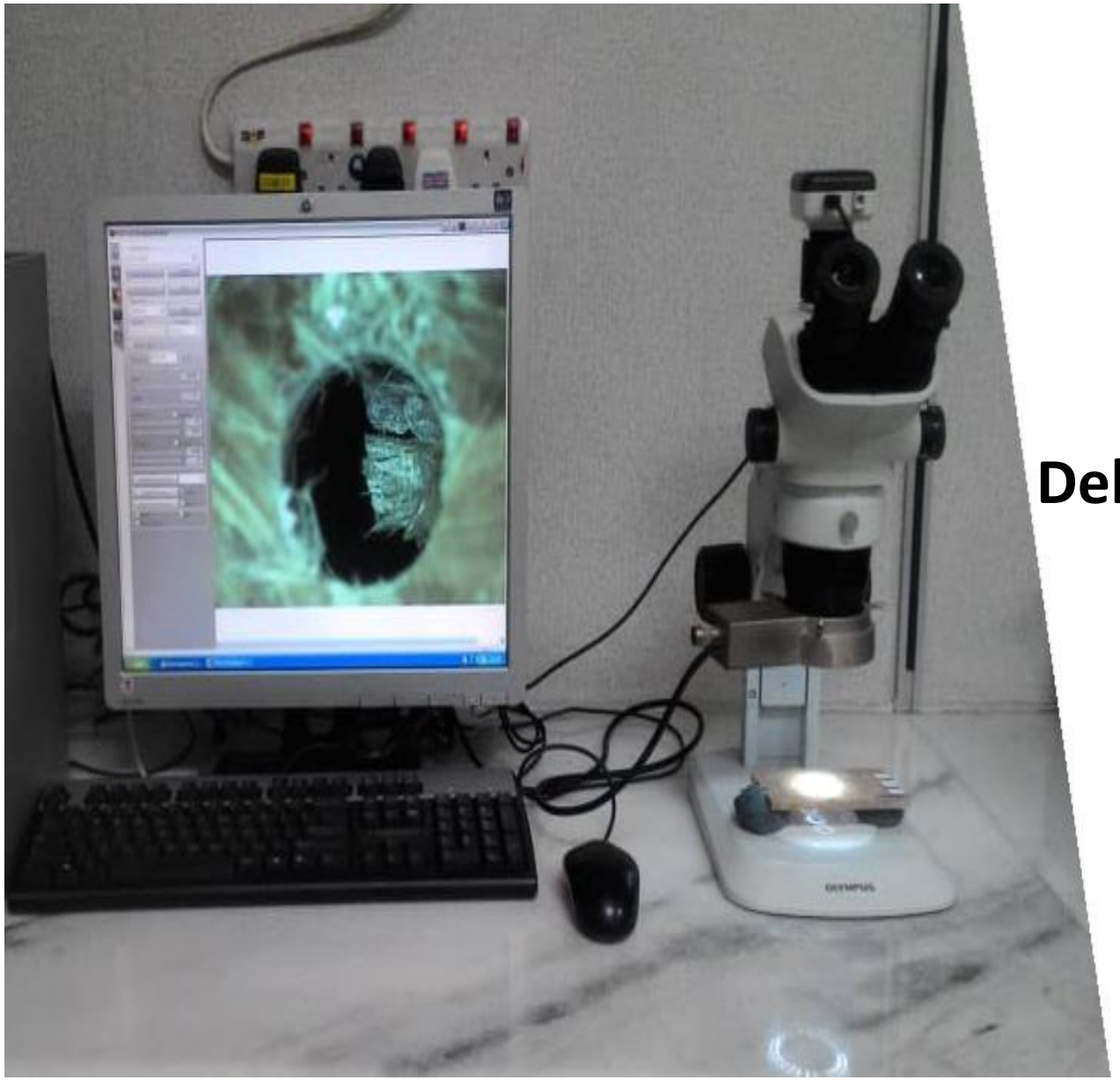


KOLOKIUM PENYELIDIKAN 2021
INSTITUT TADBIRAN AWAM MALAYSIA

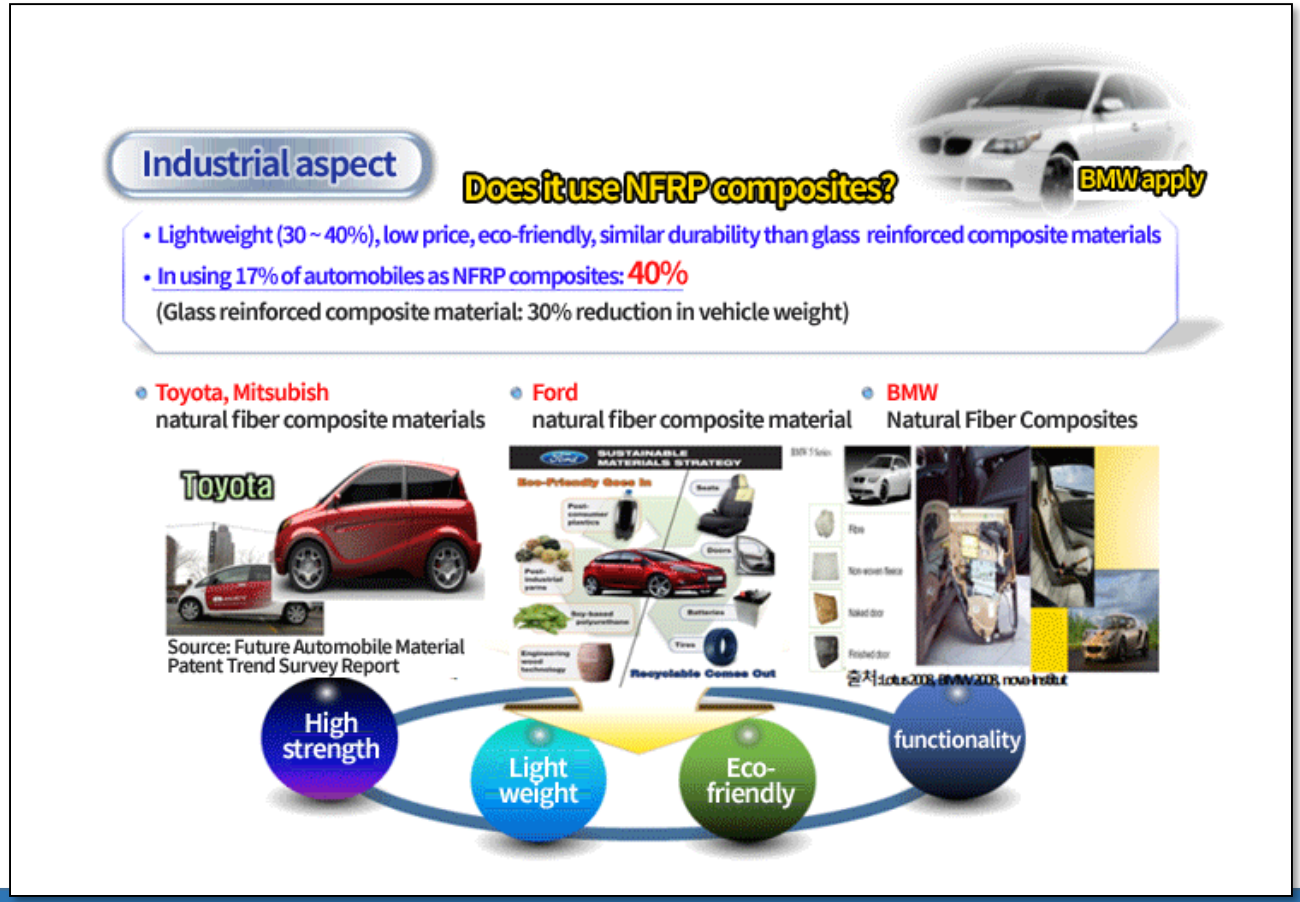
Effects of Machining Parameters on Delamination in Drilling Kenaf-Glass Fiber Reinforced Unsaturated Polyester Composite

