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Original Article

Optimal Selection of Cutting Parameters during Drilling of AA 7075 Alloy Using Taguchi Method Coupled with TOPSIS

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Abstract - *In the present study, investigations were carried out on the hole hole-making process on a drilling machine as per the Taguchi design of experiments then applied the TOPSIS method to make proper decision-making while optimal selection of combination of drilling parameters after experimental investigations based on a Taguchi design. Based on the five input factors and three levels L_{27} orthogonal array was selected as per Taguchi's design of the experiment method. In this experimental investigation, multiple performance characteristics such as burr height, thrust force and hole internal surface roughness were measured with well-calibrated apparatus. To achieve an optimal combination of input cutting parameters to meet the multi-performance characteristics of output responses, the TOPSIS method is employed for the data, which is extracted from the Taguchi design of experiments and found that speed 795rpm, feed 26 mm/min, diameter 10mm, point angle 100^o and clearance angle 8^o to the optimal combination of input cutting parameter values to give optimum responses such that burr height 0.174mm, thrust force 397N and surface roughness 1.331µm also obtained the order of preference of combination of cutting parameters while drilling on aluminium alloys to get the best quality, which is helpful to the machinists who are working on drilling to get good results.*

Keywords - *Burr size, Surface roughness, Taguchi coupled with TOPSIS, Thrust force.*

1. Introduction

Almost all engineering applications, including the medical field, require hole-making at any stage including macro and micro size. Making a hole is a primary process, irrespective of other processes. The burrs that are formed at the entry and exit sides of a hole after drilling might have adverse effects while assembled and further cause a reduction in accuracy. From the previous literature, it is found that 30% of the total production cost for parts such as aircraft engines that require high-precision manufacture and 14% of the production cost of automobile parts [1]. One of the difficulties during drilling associated with AA7075 alloys is the occurrence of burr on a hole surface. Burr is defined as the deviation outside the ideal geometrical shape of an edge as per ISO-13715 [2]. In general, burr shape and size are related to the incidence of plastic deformation present where the drill bit enters or leaves the parent material, and it is generally represented by height and thickness. In conventional manufacturing, drilling of AA 7075 alloy becomes important because of its behaviour and mechanical properties especially in the field of automotive and aeronautical industries. While drilling on aluminium alloy, machinists faced difficulty with its adhering property to the cutting tool due to smearing properties. The surface quality is an important quality parameter during any machining of any type of material. It is found from previous literature that there is a lack of in-depth studies about the 7000 series of aluminium alloys, even though it has broad applications [3]. Numerous authors in the literature define a drilling process differently, in that one of the definitions utilized by most of the researchers is drilling is a hole-making method where a multi-point cutter, here called a drill bit used to produce a desired hole by removing unnecessary material, [4]. One of the principal design considerations for extremely stressed components will be the surface condition produced during manufacturing. After performing a drill, customers see whether the quality of the performed hole meets the design considerations given in the quotation or not.

For this purpose, check the surface quality of a hole necessary at each step. To study surface quality, we must consider or have an idea upon the geometry of the drill bit, which is illustrated lucid manner in Figure 2. Another parameter during drilling is a thrust force, and torque represents how difficult to drill an AA 7075 alloy material [5]. These forces are classified as primary and secondary cutting forces. The primary cutting forces are generally obtained from the relative motion of the tool's contact with the workpiece denotes direct force, while the occurrence of vibration generates the secondary cutting forces during machining. In the case of the drilling process, the parent material is separated by shearing action taken by the drill bit through plastic deformation because the drill bit moves into the parent material and exceeds its yield strength; there is elasticity and then the plastic deformation of the material where a huge amount of forces are generated. In the drilling process, thrust force (F_{th}) is the force which is orthogonal to the workpiece surface and is required to penetrate the drill bit into the work material during its feed motion, and these forces are important characteristics to perform drilling can directly affect the quality of holes and the drill tool life, vibration, and ultimately power consumption.

The majority of researchers focused their study towards how to optimize, what type of method is suitable and the feasibility of such a method. In this view, the previous authors utilized the design of experiments-based optimization methods to optimize machining parameters. Taguchi orthogonal arrays are one of the design experiment techniques found to be the best feasible method for the selection of a proper number of experiments based on input cutting parameters and their levels. However the Taguchi method is applicable only for single objective optimization problems and is not suitable for the multi-response type of problems independently. This drawback, fulfilled by integrating the Taguchi method with MCDM techniques like TOPSIS, has been gaining more importance and attaining promising results in industrial applications. These issues motivate in application of such paradigms for analyzing and improving the performance of the drilling process to enhance quality and economy.

