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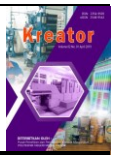

Analysis of Tension Parameters on Lamination Quality on Dry Lamination Machines

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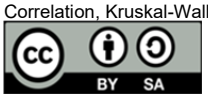

ABSTRAK

Dalam industri kemasan fleksibel, kualitas hasil laminasi sangat berpengaruh terhadap daya tarik dan fungsi proteksi produk. Salah satu permasalahan umum yang terjadi dalam proses dry laminasi adalah cacat kerut laminasi, yang dapat menurunkan standar mutu kemasan. Penelitian ini bertujuan untuk menganalisis pengaruh variasi parameter tension pada mesin dry laminasi—yakni tension pada Unwinder 1, Unwinder 2, dan Laminator—terhadap kualitas cetakan kemasan snack. Penelitian dilakukan secara kuantitatif dengan pendekatan eksperimen di PT XXX, menggunakan 64 sampel variasi tension dan pengujian kualitas melalui uji laboratorium (sealing strength, bonding strength, dan dry glue) serta inspeksi visual. Hasil uji korelasi Pearson menunjukkan hubungan yang lemah hingga sangat lemah antara parameter tension dengan hasil uji laboratorium. Uji Kruskal-Wallis sebagai metode non-parametrik menunjukkan bahwa tidak terdapat perbedaan signifikan terhadap kualitas laminasi berdasarkan variasi tension. Namun, uji korelasi Spearman terhadap cacat visual menunjukkan bahwa tension pada Laminator memiliki korelasi yang kuat terhadap kerut laminasi dan gambar ciut. Dengan demikian, kontrol parameter tension, terutama pada Laminator, menjadi kunci dalam pengurangan cacat visual pada proses dry laminasi.

ABSTRACT

In the flexible packaging industry, the quality of lamination results significantly affects both the appeal and protective function of the product. One common issue in the dry lamination process is lamination wrinkle defects, which can reduce the packaging quality standards. This study aims to analyze the effect of variations in tension parameters in the dry lamination machine specifically the tension in Unwinder 1, Unwinder 2, and the Laminator on the print quality of snack packaging. The research was conducted using a quantitative experimental approach at PT XXX, involving 64 samples with varied tension settings and quality testing through laboratory tests (sealing strength, bonding strength, and dry glue) as well as visual inspections. The Pearson correlation test results indicated a weak to very weak relationship between tension parameters and laboratory test outcomes. The Kruskal-Wallis non-parametric test showed no significant differences in lamination quality based on tension variation. However, the Spearman correlation test for visual defects revealed a strong correlation between Laminator tension and the occurrence of lamination wrinkles and shrinkage patterns. Therefore, controlling the tension parameters especially at the Laminator is essential in reducing visual defects during the dry lamination process.

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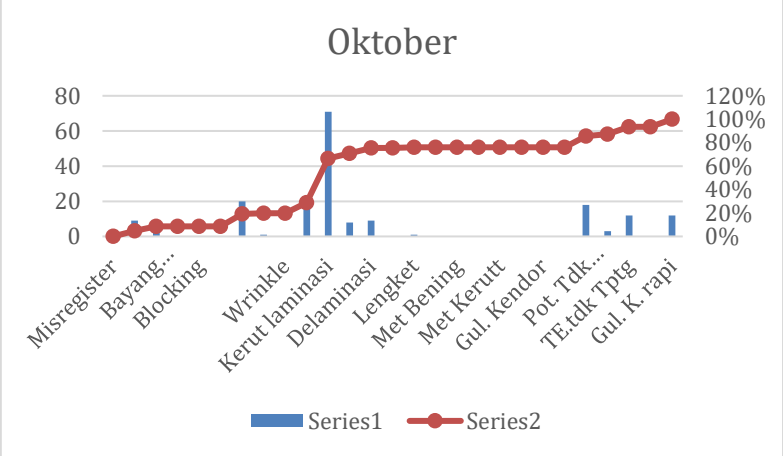
1. INTRODUCTION

Packaging is a crucial element in the product industry, as it not only serves as a protective layer for the product contents but also acts as a promotional tool to attract consumer attention. Visually appealing packaging can influence consumers' purchasing decisions (Waladow, 2017). In addition to serving as protection and promotion, packaging also becomes a unique attraction that differentiates one product from another.