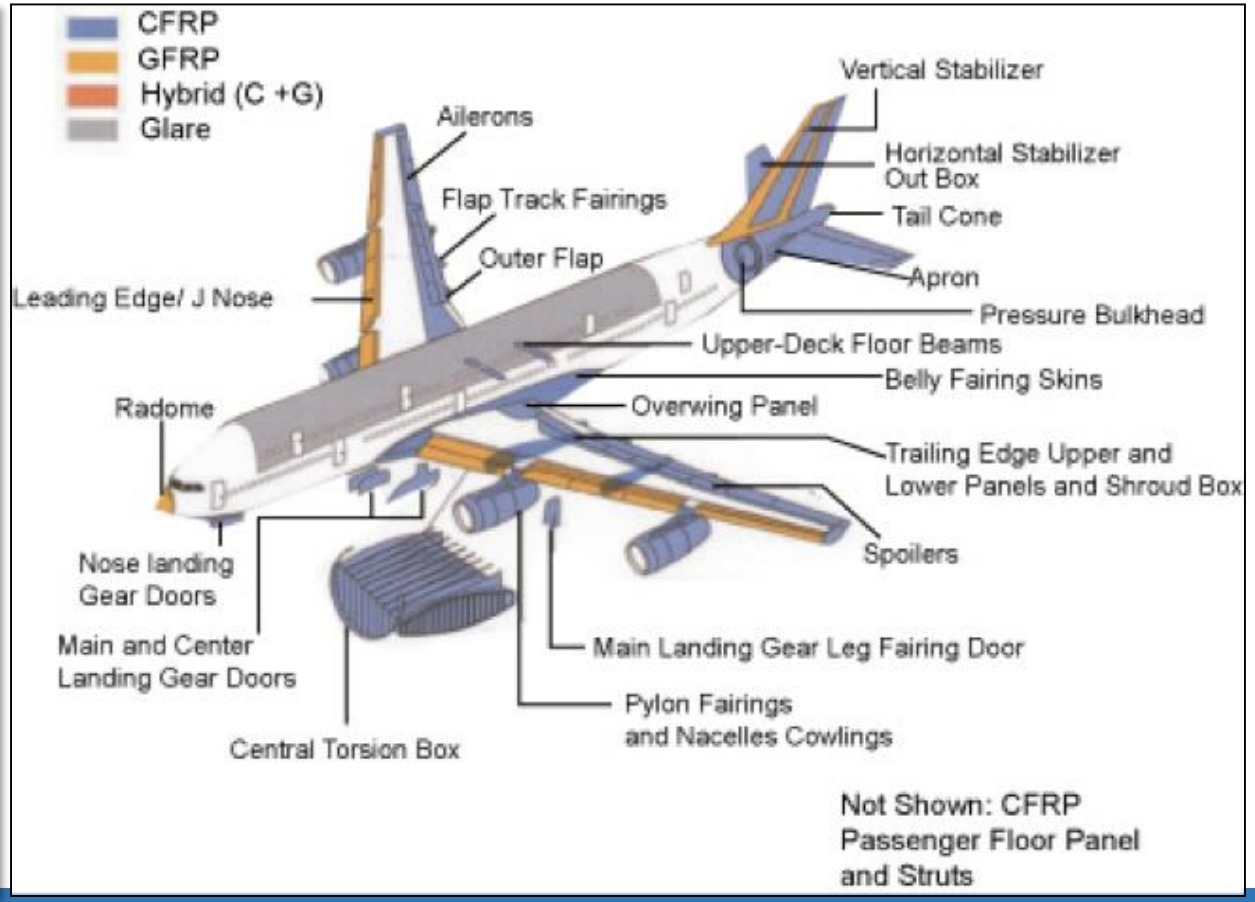
A.RAHMAD NGAH
JABATAN TENAGA MANUSIA
KEMENTERIAN SUMBER MANUSIA

Research Background

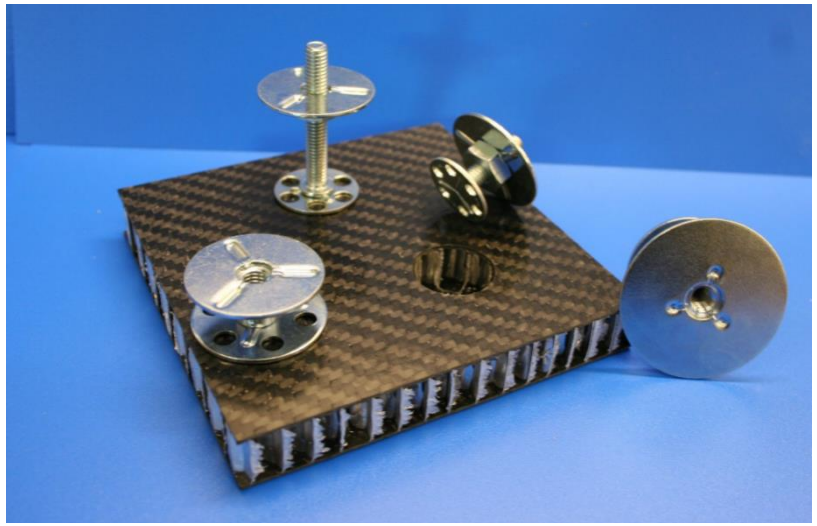
- Natural fiber composite have raised great interest among material scientists and engineers in recent years due to the considerations of developing an environmental friendly material, and partly reducing the dependency on glass fiber.

- There is a growing interest in the use of natural fibers as reinforcing materials and major fields of application for natural fiber reinforced composites can be found in the automotive and aerospace industry.





Problem Statement

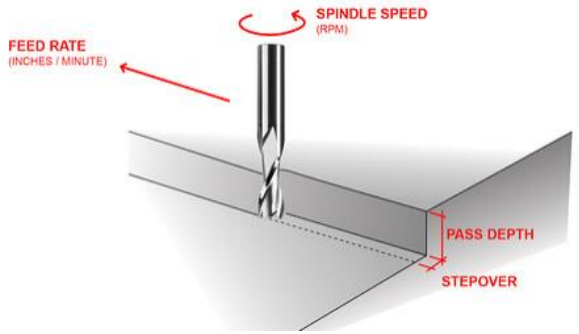


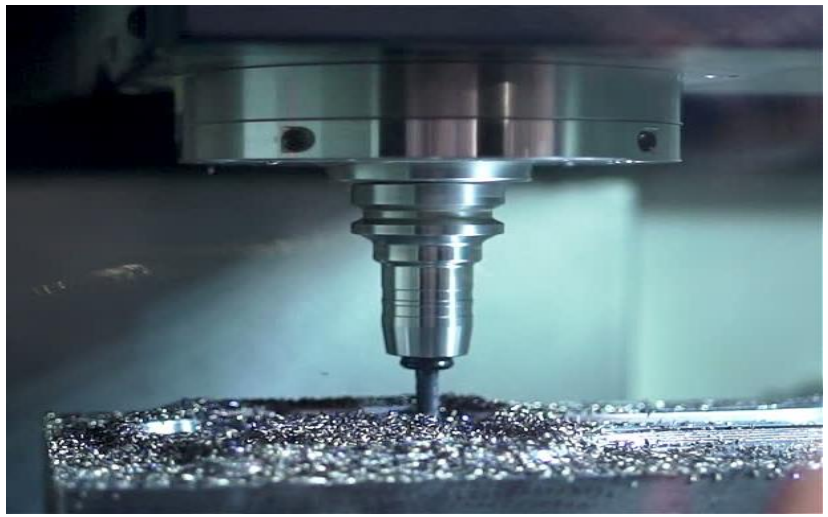
The Embedded Fasteners in Composites

The FC43 structural panel fastener prevents delamination in composites (Aerospace)

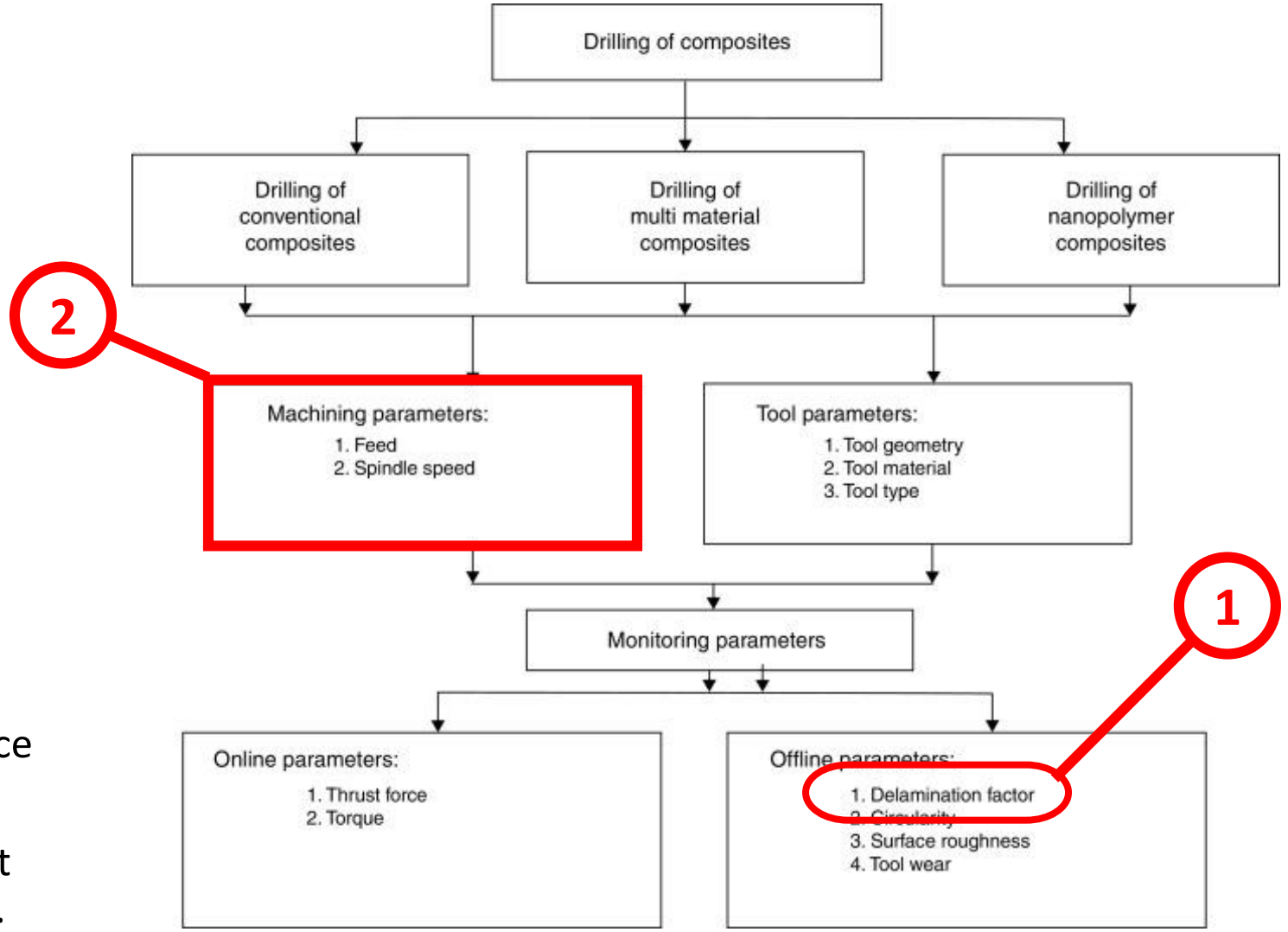
- Drilling is a secondary material removal and usually carried out to facilitate fastening of part together.
- Drilling of composite materials is not usually a problem–free process.
- Issues related to delamination composite laminates need to be addressed because it introduces the stress concentration point on the composite

Problem Statement





- Drilling of fiber reinforced polyester composite is one of the most importance process in machinability.
- There are several factors that can affect machinability during drilling composite.

