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Comparative Analysis of Coating Drilling Performance and Process Parameter Optimization on HCHCR

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Abstract: The metal cutting is very essential to try for high metal removing rate and the best product quality. The major problem in achieving high productivity and best quality is short life span of a tool. The methodology of Modified Taguchi optimization method for simultaneous minimization and maximization of Surface roughness (Ra), machining time and material removal rate of HCHCR steel affect the aesthetical aspect of the final product and hence it is essential to select the best combination values of the CNC drilling process parameters to minimize as well as maximize the responses. The experiments to be carried out by a CNC lathe, using physical vapour deposition coated Al-Cr-N ALCRONA coated and uncoated (HSS) drilling tool bit for the machining of HCHCR. By observing the output responses value minimum Roughness average, roundness error and Cylindricity Error is very low while using PVD coated drill bit. Diameter (circle) error slightly higher than uncoated drill bit. Coated drill bit is very suitable for many output responses compared than HSS drill bit. Through the medium speed and feed and higher pecking rate had been good performance were achieved by using coated drill bit.
Keywords: ***Dry drilling, Taguchi method, Analysis of Variance***

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 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.

A. Coating Deposition Techniques

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

B. 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 vapourized 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 vapour deposition.

II. EXPERIMENTAL WORK

The principal properties required of a modern cutting tool material for 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 Al-Cr-N on tough and strong substrates such as conventional Cemented Carbides reported. The earliest methods used for imparting increased surface hardness and wear resistance to cutting tools involved heat treatments, such as carburizing and nitriding.

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A. *Work Material Details*

Work material –HCHCR steel
Work material size–32 mm dia 20 mm thickness
All samples were heat treated through oil quenching process.

B. *Applications*

D3 Material is used in tooling applications requiring a high degree of accuracy in hardening, such as draw dies, forming rolls, powder metal tooling and blanking and forming dies and bushes.

III. ALCRONA (Al-Cr-N) COATED DRILL BIT

Alcrona (AlCrN), produced in the ANNOVA, is a Titanium free coating for broad application in machining and forming operations. Alcrona has remarkable wear resistance at lower speeds and feeds and under high mechanical loads. At higher speeds, where hot hardness and oxidation resistance are important, Alcrona excels, compared to Titanium based coatings, with an operating temperature up to 1,100°C.
Alcrona is applicable to HSS and carbide tooling and for forming and forging operations, as well as cutting operations. Alcrona has shown great results in machining a wide variety of hardened steels up to 54 HRC both with and without coolant as well as low alloy steels and high tensile steels.

A. *Milling Machine Set Up*

Fig: 1 Milling machine set up

BASIC SIZE
X- Axis 650
Y- 450
Z- 450mm
With forth axis rotary chuck size 200mm
Model 2011 –FANUC
SYSTEMS
Spindle speed 10 – 8000 rpm with 24 ATC. Rigid Tapping 4000 Rpm

IV. TAGHUCHI TECHNIQUE

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.

A. *Design Of Experiment*

Table: 1 Process parameters and their levels of both drill bit

LEVELS	PROCESS PARAMETERS		
	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm
1	600	0.02	1.5
2	700	0.04	3.0
3	800	0.04	4.5

B. *An Orthogonal Array L_9 Formation (Interaction)*

Table: 2 An orthogonal array L_9 formation (interaction) of both drill bit.

NO	DESIGNATION	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm
1	$A_1B_1C_1$	600	0.02	1.5
2	$A_1B_2C_2$	600	0.04	3.0
3	$A_1B_3C_3$	600	0.06	4.5
4	$A_2B_1C_2$	700	0.02	3.0
5	$A_2B_2C_3$	700	0.04	4.5
6	$A_2B_3C_1$	700	0.06	1.5
7	$A_3B_1C_3$	800	0.02	4.5
8	$A_3B_2C_1$	800	0.04	1.5
9	$A_3B_3C_2$	800	0.06	3.0

