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Two-Factor Factorial Design to Identify the Best Combination of Factors for PSL Production

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ABSTRACT

Parallel strand lumber (PSL) is an engineered wood product that is used frequently in commercial and industrial applications. PSL consists of long, thin, narrow strands of wood bonded together with adhesive under high pressure. In this study, the combinations of factors for PSL production that can withstand maximum load pressure were investigated by using two-factor factorial design. The factors that were used are strand size and type of glue. There are three levels of strand size and two types of glue were used in this study. Results show that there is a significant effect for the interaction between the two factors. Melamine-urea-formaldehyde (MUF) glue gives the best results that can withstand the maximum load pressure for the PSL production as the fiber thickness increase.

Key words: Factorial Design, Interaction Effect, PSL.

1. INTRODUCTION

Wood plays an important role to human being for ages. Human tend to use wood for daily routine of their life. But nowadays many negative impacts are immerged due to excessive logging. Many scientists find way to substitute wood. In Malaysia, wood industry had contributed directly through plywood production and market exports [1]**.** To produce plywood, it required no defect wood and any defect part will be throw out. Due to massive production of plywood, logs will decrease from time to time. This will actually increase logs price in Malaysia. Hence, alternative technology such as Parallel strand lumber (PSL) would probably be a logical choice of supplement to plywood application due to using smaller diameter and low-quality material. By using alternative material such as oil palm trunk, destruction of our virgin forest and habitat will be minimized.

Parallel strand lumber can increase properties from low strength wood to higher strength of wood due to a few factors. Strand size is one of the important factors that can increase strength properties of sample. Type of glue that applied also can be affected due to ability of each glue to bonding with fibre thus create a stronger block of PSL [2].

To know the most suitable pair to create great formulation of PSL from oil palm trunk, a few statistical designs can be used for projection of best formulation.

Two factor factorial design is a set of experiment that should be consist of two or more factors. This can be used to study the effect on many factors on responded variable. This also can be used to show the effect of interactions between factors on those responded variable. Furthermore, a factorial design is necessary when interactions maybe present to avoid misleading conclusions. Additionally, factorial designs allow the effects of a factor to be estimated at several levels of the other factors. This set of design is suitable for finding the best formulation of PSL from oil palm trunk by using strand size and type of glue as a factor.

Hence, the objective of this study is to investigate the combination of factors for PSL production that can withstand maximum load pressure by using two-factor factorial design

2. METHODOLOGY

Two-factor factorial design was used to investigate the combination of the factors for PSL production that can withstand maximum load pressure that is the responded variable. The factors were types of glue and strand size. The factorial arrangement for the treatment designed consisted of one qualitative factor, “type of glue”, with two levels that is phenol formaldehyde resin(PF) and melamine urea formaldehyde(MUF) and one quantitative factor, “strand size”, with three levels (0.3, 0.5 and 1.0 inch). Based on the factors, 6 combinations of treatment were obtained. Each of the six treatment combination was assigned with one hundred replications. The combination of the treatments is given in Table 1:

Table 1: List of Treatment Combination

No	Combination
1	0.3, PF
2	0.3, MUF
3	0.5, PF
4	0.5, MUF
5	1.0, PF
6	1.0, MUF

The two-factor factorial design model is given as shown by equation (1) and (2) [3-4].

$$y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \varepsilon_{ijk} \quad (1)$$
$$i = 1,2$$
$$j = 1,2,3$$
$$k = 1,2,\ldots,100$$

where μ is overall mean, τ_i is type of glue effect, β_j is fiber thickness effect, $(\tau\beta)_{ij}$ is the interaction effect and ε_{ijk} is random error.

Tukey's test will be done to make comparison and to determine which treatment combinations are different. The Tukey method is given as :

$$T_\alpha = q_\alpha(a, f)\sqrt{\frac{MSE}{n}} \quad (2)$$

where $a = 3$, $f = 594$, MSE is mean square error and $n = 600$. Any pair of treatment averages that differ in absolute value by more than T_α would imply that the corresponding pair of population means are significantly different.

3. RESULTS AND DISCUSSION

3.1 Model Adequacy Checking

In order to construct two-factor factorial model the errors are assumed to be independent, normally distributed with a mean of 0, and have a common variance for all treatment groups i.e $NID(0,\sigma^2)$. To test for the equality of variance, a widely used procedure is Bartlett's Test [4]. The test checked the assumption of equal variances is true before running one way ANOVA. Table 2 indicate that the variance are equal for all treatment groups, since the significance value is greater than 0.05. To test for normality assumption, a normal Q-Q plot was then constructed. Figure 1 shows that the point lies along the straight line which indicates that the residuals are normally distributed.

Table 2: Bartlett's Test

Bartlett's Test of Sphericity	Approx.Chi-Square	.000
	df	1
	Sig.	1.000

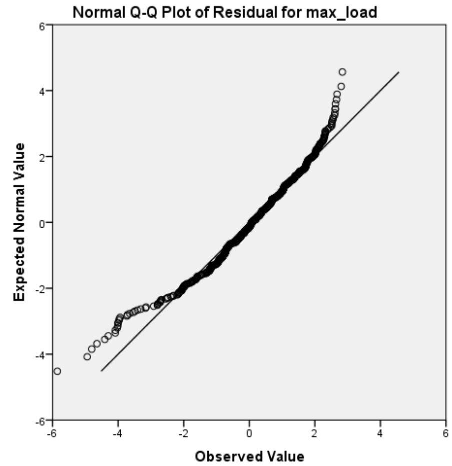

Figure 1: Normal Q-Q plot of the residual

3.2 Statistical Analysis of the two factor factorial design

Since the assumptions are fulfilled, the analysis of variance is then constructed. The ANOVA is shown in Table 3. It shows that there is a significant interaction between the strand size and the types of glue because the significance value is less than 0.05. The results also can best be interpreted with the graph of the average maximum load as shown in Figure 2. The lack of parallelism of the lines in that graph also indicates that the interaction effect is significant.

