# OPTIMIZATION OF PROCESS PARAMETERS IN DRILLING OF JUTE/COIR HYBRID NATURAL FIBER REINFORCEMENT POLYMER COMPOSITE USING TAGUCHI METHOD

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## Abstract:

In present era, day by day new engineering materials are forth coming but among all, the composites, especially epoxy polymer composites have important advantages because of its mechanical properties such as high wear resistance, electrical resistance, high strength to weight ratio, corrosion resistance, and etc. It can replace the traditional materials for manufacturing different components with required properties. Jute or coconut coir hybrid natural fiber reinforced polymer composite materials especially for the major application of automobile industry, aerospace industry, electronic industry and etc.

Drilling is one of the machining process most widely applied to composite materials but drilling of these composite materials irrespective of the application area can be considered a critical operation, owing to their tendency to delaminate when subjected to mechanical stresses. The objective of the present work is to optimize process parameters namely cuffing speed, feed and point angle in drilling of hybrid jute/coir natural fiber reinforcement polymer composites. In this work, experiments are conducted by the experimental design of taguchi and an orthogonal array used to optimize the process parameters on whole quality. Analysis of variance (ANOVA) test was conducted to determine the significance of each parameters on drilling.

This work is useful in selecting optimum values of various process parameters. that not only minimize the trust force and torque and also reduces the delamination and improve the quality of drilled hole.

**Key words**: coir and jute hybrid natural fiber reinforcement polymer composite, drilling parameters, taguchi method, optimization, SEM

## I. INTRODUCTION:

Hybrid natural fiber reinforcement polymer composites are used in wide areas of engineering applications in several industries such as energy sector, automotive, aircrafts, marine, electronics, etc. owing to low cost and superior mechanical properties like high specific strength, light weight, corrosion resistant and low thermal conductivity Natural fibers are gaining much interest in composite materials because of their potential to replace synthetic fibers in various industrial applications owing to their eco-friendly, non-abrasive, recyclable, renewable nature, and low density/costs.[1–3] Natural fiber composites (NFCs) are being used in different engineering fields such as automobile components, sport goods, non-structural parts of aerospace, and construction due to their light weight and accept- able mechanical properties

Drilling is the frequently used machining process and is often the final process used during the assembling of components. With the initiation of composite materials and their wide use in structural applications, it has become essential to drill holes into the laminates, to facilitate riveting or bolting to the main load bearing arrangement. In drilling, the chisel edge of the drill point pushes aside the material at the centre as it penetrates into the hole. The drilling of the composite materials is considerably affected by the tendency of the materials to delaminate under the action of the machining forces. To get better quality characteristics of drilled composites, some problems were encountered such as delamination, resin/fiber pull out, surface delamination etc. However, the information acquired from metal cutting cannot be directly transplanted to the fiber reinforced polymer matrix without considering the atypical material response to machining.

The objective of this paper includes fabrication, finding out properties and optimization of the process parameters like speed, feed and tool point angle to obtain minimum delamination damage, minimum torque, and minimum thrust force. For optimization, Taguchi L9 orthogonal array has been used and S/N ratios are calculated to find the optimum values of parameters. Also, Analysis of Variance (ANOVA) method is used to find the most influential parameter.

## II. Fabrication of composites:

In this experiment, Natural fiber composites were fabricated by Hand layup technique. For the fabrication of coir and jute hybrid natural fiber composite, Epoxy polymer (Araldite LY 556) and Hardener (HY 951) were taken in the ratio of 10:1 by weight by using micro weighing balance. Coir and jute fibers were cut according to the size of mold. The gel was sprayed inside the mold as a releasing agent. Alternate layers of epoxy i.e. epoxy resin with hardener and coir and jute fiber laminate was placed until the desired thickness (1 cm – 12 layers) was achieved. The orientation of fiber laminate was kept same throughout all the layers. The whole composite was allowed to cure at room temperature for 48 hrs. The care has been taken to maintain the uniform cross section of composite as much as possible. Because any variation in cross section can lead to stress concentration which will may lead to breaking of composite sample from that point only.

