ANALYSIS CAUSING AND IMPROVEMENT DEFECT BONDING ON SOCCER PRODUCTS IN PT. PDK USE DESIGN OF EXPERIMENT

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Abstract: Defect bonding is one of the biggest problems in the assembling process in the shoe manufacturing industry which can be caused by internal factors and external factors so that detailed analysis is needed about the planned repairs that need to be done to minimize the defect. PT. PDK analyzes the biggest factors of defect bonding as well as alternative repairs made on Accelerator LS shoes using experiment design analysis. From the results of the experiment design analysis using the Two Stage Nested Design method, it is known that the outsole material factor in each article had a significant effect on poor bonding defect priming outsole, while the analysis using the Two Factorial Design method revealed that alternative 1 had a significant effect on released bonding tests. and better than alternative 2. Based on the results of the experimental design analysis, changes were made to the assembling process and the structure of the product of Accelerator LS shoes.

Keywords: Accelerator LS Shoes, Defect Bonding, Design of Experiment, Two Stage Nested Design, Two Factorial Design

PT. PDK is one of the shoe companies in Indonesia that produces various shoe categories such as soccer, futsal, baseball, running and volleyball categories. Design of shoe products at PT. PDK starts at the development stage where at that stage there are several processes carried out to determine whether the shoes are feasible or not to do the mass production process. For each category held the developer is the project holder who designs shoes at the development stage from stage first develop to conform sample stage. In supporting the performance of developers in order to complete the design of shoe products according to the time line that has been determined by the buyer, Designing shoes at PT. PDK involves several parts of the division in the structure of development organizations such as division patterns, upper tooling division, bottom division, BPFC division, and commercialization division.

In designing shoes at the development stage, Buyer as a brand owner will determine the design of shoes that will be made in general through design indication. The design indication will be given by the buyer to each developer at the first develop stage so that developers design shoes based on the design. If there are no material changes, construction, and shoes that have been released as a whole, the lab test will enable the buyer to validate the shoes on the conform sample stage. After the conform sample stage, the developer will handover the product to the commercialization division to proceed to the next stage, namely the production trial. Production trials are conducted to ensure that the processes carried out at the development stage are consistent and can be implemented properly during mass production. The description of shoe design at the development stage can be seen in Figure 1.

