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M. Ramesh
Jawaharlal Nehru Technological University, Anantapur, A.P., mramesh97@gmail.com

R.P. Elvin
Sri Sai Ram Engineering College, Chennai, T.N., r.p.elvin@gmail.com

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Surface Roughness Optimization Of Machining Parameters In Machining Of Composite Materials

[1]M.Ramesh, [2]R.P.Elvin, [3]K.Palanikumar, [4]K.Hemachandra Reddy
[1]Research Scholar, Jawaharlal Nehru Technological University, Anantapur, A.P.
[2] M.E (CAD/CAM), Sri Sai Ram Engineering College, Chennai, T.N.
[3]Principal, Sri Sai Ram Institute of Technology, Chennai, T.N.
[4]Director (Academic &Planning), JNTU, Anantapur, A.P.
[1] mramesh97@gmail.com, [2] r.p.elvin@gmail.com

Abstract-The term machinability refers to the ease with which a metal can be machined to an acceptance surface finish. The factors that typically improve a material's performance often degrade its machinability. Therefore, to manufacture components economically, engineers are challenged to find ways to improve machinability without harming performance. Surface finish is an important parameter in manufacturing engineering. It is a characteristic that can influence the performance of mechanical parts and production costs.

The investigation of influence of cutting conditions in turning of Duplex Stainless Steel 2205 is made in this project. The experimental design was formed based on Taguchi's technique. An orthogonal array and analysis of variance (ANNOVA) are employed to investigate the turning conditions and machining was done using CVD triangular carbide insert. The objective was to establish correlation between cutting speed, feed rate and depth of cut and optimize the turning conditions based on surface roughness. These correlations are obtained by multiple regression analysis.

Key words - Machinability, Cutting Speed, Feed rate and Depth of cut

I. INTRODUCTION

1.1 Machinability

The term machinability refers to the case with which a metal can be machined to an acceptable surface finish. Materials with good machinability require little power to cut, can be cut quickly, easily obtain a good finish, and do not wear the tooling much; such materials are said to be free machining. The factors that typically improve a material's performance often degrade its machinability. Therefore, to manufacture components economically, engineers are challenged to find ways to improve machinability without harming performance.

Machinability can be difficult to predict machining has so many variables. In most cases, the strength and toughness of a material are the primary factors. Strong, tough materials are usually more difficult to machine simply because greater force is required to cut them. Other important factors include the chemical composition, thermal conductivity and microstructure of the material, the cutting tool geometry, and the machining parameters.

In general, machinability can be defined as an optimal combination of factors such as low cutting force, high material removal rate, good surface integrity, accurate and consistent work piece geometrical characteristics, low tool wear rate and good curl or chip breakdown of chips.

The manufacturing industry is constantly striving to decrease its cutting costs and increase the quality of the machined parts as the demand for high tolerance manufactured goods is rapidly increasing.

The machinability can evaluate by different methods. Some of the important methods are Tool life method, Tool forces and power consumption method, Surface finish method and Machinability rating.

In this project, surface roughness method is used to evaluate the machinability of duplex stainless steel. Duplex stainless steels are a family of grades combining good corrosion resistance with high strength and ease of fabrication. Their physical properties are between those of the austenitic and ferritic stainless steels but tend to be closer to those of the ferrites and to carbon steel. It is known that stainless steel have poor machinability compared to regular carbon steel they are tougher, gummier and tend to work harden very rapidly.

Surface finish is an important parameter in manufacturing engineering. A characteristic can influence the performance of mechanical parts and production costs. Various failures, sometimes catastrophic, leading to high costs, have been attributed to the surface finish of the components in question. For these reasons, there have been research developments with the objective of optimizing the cutting conditions to obtain a good surface finish. Surface roughness effect on machining.

1.2 Objective

The main objective of the project is

- To perform regressive analysis to find the correlation between the contributing factors (i.e.) cutting speed, feed and depth of cut.
- To find the cutting conditions effects on surface roughness.

- To analyze chip formation.

II. CUTTING TOOLS

The cutting tool is a very important parameter in machining. In nineteenth century, carbon steel was used as cutting tool. But it cannot be used for high speed machining.

