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# Experimental Investigation and Geometrical Effect on H11 in CNC Drilling With Coated and Uncoated Drill Bits

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**Abstract – H-11 steel is widely used for structural part and air craft landing gear. This part is mostly manufactured by turning operation. However, turning parameters could be affected by roundness and hardness of work pieces. Because it is important to be able to predict the geometrical tolerance to get more qualified materials. The aim of this project was to predict the exact roundness of internal bore in H11 material after the machining process. The purpose of this project is to study the factors, which are affecting the roundness and hardness and surface roughness of forged steel during the CNC machining process. Through this investigation it was identified that uncoated drill bits create higher surface roughness than coated drill bits. Hardness properties values in both drill bits were more are less same. While machining, the hardness changes both the drill bits give the equal changes. Through the CMM inspection the coated drill bits were less roundness error compared than without coated drill bits. Finally optimal control factor were found for CrAlN drill bit was for surface Roughness-A3(Speed -900)B1(Feed -0.03)C2(Peck Increment 1.0) and minimum hardness achieved -A1(Speed-600)B3(Feed 0.09)C2(Peck Increment 1.0) and then minimum roundness error were obtained- A3(Speed-900)B2(Feed 0.09)C1(Peck Increment 0.5).**

**Index Terms – Drill bit, CMM, CrAIN, Geometrical Tolerance.**

## 1. INTRODUCTION

Drilling is one of the basic machining process of making holes and it is essentially for manufacturing industry like automobile industry, medical industry, and aerospace industry. Especially drilling is necessary in industries for assembly related to mechanical fasteners. It is reported that around 55,000 holes are drilled as a complete single unit production of the AIR BUS A350 aircraft (3) Drilling of metals is increasing requirements for producing small products and more highly functional. With increasing demand for precise component production, the important of drilling processes is increasing rapidly. Because of the requirement of deeper and smaller holes required in the above said industries. It is required for drilling process technologies to achieve higher accuracy and higher productivity. There are several convectional and non-conventional manufacturing process by which drilling can be possible. Drilling using laser beam, electron's beam and electric discharge methods and also electrolytic polishing, electro chemical machining has been frequently used by industries and for experimental researches. However, for general application, conventional drilling process is preferred due to the higher economical benefits than other processes and also it has highly productivity than other non -convectional drilling processes. Physical vapor deposition ( PVD ) describes a variety of vacuum deposition methods used to deposit thin films by the condensation of a vaporized form of the desired film material onto various work piece surfaces (e.g., onto semiconductor wafers). 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 vapor deposition.

H11 steel is an important material with desirable properties, including high resisting in nature against wear and can be used for components which are subjected to severe abrasion, wear, high surface loading. Hence, H11 promises fruitful development for applications in the automobile sector due to its high strength. Turning is the most widely used process among all the machining processes. The increasing importance of turning operations is gaining new dimensions in the present industrial age, in which the growing competition calls for all the efforts to be directed towards the manufacture of machined parts economically and surface finish is one of the most critical quality measures in mechanical products. As the competition grows closer, the customer now has increasingly high demands on quality, making surface finish and tool wear which manufacturing industry. In a machining operation, selection of machining parameters is the most critical job (Nikolaos & Manolakos 2010).It requires a number of experiments and considerable knowledge to get optimum machining parameters for a particular machining operation. Recently, rapid developments in the manufacturing industry have increased the significance of machining processes. CNC turning is one of the most popular and efficient machining operations, with which, the high surface finish of work piece can be easily obtained. CNC turning is especially preferred in the machining of hardened steel (Diniz & Micaroni 2002).

1.2 Coating Deposition Techniques

There are many coating deposition techniques available. These techniques are divided into two common groups, metallic and non-metallic.

1.2.1 Physical Vapour Deposition (PVD)

Physical vapour deposition ( PVD ) describes a variety of vacuum deposition methods used to deposit thin films by the condensation of a vaporized form of the desired film material onto various work piece surfaces (e.g., onto semiconductor wafers). 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 vapor deposition.

1.2.2 Types of PVD Coating

1.2.2.1 Cathodic Arc Deposition

In which a high- power electric arc discharged at the target (source) material blasts away some into highly ionized vapour to be deposited onto the work piece

1.2.2.2 Electron Beam Physical Vapour Deposition

In which the material to be deposited is heated to a high vapour pressure by electron bombardment in "high" vacuum and is transported by diffusion to be deposited by condensation on the (cooler) work piece.

