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Experimental Investigation and Design Optimization of Micro Drilling Process Parameters of Austenitic Stainless Steel (Aisi 316) Sheets by Doe Concepts

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Abstract**:** *Micro holes play an important role in manufacture of Printed circuit boards, Fuel injectors, Watch parts and micro dies. Micro drilling is one of the most significant manufacturing processes for metal cutting. Recently Austenitic stainless steel (AISI 316) sheets very much used for automotive application due to their excellent properties of high toughness and corrosion resistant. The experiments are designed to* L_{27} *orthogonal array which contains spindle speed, feed rate and point angle are the input parameters and material removal rate is a response parameter of micro drilling process. The experiments are conducted in Mini drilling machine and micro holes are produced by 0.5 mm drill with help of micro drill jig. The optimum parameters of micro drilling process are predicted by using Taguchi design of experiment and analyzed by signal to noise ratio(S/N ratio) and analysis of Variance (ANOVA).*

Keywords**:** *Micro drilling, AISI 316 sheet, Drilling parameters, MRR, Taguchi DOE, S/N ratio, ANOVA.*

I. Introduction

The various methods for producing microstructures such as micro-holes which find wide spread application in highly sensitive products such as automotive fuel injection nozzles, watches, medical electronics, and camera parts requires a high degree of accuracy in its profile parameters. Micro drilling is the most ideal micromachining process to generate micro-holes, can generate deeper holes with better straightness, better roundness, and smoother surfaces. This paper focuses on all existing micro drilling techniques that have been used in producing micro-holes along with the various strategies that have been adapted to improve the accuracy in hole dimensioning and its shape.W.S. Chen et al **[1]** has Investigated on the wear and performance of micro drills and presents series the influence of various factors on the efficiency of micro drilling process. He took micro drill geometry and cutting conditions as input variable along with drilling force, torque and drill wear as judging criteria. Finally concludes greater MRR is obtained by medium level of feed rate.Hyon-ko-Sim et al **[2]** has conducted a study on condition monitoring process on glass by using drilling machine. The experiment was carried out on w/p material as glass of 1mm thickness and drill bit used were diamond and carbide tools with 0.3 mm dia. In the paper, a precision 3D machine vision measurement system was intended to measure hole quality and inspect drill wear in micro drilling of glass material. It was found that Positional errors of fine holes, shape of cracks, and quality of hole surfaces are influenced by drilling conditions. R.Vimal et al **[3]** has Modelled and analysed the Thrust force and Torque in drilling GFRP composites by multifaceted drill using fuzzy logic .The research has been made by taking Glass Fibre Reinforced Plastic using 8 facet solid carbide tool. 3 parameters such as spindle speed; feed rate and drill diameter with each having 3 levels using Taguchi L_{27} was used. Thrust force and torque were taken as judging criteria for optimization of input parameters. Fuzzy rule based model was developed to indicate thrust force and torque in drilling of GFRP composites. The results suggested that the model can be effectively used for predicting the response variable by means of which delimitation can be controlled. Yu Teng Liang et al. **[4]** has investigated the various Micro Machining Cutting Parameters of PMMA Polymer Material Using Taguchi's Method and applied Grey-Taguchi method to optimize the micro-drilling of PMMA polymer with multiple performance indices. The four machining parameters were taken as coating layer, feed rate, spindle speed, and depth of cut. The performance of the drilling process was evaluated by two judging criteria, namely drill wear and surface roughness. The orthogonal array, grey relational analysis, and analysis of variance were used to study the two judging indices. The optimal combination of parameters was determined by using the grey relational grade, a performance index formed by combining the two performance characteristics. P.F. Zhang et al **[5]** made a review on mechanical drilling process for titanium alloy which was based on micro drilling using different tools of diameter ranging from 0.05mm to 10mm with w/p material as Ti alloy. He discusses cutting force, cutting temperature, tool wear and tool life, hole diameter, surface roughness, burr and chip type as judging criteria while drilling of Ti using the mentioned processes. Boris Stirn et al **[6]** has investigated the Burr Formation in micro drilling by using aluminium alloy and steel as Work material with drill bit size 130µm, 250 µm and 500µm. Machine parameters were diameter, cutting speed and feed rate where burr size and burr type were taken as the judging criteria. The influence of the cutting parameters on characteristic indices was observed and a comparison was being made. Dong-Woo Kim et al. **[7]** reported minimization of thrust forces in the step-feed micro drilling process. An orthogonal array of L27 was used to investigate the relationship between feed rate, step-feed, and spindle rpm with that of drilling Thrust. Author had found out optimal drilling conditions based on reliable experimental results to improve the productivity in micro drilling process. M. K.A Mohammed Ariffin et al **[8]** reported an investigation to optimization of drilling cutting process which used the composite sandwich panel as testing material. Different type of drill bit material such as HSS and carbide drill bit of diameter 3mm were selected and 4 controlling parameters such as drill bit material, cutting velocity, feed rate and hole diameter were analysed by using statistical approach known as Design of Experiments. A total number of 120 holes were analysed using Regression analysis technique to obtain the optimized range of cutting speeds. Minimum damage length was obtained for both the drill bit material for different conditions of controlling parameters. Azlan Abdul Rahman et al **[9]** investigated the effect of feed rate, Spindle Speed, Drill bit diameter on material removal rate, Surface roughness, burr and dimensional accuracy by taking drill sizes of 0.5 to 1.0mm. Comparative analysis was done between surface roughness, MRR and accuracy of drilled holes by experimentation. Experimental result shows the increment of spindle speed and feed rate value mostly affects the tool wear and size of burr on the drilled hole edges. TTM.Kannan et al [10] conducted experiments on drilling on EN-8 plates with different levels and parameters which designed by Taguchi Design of experiments. He represent larger metal rate is achieved high level of spindle speed and medium level of feed rate. All the above researchers conduct experiments on different material but no one conduct micro drilling process on Austenitic stainless steel sheets.

