ANALYSIS OF THE RESULTS FOR JUMMA MACHINE

Objectives of the DOE

- Primary objective: Find the significant factors affecting the response function in this case Ablation depth
- Secondary Objective: Devise a model for the relationship between Response function and Ablation depth
- Tertiary Objective: Confirm the model with confirmatory runs

1. Steps conducted

   a. DOE conducted with 4 factors to find out significant factors (16 runs)

   b. Try to gauge the important factors and detect curvatures (7 center points)

   c. Conducted 8 more experiments to model an equation for the response found. (8 axial points augmented on DOE to model ablation depth using face centered method)

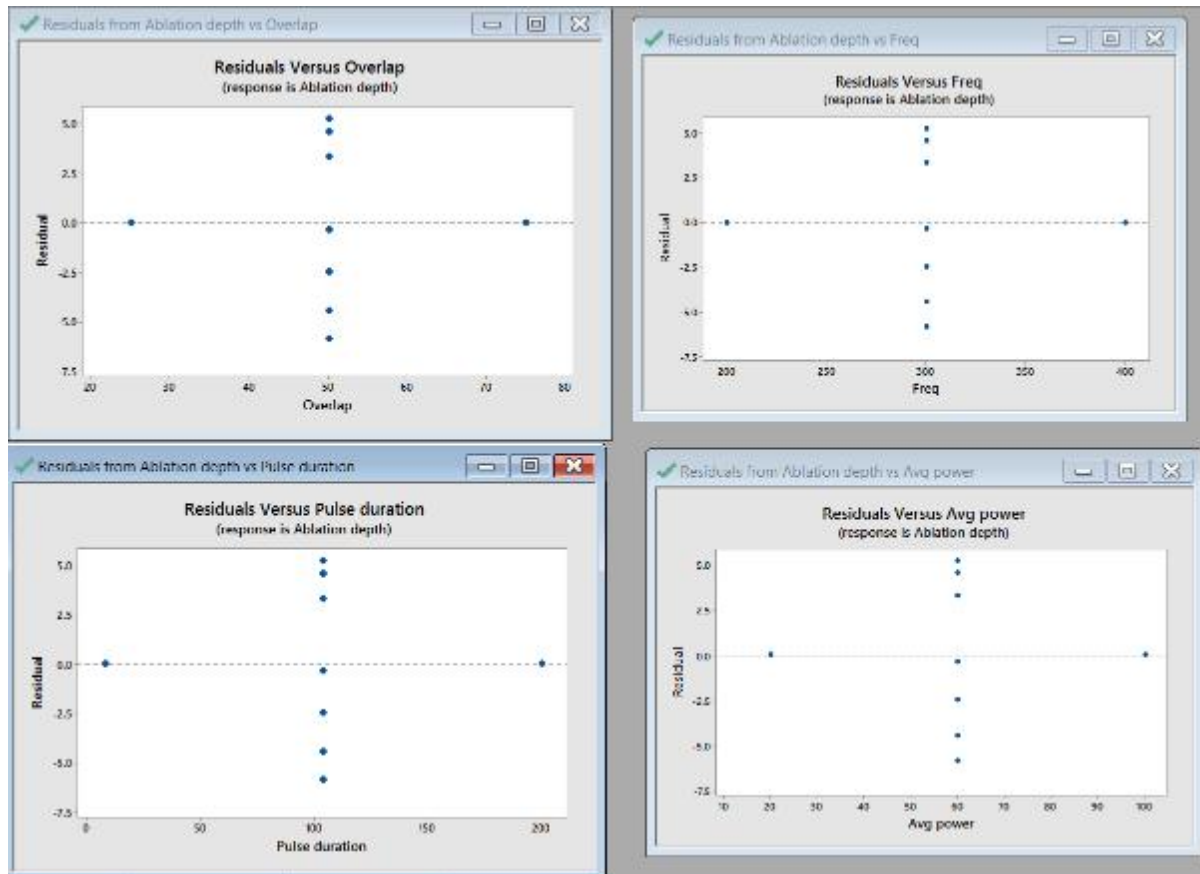Following are the Results for **ABLATION DEPTH** (response function)

