

# Optimization of Thrust Force and Torque During Drilling of Mild Steel by GRA Methodology

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**Abstract-** Drilling is a machining process through which a circular hole is created in the solid work piece. In this experiment, an attempt has been taken to minimize the Thrust forces and torque in the drilling of S275 mild steel of 100\*80\*3mm with the help of DOE (Design of Experiment) integrated with GRA (Grey Relational Analysis). For the optimization the controllable parameters are feed rate and spindle speed. For Data Acquisition system a 3-Component force sensor (Kistler 9027C) with charge amplifier (Type 5407A) is used. Drilling process was done by HSS twist drill of 1mm diameter. The resultant data was analyzed by Grey Relational Analysis to find out the optimal drilling condition. The result shows that the optimum condition is at 150 rpm speed and feed is 0.3 mm/rev.

**Key words:** Drilling process, Thrust force, Torque, Design of Experiment, GRA

## 1. Introduction

Drilling is a metal cutting operation used in various manufacturing industries. Drilling is a process through which cylindrical holes is generated in a work piece or enlarge the existing holes with the help of cutting tool called drill bit. Drilling process works at two mechanisms i.e. rotating motion of drill bit and feed motion given by hand feed or automatic feed. Optimization is a technique through which the quality of product is improved at the lower cost. The work piece material used in this experiment is S275 mild steel and the tool material is HSS twist drill. Feed rate and spindle speed is taken as input parameters. GRA (Grey Relational Analysis) is used to optimize the thrust force and torque. A 3-Component force sensor (Kistler 9027C) is used as data acquisition system. Gallih Bagus W. [1] have performed to minimize thrust force in drilling GFRP composite using Taguchi and Grey Relational Analysis. M. Ay [2] have performed to find out the significant factors for cutting force and surface roughness, when drilling of hybrid Aluminum Matrix composites. The result shows that for cutting force the spindle speed is 4500rpm and feed is 0.1 mm/rev. Booby O. P. Soepangkat [3] have performed to optimize the input parameters on the surface roughness, tool flank wear,

thrust force and torque in drilling EMS 45 steel by using Taguchi-grey method.

## 2. Experimental design

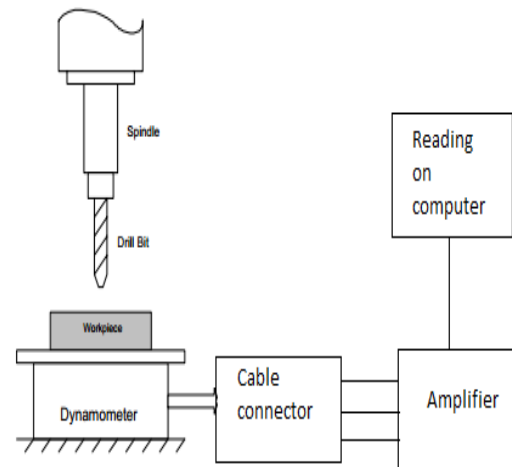


Chart 1: Experimental Setup

In this experiment S275 mild Steel material is used of dimension 100\*80\*3 mm and drill bit is HSS. The input parameters are spindle speed (80, 150 and 300 rpm) and feed rate (0.12, 0.2, 0.3 mm/rev). The output parameters are thrust force and torque which is to be optimized. For optimization, lower the better criteria are selected. Torque and thrust force was measured by 3-component force sensor (Kistler 9027C).



Chart 2: Work piece

Table 1: Parameters value

Factors	Units	Code	Level of Factors		
			1	2	3
Spindle Speed	Rpm	A	80	150	300
Feed Rate	mm/rev	B	0.12	0.2	0.3

### Design of Experiment

To find out the optimal condition of process parameter, a full factorial design was taken. The three-level design formula is 3<sup>k</sup> factorial design where k is factors. In this experiment there are two factors therefore the design of experiment is 3<sup>2</sup> = 9.

Table 2: Experimental Data

S.no	Speed(A)	Feed(B)	Thrust Force	Torque
1	2	3	108.36	272
2	2	2	119.21	352
3	1	3	127.00	380
4	3	1	223.00	482
5	2	1	241.00	431
6	1	1	328.00	340
7	3	2	225.00	232
8	1	2	329.68	308
9	3	3	226.42	341

### Optimization of drilling process

For the optimization of parameters, a grey relation analysis (GRA) is used. Firstly the experimental data is normalized to generate a grey relation grade. The normalized data for each of the thrust force and torque are given in Table 3. For the optimization of output parameters, lower the better criteria were selected. Grey relation coefficient for each performance parameters have been calculated by using the formula.

Step 1: Normalization of experimental results

$$xi(k) = \frac{\max yi(k) - yi(k)}{\max yi(k) - \min yi(k)}$$

Where Xi(k)= Value after Grey relational generation

Min Yi(k)= minimum of Yi(k) for k Response

Max Yi(k)= maximum of Yi(k) for k Response

Step 2: Grey relational coefficient

$$ei(k) = \frac{\Delta \min + \emptyset \Delta \max}{\Delta 0i(k) + \emptyset \Delta \max}$$

Where E is relational coefficient

Δ0i(k) =Difference between absolute value of Xo(k) and Xi(k)

Δmin and Δmax is minimum and maximum values of deviation sequence

Step 3: Grey Relational Grade

$$\gamma_i = \frac{1}{n} \sum_{k=1}^n \epsilon_i(k)$$

Table 3: Normalized data

Run order	Thrust force	Torque
1	1.000	0.840
2	0.951	0.520
3	0.916	0.480
4	0.482	0.000
5	0.401	0.204
6	0.008	0.568
7	0.473	1.000
8	0.000	0.696
9	0.467	0.564

**Table 4: Grey relation coefficient**

	Deviation		Grey relation coefficient	
	Thrust force	Torque	Thrust Force	Torque
1	0.000	0.160	1.000	0.758
2	0.049	0.480	0.911	0.510
3	0.084	0.592	0.856	0.458
4	0.518	1.000	0.491	0.333
5	0.599	0.796	0.455	0.386
6	0.992	0.432	0.335	0.536
7	0.527	0.000	0.487	1.000
8	1.000	0.30	0.333	0.622
9	0.533	0.436	0.484	0.534

**Table 5: Grade and Rank**

	Grade	Rank
1	0.879	1
2	0.710	3
3	0.657	4
4	0.412	9
5	0.420	8
6	0.436	7
7	0.743	2
8	0.478	6
9	0.509	5

### 3. Conclusion

The objective of this paper is to find out the optimum input parameters value, so that the thrust force and torque is to be minimized. From the grey relation method it shows that the optimum condition is spindle speed is 150rpm and feed is 0.3mm/rev.

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