II. Experimental Set-Up

The experiments conducted in AHUJA make Mini drilling machine using 0.5 mm drill with various spindle speed, feed rate and depth of cut on Austenitic stainless steel sheets(AISI 316), experiments are designed by Taguchi L_{27} orthogonal array and analyzed by Signal to noise ratio and Analysis of variance.

Fig 1 Mini Drilling machine

Fig 2 Micro drills with various point angle

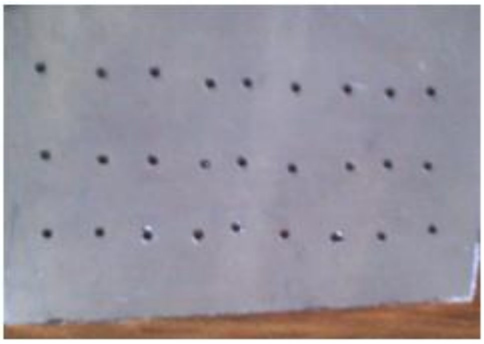

Fig 3 Micro drills (L $_{27}$) on AISI 316 sheets

Table 1 Levels and factors of Micro drilling process

Sl.No	Levels	Spindle speed	Feed Rate	Point angle
1	Low	1000	0.002	110^0
2	Medium	1500	0.001	118^0
3	High	2000	0.0005	126^0

Table 2 Mechanical properties of Austenitic stainless steel (AISI316) sheet

Max.Stress N/mm2	Yield stress N/mm2	Proof stress N/mm2	Elongation (%)	Impact Strength (j)	Hardness value (Brinell)
980	510	450	18	32	289

III. Result And Discussion

Micro drilling experiments are conducted on Portable mini drilling machine with different drilling parameters and the values of metal removal rate are calculated and tabulated in table 3.it indicates larger metal removal rate are obtained in 2000 rpm of spindle speed,0.02 mm of feed rate and 126^0 point angle.

Table 3.Micro drilling process parameters on (L $_{27}$) AISI 316 sheets.

Test No	Spindle speed (RPM)	Feed rate (mm/Rev)	Point angle (°)	MRR (mm^3/sec)
1	1000	0.02	1	15.7
2	1000	0.02	1	15.7
3	1000	0.02	1	15.7
4	1000	0.0066	2	5.18
5	1000	0.0066	2	5.18
6	1000	0.0066	2	5.18
7	1000	0.004	3	3.14
8	1000	0.004	3	3.14
9	1000	0.004	3	3.14
10	1500	0.02	2	47.12
11	1500	0.02	2	47.12
12	1500	0.02	2	47.12
13	1500	0.0066	3	15.55
14	1500	0.0066	3	15.55
15	1500	0.0066	3	15.55
16	1500	0.004	1	9.42
17	1500	0.004	1	9.42
18	1500	0.004	1	9.42
19	2000	0.02	3	78.52
20	2000	0.02	3	78.52
21	2000	0.02	3	78.52
22	2000	0.0066	1	25.91
23	2000	0.0066	1	25.91
24	2000	0.0066	1	25.91
25	2000	0.004	2	15.7
26	2000	0.004	2	15.7
27	2000	0.004	2	15.7

Table 4 Response Table for S/N ratio of Material removal rate (Larger the better)

Level	Spindle speed	Feed rate	Point angle
1	16.05	31.76	23.89
2	25.59	22.13	23.89
3	30.03	17.78	23.89
Delta	13.98	13.98	0.00
Rank	2	1	3

Table 4 represents the influence parameter Of micro drilling process is feed rate (Rank-1) and produce larger metal removal rate on AISI 316 sheets.