Factors affecting the Ablation depth are

1. Pulse duration

2. Overlap

3. Freq

4. Avg Power

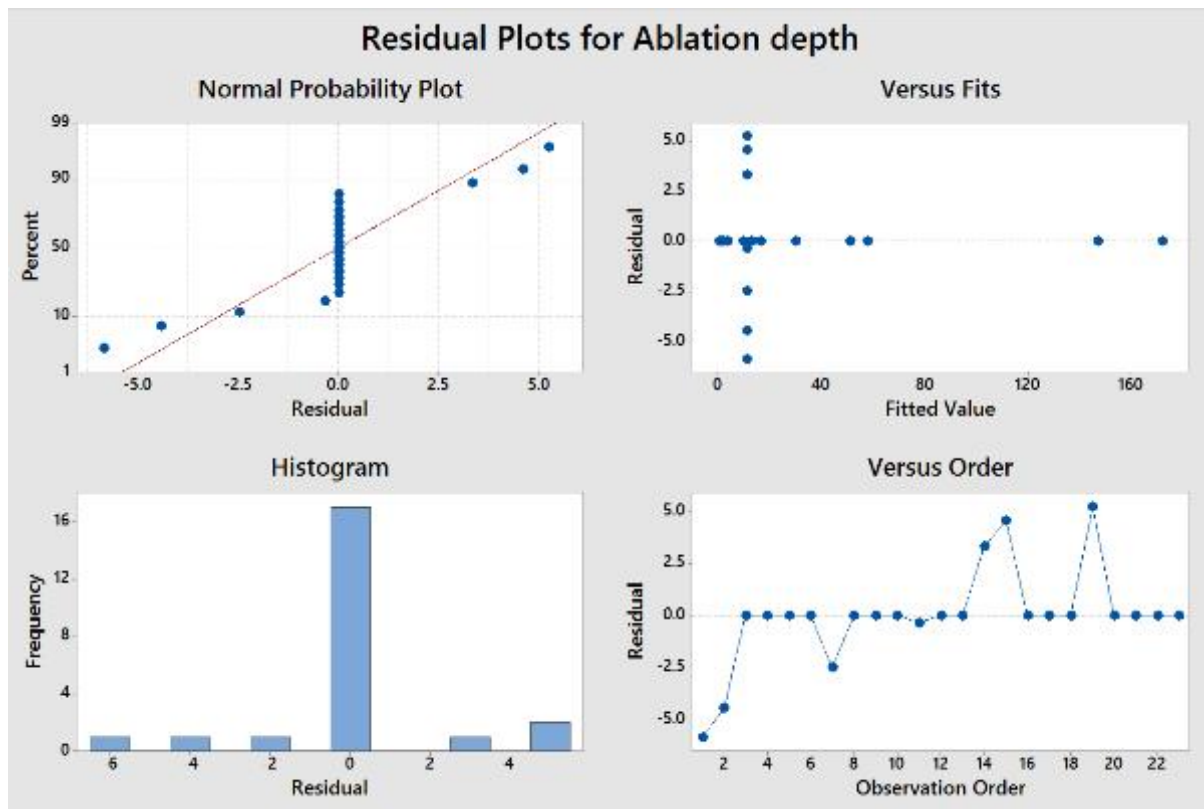The factorial analysis was conducted with all terms included. Here are the results

STEP 1: FACTORIAL ANALYSIS WITH ALL VARIABLES

Residual vs Variables

Conclusion – there is a problem as the residuals are not random for all levels

Residuals vs Fitted, Histogram, Normality of residuals and Residual vs order

Conclusion – the model cannot be utilized and residuals vs fitted show concentration on the left.