1.2.2.3 Evaporative Deposition

In which the material to be deposited is heated to a high vapour pressure by electrically resistive heating in "low" vacuum. Pulsed laser deposition: In which a high- power laser ablates material from the target into a vapour.

1.2.2.4 Sputter Deposition

In which a glow plasma discharge (usually localized around the "target" by a magnet) bombards the material sputtering some away as a vapour for subsequent deposition

1.2.3 Uses of Physical Vapour Deposition.

PVD is used in the manufacture of items, including semiconductor devices, aluminized PET film for balloons and snack bags, and coated cutting tools for metalworking. Besides PVD tools for fabrication, special smaller tools (mainly for scientific purposes) have been developed. They mainly serve the purpose of extreme thin films like atomic layers and are used mostly for small substrates. A good example is mini e-beam evaporators which can deposit monolayer's of virtually all materials with melting points up to 3500 °C. Common coatings applied by PVD are Titanium nitride, Zirconium nitride, Chromium nitride, Titanium aluminum nitride. [3] The source material is unavoidably also deposited on most other surfaces interior to the vacuum chamber, including the fixturing to hold the parts.

1.2.4 Testing PVD

Some of the techniques used to measure the physical properties of PVD coatings are: Calo tester: coating thickness test Nanoindentation: hardness test for thin-film coatings Pin on disc tester: wear and friction coefficient test Scratch tester: coating adhesion test

1.2.5 Merits

PVD coatings are sometimes harder and more corrosion resistant than coatings applied by the electroplating process. Most coatings have high temperature and good impact strength, excellent abrasion resistance and are so durable that protective topcoats are almost never necessary. Ability to utilize virtually any type of inorganic and some organic coating materials on an equally diverse group of substrates and surfaces using a wide variety of finishes. • More environmentally friendly than traditional coating processes such as electroplating and painting.

1.2.6 Demerits

Specific technologies can impose constraints; for example, line-of-sight transfer is typical of most PVD coating techniques, however there are methods that allow full coverage of complex geometries. • Some PVD technologies typically operate at very high temperatures and vacuums, requiring special attention by operating personnel.

1.2.7 Application

PVD coatings are generally used to improve hardness, wear resistance and oxidation resistance. Thus, such coatings use in a wide range of applications such as: • Aerospace • Automotive • Surgical/Medical • Dies and moulds for all manner of material processing • Cutting tools • Firearms • Optics • Watches • Thin films (window tint, food packaging, etc.)

## 2. WORK MATERIAL DETAILS

Work material –H11
Work material size–32 mm dia 20 mm thickness

### 2.1 CHEMICAL COMPOSITION

Table 2.1 Chemical properties

| C | Mn | Si | S | V | Cr |
|---|---|---|---|---|---|
| 0.33 | 0.20 | 0.80 | 0.03 | 0.30 | 4.75 |
| 0.42 | 0.50 | 1.2 | 1.2 | 0.50 | 5.5 |

### 2.2 PHYSICAL PROPERTIES

Table 2.2 Physical properties

| Properties Metric Imperial | Properties Metric Imperial | Properties Metric Imperial |
|---|---|---|
| Density | 7.81 G/CM$^3$ | 0.282 LB/IN |
| Melting Point | 1427$^0$C | 2600$^0$F |

### 2.3 Application

HDS11 tool steels are suitable for designing highly stressed structural parts such as aircraft landing gear.

## 3. TAGUCHI'S APPROACH

### 3.1 Introduction

Basically, experimental design methods were developed original fisher. However experimental design methods are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases, to solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The experimental results are then transformed into a signal– to – noise (S/N) ratio to measure the quality characteristics deviating from the desired values Usually, there are three categories of quality characteristics in the analysis of the S/N ratio, i.e., the–lower–better, the–higher–better, and the–nominal–better. The S/N ratio for each level of process parameter is compared based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio Furthermore, a statistically significant with the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. There are 3Signal-to-Noise ratios of common interest for optimization of Static Problems. The formulae for signal to noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment. Therefore a method of calculating the Signal-To-Noise ratio we had gone for quality characteristic.

