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EGR 7050 Design and Analysis of Engineering experiments

Homework 4

1. *A product developer is investigating the tensile strength of a new synthetic fiber that will be used to make cloth for men's shirts. Strength is usually affected by the percentage of cotton used in the blend of materials for the fiber. The engineer conducts a completely randomized experiment with five levels of cotton content and replicates the experiment five times. The data are shown in the following table.*

Cotton weight percent	***Observations***				
15	*7*	*7*	*15*	*11*	*9*
20	*12*	*17*	*12*	*18*	*18*
25	*14*	*19*	*19*	*18*	*18*
30	*19*	*25*	*22*	*19*	*23*
35	*7*	*10*	*11*	*15*	*11*

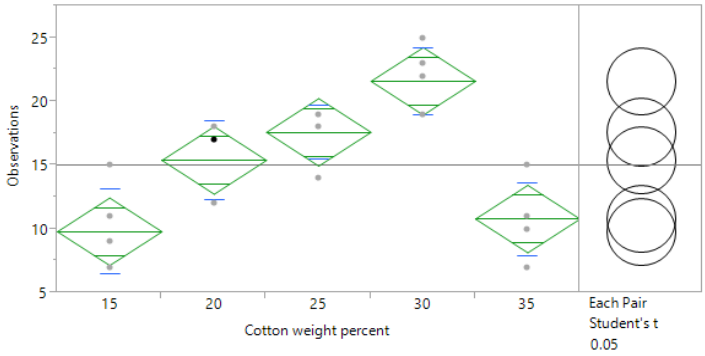
a. *Is there evidence to support the claim that cotton content affects the mean tensile strength? Use* α *=0.05.*

Solution:

a. H_0: *Percentage of cotton used in the fiber does not affect mean the tensile strength*
H_1: *Percentage of cotton used in the fiber affects the mean tensile strength*

Given, $\alpha = 0.05$

Oneway Analysis of Observations By Cotton weight percent



Oneway Anova

Summary of Fit

Rsquare	0.746923
Adj Rsquare	0.696307
Root Mean Square Error	2.839014
Mean of Response	15.04
Observations (or Sum Wgts)	25

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Cotton weight percent	4	475.76000	118.940	14.7568	<.0001*
Error	20	161.20000	8.060		
C. Total	24	636.96000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
15	5	9.8000	1.2696	7.152	12.448
20	5	15.4000	1.2696	12.752	18.048
25	5	17.6000	1.2696	14.952	20.248
30	5	21.6000	1.2696	18.952	24.248
35	5	10.8000	1.2696	8.152	13.448

Std Error uses a pooled estimate of error variance

P value is less than significance level $\alpha = 0.05$ and $F_0 > F_{0.05,4,20}$. Therefore, reject null hypotheses.

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.08596	0.05

LSD Threshold Matrix

Abs(Dif)-LSD

	30	25	20	35	15
30	-3.7455	0.2545	2.4545	7.0545	8.0545
25	0.2545	-3.7455	-1.5455	3.0545	4.0545
20	2.4545	-1.5455	-3.7455	0.8545	1.8545
35	7.0545	3.0545	0.8545	-3.7455	-2.7455
15	8.0545	4.0545	1.8545	-2.7455	-3.7455

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
30	A	21.600000
25	B	17.600000
20	B	15.400000
35	C	10.800000
15	C	9.800000

Levels not connected by same letter are significantly different.

From connecting letters report, we could see that level 30 is different from the rest of the levels. Similarly, levels 25, 20 are different from levels 35, 15. We cannot detect a significant difference between levels 25, 20 and levels 35,15.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
30	15	11.80000	1.795550	8.05455	15.54545	<.0001*
30	35	10.80000	1.795550	7.05455	14.54545	<.0001*
25	15	7.80000	1.795550	4.05455	11.54545	0.0003*
25	35	6.80000	1.795550	3.05455	10.54545	0.0012*
30	20	6.20000	1.795550	2.45455	9.94545	0.0025*
20	15	5.60000	1.795550	1.85455	9.34545	0.0054*
20	35	4.60000	1.795550	0.85455	8.34545	0.0186*
30	25	4.00000	1.795550	0.25455	7.74545	0.0375*
25	20	2.20000	1.795550	-1.54545	5.94545	0.2347
35	15	1.00000	1.795550	-2.74545	4.74545	0.5838

Fig. 1 *OneWay ANOVA*

Thus, it could be concluded that the percentage of cotton used in the fiber affects the mean tensile strength.

b. Analyze the residuals from this experiment and comment on model adequacy.