Data points sheet

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
	StdOrder	RunOrder	PtType	Blocks	Pulse duration	Avg power	Overlap	Freq	Ablation depth	Rz value	FITS1	RESI1	
1	31	2	0	1	104	60	50	300	5.139	6.7325	10.989	-5.85007	
2	30	3	0	1	104	60	50	300	6.543	6.5886	10.989	-4.44563	
3	8	4	1	1	200	100	75	200	172.181	34.7602	172.181	-0.00000	
4	2	5	1	1	200	20	25	200	1.058	2.9709	1.058	-0.00000	
5	1	6	1	1	8	20	25	200	0.305	2.8620	0.305	-0.00000	
6	13	7	1	1	8	20	75	400	1.630	2.8769	1.630	-0.00000	
7	29	8	0	1	104	60	50	300	8.506	7.3554	10.989	-2.48290	
8	11	9	1	1	8	100	25	400	0.838	21.8105	0.838	0.00000	
9	3	10	1	1	8	100	25	200	16.388	37.9083	16.388	0.00000	
10	14	11	1	1	200	20	75	400	3.090	3.4436	3.090	-0.00000	
11	27	12	0	1	104	60	50	300	10.642	9.8387	10.989	-0.34691	
12	12	13	1	1	200	100	25	400	3.497	24.9796	3.497	-0.00000	
13	4	14	1	1	200	100	25	200	29.928	33.7215	29.928	0.00000	
14	28	15	0	1	104	60	50	300	14.307	9.3729	10.989	3.31815	
15	25	16	0	1	104	60	50	300	15.569	11.7102	10.989	4.58045	
16	6	18	1	1	200	20	75	200	12.818	13.4966	12.818	-0.00000	
17	5	20	1	1	8	20	75	200	9.578	4.4498	9.578	-0.00000	
18	15	22	1	1	8	100	75	400	50.949	18.9417	50.949	0.00000	
19	26	25	0	1	104	60	50	300	16.216	10.4101	10.989	5.22691	
20	10	28	1	1	200	20	25	400	0.679	2.7754	0.679	0.00000	
21	7	29	1	1	8	100	75	200	147.061	30.3521	147.061	0.00000	
22	16	30	1	1	200	100	75	400	57.720	18.5460	57.720	0.00000	
23	9	31	1	1	8	20	25	400	0.883	4.0989	0.883	0.00000	
24													
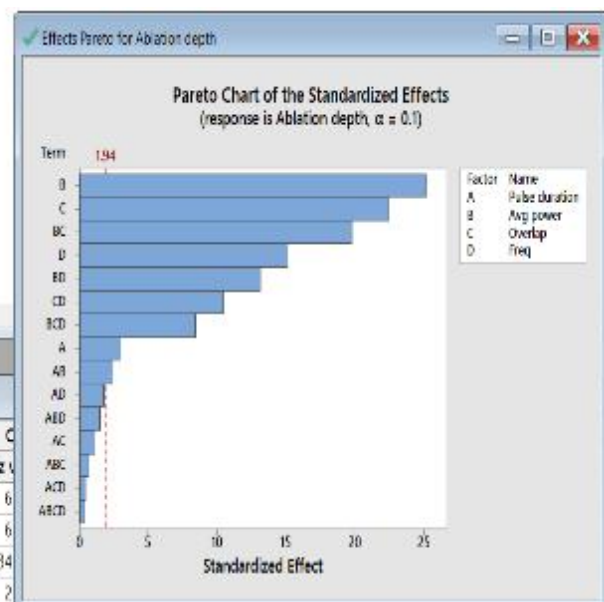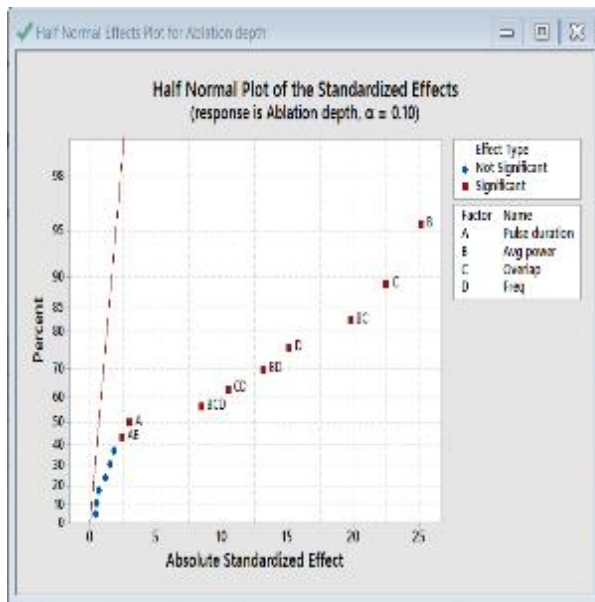
Terms which show the most significant terms.

