

# **Experimental Investigation and Roundness Error on D3 Steel in CNC Drilling Process by Using CrAlN Drill Bit**

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**ABSTRACT:** D3 steel is widely used for die components part. This part is mostly manufactured by turning operation. However, turning parameters could be affected by roundness and hardness of work pieces. It is used in the packaging, textiles, chemicals, leather, construction and heavy machinery manufacturing sectors. Particularly, in the manufacture of machine parts like gears, eccentric cam cylindrical of which is crucial, it has superseded many metals because it is important to be able to predict the geometrical tolerance to get more qualified materials. The aim of this project is to predict the exact roundness of internal bore in D3 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 High carbon steel during the CNC machining process. Through this investigation it was identified that un coated drill bits create higher surface roughness than coated drill bits. Hardness properties values in both drill bits were more or 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).

**KEYWORDS:** D3 steel, roundness, CNC machining process, CMM inspection and CrAlN drill bit.

## **I. 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 )

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

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. D3 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, D3 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 [1]. 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 [2].

## II. RELATED WORK

The behavior of a material is greatly dependent upon its surface, the environment and its operating conditions. Surface engineering can be defined as the branch of science that deals with methods for achieving desired surface requirements and behavior in service for engineering components. Engineering components must perform certain functions completely and effectively under various conditions, possibly in aggressive environments. Modern process environments, which contribute to wear, can be very complex, involving a combination of chemical and physical degradation. Surface properties of the component used in a particular working environment have to be designed with that environment in mind.

**P.Venkataramaiah** [3] et al has Investigated on the controllable parameters (cutting speeds, feed rates, type of drill tool, cutting fluids) of drilling operations with influence the response of (torque, cutting force, surface roughness, material removal rate, power) in En8. Drilling is undertaken HSS tool only, by using taguchi method. It consist of two phases artificial neural network (ANN) continued to that ANN is analyzed with S/N ratio of Taguchi approach. This work is useful in predicting the multi responses while cutting different materials in different drilling parameters.

**A. Navanth, T. Karthikeya Sharma** [4] A study of taguchi method based optimization of drilling parameter in dry drilling of al 2014 alloy at low speeds; International Journal of Engineering Sciences & Emerging Technologies, August 2013. International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-1, October 2012

**M. Montoya** [5] et al this paper aims to establish the wear mechanisms of coated and uncoated tungsten carbide drills when drilling carbon fiber reinforced plastics (CFRP)/aluminum alloy (Al) stacks. During the drilling experiments, thrust forces were measured. For both coated and uncoated drills, abrasion was the dominant tool wear mechanism, affecting the entire cutting edges higher wear was observed on uncoated tools which caused a significant increase in thrust force during drilling both Al and CFRP materials.

**Yogendratyagi** [6] et al In this paper the drilling of mild steel with CNC drilling machine by using a tool high speed steel by applying Taguchi methodology. A L9 array, taguchi method and analysis of variance (ANOVA) are used to formulate the procedure tried on the change of parameter. Design offers a systematic method for optimization surface finish as well as high material removal rate (MRR).

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**Turgaykivak** [7] et al this paper focuses on the optimization of drilling parameters using the Taguchi technique to obtain minimum surface roughness (Ra) and thrust force (Ff). A number of drilling experiments were conducted using the L16 orthogonal array on a CNC vertical machining centre. The experiments were performed on AISI 316 stainless steel blocks using uncoated and coated M35 HSS twist drills under dry cutting conditions. It was found that the cutting tool was the most significant factor on the surface roughness and that the feed rate was the most significant factor on the thrust force

**A.I. Fernández-Abia** [8] et al analyzed the market of turning tools is coped majority by hard metal tools with CVD coating. However, availability of tools with sharp cutting edges is essential in light turning of small parts. In this context, PVD process is optimum for obtaining sharp edges. Therefore, a methodology is presented to evaluate the performance of PVD advanced tools for turning of difficult to machine materials. Four coatings were tested: AlTiSiN (nACo®), AlCrSiN (nACRo®), AlTiN and TiAlCrN. The analysis was developed carrying out wear tests and analyzing different signals such as cutting forces, EDX analysis of inserts, part roughness and insert image analysis. Results indicate that the best coatings for turning of difficult to machine materials as austenitic stainless steels are nACo® and AlTiN coatings, since they offer the best performance.

**Mustafa Kurt** [9] et al the aim of the work reported here was to utilize Taguchi methods to optimize surface finish and hole diameter accuracy in the dry drilling of Al 2024 alloy. Although modern metal-cutting cutting speeds (30, 45, and 60 m/min), feed rates (0.15, 0.20, and 0.25 mm/rev), depths of drilling (15 and 25 mm), and different drilling tools (uncoated and TiN- and TiAlN- coated) with a 118° point angle. Confirmation tests with the optimal levels of machining parameters are carried out.