**Fig a**. Coir and jute fibers

**fig b**. hand layup technique

**fig c**. final composite

## III. EXPERIMENTAL SET UP

*A. Mechanical properties*

All the mechanical testing methods that were carried out were based on American Standard Testing Methods (ASTM). There are four tests performed, namely Tensile Test (ASTM D638), Flexural Test (ASTM D256), Hardness (ASTM D2240) and Impact Test (ASTM D790) respectively

**Table 1**: Material testing values

| TEST | Maximum load(N) | Stress At maximum load(mpa) | Young's modulus (mpa) |
|---|---|---|---|
| Tensile test | 897.24 | 29.91 | 3753.44 |
| Flexural test | 80 | 44.99 | 10600.46 |
| Impact test | 1.9(J) | - | - |

### *B. Drilling*

The experiment was conducted on a CNC drilling machine of Model No. JV55 by using HSS drill bits in dry conditions. Experiments were conducted by choosing different levels of input parameters for cutting speeds, feed rates, and tool point angle of drill bits.

In this work three types of tool point angles are used with same diameter 11mm, the angles are $90^0$, $118^0$, and $135^0$ degrees. Thrust force and torque have been measured by using digital drilling tool dynamometer.

The number of factors and levels are as shown in below the table:

**Table 2:** Process parameters and levels

| Drilling parameters/ Factors | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Speed (rpm) | 400 | 800 | 1200 |
| Feed rate (mm/min) | 20 | 30 | 40 |
| Tool point angle(degrees) | $90^0$ | $118^0$ | $135^0$ |

**fig d.** drilling operation

**fig e**. drilled holes

In this working process jute and coir natural fiber reinforcement polymer composite drilled by CNC drilling machine.The number of experiments is planned according to the Taguchi's L9 orthogonal array as shown in Table II which has 9 rows corresponding to number of experiments.

**Table 3**: ORTHOGONAL L9 ARRAY OF TAGUCHI:

| Experiment no. | Speed (rpm) | Feed (mm/min) | Tool point angle (degrees) |
|---|---|---|---|
| 1 | 400 | 20 | 90 |
| 2 | 400 | 30 | 118 |
| 3 | 400 | 40 | 135 |
| 4 | 800 | 20 | 90 |
| 5 | 800 | 30 | 118 |
| 6 | 800 | 40 | 135 |
| 7 | 1200 | 20 | 90 |
| 8 | 1200 | 30 | 118 |
| 9 | 1200 | 40 | 135 |

The output parameters studied are delamination damage, torque, and thrust force. The delamination was measured using SEM (scanning electron microscope). Delamination factor ($F_D$) is calculated as a measure of delamination damage. Fig 1 shows photographic image of drilled hole with damage on coir and jute hybrid natural fiber reinforcement polymer composite

$$F_D = D_{max}/D_{drill}$$

where, $D_{max}$ is the maximum diameter of the delamination zone and $D_{drill}$ is the drill diameter

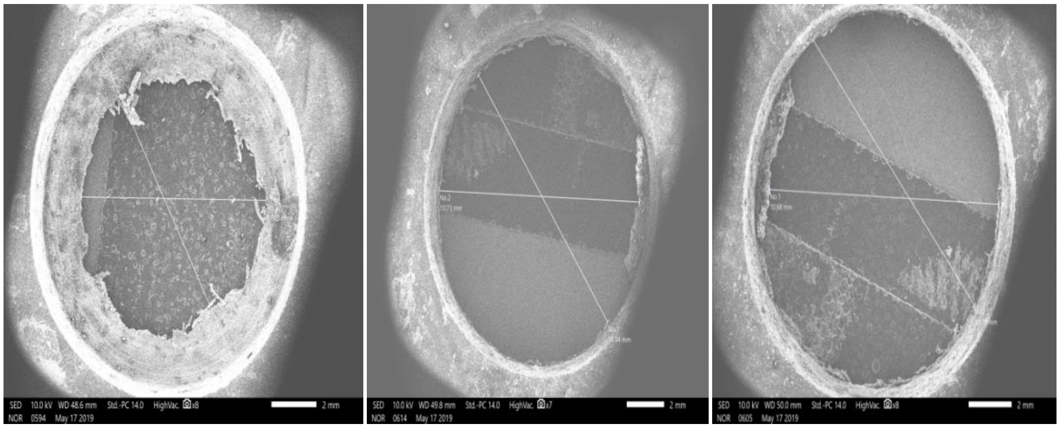

**Fig f**. SEM images:

**Torque and thrust force calculation:**

Torque and thrust force values are calculated by using dynamometer, the values are shown the dynamometer under the working process

