Optimization of Thrust force, Surface roughness and Delamina-tion in drilling of EN-24 steel using Taguchi based VIKOR-Entropy Method

Heruthunnisa.Shaik, Ismail.Kakaravada

Abstract: The present article presents Taguchi based multi-response optimization for multi response during drilling of EN-24 steel under minimum quantity lubrication (MQL) condition. The Taguchi method is one of the most authoritative tool used in designing of the hole quality optimization. The intend of this paper is to explore the influence of cutting edge speed, drill feeding rate and effect of coating on drill tool upon the superficial integrity, thrusting force, and delamination factor during the procedure for drilling of EN-24 steel. The experiments were performed on the computer controlled vertical machining centre (VMC). The design of experiments (DOE) was based on L_{27} Taguchi's orthogonal array; the experiments were executed under minimum quantity lubrication used as mineral oil at a course rate of 60 ml/min. The selected machining parameters for drilling operation were spindle speed at 150, 350 and 550 rpm, drill feeding rate at 0.15 mm/rev, 0.25 mm/rev and 0.35 mm/rev and HSS (uncoated/coated with TiN and TiAlN) drills were used. The orthogonal array, the VIKOR-Entropy grade, and ANOVA were engaged to investigate for the prime machining parameter which optimizes the process. From the analysis of experimental consequences, it has been observed that the drill feeding rate is the most influencing parameter and the spindle rotating speed is the least impelling parameter. These results indicates the selection of optimal parameter for drilling of EN-24 steel without compromising the hole quality.

Keywords: Drilling, Orthogonal array, Multi-response optimization, VIKOR-Entropy, ANOVA.

I. INTRODUCTION

Drilling is the most widely machining processes in fabrication of components in various industries. These processes reports 40% total material removal processes in automotive and aerospace industries [1]. It can create a new hole or enlarge a new hole in a work piece by the motion drill bit. The various methods in drilling processes are in practice in current industries, such as conventional vertical drilling, deep hole drilling with larger radius and peck drilling. The choice of drilling processes depends up on requirement of production like the size, tolerance and surface finish required. The EN-24 alloy steel is very popular grade which is most suitable material for fabrication of heavy duty shafts and axles, gears, bolts and studs because of its superior tensile strength and wear resistance [2]. Quite a lot of factors impact the quality of drilled holes in conventional type of drilling during drilling of steel. In that the most observable one is the cutting parametric variants which includes the speed of the spindle speed and feed of the tool, feeding rate of the tool, drill nomenclature variable function like tool material, diameter of drill, and geometry and finally the cutting environments like dry, flooded and minimum quantity type cooling and cryogenic cooling. The selection properties of cutting speed and feed rates are deepens upon the mechanical and machining properties of work piece material. Kumar J.P. et al. [3] examined the stimulus of processes parametric variables over the output responses like MRR, tool wear, surface roughness and delamination in penetrating of OHNS material. High speed steel drill used for to conduct experimental investigation. Minitab 13 version software was used to analyze the effect of input parameter. The experiments substantiate that, feeding rate of the drilling machine and spindle speed rate are the most influencing factors on the output response characteristics. Çiçek.A et al [4] conducted experimental investigation on AISI 316 austenitic stainless steel and explored the consequence of deep cryogenic method of treatment of drill tool on the surface roughness of drilled hole. The experiment were conducted with various selected machining parameters like cutting speed and feed rates. L_8 orthogonal array was opted for conducting experimentation and numerous regression analyses was accomplished upfront to estimate extrapolative surface roughness of drilled hole. Jayabal.S and Natarajan.U [5] reported the effect of drilling parameters like cutting traversing speed, point angle at the joint and feed rate against the torque and thrust force during drilling of glass fiber reinforced composite. A mathematical model is generated for correlating of processes parameters and their interactions over the torque and thrust force. From the experimental results it is observed that tool feed rate and point angle of drill is the most influencing parameter on output responses in drilling. Raj.A.M et al. [6] investigated the drilling responses on AA6061/SiC/Graphite composite material with machining parameters as spindle speed, drill diameter, feed rate and type of drill upon surface roughness as response parameter. Response surface methodology (RSM) methodology adopted to find the optimal parameter for surface roughness. Kilickap.E et al [7] reported that the least value surface roughness was attain at inferior cutting speeds and also observed that increase in tool feed rate deteriorates surface of drilled hole during drilling of steel.