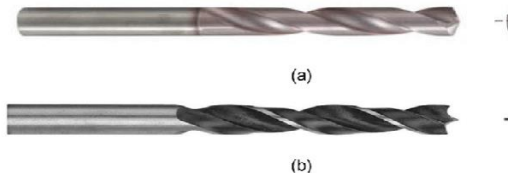


(Panchagnula & Palaniyandi, 2017)

Research Objective

Research Objective

1. To analyze delamination in drilling kenaf-glass fiber reinforced unsaturated polyester composite
2. To compare drilling quality between 2 types of drill bits.



6 mm

Research Analysis

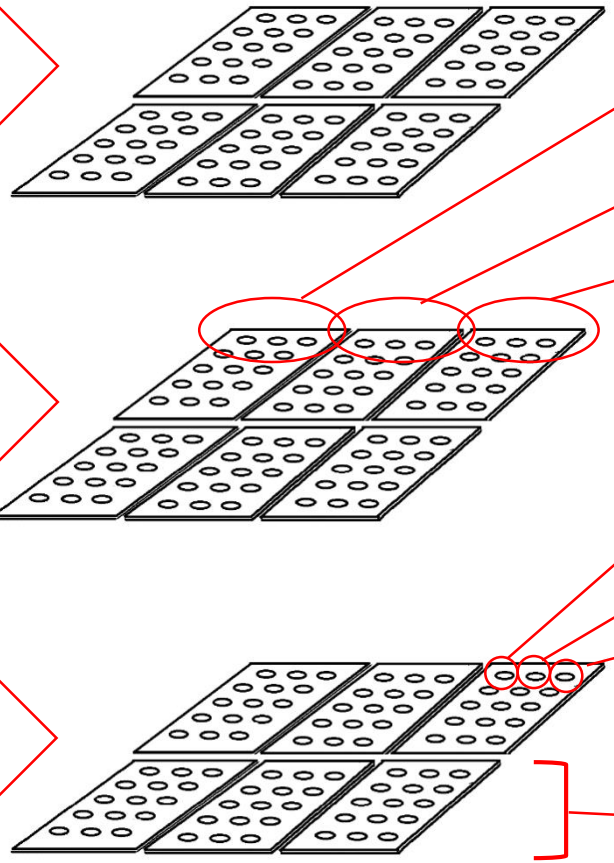
- Delamination → Minimum Fd, Maximum Fd
  - → Taguchi Analysis
    - Means
    - SNRA
    - ANOVA
- Delamination → Minimum Fd, Maximum Fd
- No-Go Specimen test →
  - Ok :Fit
  - NG :Not Fit
  - NG :Oversized

Research Methodology

GFRP

KFRP

KGFRP



700 rpm

1400 rpm

2100 rpm

0.05 mm/rev

0.12 mm/rev

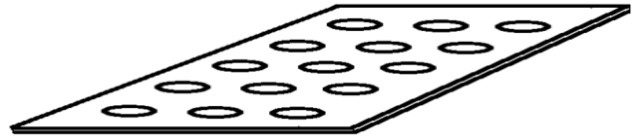
0.20 mm/rev

Twist drill bit

Brad drill Bit

Material	Spindle Speed	Feed Rate
GFRP	700 rpm	0.05 mm/rev
KFRP	1400 rpm	0.12 mm/rev
KGFRP	2100 rpm	0.20 mm/rev

Upper Delamination



Bottom Delamination

= 270 data

= 270 data

= 540 data

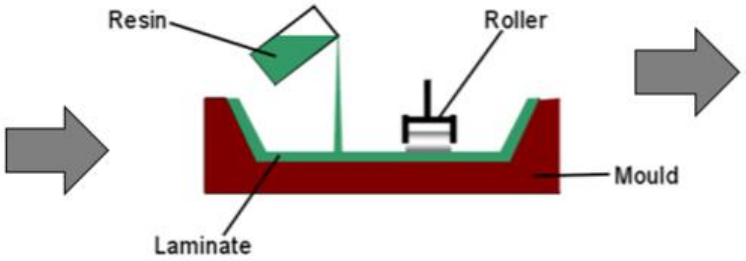
Research Methodology

Polyester

Kenaf

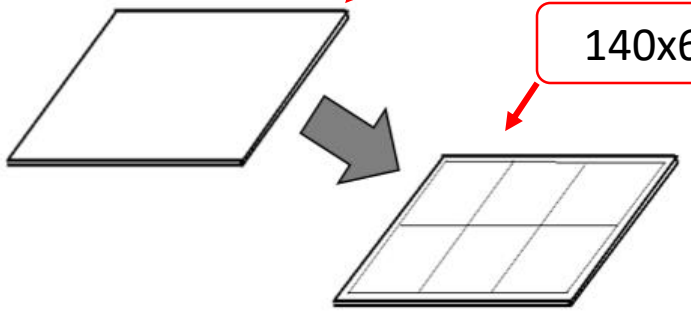
Hardener

E-Glass

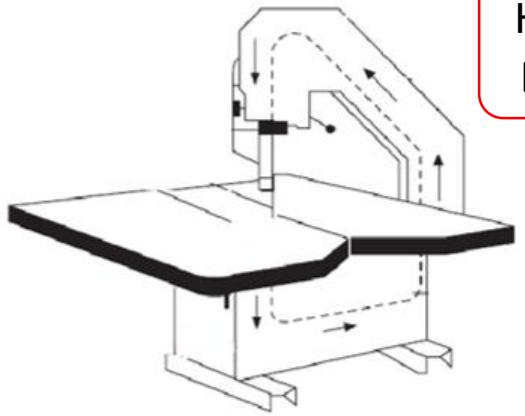


300x200x6 mm

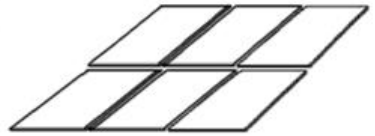
140x60x6 mm



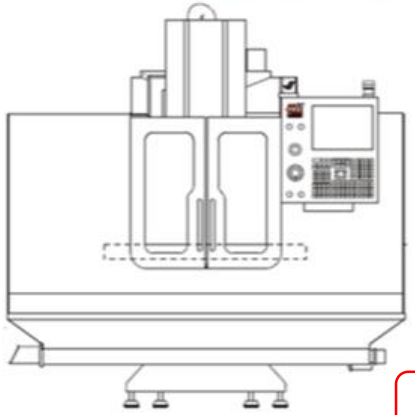
Horizontal Band Saw

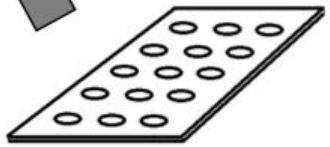


HSS Uncoated 6mm (Twist & Brad)



