

# The Assessment of Delamination in the Drilling of EN8 Steel by using Taguchi Method

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**Abstract-** The application of EN8 steel is increased in engineering field particularly in textiles industries and automobile industries. Drilling of these material cannot be avoided to get the hole of required accuracy. The delamination occurs due to various parameters leading to poor machinability and surface finish. The aim of this paper is to study the relationships and parametric interaction between cutting parameters namely spindle speed, drill diameter and feed rate on the delamination factor at the exit of holes in drilling of EN8 steel. Delamination factor reduces the performance and aesthetical aspects of the final product [2, 11]. The experiments have been as per Taguchi's L<sub>27</sub> orthogonal array. Analysis of variance (ANOVA) was performed to verify the sufficiency of the mathematical model and it is used to find out the percentage contribution of each parameter, it shows that the delamination factor increase in feed rate and decrease in spindle speed.

**Keywords:** EN8 steel, Drilling, Delamination factor, ANOVA

## 1. INTRODUCTION

The application of EN8 steel is increased day by day especially textiles industries and automobile industries. EN8 is an unalloyed medium carbon steel. It is a medium strength steel, good tensile strength. Suitable for shafts, stressed pins, studs, keys etc. AISI 1040. Available as normalised or rolled. The chemical composition of EN8 is tabulated as given below

Table 1: Chemical composition of EN8 steel

Materials	Composition
Carbon	0.36-0.44%
Silicon	0.10-0.40%
Manganese	0.60-1.00%
Sulphur	0.050%
Phosphorus	0.050%

EN8 is a through-hardening medium carbon steel. Hardness of En8 never goes above approximately 30-35 HRC. It is low carbon steel and it can be toughened. The degree of smoothness and accuracy of the hole while drilling of EN8 steel is affected by the delamination tendency of the material. The delamination affects the aesthetic aspects, reduction of strength, resulting in poor assembling. Taguchi design of experiments which is used to find out optimal cutting parameters for drilling operation. The main objective of this paper is to understand the influence of drilling parameters, to construct a mathematical model and to analyse the delamination factor with respect to various cutting parameters such as feed rate, spindle speed, drill diameter.

## 2. EXPERIMENTAL DETAILS

### 2.1 Material

In this paper deals EN8 steel material. The mechanical properties of EN8 steel material is given below:

Table 2: Mechanical Properties of EN8 Steel

Properties	Values
Maximum stress	700-850 N/mm <sup>2</sup>
Yield stress	465 N/mm <sup>2</sup>
0.2% proof stress	450 N/mm <sup>2</sup>
Elongation	16%
Impact	28 J

### 2.2 Experimentation

In this paper high speed steel drill bits are used. Whose diameters are 6mm, 9mm, 12mm the drilling operations were carried in "Heavy duty universal radial and pillory type drilling machine". Delamination has been measured using different techniques. In this paper we are using inexpensive technique. Delamination is measured during drilling process using a video profile projector. The equipment's required for this technique are: video profile projector of 1/3 inch CCD video camera with high resolution tele-centric zoom lens. The magnification of 30-190 X is used. The specimen is placed directly on the top plate of the projector by means of imaging device, hole pictures are

captured and exported to 2D geometric measurement software and delamination values are calculated and tabulated [2].

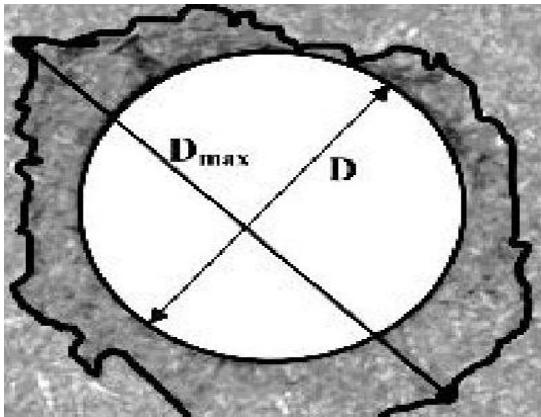


Fig.1 delamination zone

### 3. DESIGN OF EXPERIMENTS

Design of experiments (DOE) is a systematic method to determine the relationship between factors affecting a process and the output of that process [6, 14]. In this paper the factors are considered such as feed rate, spindle speed, drill diameter. DOE, which give well designed set of experiments.

