# MACHINABILITY STUDY OF DUPLEX STAINLESS STEEL 2205 USING CRYOGENIC COOLANT


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## ABSTRACT

In this project we are going to use duplex stainless steel as a work material and carbide as a tool material. In this method carbide tool is coated with TiN.From this project the machinability of duplex stainless steel such as Temperature, surface roughness, Material Removal Rate(MRR) has been analyzed thoroughly.An chart is prepared for the verification of different parameter values and ranks were given for the different trials for the identification of best process using TOPSIS method.


## STEEL

Iron and the most common iron alloy, steel, are from a corrosion viewpoint relatively poor materials since they rust in air, corrode in acids and scale in furnace atmospheres. In spite of this there is a group of iron-base alloys, the iron-chromium-nickel alloys known as stainless steels, which do not rust in sea water, are resistant to concentrated acids and which do not scale at temperatures up to 1100°C. It is this largely unique universal usefulness, in combination with good mechanical properties and manufacturing characteristics, which gives the stainless steels their raison d'être and makes them an indispensable tool for the designer. The usage of stainless steel is small compared with that of carbon steels but exhibits a steady growth, in contrast to the constructional steels. Stainless steels as a group is perhaps more heterogeneous than the constructional steels, and their properties are in many cases relatively unfamiliar to the designer.

## STAINLESS STEEL

Stainless steel is primarily when corrosion or oxidation are a problem. The function that they perform cannot be duplicated by other materials for their cost. Over 50 years ago, it was discovered that a minimum of 12% chromium would impart corrosion and oxidation resistance to steel. Hence the definition "Stainless Steels", are those ferrous alloys that contain a minimum of 12% chromium for corrosion resistance. This development was the start of a family of alloys which has enabled the advancement and growth of chemical processing and power generating systems upon which our technological society is based.

## AUSTENITIC GRADES

Austenitic grades are those alloys which are commonly in use for stainless applications. The austenitic grades are not magnetic. The most common austenitic alloys are iron- chromium-nickel steels and are widely known as the 300 series. The austenitic stainless steels, because of their high chromium and nickel content, are the most corrosion resistant of the stainless group providing unusually fine mechanical properties.

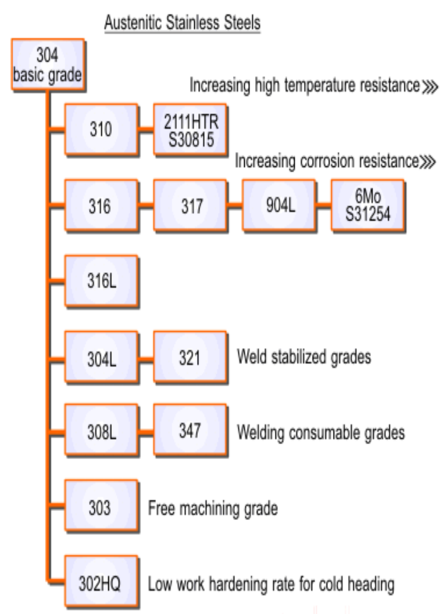


Fig 1.1. *Austenitic grades*

## MARTENSITIC GRADES

Martensitic grades were developed in order to provide a group of stainless alloys that would be corrosion resistant and hardenable by heat treating. The martensitic grades are straight chromium steels containing no nickel. They are magnetic and can be hardened by heat treating.

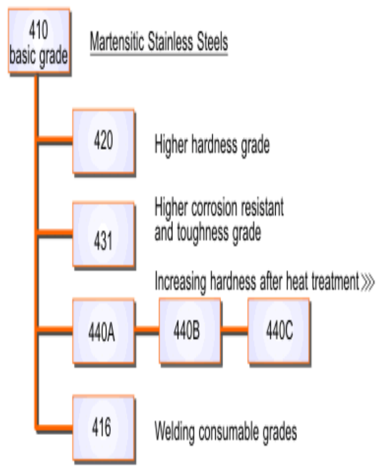


Fig 1.2. *Martensitic grades*

## FERRITIC GRADES

Ferritic grades have been developed to provide a group of stainless steel to resist corro- sion and oxidation, while being highly resistant to stress corrosion cracking. These steels are magnetic but cannot be hardened or strengthened by heat treatment. They can be cold worked and softened by annealing.