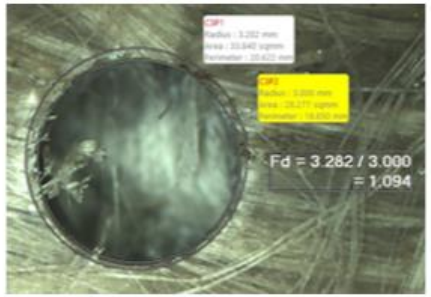
CNC Machine





Tool Maker Microscope

Motic Image Plus 2.0 ML Software

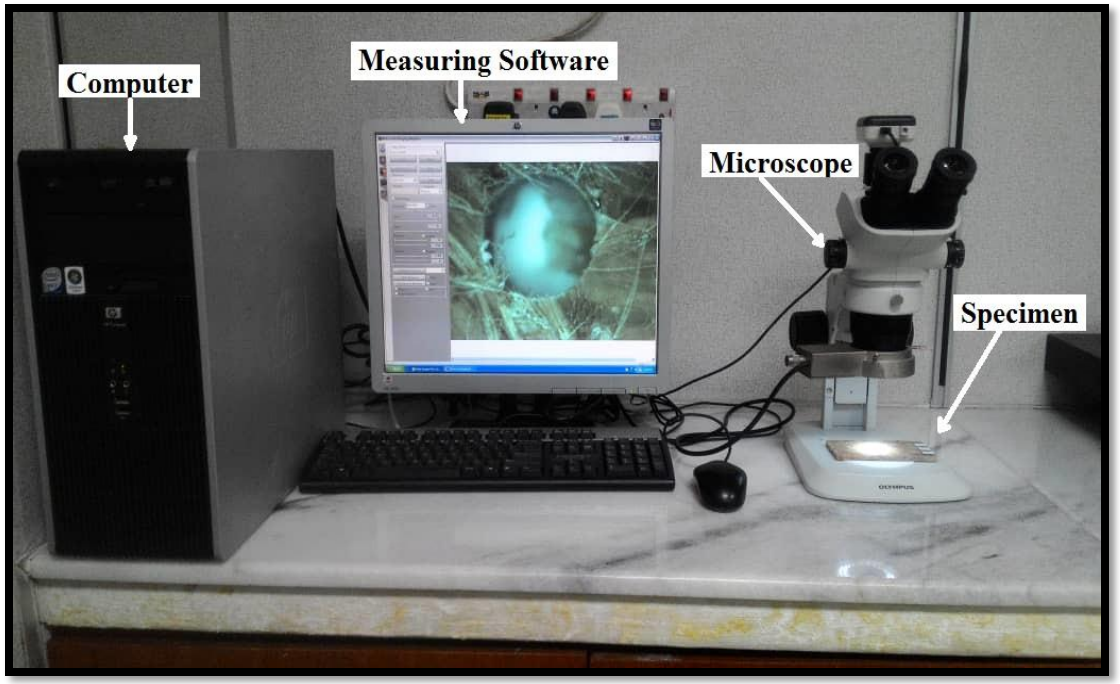


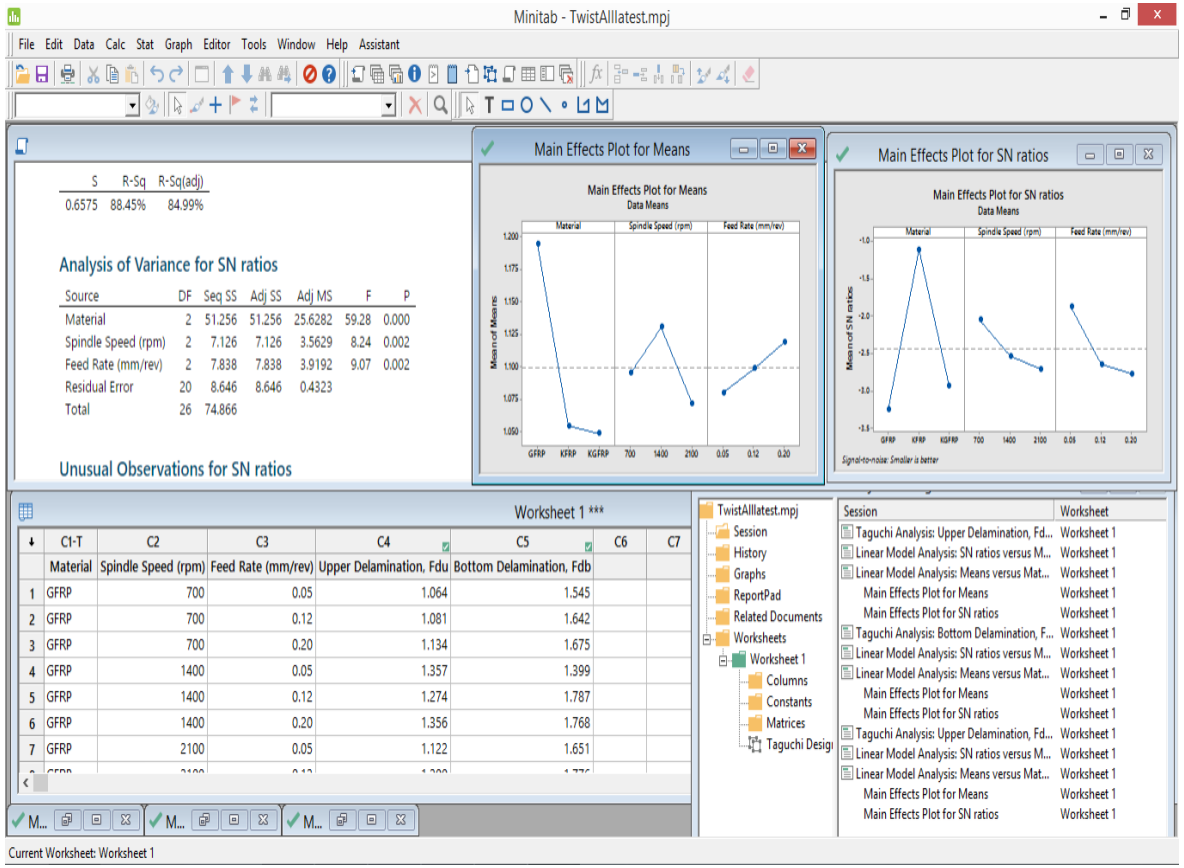
Research Methodology

Motic Images Plus 2.0ML
Multi-functional & Multi-language Microscopy Software

Minitab® 18

- Taguchi Analysis
- ANOVA





Results & Analysis

Dmax value (inlet and outlet) for twist drill bit.

Experiment No	Material	Spindle Speed (rpm)	Feed Rate (mm/rev)	Dmax (Inlet)	Dmax (outlet)
1	Glass Fiber Reinforced Unsaturated Polyester (GFRP)	700	0.05	6.387	9.270
2			0.12	6.484	9.850
3			0.20	6.806	10.051
4		1400	0.05	8.142	8.392
5			0.12	7.643	10.720
6			0.20	8.134	10.608
7		2100	0.05	6.734	9.907
8			0.12	7.200	10.656
9			0.20	6.967	11.107
10	Kenaf Fiber Reinforced Unsaturated Polyester (KFRP)	700	0.05	6.250	6.072
11			0.12	7.103	6.105
12			0.20	6.862	6.072
13		1400	0.05	6.032	6.757
14			0.12	6.097	8.263
15			0.20	6.048	7.643
16		2100	0.05	6.040	6.685
17			0.12	6.089	8.610
18			0.20	6.403	9.238
19	Kenaf Glass Fiber Reinforced Unsaturated Polyester (KGFRP)	700	0.05	6.129	8.626
20			0.12	6.347	9.890
21			0.20	6.749	10.921
22		1400	0.05	6.524	9.705
23			0.12	6.138	10.204
24			0.20	6.282	10.430
25		2100	0.05	6.073	9.898
26			0.12	6.194	10.905
27			0.20	6.170	10.438

Dmax value (inlet and outlet) for brad drill bit.

Experiment No	Material	Spindle Speed (rpm)	Feed Rate (mm/rev)	Dmax (Inlet)	Dmax (outlet)
1	Glass Fiber Reinforced Unsaturated Polyester (GFRP)	700	0.05	8.054	8.360
2			0.12	9.866	17.155
3			0.20	8.465	19.539
4		1400	0.05	7.136	10.848
5			0.12	8.151	15.117
6			0.20	11.557	22.028
7		2100	0.05	8.481	13.338
8			0.12	11.203	18.564
9			0.20	11.356	19.789
10	Kenaf Fiber Reinforced Unsaturated Polyester (KFRP)	700	0.05	7.338	7.410
11			0.12	7.619	19.040
12			0.20	7.555	20.336
13		1400	0.05	7.184	12.266
14			0.12	7.200	18.098
15			0.20	7.362	18.726
16		2100	0.05	6.943	15.681
17			0.12	7.354	19.974
18			0.20	7.039	24.033
19	Kenaf Glass Fiber Reinforced Unsaturated Polyester (KGFRP)	700	0.05	6.564	11.260
20			0.12	7.072	18.476
21			0.20	7.241	19.410
22		1400	0.05	6.693	13.611
23			0.12	6.790	21.134
24			0.20	6.927	23.140
25		2100	0.05	6.765	18.274
26			0.12	6.766	23.687
27			0.20	7.023	24.138

Results & Analysis

Upper and bottom delamination factor (Fd) for twist drill bit.

Experiment No	Material	Spindle Speed (rpm)	Feed Rate (mm/rev)	Upper Delamination, Fd_u	Bottom Delamination, Fd_b
1	Glass Fiber Reinforced Unsaturated Polyester (GFRP)	700	0.05	1.064	1.545
2			0.12	1.081	1.642
3			0.20	1.134	1.675
4		1400	0.05	1.357	1.399
5			0.12	1.274	1.787
6			0.20	1.356	1.768
7		2100	0.05	1.122	1.651
8			0.12	1.200	1.776
9			0.20	1.161	1.851
10	Kenaf Fiber Reinforced Unsaturated Polyester (KFRP)	700	0.05	1.042	1.012
11			0.12	1.184	1.018
12			0.20	1.144	1.012
13		1400	0.05	1.005	1.126
14			0.12	1.016	1.377
15			0.20	1.008	1.274
16		2100	0.05	1.007	1.114
17			0.12	1.015	1.435
18			0.20	1.067	1.540
19	Kenaf Glass Fiber Reinforced Unsaturated Polyester (KGFRP)	700	0.05	1.022	1.438
20			0.12	1.058	1.648
21			0.20	1.125	1.820
22		1400	0.05	1.087	1.617
23			0.12	1.023	1.701
24			0.20	1.047	1.738
25		2100	0.05	1.012	1.650
26			0.12	1.032	1.818
27			0.20	1.028	1.740

Upper and bottom delamination factor (Fd) for brad drill bit.

Experiment No	Material	Spindle Speed (rpm)	Feed Rate (mm/rev)	Upper Delamination, Fd_u	Bottom Delamination, Fd_b
1	Glass Fiber Reinforced Unsaturated Polyester (GFRP)	700	0.05	1.342	1.393
2			0.12	1.644	2.859
3			0.20	1.411	3.257
4		1400	0.05	1.189	1.808
5			0.12	1.358	2.520
6			0.20	1.926	3.671
7		2100	0.05	1.413	2.223
8			0.12	1.867	3.094
9			0.20	1.893	3.298
10	Kenaf Fiber Reinforced Unsaturated Polyester (KFRP)	700	0.05	1.223	1.235
11			0.12	1.270	3.173
12			0.20	1.259	3.389
13		1400	0.05	1.197	2.044
14			0.12	1.200	3.016
15			0.20	1.227	3.121
16		2100	0.05	1.157	2.614
17			0.12	1.226	3.329
18			0.20	1.173	4.006
19	Kenaf Glass Fiber Reinforced Unsaturated Polyester (KGFRP)	700	0.05	1.094	1.877
20			0.12	1.179	3.079
21			0.20	1.207	3.235
22		1400	0.05	1.115	2.269
23			0.12	1.132	3.522
24			0.20	1.154	3.857
25		2100	0.05	1.128	3.046
26			0.12	1.128	3.948
27			0.20	1.170	4.023

Results & Analysis

Upper and bottom delamination factor (Fd) for twist drill bit.

Experiment No	Material	Spindle Speed (rpm)	Feed Rate (mm/rev)	Upper Delamination, Fd_u	Bottom Delamination, Fd_b
1	Glass Fiber Reinforced Unsaturated Polyester (GFRP)	700	0.05	1.064	1.545
2			0.12	1.081	1.642
3			0.20	1.134	1.675
4		1400	0.05	1.357	1.399
5			0.12	1.274	1.787
6			0.20	1.356	1.768
7		2100	0.05	1.122	1.651
8			0.12	1.200	1.776
9			0.20	1.161	1.851
10	Kenaf Fiber Reinforced Unsaturated Polyester (KFRP)	700	0.05	1.042	1.012
11			0.12	1.184	1.018
12			0.20	1.144	1.012
13		1400	0.05	1.005	1.126
14			0.12	1.016	1.377
15			0.20	1.008	1.274
16		2100	0.05	1.007	1.114
17			0.12	1.015	1.435
18			0.20	1.067	1.540
19	Kenaf Glass Fiber Reinforced Unsaturated Polyester (KGFRP)	700	0.05	1.022	1.438
20			0.12	1.058	1.648
21			0.20	1.125	1.820
22		1400	0.05	1.087	1.617
23			0.12	1.023	1.701
24			0.20	1.047	1.738
25		2100	0.05	1.012	1.650
26			0.12	1.032	1.818
27			0.20	1.028	1.740

Minimum

Max

Minimum

Max

Minimum

Max

Upper and bottom delamination factor (Fd) for brad drill bit.

