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# Influence of Drilling Parameters In Super Duplex Stainless Steel

1Kanagaraju.T, [2]Kumar.M, [3]Mahesh.R, [4]Manikandan.R, [5]Shanmugapandiyan.S,
[1]Assistant professor, Mechanical department,kings engineering college, Irungattukkottai,chennai.
[2]Student, Mechanical department, kings engineering college, irungattukkottai,chennai.
[3]Student, Mechanical department, kings engineering college, irungattukkottai,chennai
[4]Student, Mechanical department, kings engineering college, irungattukkottai,chennai
[5]Student, Mechanical department, kings engineering college, irungattukkottai,chennai
kanagaraju1982@gmail.com, mlkumar4025@gmail.com, ravimahesh2205@gmail.com, ramanmani17@gmail.com, sspandiyan1007@gmail.com

***Abstract*-Super duplex stainless steel is very harder and very difficult to machining than the other materials. To find the parameters of super duplex stainless steel alloy during drilling process. There are different types of tools are used for drilling the super duplex alloys but the most widely used tool is solid carbide drill bit. Solid carbide drill bits are used in two ways by either coating or without coating for increasing their performance during drilling. In our project super duplex alloy is machined in dry drilling method to predict which tool is efficient to drill holes in the super duplex alloy plates. Three types of solid carbide drill bits are used in our experiment they without coated solid carbide drill bit, single coated solid carbide drill bit, multi coated solid carbide drill bit. We have to calculate the cutting force and torque required to drill holes in the super duplex alloy plates by using Dynamometer. Whenever the values are noted from the dynamometer then we have to analyze which drill bit has desirable values of force and torque to drill holes in the super duplex alloy plates.This analysis has been successfully done with the help of MINITAB software. At last the most efficient drill bit which is used to drill the super duplex alloy plate during dry drilling process is determined.***

***Keywords-Super duplex stainless steel, Drilling, Solid carbide tool, Dynamometer, Minitab.***

## INTRODUCTION

Stainless steel is the world consumption has increased year-on-year worldwide at a compound rate of 5% over the last 20 years more than other metals. Duplex stainless steels which were originally developed in the 1920's are becoming ever more main stream materials with increasing applications in the marine, industrial, construction and chemical processing industries.Duplex alloys are desirable engineering materials which offer significant beneficial features such as corrosion resistance, high tensile strengths and lower cost due to the lower content of nickel and molybdenum. Furthermore, due to high tensile strength compared to 300 series, duplex stainless steels are increasingly used as an alternative to austenitic stainless steels.

The duplex alloys are more difficult to machine than the austenitic grades though these have good mechanical properties. The common basis for its poor machining behavior stem primarily from the resulting high strength alloy but being exacerbated by lack of nonmetallic inclusions and the low carbon content. Due to the above mentioned difficulties super duplex stainless plates are drilled with three carbide drill bits. During these dry drilling process the cutting force and torque required by the drill bit to drill holes in the plate was determined with the help of dynamometer. Whenever the values are noted from the dynamometer then we have to analyze which drill bit has desirable values of force and torque to drill holes in the super duplex alloy plates. This analysis has been successfully done with the help of MINITAB software.

## OBJECTIVES

To select the process parameters in the drilling process. Choose, which one is most influenced processing parameters in the drilling process by using ANOVA table techniques. Dry drilling process are carried out and finally compare the process with the Minitab results and the table values.

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SUPER DUDLEX STAINLESS STEEL (SAF2507)

The superior mechanical properties of duplex stainless steel originates from a 1:1 matrix of austenite (γ) and ferrite (α) phases presenting in a banded structure as depicted in Fig. 1 where the lighter phase is austenite and the darker phase is ferrite. The γ phase is responsible for the relative ductility and resistance to uniform corrosion; while the α phase is responsible for the superior strength as well as corrosion resistance. Both phases exist in relatively large separate volumes and in approximately equal fractions rather than an inclusion phase embedded in the matrix formed by one of the other phases. Stainless steels in general are regarded as difficult to machine materials due to their high tendency to work harden; their toughness and relatively low thermal conductivity.