**Table 4:** torque, thrust force, and delamination values**:**

| S no. | Torque (N-M) | Thrust force(N) | Delamination Factor(fd) |
|---|---|---|---|
| 1 | 0.7612 | 4.28 | 1.426 |
| 2 | 1.4811 | 7.34 | 1.107 |
| 3 | 2.3241 | 10.8 | 1.100 |
| 4 | 0.5661 | 5.59 | 1.341 |
| 5 | 1.2812 | 8.94 | 1.175 |
| 6 | 1.7612 | 14.41 | 1.029 |
| 7 | 0.3921 | 5.94 | 1.037 |
| 8 | 0.9211 | 11.21 | 1.025 |
| 9 | 1.3211 | 16.12 | 1.026 |

From the results of the experiment, Signal-to-Noise ratio (S/N ratio) values were determined for each level of each factor. Since we wanted to reduces the delamination, and minimize the torque and thrust force we used the formula for smaller is the better ratio.

## IV. Taguchi Design:

**Design Summary**

Taguchi Array L9(3^3)

Factors: 3

Runs: 9

Columns of L9(3^4) array: 1 2 3

Taguchi Analysis: Delamination versus SPEED, FEED, TOOL POINT ANGLE

Linear Model Analysis: SN ratios versus SPEED, FEED, TOOL POINT ANGLE

ANOVA Table for Delamination is given in Table 5. It is noted from the ANOVA table that speed contributes 81.67% amongst the various parameters to the delamination Hence it is ranked at first position.

**Table 5**: ANOVA table for Delamination:

| Source | DF | SEQ SS | ADJ SS | ADJ MS | F | P |
|---|---|---|---|---|---|---|
| Speed | 2 | 7.4580 | 7.4580 | 3.7290 | 25.08 | 0.038 |
| Feed | 2 | 0.9303 | 0.9303 | 0.4652 | 3.13 | 0.242 |
| Tool point angle | 2 | 0.4455 | 0.4455 | 0.2228 | 1.50 | 0.400 |
| Residual error | 2 | 0.2973 | 0.2973 | 0.1487 | | |
| Total | 8 | 9.1312 | | | | |

Feed rate contributes for 10.18 % of the delamination. And tool point angle contributes for 4.87% of delamination.

ANOVA Table for delamination is shown in Table 5.speed contributes a maximum of 81.67% to the delamination and is ranked at first position. While the feed rate contributes for 10.18% of the delamination, and tool point angle contributes for 4.87% of the delamination third rank.

**Response Table for Signal to Noise Ratios**
Smaller is better

**Table 6:** S/N RATIO VALUES FOR DELAMINATION FACTOR

| Level | Speed | Feed | Tool point angle |
|---|---|---|---|
| 1 | -2.3439 | -0.6436 | -0.8356 |
| 2 | -0.6755 | -1.1998 | -1.0375 |
| 3 | -0.2286 | -1.4046 | -1.3749 |
| Delta | 2.1153 | 0.7609 | 0.5394 |
| Rank | 1 | 2 | 3 |

Table 6: and Fig. (f) Shows influence of process parameters on the delamination factor. The optimum process parameters are on the delamination factor are obtained as speed at 400rpm(level 1), feed rate at 40 mm/min (level 3) and tool point angle135 (level 3). It is seen that smaller values of S/N ratio are obtained for lower speed and higher feed rate.