Experiment No	Material	Spindle Speed (rpm)	Feed Rate (mm/rev)	Upper Delamination, Fd_u	Bottom Delamination, Fd_b
1	Glass Fiber Reinforced Unsaturated Polyester (GFRP)	700	0.05	1.342	1.393
2			0.12	1.644	2.859
3			0.20	1.411	3.257
4		1400	0.05	1.189	1.808
5			0.12	1.358	2.520
6			0.20	1.926	3.671
7		2100	0.05	1.413	2.223
8			0.12	1.867	3.094
9			0.20	1.893	3.298
10	Kenaf Fiber Reinforced Unsaturated Polyester (KFRP)	700	0.05	1.223	1.235
11			0.12	1.270	3.173
12			0.20	1.259	3.389
13		1400	0.05	1.197	2.044
14			0.12	1.200	3.016
15			0.20	1.227	3.121
16		2100	0.05	1.157	2.614
17			0.12	1.226	3.329
18			0.20	1.173	4.006
19	Kenaf Glass Fiber Reinforced Unsaturated Polyester (KGFRP)	700	0.05	1.094	1.877
20			0.12	1.179	3.079
21			0.20	1.207	3.235
22		1400	0.05	1.115	2.269
23			0.12	1.132	3.522
24			0.20	1.154	3.857
25		2100	0.05	1.128	3.046
26			0.12	1.128	3.948
27			0.20	1.170	4.023

Min

Max

Min

Max

Min

Max

Results & Analysis

Composite	Drill bit	Spindle Speed	Feed Rate	Type Delamination
GFRP	Twist	700 rpm	0.05 mm/rev	Upper (1.064)
KFRP	Twist	1400 rpm	0.05 mm/rev	Upper (1.005)
KGFRP	Twist	2100 rpm	0.05 mm/rev	Upper (1.012)

Suitable drill bit

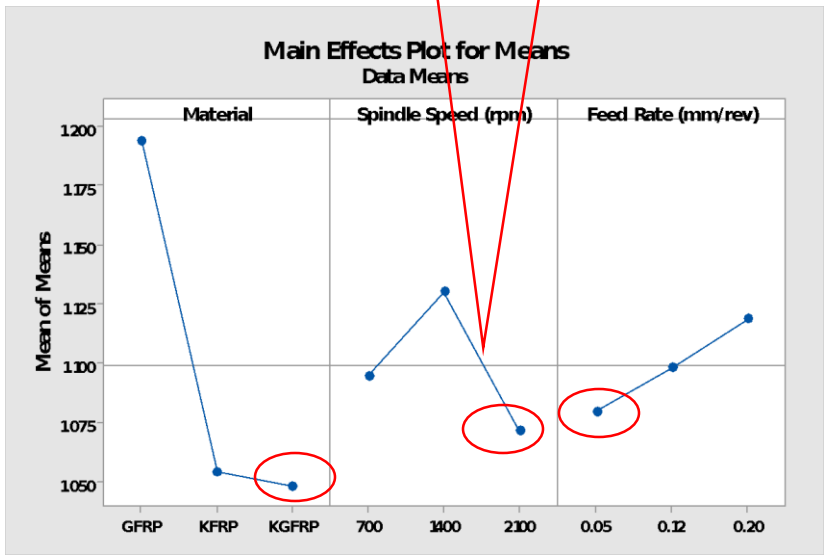
Suitable machining parameter for machining composite

Low delamination factor at upper delamination

Results & Analysis

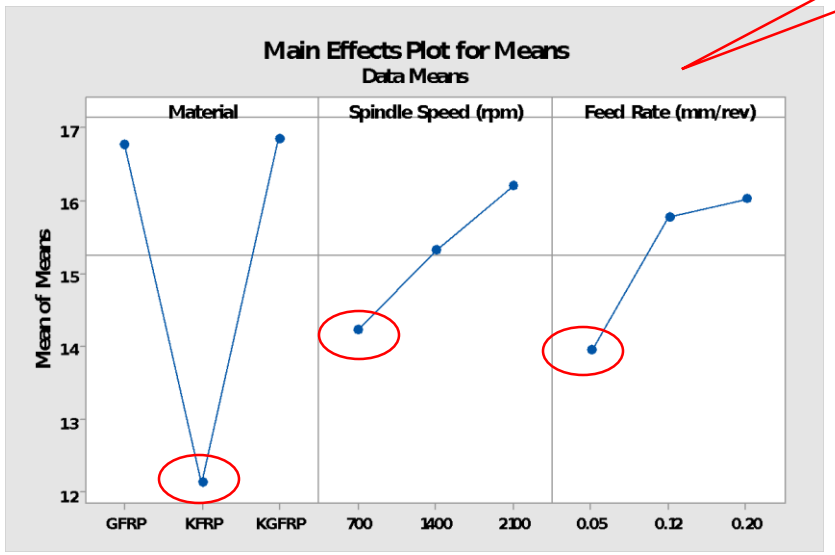
TWIST

Spindle speed ↑, fd ↓
Feed rate ↑, fd ↑

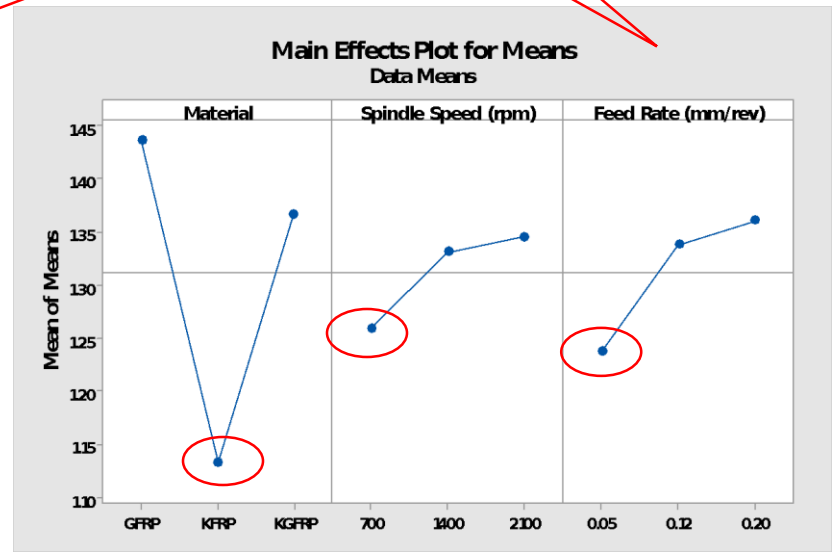


(Upper Delamination)

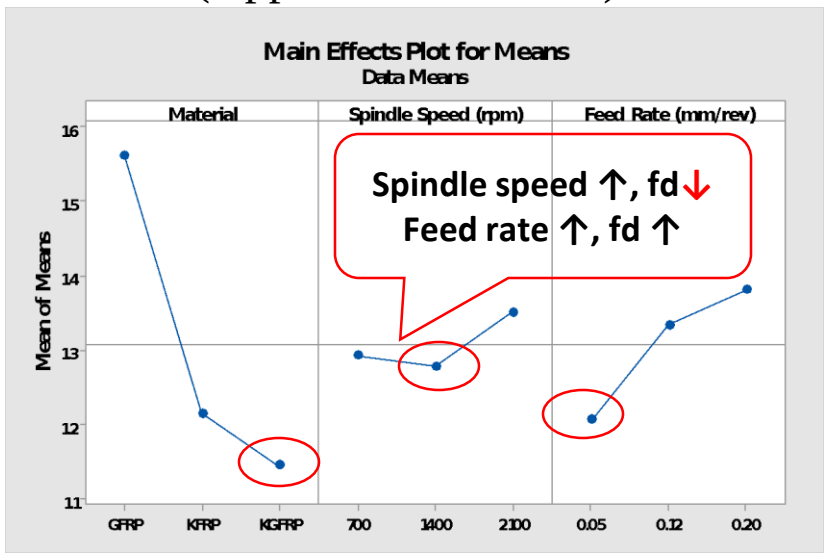
Spindle speed ↑, fd↑
Feed rate ↑, fd ↑



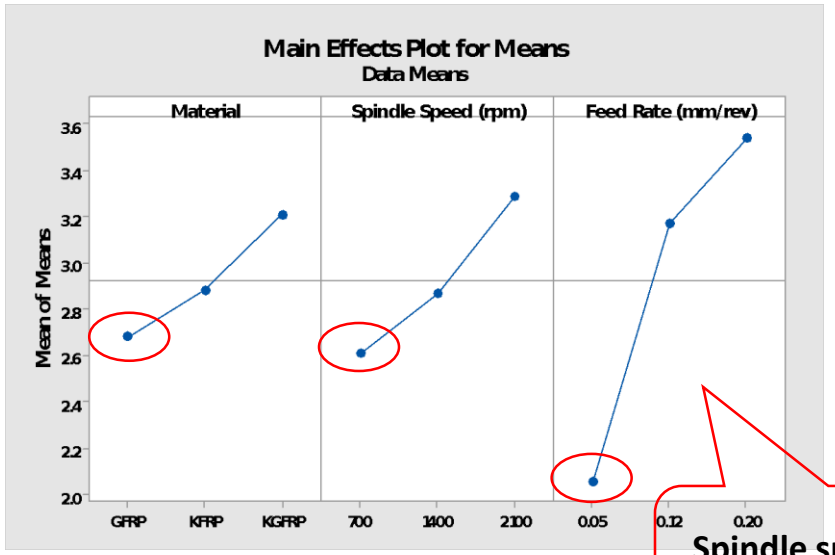
(Bottom Delamination)