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And also it is conformed that surface roughness was much better under minimum quantity lubrication condition when compared to dry drilling process. Nalawade.P.S and Shinde.S.S [8] reported the effect of processes parameters on EN-31 alloy steel during drilling. The processes parameters were selected and optimized to obtain better surface finish and delamination factor. The experiments were accompanied through Taguchi L_9 orthogonal array with the processes parameters as speed of the spindle, feed rate quality, and type of tool and depth of cut given to the job. From the existing analysis work it is clinched that lower feed rate, higher spindle speed and uncoated is the optimal parametric variable functions to obtain better experimental results. Shivapragash.B et al. [9] studied to find the optimal drilling parameters like cutting speed, feed rate, and depth of cut during drilling composite Aluminium-TiB_2. The experimentation was conducted by following L_9 orthogonal array. For the multi response optimization Taguchi based grey relational analysis was to optimize the factors. From the results it has been found that for optimal experimental procedural run to minimize thrust force and surface roughness is feed rate at 1.5 mm/rev, higher spindle speed at 1000 rpm and depth of cut at 0.15 mm. Reddy.I.S [10] examined the influence of input parameters, such as point angle, feed rate and cutting speed over the surface roughness in drilling of AA6463 alloy. The experiments were conducted on computer numerical control vertical machining centre by using L_9 orthogonal array. For the mono response optimization Taguchi Signal and noise creation ratio (S/N) and analysis of variance function polynomial (ANOVA) has been emphasized to substantiate out the optimal drilling parameter. From the results, it was found that feed rate most significant parameter on the material removal rate and spindle speeds highest significant parameter on surface roughness. Murthy.B et.al [12] studied the consequences of process parameters like feed rate, drill diameter, point angle, material thickness and spindle speed generated during drilling of glass fiber reinforced polymer (GFRP) composite material by using solid carbide drill tool. Taguchi's Response Surface Methodology selected for conducting experimentation. From the result it was found that, thrust force is significantly effect by spindle speed. On other hand larger thrusting force and torque was observed at higher drill diameter, higher point angle drill increase the thrust force and lower the cutting torque decreases. Sundeep.M et al. [13] investigated drilling characteristics on Austenitic stainless steel (AISI 316) to investigate the influence of parametric variable function like like spindle speed drill diameter and feed rate. L_9 Taguchi array was used to conduct the investigation. rom the results it is stated that spindle speed plays the most significant role in material removal and surface finish in drilling. Kadam.K [2] has done an experimental analysis on drilling on EN-24 steel by considering input parameter spindle seed, drill diameter and feed rate. The experiments were conducted by means of Taguchi L_9 array with uncoated M32 HSS drill under dry condition. S/N ratio was employed to get optimal parameter for considered each mono response. The analysis results exhibit that, cutting speed was the most significant factor on tool life and surface roughness of hole during drilling of steel. Rane V.N. et al [14] studied the effectual consequences of machining parameters on hardened boron steel by using feed rate, point angle and cutting speed as input parameters. Taguchi L_{16} orthogonal array has been followed to perform the experiment. ANOVA was performed to find out effects of each control factors over the surface roughness. the results depicted that point angle was the main significant factor on surface roughness quality of the work done, drill impending rate has significant role in tool wear during drilling processes. Ismail. Kakaravada et.al [15] investigated the effect of drill diameter, % of reinforcement, spindle speed during drilling of A356-TiB_2/TiC in-situ composite. Taguchi L_{16} orthogonal array has opted to perform the experiments to evaluate surface roughness, delamination and material removal rate. Finally Entropy- VIKOR grade method was opted to combine the multi response optimization. From the its is stated that moderate reinforcement, higher spindle speed and greater drill diameter is optimal machining condition for composite.