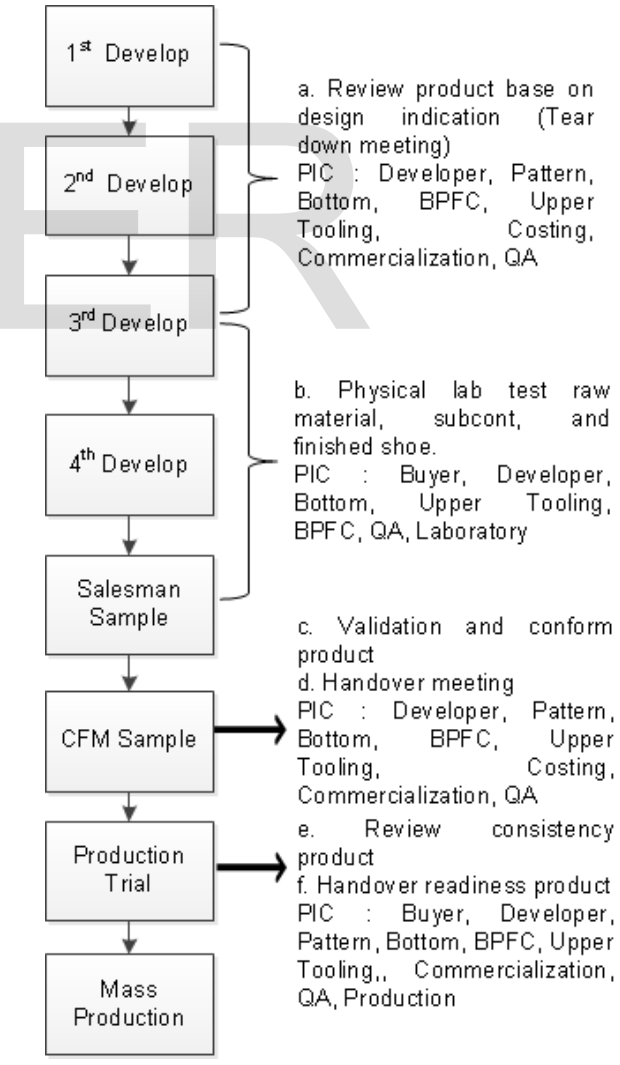

Figure 1 Shoe Design on Development Stage

The background of this study is that quality control has not run well for rejected cases of bonding at the development stage, especially for soccer category products which have often been produced due to lack of analysis and further action to analyze in detail the bonding cases so rejected bonding is still common at the production stage even though during the physical lab development phase the product test has released a bonding test.

The rejected shoes case is because bonding is one of the major defects that occur in the production process in the assembling process and until now the biggest cause is not known because it can consist of several factors such as human factors, machine/tooling, material, and chemical. One of the biggest defects occurred in soccer shoes LS Accelerator model which is a shoe top shoe with high demand. Images of rejected open bonding shoes can be seen in Figure 2 below.

Fig 2. ***Rejected Bonding***

The main objective in this study was to determine the factors that most influence rejected bonding problems on the soccer category LS Accelerator shoes and determine the best process to be used in the production of soccer shoes LS Accelerator model using experimental design analysis through Two Stage Nested Design and Two Factorial Design. The second objective in this study was to make improvements to the factors that most influenced the rejected bonding case on the soccer category LS Accelerator shoes through process improvement and product structure review.

1. Literature Review

A. Design of Experiment

Basically an experiment is carried out to find out the best results of a process. According to Suhaemi (2011) theoretically. the experiment was interpreted as a planned test or investigation to get new facts. The experimental design is a test or series of tests using either descriptive statistics or inference statistics that aim to change the input variable into an output which is the response of the experiment.

Some experimental design terms according to Ansori (2006) such as:

- Treatment

Treatment is a procedure or method expected in the experimental unit. Examples of procedures or methods applied such as giving different types of fertilizers.

- Level

The level is the values of the independent variables (factors) that are tried are divided into 3 levels, namely varieties A, varieties B, and varieties C.

- Factor

The factor is that the independent variable that was tried in the experiment as the compiler of the treatment structure that was tried could be either a qualitative variable or a quantitative variable that was tried in the experiment as a structure of treatment.

- Recurring Observations

It is an observation that is done repeatedly in different times at the same place to look for variations / variations that appear in the response.

B. Factorial Experiment

According to Arifianto (2013), factorial experiments are experiments that use more than one factor with each level of factor combined with the levels of other factors. The purpose of the factorial experiment is to see the interaction between the factors used where sometimes both factors synergize with the response (positive), but sometimes the presence of one factor actually inhibits the performance of other factors (negative).

The mathematical model for two factorial design method is as follows:

$$Y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \in_{ijk}$$

Where:

μ = General average of population

τ_i = The effect of treatment A is the i-th

β_j = The effect of treatment B is the j-th

$(\tau\beta)_{ij}$ = The effect of the combination of treatment A of the i-th stage and treatment B at the j-th stage

$\in_{ijk}$ =The residual effect of the k-th replication unit and the i-th and j-th treatment

C. Two Stage Nested Design

Nested design is one case of a multi-factor design where the level of one factor (example factor B) is similar but not identical for each level different from the other (factor A). Thus the level of factor B is nested below the level of factor A so a design like this is called hierarchical design.