#### 3.1 Experimental Parameters and Levels

The cutting parameters are feed rate, spindle speed, drill diameter these are influencing parameters which affects the delamination in drilling. The parameters and levels are set at three different levels, namely low, medium and high as shown in Table 3.

#### 3.2 Taguchi $L_{27}$ Orthogonal Array

In this paper we are using Taguchi  $L_{27}$  Orthogonal Array from which parameter values are derived and tabulated.

Table 4: parameters  
 Thus 27 experiments were conducted from which the delamination factor are measured and tabulated as above.

Test No	Parameter values			Delamination Factor $F_d$
	f mm/min	N Rpm	d mm	
1	100	500	6	1.02
2	100	500	9	1.04
3	100	500	12	1.05
4	100	1000	6	1.03
5	100	1000	9	1.05
6	100	1000	12	1.07
7	100	1500	6	1.05
8	100	1500	9	1.07
9	100	1500	12	1.09
10	300	500	6	1.13
11	300	500	9	1.15
12	300	500	12	1.16
13	300	1000	6	1.14
14	300	1000	9	1.15
15	300	1000	12	1.17
16	300	1500	6	1.18
17	300	1500	9	1.17
18	300	1500	12	1.19
19	500	500	6	1.24
20	500	500	9	1.26
21	500	500	12	1.28
22	500	1000	6	1.27
23	500	1000	9	1.32
24	500	1000	12	1.29
25	500	1500	6	1.26
26	500	1500	9	1.27
27	500	1500	12	1.29

Table 3: Parameters and levels

S.No	Parameters	Symbol	Units	Levels in Taguchi Design		
				Level I (Low)	Level II (Medium)	Level III (High)
1	Feed	F	mm/min	100	300	500
2	Spindle Speed	N	Rpm	500	1000	1500
3	Drill diameter	D	Mm	6	9	12

#### 4. RESULTS AND DISCUSSION

##### 4.1 Determination of the Regression model and Evaluation of Statistical

The Regression equation, ANOVA and Graph is generated by using Minitab software. The regression equation is give the relationship among feedrate, spindle speed tool diameter and delamination factor. The equation is given by,

$$\text{Delamination Factor } (F_d) = 0.923 + 0.000558 \text{ Feed Rate} + 0.000027 \text{ Spindle Speed} + 0.005 \text{ Tool Diameter}$$