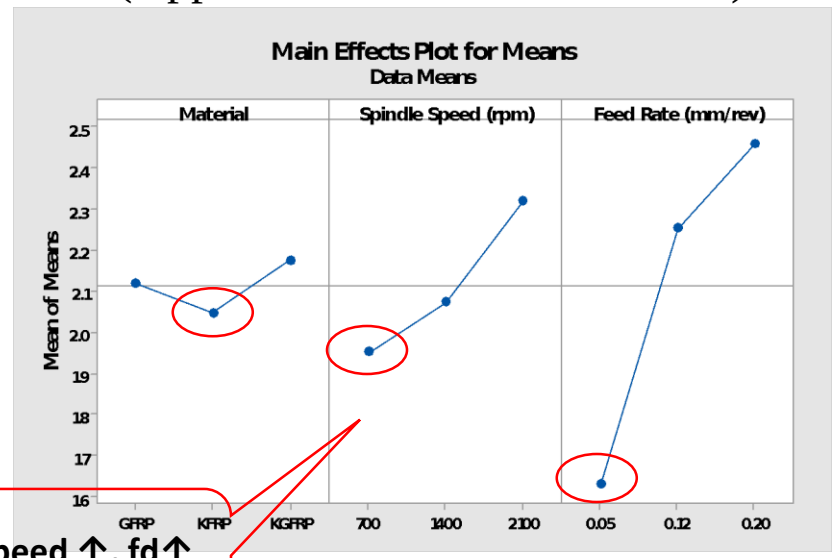


(Upper & Bottom Delamination)



Spindle speed ↑, fd↓
Feed rate ↑, fd ↑





Spindle speed ↑, fd↑
Feed rate ↑, fd ↑

BRAD

Results & Analysis

Greater influence for minimum delamination

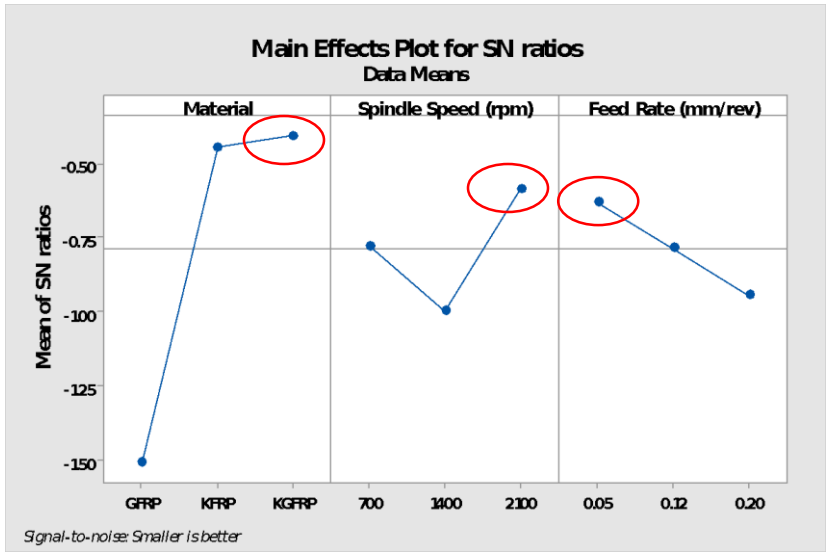
Types	Material	Spindle Speed	Feed Rate
Twist - Upper	KGFRP	2100 rpm	0.05 mm/rev
Twist - Bottom	KFRP	700 rpm	0.05 mm/rev
Twist - Both	KFRP	700 rpm	0.05 mm/rev
Brad - Upper	KGFRP	1400 rpm	0.05 mm/rev
Brad – Bottom	GFRP	700 rpm	0.05 mm/rev
Brad - Both	KFRP	700 rpm	0.05 mm/rev

Greater influence for minimum delamination

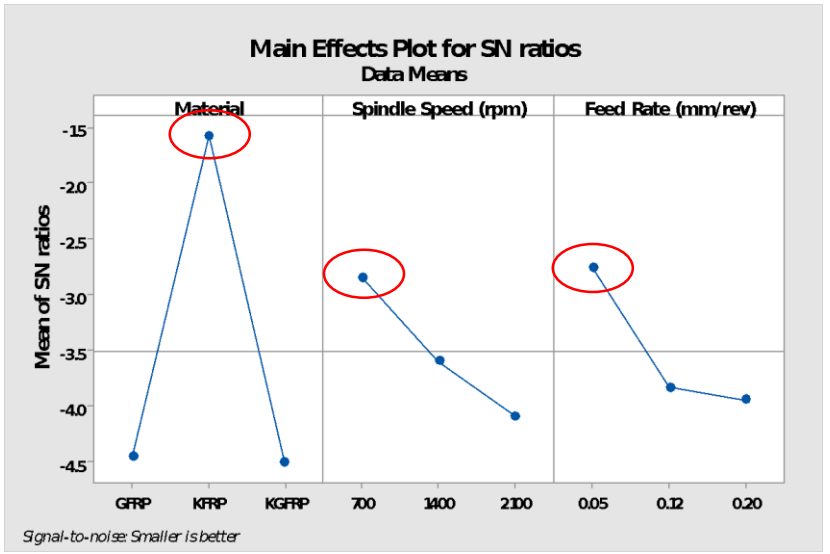
TWIST

Results & Analysis

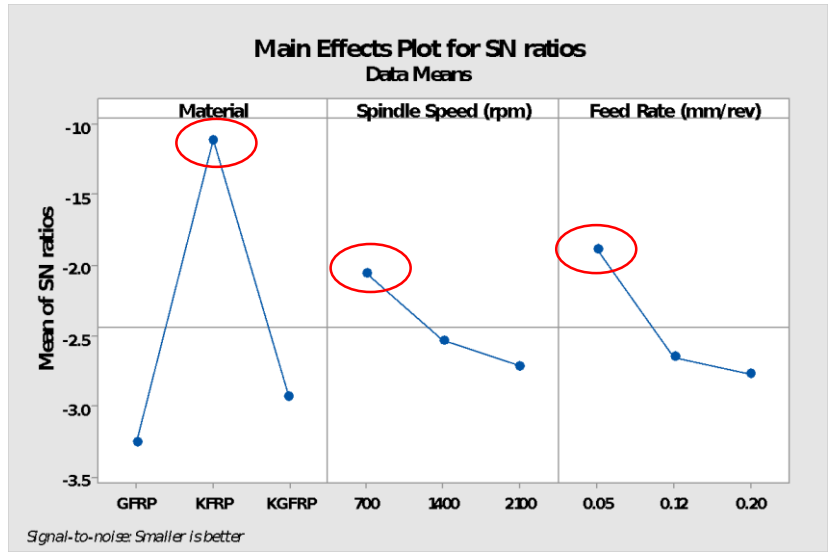
Optimum Value



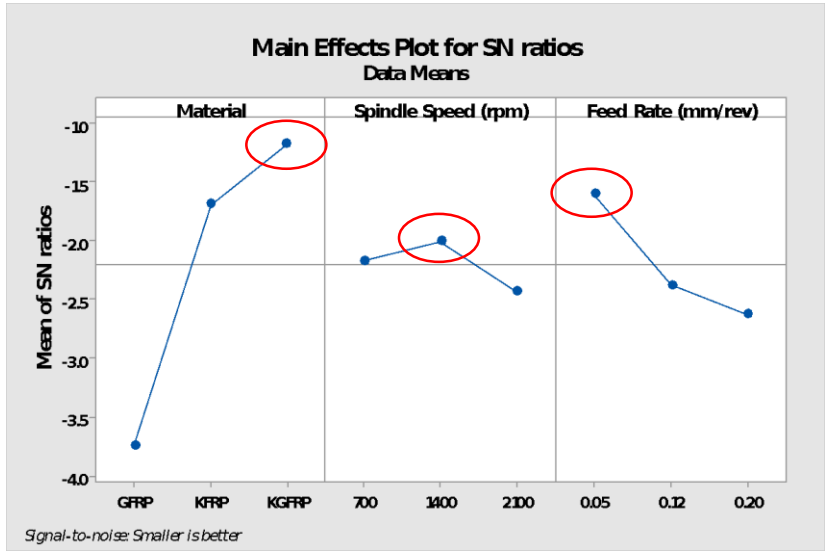
(Upper Delamination)