The current aims to presents a well-organized approach for the optimization of multiple responses in drilling of EN-24 steel based on the Taguchi's method. The drilling experiments were performed on EN-24 steel plate by using uncoated high-speed steel drill as well coated with TiN and TiAlN through physical vapor deposition method under minimum quantity lubrication condition. The experiments were conducted with considerable machining parameters such as speed of the machinery spindle, tool penetration rate, tool type were optimized with estimated of multiple responses like surface texture, thrusting force and delamination proportion of drilled hole. The novel VIKOR-Entropy method was adopted to combine and optimize the multi responses. The analysis of variance polynomial function (ANOVA) was performed for VIKOR-Entropy grade to determine the most significant parameter to affects the drilling responses.

II. EXPERIMENTAL PROCEDURAL DETAILS

In the current experimental investigation, 10 mm diameter of holes was drilled on EN-24 grade alloy steel flat with the dimensions of 150×50×15 used in automobile industry. The chemical composition of EN-24 steel flat as shown in Table.1

Table.1: Chemical composition of EN-24 alloy steel

Component	C	Si	Mn	S	P	Cr	Mo	Ni
% age	0.44	0.35	0.70	0.040	0.035	1.400	0.35	1.70

The drilling trials were led by gradually varying the cutting edge speeds from 150 to 550 rpm and drill bit feeding rates from 0.15 to 0.35 mm/rev. The cutting tools used for the minimum quantity lubrication condition at a flow rate of 60 ml/min (mineral oil) drilling are HSS drill (Make: Addison Tools India Ltd), TiAlN Black Coated-KC7325 Grade HSS drill, TiN Golden coated – WU25PD Grade HSS drill (Make: Kennametal drill tools). The machining parameters and their levels are shown in Table 2.

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Experiment trails are piloted to examine the predominant effect of the epitomic drilling procedural parameter and drill bit type on the surface quality texture, thrust force and delamination value deviation/damage of the work piece material.

2.1. Machining setup

The experiments were carried out by using VMC 850 CNC vertical milling machine (Jyothi CNC automation Limited) as shown in figure 1. The thrust force was measured during drilling of EN-24 steel through Kistler multi-component dynamometer (Model: 9255C with multi charge amplifier). The surface integrity value R_a measured by using of SJ210 stylus type surface roughness tester (Mitutoya Make, 0.001μm) with measuring length of 7 mm. For better outcomes, average of any predetermined three values was found. The delamination factor of hole was measured by using Metallurgical microspore with 1000 X magnifications and 1mm resolution (Metzger Optical Instruments Private Limited, Mathura, India).

2.1.1. Measurement of Thrust force

The thrust force generated during drilling of EN-24 steel was recorded by using of a piezoelectric multi-component dynamometer. The multi charge amplifier (Model: 5070A with eight channel charge amplifier was connected to USB data acquisition system (Model: 5697A) used to record the data for analyzing with appropriate dynaware software. From the response graph of the drilling processes divided three stages according to the drill cutting edge position with respective to the plate. At entry stage, initially there is no contact of chisel edge with the work piece during drilling due to this there is no cutting force was recorded. As well it will come full engage of chisel of drill to the work piece the maximum thrust force was recorded. When it will come to the exit of chisel edge of drill large amount of fluctuation and sudden decrement in thrust force was observed. The average value of thrust force was recorded by dynamometer was considered for analysis.

