Experimental Investigation of Control Variable in Drilling of Titanium grade2 Using Taguchi Method

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Abstract: 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. Drilling is use in industry of the drilling of the material to produce require holes. Drilling can be done in different environment like with coolant and without coolant. Titanium is regarded as hard to machine materials. Titanium is a chemical element and is a lustrous transition metal with a silver colour, low density and high strength. Drilling of titanium can be done through carbide tip bit and High Speed Steel (HSS). In the present research work Drilling of Titanium (Ti) was performed with varying input control variables and its effect on the Burr Height was investigated. Minitab 17 software was used to perform the statistical analysis and obtain combination of the Optimum level parameter for minimum Burr Height.

Keywords: drilling, burrs, titanium, high speed steel drill bit, carbide tip drill bit

Introduction

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 (Todd, Robert H.; Allen, Dell K.; Alting, Leo,1994). This forces the cutting edge against the workpiece, cutting off chips (swarf) from the hole as it is drilled. Exceptionally, specially shaped bits can cut holes of non-circular cross-section; a square cross section is possible. Drilled holes are characterized by their sharp edge on the entrance side and the presence of burrs on the exit side (unless they have been removed) (Bralla, James G.1999). In addition, the inside of the hole usually has helical feed marks. **Carbides** are extremely hard, and can drill virtually all materials while holding an edge longer than other bits. The material is expensive and much more brittle than steels; consequently they are mainly used for drill bit tips, small pieces of hard material fixed or brazed onto the tip of a bit made of less hard metal (Stephen Ambrose Morse, 1863). However, it is becoming common in job shops to use solid carbide bits. In some industries, most notably PCB manufacturing, requiring many holes with diameters less than 1 mm, solid carbide bits are used. **High speed steel** (HSS) is a form of tool steel; HSS bits are hard, and much more resistant to heat than high carbon steel (Roberts, George 1998). They can be used to drill metal, hardwood, and most other materials at greater cutting speeds than carbon steel bits, and have largely replaced carbon steels. Drilling can be performed Aluminium, Brass, Copper, Wood, Titanium, Steel, Chromium, iron. **Coolant** is designed specifically for metalworking processes, such as machining and stamping (Hartness, James, 1915). The coolant should keep the workpiece at a stable temperature (critical when working to close tolerances). Very warm is acceptable, but extremely hot or alternating hot-and-cold are avoided, should maximize the life of the cutting tip by lubricating the working edge and reducing tip welding and it does not affect the properties of the tool and material (OSHA,1999). In the absence of the coolant temperature is not stable which leads to rise in the temperature of material and drill bit, properties of material and drill bit are affected, life of the cutting tip gets minimized and efficiency of the drilling process gets reduced (Smid, Peter 2010).

Figure 1: Drill done with the help of coolant

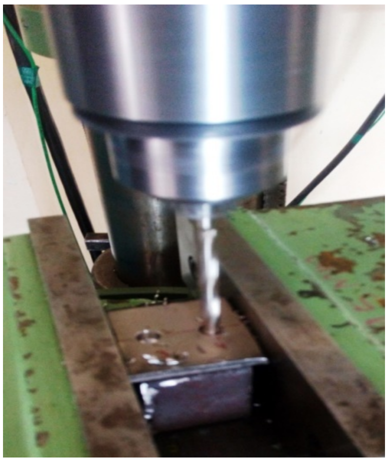

Figure 2: Drill done without the help of coolant

Methodology

For the present research work the experiment work was designed strategically using the DOE (Design of Experiment) statistical tool.

The **design of experiments** (**DOE**, **DOX**, or **experimental design**) is the design of any task that aims to describe or explain the variation of information under conditions that are hypothesized to reflect the variation (Dunn, Peter January 1997). The term is generally associated with true experiments in which the design introduces conditions that directly affect the variation, but may also refer to the design of quasi-experiments, in which natural conditions that influence the variation are selected for observation (Creswell, J.W. 2008). In its simplest form, an experiment aims at predicting the outcome by introducing a change of the preconditions, which is reflected in a variable called the predictor. The change in the predictor is generally hypothesized to result in a change in the second variable, hence called the outcome variable (Dr. Hani 2009). Experimental design involves not only the selection of suitable predictors and outcomes, but planning the delivery of the experiment under statistically optimal conditions given the constraints of available resources (Burman, Leonard E.; Robert W. Reed; James Alm 2010). Main concerns in experimental design include the establishment of validity, reliability, and replicability. **Orthogonal array testing** is a black box testing technique that is a systematic, statistical way of software testing. It is used when the number of inputs to the system is relatively small, but too large to allow for exhaustive testing of every possible input to the systems (Rao, Calyampudi Radhakrishna, 2009). It is particularly effective in finding errors associated with faulty logic within computer software systems. Orthogonal arrays can be applied in user interface testing, system testing, regression testing, configuration testing and performance testing. The permutations of factor levels comprising a single treatment are so chosen that their responses are uncorrelated and therefore each treatment gives a unique piece of information. The net effects of organizing the experiment in such treatments are that the same piece of information is gathered in the minimum number of experiments (Delius, Gustav W May 2004).