The mathematical model for two-stage nested design method is as follows:

$$Y_{ijk} = \mu + \tau_i + \beta_{j(i)} + \in_{(ij)k}$$

Where:

μ = General average of population

τ_i = Trial average from factor A

$\beta_{j(i)}$ = Trial average of factor B, The index j(i) states that factor B is nested in factor A

$\in_{(ij)k}$ = Random error

D. Bonding

Bonding is one type of defect that occurs in shoes caused by internal factors and external factors so that the upper does not stick well to the outsole. Internal factors occur due to operator errors in the gluing process or attachment, the machine/tooling used is not in accordance with the standard, and others related to the assembling process. While external factors

occur because raw materials and subconts sent by tier 2 and tier 3 suppliers for use in the assembling process do not have good quality. The categories of internal factors and external factors that cause defect bonding include:

A. **Internal Factor**

- Poor Pressing is caused because the tooling used in the attaching process, namely the pressing pad, is not periodically validated so that the upper does not stick well to the outsole and visually there are several upper areas that have no failure to the outsole.
- Poor Primering is caused by the primary process on one component, namely the upper or outsole, which is not carried out evenly so that one of the components cannot absorb the glue properly and creates an upper with the outsole not sticking perfectly.
- Over Dry Cement is caused by the time interval of attaching to the manual process using a universal press that is too long and the shoe is outside the heater machine due to the buildup so that the glue is in dry conditions on both components (upper and outsole).

B. **External Factor**

- Coating Delamination/Failure Material is caused by surface coating on synthetic or leather material that does not have good adhesion strength with a microfiber or non woven backer so that the backer does not fail to the bottom.

2. Research Methodology

This research was conducted at the development and quality department at PT. PDK where the two departments have their respective roles, namely development has a role in designing products to fit the specifications desired by buyers and ensuring product readiness when produced is not problematic, while the quality department has an important role in controlling quality from raw materials, work in process (raw material which process in subcont supplier), production process until the finished product. The steps in this research methodology are as in Figure 3.

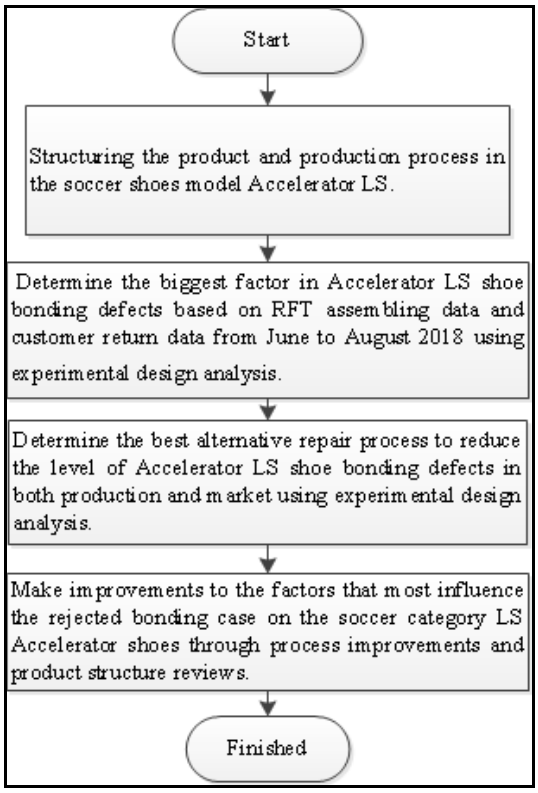

Fig 3. Research Methodology

3. Result and Discussion

A. Product Structure and Process of Accelerator LS Shoes Assembling

Before determining the biggest factor in the defect bonding of the Accelerator LS shoes, a description of the structure of the product and the production process will be made first in the Accelerator LS shoes. The structure of the Accelerator LS shoes product can be seen in Figure 4 and for the production process can be seen in Figure 5