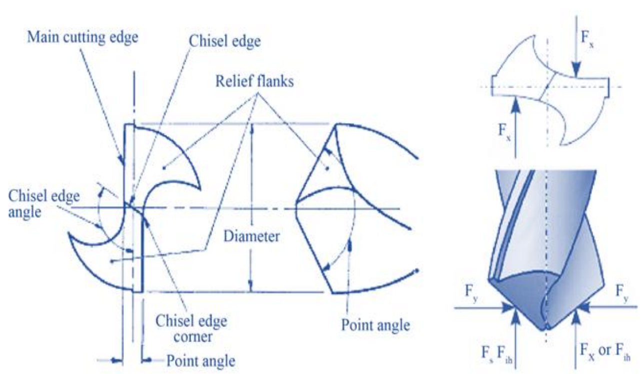

Fig. 1 Cutting edge geometry of a twist drill bit

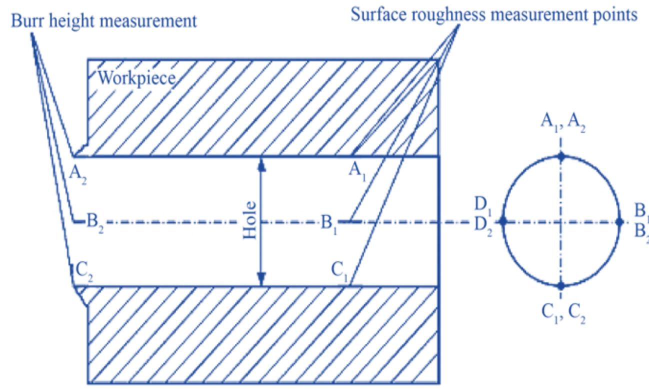

Fig. 2 Burr height and Surface-roughness measurement on a hole

2. Methodology of Taguchi Method Coupled with TOPSIS

Taguchi method is a standard experimental design technique incorporated to optimize the machining parameters in all stages of design, planning, scheduling and production for enhancing the quality characteristics. The objective of Orthogonal Arrays (OA) is to find out the systematic experimental design based on the chosen input level of factors. The influence of input parameters on output responses based on the selection of the optimum level of combination obtained from the Taguchi method is insensitive to the environment and other noise factors (S/N). Even though the Taguchi method was designed to optimize single-performance characteristics coupled with other methods can apply this method for multiple performance characteristics wherever needed in the optimization of machining parameters. In this experimental investigation to solve the multiple performance characteristics problems, the Taguchi method is coupled with TOPSIS (technique for order of preference by similarity to ideal solution).

TOPSIS is a unique and multiple-criteria decision making to find solutions from a limited set of choices. The fundamental principle of this method is based on the idea that the selected choice has the closest distance from the Positive Ideal Solution (PIS) and, on the other side, the utmost distance from the negative ideal solution (NIS). The positive ideal solution maximizes the main motive of the objective chosen and minimizes attributes considered initially, whereas the negative ideal solution maximizes the attributes considered initially and minimizes the main motive of the objective [7-14]. Therefore, the positive ideal solution (PIS) is a set of the finest values attained based on selected input or required output, whereas the negative ideal solution (NIS) contains all the nastiest values attained. In the present work, Taguchi's design of experiments method coupled with TOPSIS is illustrated in detail in the block diagrams shown in Figures 3 and 4. In the TOPSIS method, a specific weight is allowed for the output responses in order to decide their rank [15-18]. The steps engaged in the TOPSIS method are elaborately described below.