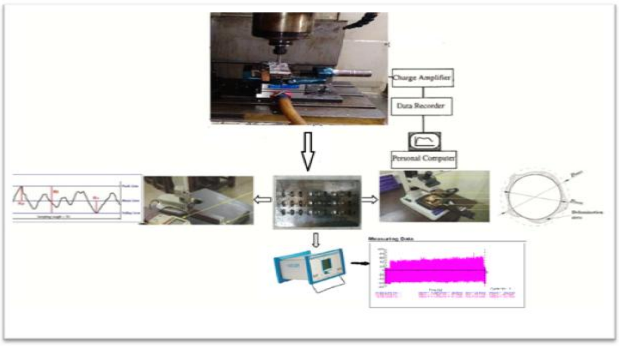

Figure.1: Schematic diagram of experimental set up.

2.1.2. Measurement of Surface Roughness

Mathematical average means surface roughness quality and its incremental analysis (R_a) is the arithmetic average elevation of peak and valley values in the direction of the work/job pertaining to the horizontal-axis and magnitude pertaining to the vertical-axis of the work from the mean line of axis considered for the purpose of the experimental set up. Simply, R_a is the average measurements of a surfaces peak heights and valleys Equation 1.

$$R_a = \left(\frac{1}{l}\right)\int_0^l |Z(x)| dx \tag{1}$$

Most of the automobile industries prefer the average surface roughness value (R_a) of hole. The average values are considered for the analysis during the experimentation. It is measured by Mitutoya SJ- 210 stylus type surface roughness tester, and an average of three replicates was found out R_a value varies with respect to stylus probe movement along the cross section of drilled hole.

2.1.3. Measurement of Delamination

Drilling of EN-24 steel involves damages of edges of hole at the entry diameter of hole and the exit diameter of the drilled hole due drill tool wear in drilling operation is designated as the delamination factor. As a quantitative relation of exit the process of delamination, the inferior surfaces of each hole were examined by a metallurgical microscopic apparatus. The delamination factor was estimated as per the below substantiated ratio using Equation 2.

$$D_f = \frac{D_{max}}{D_{min}} \tag{2}$$

III. OPTIMIZATION AND MODELING

In the present analysis, three drilling parametric functional variables were used as regulators establishing the response factors for the drilling experiment, and each machining parametric variable having three predominant levels. The input drilling parameters and their levels elected for the experimental design procedure are presented in Table 2.

Table: 2. Speed of the machine spindle, Feed ratio and Tool type used for Experimentation

Parametric function	Level 1	Level 2	Level 3
Spindle speed (rpm)	150	350	550
Drill feed Rate (mm/rev)	0.15	0.25	0.35
Tool Type	HSS	HSS+TiN	HSS+TiAlN

The experimental evaluations are conceded out on the basis of L_{27} (3^{13}) orthogonal array. The responses were recorded with respective experimental as shown in Table 3, to investigate the software tool version 16 was used for the arithmetical analysis of the experimental data. Taguchi method combined with the VIKOR-Entropy grade method and the scheme of least squares parametric functional values is mostly used for the regression analysis and to calculate the coefficients of regression and the accurate functional characteristic relationship between Y_{xt} and the set of machining parameters in a and polynomials compound linear regression model. If the response variables are well modeled by a linear variant function of the input variables, and the approximation function in the first order differential is given by:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + ...\beta_k X_k \tag{3}$$

Polynomial second order of higher degree equation must be used, such as the second order model: this model is almost useful for the all the engineering problems. But it is unlikely that the polynomial equation which will give accurate results for the accurate functional relationship over the complete space of the selected process variables, but for a relatively little region, they usually work quite well.