One type of packaging that is widely used today is flexible packaging, which is made from plastic materials. This type of packaging is favored due to its lightweight nature, ease of shaping, and efficiency in both production and distribution processes. In the packaging printing industry, the lamination process plays a vital role in producing packaging that is not only strong but also innovative and functional (Lambelu, 2023). Lamination itself is divided into two categories: extrusion lamination, which uses resin-based materials, and dry lamination, which uses adhesive materials.

The final quality of the packaging heavily depends on the lamination process. Any disruptions during this process may lead to product defects. One common type of defect found is wrinkling in the laminated layer, which can affect both the visual and structural quality of the packaging. Defective products like these do not meet the company's quality standards and require rework to be improved into sellable products (Dewanto & Galingging, 2022). Therefore, companies in the packaging industry strive to minimize the occurrence of product defects.



Picture 1 Pareto Chart

PT XXX is one of the leading companies engaged in the production of flexible packaging. The company is committed to maintaining product quality to ensure customer satisfaction. However, during the period of October 2024, the company experienced an increase in the number of rejected products, particularly in snack packaging. One of the most dominant types of defects in this process was lamination wrinkles, as illustrated in the Pareto Diagram (Figure 1). This issue is classified as a Critical Control Point (CCP) in the dry lamination process, which serves as a crucial checkpoint to ensure the quality of the packaging.

2. METHOD

The research was conducted experimentally at PT XXX using a 4x4x4 factorial design, which included four variations of tension for Unwinder 1 (11–14 Kgf), Unwinder 2 (4–7 Kgf), and the Laminator Tension (14–17 Kgf). This approach was chosen to analyze the effect of tension on the quality of lamination results on the dry lamination machine. The testing was carried out on visual inspection, bonding strength (g/15mm), sealing strength (g/15mm), and dry glue (g/mm). The data were analyzed using Pearson correlation and Kruskal-Wallis test to determine the effect on laboratory testing, and Spearman correlation to identify the effect on visual quality based on each tension variation applied.

Table 1 Sample of Tension Variations and Speed Variations

unwinder 1	unwinder2	Tension Laminator
11	4	14
11	4	15
11	4	16
11	4	17
11	5	14
11	5	15
11	5	16
11	5	17
11	6	14
11	6	15
11	6	16
11	6	17
11	7	14
11	7	15
11	7	16
11	7	17
12	4	14
12	4	15
12	4	16
12	4	17
12	5	14
12	5	15
12	5	16
12	5	17
12	6	14
12	6	15
12	6	16
12	6	17
12	7	14
12	7	15
12	7	16
12	7	17
13	4	14
13	4	15
13	4	16

unwinder 1	unwinder2	Tension Laminator
13	4	17
13	5	14
13	5	15
13	5	16
13	5	17
13	6	14
13	6	15
13	6	16
13	6	17
13	7	14
13	7	15
13	7	16
13	7	17
14	4	14
14	4	15
14	4	16
14	4	17
14	5	14
14	5	15
14	5	16
14	5	17
14	6	14
14	6	15
14	6	16
14	6	17
14	7	14
14	7	15
14	7	16
14	7	17

In identifying problems or determining improvements, the following steps are used for the technical data analysis process. These are the steps taken to analyze the data:

Correlation Spearman.

The Spearman correlation is used for significant data to examine the relationship between two specific variables.

1. The data sources used in this correlation analysis do not have to be the same,
2. the variables do not need to be normally distributed,
3. and they can originate from ordinal data.

$$rho = 1 - \frac{6\sum d^2}{n(n^2-1)}$$

Picture 2 formula correlation Spearman

Description:
rho : Spearman's rank correlation coefficient
d² : Squared difference in ranks
n : Number of data points (samples)

Table 2 Table Interpretation of rho Values

Rho positif	Rho negatif	Kategori
0,9 < rho < 1	-0,9 < rho < -1	Very strong
0,7 < rho < 0,9	-0,7 < rho < -0,9	strong
0,5 < rho < 0,7	-0,5 < rho < -0,7	Moderate
0,3 < rho < 0,5	-0,3 < rho < -0,5	Weak
0 < rho < 0,3	-0 < rho < -0,3	Very Weeak

Kruskal Wallis

The Kruskal-Wallis test is a non-parametric alternative to one-way ANOVA, used for analyzing data that does not meet parametric assumptions. This test is used to determine whether there are significant differences among three or more groups. According to Rozi & Maulidiya (2022), the Kruskal-Wallis test is a non-parametric method used to assess whether there are differences in the mean ranks across more than two independent sample groups.