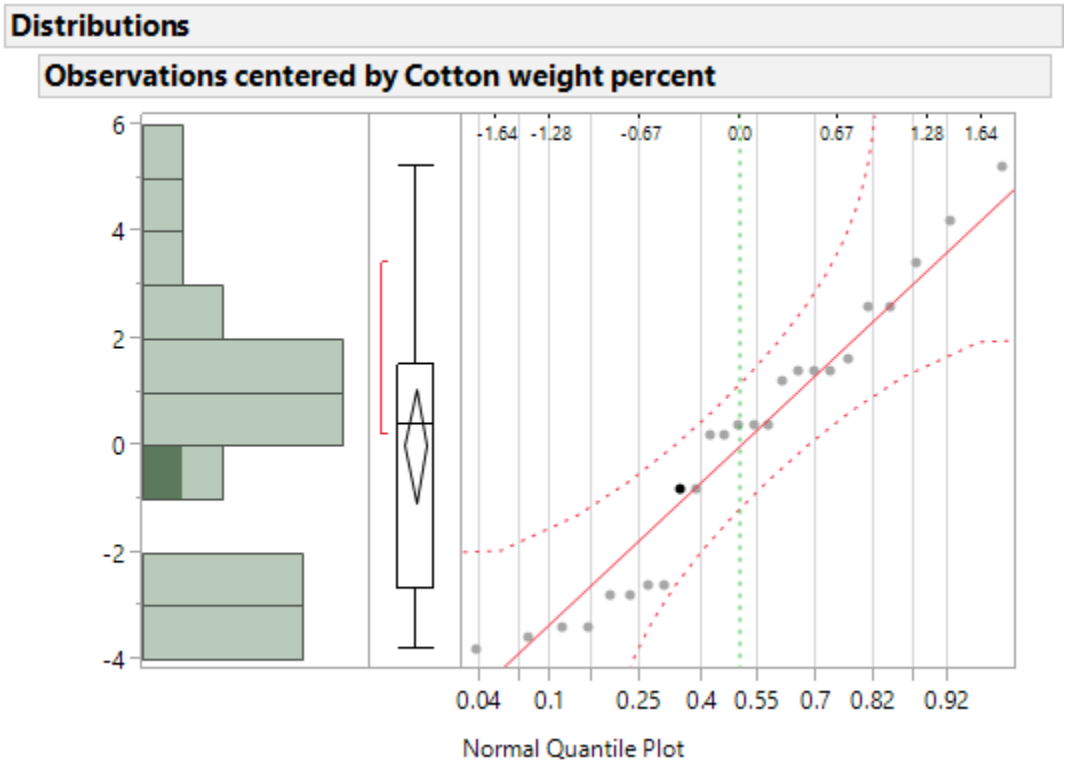


Fig.2 *Normal quantile plot*

Points are close to the line and are within the error bounds. There is no significant evidence of deviation from normality for the residuals.