For this reason L4 array was selected and the following control input variable with different level has been used:-

Table No. 1: Input Control Variables and their levels

Input control Variables	**Levels**	
	Level 1	**Level 2**
Spindle Speed (RPM)	100	600
Cutting Tool Material	High Speed Steel (HSS)	Carbide
Drilling Environment (Dry/Wet)	Without Coolant (WTC)	With Coolant (WC)

In the above **Table No.1** the third input control variable i.e “Drilling Environment (Dry/Wet)” refers to the absence or presence of coolant during the Drilling Operation.

Therefore the above values of the selected controlled parameters were assigned to the L4 Orthogonal Array. The following table presents the same:

Table No.2: Control log of L4 Orthogonal Array

S.No	**Trial No.**	**Spindle Speed (RPM)**	**Drill bit**	**Coolant**	**Burr Height (mm)**
1	T1	R1	D1	WC	H1
2	T2	R2	D2	WTC	H2
3	T3	R3	D3	WTC	H3
4	T4	R4	D4	WC	H4

The output parameter measured was the **Burr Height**.

For this present research work **Titanium (Ti) grade2** was selected as specimen material.

Titanium is a chemical element with symbol **Titanium (Ti)** and atomic number 22. It is a lustrous transition metal with a silver colour, low density and high strength. It is highly resistant to corrosion in sea water, aqua regia, and chlorine (Andersson, N.; et al. 2003). Titanium can be alloyed with iron, aluminium, vanadium, and molybdenum, among other elements, to produce strong, lightweight alloys for aerospace (jet engines, missiles, and spacecraft), military, industrial process (chemicals and petro-chemicals, desalination plants, pulp, and paper), automotive, agri-food, medical prostheses, orthopedic implants, dental and endodontic instruments and files, dental implants, sporting goods, jewelry, mobile phones, and other applications(Donachie, Matthew J., Jr. 1988). Titanium is used in steel as an alloying element (ferro-titanium) to reduce grain size and as a deoxidizer, and in stainless steel to reduce carbon content (Sikka, S. K.; Vohra, Y. K.; Chidambaram, R. 1982).

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Table No. 3: Chemical composition of Titanium Grade 2

Component	C	Fe	H	N	O	Ti
Wt.%	Max 0.1	Max 0.3	Max 0.015	Max 0.03	Max 0.25	99.2

Table No. 4 Various properties of Titanium (Ti)

Physical property	Metric	Comments
Density g/cc	4.51	
Mechanical Property		
Hardness Rockwell B	80	
Tensile Strength, Ultimate (Mpa)	344	
Tensile strength, Yield (Mpa)	275 - 410	
Modulus of Elasticity (Gpa)	105	
Poisson's Ratio	0.37	
Fatigue Strength (Mpa)	300	1E+7 cycles, Unnotched
Shear Modulus (Gpa)	45	
Electrical Properties		
Electrical Resistivity (ohm-cm)	5.2e-005	
Thermal Properties		
Thermal Conductivity (W/m-K)	16.4	Annealed
Melting Point (°C)	Max 1665	Liquidus

Chemical Property

Titanium readily reacts with oxygen at 1,200 °C (2,190 °F) in air, and at 610 °C (1,130 °F) in pure oxygen, forming titanium dioxide. It is however, slow to react with water and air at ambient temperatures because it forms a passive oxide coating that protects the bulk metal from further oxidation. When it first forms, this protective layer is only 1–2 nm thick but continues to grow slowly; reaching a thickness of 25 nm in four years (Forrest, A. L. 1981).

Application of Titanium are Pigments, additives, coatings, Aerospace and marine, Industrial, Consumer and architectural, Jewellery, Medical and Nuclear waste storage.