They are

Smaller-The-Better, ,

Larger-The-Better

Nominal is Best

### 3.2 DESIGN OF EXPERIMENT

Table 3.1 Process parameters and their levels

| **Levels** | **Process parameters** | | |
|---|---|---|---|
| | **Spindle Speed (N) (rpm)** | **Feed ( f ) (mm/rev)** | **Peck increment(mm)** |
| 1 | 700 | 0.03 | 0.5 |
| 2 | 800 | 0.06 | 1.0 |
| 3 | 900 | 0.09 | 1.5 |

### 3.3AN ORTHOGONAL ARRAY L9 FORMATION (INTERACTION)

Table 3.2 An orthogonal array L9 formation (interaction)

| **TRIAL NO.** | **DESIGNATION** | **(A)SPEED (N) (rpm)** | **(B)FEED ( f ) (mm/rev)** | **C-Peck increment(mm)** |
|---|---|---|---|---|
| 1 | $A_1B_1C_1$ | 700 | 0.03 | 0.5 |

| | | | | |
|---|---|---|---|---|
| 2 | $A_1B_1C_2$ | 700 | 0.06 | 1.0 |
| 3 | $A_1B_1C_3$ | 700 | 0.09 | 1.5 |
| 4 | $A_1B_2C_1$ | 800 | 0.03 | 1.0 |
| 5 | $A_1B_2C_2$ | 800 | 0.06 | 1.5 |
| 6 | $A_1B_2C_3$ | 800 | 0.09 | 0.5 |
| 7 | $A_1B_3C_1$ | 900 | 0.03 | 1.5 |
| 8 | $A_1B_3C_2$ | 900 | 0.06 | 0.5 |
| 9 | $A_1B_3C_3$ | 900 | 0.09 | 1.0 |

3.4 EXPERIMENTAL DATA FOR H11 STEEL [CrAlN-Drill Bit]

Table 3.3 Experimental data for H11 STEEL-[CrAlN-Drill Bit]

| | DESIG NATION | (A)SPEED (N) (rpm) | (B)FEED ( f ) (mm/rev) | C-Peck increment(mm) | SURFACE ROUGHNE | HARDNESS HRB | OVALITY ERROR |
|---|---|---|---|---|---|---|---|
| 1 | $A_1B_1C_1$ | 700 | 0.03 | 0.5 | 1.280 | 88 | 0.007 |
| 2 | $A_1B_1C_2$ | 700 | 0.06 | 1.0 | 0.980 | 86 | 0.006 |
| 3 | $A_1B_1C_3$ | 700 | 0.09 | 1.5 | 1.016 | 86 | 0.003 |
| 4 | $A_1B_2C_1$ | 800 | 0.03 | 1.0 | 0.807 | 90 | 0.005 |
| 5 | $A_1B_2C_2$ | 800 | 0.06 | 1.5 | 1.005 | 88 | 0.004 |
| 6 | $A_1B_2C_3$ | 800 | 0.09 | 0.5 | 0.783 | 88 | 0.014 |
| 7 | $A_1B_3C_1$ | 900 | 0.03 | 1.5 | 1.154 | 87 | 0.001 |
| 8 | $A_1B_3C_2$ | 900 | 0.06 | 0.5 | 1.163 | 87 | 0.014 |
| 9 | $A_1B_3C_3$ | 900 | 0.09 | 1.0 | 2.151 | 88 | 0.007 |

3.5 EXPERIMENTAL DATA FOR H11 STEEL [HSS -Drill Bit]

Table 3.4 Experimental data for H11 STEEL-[HSS Drill bit]

| | DESIGNATI ON | (A)SPEED (N) (rpm) | (B)FEED ( f ) (mm/rev) | C-Peck increment(m m) | SURFACE ROUGHNES S | HARDNESS HRB | OVALITY ERROR |
|---|---|---|---|---|---|---|---|
| 1 | $A_1B_1C_1$ | 700 | 0.03 | 0.5 | 3.751 | 84 | 0.004 |
| 2 | $A_1B_1C_2$ | 700 | 0.06 | 1.0 | 1.179 | 88 | 0.033 |
| 3 | $A_1B_1C_3$ | 700 | 0.09 | 1.5 | 3.009 | 87 | 0.041 |
| 4 | $A_1B_2C_1$ | 800 | 0.03 | 1.0 | 3.458 | 87 | 0.022 |
| 5 | $A_1B_2C_2$ | 800 | 0.06 | 1.5 | 3.852 | 83 | 0.001 |
| 6 | $A_1B_2C_3$ | 800 | 0.09 | 0.5 | 2.565 | 90 | 0.016 |
| 7 | $A_1B_3C_1$ | 900 | 0.03 | 1.5 | 3.820 | 85 | 0.009 |
| 8 | $A_1B_3C_2$ | 900 | 0.06 | 0.5 | 3.786 | 90 | 0.002 |
| 9 | $A_1B_3C_3$ | 900 | 0.09 | 1.0 | 2.294 | 890 | 0.004 |