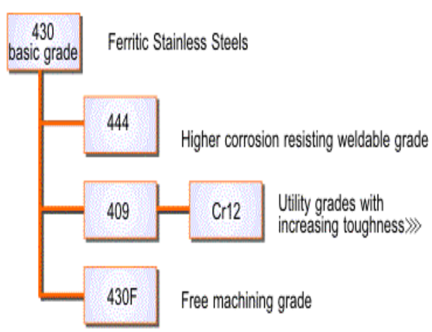


Fig 1.3. *Ferritic grades*

## DUPLEX STAINLESS STEEL

Duplex stainless steels are called "duplex" because they have a two-phase microstructure consisting of grains of ferritic and austenitic stainless steel. The picture shows the yellow austenitic phase as "islands" surrounded by the blue ferritic phase. When duplex stainless steel is melted it solidifies from the liquid phase to a completely ferritic structure. As the material cools to room temperature, about half of the ferritic grains transform to austenitic grains ("islands"). The result is a microstructure of roughly 50% austenite and 50% ferrite.

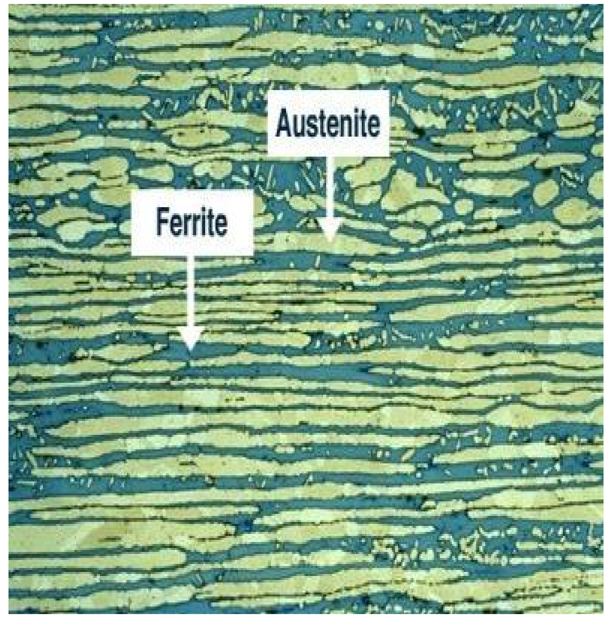


Fig 1.4 .*Duplex stainless steel microstructure*

## THE EFFECTS OF THE ALLOYING ELEMENTS

The alloying elements each have a specific effect on the properties of the steel. It is the combined effect of all the alloying elements and, to some extent, the impurities that determine the property profile of a certain steel grade. In order to understand why different grades have different compositions a brief overview of the alloying elements and their effects on the structure and properties may be helpful. The effects of the alloying elements on some of the important materials properties will be discussed in more detail in the subsequent sections. It should also be noted that the effect of the alloying elements differs in some aspects between the hardenable and the non-hardenable stainless steels.

## DRILLING

Drilling is a cutting process that uses a drill bit to cut a hole of circular cross-section in solid materials. The drill bit is usually a rotary cutting tool, often multipoint. The bit is pressed against the workpiece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the workpiece, cutting off chips (swarf) from the hole as it is drilled.In rock drilling, the hole is usually not made through a circular cutting motion, though the bit is usually rotated. Instead, the hole is usually made by hammering a drill bit into the hole with quickly repeated short movements. The hammering action can be performed from outside of the hole (top-hammer drill) or within the hole (down-the-hole drill, DTH). Drills used for horizontal drilling are called drifter drills.

## DRILL BITS

Drill bits are cutting tools used to remove material to create holes, almost always of circular cross-section. Drill bits come in many sizes and shape and can create different kinds of holes in many different materials.

Drill bits come in standard sizes, described in the drill bit sizes article. A comprehensive drill bit and tap size chart lists metric and imperial sized drill bits alongside the required screw tap sizes. There are also certain specialized drill bits that can create holes with a non-circular cross-section. While the term drill may refer to either a drilling machine or a drill bit for use in a drilling machine. In this article, for clarity, drill bit or bit is used throughout to refer to a bit for use in a drilling machine, and drill refers always to a drilling machine.

## CRYOGENIC COOLANT

In physics cryogenics is the study of the production and behaviour of materials at very low temperatures.Cryogenic coolant is the coolant whose temperature is below 0 degree celcius.It is not well defined at what point on the tempetature scale refrigeration ends and cryogenics begins, But scientists assume a gas to be cryogenic if it can be liquefied at or below -150°C

## CRYOGENIC FLUIDS

Cryogenic fluids contains very low temperatures and they were mostly use for cooling purposes and used as coolant in many machining processes.Some cryogenic coolant with their boiling points can be given as follows

| Fluid | Boiling point (K) |
|---|---|
| Helium-3 | 3.19 |
| Helium-4 | 4.214 |
| Hydrogen | 20.27 |
| Neon | 27.09 |
| Nitrogen | 77.36 |
| Air | 78.8 |
| Fluorine | 85.24 |
| Argon | 87.24 |
| Oxygen | 90.18 |
| Methane | 111.7 |

Table 1.1. *Cryogenic Fluids*

## TOPSIS

TOPSIS is one of the famous classical Multi-Criteria Decision Making (MCDM) method, which was initiated for the first time by Hwang and Yoon that shall be used with both normal numbers and fuzzy numbers.