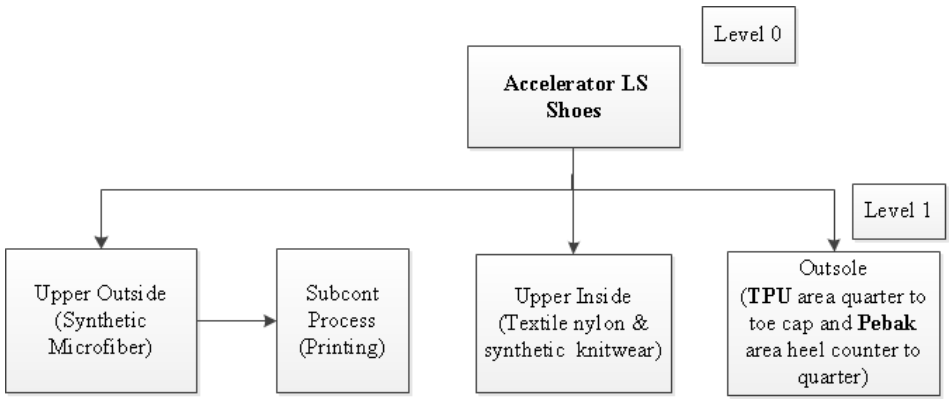

Fig 4. Product Structure of Accelerator LS Shoes

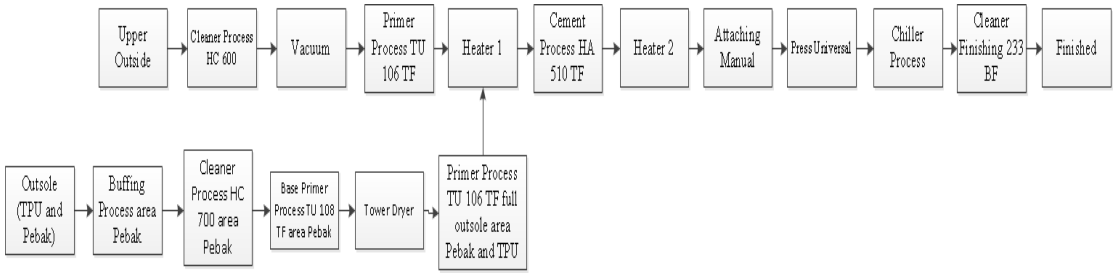

Fig 5. Assembling Process of Accelerator LS Shoes

Based on the product structure in Figure 4, Accelerator LS shoes in the main upper material at level 1 consist of 4 types of materials, namely synthetic, textile, pebak, and TPU where 4 types of material are supplied by tier 2 suppliers. In the upper outside component, there is a printing process that is carried out in the supplier tier 3. Meanwhile, based on Figure 5, the assembling process for outsole components is higher than the upper component because the outsole component in the heel area has a buffing process before the cleaner process and for the primary process 2 times before the cementing process, different from the upper outside component which does not have a buffing process and for the primary process it is only done once.

The buffing process in the outsole pebak component is done to make the previously slippery surface outsole rough so that during the primary process the glue can absorb well on the outsole. But on the other hand if the buffing process is not carried out according to standards such as not following the bonding marking it will make the outside edge of the outsole defect and if the buffing process is not carried out evenly or too thinly, the primary process will not run optimally causing bonding.

B. Data On The Rejected Bonding Shoe Accelerator LS

The production process of Accelerator LS shoes for 3 articles was carried out in the production of plant 2 cell 1 and plant 2 cell 2. Accelerator LS shoe bonding found during the inspection process in final inspection and after the market will be one of the data that can be used to be known any improvement plan that needs to be done so that defect cases because the bonding can be minimized will not even occur again in the future. The rejected data bonding is taken during the period from June to August 2018 and can be seen in Table 1.

Based on Table 1 it can be seen that the Accelerator LS shoes produced by PT. PDK has 3 articles with 3 different colorways and the biggest rejected article from the 3 articles found in final inspection and customer return is in article 011. In article 011 rejected bonding in the final inspection area was found in the B grade and C grade categories.