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_{i}^{\cdot} X_i \sum_{\prec j}^{\cdot} \beta_{ij} X_i X_j \tag{4}$$

3.1 Entropy weight method

The entropy weight measurement procedure the number of substitutes and various principles considered to examine the multi response optimization by considering a qualified decision matrix. If numbers of alternatives are spindle speed, drill feed rate and tool type considers as ‘M’ and numbers of criterion are assumed Thrust force, delamination and surface roughness considers as ‘N’ then assessment matrix having an order of M×N.

$$D = \begin{bmatrix} X_{11} & X_{12} & X_{13} & X_{1n} \\ X_{21} & X_{22} & X_{23} & X_{24} \\ X_{31} & X_{32} & X_{33} & X_{34} \\ X_{m1} & X_{m2} & X_{m3} & X_{mn} \end{bmatrix}$$

The decision matrix is normalized by greatest values (i.e. favorable attribute) and smallest values (unfavorable attribute). The normalized values calculated by following mathematical equations 5 and 6 and values are tabulated in Table 3

$$r_{ij} = \frac{x_{ij} - \min(x)_{ij}}{\max(x_{ij}) - \min(x_{ij})} \tag{5}$$

$$r_{ij} = \frac{x_{ij} - \min(x)_{ij}}{\max(x_{ij}) - \min(x_{ij})} \tag{6}$$

Where i=1,2., …..M. j =1, 2, 3...N in equation

3.2 Generation of entropy weight for model

In this step the various principles are determined by the entropy method projection values ( ) are evaluated by equation (7).and the projection of alternative is used to establish the entropy index (eij) using equation (8). The projection and entropy indexed values tabulate in Table 3

$$T_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \tag{7}$$

$$e_{ij} = -\frac{1}{\ln m} \sum_{i=1}^{n} T_{ij} \ln T_{ij} \tag{8}$$

3.3 VIKOR method of optimization

The VIKOR method is implemented for multi response optimization to find a concluding solution. In this method arithmetical procedure to implement to find the solution close to ideal optimistic solution ($f*$) and the ideal pessimistic solution ($f-$) were identified by following equations 9 and 10.

$$f^* = f^- \left\{ \left(\min f_{ij} / j \in J \right) or \left((\max f_{ij}) / j \in j' \right) \right\} \tag{9}$$

$$f^- = \left\{ \left(\min f_{ij} / j \in J \right) or \left((\max f_{ij}) / j \in j' \right) \right\} \tag{10}$$

thus J= {j=1, 2, 3...n}, fij if desired responses is large. J’= {1, 2,3…n}, fij if desired responses is small For the calculation of utility index and regret measure value for each response calculated by the following equation 11 and 12 respectively and Tabulated in Table 3.

$$S_i = \sum_{j=1}^{n} W_j \frac{\left(f^* - f_{ij} \right)}{\left(f_j^* - f_j^- \right)'} \tag{11}$$

$$R_i = \max{}_j \left[w_j \frac{\left(f^* - f_{ij} \right)}{\left(f_j^* - f_j^- \right)'} \right]' \tag{12}$$

Where $s_i$utility index, Ri is the regret measure value wj is the respective weight of the jth element. The individual entropy weight calculated by entropy weight method and finally the VIKOR index calculated by equation 13 and presented in Table 3 and to determine rank of VIKOR indexed values the least index value treated as first rank.

$$Q_i = v \left[\frac{s_i - s^*}{s^- - s^*} \right] + (1+v) \left[\frac{R_i - R^*}{R^- - R^*} \right] \tag{13}$$

Thus, Q_i is the predefined VIKOR index of the variable at the i^{th} stage of the result of alternative and v is the superior weight factor of the prescribed group index of utility. Commonly the value of v *was* taken as 0.5. In the above equation $s^-= max_i\ s_i$, $s^*= mi$, $R^- = max_i\ R_i$, And $R^* = min_i\ R_i$ are the higher and lower values of utility index and regret measure. The following clauses must be satisfied to conciliation the results of the consider weight for given alternative. The alternative $A^1$is considered lesser VIKOR index values by measure Q (minimum) and A^2 is the second smallest VIKOR index in list.

a) Acceptable advantage $Q(A^2) - Q(A^1) \geq DQ = \frac{1}{(m-1)}$ where ‘m’ number of conducted experiments.

