fig.11. Types of surface coating methods

5.3.2.1 Coating on cutting tool by using Plasma Spray Technique:

Titanium Oxide and Titanium nitride powder Coating on SS316, SS304, SS410, SS440C, Ti-6Al and HSS Materials specimens is conducted by using plasma spray coating technique, The plasma spray coating method is used which is efficient and economical, method used to coat Titanium Oxide and Titanium nitride successfully on SS316, SS304, SS410, SS440C, Ti-6Al-4V and HSS Materials.

Procedure: A high temperature plasma arc is passed within the torch. The ionized gas, and free electrons are been stripped from the atoms and release thermal energy. The plasma stream can reach temperatures of 10,000 -50,000 degrees Fahrenheit and then started the coating process and coating thickness on SS316, SS304, SS410, SS440C, Ti- 6Al-4V and HSS Materials specimens is 150-250 microns achieved the Table.5.1 shows the Specification of Plasma Spray coating machine and Figure.29.Shows the Titanium Oxide and Titanium nitride powder coating on SS316, SS304, SS410, SS440C, Ti-6Al - 4V and HSS Materials specimens.

Table.5.1 Shows the Specification of Plasma Spray

Sl. No	Description	Details
1	Gun	3mb
2	Nozzle	GH
3	Argon Pressure	100 to 150 psi
4	Flow Rate	80 to 90 lpm
5	Hydrogen Pressure	50 psi
6	Flow Rate	15 to 18 lpm
7	Temperature	500 ^{o}c
8	Voltage	65 to 70 v
9	Powder Feed	50 to 65g/min
10	Spray Distance	2 to 4 inches

5.3.2.2 Different Powder Particles Used for Coating:- Different Powder Particles Used for Coating are (a)Titanium Nitride (b)Titanium Oxide

Fig (a) Fig (b)

Fig.12 Different Powder Particles Used for Coating (a) Titanium Nitride (b) Titanium

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Fig.13. Single point cutting tools before coating

Fig.14 Plasma Spray Process

Fig.15. Different coated tools (a) Titanium Nitride powder coated on tools (b) Titanium Oxide powder coated on tools

VI. RESULT AND DISCUSSIONS

6.1 HARDNESS TEST:- Hardness test results of Annealing Heat treatment process of Six different materials as indicated within the table 6.1

6.1.1 Annealing:-

Heat treatment process Annealing – Temperature - 950^{0}c - Tool- Diamond-C-Scale (Rockwell hardness test at 150kg load and 1/16" ball indenter)

Table 6.1: Hardness test result of six different materials for annealing Process

Sl. No	Six different Alloys	Rockwell Hardness Number- Before Heat treatment process Annealing	Heat treatment process Annealing- Temperature	Load	Rockwell Hardness Number- After heat treatment process Annealing
1	SS316,	165	950^{0}c	150kg	174
2	SS304	173	950^{0}c	150kg	182
3	SS410	185	950^{0}c	150kg	195
4	SS440C	190	950^{0}c	150kg	202
5	Ti-6Al-4V	205	950^{0}c	150kg	215
6	HSS	215	950^{0}c	150kg	232

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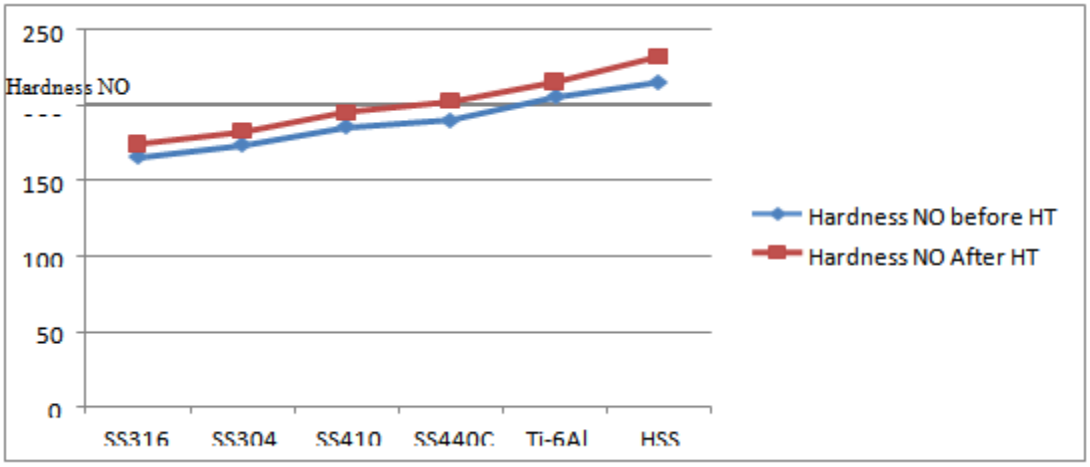