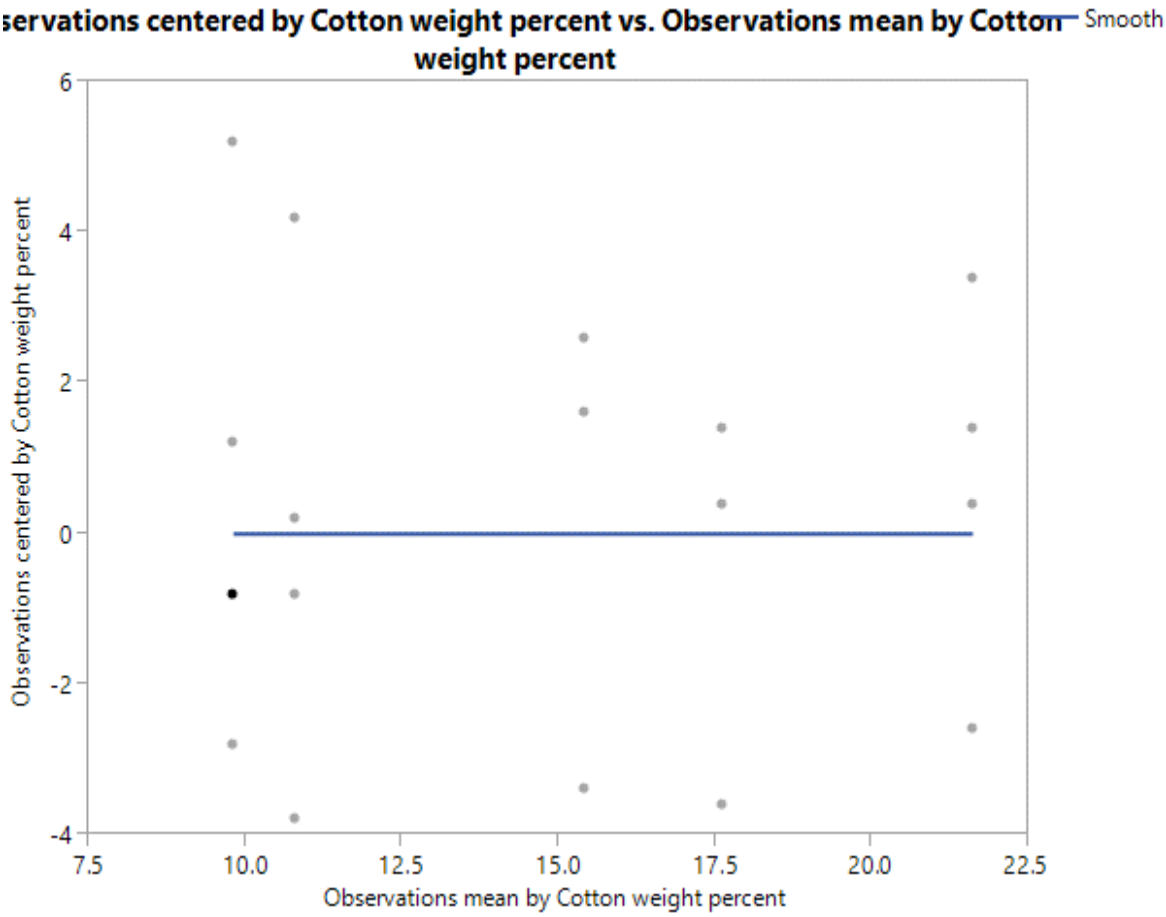


Fig. 3 *Residual vs. Fitted*

There are no outliers in the residual vs. fitted plots. There is a similar range of variation across different fitted values. There is no significant deviation from equal variance assumption.

2. *An experiment was performed to investigate the effectiveness of five insulating materials. Four samples of each material were tested at an elevated voltage level to accelerate the time to failure. The failure times (in minutes) are shown below:*

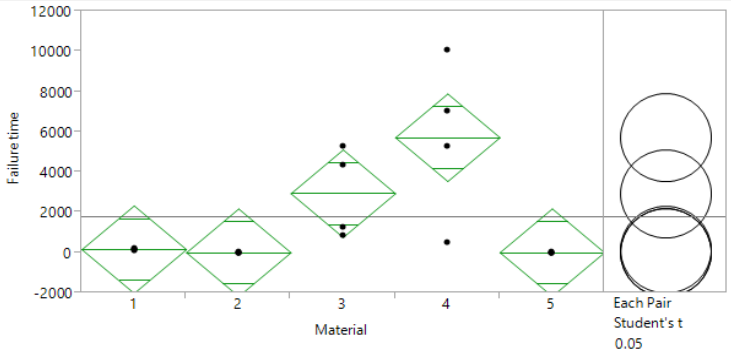
Material	***Failure Time (minutes)***			
1	*110*	*157*	*194*	*178*
2	*1*	*2*	*4*	*18*
3	*880*	*1256*	*5276*	*4355*
4	*495*	*7040*	*5307*	*10050*
5	*7*	*5*	*29*	*2*

Solution:

a. Do all five materials have the same effect on mean failure time?