Other problems stem from their high fracture toughness, which increase tool chip interface temperatures leading to poor surface finish and poor chip breaking. Furthermore, built-up-edge (BUE) formation is present even at elevated cutting speeds. This deteriorates the finish of the machined surface and increases the cutting forces. The duplex alloys are more difficult to machine than the austenitic grades though these have better mechanical properties. The common basis for its poor machining behavior stem primarily from the resulting high strength of the alloy but being exacerbated by lack of non-metallic inclusions and the low carbon content. However, there is still a deficient understanding in machining of duplex stainless steel. Investigating the material response during machining processes is a general strategy to understand the machinability of any material.

These also provide insight to what are the essential questions, and draw out key areas requiring central focus. There are some studies to investigate machinability of duplex alloys. They established a correlation between the pitting resistance equivalent (PRE), and the machinability of duplex alloys.

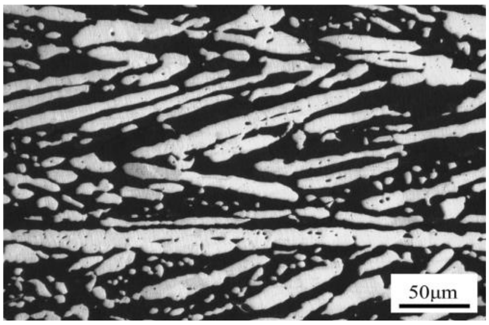


**Fig. No 1 Structure of Super Duplex Stainless Steel**

A duplex with higher PRE value gives worse tool life. Moreover, it was revealed that tool wear in drilling, using TiN coated cemented carbide drills with through coolant, increased continuously at lower cutting speeds.

## Chemical composition (%)

| C | Si | Mn | P | S | Cr | Ni | Mo | Others |
|---|---|---|---|---|---|---|---|---|
| ≤0.030 | ≤0.8 | ≤1.2 | ≤0.035 | ≤0.015 | 25 | 7 | 4 | N=0.3 |

**Table No. 1 Chemical Composition**

## Tungsten Carbide drill bits

**Fig. No 2. Carbide Drill Bit Tools**

Sintered tungsten carbide cutting tools are very abrasion resistant and can also withstand higher temperatures than standard high speed steel tools. Carbide cutting surfaces are often used for 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. Because carbide tools maintain a sharp cutting edge better than other tools, they generally produce a better finish on parts, and their temperature resistance allows faster machining. The material is usually called cemented carbide, hard metal or tungsten-carbide cobalt: it is

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a metal matrix composite where tungsten carbide particles are the aggregate and metallic cobalt serves as the matrix. Manufacturers use tungsten carbide as the main material in some high-speed drill bits, as it can resist high temperatures and is extremely hard.

COATING MATERIALS

TITANIUM NITRIDE

It is an extremely hard ceramic material, often used as a coating on titanium alloys, steel, carbide, and aluminium components to improve the substrate's surface properties. Applied as a thin coating, TiN is used to harden and protect cutting and sliding surfaces, for decorative purposes (due to its gold appearance), and as a non-toxic exterior for medical implants

ALUMINIUM OXIDE

Alumina is one of the most cost effective and widely used material in the family of engineering ceramics. The raw materials from which this high performance technical grade ceramic is made are readily available and reasonably priced, resulting in good value for the cost in fabricated alumina shapes. With an excellent combination of properties and an attractive price, it is no surprise that fine grain technical grade alumina has a very wide range of applications.