3.6 COMPARISION VARIOUS PROPERTIES OF BOTH DRILL BIT

1. SURFACE ROUGHNESS PROPERTIES

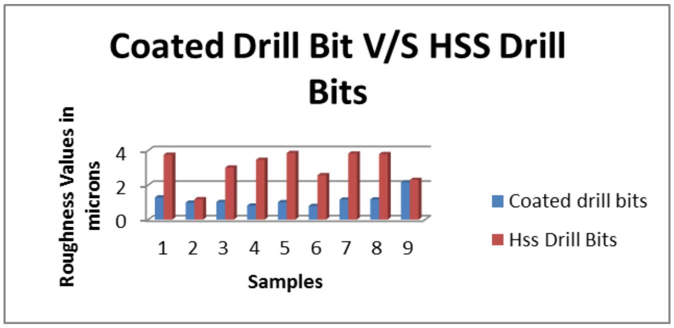


Figure 3.1 Surface Roughness Comparison

By observing the graph it is identified that un coated drill bits create higher surface roughness than coated drill bits.

2. MECHANICAL PROPERTIES HARDNESS

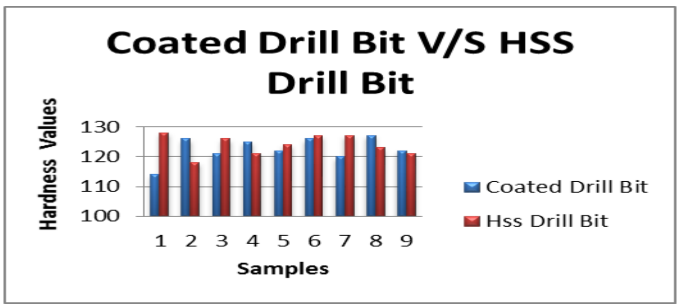


Figure 3.2 Hardness comparison

Hardness properties changes both drill bits are more are less same. While machining hardness changes in both the drill bits give the equal changes.

3. GEOMETRICAL PROPERTIES COMPARISION ROUNDNESS

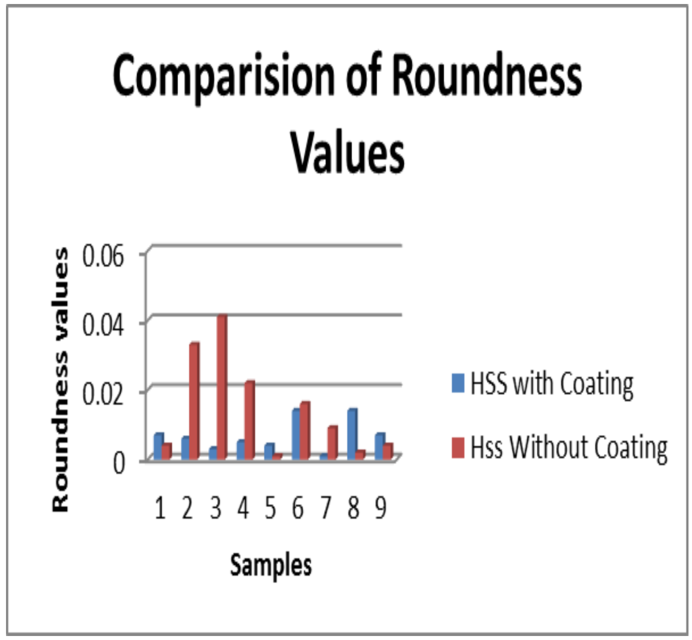


Figure 3.3 comparison of Roundness values

By observing the value the coated drill bits has less roundness error compared than without coated drill bit.