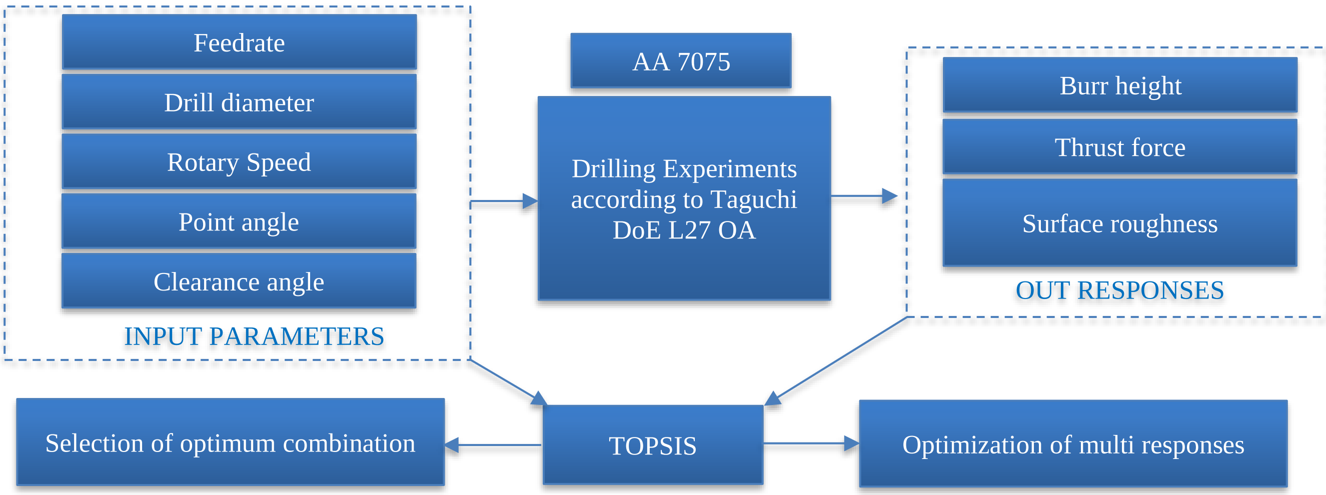

Fig. 3 Methodology of Taguchi method coupled with TOPSIS

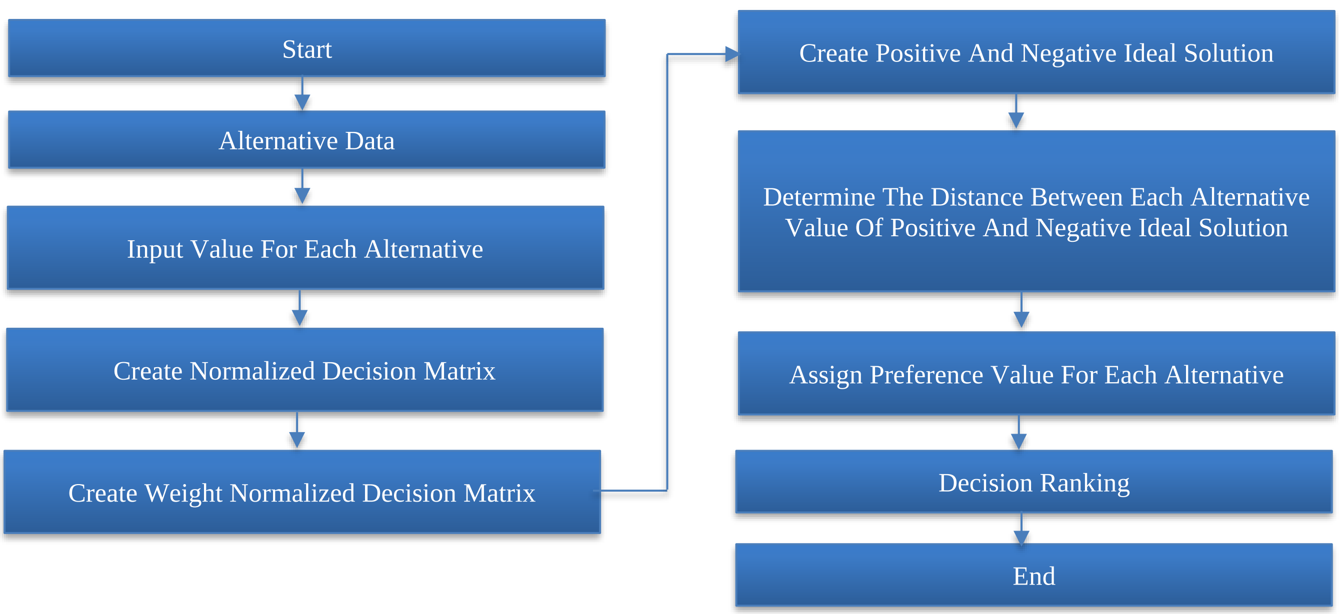

Fig. 4 Steps involved in the structure of TOPSIS

STEP 1

In the TOPSIS technique, all the dimensions of parameters, including units, are erased and modified into normalized form.

The normalized quantity (y_{ij}) is obtained using Equation 1. The normalized and weighted normalized quantities of all measured output responses are shown in Table 3.

$$y_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}, i = 1\ldots27, j = 1\ldots27 \qquad (1)$$

Where,
i = alternative numbers
j = output responses of all trials
x_{ij}= denotes the original measured value of the i_{th} value of the j_{th} trial of the experiment.

STEP 2

The value of a weighted normalized quantity (η_{ij}) is obtained by making the product of the value of the normalized quantity and its assumed weights and substituted in Equation 2.

$$\eta_{ij} = w_{ij} * y_{ij}, i = 1\ldots27, j = 1\ldots27 \qquad (2)$$

From the literature, found that most of the authors considered the weightage of all measured responses equally [18-20]. So, w_{ij} *is* assumed to be 0.33in this case also.

STEP 3

Then, the positive ideal solution (PIS) is represented with 'Z^+', and the negative ideal solution (NIS) is represented by 'Z^-'has been estimated using Equation.3a &Equation 3b.

$$Z^{+} = (\max(\eta_{ij}) : J \in J^{*}, \min(\eta_{ij}) : J \in J^{*})......(3a)$$

$$Z^{-} = (max(\eta_{ij}): J \in J^{*}, min(\eta_{ij}): J \in J^{*}) \ldots\ldots (3b)$$

Where J is a set of feasible solutions of alternatives and J^{*} is a set of non-feasible alternatives.

STEP 4

The division of each alternative from positive ideal solution ‘Z^{+}’ and negative ideal solution ‘Z^{-}‘ is determined as per Equation 4 and Equation 5.

$$S_i^{+} = \sqrt{\sum_{i=1}^{27} \left(\eta_{ij} - Z^{+}\right)_j^2} \qquad (4)$$

$$S_i^{-} = \sqrt{\sum_{i=1}^{27} \left(\eta_{ij} - Z^{-}\right)_j^2} \qquad (5)$$

STEP 5

The value of the closeness coefficient (AAi) of each alternative is calculated from Equation 6 and tabulated in Table 4.

$$AA_i = \frac{S_i^{-}}{(S_i^{-} + S_i^{+})} \qquad (6)$$

3. Experimentation as per Taguchi Orthogonal Array

In the current work, a standard radial drilling machine supplied by M/S Siddapura Machine Tools, Gujarat, INDIA, to carry out the different sizes of holes on aluminium 7075 alloys with an HSS-R (DIN 338) twist drill bits purchased from Miranda, INDIA, with diameters of 8, 10 and 12mm with 118° point angle, 8°clearance angle and 30° constant helix angle. Also, the drill bit geometry was modified with 3 levels using a tool and cutter grinding machine to do the experimentation as per Taguchi orthogonal array to reduce burr formation. The composition of Aluminium 7075 alloy comprises the elements determined from EDX analysis as Silicon (Si) 0.38%, Iron (Fe) 0.48%, Copper (Cu) 1.06%, Manganese (Mn) 0.26%, Magnesium (Mg) 2.04%, Chromium (Cr) 0.23% Zinc (Zn) 4.72%, Titanium (Ti) 0.21% and remaining is aluminium. The drill bit geometrical specifications and the drilling parameters with their levels are depicted in Table 1.

Table 1. Input parameters along with drill bit geometry

Parameter	Unit	Symbol	Level of Value
Diameter	mm	d	8,10,12
Helix angle	degrees	δ	30° constant
Point angle	degrees	φ	100°,110°,118°
Chisel edge angle	degrees	γ	136° constant
Clearance angle	degrees	ψ	4°, 6°, 8°
Feed rate	mm/min	*f*	15, 20, 25
Rotary speed	rpm	n	500, 700,800

L_{27} orthogonal array of the Taguchi method helps to reduce the number of experimental runs. The three cutting parameters such as rotary speed, feed rate, drill diameter, point angle and clearance angle with three different levels are used for the experimentation. The drilling experiments are carried out in a radial drilling machine whose cutting speed ranges from 400 to 800 rpm and feed ranges from 15 to 30 mm/min. The drilling tests are carried out in a dry condition with high speed steel twist drill bit. During the experiments, single setup experiments have been carried out with different conditions of parameter setting. The aluminium 7075 alloy workpiece of size 300 mm x 50 mm x 10 mm was mounted on a drill tool dynamometer (Kistler 9257B) with the suitable fixture on the machine, as shown in Figure 5(a).