Graph 6.1 Shows Comparison of Graph's for SS316, SS304, SS410, SS440C, Ti-6Al-4V and HSS Materials Hardness Number (HRC) (before hardening) and Hardness Number(HRC) (after annealing Process) of Composite materials.

Discussion:-
From the Graph 6.1 the results show that In Annealing heat treatment process HSS and Titanium will have very good hardness property. Anyhow HSS will have very good hardness property other compare to other alloys.

6.1.2. Hardening:-
Heat treatment process for Hardening Temperature 950^{0}c Tool- Diamond-C-Scale

Table 6.2: Hardness test result of six different materials for Hardening Process

Sl. No	Six different Alloys	Rockwell Hardness Number- Before Heat treatment process Hardening	Heat treatment process Hardening Temperature	Load	Rockwell Hardness Number- After heat treatment process Hardening
1	SS316,	178	950^{0}c	150kg	188
2	SS304	173	950^{0}c	150kg	185
3	SS410	179	950^{0}c	150kg	190
4	SS440C	182	950^{0}c	150kg	195
5	Ti-6Al-4V	205	950^{0}c	150kg	215
6	HSS	215	950^{0}c	150kg	230

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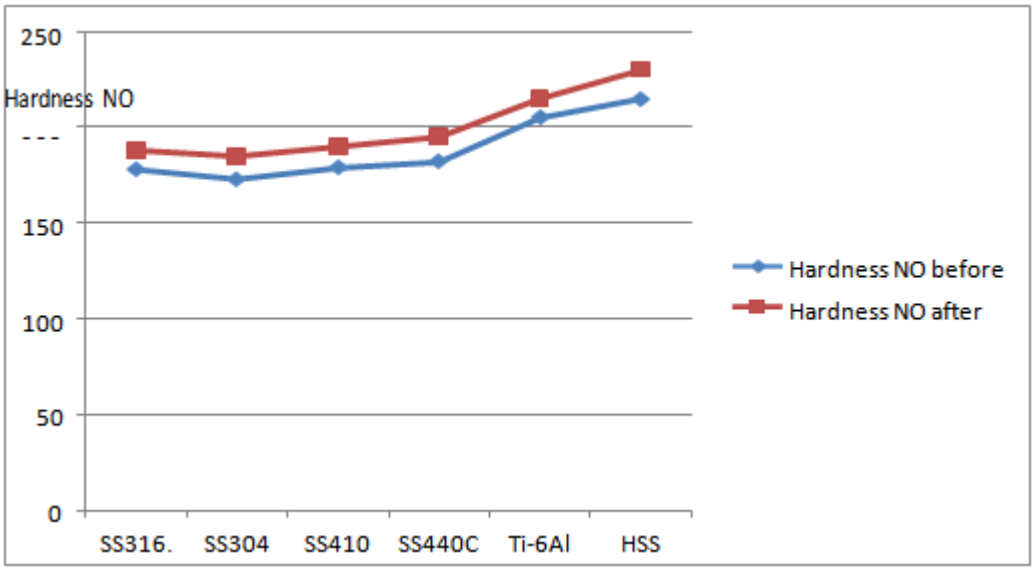

Graph 6.2 Shows Comparison of Graph's for SS316, SS304, SS410, SS440C, Ti-6Al-4V and HSS Materials Hardness Number (HRC) (before hardening) and Hardness Number (HRC) (after Hardening Process) of Composite materials.