Conclusion: Remodel with only the significant terms

STEP 2: RE-ANALYZE WITH SIGNIFICANT TERMS IE (P<0.1)

Now the model was remodeled with only the significant terms

Residuals vs variable
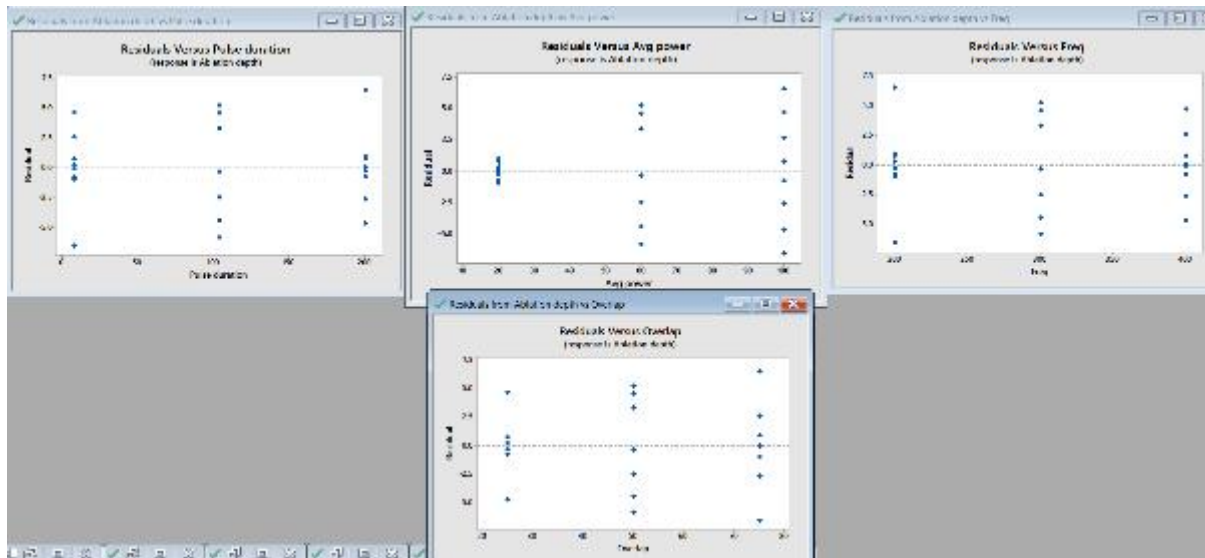
Conclusion- Residual vs avg power shows an increasing trend, which can be got ridden off through a transformation