Fig. 5 (a) Experimental setup with KISTLER dynamometer

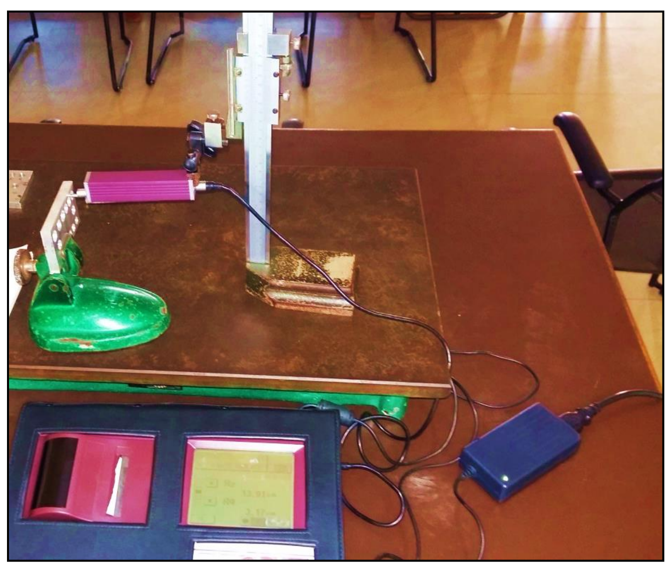

Fig. 5 (b) Surface roughness measurement apparatus

Fig. 5(c) Samples of AA7075 alloy workpieces after drilling

At the entry stage, initially, there is no contact of the chisel edge with the workpiece during drilling due to this there is no cutting force was recorded. Also, it will come with full engagement of the chisel of drill to the workpiece the maximum thrust force was recorded. When it came to the exit of the chisel edge of drill large amount of fluctuation and sudden decrement in thrust force was observed.

The average value of thrust force recorded by the dynamometer was considered for analysis. The surface roughness (Ra) of the drilled hole was evaluated using surf-test SJ-301 series (Mitutoyo make, Japan) (shown in Figure 5b), having a cut-off length of 0.75 mm. Over the workpiece samples, on the middle portion, two holes are performed to fix the drill dynamometer and to prevent burr during the drilling test.

The burr height was measured by using a dial indicator of 0.001mm accuracy at three different positions along the circumference of the drilled hole on the workpiece, and reading was taken. The responses were measured after each experiment and recorded then depicted values in Tables 2 and 3.

Table 2. Experimental trials as per Taguchi design method

Exp. Run	**Speed (rpm) n**	**Feed Rate (mm/min) *f***	**Drill dia. (mm) d**	**Point angle (deg's) φ**	**clearance angle (deg's) ψ**
1	465	18	8	100	4
2	465	18	8	100	6
3	465	18	8	100	8
4	465	20	10	110	4
5	465	20	10	110	6
6	465	20	10	110	8
7	465	26	12	118	4
8	465	26	12	118	6
9	465	26	12	118	8
10	695	18	10	118	4
11	695	18	10	118	6
12	695	18	10	118	8
13	695	20	12	100	4
14	695	20	12	100	6
15	695	20	12	100	8
16	695	26	8	110	4
17	695	26	8	110	6
18	695	26	8	110	8
19	795	18	12	110	4
20	795	18	12	110	6
21	795	18	12	110	8
22	795	20	8	118	4
23	795	20	8	118	6
24	795	20	8	118	8
25	795	26	10	100	4
26	795	26	10	100	6
27	795	26	10	100	8

Table. 3 Output responses measured during experimentation

Exp. Run	Burr height Bh (mm)	Thrust force Ft (N)	Surface roughness, Ra(μm)
1	0.251	282	1.634
2	0.234	235	2.188
3	0.231	396	1.566
4	0.271	232	1.334
5	0.342	291	1.345
6	0.244	266	1.261
7	0.321	337	1.271
8	0.332	284	1.731
9	0.334	252	2.851
10	0.302	242	1.622
11	0.257	237	2.103
12	0.306	396	1.531
13	0.312	262	1.212
14	0.374	208	1.311
15	0.371	268	1.215
16	0.322	347	1.242
17	0.287	281	1.741
18	0.357	252	2.821
19	0.396	247	1.636
20	0.292	237	2.351
21	0.341	306	1.562
22	0.285	272	1.143
23	0.217	298	1.362
24	0.184	345	1.291
25	0.174	397	1.331
26	0.222	286	1.725
27	0.209	362	2.852

The Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS) in the conventional TOPSIS are both taken from the actual data obtained from experimental results using well-calibrated measuring devices of the choices, so different sets of choices will have different PIS and NIS. The positive ideal solution and the negative ideal solution must be re-selected and calculated when new choices are added, or some of the choices are removed, and the result of the ranking may be altered, which is called the reverse order phenomenon [19-22] and the obtained values are depicted in Tables 4, 5, and 6. In order to solve this task, these investigations put forward the concept of an absolute ideal solution, which is to take the limit value of the optimal state and the worst state of each criterion of the choice, the positive ideal solution and the negative ideal solution.

Table. 4 Normalized values of alternatives

Exp. No	Normalized Performance Value		
	Bh	Ft	Ra
1	0.04026	51.8446	0.48071
2	0.03581	36.1671	0.84221
3	0.03398	102.4731	0.42876
4	0.04672	35.2199	0.31099
5	0.07511	55.4397	0.32087
6	0.03896	46.0858	0.27741
7	0.06643	74.0741	0.28138
8	0.07027	52.6207	0.52037
9	0.06984	41.5842	1.42375
10	0.05829	38.1937	0.45718
11	0.04292	36.7847	0.76786
12	0.07071	102.4731	0.40712
13	0.05442	44.9131	0.25622
14	0.09506	28.3401	0.29852
15	0.08863	47.0981	0.25876
16	0.06068	78.5408	0.26778
17	0.05868	51.5137	0.52341
18	0.08243	41.5842	1.38902
19	0.10223	39.7581	0.46857
20	0.05557	36.5679	0.96718
21	0.07782	61.1783	0.42493
22	0.05291	48.4056	0.22861
23	0.02851	58.1371	0.32233
24	0.02014	78.0431	0.28943
25	0.01789	102.9914	0.30821
26	0.02688	53.7395	0.52098
27	0.03191	85.7702	1.42675