H_0: *Mean failure time is same for all materials*
H_1: *Mean failure time is different for all materials*

Oneway Analysis of Failure time By Material



Oneway Anova

Summary of Fit

Rsquare	0.622772
Adj Rsquare	0.522177
Root Mean Square Error	2041.334
Mean of Response	1768.3
Observations (or Sum Wgts)	20

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Material	4	103191489	25797872	6.1909	0.0038*
Error	15	62505657	4167043.8		
C. Total	19	165697146			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	4	159.75	1020.7	-2016	2335.3
2	4	6.25	1020.7	-2169	2181.8
3	4	2941.75	1020.7	766	5117.3
4	4	5723.00	1020.7	3547	7898.5
5	4	10.75	1020.7	-2165	2186.3

Std Error uses a pooled estimate of error variance

P value is less than significance level $\alpha = 0.05$ and $F_0 > F_{0.05,4,15}$. Therefore, reject null hypothesis.

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.13145	0.05

LSD Threshold Matrix

Abs(Dif)-LSD

	4	3	1	5	2
4	-3076.6	-295.4	2486.6	2635.6	2640.1
3	-295.4	-3076.6	-294.6	-145.6	-141.1
1	2486.6	-294.6	-3076.6	-2927.6	-2923.1
5	2635.6	-145.6	-2927.6	-3076.6	-3072.1
2	2640.1	-141.1	-2923.1	-3072.1	-3076.6

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
4	A	5723.0000
3	A B	2941.7500
1	B	159.7500
5	B	10.7500
2	B	6.2500

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
4	2	5716.750	1443.441	2640.13	8793.372	0.0013*
4	5	5712.250	1443.441	2635.63	8788.872	0.0013*
4	1	5563.250	1443.441	2486.63	8639.872	0.0016*
3	2	2935.500	1443.441	-141.12	6012.122	0.0601
3	5	2931.000	1443.441	-145.62	6007.622	0.0604
3	1	2782.000	1443.441	-294.62	5858.622	0.0731
4	3	2781.250	1443.441	-295.37	5857.872	0.0732
1	2	153.500	1443.441	-2923.12	3230.122	0.9167
1	5	149.000	1443.441	-2927.62	3225.622	0.9192
5	2	4.500	1443.441	-3072.12	3081.122	0.9976

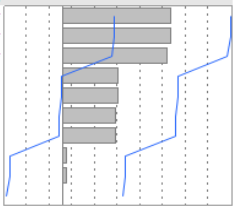


Fig. 4 *OneWay ANOVA*

Therefore, we could conclude that mean failure time is not the same for all materials.

b. *Plot the residuals versus the predicted response. Construct a normal probability plot of the residuals. What information is conveyed by these plots?*