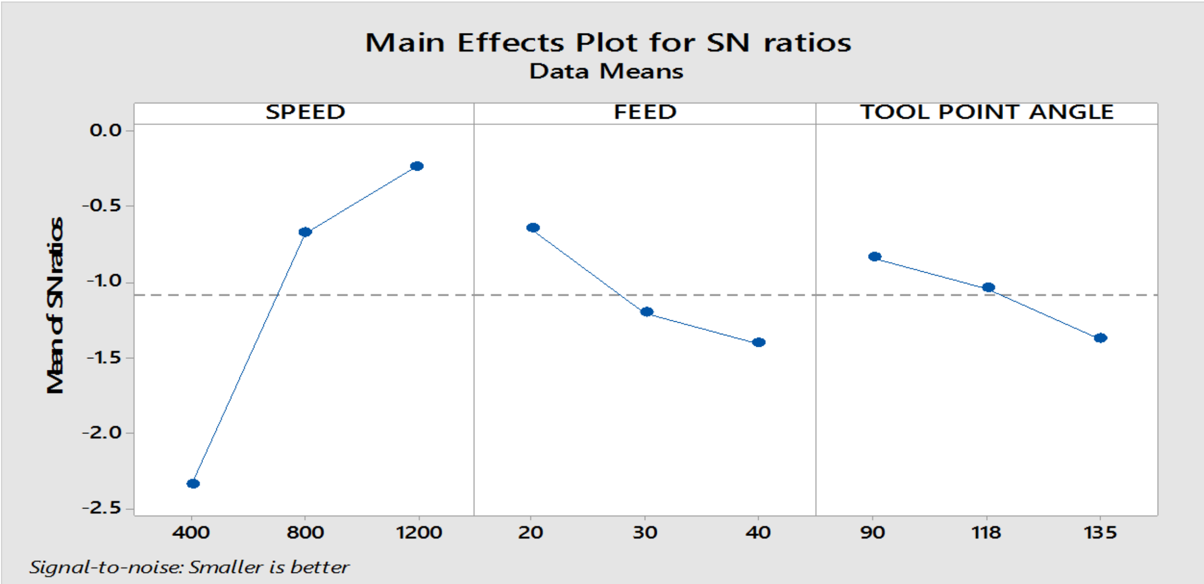


**Fig g.** Main Effects Plot for SN ratios

Taguchi Analysis: Torque versus SPEED, FEED, TOOL POINT ANGLE
Linear Model Analysis: SN ratios versus SPEED, FEED, TOOL POINT ANGLE

ANOVA Table for Torque is given in Table 7. It is noted from the ANOVA table that Feed rate contributes 80.67% amongst the various parameters to the torque Hence it is ranked at first position.

**Table 7:** ANOVA table for TORQUE

| SOURCE | DF | SEQ SS | ADJ SS | ADJ MS | F | P |
|---|---|---|---|---|---|---|
| Seed | 2 | 36.774 | 36.774 | 18.3871 | 51.12 | 0.019 |
| Feed | 2 | 157.151 | 157.151 | 78.5754 | 218.45 | 0.005 |
| Tool point angle | 2 | 0.149 | 0.149 | 0.0743 | 0.21 | 0.829 |
| Residual Error | 2 | 0.719 | 0.179 | 0.3597 | | |
| Total | 8 | 194.793 | | | | |

Feed rate contributes for 80.67 % of the torque, speed contributes for 18.87%, and tool point angle contributes for 0.07% of torque.

ANOVA Table for torque is shown in Table7 .Feed rate contributes a maximum of 80.67% to the torque and is ranked at first position. While the speed contributes for 18.87% of the torque, and tool point angle contributes for 0.07% of the torque third rank.

**Table 8**. S/N RATIO VALUES FOR TORQUE

| Level | Speed | Feed | Tool point angle |
|---|---|---|---|
| 1 | -2.7889 | 5.1481 | -0.6108 |
| 2 | -0.7088 | -1.6167 | -0.2961 |

| | | | |
|---|---|---|---|
| 3 | 2.1424 | -4.8867 | -0.4485 |
| Delta | 4.9313 | 10.0347 | 0.3147 |
| Rank | 2 | 1 | 3 |

Table 8: and Fig. (g) Shows influence of process parameters on the delamination factor. The optimum process parameters are on the delamination factor are obtained as speed at 400 rpm(level 1), feed rate at 40 mm/min (level 3) and tool point angle90 (level 1). It is seen that smaller values of S/N ratio are obtained for lower speed and higher feed rate.