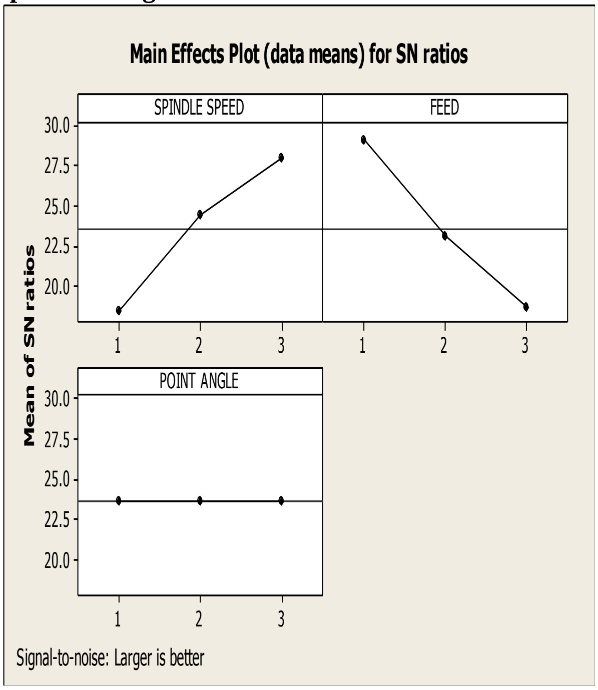

Fig 4 Main effect plot of Micro drilling Process parameters of AISI 316 sheet

Fig 4 shows that graphical representation of optimum micro drilling parameter of AISI 316 sheets which denotes larger metal removal rate is obtained in high level spindle speed,low level feed rate and high level of point angle.

Table 5 Analysis of Variance for MRR for Micro drilling process on AISI 316

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% contrib Ution
Spindle speed	2	1597.2	1597.2	798.63	83.0	0.00	37.24
Feed rate	2	2307.1	2307.1	1153.5	120.	0.00	53.79
Point angle	2	192.26	192.26	96.13	10.0	0.00	4.48
Error	20	192.26	192.26	9.61	-	-	4.48
Total	26	4288.9	-	-	-	-	100

Table 5 shows that Feed rate is a dominating parameter of micro drilling process of AISI 316 sheets which contribute 53.79 %.The optimum parameters of micro drilling process are influenced by feed rate and the spindle speed using 0.5 micro drills.

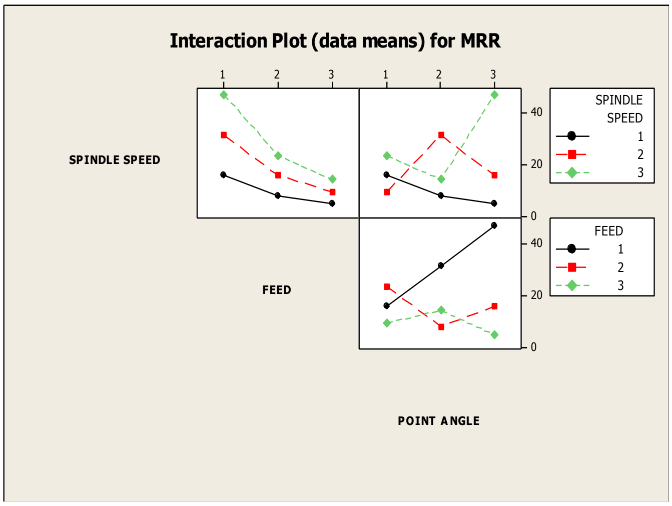

Fig 5 Interaction plot for micro milling process on AISI 316 sheets

Fig 5 shows that interaction plot for micro drilling process of AISI 316 sheets using 0.5mm micro holes in mini drilling machine. It represents spindle speed and feed rate are dependable parameter of Micro drilling process and produce larger metal removal rate and point angle is an independent parameter and not significant in micro drilling process.

IV. Conclusion

After performing 27 experiments of Micro drilling process on Austenitic stainless steel (AISI 316) sheets using 0.5 mm HSS drill, the following conclusions are derived:

1) Spindle speed and feed rate are most influencing parameters of micro drilling process.
2) Optimum parameter of Larger Metal removal rate of micro drilling process on AISI 316 sheets are 2000 rpm of Spindle speed,0.02 mm of feed rate and 126 ^{0} of point angle.
3) Point angle of drill is not significant in micro drilling process on AISI 316 sheets.
4) Minimum tool wear occur in HSS micro drill during Micro drilling process.
5) From mathematical calculations feed rate of micro drilling process provide 53.79 % of contribution during machining process.
6) Conventional mini drilling machining is suitable for performing micro holes with high degree of accuracy

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