3.7 SURFACE ROUGHNESSES-CrAlN Drill Bit (ANALYSIS OF RESULT)

Table 3.5 S/N ratios values for the surface roughness

| S.no | DESIGNATION | (A)SPEED (N) (rpm) | (B)FEED ( f ) (mm/rev) | C-Peck increment (mm) | SURFACE ROUGHNESS Ra (µm) | S/N Response valve (db) for ROUGHNESS (Ra) |
|---|---|---|---|---|---|---|
| 1 | $A_1B_1C_1$ | 700 | 0.03 | 0.5 | 1.280 | -2.14420 |
| 2 | $A_1B_1C_2$ | 700 | 0.06 | 1.0 | 0.980 | 0.17548 |
| 3 | $A_1B_1C_3$ | 700 | 0.09 | 1.5 | 1.016 | -0.13787 |
| 4 | $A_1B_2C_1$ | 800 | 0.03 | 1.0 | 0.807 | 1.86253 |
| 5 | $A_1B_2C_2$ | 800 | 0.06 | 1.5 | 1.005 | -0.04332 |
| 6 | $A_1B_2C_3$ | 800 | 0.09 | 0.5 | 0.783 | 2.12476 |
| 7 | $A_1B_3C_1$ | 900 | 0.03 | 1.5 | 1.154 | -1.24412 |
| 8 | $A_1B_3C_2$ | 900 | 0.06 | 0.5 | 1.163 | -1.31159 |
| 9 | $A_1B_3C_3$ | 900 | 0.09 | 1.0 | 2.151 | -6.65281 |

3.8 ROUGHNESS RESPONSE FOR EACH LEVEL OF THE PROCESS PARAMETER OF H11 STEEL-CrAlN Drill bit

Table 3.6 Response Table for Surface roughness( Smaller is better)

| LEVELS | SPEED | FEED | PECK INCREMENT |
|---|---|---|---|
| 1 | -0.7022 | -0.5086 | -0.4437 |
| 2 | 1.3147 | -0.3931 | -1.5383 |
| 3 | -3.0695 | -1.5553 | -0.4751 |
| Delta | 4.3842 | 1.1622 | 1.0946 |
| Rank | 1 | 2 | 3 |

3.8.1 ANALYSIS OF VARIANCE (ANOVA)

Table: 3.7 Analysis of Variance results for the Roughness for drilling with coated drill bit

| Source | DOF | (SS) | AdjMS | F | P | % contribution |
|---|---|---|---|---|---|---|
| SPEED | 2 | 0.5992 | 0.2996 | 1.22 | 0.450 | 45 |
| FEED | 2 | 0.1283 | 0.0641 | 0.26 | 0.793 | 9 |
| PECK INCR | 2 | 0.1213 | 0.0607 | 0.25 | 0.802 | 9 |
| Error | 2 | 0.4905 | 0.2453 | | | 37 |
| Total | 8 | 1.3393 | | | | 100 |

S = 0.495234 R-Sq = 63.38% R-Sq(adj) = 0

3.9 HARDNESS –CrAlN Drill bit (ANALYSIS OF RESULT)

Table 3.8 S-N Ratio value for Hardness ( Smaller is better)

| | DESIG NATION | SPEED(N ) (rpm) | FEED ( f ) (mm/rev) | PECK INCREMENT | HARDNESS HRB | S/N) FOR HARDNESS |
|---|---|---|---|---|---|---|
| 1 | $A_1B_1C_1$ | 700 | 0.03 | 0.5 | 88 | -38.8897 |
| 2 | $A_1B_1C_1$ | 700 | 0.03 | 1.0 | 86 | -38.6900 |
| 3 | $A_1B_1C_2$ | 700 | 0.06 | 1.5 | 86 | -38.6900 |
| 4 | $A_1B_1C_3$ | 800 | 0.09 | 1.0 | 90 | -39.0849 |
| 5 | $A_1B_2C_1$ | 800 | 0.03 | 1.5 | 88 | -38.8897 |
| 6 | $A_1B_2C_2$ | 800 | 0.06 | 0.5 | 88 | -38.8897 |
| 7 | $A_1B_2C_3$ | 900 | 0.09 | 1.5 | 87 | -38.7904 |
| 8 | $A_1B_3C_1$ | 900 | 0.03 | 0.5 | 87 | -38.7904 |
| 9 | $A_1B_3C_2$ | 900 | 0.06 | 1.0 | 88 | -38.8897 |

3.10 HARDNESS RESPONSE FOR EACH LEVEL OF THE PROCESS PARAMETER OF H11 STEEL-CrAlN Drill bit

Table 3.9 Response Table for Hardness ( Smaller is better)

| Level | SPEED | FEED | PECK |
|---|---|---|---|
| 1 | -38.84 | -38.81 | -38.86 |
| 2 | -38.86 | -38.82 | -38.89 |
| 3 | -38.84 | -38.94 | -38.79 |

| | | | |
|---|---|---|---|
| Delta | 0.02 | 0.12 | 0.10 |
| Rank | 3 | 1 | 2 |

ANALYSIS OF VARIANCE (ANOVA)