Dimensions of specimen were: 40 X 40 X 5 mm

No. of specimens used were 16 pieces

Figure 3: Burr formed on Titanium (Ti)

Therefore the experiment where perform on the Titanium (Ti) Grade2 specimen with varying level of the controlled variables levels and Burr were formed with the significant Burr height. That was measured later on with the help of a micro meter.

Figure 4: Measuring Burr Height through Micro Meter

Results & Discussion

Table No.5: Various levels of Input control variables

Sr no.	Spindle Speed (RPM)	Drill bit	Coolant	Burr Height (mm)
1	100	HSS	WC	1.325
2	100	Carbide	WTC	2.995
3	600	HSS	WC	1.300
4	600	Carbide	WTC	2.050

Table No.6: Response Table

Level	Spindle Speed (RPM)	Drill bit	Drilling Environment
1	**-5.986**	**-7.882**	-2.362
2	-4.257	-2.362	**-7.882**
Delta	1.729	5.520	5.520
Rank	3	1.5	1.5

According to **Table No.6, first level** of Spindle speed (100RPM), **first level** of Drill bit (HSS) and the **second level** of Drilling Environment (without Coolant) was found to be **Optimum Combination** in order to achieve minimum Burr Height.

Table No. 7: ANOVA for obtained Observations

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Spindle Speed (RPM)	1	0.2352	0.2352	1.11	0.483
Drill bit	1	1.4641	1.4641	6.92	0.231
Error	1	0.2116	0.2116		
Total	3	1.9109			

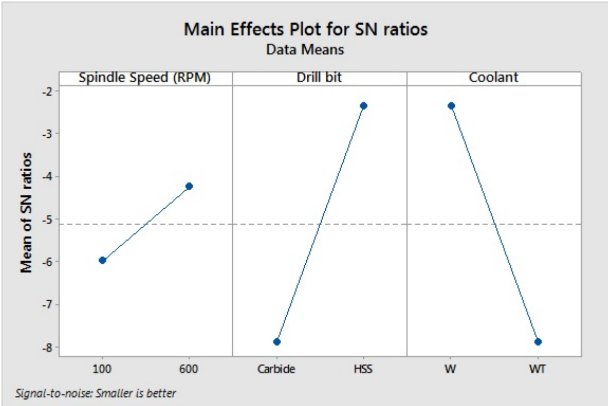

Figure 5: Main Effects plot for SN ratios

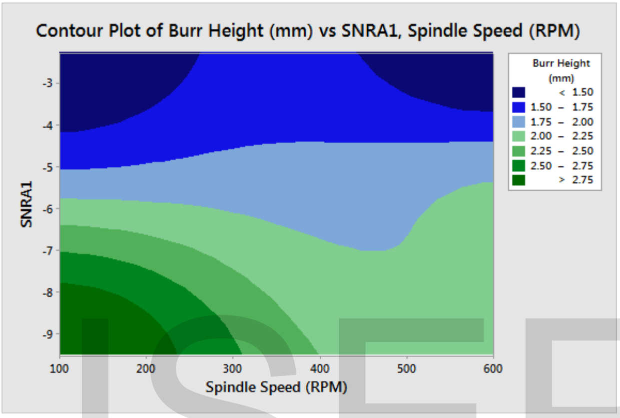

Figure 6: Contour Plot of Burr Height vs SNRA1, Spindle Speed

Table No. 8: Various levels of Input control variables

Sr no.	Spindle Speed (RPM)	Drill bit	Coolant	Burr Height (mm)
1	100	Carbide	WC	2.325
2	100	HSS	WTC	1.255
3	600	Carbide	WC	1.825
4	600	HSS	WTC	1.625

Table No.9: Response Table

Level	Spindle Speed (RPM)	Drill bit	Drilling Environment
1	-4.651	**-6.277**	**-6.277**
2	**-4.721**	-3.095	-3.095
Delta	0.070	3.182	3.182
Rank	3	1.5	1.5

According to **Table No.8, second level** of Spindle speed (600 RPM), **first level** of Drill bit (Carbide) and the **second level** of Drilling Environment (with Coolant) was found to be **Optimum Combination** in order to achieve minimum Burr Height.