**A. Rivero** [10] et al As a result of the need to automate assembly in the aircraft industry. The main difficulties' in dry drilling are accelerated tool wear due to work piece. Dry drilling tests were performed using uncoated drills and two different coatings produced by means of an arc Evaporation PVD process. Experiments consisted of machining with a 10-mm diameter three-edged drill to produce 25-mm deep joining process in aircraft manufacturing .Tool wear evolution and burr size were analyzed, as well as the impact of the process parameters on torque, power, feed, force and tool temperature.

**Sonny Irawan** [11] et al has investigated on Drilling optimization aims to optimize controllable variables during drilling operation such as weight on bit and bit rotation speed for obtaining maximum drilling rate. From the research the constants that represented several drilling variables had been determined. The rate of penetration for the field had been predicted based on constants for every data vs. Depth. Finally, optimized weight on bit had been calculated for several data points. In the end, drilling simulator (Drill-Sim 500) was used to prove the results based on actual field data.

### III. PROPOSED TECHNIQUE

The principal properties required of a modern cutting tool material or a high production rate and high precision machining include good wear resistance, toughness, chemical stability under high temperature and large sliding forces and sufficiently high flow strength. It is not possible to achieve all these properties, some of which are mutually exclusive, in a single material. Techniques have been developed to exploit the beneficial properties of a number of materials in a single application. One effective technique is the coating of thin layers of one or more highly wear resistant materials such as TiC, TiN, Ti (N, C), Al<sub>2</sub>O<sub>3</sub> and Ti (N, C, O) on tough and strong substrates such as conventional Cemented Carbides reported by Chattopadhyay et al [12]. The earliest methods used for imparting increased surface hardness and wear resistance to cutting tools involved heat treatments, such as carburizing and nitriding, when the tools were essentially made of Carbon Steels and High Speed Steels. Coating of cutting tool has to have some characteristics of which some are shown below.

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## 1. Hardness:

A high surface hardness of the coating is one of the best ways to increase tool life. Generally speaking, the harder the material or surface, the longer the tool will last.

## 2. Wear Resistance:

This is the ability of the coating to protect against abrasion. Although a material may not be hard, elements and processes added during production may aid in the breakdown of cutting edges.

## 3. Surface Lubricity:

A high coefficient of friction causes increased heat, leading to a shorter coating life or coating failure. However, a lower coefficient of friction can greatly increase tool life.

## 4. Oxidation Temperature:

This is the point at which the treatment starts to break down. A higher oxidation temperature rating improves success in high heat applications have pointed out.

### 3.1. CMM

The typical 3 "bridge" CMM is composed of three axes, an X, Y and Z. These axes are orthogonal to each other in a typical three-dimensional coordinate system. Each axis has a scale system that indicates the location of that axis. The machine will read the input from the touch probe, as directed by the operator or programmer. The machine then uses the X, Y and Z coordinates of each of these points to determine size and position with micrometer precision typically.

A coordinate measuring machine (CMM) is also a device used in manufacturing and assembly processes to test a part or assembly against the design intent. By precisely recording the X, Y, and Z coordinates of the target, points are generated which can then be analyzed via regression algorithms for the construction of features. These points are collected by using a probe that is positioned manually by an operator or automatically via Direct Computer Control (DCC). DCC CMMs can be programmed to repeatedly measure identical parts, thus a CMM is a specialized form of industrial robot.

### 3.2. TAGUCHI APPROACH

Dr Genichi Taguchi is a Japanese quality management consultant who has developed and promoted a philosophy and methodology for continuous quality improvement in products and processes. Within this philosophy Taguchi shows how the statistical design of experiments (SDOE or DOE) can help industrial engineers design and manufacture products that are both of high quality and low cost. His approach is primarily focused on eliminating the causes of poor quality and on making product performance insensitive to variation.

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. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. [13] There are 3 Signal-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. [14] .They are,

1. Smaller-The-Better,
2. Larger-The-Better,
3. Nominal is Best.

#### 1. Smaller is better

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the smaller-is-better S/N ratio using base 10 log is:

$$S/N = -10 \cdot \log(S(Y^2)/n)$$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

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## 2. Larger is better

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the larger-is-better S/N ratio using base 10 log is:

$$S/N = -10 \cdot \log(S(1/Y^2)/n)$$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

## 3. Nominal is best

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the nominal-is-best S/N ratio using base 10 log is:

$$S/N = -10 \cdot \log(s^2)$$

Where s = standard deviation of the responses for all noise factors for the given factor level combination.