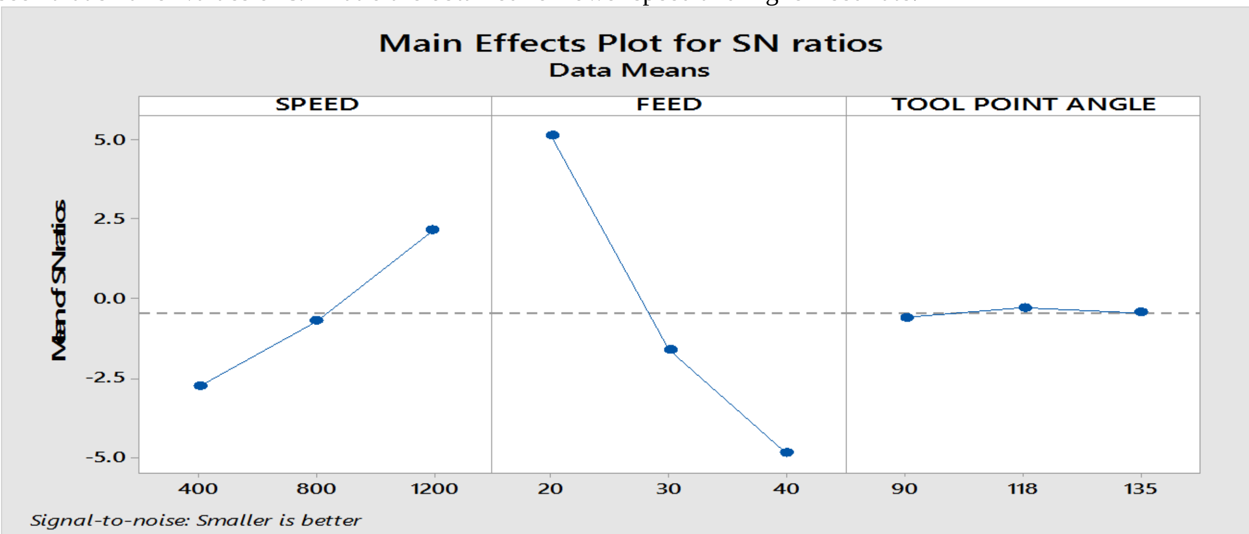


**Fig h.** Main Effects Plot for SN ratios

Taguchi Analysis: Thrust force versus SPEED, FEED, TOOL POINT ANGLE
Linear Model Analysis: SN ratios versus SPEED, FEED, TOOL POINT ANGLE

ANOVA Table for thrust force is given in Table 9. It is noted from the ANOVA table that Feed rate contributes 85.42% amongst the various parameters to the thrust force Hence it is ranked at first position.

**Table 9**: ANOVA for THRUST FORCE:

| Source | DF | SEQ SS | ADJ SS | ADJ MS | F | P |
|---|---|---|---|---|---|---|
| Speed | 2 | 17.203 | 17.203 | 8.6016 | 141.75 | 0.007 |
| Feed | 2 | 104.365 | 104.365 | 52.1827 | 859.96 | 0.001 |
| Tool point angle | 2 | 0.480 | 0.480 | 0.2398 | 3.95 | 0.202 |
| Residual Error | 2 | 0.121 | 0.121 | 0.0607 | | |
| Total | 8 | 122.170 | | | | |

Feed rate contributes for 85.42% of the thrust force, speed contributes for 14.08%, and tool point angle contributes for 0.3% of thrust force.

ANOVA Table for thrust force is shown in Table 9.Feed rate contributes a maximum of 85.42% to the thrust force and is ranked at first position. While the speed contributes for 14.08% of the thrust force, and tool point angle contributes for 0.3% of the thrust force third rank.

**Table 10**: S/N RATIO VALUES FOR THRUST FORCE

| Level | Seed | Feed | Tool point angle |
|---|---|---|---|
| 1 | -16.87 | -14.35 | -18.93 |
| 2 | -19.05 | -19.11 | -18.80 |
| 3 | -20.21 | -22.66 | -18.39 |
| Delta | 3.33 | 8.31 | 0.54 |
| Rank | 2 | 1 | 3 |

Table 10: and Fig. (i) Shows influence of process parameters on the delamination factor. The optimum process parameters are on the delamination factor are obtained as speed at 1200 rpm(level 3), feed rate at 40 mm/min (level 3) and tool point angle90 (level 1). It is seen that smaller values of S/N ratio are obtained for higher speed and higher feed rate.