PHYSICAL VAPOUR DEPSITION METHOD

The coating method involves purely physical processes such as high-temperature vacuum evaporation with subsequent condensation, or plasma sputter bombardment rather than involving a chemical reaction at the surface to be coated as in chemical vapour deposition. The term physical vapor deposition originally appeared in the 1966 book VaporDeposition by C. F. Powell, J. H. Oxley and J. M. Blocher Jr., (but Michael Faraday was using PVD to deposit coatings as far back as 1838). Physical vapour deposition coating is a process that is currently being used to enhance a number of products, including automotive parts like wheels and pistons, surgical tools, drill bits, and guns. The current version of physical vapour deposition was completed in 2010 by NASA scientists at the NASA Glenn Research Center in Cleveland, Ohio. This physical vapour deposition coating is made up of thin layers of metal that are bonded together through a rig that NASA finished developing in 2010. In order to make the coating, developers put the essential ingredients into the rig, which drops the surrounding atmospheric pressure (1/760 of our everyday atmosphere). From there, the coating is heated with a plasma torch that reaches 17,540 degrees Fahrenheit or 9,727 degrees Celsius. NASA's PS-PVD is one of only two such facilities in the USA and one of four in the world.

CNC DRILLING MACHINE


**Fig. No 3 CNC Drilling Machine**

The CNC drilling machine is a useful tool that was made to give you value for your money. Its programming and operation is simple, and that is why it is increasingly popular. It will enable you to save you time without incurring much loss. There are many types of this machine. However, it has several fundamental constructions, which cover various amounts of widths. These constructions depend on the manufacturer that has produced it.The CNC drilling machine can be programmed to enable its fast and effortless use. Therefore, you will not need to use manuals most of the time. In addition, the machine can have built-in software that will calculate precise position of holes. These positions are important in making matrix, PCD patterns, line and skip drilling. You can use the drilling machine for any kind of drilling and tapping. This includes thermal or form drilling, which requires highly sophisticated equipment to carry out successfully. This drilling machine can work at incredible speeds. If you want to perform pendulum work, you should get yourself the fixed bed design that provides a firm support and stability. It is extremely efficient and convenient because you can use it to do one thing while being busy with another. For instance, you can use it to drill and tap parts at one end as you load or unload things at the other end. If you want the best machine, you should look for additional features such as tool length sensing, tool changers, work holding vices and spindle coolants.

DYNAMOMETER

Dynamometer or spring balance is a measuring instrument for greatness force , usually

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graduated in unit N (Newton). A simple dynamometer consits of a helicak spring where one or two cardboard sleeves are graded and shows the power in relation to how much the sprimg is pulled out of the force to be measured. An example of a dynamometer can be a fishway where the grading is in kilograms. Other versions on dynamometers are common in school physics labs. In everyday use puts you often equate one kilogram and ten Newton.A machine-tool dynamometer is a multi-component dynamometer that is used to measure forces during the use of the machine tool. Empirical calculations of these forces can be cross-checked and verified experimentally using these machine tool dynamometers.With advances in technology, machine-tool dynamometers are increasingly used for the accurate measurement of forces and for optimizing the machining process. These multi-component forces are measured as an individual component force in each co-ordinate,

depending on the coordinate system used. The forces during machining are dependent on depth of cut, feed rate, cutting speed, tool material and geometry, material of the work piece and other factors such as use of lubrication cooling during machining.

**Fig. No 4. Kistler dynamometer**

TAGUCHI CALCULATION

| LEVEL<br>FACTOR | 1 | 2 | 3 |
|---|---|---|---|
| SPEED | 800 | 1000 | 1200 |
| FEED | 0.15 | 0.20 | 0.25 |
| TOOL | MC | SC | WC |