Table 1 Data of the Rejected Bonding Accelerator LS Shoe in June – August 2018

Data of The Rejected Bonding Accelerator LS Shoe in 2018						
Article	Colorway (Upper / Outsole)	PO Number	Qty Order (Pairs)	Qty Defect Bonding (Final Inspection)		Qty Defect Bonding (Customer Return)
				B Grade (Pairs)	C Grade (Pairs)	
010	Black / Black	SP-180203-S010	3.200	43	0	2
		SP-180308-S010	4.000	12	0	0
011	Blue / Purple	SP-180203-S011	2.400	318	88	15
		SP-180310-S011	3.800	625	132	8
		SP-180405-S011	6.200	428	72	22
012	Gold / Chinesse Red	SP-180405-S012	1.500	72	0	0
		SP-180410-S012	2.200	34	0	4

(Source: Dept. Quality Integration Program (QIP) PT. PDK, Juni – Agustus 2018)

The inspection process in the final inspection on Accelerator LS shoes is not done randomly but 100% because the model is the top shoe category. The defect bonding found at the customer will directly reduce the brand image of the product so that detailed identification of the causes of rejected bonding is required in the Accelerator LS shoe.

Based on analysis from the QA division, the causes of rejected bonding that occurred in the final inspection and customer areas were caused by 3 categories, namely poor priming outsole, poor pressing, and over dry cement. Of the 3 categories, the biggest defect is more due to poor priming outsole and can be seen in Figure 6 and Figure 7.

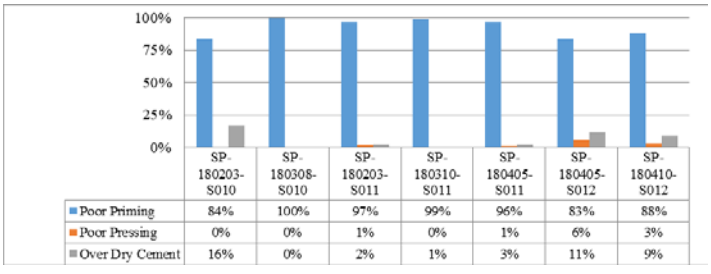

Fig 6. Data of the Rejected Bonding Accelerator LS Shoe June - August 2018 (Final Inspection)

Fig 7. Data of the Rejected Bonding Accelerator LS Shoe June - August 2018 (Customer Return)

For rejected because poor priming outsole can be due to several factors such as human factors, machinery, materials, and methods. The cause of the poor poor priming outsole is found in the causal diagram in Figure 8.

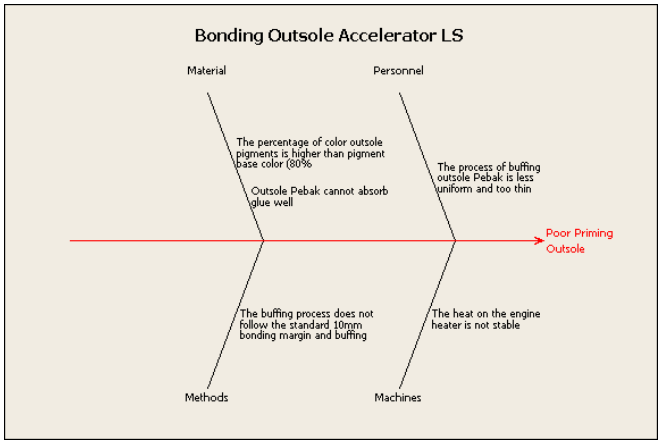

Fig 8. Cause Diagram Poor Priming Outsole Accelerator LS

C. Analysis Data of Rejected Bonding Use Two Stage Nested Design

To find out for sure the factors that have the most influence on rejected bonding because of poor priming outsole, the QA division randomly picked up shoes from each article as much as 5 pairs by replicating three times to test the bonding test at the PT. PDK. The analysis of bonding test results use software "Minitab" and the "Two Stage Nested Design" experimental design method with a probability of 5% which can be seen in Table 2 and Figure 9