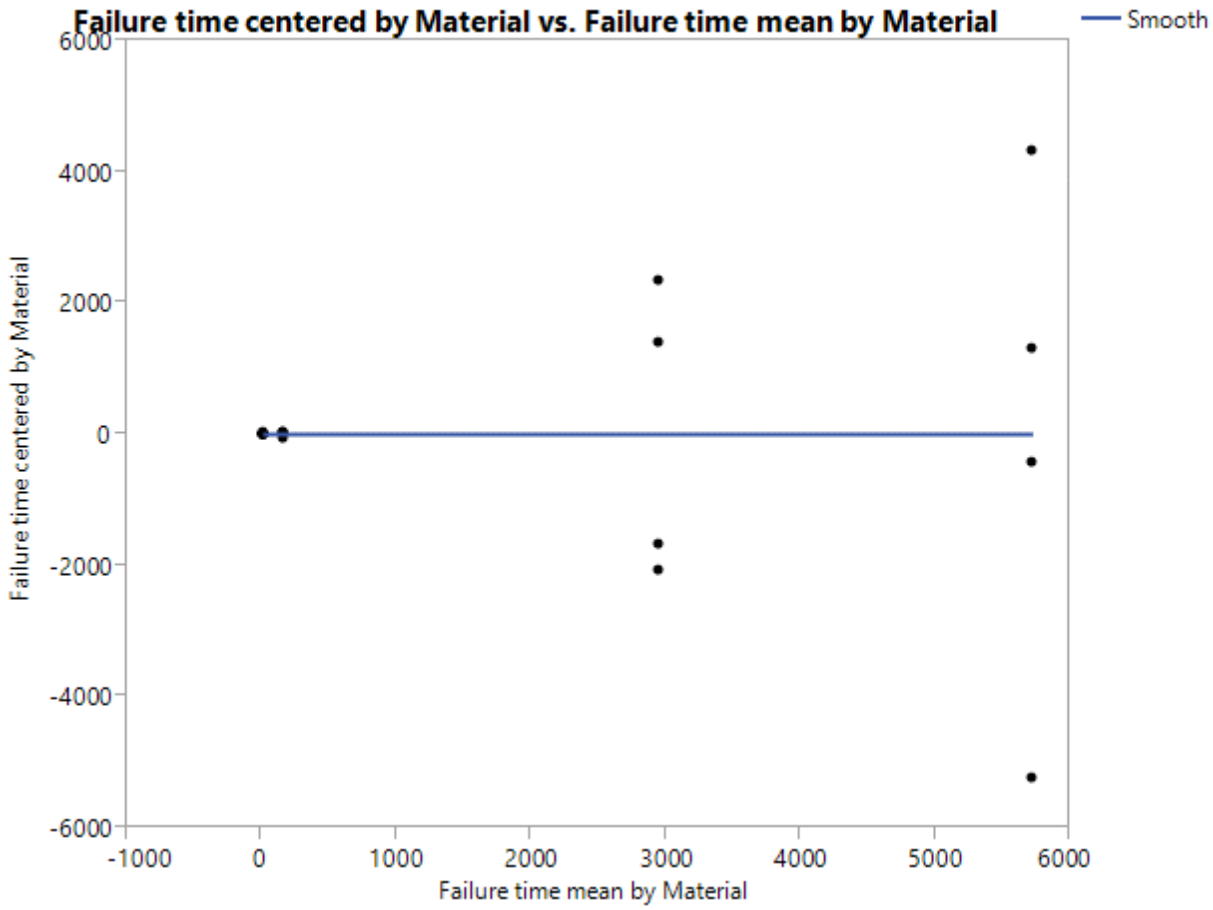


Fig. 5 *Residuals vs. Predicted*

The figure shows that variance is not constant for all the predicted values.

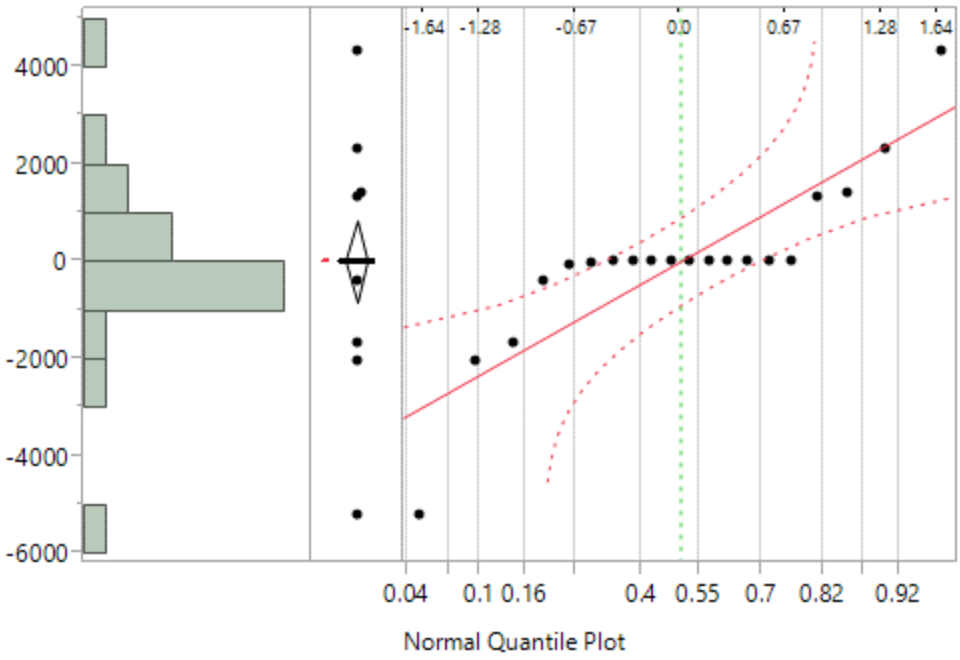


Fig. 6 *Normal quantile plot*

The figure clearly shows that points are not close to the line and outside the error bounds. This shows that normality assumption is not valid.

c. *Based on your answer to part (b) conduct another analysis of the failure time data and draw appropriate conclusions.*

Let us plot a bivariate fit of Log(Mean) and Log(Standard deviation).