2.1 Identification systems for indexable inserts

The size of index able insert is determined by the diameter of an inscribed circle, except for rectangular and parallelogram insert where the length and width dimensions are used. To describe an insert in its entirety, a standard ANSI B212.4-1986 identification system is used where each position number designates a feature of the insert. The ANSI standard includes items now commonly used and facilitates identification of items not in common use.

Identification consists of up to ten positions; each position defines a characteristic of the insert as shown below

1	2	3	4	5	6	7	8	9	10
T	N	M	G	5	4	3			A

Eight, ninth and tenth positions are used only when required.

2.2 Duplex stainless steel

Duplex stainless steel is a family of grades combining good corrosion resistance with high strength and ease of fabrication. Their physical properties are between those of the austenitic and ferrite stainless steel but tend to be closer to the ferrite and to carbon steel. The chloride pitting and crevice corrosion resistance of the duplex stainless steel is a function of chromium, molybdenum and nitrogen content. It may be similar to that of Type 316 or range up to that of the seawater stainless steel such as the 6% Mo austenitic. All the duplex stainless steel has chloride stress corrosion cracking resistance significantly greater than that of the 300 series austenitic. They all provide significantly greater strength than the austenitic grades while good ductility and toughness.

Duplex stainless steels, meaning those with a mixed microstructure of about proportions of austenite and ferrite, have existed for more than 60 years. The early grades were alloys of chromium, nickel and molybdenum. The first wrought stainless steel was produced in Sweden in 1930 and was used in the sulfide paper industry. These grades were developed to reduce the intergranular corrosion problems in the early, High-carbon austenitic stainless steels.

Duplex castings were produced in Finland in 1930, and a patent was granted in France in 1936 for the forerunner of what would eventually be known as Uranus 50. One of the first duplex grades developed specifically for improved resistance to chloride stress corrosion cracking (SCC) was 3RE60.AISI Type 329 became well established after World War II and was extensively for heat exchanger tubing for nitric acid service. In subsequent years, both wrought and cast duplex grades have been for a variety of process industry applications including vessels, heat exchangers and pumps.

These first generation duplex stainless steels provided good performance characteristics but had limitations in the as welded condition. The heat-affected zone (HAZ) of welds had low toughness because of excessive ferrite and significantly lower corrosion resistance than that of the base metal. These limitations confined the use of the first generation duplex stainless steels, usually in the unwelded condition, to a few specific applications.

In 1968 the invention of the stainless steel refining process. Argon Oxygen Decarburization (AOD) opened the possibility of a broad spectrum of new stainless steel. Among the advances made possible with the AOD was the deliberate addition of nitrogen as an alloying element. Nitrogen alloying of duplex stainless steel makes possible heat-affected zone toughness and corrosion resistance, which approaches that of the base metal in the as welded condition. Nitrogen also reduces the rate at which detrimental intermetallic phases form.

The second generation duplex stainless steels raw defined by their nitrogen alloying. This new commercial development, which began in the late 1970s, coincided with the development of offshore gas and oil fields in the North Sea and the demand for stainless steels with excellent chloride corrosion resistance, good fabric ability and high strength. DSS 2205 became the workhorse of the second generation duplex grades and was used extensively for gas gathering line pipe and process applications on offshore platforms, The high strength of those steels allowed for reduced wall thickness and reduced weight on the platforms and provided considerable inventive to the use of these stainless steels.

The chemical composition of duplex stainless steel 2205(UNS number S31803) is given in the table below.

Cutting speed (m/min)	**Feed (mm/rev)**	**Depth of cut (mm)**
150	0.1	0.5
150	0.1	1
150	0.1	1.5
150	0.15	0.5
150	0.15	1
150	0.15	1.5
150	0.2	0.5
150	0.2	1
150	0.2	1.5
200	0.1	0.5
200	0.1	1
200	0.1	1.5
200	0.15	0.5
200	0.15	1
200	0.15	1.5
200	0.2	0.5
200	0.2	1
200	0.2	1.5
250	0.1	0.5
250	0.1	1
250	0.1	1.5
250	0.15	0.5
250	0.15	1
250	0.15	1.5
250	0.2	0.5
250	0.2	1
250	0.2	1.5

2.3 Cemented carbides

Cemented carbide, also called tungsten carbide cobalt or hard metal, hard material are used in machining through materials such as carbon steel or stainless steel, as well as in situations where other tools would wear away, such as high quantity production runs. Most of the time, carbide will leave a better finish on the part, and allow faster machining. Carbide tools can also withstand higher temperatures than standard high speed steel tools.