Note that the significance value in Table 3 also shows that the main effect is significant. However, further study will be only on the interaction effect because the knowledge of the interaction is more useful than knowledge of the main effects. A significant interaction will often mask the significance of main effects.

Table 3 : Analysis of Variance
Dependent Variable: maximum load

Source	Sum of Squares	df	Mean Square	F	Sig
Strand Size	4884.952	2	2442.476	1113.110	.000
Type of Glue	2492.150	1	2492.150	1135.748	.000
Interaction	74.663	2	37.331	17.013	.000
Error	1303.403	594	2.194		
Total	8755.167	599			

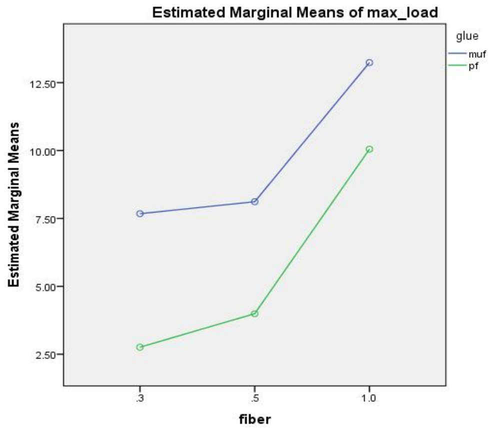

Figure 2: Interaction Plot

3.3 Multiple Comparison

The significance of the interaction means that at least one pair of treatment combination means is different. To figure out, which pair is different, we will proceed with the multiple comparison test named as Tukey's test. But when the interaction effect is significant, the comparison between the means of one factor maybe obscured by the interaction. In this study, one approach is to fix one factor at a specific level and apply Tukey's test. Therefore, we fix the type of glue MUF and compare the different among the three levels of strand size.

In Table 4, we first obtain the mean of maximum load for each fiber thickness, fixed at glue type MUF. Then, the mean difference is compared with T_α, calculated with the formula as shown in equation (2). The null hypothesis is rejected since the mean difference in each combination is greater than T_α. The null hypothesis here indicates that there is no different between the treatment combinations.

Table 4: Mean of strand size fixed at MUF glue

$\bar{y}_{0.3,MUF}$	7.675
$\bar{y}_{0.5,MUF}$	8.116
$\bar{y}_{1.0,MUF}$	13.240

Calculated T_α as stated in equation (2) yield:

$$T_{0.05} = q_{0.05}(3,594)\sqrt{\frac{2.194}{100}} = 0.492$$

Thus, any pair of treatment averages that differ in absolute value by more than 0.492 would imply that the corresponding pairs are significantly different.

The difference in each treatment averages are:

$$\left|\bar{y}_{0.3,MUF} - \bar{y}_{0.5,MUF}\right| = 0.441 < T_{0.05} = 0.492$$

$$\left|\bar{y}_{0.3,MUF} - \bar{y}_{1.0,MUF}\right| = 5.565 > T_{0.05} = 0.492*$$

$$\left|\bar{y}_{0.5,MUF} - \bar{y}_{1.0,MUF}\right| = 5.124 > T_{0.05} = 0.492*$$

The starred values indicate the pairs of mean that are significantly different. At MUF type of glue, the maximum load that a PSL can withstand is the same between the strand size 0.3 and 0.5, while the maximum load is significantly differs between strand size 0.3 and 1.0 and 0.5 and 1.0.

Further analysis are done using Tukey's test but now, we fix the type of glue PF and compare the different among the three levels of strand size.

Table 5: Mean of strand size fixed at PF glue

$\bar{y}_{0.3,PF}$	2.760
$\bar{y}_{0.5,PF}$	3.993
$\bar{y}_{1.0,PF}$	10.051

The different between each pair of treatments average are calculated and then been compared with the value of T_α that is 0.492.

The difference in each treatment averages are:

$$\left|\bar{y}_{0.3,PF} - \bar{y}_{0.5,PF}\right| = 1.233 > T_{0.05} = 0.492*$$

$$\left|\bar{y}_{0.3,PF} - \bar{y}_{1.0,PF}\right| = 7.291 > T_{0.05} = 0.492*$$

$$\left|\bar{y}_{0.5,PF} - \bar{y}_{1.0,PF}\right| = 6.058 > T_{0.05} = 0.492*$$

The starred values indicate the pairs of mean that are significantly different. Clearly, all pairs of means are significantly different by using the type of glue PF[5-7].

4.CONCLUSION

In this study, we can conclude that the combination of strand size 0.3 and 0.5 with MUF glue are not significant while the others combination are significant. This indicate that for PSL production that can withstand maximum load pressure are equal either we use strand size 0.3 or 0.5 by using MUF glue. The combination of each strand size for PF glue is significant. However, the maximum load for these combinations is lower than the combination of all strand size with MUF glue. Strand size 1.0 with MUF glue seems to give the best result for PSL production that can withstand the maximum load pressure. Sajeeb, Sajith, and Muhammad Arif stated that MUF is better than PF glue due to involvement of heat in production line. The heat cured the glue faster hence increase the bonding of strand and glue.

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