Discussion: - From the Graph 6.2 the result shows that In Hardening heat treatment process HSS and Titanium will have very good hardness property. Anyhow HSS will have very good hardness property other compare to other alloys.

6.1.3 Normalizing:-

Heat treatment process normalizing temperature - 950^0c -tool- diamond-c-scale

Table 6.3: Hardness test result of Six different materials for Normalizing Process

Sl. No	Six different Alloys	Rockwell Hardness Number-Before Heat treatment process Normalizing,	Heat treatment process Normalizing, Temperature	Load	Rockwell Hardness Number-After Heat treatment process Normalizing,
1	SS316,	163	950^0c	150kg	176
2	SS304	173	950^0c	150kg	185
3	SS410	178	950^0c	150kg	188
4	SS440C	185	950^0c	150kg	197
5	Ti-6Al-4V	204	950^0c	150kg	216
6	HSS	213	950^0c	150kg	228

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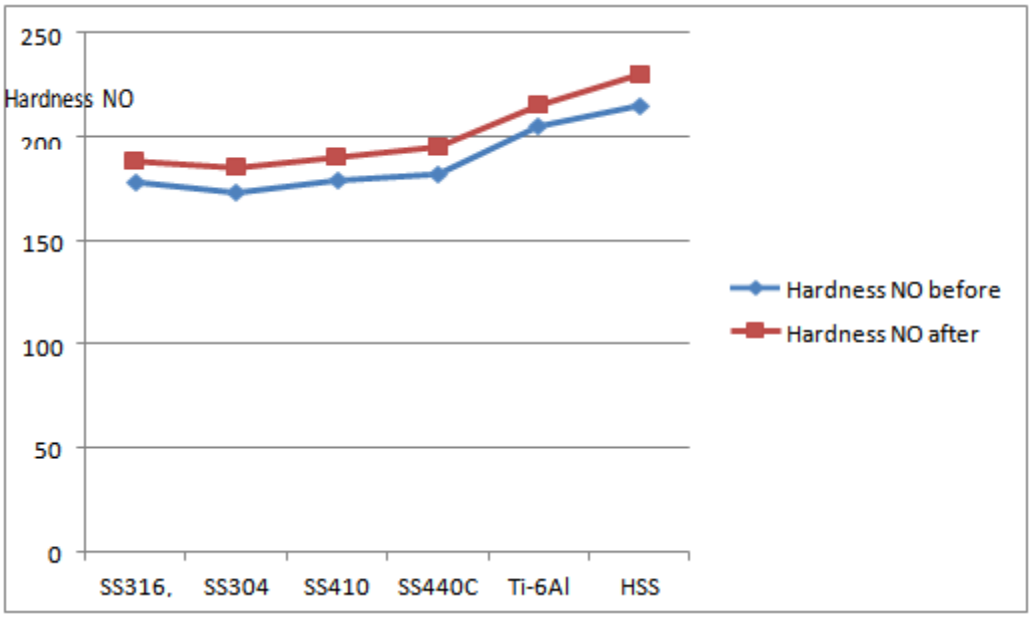

Graph 6.3 Shows Comparison of Graph's for SS316, SS304, SS410, SS440C, Ti-6Al-4V and HSS Materials Hardness Number (HRC) (before hardening) and Hardness Number (HRC) (after Normalizing Process) of Composite materials.

Discussion:- From Graph 6.3.the results shows that In Normalizing heat treatment process HSS and Titanium will have very good hardness property. Anyhow HSS will have very good hardness property other compare to other alloys.