Table No.10: ANOVA for obtained Observations

Analysis of Variance					
Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Spindle Speed (RPM)	1	0.004225	0.004225	0.02	0.906
Drill bit	1	0.403225	0.403225	2.13	0.382
Error	1	0.189225	0.189225		
Total	3	0.596675			

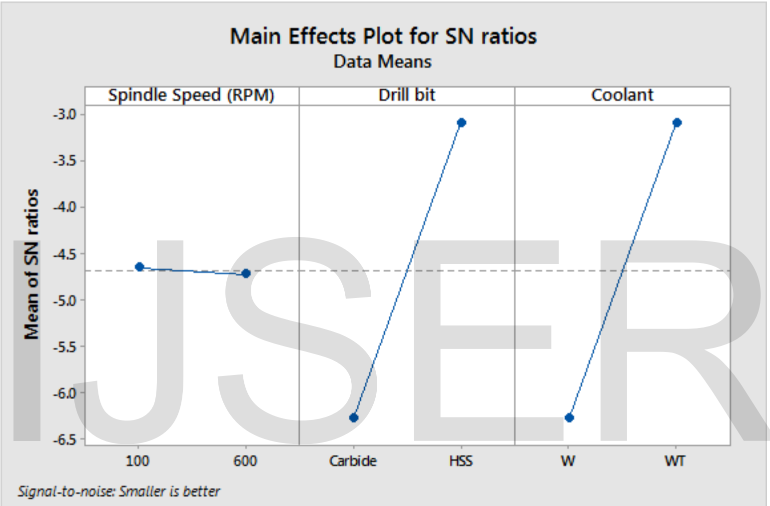

Figure 7: Main Effects Plot for SN ratio

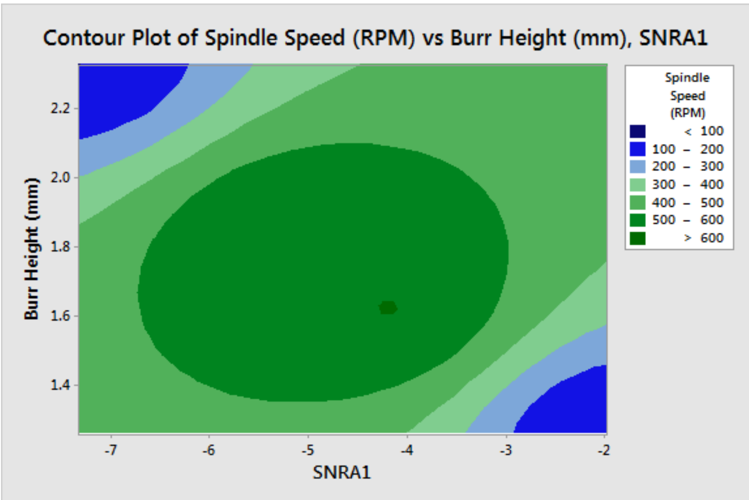

Figure 8: Contour Plot of Spindle Speed vs Burr Height, SNAR1

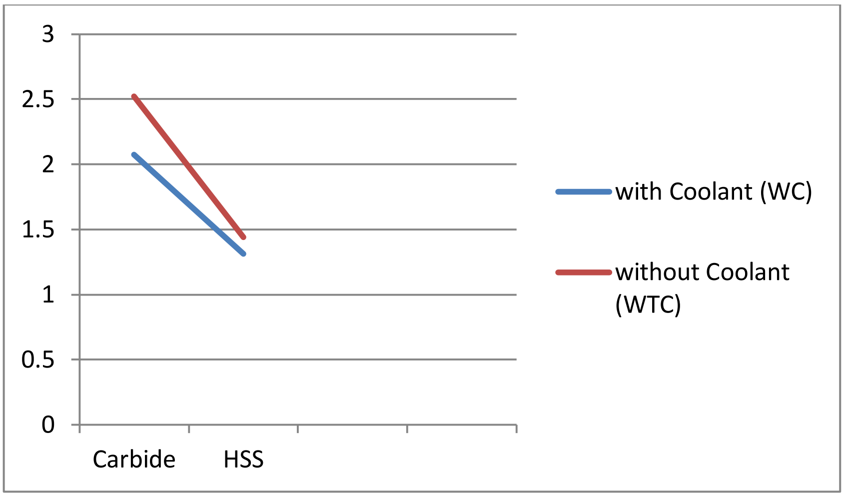

Figure 9: Comparision of the results obtained under the influence of different drill bits and Drilling Environment

Conclusion

- The present research work was performed at Tool Room Training Centre, Patna, Bihar, India.
- Drilling Operation was performed using two types of Drill bits, in two different Drilling Environment and at two different spindle speeds and Height of the formed Burrs was measured as the response data .
- Table No. 6 and 8 give the combinations of the Optimal Levels of the Input control variables in order to get the minimum Burr Height.
- ANOVA Tables (Table No. 7 and 10) conclude that there was no significant level of any of the input control variables that could affect the response data considerably

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