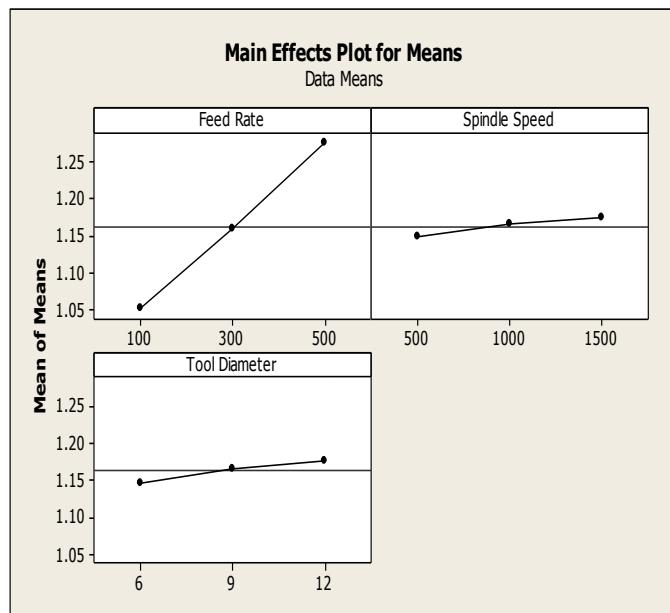
##### Regression Analysis

The goodness of fit was clarified by the determination coefficient ( $R^2$ ). In this study, the value of determination coefficient is 0.984 which is indicated that 2% of the total variations were not explained by the regression model. The adjusted determination coefficient is 0.982. So we noticed that the adjusted determination coefficient is very closer to the determination coefficient which means a good correlation between the responses and the experimental results.

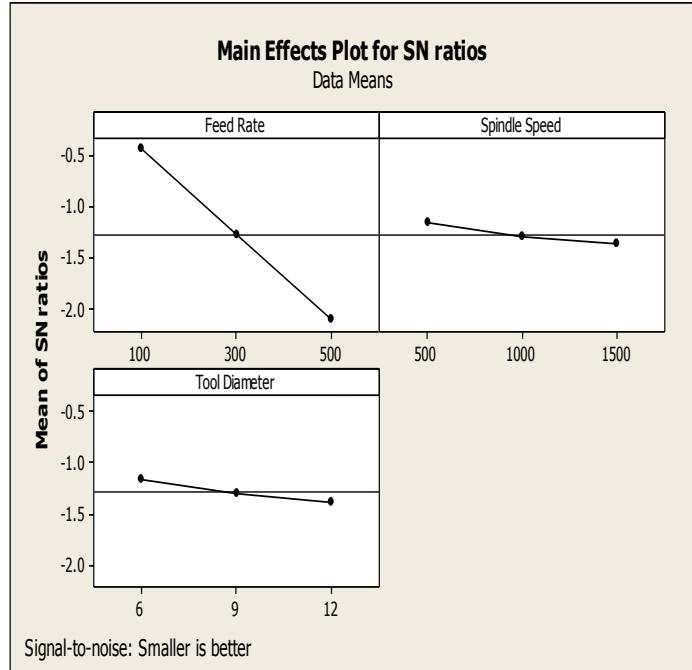
##### 4.2 Taguchi Analysis

This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulates the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter.

The crux of the orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment. The experiments were conducted and the delamination values were measured from which the following graphs were drawn by using Minitab software.



Graph 1: Mean Plot Graph



Graph 2: Signal to noise ratio Graph

Taguchi analysis is done as above we got signal to noise ratio graph and mean plot graph as shown in the figure. From which a major influencing factor is obtained such as feed rate. The second influencing factor is Tool diameter and the third influencing factor is Spindle Speed whose contribution is very less compared to other influencing factor

##### 4.3 Normal Probability plot Graph

The normal probability plot graph is obtained by using the regression equation and the experimental values. It is a graphical representation for assessing whether data set is normally distributed or not. The graph should give approximately in a line. So the errors are distributed normally.

#### 4.4 ANOVA

Analysis of variance (ANOVA) is a collection of statistical models used to analyse the differences among group means and their associated procedures. ANOVA was performed by the Minitab Software. Which give the effective values.

#### Regression Analysis

Table 5

Predictor	Coefficient	SE Coefficient	T	P
Constant	0.92343	0.01212	76.21	0.00
Feed rate	0.00055833	0.00001519	36.77	0.00
Spindle Speed	0.00002667	0.00000607	4.39	0.00
Tool Diameter	0.005000	0.001012	4.94	0.00

S=0.0128850	R <sup>2</sup> =0.984	R <sup>2</sup> (adj)=0.982
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#### 4.2 Taguchi Analysis: Response Table for Signal to Noise Ratios