4 in 1 residuals graphs after remodelling with only significant terms

Residual Plots for Ablation depth
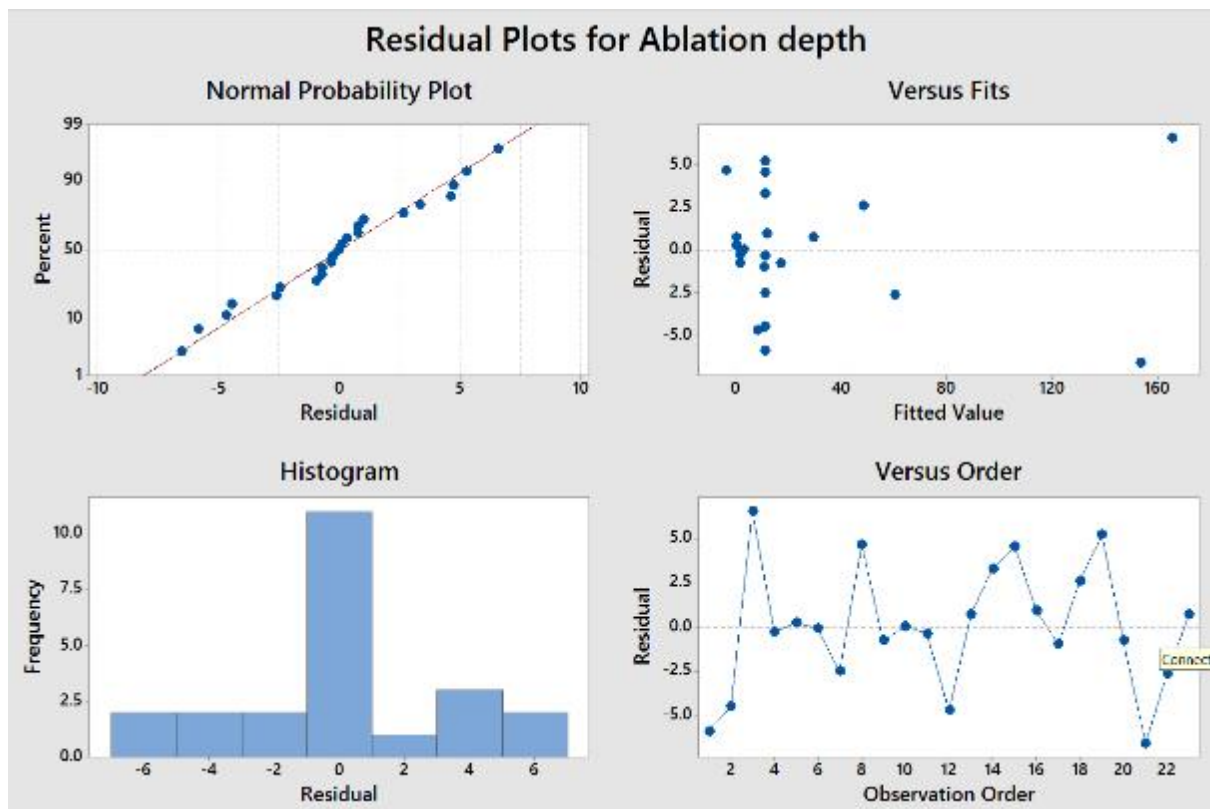
Conclusion – The histogram plot seems acceptable, residual vs order is random which is indicating no time trend.

However the residual vs fit shows a clustering for the low values and 2 outliers at the right side. The outliers were not deleted.

ANOVA checking

```
    Pulse duration           1    177.8    177.8     7.98   0.015
    Avg power                1  12573.1  12573.1   564.41   0.000
    Overlap                  1  10072.7  10072.7   452.17   0.000
    Freq                     1   4557.3   4557.3   204.58   0.000
  2-Way Interactions         4  13532.9   3383.2   151.87   0.000
    Pulse duration*Avg power 1    114.7    114.7     5.15   0.042
    Avg power*Overlap        1   7791.2   7791.2   349.75   0.000
    Avg power*Freq           1   3453.8   3453.8   155.04   0.000
    Overlap*Freq             1   2173.2   2173.2    97.55   0.000
  3-Way Interactions         1   1419.7   1419.7    63.73   0.000
    Avg power*Overlap*Freq   1   1419.7   1419.7    63.73   0.000
  Curvature                  1   2106.5   2106.5    94.56   0.000
Error                       12    267.3     22.3
  Lack-of-Fit                6    147.7     24.6     1.24   0.402
  Pure Error                 6    119.6     19.9
Total                       22  44707.4
```

Model Summary

```
      S    R-sq  R-sq(adj)  R-sq(pred)
4.71981  99.40%     98.90%      97.29%
```

Coded Coefficients

```
Term                     Effect    Coef  SE Coef  T-Value  P-Value   VIF
Constant                          31.79     1.18    26.94    0.000
Pulse duration             6.67    3.33     1.18     2.83    0.015  1.00
Avg power                 56.06   28.03     1.18    23.76    0.000  1.00
Overlap                   50.18   25.09     1.18    21.26    0.000  1.00
Freq                     -33.75  -16.88     1.18   -14.30    0.000  1.00
Pulse duration*Avg power   5.36    2.68     1.18     2.27    0.042  1.00
Avg power*Overlap         44.13   22.07     1.18    18.70    0.000  1.00
Avg power*Freq           -29.38  -14.69     1.18   -12.45    0.000  1.00
Overlap*Freq             -23.31  -11.65     1.18    -9.88    0.000  1.00
Avg power*Overlap*Freq   -18.84   -9.42     1.18    -7.98    0.000  1.00
Ct Pt                            -20.80     2.14    -9.72    0.000  1.00
```