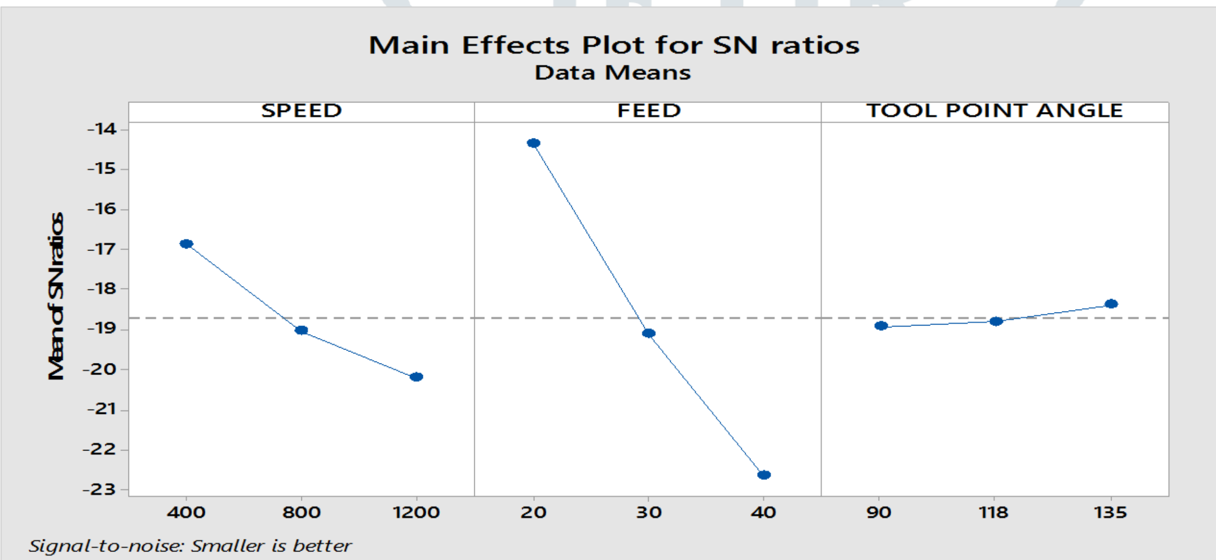


**Fig i.** Main Effects Plot for SN ratios

Taguchi Analysis: Delamination, Torque and thrust force versus SPEED, FEED, AND TOOL POINT ANGLE
Linear Model Analysis: SN ratios versus SPEED, FEED, TOOL POINT ANGLE

ANOVA Table for delamination, torque, and thrust force are given in Table 11. It is noted from the ANOVA table that Feed rate contributes 87.92% amongst the various parameters to the delamination, torque, and thrust force Hence it is ranked at first position.

**Table 11**: ANOVA TABLE FOR DELAMINATION, TORQUE, AND THRUST FORCE:

| Source | DF | SEQ SS | ADJ SS | ADJ MS | F | P |
|---|---|---|---|---|---|---|
| Speed | 2 | 14.625 | 14.625 | 7.3125 | 151.70 | 0.007 |
| Feed | 2 | 101.243 | 101.243 | 50.6213 | 1050.18 | 0.001 |
| Tool point angle | 2 | 0.490 | 0.490 | 0.2449 | 5.08 | 0.164 |
| Residual error | 2 | 0.096 | 0.096 | 0.0482 | | |
| Total | 8 | 116.454 | | | | |

Feed rate contributes for 87.92% of the delamination, torque, and thrust force, speed contributes for 12.55%, and tool point angle contributes for 4.2% of delamination, torque, and thrust force.

ANOVA Table for delamination, torque, and thrust force is shown in Table 11.Feed rate contributes a maximum of 87.42% to the ranked at first position. While the speed contributes for 12.55% to the second rank, and tool point angle contributes for 4.2% of the delamination, torque, and thrust force third rank.

**Table 12**: S/N RATIO VALUES FOR DELAMINATION, TORQUE ANDTHRUST FORCE

| Level | Speed | Feed | Tool point angle |
|---|---|---|---|
| 1 | -12.439 | -9.839 | -14.359 |
| 2 | -14.422 | -14.516 | -14.214 |
| 3 | -15.520 | -18.027 | -13.808 |
| Delta | 3.080 | 8.188 | 0.551 |
| Rank | 2 | 1 | 3 |

Table 12: and Fig. (j) Shows influence of process parameters on the delamination factor. The optimum process parameters are on the delamination factor are obtained as speed at 1200 rpm(level 3), feed rate at 40 mm/min (level 3) and tool point angle90 (level 1). It is seen that smaller values of S/N ratio are obtained for higher speed and higher feed rate.