The alternative A^1 is the smallest VIKOR index ranked by S or/ and R the clarification for stable in decision making. This could be the strategy of highest of utility value v is more than 0.5 needed or same as to 0.5 or with veto lower than 0.5 if one condition not pleased the following must be followed.

I. The alternatives A^1 *and* A^2 if only second condition is not pleased. II. The first clause not pleased A^n is calculated by the following relation ( )-Q (A^1)< DQ for maximum of n

From the above equation Q value is smallest, which results the lowest rank which conciliation of the excellent results for multi response optimization problem.

IV. RESULTS AND DISCUSSION

This investigation explores the grouping of weighted Entropy measurement and VIKOR technique to appraise the decision matrix D m×n is represent by the experimental results as shown in Table 3. For the computation of weight of Entropy for each response equation 1 and 2 are used. For the Thrust force, surface roughness and delamination factor non beneficial attribute equation was used. After estimation the entropy method projection values (Tij) are calculated by equation (7). The projections of values are used to conclude the entropy index (eij) by using equation (8). The projection and entropy indexed values tabulated in Table 3. Finally the VIKOR method was opted for multiresponse optimization. From the individual matrix is analyzed $f*$ and $f-$ possible best solution values are (10.3879, 0.360829, and 0.001351) and worst solution values (22.09073, 0.526529, and 0.003775) were analyzed by equation 9 and 10. The values pertaining to the measure of utility measurement and regret measure is by equation 11 and 12, respectively. The maximum altitude and minimum penetration utility and regret measure are (1.007, 0.0028 and 1.0034, 0.0028) respectively. The lowest VIKOR index calculated using equation 13 and lowest index values ranked as 1 as shown in Table 4. The validation of experiment calculated acceptable advantage equation is satisfied with the value is less than DQ value. Therefore condition is acceptable.

4.1 optimal parameter selection and ANOVA

To find the most favorable level of drilling parameters and the main effect of parameter are appraise VIKOR index as shown in figure 2. From the figure 2 it is found that spindle speed at 350 rpm feed rate at 0.15 mm/rev and HSS+TiAlN coated drill was the optimal parameter for the multi character machining. Table 4 shows the difference value of greatest and lowest values and their rank among the processes parameter for the selective model. The results of ANOVA test for VIKOR index shown in Table 5. From the table it has been observed that contribution each parameter on output response. And finally the interaction process parameters are significant at 82.29% of confidence.

Table. 4. Main effect factors for Entropy -VIKOR index

Parameter	Level 1	Level 2	Level 3	Max-Min	Rank
Spindle speed	0.32033	0.32761	0.37721	**0.05688**	3
feed rate	0.07112	0.27310	0.68092	**0.6098**	1
Tool type	0.42517	0.33069	0.15589	**0.26928**	2

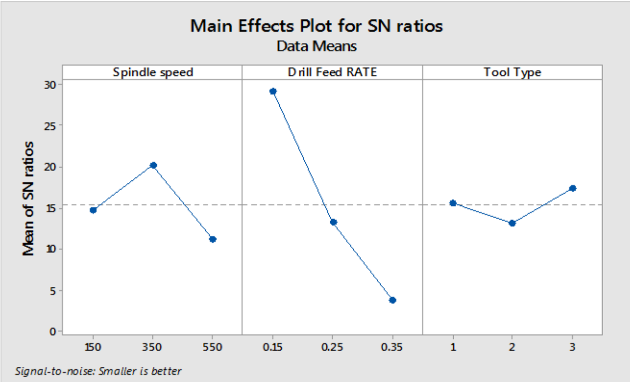

Figure. 2: Main effect plot for Entropy -VIKOR index

Table.3: Taguchi L_{27} orthogonal array with machining parameters, experimental results, projected values, individual weighted Entropy Index values, utility, regret measures values and VIKOR index of alternative with their ran