Regression Equation in Uncoded Units

Ablation depth = 5.9 - 0.0071 Pulse duration - 0.786 Avg power - 0.617 Overlap + 0.0021 Freq
               + 0.000697 Pulse duration*Avg power + 0.05033 Avg power*Overlap
               + 0.001037 Avg power*Freq + 0.000990 Overlap*Freq
               - 0.000094 Avg power*Overlap*Freq - 20.80 Ct Pt

Model seems to fit well but cannot predict for increasing values after ablation depth of 70 since it is not well distributed. **However what we can conclude are the significant factors from the DOE have been found for the ablation depth – please see coded coefficients above.**

(Would this statement be correct since significant factors are calculated from the t-test?? Since residual analysis would be more for model fitting, so it doesn't matter about the residual graphs at all for finding significant terms??)

However since the residual vs fits was troubling I transformed the response function using square root. Here are the following results

STEP 2A: AN EXTRA SQR ROOT TRANSFORMATION WAS TRIED (NOT NECESSARY I THINK)

AFTER SQUARE ROOT TRANSFORMATION

```
Source                  DF   Adj SS   Adj MS   F-Value   P-Value
Model                    8  244.368  30.5460    116.00     0.000
  Linear                 4  197.099  49.2748    187.12     0.000
    Pulse duration       1    1.663   1.6630      6.32     0.025
    Avg power            1   96.204  96.2038    365.34     0.000
    Overlap              1   72.439  72.4394    275.09     0.000
    Freq                 1   26.793  26.7928    101.75     0.000
  2-Way Interactions     3   43.892  14.6308     55.56     0.000
    Avg power*Overlap    1   28.396  28.3956    107.83     0.000
    Avg power*Freq       1   11.884  11.8836     45.13     0.000
    Overlap*Freq         1    3.613   3.6132     13.72     0.002
  Curvature              1    3.376   3.3762     12.82     0.003
Error                   14    3.687   0.2633
  Lack-of-Fit            8    0.759   0.0948      0.19     0.981
    Pure Error           6    2.928   0.4880
Total                   22  248.054


Model Summary for Transformed Response

       S    R-sq  R-sq(adj)  R-sq(pred)
0.513153  98.51%     97.66%      97.17%


Coded Coefficients for Transformed Response

Term               Effect    Coef  SE Coef  T-Value  P-Value   VIF
Constant                    4.084    0.128    31.83    0.000
Pulse duration      0.645   0.322    0.128     2.51    0.025  1.00
Avg power           4.904   2.452    0.128    19.11    0.000  1.00
Overlap             4.256   2.128    0.128    16.59    0.000  1.00
Freq               -2.588  -1.294    0.128   -10.09    0.000  1.00
Avg power*Overlap   2.664   1.332    0.128    10.38    0.000  1.00
Avg power*Freq     -1.724  -0.862    0.128    -6.72    0.000  1.00
Overlap*Freq       -0.950  -0.475    0.128    -3.70    0.002  1.00
Ct Pt                      -0.833    0.233    -3.58    0.003  1.00


Regression Equation in Uncoded Units

Ablation depth^0.5 = -3.05 + 0.00336 Pulse duration + 0.0593 Avg power + 0.0622 Overlap
                     + 0.00949 Freq + 0.001332 Avg power*Overlap - 0.000215 Avg power*Freq
                     - 0.000190 Overlap*Freq - 0.833 Ct Pt
```

<u>The significant terms BCD, AB are not relevant anymore after square root transformation.</u>   Thus can I conclude that finding significant factors should be done before transforming the function ????

The 4 in 1 residual plot