V. EXPERIMENTAL DATA ANALYSIS AND OPTIMIZATION

A. *Experimental Data Analysis And Optimization*

Table: 3 Experimental data and output response analysis

EXP	HSS				ALCRONA				MT
	RA	CL	RE	CY	RA	CL	RE	CY	
1	1.763	8.014	0.021	0.060	1.281	8.301	0.005	0.012	2.09
2	3.591	8.038	0.021	0.060	2.951	8.316	0.005	0.014	1.04
3	3.007	8.074	0.035	0.031	1.282	8.329	0.013	0.019	0.43
4	6.213	8.023	0.031	0.020	3.767	8.302	0.007	0.014	1.48
5	3.536	8.010	0.026	0.055	0.979	8.314	0.003	0.007	0.55
6	4.776	8.115	0.023	0.027	1.718	8.293	0.009	0.018	0.38
7	5.786	8.005	0.025	0.083	4.001	8.304	0.006	0.010	1.34
8	4.734	8.174	0.033	0.063	1.718	8.314	0.009	0.014	0.50
9	2.998	8.051	0.020	0.040	3.831	8.285	0.011	0.024	0.33

B. *Comparision Surface Roughness Hss Drill And Alcrona Drill*

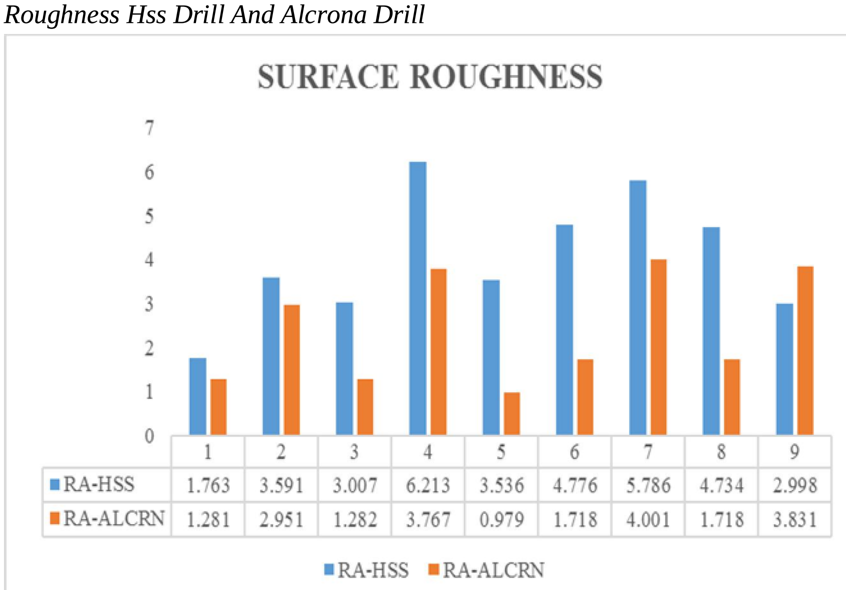
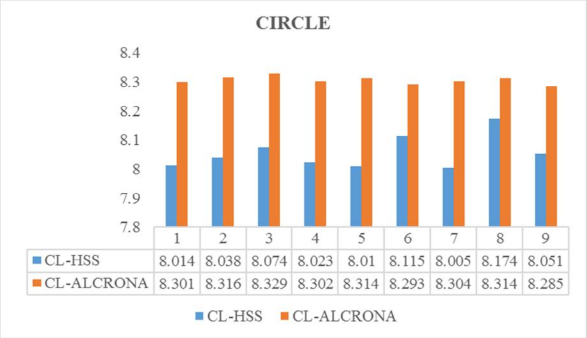


Fig: 2 Comparison surface roughness HSS drill and ALCRONA drill

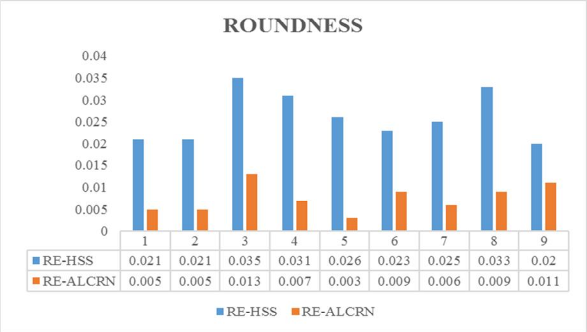
C. *Comparison Circle Error HSS Drill And ALCRONA Drill*



	1	2	3	4	5	6	7	8	9
CL-HSS	8.014	8.038	8.074	8.023	8.01	8.115	8.005	8.174	8.051
CL-ALCRONA	8.301	8.316	8.329	8.302	8.314	8.293	8.304	8.314	8.285