Trail. No	Machining Parameters			Experimental results			Projection values (T_{ij})			Entropy Index (T_{ij})ln (T_{ij})			Utility Measure (S_{ij})	Regret Measure (R_{ij})	VIKOR index (Q_{ij})	Rank order
	Spindle speed	Feed rate	Tool type	Thrust force	Delamination	surface roughness	C-1	C-2	C-3	C-1	C-2	C-3				
A-1	150	0.15	HSS	160	1.02241	5.95	10.5194	0.360829	0.003775	24.7544	-0.36781	-0.02106	0.0113	0.0051	0.0051	2
A-2	150	0.15	HSS+TiN	172	1.08091	4.82	11.30835	0.381475	0.003058	27.4288	-0.36763	-0.0177	0.0789	0.0743	0.0743	7
A-3	150	0.15	HSS+TiAlN	183	1.12019	3.67	12.03156	0.395338	0.002328	29.9289	-0.36688	-0.01412	0.1409	0.1377	0.1376	9
A-4	150	0.25	HSS	231	1.12091	4.78	15.18738	0.395592	0.003032	41.3167	-0.36686	-0.01758	0.4115	0.4075	0.4072	19
A-5	150	0.25	HSS+TiN	206	1.17941	3.19	13.54372	0.416238	0.002024	35.2939	-0.36483	-0.01255	0.2706	0.2685	0.2683	13
A-6	150	0.25	HSS+TiAlN	202	1.22020	4.82	13.28074	0.430633	0.003058	34.3481	-0.36281	-0.0177	0.2480	0.2453	0.2451	12
A-7	150	0.35	**HSS**	305	1.21724	3.95	20.0526	0.429589	0.002506	60.1248	-0.36297	-0.01501	0.8287	0.8265	0.8259	25
A-8	150	0.35	HSS+TiN	250	1.27574	4.71	16.43655	0.450235	0.002988	46.0142	-0.35928	-0.01737	0.5186	0.5167	0.5163	21
A-9	150	0.35	HSS+TiAlN	230	1.21658	4.32	15.12163	0.429356	0.002741	41.0722	-0.36301	-0.01617	0.4059	0.4034	0.4032	18
A-10	350	0.15	**HSS**	164	1.23258	3.41	10.78238	0.435003	0.002163	25.6395	-0.3621	-0.01327	0.0338	0.0322	0.0322	6
A-11	350	0.15	HSS+TiN	162	1.10108	4.35	10.65089	0.388594	0.00276	25.1962	-0.36731	-0.01626	0.0225	0.0186	0.0185	3
A-12	**350**	**0.15**	**HSS+TiAlN**	**158**	**1.49192**	**3.13**	**10.3879**	**0.526529**	**0.001351**	**24.3143**	**-0.33774**	**-0.00893**	**0.0028**	**0.0028**	**0.0028**	**1**
A-13	350	0.25	HSS	163	1.13108	4.89	10.71663	0.399181	0.003102	25.4176	-0.36658	-0.01792	0.0282	0.0242	0.0242	4
A-14	350	0.25	HSS+TiN	227	1.18958	5.62	14.92439	0.419827	0.003565	40.3405	-0.36437	-0.0201	0.3890	0.3852	0.3850	16
A-15	350	0.25	HSS+TiAlN	179	1.23041	2.8	11.76857	0.434237	0.001776	29.0146	-0.36223	-0.01125	0.1184	0.1172	0.111	8
A-16	**350**	**0.35**	**HSS**	**336**	**1.22741**	**4.94**	**22.09073**	**0.433178**	**0.003134**	**68.3743**	**-0.3624**	**-0.01807**	**1.0034**	**1.0007**	**1.0000**	**27**
A-17	350	0.35	HSS+TiN	294	1.28591	2.38	19.32939	0.453824	0.00151	57.2464	-0.35854	-0.00981	0.7667	0.7665	0.7660	24
A-18	350	0.35	HSS+TiAlN	265	1.32674	3.13	17.42275	0.468234	0.001986	49.7903	-0.35529	-0.01235	0.6032	0.6030	0.6026	23
A-19	550	0.15	HSS	192	1.13208	3.95	12.62327	0.399534	0.002506	32.0068	-0.36656	-0.01501	0.1917	0.1884	0.1882	11
A-20	550	0.15	HSS+TiN	185	1.16058	3.73	12.16305	0.409592	0.002366	30.3882	-0.3656	-0.01431	0.1522	0.1495	0.1493	10
A-21	550	0.15	HSS+TiAlN	164	1.20141	3.06	10.78238	0.424002	0.001941	25.6395	--0.3638	-0.01212	0.0338	0.0321	0.0321	5
A-22	550	0.25	HSS	229	1.30058	4.32	15.05588	0.459001	0.002741	40.8280	-0.35743	-0.01617	0.4002	0.3989	0.3986	17
A-23	550	0.25	HSS+TiN	210	1.25908	3.28	13.80671	0.444355	0.002081	36.2447	-0.36043	-0.01285	0.2931	0.2920	0.2918	14
A-24	550	0.25	HSS+TiAlN	215	1.29991	3.12	14.13544	0.458765	0.001979	37.4403	-0.35748	-0.01232	0.3213	0.3208	0.3206	15
A-25	550	0.35	HSS	326	1.29691	4.26	21.43327	0.457706	0.002703	65.6917	-0.35771	-0.01598	0.9470	0.9457	0.9451	26
A-26	550	0.35	HSS+TiN	248	1.31541	3.26	16.30506	0.464235	0.002068	45.5151	-0.35624	-0.01278	0.5073	0.5070	0.5066	20
A-27	550	0.35	HSS+TiAlN	258	1.29624	3.57	16.96252	0.45747	0.002265	48.0210	-0.35776	-0.01379	0.5637	0.5629	0.5625	22