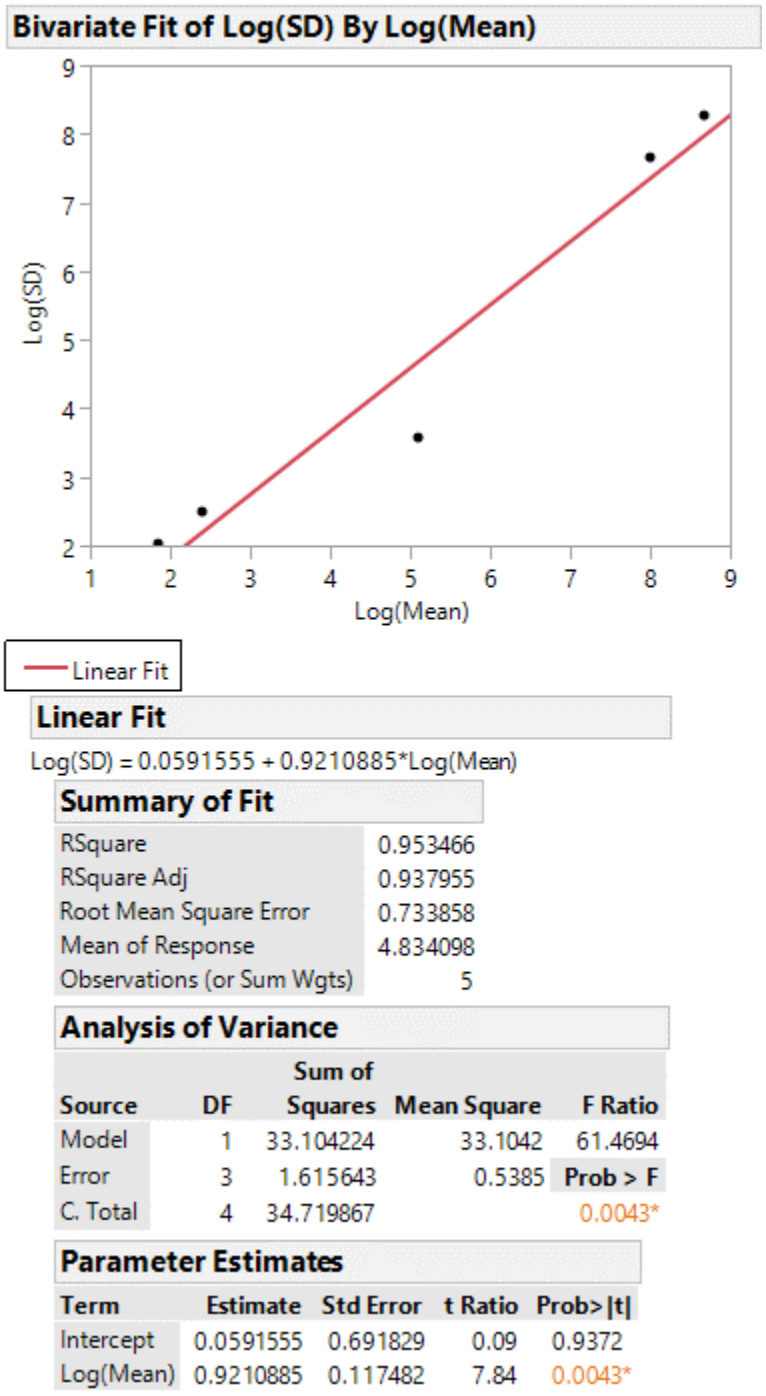
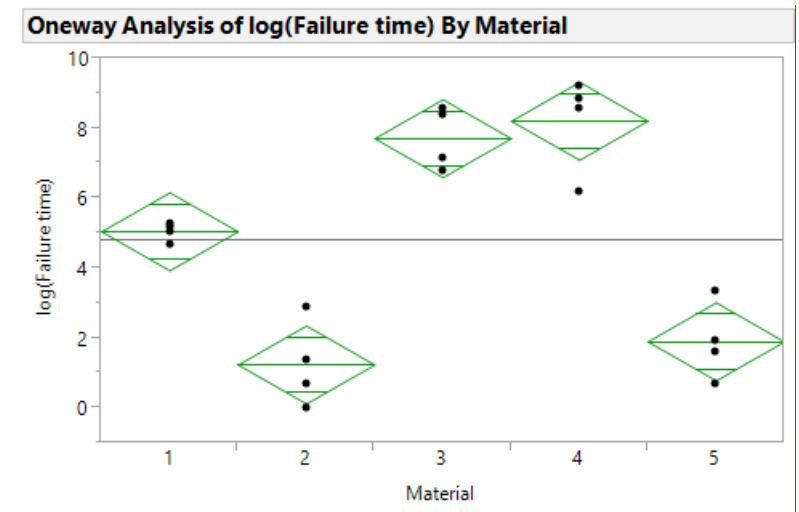