Fig: 3 Comparison circle HSS drill and ALCRONA drill

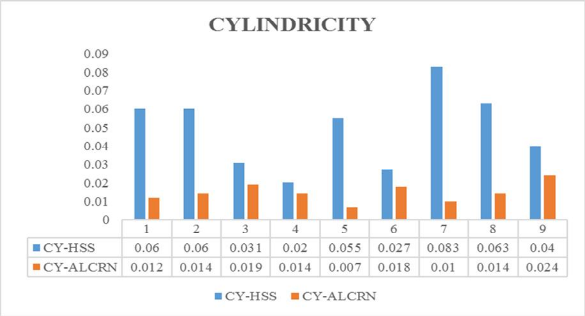
D. *Comparison Roundness Error HSS Drill and ALCRONA Drill*



	1	2	3	4	5	6	7	8	9
RE-HSS	0.021	0.021	0.035	0.031	0.026	0.023	0.025	0.033	0.02
RE-ALCRN	0.005	0.005	0.013	0.007	0.003	0.009	0.006	0.009	0.011

Fig: 4 comparison roundness HSS drill and ALCRONA drill

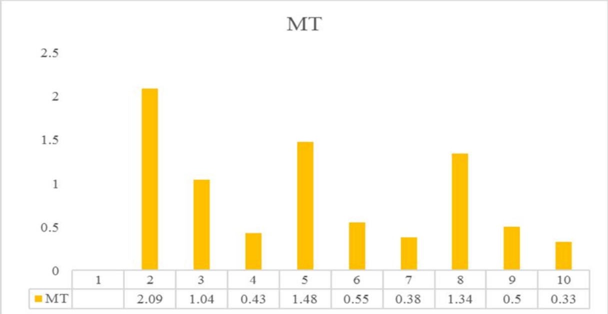
E. *Comparision Cylindricity HSS Drill and ALCRONA Drill*



	1	2	3	4	5	6	7	8	9
CY-HSS	0.06	0.06	0.031	0.02	0.055	0.027	0.083	0.063	0.04
CY-ALCRN	0.012	0.014	0.019	0.014	0.007	0.018	0.01	0.014	0.024

Fig: 5 comparison Cylindricity HSS drill and ALCRONA drill

F. *Comparision Machining Time HSS Drill and ALCRONA Drill*



	1	2	3	4	5	6	7	8	9	10
MT		2.09	1.04	0.43	1.48	0.55	0.38	1.34	0.5	0.33

Fig: 6 comparison machining time HSS drill and ALCRONA drill

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VI. RESULTS OBTAINED

By observing the output responses value minimum Roughness average, roundness error and Cylindricity Error is very low while using PVD coated drill bit. Diameter (circle) error slightly higher than uncoated drill bit.

A. RA (Analysis of Result)

Table: 4 RA and S/N RATIO Values for the Experiments

NO	DESIGNATION	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm	RA	SN-RAIO
1	$A_1B_1C_1$	600	0.02	1.5	1.281	-2.1510
2	$A_1B_2C_2$	600	0.04	3.0	2.951	-9.3994
3	$A_1B_3C_3$	600	0.06	4.5	1.282	-2.1578
4	$A_2B_1C_2$	700	0.02	3.0	3.767	-11.5199
5	$A_2B_2C_3$	700	0.04	4.5	0.979	0.1843
6	$A_2B_3C_1$	700	0.06	1.5	1.718	-4.7005
7	$A_3B_1C_3$	800	0.02	4.5	4.001	-12.0434
8	$A_3B_2C_1$	800	0.04	1.5	1.718	-4.7005
9	$A_3B_3C_2$	800	0.06	3.0	3.831	-11.6662

B. RA for Each Level of the Process Parameter

Table: 5 Response Table for Signal to Noise RA-Smaller is better

LEVEL	SPEED	FEED	PECKING
1	-4.569	-8.571	-3.851
2	-5.345	-4.639	-10.862
3	-9.470	-6.175	-4.672
Delta	4.901	3.933	7.011
Rank	2	3	1