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Table.5: ANOVA for Entropy -VIKOR index

Source	DF	Adj SS	Adj MS	F-Value	% of Contribution
Spindle speed	2	0.01725	0.008624	0.43	0.76105
feed rate	2	1.73690	0.868452	43.27	76.630
Tool type	2	0.11100	0.055498	2.76	4.89
Error	20	0.40145	0.055498		17.71
Total	26	2.26660			100

4.2 Conformation/Validation test

To validate the prescribed model entity the conformation experiment was conducted and analyzed. The predicted value of conformation experiment is obtained through regression equation. From the confirmation experiment the error percentage with its experimental value and evaluated by regression equation with correspond processes parameter of lowest VIKOR index. The results are shown in Table 6.

Regression equation for VIKOR index
Entropy-VIKOR index = 0.3417-0.0214
Spindle speed_150-0.0141
Spindle speed_350+ 0.0355
Spindle speed_550 - 0.2706
feed rate_0.15-0.0686
feed rate_0.25+ 0.3392
feed rate_0.35+ 0.0835
Tool Type_10.0110
Tool Type_2 - 0.0724
Tool Type_3

Table 6 Results of conformation experiment

Numerical index	Optimal level parameters	Predicted value	Experimental value	Error
VIKOR index	Spindle speed = 350	0.0024	0.0028	0.0004
	Feed rate = 0.15			
	Tool type = (HSS+TiAlN)			

V. CONCLUSIONS`

The present work is based on the experimental investigation during drilling of EN-steel. The machining capacity of drilling is evaluated in terms of thrust force, surface roughness and delamination under minimum quantity lubrication condition. The Entropy-VIKOR index analysis of the experimental results has established Thrust force, delamination and composite VIKOR index. From the ANOVA of Entropy-VIKOR index discloses the moderate spindle speed (350 rpm), lower feed rate (0.15 mm/rev) and HSS drill coated with titanium aluminium nitride (TiAlN) is the optimum parameters for machinability of EN-24 steel Finally it has been concluded that the VIKOR index of predicted and experiment values are attained with less error value. The consequences imply that, the optimization of multiple performance characteristics can be greatly simplified.

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