6.1.4 Tempering:-

Heat treatment process for Tempering Temperature-650^0 c Tool- Diamond-C-Scale

Table 6.4: Hardness test result of six different materials for Tempering Process

Sl no	**Six different Alloys**	**Rockwell Hardness Number- Before heat treatment process Tempering**	**heat treatment process Tempering Temperature**	**Load**	**Rockwell Hardness Number- After heat treatment process Tempering**
1	SS316,	170	650^0 c	150kg	180
2	SS304	173	650^0 c	150kg	185
3	SS410	185	650^0 c	150kg	197
4	SS440C	190	650^0 c	150kg	198
5	Ti-6Al-4V	208	650^0 c	150kg	218
6	HSS	223	650^0 c	150kg	238

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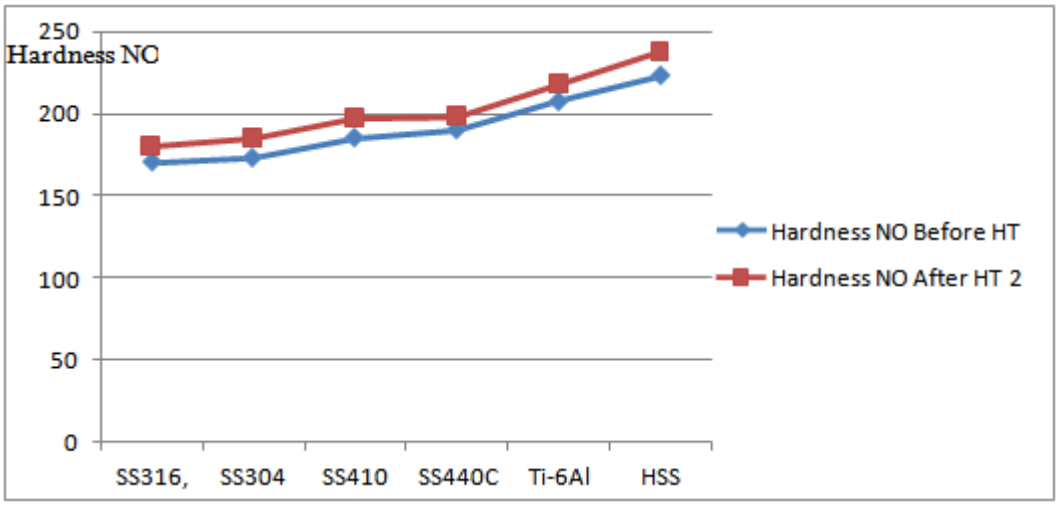

Graph 6.4 Shows Comparison of Graph's for SS316, SS304, SS410, SS440C, Ti-6Al-4V and HSS Materials Hardness Number (HRC) (before hardening) and Hardness Number (HRC) (after Tempering Process) of Composite materials.

Discussion:- From the Graph 6.4. The results show that In Tempering heat treatment process HSS and Titanium will have very good hardness property. Anyhow HSS will have very good hardness property other compare to other alloys.

6.2 PREPERATION OF SINGLE POINT CUTTING TOOL: - The tool is prepared according to cutting tool standard dimensions by using milling machines with parameters.

6.3 COATING:-

Coating is carried out on all specimens it is found that in plasma spray coating process the Titanium Oxide powder shows very good bonding or adhesive property on all the specimens compare to titanium nitrate powder.

VII. RESULT AND DISCUSSION

1. In Annealing heat treatment process HSS and Titanium will have very good hardness property.
2. In tempering heat treatment process HSS and Titanium will have very good hardness property.
3. In hardening heat treatment process HSS and Titanium will have very good hardness property.
4. In Normalizing heat treatment process HSS and Titanium will have very good hardness property.
5. In all heat treatment process HSS will have very good hardness property other compare to other alloys.
6. In plasma spray coating process the Titanium Oxide powder shows very good bonding or adhesive property on all the specimens.

VIII. SCOPE OF WORK

1. To find out the Flank wear of all the single point cutting tools can be found out by using lathe machine.
2. By changing nose radius of the all the single point cutting tools find out the Flank wear
3. FEA analysis can be carried out.
4. SEM analysis can be carried out.
5. PVD and CVD coating can be carried out for all these single point cutting tool. Hardness test is carried out.

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