Table 2. Data of Result Bonding Test"Poor Priming Outsole" Shoe Accelerator LS

Accelerator LS	Article 010		Article 011		Article 012	
Plant Cell	P2C1 (Qty Defect)	P2C2 (Qty Defect)	P2C1 (Qty Defect)	P2C2 (Qty Defect)	P2C1 (Qty Defect)	P2C2 (Qty Defect)
Replication 1	1	0	4	2	0	1
Replication 2	0	1	3	1	1	0
Replication 3	1	1	2	2	1	0

(Source: Dept. Quality Assurance (QA) PT. PDK, June – August 2018

Nested ANOVA: Defect versus Article; Cell

Analysis of Variance for Defect

Source	DF	SS	MS	F	P
Article	2	13,4444	6,7222	6,722	0,078
Cell	3	3,0000	1,0000	2,250	0,135
Error	12	5,3333	0,4444		
Total	17	21,7778			

Fig 9. Result of ANOVA Nested Design

The article in the table describes raw material in the outsole pebak, while the plant cell in the table describes the assembling machine in the LS accelerator shoe production. Based on the results of the ANOVA in Figure 9, it can be concluded that:

- The difference in articles on shoes had a significant effect on the number of defect bonding "poor priming outsole" in the production of Accelerator LS shoes.
- The difference in plant cell did not significantly influence the number of defensive bonding "poor priming outsole" in the production of Accelerator LS shoes.

So that it can be said that the biggest cause of poor bonding defect is priming outsole due to the inconsistent and biggest outsole material in each article occurring in article 011 so it is necessary to review the product again to identify any improvement process that needs to be done to minimize the defect.

D. Analysis Improvement Process with Two Factorial Design

Based on analysis above where the main problem of bonding poor defect is priming outsole due to outsole material, then the QA and BPFC division conducts a trial test as a process improvement plan with several alternatives including:

1. First alternative: Changes in raw outsole material from TPU and Pebak became TPU, thus eliminating the buffing process on the outsole and eliminating the TU 106 TF primary base (Figure 10).