## IV. EXPERIMENTAL RESULTS

**Table 1 Experimental data for D3 STEEL**

	Designation	(A)Speed (N) (rpm)	(B)Feed ( f ) (mm/rev)	C-Peek increment(mm)	Surface Roughness	Hardness HRB	Ovality Error
1	A <sub>1</sub> B <sub>1</sub> C <sub>1</sub>	700	0.03	0.5	1.280	114	0.007
2	A <sub>1</sub> B <sub>1</sub> C <sub>2</sub>	700	0.06	1.0	0.980	126	0.006
3	A <sub>1</sub> B <sub>1</sub> C <sub>3</sub>	700	0.09	1.5	1.016	121	0.003
4	A <sub>1</sub> B <sub>2</sub> C <sub>1</sub>	800	0.03	1.0	0.807	125	0.005
5	A <sub>1</sub> B <sub>2</sub> C <sub>2</sub>	800	0.06	1.5	1.005	122	0.004
6	A <sub>1</sub> B <sub>2</sub> C <sub>3</sub>	800	0.09	0.5	0.783	126	0.014
7	A <sub>1</sub> B <sub>3</sub> C <sub>1</sub>	900	0.03	1.5	1.154	120	0.001
8	A <sub>1</sub> B <sub>3</sub> C <sub>2</sub>	900	0.06	0.5	1.163	127	0.014
9	A <sub>1</sub> B <sub>3</sub> C <sub>3</sub>	900	0.09	1.0	2.151	122	0.007

**Table 2 Experimental data for D3 STEEL**

	Designation	(A)Speed (N) (rpm)	(B)Feed ( f ) (mm/rev)	C-Peek increment(mm)	Surface Roughness	Hardness HRB	Ovality Error
1	A <sub>1</sub> B <sub>1</sub> C <sub>1</sub>	700	0.03	0.5	3.751	128	0.004
2	A <sub>1</sub> B <sub>1</sub> C <sub>2</sub>	700	0.06	1.0	1.179	118	0.033
3	A <sub>1</sub> B <sub>1</sub> C <sub>3</sub>	700	0.09	1.5	3.009	126	0.041
4	A <sub>1</sub> B <sub>2</sub> C <sub>1</sub>	800	0.03	1.0	3.458	121	0.022
5	A <sub>1</sub> B <sub>2</sub> C <sub>2</sub>	800	0.06	1.5	3.852	124	0.001
6	A <sub>1</sub> B <sub>2</sub> C <sub>3</sub>	800	0.09	0.5	2.565	127	0.016
7	A <sub>1</sub> B <sub>3</sub> C <sub>1</sub>	900	0.03	1.5	3.820	127	0.009
8	A <sub>1</sub> B <sub>3</sub> C <sub>2</sub>	900	0.06	0.5	3.786	123	0.002
9	A <sub>1</sub> B <sub>3</sub> C <sub>3</sub>	900	0.09	1.0	2.294	121	0.004

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## 4.1. COMPARISON VARIOUS PROPERTIES OF BOTH DRILL BIT 1. SURFACE ROUGHNESS PROPERTIES