Further more, TOPSIS is more applicable in that limited subjective input is required from decision makers. The only subjective input required is weights.

The TOPSIS procedure is shown in Figure in five main steps.

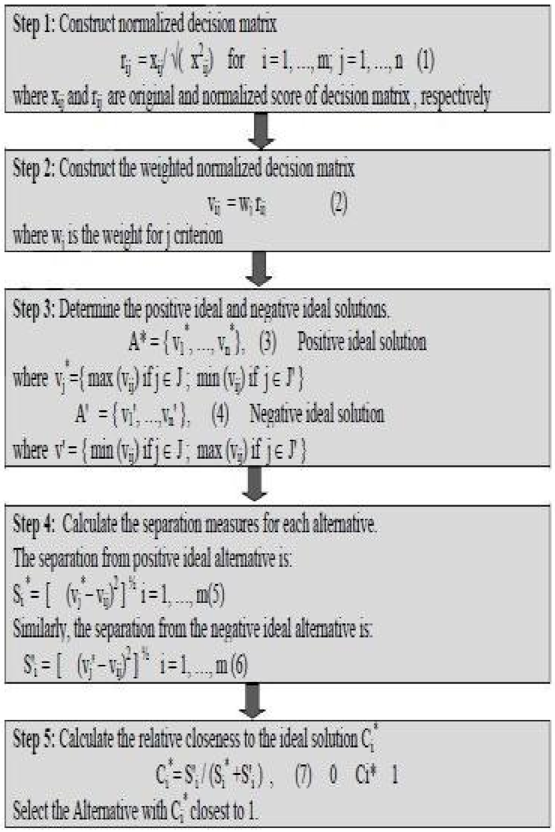


Fig1.15. *Procedure of TOPSIS method*

## EXPERIMENTATION PROCESS

## DRILLING OF HOLES

A 10 mm cabide tool is fixed on the vertical drilling machine and also the work piece duples steel 2205.Then the holes were made in the work piece as marked and the coolant is applied manually on the tool. Thus the required nine holes were drilled by changing the speed and feed values as required.

## MEASUREMENT OF TEMPERATURE

The temperature measurement is carried out by means of a thermocouple respective holes were made in the work piece to place the thermocouple and the temperature is measured

## COLLECTION OF CHIPS

Chips were collected for every drill made and they were placed in different packs for the further testing.

## READINGS

| Speed | Feed | Feed mm/min | Temp |
|---|---|---|---|
| 800 | 0.02 | 16 | 70.5 |
| 800 | 0.04 | 32 | 70.2 |
| 800 | 0.06 | 48 | 79.1 |
| 1000 | 0.02 | 20 | 85.5 |
| 1000 | 0.04 | 40 | 83.5 |
| 1000 | 0.06 | 60 | 80.2 |
| 1200 | 0.02 | 24 | 78.1 |
| 1200 | 0.04 | 48 | 80.1 |
| 1200 | 0.06 | 72 | 79.3 |

Table 5.1. *Temperature Readings*

## FORMULAS USED

i. Material removal rate(MRR)= $\frac{\pi D^2}{4} f$ $mm^3$/min

Where,

D – Drill diameter(mm)

F – Feed rate(mm/min)

ii. Normalized Material Removal Rate,N-NMRR = $\frac{MRR}{MRR_{avg}}$

iii. Normalized Temperature,N-Temp $= \frac{Temp}{Temp_{avg}}$

iv. Normalized Surface Roughness,N-Ra $= \frac{Ra}{Ra_{avg}}$

v. Closeness coefficient value,Ci $= \frac{D_{ij}^-}{D_{ij}^+ + D_{ij}^-}$

Where,

$D_{ij}^+$- Positive ideal distance

$D_{ij}^-$ -Negative ideal distance

vi. $D_{ij}^+ = \sqrt{\sum_{i=1}^{n} (S^+ - D_{ij})^2}$

Where,

$S_+$ =($Ra_{low}$,$MRR_{high}$,$Temp_{low}$)

vii. $D_{ij}^- = \sqrt{\sum_{i=1}^{n} (S^- - D_{ij})^2}$

Where,

$s^-$ = ($Ra_{high}$,$MRR_{low}$,$Temp_{high}$)