Metal carbide tools, which are also often called hard metal tools, are made by mixing together powders of cobalt (chemical symbol Co) and metal carbide (usually tungsten carbide, WC). These are then sintered using powder processing techniques. The particle of carbide (which are hard and very strong, even at machining temperatures) from the cutting surfaces of the tool and the function of the cobalt is simply to hold together all the carbides particles.

The straight tungsten carbides are finely powdered tungsten carbide (85-95%) and cobalt (5-15%) which acts as a bonding medium.

III. SURFACE ROUGHNESS

Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficient than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion.

3.1 Measurement

Roughness may be measured using contact or non-contact method.

Elements	**%Composition**
Carbon	0.03 max
Manganese	2
Silicon	1
Phosphorous	0.03
Sulphur	0.02
Chromium	21-23
Molybdenum	2.5-3.5
Nickel	4.5-6.5
Nitrogen	0.08-0.2
Copper	Nil

The surface roughness for the machined work piece is measured by contact method. The instrument used is matutoyo SJ 201.

3.2 Technical data

X-axis (drive unit)

Measuring range: 12.5mm

Measuring speed: 0.25, 0.5mm/s (0.25mm/s: S-type)

Traversing direction: backwards

Detector range: 350µm (-200µmto+150µm)

Detecting method: skid measurement

Measuring force: 4mN

Stylus tip: diamond, 90°/5µmR

Skid radius of curvature: 40mm

Skid force: less than 400mN

Detecting method: differential inductance

Power supply: rechargeable battery

DIMENSIONS (W×D×H)

Control unit: 307×165×94mm

Drive unit: 115×23×26mm

MASS

Control unit: approx.0.3kg (SJ-201)

Drive unit: 0.2kg

3.3 Design of experiments

Taguchi method is a powerful tool for design of experiments. He developed philosophy and methodology for continuous quality improvement in product and process.

Factors	**Level1**	**Level2**	**Level3**
Cutting speed(m/min)	150	200	250
Feed(mm/rev)	0.1	0.15	0.2
Depth of cut(mm)	0.5	1	1.5

The machining parameters chosen for the experiments were 1. Cutting speed, 2. Feed, 3.depth of cut.

3.4 Cutting conditions

From the machining handbook maximum cutting speed up to which cemented carbide tool can be used is 300m/min. the feed rate was 0.1,0.15,0.2 mm/rev. depth of cut used was 0.5,1,1.5mm.

Chemical composition of 2205 duplex stainless steel

Elements	%composition
Carbon	0.03max
Manganese	2
Silicon	1
Phosphorous	0.03
Sulphur	0.02
chromium	21-23
Molybdenum	2.5-3.5
Nickel	4.5-6.5
nitrogen	0.08-0.2
copper	Nil

3.5 Experimental procedure

The work piece was first fixed in the chuck of the cnc machine. The length of work piece is 110mm in which the 40mm was used for holding on the chuck. The remaining length (i.e.) 60mm was used for machining. The cutting tool was allowed to slightly touch the right side of the work piece material and the coordinates of the start of the work piece were set on the cnc lathe. The cutting tool was then allowed to slightly touch the surface of the work piece material, and the diameter of the work piece was set in the cnc lathe. Then machining was carried out in different cutting condition, totally there were 27 cutting conditions (i.e.) with constant cutting speed and feed we varied the depth of cut. Similarly machining was carried out in all the work pieces. After machining the surface roughness of the work piece at different cutting conditions were measured using Mitutoyo SJ201.the chip produces during each cutting condition was collected and chip analysis was carried out.

IV. RESULT

Minitab16 software was used for performing the regression analysis to find the correlation between the contributing factors and graph was plotted to find the effect of contribution factor on surface roughness.

4.1 Regression analysis

It is used to investigate and model the relationship between a response variable and one or more predictors. Mintlab provides least square, partial least square and logistic regression procedures.