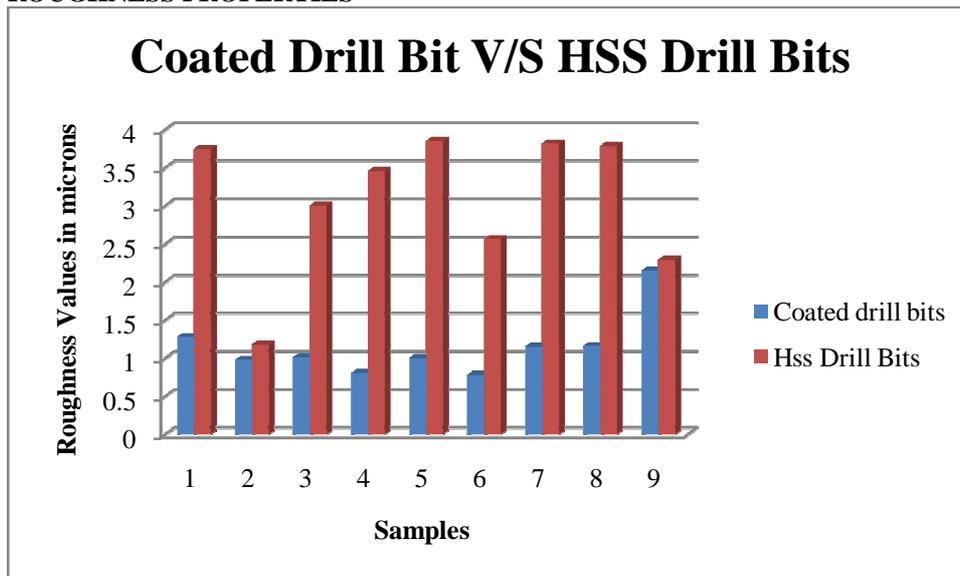


Figure 1 Surface Roughness Comparison

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

## 2. MECHANICAL PROPERTIES HARDNESS

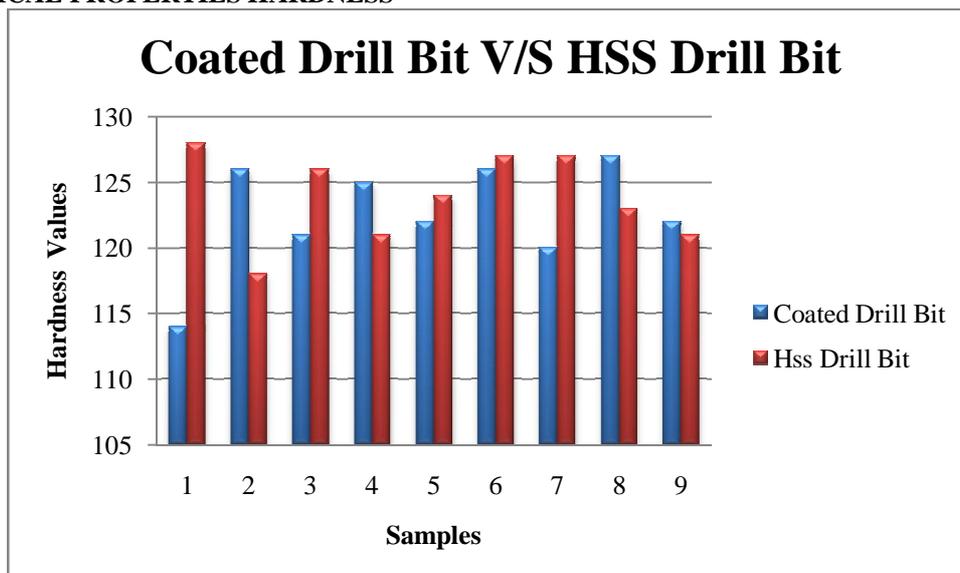


Figure 2 Hardness Comparison

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

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### 4. GEOMETRICAL PROPERTIES COMPARISON ROUNDNESS

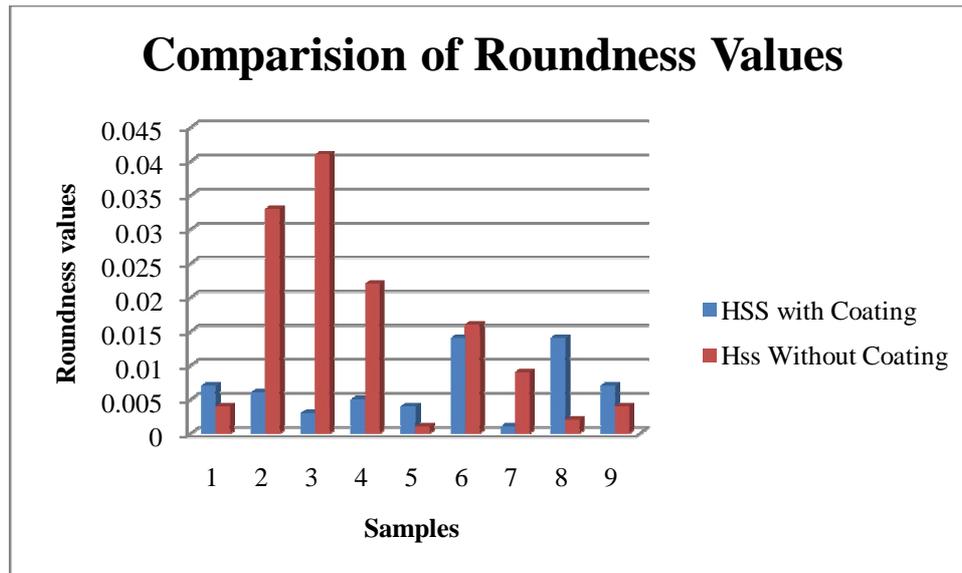


Figure 3 Comparison of Roundness values

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

### V. CONCLUSION

In this study, the Taguchi technique and ANOVA were used to obtain optimal drilling parameters in the drilling of D3 under dry conditions. Of both drill bits The experimental results were evaluated using TAGUCHI&ANOVA. The following conclusion can be drawn and optimal control factor of Chromium Aluminum Nitrate drill bits.

#### 5.1. Optimal Control Factor-CrAlN

1. Surface Roughness-A3 (Speed -900) B1 (Feed -0.03) C2 (Peck Increment 1.0)
2. Hardness -A1 (Speed-600) B3 (Feed 0.09)C2(Peck Increment 1.0)
3. Roundness Error- A3 (Speed-900) B2 (Feed 0.09)C1(Peck Increment 0.5)

#### 5.2. Percentage of contribution of process parameter

1. Surface Roughness-Speed-45%
2. Hardness –Peck Increment-73
3. Roundness Error- Peck Increment-75%

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