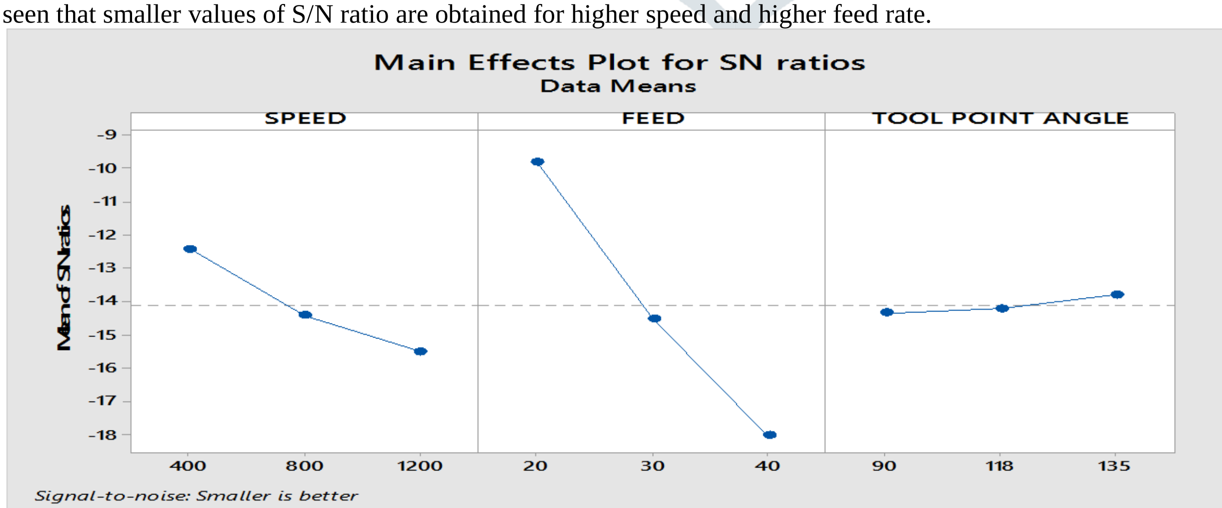


**Fig j**. Main Effects Plot for SN ratios

**Table 13** : OUT PUT VALUES OF S/N RATIOS,STANDARD DEVIATION AND MEANS.

| S. no | Speed (rpm) | Feed (Mm/min) | Tool point angle | delamination | Torque (N-M) | Thrust (N) | SNRA | STDE | MEAN |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 400 | 20 | 90 | 1.175 | 0.761 | 4.28 | 10.156 | 1.923 | 2.267 |
| 2 | 400 | 30 | 118 | 1.341 | 1.481 | 7.34 | 12.853 | 3.423 | 3.387 |
| 3 | 400 | 40 | 135 | 1.426 | 2.324 | 10.8 | 16.165 | 5.172 | 4.850 |
| 4 | 800 | 20 | 90 | 1.037 | 0.566 | 5.59 | 10.366 | 2.774 | 2.397 |
| 5 | 800 | 30 | 118 | 1.100 | 1.281 | 8.94 | 14.407 | 4.475 | 3.773 |
| 6 | 800 | 40 | 135 | 1.107 | 1.761 | 14.41 | 18.491 | 7.498 | 5.759 |
| 7 | 1200 | 20 | 90 | 1.025 | 0.392 | 5.94 | 10.850 | 3.036 | 2.452 |
| 8 | 1200 | 30 | 118 | 1.026 | 0.921 | 11.21 | 16.286 | 5.910 | 4.385 |
| 9 | 1200 | 40 | 135 | 1.029 | 1.321 | 16.12 | 19.422 | 8.629 | 6.156 |

The table shows the s/n ratio values, standard deviation values, and mean values of the delamintion, torque and thrust force with process of taguchi analysis using mini tab tool

## V. CONCLUSIONS:

In this work presents the optimization of cutting process parameters namely, cutting speed, feed and tool point angles in drilling of coir and jute hybrid natural fiber reinforcement polymer composites using the application of taguchi and ANOVA analysis in mini tab tool. The conclusions drawn from this work are as follows:

The optimum process parameters in the drilling of coir and jute hybrid natural fiber reinforcement polymer composites are:

- The optimum values of the minimum delamination, the process parameters are speed 400rpm, feed 40 mm/min and tool point angle 135, this values maintain the minimum delamination levels.
- The optimum values of the minimum torque , the process parameter are speed 400rpm, feed 40 and tool point angle 90,this values maintain the minimum torque value.
- The optimum values of the minimum thrust force, the process parameters are speed 1200rpm, feed 40 and tool point angle 90,this values maintain the minimum thrust force value

The optimum values of the minimum delamination, minimum torque and minimum thrust force levels, the process parameters speed 1200rpm, feed 40, and tool point angle 90

This work useful in selecting optimum values of speed, feed and tool point angle and minimize the torque and thrust force and also reduces the delamination and improve quality of drilled hole.

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