Table. 5 Values of weighted normalized alternatives

Exp. No	Weighted Normalized Value		
	Bh	Ft	Ra
1	0.01328	17.1087	0.01577
2	0.01182	11.9351	0.02043
3	0.01124	33.8161	0.01791
4	0.01542	11.6226	0.02133
5	0.02478	18.2951	0.01976
6	0.01288	15.2083	0.02276
7	0.02192	24.4445	0.01929
8	0.02319	17.3648	0.01798
9	0.02305	13.7228	0.01821
10	0.01924	12.6039	0.01821
11	0.01417	12.1389	0.02317
12	0.02334	33.8161	0.02199
13	0.01796	14.8213	0.01842
14	0.03137	9.35221	0.02205
15	0.02925	15.5424	0.01888
16	0.02002	25.9185	0.02101
17	0.01937	16.9995	0.01829
18	0.02721	13.7228	0.02271
19	0.03374	13.1202	0.01945
20	0.01834	12.0674	0.02056
21	0.02568	20.1888	0.01961
22	0.01746	15.9738	0.02037
23	0.00941	19.1853	0.01844
24	0.00665	25.7542	0.02088
25	0.00591	33.9872	0.01931
26	0.00887	17.7341	0.02023
27	0.0105	28.3041	0.01884
	PIS(Z^+) 0.0337	PIS(Z^+) 33.987	PIS(Z^+) 0.0232
	NIS(Z^-) 0.0088	NIS(Z^-) 9.3522	NIS(Z^-) 0.0157

Table. 6 Closeness coefficient and its alternatives rank

Exp. No.	S^+_i	S^-_i	AA_i	Rank
1	16.8784	7.75653	0.31485	14
2	22.0520	2.58293	0.10484	26
3	0.17262	24.4638	0.99299	3
4	22.3645	2.27040	0.09216	4
5	15.6920	8.94293	0.36302	11
6	18.7788	5.85613	0.23771	18
7	9.54268	15.0923	0.61263	8
8	16.6223	8.01267	0.32525	13
9	20.2643	4.37062	0.17741	21
10	21.3832	3.25173	0.13199	23
11	21.8482	2.78678	0.11312	24
12	0.17139	24.4638	0.99304	2
13	19.1658	5.46911	0.22201	19
14	24.6349	0.02336	0.00094	27
15	18.4447	6.19021	0.25127	17
16	8.06868	16.5663	0.67247	6
17	16.9876	7.64735	0.31042	15
18	20.2643	4.37064	0.17741	20
19	20.8670	3.76803	0.15295	22
20	21.9197	2.71525	0.11022	25
21	13.7983	10.8366	0.43988	9
22	18.0133	6.62165	0.26879	16
23	14.8019	9.83306	0.39915	10
24	8.23297	16.4020	0.66580	7
25	0.02810	24.6349	0.99886	1
26	16.2531	8.38184	0.34024	12
27	5.68311	18.9519	0.76931	5

4. Results and Discussion

In this experimental investigation, as per Taguchi, the S/N response table depicted in Table 7 reveals that clearance angle, feed rate, diameter of the drill bit, spindle speed and point angle influenced output responses by taking the problem with a single objective function. The main effects plot drawn for signal-to-noise ratios was obtained on the basis of L_{27} orthogonal array results. This graph describes (shown in Figure 6) how the input level of factors influences over output responses. The input factors such as rotary speed, feed rate, clearance angle and point angle influence were found to be high on the burr size and less influence on the diameter or size of the drill bit. Generally, the Taguchi method is utilized for single objective functions for finding the combination of machining parameters, But in the present situation, multi-objective optimization is required to search for proper decisions to find the optimal combination of input parameters to satisfy three output responses. For this purpose, again, ANOVA was conducted for the output of the closeness coefficient obtained from Table 8 of the TOPSIS method. The main effects plot from Figure 6 reveals that the optimum combination of input factors was recognized as rotary speed 795 rpm, feed rate 26 mm/min, drill diameter 10mm, point angle 100°, and clearance angle 8°.

Table 7. Response table for Signal-to-Noise ratios

Level	Rotary Speed, n (rpm)	Feed Rate, (mm/ min) *f*	Drill Dia., d (mm)	point angle, (deg's) φ	clearance angle, (deg's) ψ
1	-11.19	-12.1	-9.02	-14.09	-10.76
2	-16.75	-16.7	-10.02	-12.58	-18.24
3	-08.57	-7.7	-17.46	-09.83	-07.519
Delta	08.175	09.01	08.43	04.26	10.736
Rank	4	2	3	5	1

Table. 8 ANOVA (Analysis of variance) for S/N ratios

Source	DoF	SS	Adj SS	Adj MS	F	P
Rotary Speed n (rpm)	2	313.8	313.7	156.8	1.43	0.27
Feed Rate *f* (mm/ min)	2	365.8	365.8	182.9	1.67	0.22
Drill diameter d (mm)	2	382.5	382.5	191.3	1.74	0.21
point angle, (deg's) φ	2	83.95	83.9	41.98	0.38	0.68
clearance angle, (deg's) ψ	2	545.5	545.5	272.7	2.48	0.11
Residual Error	16	1757	1757	109.8		
Total	26	3448				

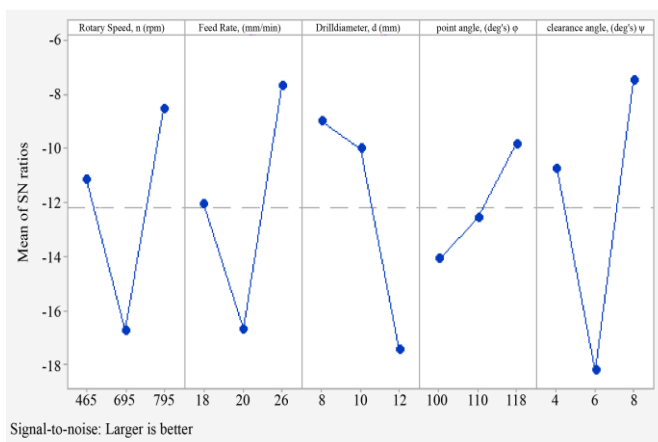

Fig. 6 Main effects plot for S/N ratios

The maximum values of the closeness coefficient stand for good performance. The main aim of drawing residual plots for S/N ratios is to identify the probable error that occurred due to unknown and unpredicted environmental effects during a machining operation. So, from Figure 7, it is observed that all the residual errors distributed evenly on average (mean) line out of 27 experiments conducted on a drilling machine and found during the 25th experimental run undergo more influence, it may be due to impurities in the case of material or maybe in a drill bit.