2. Second alternative: Add cement process from 1 time to 2 times without eliminating other processes (Figure 11).

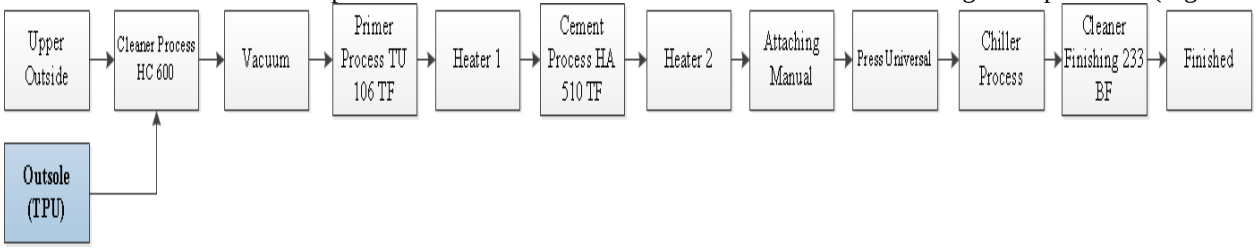

Fig 10. Assembling Process of Accelerator LS Shoes for Alternative 1

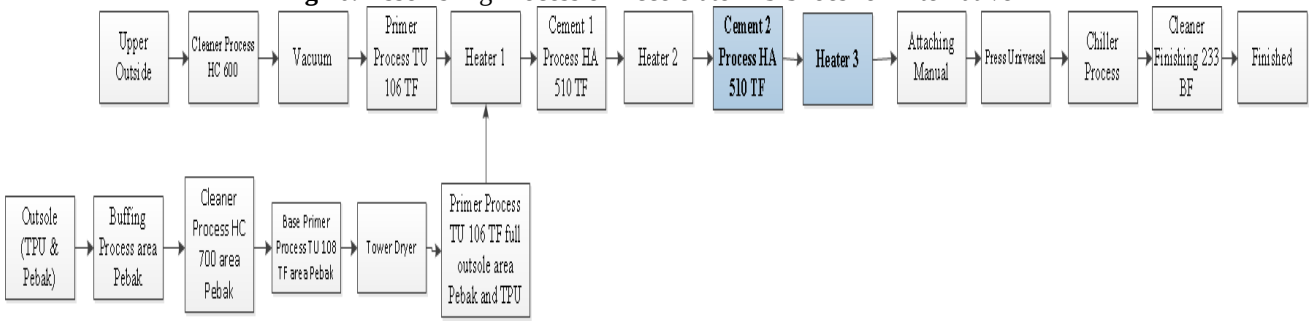

Fig 11. Assembling Process of Accelerator LS Shoes for Alternative 2

As for the two alternatives, a trial test was carried out on each Accelerator LS shoe article, namely articles 010, 011, and 012 where the trial was conducted in 2 trials before consistency of 3 pairs and consistency of 5 pairs. As for the two alternatives, a trial test was carried out on each Accelerator LS shoe article, namely articles 010, 011, and 012 where the trial was conducted in 2 trials before consistency of 3 pairs and consistency of 5 pairs. To find out the Anova from this trial results, will use software "Minitab" with method "Two Factorial Design".

Table 3. Data Result Trial of Improvement Process With Alternative 1 and Alternative 2

Alternative	Replication	Article		
		010 (Qty Released Test)	011 (Qty Released Test)	012 (Qty Released Test)
1	Before Consistency (3 Pairs)	3	3	3
	Consistency (5 Pairs)	5	5	5
2	Before Consistency (3 Pairs)	2	0	1
	Consistency (5 Pairs)	2	1	1

General Linear Model: Released versus Alternatif; Article

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Factor      Type   Levels  Values
Alternatif  fixed       2  1; 2
Article     fixed       3  10; 11; 12


Analysis of Variance for Released, using Adjusted SS for Tests

Source              DF  Seq SS  Adj SS  Adj MS      F      P
Alternatif           1  24,083  24,083  24,083  22,23  0,003
Article              2   1,167   1,167   0,583   0,54  0,609
Alternatif*Article   2   1,167   1,167   0,583   0,54  0,609
Error                6   6,500   6,500   1,083
Total               11  32,917
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Fig 12. Result of ANOVA Two Factorial Design

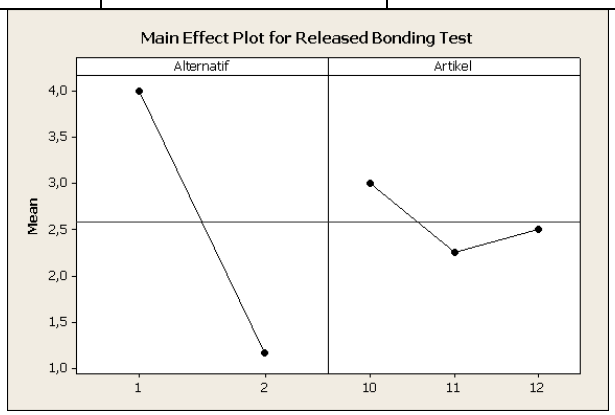

Fig 13. Main Effect Plot for Released Bonding Test

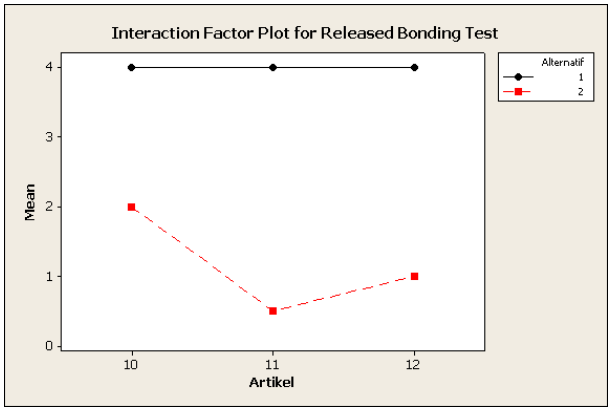

Fig 14. Interaction Plot for Released Bonding Test

Based on the results of the ANOVA in Figure 12, it can be concluded that:

- There is a significant influence from the alternatives used in the trial of the released bonding test where alternative 1 can be seen manually better than alternative 2.
- There is no significant influence from shoe articles on the released bonding test.
- There was no significant effect of the interaction between alternative factors with the article on the released bonding test.

E. Re-Structure of the Accelerator LS Product

Based on the analysis of the trial test data in Table 3 to determine the best process in minimizing the level of defect bonding test on the Accelerator LS shoes, it is known that alternative 1 is better than alternative 2 so that for the next season or order the product must be re-structured Accelerator LS by changing the outsole component of the TPU and Pebak it is only TPU. The re-structure of the product can be seen in Figure 15.

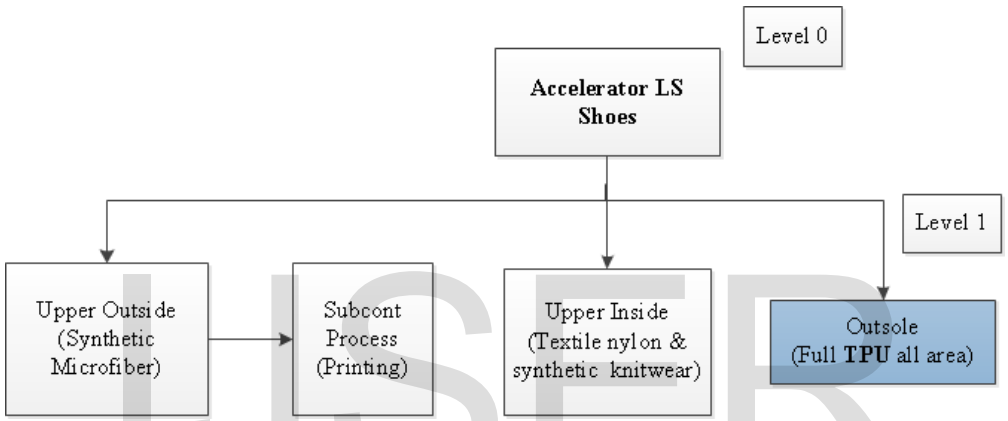

Fig 15. Re-Structure of the Accelerator LS Product

4. Conclusion and Suggestion

A. Conclusion

Based on the results of the process flow chart assembling analysis with experimental design analysis, the conclusions can be given as follows:

a. By using the "Two Stage Nested Design" experimental design method, it can be seen that article differences significantly influence poor bonding defect priming so that the biggest cause of bonding is due to inconsistent outsole material Pebak in each article especially for article 011.

b. By using the "Two Factorial Design" experimental design method, it can be seen that there are significant effects on the alternatives used to improve the poor process priming outsole where alternative 1 is better than alternative 2.

c. After finding out that alternative 1 is better than alternative 2, then the process is improved with and re-structured the product by replacing the outsole material which was initially TPU and Pebak becomes full TPU outsole so that the buffering process is not done once and primering process only one times.

B. Suggestion

Based on the results of the process flow chart assembling analysis with experimental design analysis, the suggestions that can be given are as follows:

a. The quality improvement process using experimental design analysis was carried out earlier when the product was still designed at the development stage so that potential defects in the product could be minimized as well as possible during mass production.

b. Control continuously the process improvements that have been made to the product to determine the consistency of the process and product.

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