Fig. 7 *Log(Mean) vs. Log(S.D)*

From the plot, we could see that slope of the fit line is 0.9210 which is close to 1. So, from the table 3.9, a log transformation would be appropriate.



Oneway Anova

Summary of Fit

Rsquare	0.909435
Adj Rsquare	0.885285
Root Mean Square Error	1.046801
Mean of Response	4.825681
Observations (or Sum Wgts)	20

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Material	4	165.05646	41.2641	~~37.6569~~	<.0001*
Error	14 ~~15~~	16.43689	~~1.0958~~ 1.17406	~~35.1463~~	
C. Total	19	181.49335			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	4	5.05159	0.52340	3.9360	6.1672
2	4	1.24245	0.52340	0.1269	2.3581
3	4	7.71640	0.52340	6.6008	8.8320
4	4	8.21401	0.52340	7.0984	9.3296
5	4	1.90395	0.52340	0.7883	3.0195

Std Error uses a pooled estimate of error variance

P value is less than significance level $\alpha = 0.05$. Therefore, reject null hypotheses.

After changing the error degree of freedom, other values are adjusted. P value is still small.

Fig. 8 *OneWay ANOVA*

Therefore, we could conclude that mean failure time is not the same for all the materials.

Lower t

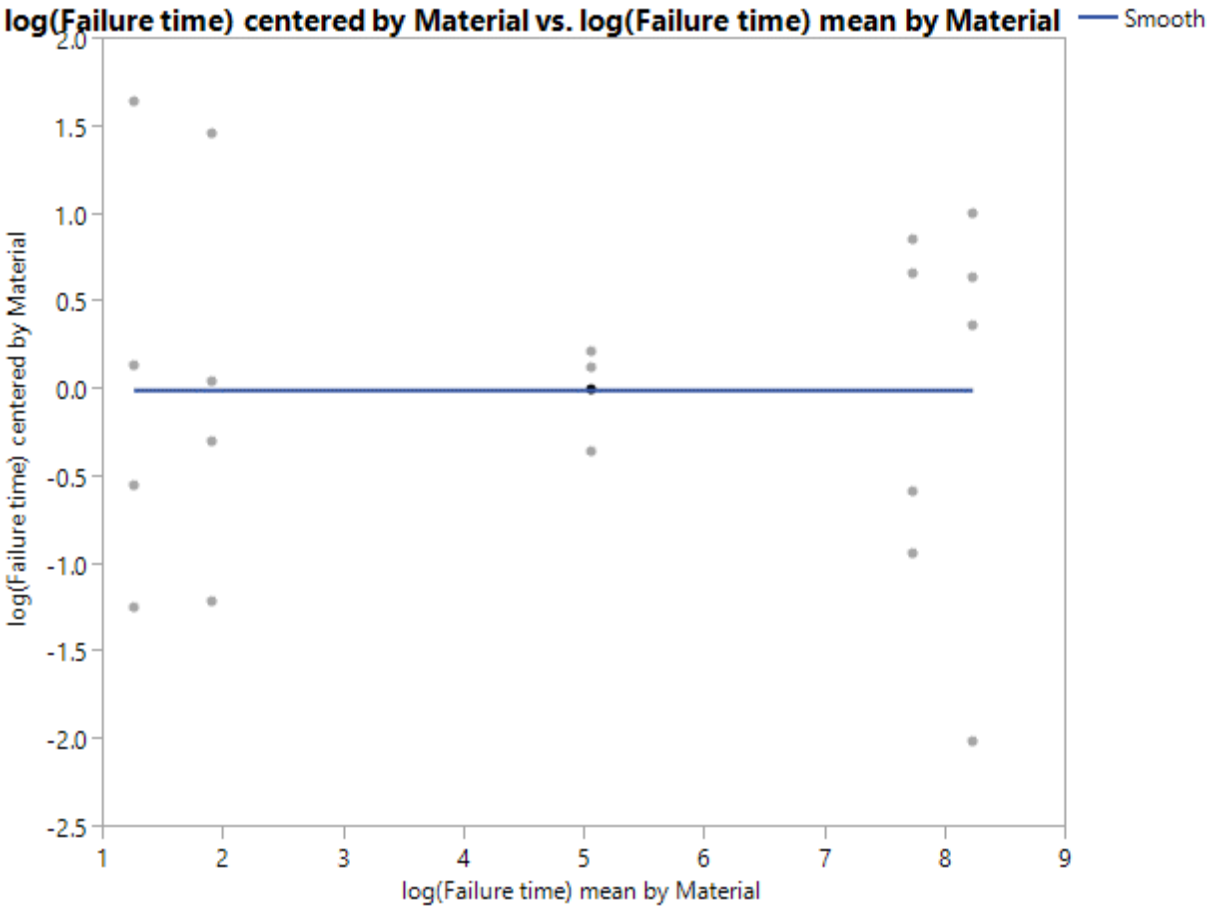


Fig. 9 *Residuals vs. Predicted*

This plot has been improved with transformed data although range of variation of one of the materials is lower than others.

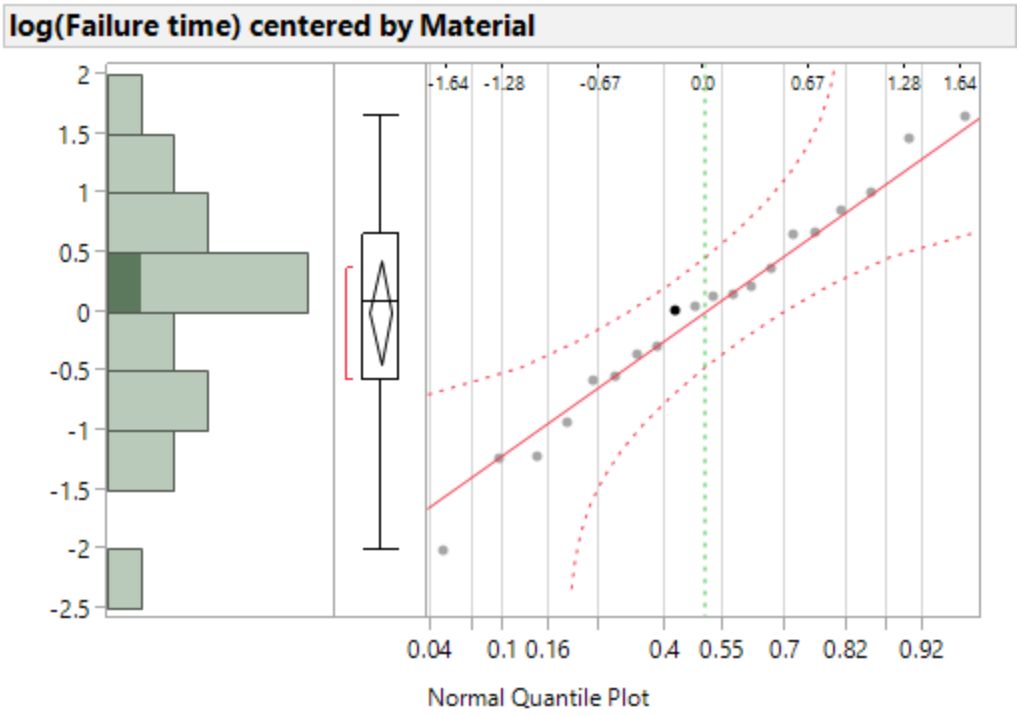


Fig. 10 *Normal quantile plot*

This shows that all points lie close to the line and within the error bounds. Hence the assumptions are not violated.