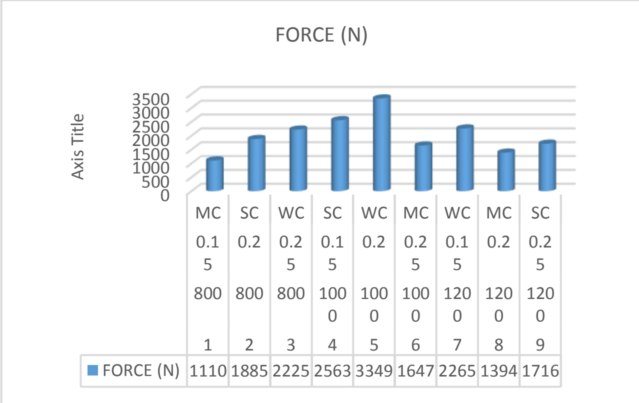


**Fig. No 5. Force chart**

**RESPONSE TABLE FOR FORCE**

| LEVEL | SPEED | FEED | TOOL |
|---|---|---|---|
| **1** | 1740 | 1980 | 1384 |
| **2** | 2520 | 2210 | 2055 |
| **3** | 1792 | 1863 | 2613 |
| **DELTA** | 780 | 347 | 1229 |
| **RANK** | **2** | **3** | **1** |

ANOVA RESULTS FOR FORCE

| VARIANCE | SUM OF SQUARE | DOF | MEAN | $F_{CAL}$ | $F_{TABLE}$ AT $\alpha$=0.05 | REMARKS |
|---|---|---|---|---|---|---|
| A<br>B<br>C | 1140083<br>187074<br>2271971 | 2<br>2<br>2 | 570041<br>93537<br>1135985 | 35.15<br>5.77<br>70.04 | 19.00 | Significant<br>Insignificant<br>Significant |
| **Error** | 32438 | 2 | 16219 | | | |
| **Total** | 3631566 | 8 | | | | |

In factor ‘A’, ‘C’ $F_{cal}$>$F_{tab}$. It is clear that the factor A and C have sign

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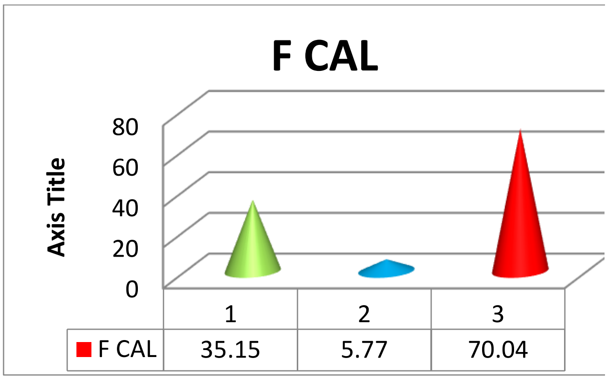



Fig. No 6. Force calculation

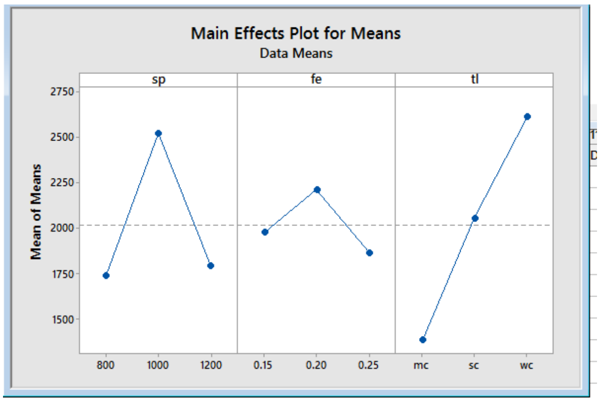
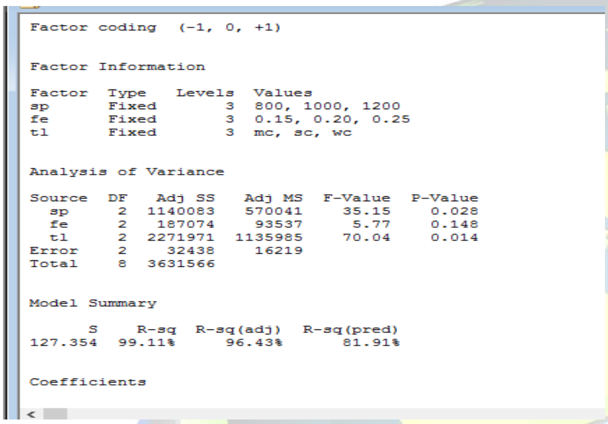