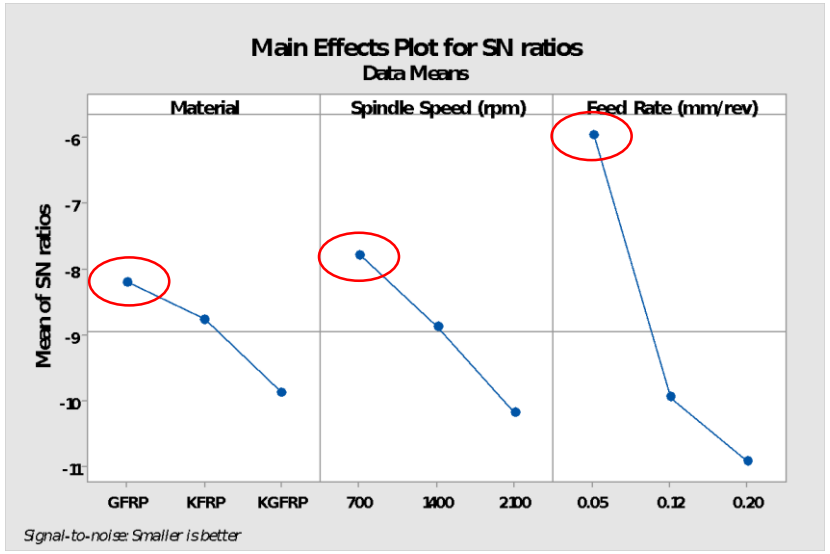


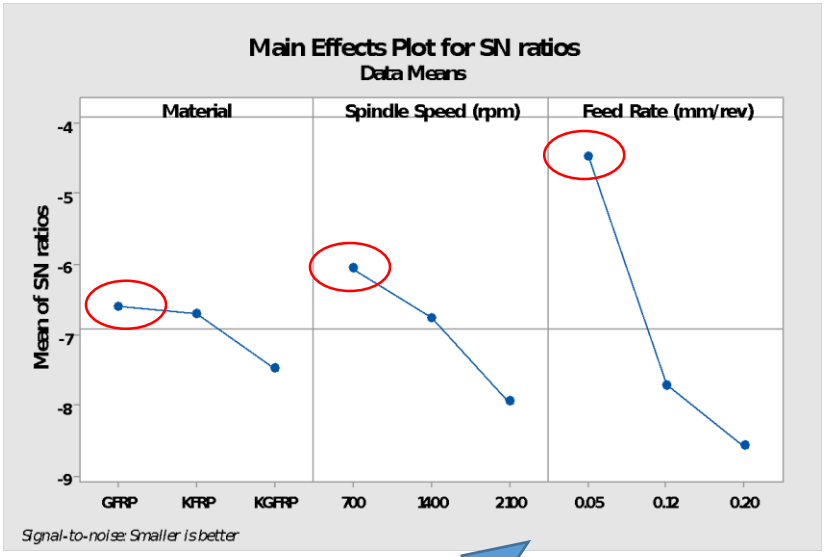
(Bottom Delamination)



(Upper & Bottom Delamination)







BRAD

Results & Analysis

Summary of Optimum Value

Types	Material	Spindle Speed	Feed Rate
Twist - Upper	KGFRP	2100 rpm	0.05 mm/rev
Twist - Bottom	KFRP	700 rpm	0.05 mm/rev
Twist - Both	KFRP	700 rpm	0.05 mm/rev
Brad - Upper	KGFRP	1400 rpm	0.05 mm/rev
Brad – Bottom	GFRP	700 rpm	0.05 mm/rev
Brad - Both	GFRP	700 rpm	0.05 mm/rev

TWIST

Results & Analysis

BRAD

Upper Delamination

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Material	2	7.0772	7.0772	3.5386	10.40	0.001
Spindle Speed (rpm)	2	0.7702	0.7702	0.3851	1.13	0.342
Feed Rate (mm/rev)	2	0.4444	0.4444	0.2222	0.65	0.531
Residual Error	20	6.8034	6.8034	0.3402		
Total	26	15.0952				

Not significant

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Material	2	33.2812	33.2812	16.6406	23.62	0.000
Spindle Speed (rpm)	2	0.8163	0.8163	0.4081	0.58	0.569
Feed Rate (mm/rev)	2	5.1368	5.1368	2.5684	3.65	0.045
Residual Error	20	14.0894	14.0894	0.7045		
Total	26	53.3237				

Bottom Delamination

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Material	2	51.256	51.256	25.6282	59.28	0.000
Spindle Speed (rpm)	2	7.126	7.126	3.5629	8.24	0.002
Feed Rate (mm/rev)	2	7.838	7.838	3.9192	9.07	0.002
Residual Error	20	8.646	8.646	0.4323		
Total	26	74.866				

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Material	2	13.03	13.03	6.513	4.99	0.017
Spindle Speed (rpm)	2	25.74	25.74	12.870	9.87	0.001
Feed Rate (mm/rev)	2	125.54	125.54	62.769	48.12	0.000
Residual Error	20	26.09	26.09	1.304		
Total	26	190.39				

Upper & Bottom Delamination

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Material	2	24.092	24.092	12.0459	108.01	0.000
Spindle Speed (rpm)	2	2.087	2.087	1.0435	9.36	0.001
Feed Rate (mm/rev)	2	4.171	4.171	2.0855	18.70	0.000
Residual Error	20	2.231	2.231	0.1115		
Total	26	32.580				

P ≤ 0.05

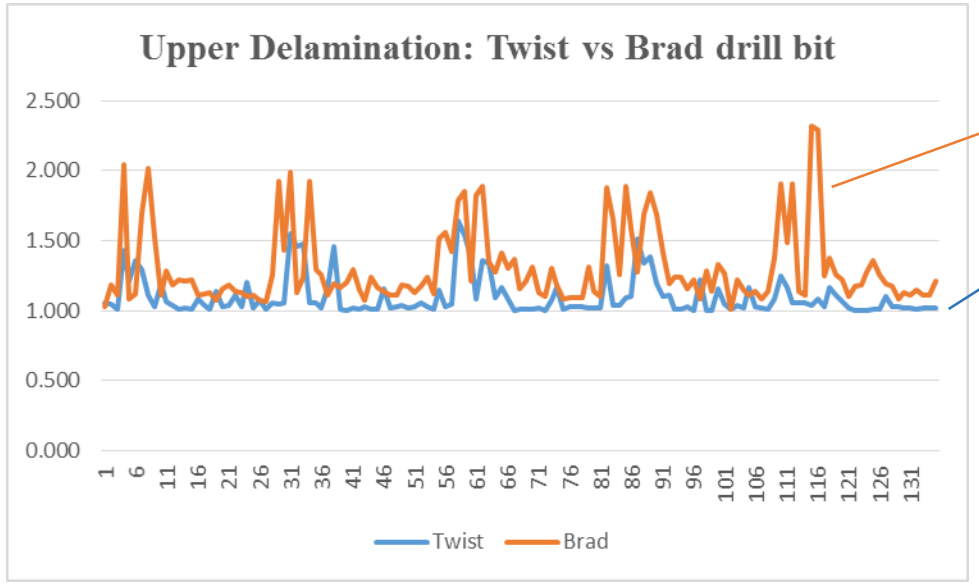
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Material	2	4.099	4.099	2.0495	3.16	0.064
Spindle Speed (rpm)	2	16.502	16.502	8.2512	12.72	0.000
Feed Rate (mm/rev)	2	84.818	84.818	42.4088	65.39	0.000
Residual Error	20	12.970	12.970	0.6485		
Total	26	118.389				

Results & Analysis

Types	Significant, P ≤ 0.05	Machining parameter
Twist - Upper	Not Significant	Not Avalaible
Twist - Bottom	0.002	Feed Rate
Twist - Both	0.000	Feed Rate
Brad - Upper	0.045	Feed Rate
Brad – Bottom	0.000	Feed Rate
Brad - Both	0.000	Feed Rate

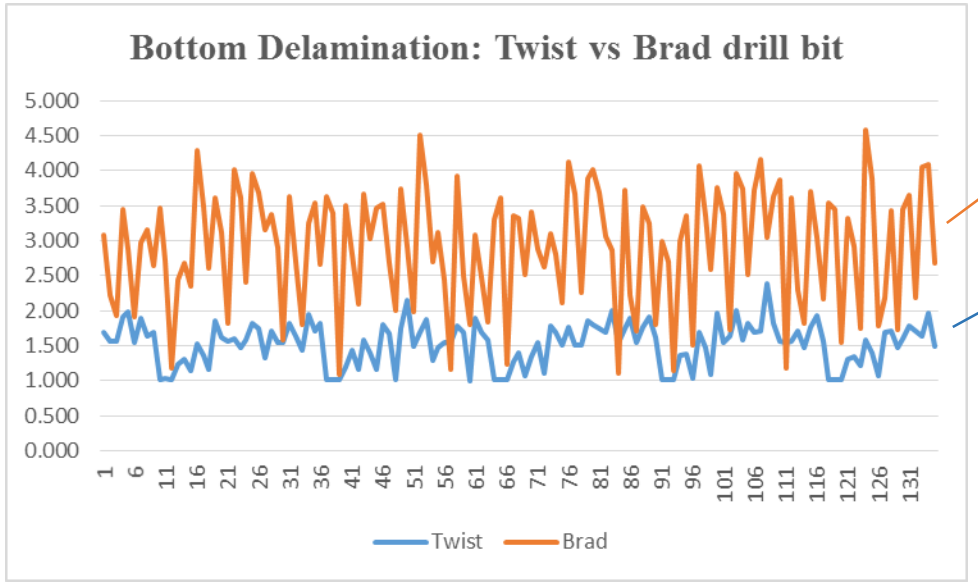
(Kilicap, 2010) (M. S. Abdullah et al., 2019)