Cutting speed (m/min)	**Feed (mm/rev)**	**Depth of cut (mm)**	**Ra(μm)**
150	0.1	0.5	1.68
150	0.1	1	1.6
150	0.1	1.5	1.59
150	0.15	0.5	1.87
150	0.15	1	1.14
150	0.15	1.5	2.62
150	0.2	0.5	2.24
150	0.2	1	2.39
150	0.2	1.5	2.3
200	0.1	0.5	0.6
200	0.1	1	1.67
200	0.1	1.5	2.78
200	0.15	0.5	1.97
200	0.15	1	1.72
200	0.15	1.5	2.55
200	0.2	0.5	2.02
200	0.2	1	3.31
200	0.2	1.5	2.78
250	0.1	0.5	1.16
250	0.1	1	0.79
250	0.1	1.5	1.69
250	0.15	0.5	0.8
250	0.15	1	1.35
250	0.15	1.5	1.02
250	0.2	0.5	1.64
250	0.2	1	1.79
250	0.2	1.5	2.09

4.2 Regression Analysis (RA) versus speed, feed, depth of cut

Ra=1.18-0.00567 speed + 7.78 feed +0.604 depth of cut

Predictor	**Coef SE**	**Coef**	**T**	**P**
Constant	1.183	0.6473	1.83	0.00
Speed	-0.005	0.0023	-2.38	0.026
Feed	7.78	2.377	3.27	0.000
doc	0.6044	0.2377	2.54	0.018

S=0.504186 R-Sq = 49.8% R-Sq (adj) =43.3%

Press=7.76 R-Sq (pred) =33.43%

Analysis of variance

source	**df**	**ss**	**ms**	**f**	**p**
Regression	3	5.81	1.94	7.62	0.001
Residual error	23	5.85	0.25	-	-
Total	26	11.65	-	-	-

Sequential sum of squares

Source	**df**	**Seq ss**
Speed	1	1.445
Feed	1	2.722
doc	1	1.644

Unusual observation

Ob	Speed	Ra	fit	SE fit	Residual	St resid
5	150	1.14	2.10	0.15	-0.96	-2.01R
12	200	2.78	1.73	0.19	1.04	2.25R
17	250	3.31	2.20	0.15	1.10	2.29R

R denotes observation with a large standardized residual.

Residual plots for surface roughness:

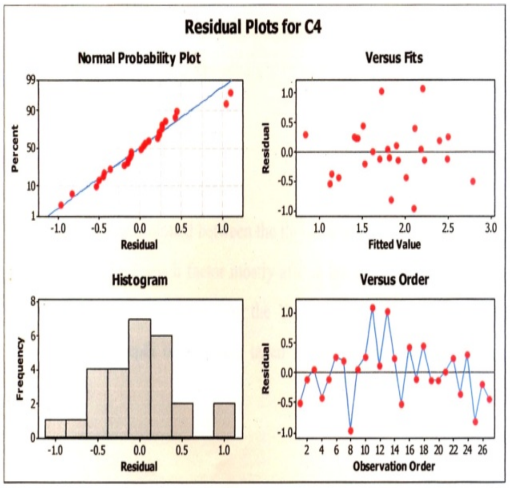

Figure 9.1 Residual plot

Graph:

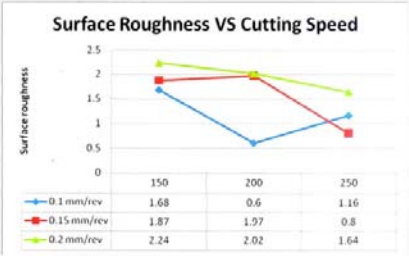

Figure 9.2 Surface roughness VS Cutting speed at depth of cut=0.5mm

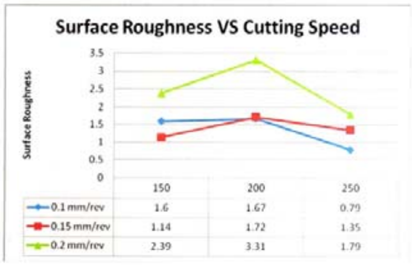

Figure 9.3 Surface roughness VS Cutting speed at depth of cut =1mm

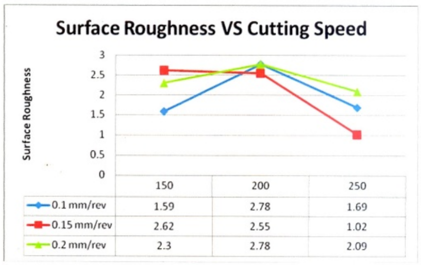

Figure 9.4 Surface roughness VS Cutting speed at depth of cut =1.5mm

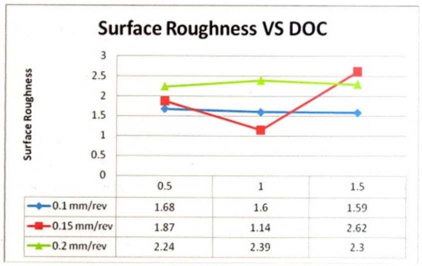

Figure 9.5 Surface roughness VS Depth of cut at cutting speed= 150 m/min

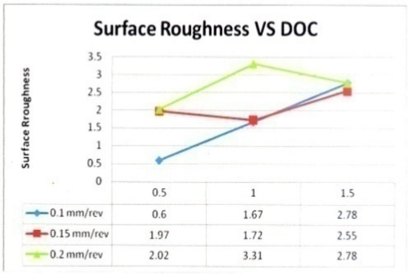

Figure 9.6 Surface roughness VS Depth of cut at cutting speed= 200 m/min

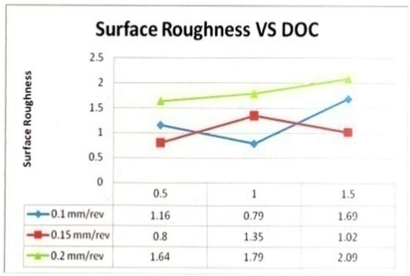

Figure 9.7 Surface roughness VS Depth of cut at cutting speed= 250 m/min

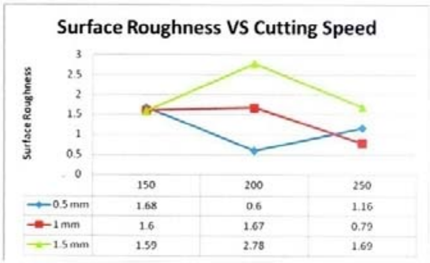

Figure 9.8 Surface roughness VS Cutting speed at feed =0.1mm/rev

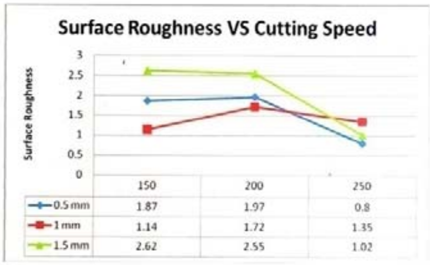

Figure 9.9 Surface roughness VS Cutting speed at feed =0.15mm/rev

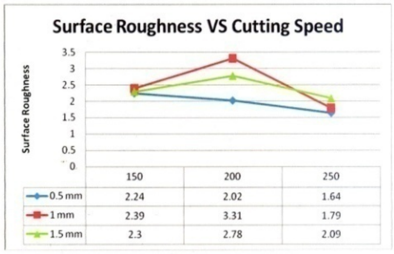

Figure 9.10 Surface roughness VS Cutting speed at feed =0.2mm/rev

4.3 Chip analysis

Chips formed at different cutting conditions were analyzed. If material is ductile, fracture will not occur and chip will be form of a continuous ribbon.

V. CONCLUSION

The Regression equation is

Ra=1.18-0.00567 speed + 7.78 feed +0.604 depth of cut

From the graph most important factor which affects the surface roughness is rated as follows they are feed, speed, depth of cut has very little

From the above discussions the optimum cutting conditions for machining is higher cutting speed, lower cutting feed and dept of cut. Cutting conditions 10, 20 and 22 may be considered as optimum.

Suplex stainless steel is ductile material so fracture will not occur and the chip formation during machining is continuous ribbon type chip, (i.e.) continuous chip is formed

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