Fig. No 9.Main effects plots for mean



```
Factor coding  (-1, 0, +1)

Factor Information

Factor  Type   Levels  Values
sp      Fixed       3  800, 1000, 1200
fe      Fixed       3  0.15, 0.20, 0.25
tl      Fixed       3  mc, sc, wc

Analysis of Variance

Source  DF   Adj SS   Adj MS  F-Value  P-Value
  sp     2  1140083   570041    35.15    0.028
  fe     2   187074    93537     5.77    0.148
  tl     2  2271971  1135985    70.04    0.014
Error    2    32438    16219
Total    8  3631566

Model Summary

      S    R-sq  R-sq(adj)  R-sq(pred)
127.354  99.11%     96.43%      81.91%

Coefficients
```

Fig. No 7 Minitab results

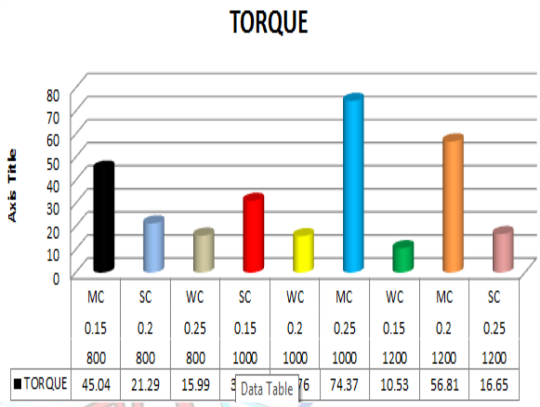



Fig.No 10. Torque chart

RESPONSE TABLE FOR TORQUE

| LEVEL | SPEED | FEED | TOOL |
|---|---|---|---|
| **1** | 27.44 | 28.89 | 58.74 |
| **2** | 40.41 | 31.67 | 23.01 |
| **3** | 28 | 35.67 | 14.09 |
| **DELTA** | 12.97 | 6.78 | 44.69 |
| **RANK** | **2** | **3** | **1** |

ANOVA RESULTS FOR TORQUE

| VARIANCE | SUM OF SQUARE | DOF | MEAN | $F_{CAL}$ | $F_{TABLE}$ AT α=0.05 | REMARKS |
|---|---|---|---|---|---|---|
| A | 322.45 | 2 | 161.23 | 1.90 | | Insignificant |
| B | 70.69 | 2 | 33.49 | 0.42 | 19 | Insignificant |
| C | 3349.46 | 2 | 1674.73 | 19.70 | | Significant |
| **Error** | 170.04 | 2 | 85.02 | | | |
| **Total** | 3912.94 | 8 | | | | |

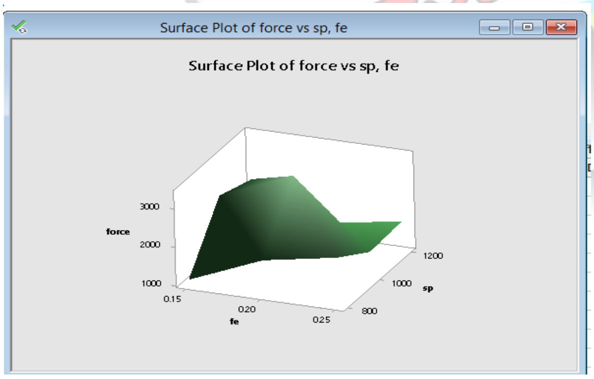



Fig. No 8. Surface plots of force

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In factor 'C' $F_{cal} > F_{tab}$. It is clear that the factor C have significant effect on torque. Since $F_{cal}$ the factor C is greater than $F_{tab.}$ Hence factor C is the best factor among the three factors available to us. So increasing the value of factor C.