Table: 6 Analysis of Variance for RA

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
SPEED	2	2.968	1.4842	2.49	0.287	24
FEED	2	1.987	0.9937	1.67	0.375	16
PECKING	2	6.086	3.0432	5.11	0.164	50
ERROR	2	1.192	0.5961			10
TOTAL	8	12.234				100

Regression Equation

RA = 2.392 - 0.554 SPEED_600 - 0.237 SPEED_700 + 0.791 SPEED_800 + 0.624 FEED_0.02- 0.509 FEED_0.04 - 0.115 FEED_0.06 - 0.820 PECKING_1.5 + 1.124 PECKING_3.0 - 0.305 PECKING_4.5

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C. *Diameter Error (Analysis of Result)*

Table: 7 Circle (Analysis of Result)

NO	DESIGNATION	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm	CL ERR	SNRA1
1	$A_1B_1C_1$	600	0.02	1.5	8.301	-18.3826
2	$A_1B_2C_2$	600	0.04	3.0	8.316	-18.3983
3	$A_1B_3C_3$	600	0.06	4.5	8.329	-18.4119
4	$A_2B_1C_2$	700	0.02	3.0	8.302	-18.3837
5	$A_2B_2C_3$	700	0.04	4.5	8.314	-18.3962
6	$A_2B_3C_1$	700	0.06	1.5	8.293	-18.3742
7	$A_3B_1C_3$	800	0.02	4.5	8.304	-18.3857
8	$A_3B_2C_1$	800	0.04	1.5	8.314	-18.3962
9	$A_3B_3C_2$	800	0.06	3.0	8.285	-18.3659

1) *Circle For Each Level of The Process Parameter*

Table: 8 Response Table for Signal to Noise Ratio- Circle Smaller Is Better

LEVEL	SPEED	FEED	PECKING
1	-18.40	-18.38	-18.38
2	-18.38	-18.40	-18.38
3	-18.38	-18.38	-18.40
Delta	0.01	0.01	0.02
Rank	2	3	1

Table: 9 Analysis of Variance of Circle

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
SPEED	2	0.000362	0.000181	1.01	0.497	26
FEED	2	0.000304	0.000152	0.85	0.540	22
PECKING	2	0.000387	0.000193	1.08	0.480	27
ERROR	2	0.000358	0.000179			25
TOTAL	8	0.001410				100

Regression Equation

CL = 8.30644 + 0.00889 SPEED_600 - 0.00344 SPEED_700 - 0.00544 SPEED_800 - 0.00411 FEED_0.02 + 0.00822 FEED_0.04 - 0.00411 FEED_0.06 - 0.00378 PECKING_1.5 - 0.00544 PECKING_3.0 + 0.00922 PECKING_4.5

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D. Roundness Error (Analysis of Result)

Table: 10 S/N RATIO Values for the ROUNDNESS

NO	DESIGNATION	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm	RE ERR	SNRA1
1	$A_1B_1C_1$	600	0.02	1.5	0.005	46.0206
2	$A_1B_2C_2$	600	0.04	3.0	0.005	46.0206
3	$A_1B_3C_3$	600	0.06	4.5	0.013	37.7211
4	$A_2B_1C_2$	700	0.02	3.0	0.007	43.0980
5	$A_2B_2C_3$	700	0.04	4.5	0.003	50.4576
6	$A_2B_3C_1$	700	0.06	1.5	0.009	40.9151
7	$A_3B_1C_3$	800	0.02	4.5	0.006	44.4370
8	$A_3B_2C_1$	800	0.04	1.5	0.009	40.9151
9	$A_3B_3C_2$	800	0.06	3.0	0.011	39.1721

1) Roundness For Each Level Of The Process Parameter

Table: 11 Response Table for Roundness - Smaller is better

LEVEL	SPEED	FEED	PECKING
1	43.25	44.52	42.62
2	44.82	45.80	42.76
3	41.51	39.27	44.21
Delta	3.32	6.53	1.59
Rank	2	1	3

Table: 12 Analysis of Variance- Roundness

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
SPEED	2	0.000008	0.000004	0.41	0.711	10
FEED	2	0.000054	0.000027	2.65	0.274	66
PECKING	2	0.000000	0.000000	0.01	0.989	0
ERROR	2	0.000020	0.000010			24
TOTAL	8	0.000082				100