Smaller is better

Table 6

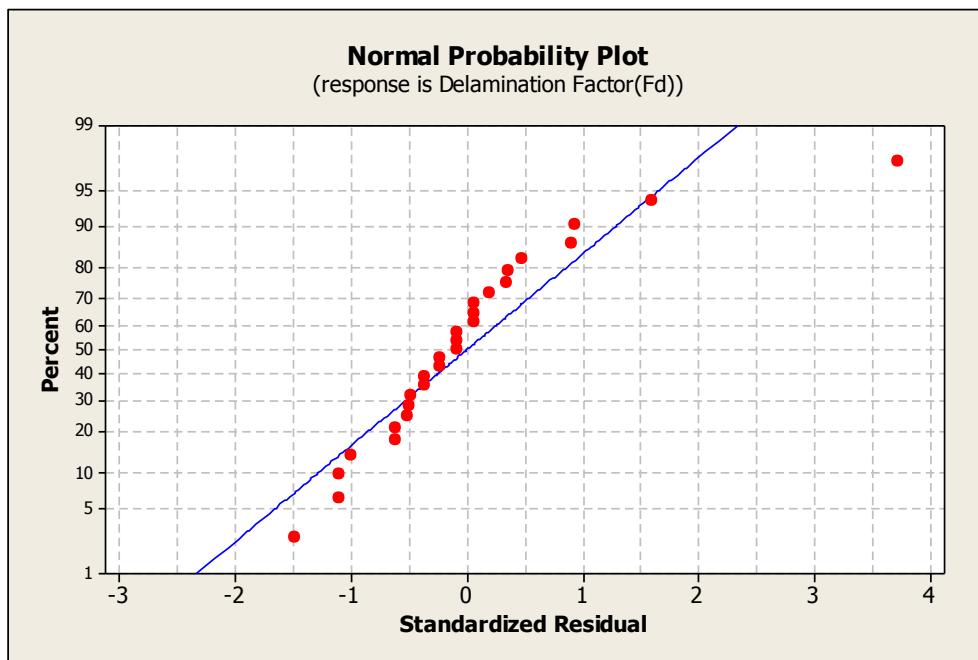
Level	Feed Rate	Spindle Speed	Tool Diameter
1	-0.4405	-1.1690	-1.1620
2	-1.2881	-1.2981	-1.2932
3	-2.1127	-1.3742	-1.3880
Delta	1.6722	0.2052	0.2278
Rank	1	3	2

#### Response Table for Means

Table 7

Level	Feed Rate	Spindle Speed	Tool Diameter
1	1.052	1.148	1.147
2	1.160	1.166	1.164
3	1.276	1.174	1.177
Delta	0.223	0.027	0.030
Rank	1	3	2

#### 4.3 Normal Probability plot Graph



Graph 3 Normal probability plot

#### 4.4. ANOVA TABLE

Table 8

Sources	DOF	SS	MS	F	P	% Contribution
Feed Rate	2	0.224541	0.112705	352.48	0.000	94.47
Spindle Speed	2	0.003319	0.0016595	5.21	0.016	1.43
Tool Diameter	2	0.004096	0.002048	0.16	0.852	1.72
Error	20	0.005733	0.0028665			2.48
Total	26	0.237689				100

#### 4.5. Confirmation Test

Table 9

Trial No	Feed Rate	Spindle Speed	Tool Diameter	Experimental Delamination	Predicated Delamination	% Error
1.	150	700	6	1.04	1.05	0.96
2.	350	1250	9	1.21	1.19	1.65
3.	450	1800	12	1.27	1.28	0.78

#### 5. CONCLUSION

In this paper, Taguchi Orthogonal is used to obtain the delamination factor in drilling process of EN8 steel. The following conclusions are done by this experiment

- In Regression analysis, the adjusted determination coefficient is very closer to the determination coefficient so evaluation of delamination factor is done by effectively and efficiently.
- Delamination factor increases with increase in feed and decrease in speed.
- Feed was found to be the first influencing factor for the delamination of EN8 steel followed by drill diameter.
- The normal probability plot graph is obtained in the form of straight line so the errors are distributed normally.

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