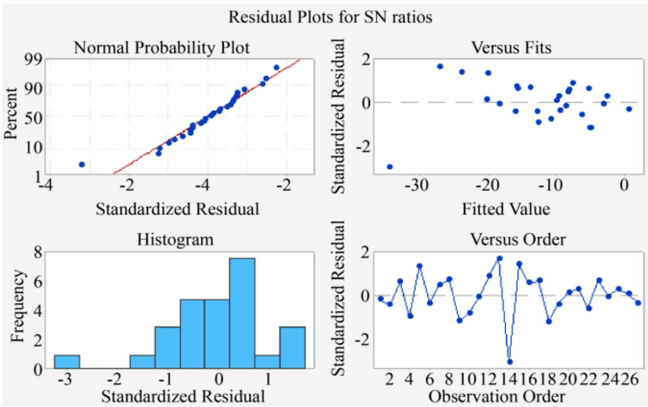

Fig. 7 Residual plots for S/N ratios

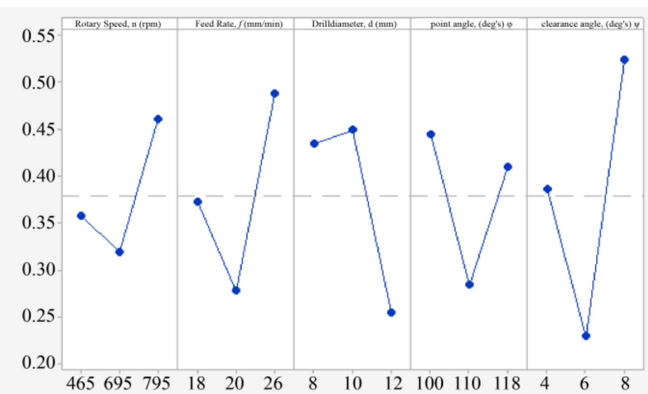

Fig. 8 Main effects plot for closeness coefficient

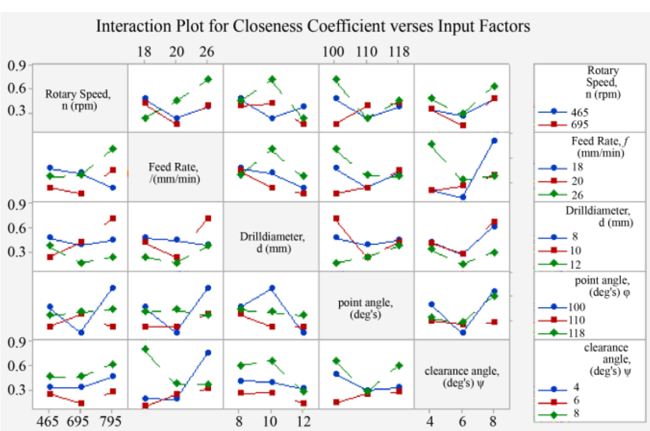

Fig. 9 Interaction plot for closeness coefficient versus input factors

From Table.4, it is observed that the 25th experiment understands the maximum closeness coefficient among 27 experiments and the optimal condition to attain multiple performance characteristics, i.e. rotary speed 795 rpm, feed rate 26 mm/min, the diameter of the drill bit 10mm, point angle 100°, clearance angle 8°. The chronological order of preference of choosing experimentation obtained by applying TOPSIS coupled with Taguchi method was given by 14-26-3-4-11-8-13-21-23-24-2-19-27-17-6-15-20-22-25-9-16-10-7-1-12-5.

To know the influence of the combined interaction of input level factors versus output result of TOPSIS, i.e. closeness coefficient was drawn by keeping one of the input factors assumed to be constant and the remaining factors varying and found from Figure 9. The purpose of 2D contour plots was found from previous literature that wherever ambiguity existed to finalize the efficacy of a particular method, these graphs allowed to remove such ambiguity.

From Figure 10(a), it is observed that feed rate influence was found to be more than other factors with constant spindle speed and drill diameter found to be an average influence on output responses from Figure 10(b).

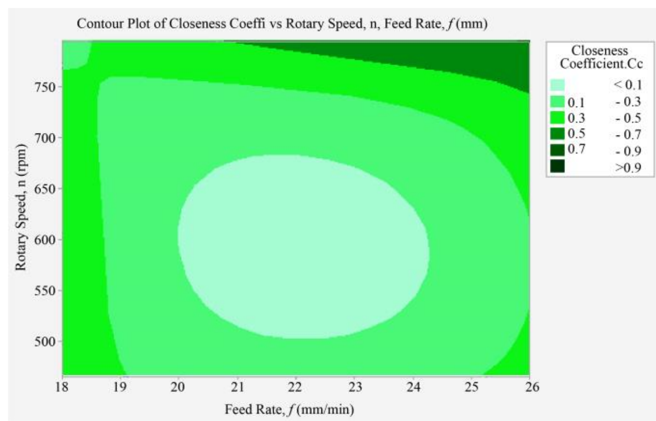

Fig. 10 (a) Contour plot of closeness coefficient between rotary speed and feed rate