Results & Analysis



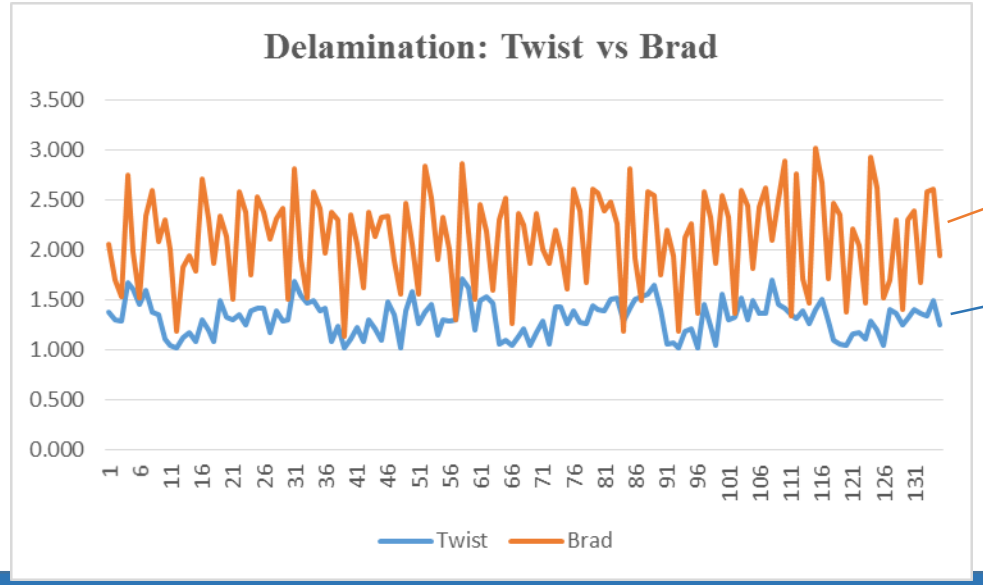
Brad

Twist



Brad

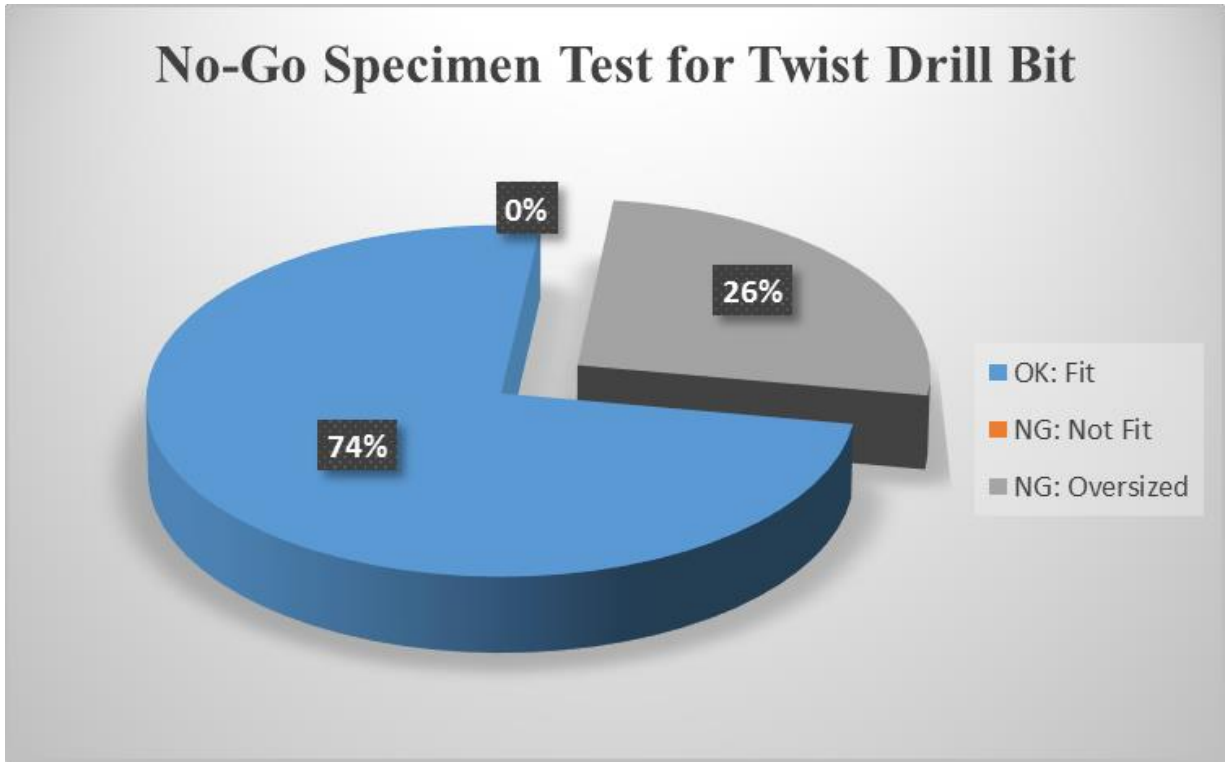
Twist

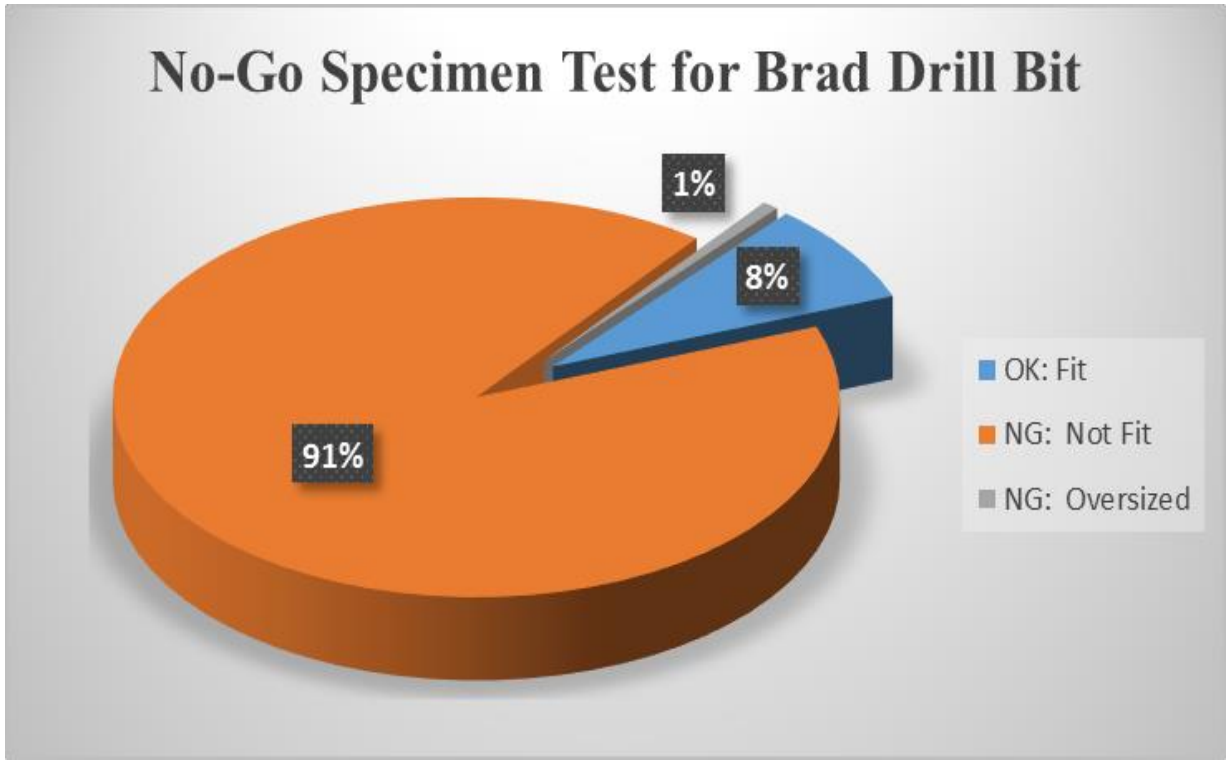


Brad

Twist

Results & Analysis





Result Conclusions

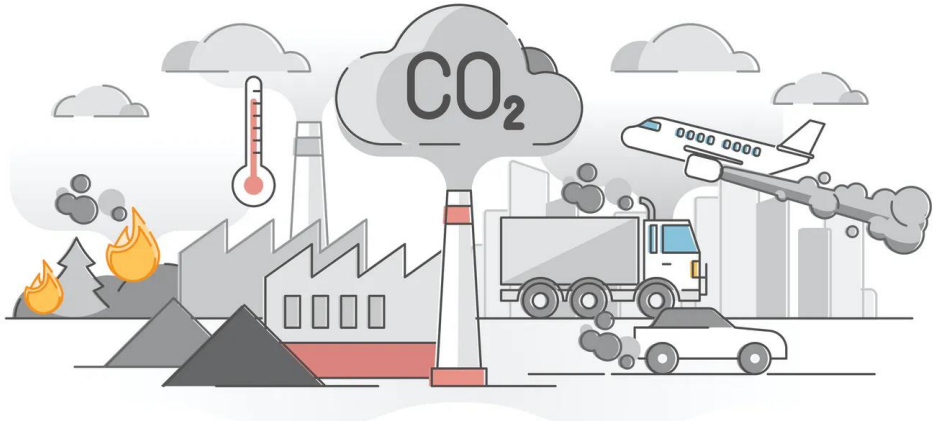
- Based on the findings, the delamination at upper and bottom specimen of GFRP, KFRP and KGFRP have been measured and:
  - Optimal value of the machining parameters is feed rate.
  - Most significant value of the machining parameters also feed rate.
- The lowest feed rate and spindle speed have the lowest value of delamination factor. (GFRP & KFRP)
- The lowest feed rate and increase spindle speed have the lowest value of delamination factor. (Upper KGFRP only)
- The delamination factor (Fd) made by twist drill bit showed a superior results than brad drill bit.

Result Recommendation

- Firstly, there are many **techniques to fabricate** Fiber Reinforced Polyester (FRP).
  - **Method**: vacuum, injection moulding and transfer resin.
  - **Polymer matrix or glue**: vinyl ester resin, epoxy or others resins.
  - **Orientation of fiber**: unidirectional, random, bidirectional and multi-directional.
  - **Content of fiber**: length of specific fibres, directions of fiber, extent of combination of fibres, matrix bonding and arrangement of fibers.
- Secondly, this research had been drilled using two tool geometries which are twist and brad drill bits. In the future, can be develop with **various types of drill bits** to determine the pattern of the results. Moreover, **materials of the drill bits** also recommended for upcoming study on this hybrid composites.
- Thirdly, to **measure the delamination**:
  - Computerized Tomography (CT),
  - Ultrasonic C-Scan,
  - Acoustic Emission (AE),
  - Radiography or other high technology instruments compared to Tool Maker Microscope.

Research findings & Implications for Government Policy

1. “First Reference” or new research about KGFRP for Composite Technology.
2. Encouragement to universities / researcher to expand the scope of composite hybrid.
3. Using Natural fiber – reduce greenhouse effect / carbon dioxide emissions
4. Assisting the manufacturing Industry (Composite) – Automotive , aeroplane, boat, lrt, mrt and others.



THANK YOU