Rozi & Maulidiya (2022) also state that the Kruskal-Wallis test has the following requirements:

1. The data must be non-normally distributed.
2. There must be more than two independent sample groups that are not related or do not influence each other.
3. The samples must be on an ordinal or interval scale.

The Kruskal-Wallis formula is as follows:

$$H = \frac{12}{n(n-1)} \sum_{i=1}^{k} \frac{\mathrm{Ri}^2}{\mathrm{ni}} - 3(n+1)$$

Picture 3. Formula *Kruskal Wallis*

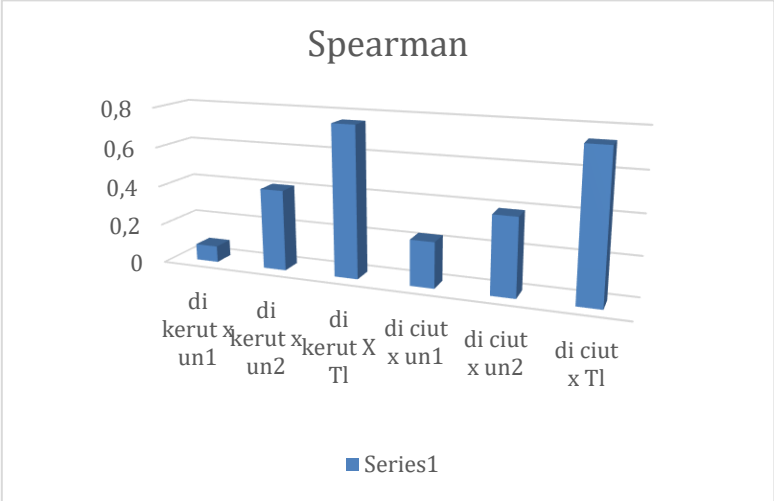
Description:
Ri = Sum of ranks for the i-th sample
N = n1 + n2 +...+ nk

3. RESULT AND DISCUSSION

To validate the value of the Pearson correlation, the data is verified using a non-parametric ANOVA data processing method, namely the Kruskal-Wallis test.

1. Kruskal-Wallis test for sealing strength with tension variations resulted in a value of (53.03 < Chi-square table value), thus it is assumed that H0 is accepted, meaning there is no significant difference in the lab test results of sealing strength based on tension variations.
2. Kruskal-Wallis test for bonding strength with tension variations resulted in a value of (53.16 < Chi-square table value), thus it is assumed that H0 is accepted, meaning there is no significant difference in the lab test results of bonding strength based on tension variations.
3. Kruskal-Wallis test for dry glue with tension variations resulted in a value of (52.34 < Chi-square table value), thus it is assumed that H0 is accepted, meaning there is no significant difference in the lab test results of dry glue based on tension variations.

To verify the visual results against tension variations, a Spearman correlation calculation is required. The Spearman correlation demonstrates that there is a strong relationship between tension variations and the visual inspection results. The Spearman correlation value between Unwinder 1 and lamination wrinkles is 0.08, indicating a very weak relationship, and 0.2 with shrink marks, indicating a weak relationship. The correlation between Unwinder 2 and lamination wrinkles is 0.4, indicating a moderate relationship, and 0.3 with shrink marks, indicating a weak relationship. Furthermore, the correlation between Laminator Tension and lamination wrinkles is 0.7, indicating a strong relationship, and 0.74 with shrink marks, also indicating a 40 relationship.



Picture 4 *Spearman Correlation Bar Chart*

4. CONCLUSION

Based on the results of the discussion, it can be concluded that laminator tension has a significant impact on the visual appearance of wrinkles and shrinkage in lamination. By updating the lamination standards, particularly the tension parameter, the issue of lamination wrinkles can potentially be eliminated, achieving zero defects, especially in visual aspects. Laminator tension serves as a key initial step in addressing defects such as image shrinkage and lamination wrinkles. From this research, the following recommendations can be made for the company and future studies:

1. Always update the parameter standards to ensure the process runs smoothly without defects in the packaging. Based on this study, it is recommended to update the standard with the following settings: Unwinder 1 (11–13 kgf), Unwinder 2 (4–6 kgf), and Laminator Tension (14–16 kgf).

2. To further deepen this research, it is advisable to consider other variables that may affect the visual appearance of lamination wrinkles. Additionally, future studies could compare the test results before and after the standard update.
3. It is recommended that the company increase its focus on visual inspection for defects such as lamination wrinkles and shrinkage, as the research results show a strong correlation between tension and these visual aspects.

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