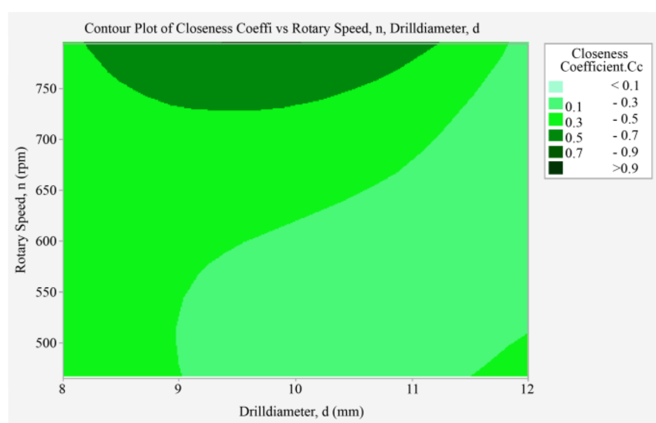

Fig. 10 (b) Contour plot of closeness coefficient between rotary speed and drill diameter

From Figure 11(a), it is observed that point angle influence was found to be low compared to other factors with constant spindle speed and also Figure 11(b) reveals clearance angle influence more on output responses with the same constant input factor.

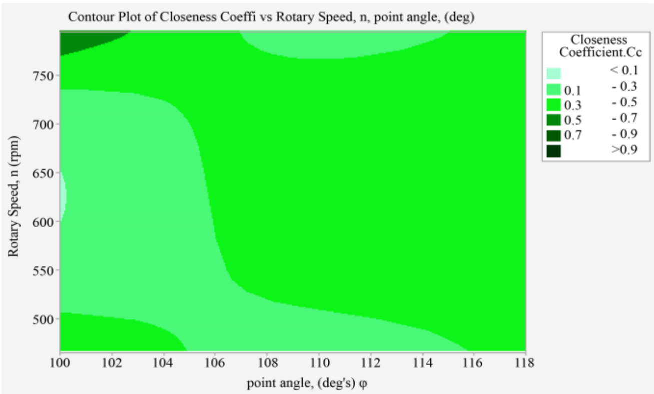

Fig. 11(a) Contour plot of closeness coefficient between rotary speed and point angle and clearance angle

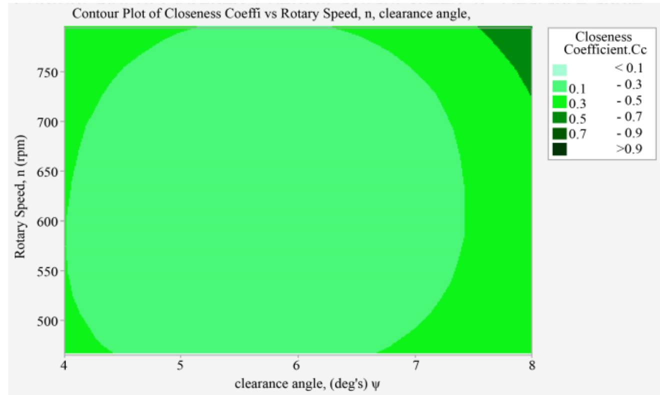

Fig. 11(b) Contour plot of closeness coefficient between rotary speed and clearance angle

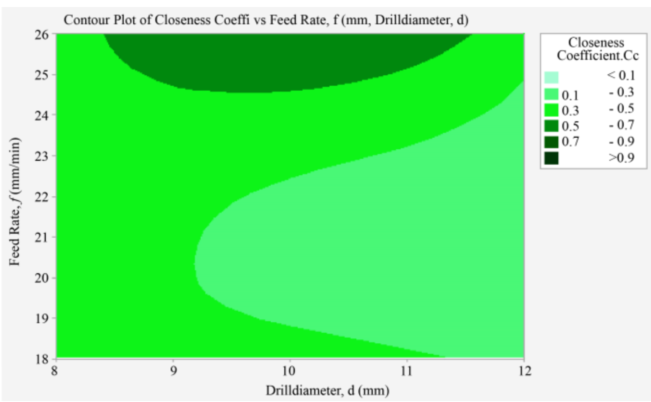

Fig. 12(a) Contour plot of closeness coefficient between feed rate and drill diameter

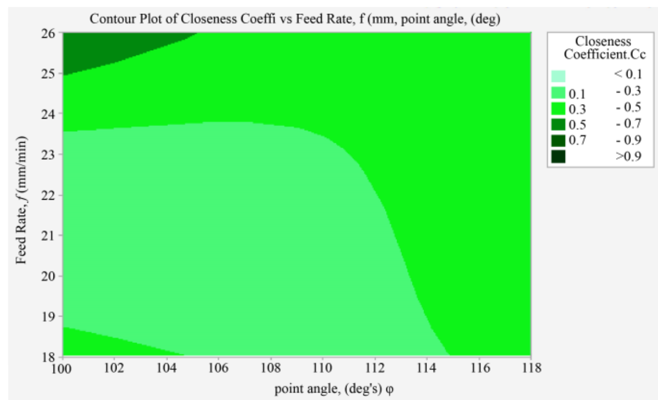

Fig. 12(b) Contour plot of closeness coefficient between feed rate and point angle

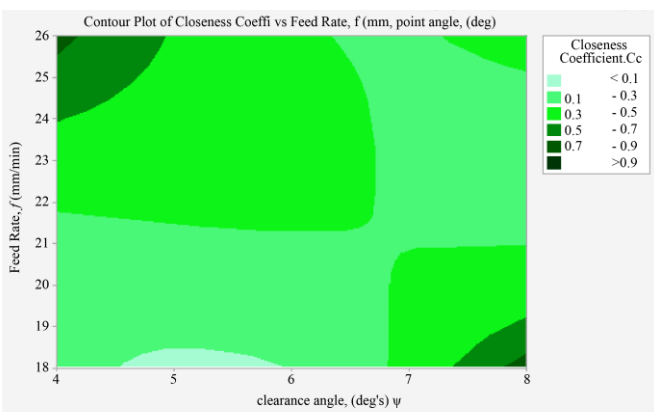

Fig. 13(a) Contour plot of closeness coefficient between feed rate and clearance angle