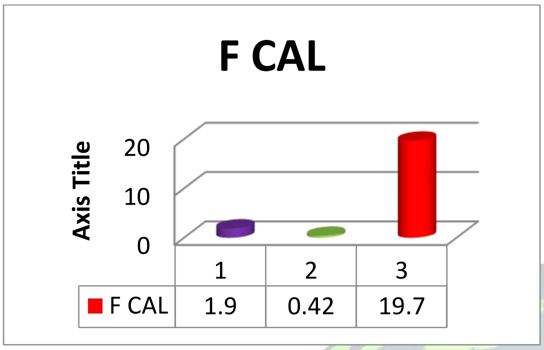


**Fig. No11. Torque calculation**

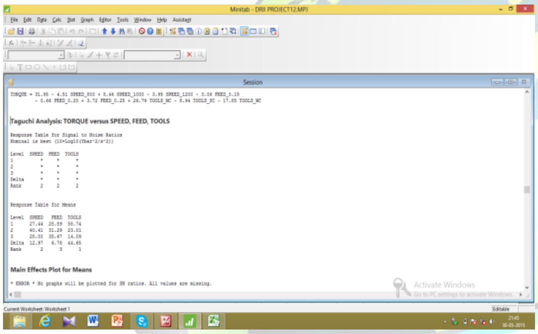

**Fig.No 12. Minitab results**

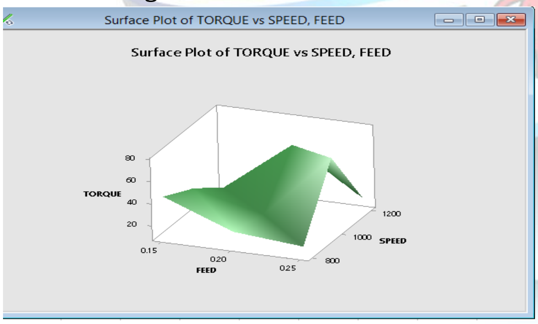


**Fig.No 13. Surface plots for Area**

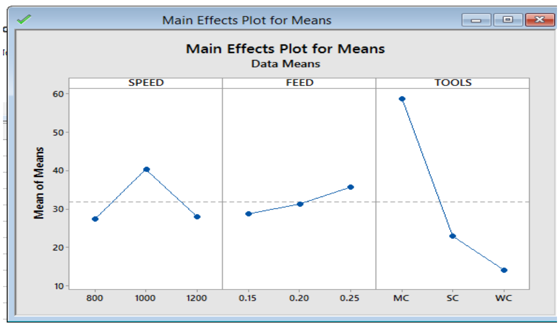


**Fig. No 14.Main effects plots for mean**

## APPLICATIONS

- Oil and gas industry equipment
- Offshore platforms, heat exchangers, process and service water systems, fire-fighting systems, injection and ballast water systems
- Chemical process industries, heat exchangers, vessels, and piping
- Desalination plants, high pressure RO-plant and seawater piping
- Mechanical and structural components, high strength, corrosion-resistant parts
- Power industry FGD systems, utility and industrial scrubber systems, absorber towers, ducting, and piping

## CONCLUSION

From this project we can clearly understand the requirement of force and torque value for different carbide drill bits during dry drilling of super duplex stainless steel SAF2507. To reduce the lubrication expenses we go ahead with the dry machining .Due to the combination of both austenite and ferritic structure SAF2507 exhibits extreme hardness, low thermal conductivity.

Usually carbide drill bits are used for machining these types of difficult-to-machine materials. In this case carbide drill bits are used in 3 modes such as single coating, multi coating, without coating. From the Minitab analysis we can clearly predict that multi coated tool is better than rest of the tools for machining the super duplex stainless steel SAF 2507.

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