Regression Equation
RE = 0.00756 + 0.00011 SPEED_600 - 0.00122 SPEED_700 + 0.00111 SPEED_800 - 0.00156 FEED_0.02 - 0.00189 FEED_0.04 + 0.00344 FEED_0.06 + 0.00011 PECKING_1.5 + 0.00011 PECKING_3.0 - 0.00022 PECKING_4.5

E. Cylindricity (Analysis Of Result)

Table: 13 CY and S/N RATIO Values for the Experiments

NO	DESIGNATION	SPINDLE SPEED (N) (RPM)	FEED (F) (mm/rev)	PECKING mm	CY	SNRA1
1	$A_1B_1C_1$	600	0.02	1.5	0.012	38.4164
2	$A_1B_2C_2$	600	0.04	3.0	0.014	37.0774
3	$A_1B_3C_3$	600	0.06	4.5	0.019	34.4249
4	$A_2B_1C_2$	700	0.02	3.0	0.014	37.0774
5	$A_2B_2C_3$	700	0.04	4.5	0.007	43.0980
6	$A_2B_3C_1$	700	0.06	1.5	0.018	34.8945
7	$A_3B_1C_3$	800	0.02	4.5	0.010	40.0000
8	$A_3B_2C_1$	800	0.04	1.5	0.014	37.0774
9	$A_3B_3C_2$	800	0.06	3.0	0.024	32.3958

1) CY for Each Level of The Process Parameter

Table: 14 Response Table for Signal to Noise CY-Smaller is better

LEVEL	SPEED	FEED	PECKING
1	36.64	38.50	36.80
2	38.36	39.08	35.52
3	36.49	33.91	39.17
Delta	1.87	5.18	3.66
Rank	3	1	2

Table: 15 Analysis of Variance for CY

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
SPEED	2	0.000014	0.000007	3.00	0.250	7
FEED	2	0.000145	0.000072	31.00	0.031	70
PECKING	2	0.000043	0.000021	9.14	0.099	21
ERROR	2	0.000005	0.000002			2
TOTAL	8	0.000206				100

Regression Equation

CY= 0.014667 + 0.000333 SPEED_600 - 0.001667 SPEED_700 + 0.001333 SPEED_800 - 0.002667 FEED_0.02 - 0.003000 FEED_0.04 + 0.005667 FEED_0.06 - 0.000000 PECKING_1.5 + 0.002667 PECKING_3.0 - 0.002667 PECKING_4.5

VII. CONCLUSION

This project addresses the issue of determining the effects of drilling parameters on the surface roughness and geometrical precision on drilling of HCHCR by using HSS, ALCRONA (Al-Cr-N) drilling cutting tool. The spindle speed, feed rate and Pecking were the factors while machining and geometrical were recorded as responds. The Taguchi Design was used to develop the model of this experiment and the analysis of the result was performed by using ANOVA. By observing the output responses value minimum Roughness average, roundness error and Cylindricity Error is very low while using PVD coated drill bit. Diameter (circle) error slightly higher than uncoated drill bit. Coated drill bit is very suitable for many output responses compared than HSS drill bit. Experimentally found fifth specimen (RPM -700) (Feed -0.04 mm/Rev) (PECKING 4.5) obtained good geometrical exactness and minimum Surface roughness finish. Through the medium speed and feed and higher pecking rate had been good performance were achieved by using coated drill bit. Hence, the result of the experiment were summarized and concluded as follows:

A. Optimal Control Factor For Alcrona Coated Tool

1) *Surface Roughness:* A_2 (RPM -700) B_3 (Feed -0.06 mm/Rev) C_1 (PECKING 1.5)
2) *Circular Error:* A_2 (RPM -700) B_3 (Feed -0.06 mm/Rev) C_1 (PECKING -1.5)
3) *Roundness Error:* A_2 (RPM -700) B_1 (Feed -0.02 mm/Rev) C_3 (PECKING-1.5)
4) *Cylindercity Error:* A_3(RPM -800) B_1 (Feed -0.02 mm/Rev) C_2 (PECKING -3.0)

B. Percentage Contribution Of Process Parameter

1) *Surface Roughness:* Pecking 50%
2) *Circular Error:* Pecking 27%
3) *Roundness Error:* Feed -66%
4) *Cylindercity Error:* Feed -70%

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