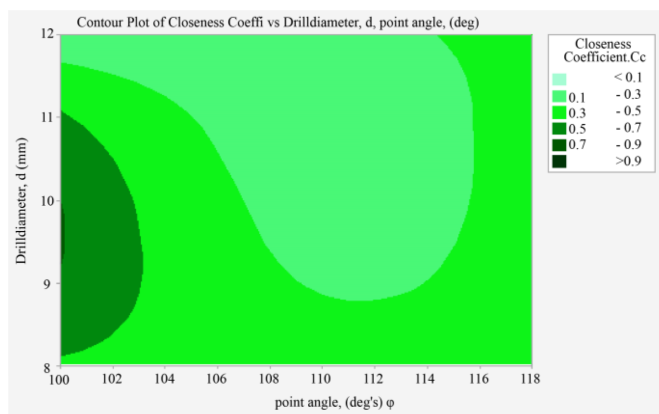

Fig. 13(b) Contour plot of closeness coefficient between drill diameter and point angle

From Figure 12(a), it is observed that the diameter of the drill bit has be moderate influence compared to other factors with constant feed rate, and point angle influences very less on output responses with the same constant feed rate observed from Figure 12(b).

Similarly, Figure 13(a) shows that clearance angle has less influence compared to other factors with constant feed rate and lower point angles; the drill diameter influence very less on output responses with the same constant feed rate observed from Figure 13(b).

From Figure 14(a), it is observed that the clearance angle has be high influence compared to other factors with a constant diameter of the drill bit, and Figure 14(b) reveals that clearance angle influences very less output responses by maintaining a constant point angle.

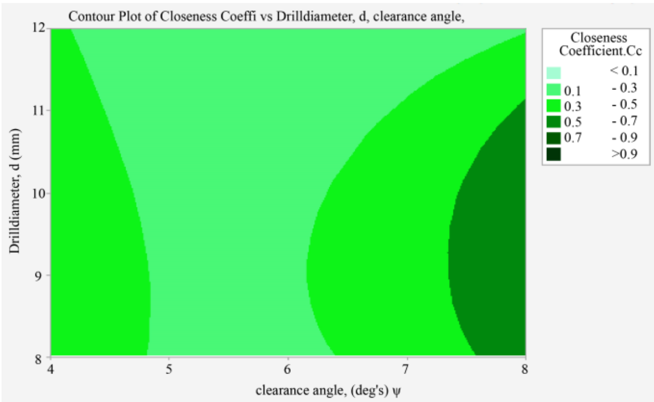

Fig. 14(a) Contour plot of closeness coefficient between drill diameter and clearance angle

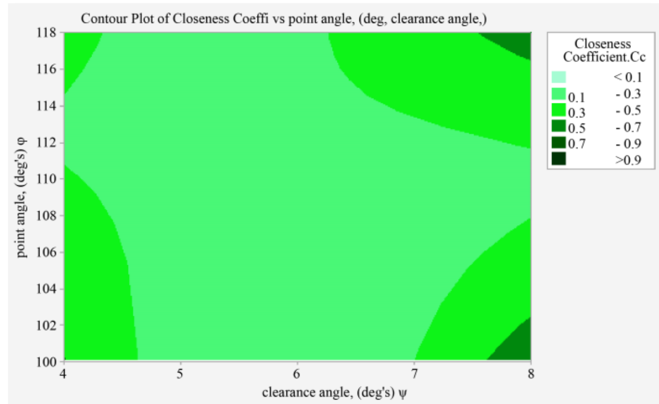

Fig. 14(b) Contour plot of closeness coefficient between point angle and clearance angle

Table. 9 Mean response table of closeness coefficient of alternatives

Level	FACTOR				
	Rotary Speed	**Feed Rate**	**Drill diameter**	**Point angle**	**Clearance angle**
1	0.36	0.373	0.434	0.444	0.385
2	0.32	0.277	0.449	0.284	0.229
3	0.46	0.487	0.255	0.409	0.523
Max-Min	0.14	0.21	0.194	0.159	0.293
Rank	**5**	**2**	**3**	**4**	**1**

The closeness coefficient for the obtained optimum combination of parameters [6] was obtained from Equation 7, and it is greater than the maximum closeness coefficient corresponding to rank 1 in Table 7. Hence the values obtained were optimal.

$$\boldsymbol{\beta_{opt}} = \boldsymbol{\beta_m} + \sum_{i=1}^{p} \left[\left(\bar{\boldsymbol{\beta}_j} \right) - (\boldsymbol{\beta_m}) \right] \qquad (7)$$

5. Conclusion

In the present work, the optimum combination of the setting of input factors to optimize output responses was investigated qualitatively and quantitatively estimated while drilling of alluminium7075 alloy with a modified twist drill bit on a standard radial drilling machine according to the Taguchi method coupled with a technique for order of preference by similarity to ideal solution (TOPSIS) and judged the following conclusions:

- An optimum combination of input parameters achieved as rotary speed of 795 rpm, feed of 26 mm/min, drill bit diameter of 10mm, point angle 100°, and clearance angle 8° leading to the optimum value of output responses of burr height 0.174 mm, thrust force 397 N and surface roughness 1.331 µm using TOPSIS method.
- From the assessment of closeness coefficients shown in Table 9, the input parameters while drilling with the best combination can be positioned in an order using the TOPSIS method was given with experiment wise 14 – 26 - 3- 4 – 11 -8- 13 -21 – 23 – 24 – 2 – 19 – 27 – 17 – 6 – 15 – 20 – 22 – 25 - 9 – 16 – 10 – 7 - 1- 12 – 5 respectively.
- Finally concluded that TOPSIS, a decision-making method based on multiple criteria while a selection of optimal combination of cutting parameters during drilling on an aluminium 7075 alloy material to optimize output responses like burr size, thrust force and surface roughness has been given good response with Taguchi method.

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