Table 3.10 Analysis of Variance results for the Hardness

| Source | DF | Seq SS | Adj MS | F | P | % of contribution |
|---|---|---|---|---|---|---|
| SPEED | 2 | 0.5195 | 0.2598 | 0.07 | 0.932 | 4 |
| FEED | 2 | 2.1640 | 1.0820 | 0.31 | 0.766 | 17 |
| PECK | 2 | 2.7090 | 1.3545 | 0.38 | 0.723 | 22 |
| Error | 2 | 7.0805 | 3.5402 | | | **57** |
| Total | 8 | 12.2222 | | | | 100 |

S R-sq R-sq(adj) R-sq(pred) 1.88155 42.07% 0.00% 0.00%

3.11 ROUNDNESS ERROR (ANALYSIS OF RESULT)

Table 3.11 -N Ratio value for Roundness Error

| SL.NO | DESIG NATION | SPEED(N) (rpm) | FEED ( f ) (mm/rev) | PECK INCREMENT mm | ERROR | SNRA1 |
|---|---|---|---|---|---|---|
| 1 | $A_1B_1C_1$ | 700 | 0.03 | 0.5 | 0.007 | 43.0980 |
| 2 | $A_1B_1C_1$ | 700 | 0.06 | 1.0 | 0.006 | 44.4370 |
| 3 | $A_1B_1C_2$ | 700 | 0.09 | 1.5 | 0.003 | 50.4576 |
| 4 | $A_1B_1C_3$ | 800 | 0.03 | 1.0 | 0.005 | 46.0206 |
| 5 | $A_1B_2C_1$ | 800 | 0.06 | 1.5 | 0.004 | 47.9588 |
| 6 | $A_1B_2C_2$ | 800 | 0.09 | 0.5 | 0.014 | 37.0774 |
| 7 | $A_1B_2C_3$ | 900 | 0.03 | 1.5 | 0.001 | 60.0000 |
| 8 | $A_1B_3C_1$ | 900 | 0.06 | 0.5 | 0.014 | 37.0774 |
| 9 | $A_1B_3C_2$ | 900 | 0.09 | 1.0 | 0.007 | 43.0980 |

3.12 ROUNDNESS ERROR RESPONSE FOR EACH LEVEL OF THE PROCESS PARAMETER OF H11 STEEL

Table 3.12 Response Table for Roundness Error (smaller is better)

| Level | SPEED | FEED | PECK INCR |
|---|---|---|---|
| 1 | 46.00 | 49.71 | 39.08 |
| 2 | 43.69 | 43.16 | 44.52 |
| 3 | 46.73 | 43.54 | 52.81 |
| Delta | 3.04 | 6.55 | 13.72 |
| Rank | 3 | 2 | 1 |

ANALYSIS OF VARIANCE (ANOVA)

Table 3.13 Analysis of Variance (ANOVA) results for the Roundness Error

| Source | DOF | Sum of squares(S) | Adj MS | F ratio(F) | P value (p) | % of contribution |
|---|---|---|---|---|---|---|
| SPEED | 2 | 0.000010 | 0.000005 | 3.31 | 0.232 | 7 |
| FEED | 2 | 0.000027 | 0.000013 | 9.31 | 0.097 | 16 |
| PECK INCR | 2 | 0.000124 | 0.000062 | 43.00 | 0.023 | 75 |
| Error | 2 | 0.000003 | 0.000001 | | | 2 |
| Total | 8 | 0.000164 | | | | 100 |

## 4. CONCLUSION

In this experimental study, the Taguchi technique and ANOVA were used to obtain optimal drilling parameters in the drilling of H11 under dry conditions of both drill bits. By observing surface roughness value it is identified that uncoated drill bits create higher surface roughness than coated drill bits. Hardness properties changes while machining hardness changes in both of the drill bits give the equal changes. By comparing the value of the coated drill bits has less roundness error compared than without coated drill bit. The experimental results were evaluated using TAGUCHI&ANOVA. The following conclusion can be drawn and optimal control factor of Chromium Aluminium Nitrate drill bits.

OPTIMAL CONTROL FACTOR-CrAlN Drill bit

1.Surface Roughness-A1(Speed 700)B2(Feed -0.06)C3(Peck Increment 1.5)

2.Hardness –A3(Speed-900)B1(Feed 0.03)C2(Peck Increment 1.0)

3.Roundness Error- A3(Speed-900)B2(Feed 0.06)C1(Peck Increment 0.5)

PERCENTAGE OF CONTRIBUTION OF PROCESS PARAMETER

1. Surface Roughness-Speed-45%

2. Hardness –Peck Increment-73

3. Roundness Error- Peck Increment-22%

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