## RESULTS

| Speed | Feed | Feed mm/min | dia | MRR | Temp | Ra | N-MRR | N-Temp |
|---|---|---|---|---|---|---|---|---|
| 800 | 0.02 | 16 | 10 | 1256.6 | 70.5 | 1.9 | 0.123127 | 0.298788 |
| 800 | 0.04 | 32 | 10.02 | 2523.263 | 70.2 | 1.67 | 0.24724 | 0.297517 |
| 800 | 0.06 | 48 | 9.98 | 3754.736 | 79.1 | 1.64 | 0.367904 | 0.335236 |
| 1000 | 0.02 | 20 | 9.92 | 1545.719 | 85.5 | 1.96 | 0.151456 | 0.36236 |
| 1000 | 0.04 | 40 | 9.8 | 3017.097 | 83.5 | 2.08 | 0.295627 | 0.353884 |
| 1000 | 0.06 | 60 | 9.94 | 4655.873 | 80.2 | 1.93 | 0.456201 | 0.339898 |
| 1200 | 0.02 | 24 | 9.96 | 1869.851 | 78.1 | 1.63 | 0.183216 | 0.330998 |
| 1200 | 0.04 | 48 | 9.82 | 3635.309 | 80.1 | 1.99 | 0.356202 | 0.339475 |
| 1200 | 0.06 | 72 | 10.02 | 5677.341 | 79.3 | 2.01 | 0.556289 | 0.336084 |
| | | | | 10205.74 | 235.9529 | 5.624811 | | |

| N-Ra | WN-MRR | WN-Temp | WN-Ra | D+ | D- | Ci | RANK |
|---|---|---|---|---|---|---|---|
| 0.337789 | 0.020932 | 0.0986 | 0.168895 | 0.077451 | 0.026344 | 0.253811 | 8 |
| 0.296899 | 0.042031 | 0.098181 | 0.148449 | 0.052658 | 0.047214 | 0.472745 | 4 |
| 0.291565 | 0.062544 | 0.110628 | 0.145783 | 0.034371 | 0.057797 | 0.627088 | 3 |
| 0.348456 | 0.025747 | 0.119579 | 0.174228 | 0.077812 | 0.011704 | 0.130743 | 9 |
| 0.36979 | 0.050257 | 0.116782 | 0.184895 | 0.062527 | 0.029453 | 0.32021 | 7 |
| 0.343123 | 0.077554 | 0.112166 | 0.171561 | 0.034587 | 0.058635 | 0.628985 | 2 |
| 0.289788 | 0.031147 | 0.109229 | 0.144894 | 0.064377 | 0.04255 | 0.397934 | 6 |
| 0.35379 | 0.060554 | 0.112027 | 0.176895 | 0.048711 | 0.041112 | 0.457703 | 5 |
| 0.357345 | 0.094569 | 0.110908 | 0.178673 | 0.036097 | 0.074401 | 0.673326 | 1 |
| Min | 0.020932 | 0.098181 | 0.144894 | | | | |
| Max | 0.094569 | 0.119579 | 0.184895 | | | | |
| | | | | | | | |

## CONCLUSION

The following conclusions can be drawn from the results

i. The drilling parameters of Duplex stainless steel 2205 was studied and their surface roughness,Material Removal rate (MRR) were calculated.

ii. The calculation were made by following the TOPSIS method of decision making to find out the best one is found by using ranking in TOPSIS method.

iii. The usage of Cyogenic coolant increases the tool life by reducing the temperature during drilling process

## REFERENCE


N.R.Baddoo, Stainless steel in construction: a review of research, applications, challenges and opportunities, Journal of Constructional Steel Research 64(11) (2008)1199–1206.

J. Nomani et.al Machinability study of first generation duplex (2205), second generation duplex (2507) and austenite stainless steel during drilling process journal of Wear 304(2013)20–28

Practical guidelines for the fabrication of duplex stainless steel
Tool wear and machinability of HIPed P/M and conventional cast duplex stainless steels Jukka Paro et.al Wear 249 (2001) 279–284
Overview Super duplex stainless steels J.-O. Nilsson
Influence of Drilling Parameters for Thrust force in Friction Drilling of Aluminium 6061-T6 Alloy. T. Kanagaraju et.al international national conference on ICAIEA 2010 at C.E.G Anna University.
8. Work-hardening in the drilling of austenitic stainless steels S. Dolinsek et.al Journal of Materials Processing Technology 133 (2003) 63–70
9. Tool wear and failure in the drilling of stainless steel mauri routio et.al journal of material processing technology 52 (1995) 35-43