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Quality And Productivity Analysis Of The Putty Dispenser In The Armature Balancing Process

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Abstract

An electric motor is a device that converts electrical energy into mechanical energy. One of its important components is the armature which functions as the center of movement. Armature is paired with another component of electric motor. In order to achieve a good quality of electric motor, armature quality must be controlled through a standard experiment called balancing test. An adhesive material called putty will be added into armature if the balancing test result is not up to standard. This study conducted in one of automotive industry in Indonesia. The company face a problem in balancing test process. Putty addition carried by factory workers only based on their estimation, resulting in the mass of putty used not in accordance with predetermined standards and also inconsistent, so that the balancing process takes a long time. This research offer a solution for the problem, i.e. putty dispenser to replace the manual putty-picking process with a standardized semi-automatic one. The research objective is to analyze the quality and productivity of the putty dispenser tool design in the armature balancing process. Through 100 armature samples consist of type A and type B, this study examines the quality of the putty mass provided using the most frequently occurring value and uses the independent T-test method to examine the hypothesis that there is a real difference in cycle time before and after the putty dispenser tool. Frame strength testing was also carried out using Solidworks software simulation with 632 N loading. The results of the research on the putty dispenser tool are that the frame used is proven safe, a decrease in cycle time with a percentage of 34.16%, an increase in productivity of 34.13%, also improved quality through the aspects of %NG reduction of 42.29%, and a standardized and constant putty mass of 100 mg for armature type A and 200 mg for armature type B.

Keywords:
Armature, balancing, putty, independent T-test, putty dispenser.

1 Introduction

An electric motor is a device that converts electrical energy into mechanical energy to produce motion. This motor consists of several important components that work synergistically to create rotation. One of the main components of an electric motor is the armature, which functions as the center of motion or a rotating shaft [1]. Before the armature is paired with other components, quality control must be performed through an experiment called the balancing test. The balancing test in the armature involves balancing the shaft rotation with the aim of minimizing vibration and noise in rotating objects [2], [3]. Balancing testsare conducted by reducing the centrifugal force by aligning the main axis of inertia with the geometric axis of rotation through the addition or removal of materials[4]–[6]. The material removed or added in the balancing test is called putty [7]–[9]. The balancing test in this research was conducted by placing the armature on the balancing machine test; if the armature balance value obtained on the right side and/or left side exceeds the set standard, a putty must be added so that the balance value is in accordance with the set standard. Putty has a ballast and adhesive composition that has been used since the 19th century [10].

This study was conducted in an automotive company located in Indonesia. The company faced a problem in that putty addition carried out by operators was performed based on their estimation. This condition resulted in putty mass, which was added to the armature according to the standardsset by the company. The operator estimating the putty size also affected the armature balancing test cycle time. This study offers a solution to industry problems related to the armature balancing process by designing and manufacturinga putty dispenser with a semi-automatic control using compressed air. The purpose of this study is to analyzeputty addition quality and productivity of putty dispensers as a solution tothe armature balancing test industrial case study.

The design of this tool will have a significant effect [11], [12] on the consistency of the putty mass given to the armature, so that these conditions can shorten the process of adding putty and improve the quality and productivity in the armature balancing process.

2 Research Methods/Materials and Methods

The research method consisted of problem identification, design processes, fabrication, and testing. The first method is problem identification, which is a process in which researchers identify the problem occurring in the balancing process. The design process was then conducted using Shigley’s method with a computer-aideddesign (CAD) tool using SoliWorks. The next step is design fabrication, which is conducted in Indonesia’s automotive industry. The last step is testing, where two kinds of armature are used: armature A and armature B.

2.1 Problem Identification

Ishikawa diagram [13], [14] was used to identify potential problem sources for problem identification. The fish heads in the Ishikawa diagram represent the main problem. Furthermore, the basic categories of Ishikawa diagrams were selected to analyze the problem: people, methods, materials, and machines. The main causes of the design process areselected from the indications of the potential causes of problems. This allowed further analysis to identify the source of the cause. The 5 Why method is used to determine the reason why the addition of putty mass to the armature is repeated. Until the question "why" is answered, certain corrective actions can be taken based on that answer.

After determining the root of the problem, corrective action is proposed to eliminate or reduce the source of the problem after the cause is identified in the form of making a putty dispenser. This tool adopts a medical dispenser that can dispense drugs or pills according to the prescription produced by the machine. After the machine diagnoses the patient's health problem, it gives instructions to the dispenser to dispense the appropriate medicine. The concept of this medical dispenser provides a number of benefits.First, it reduces human errors in calculating doses or giving the wrong medication.Second, medical dispensers can increase the efficiency and quality of health services [15]. Adopting the medical dispenser concept when dispensing drugs can offer a solution to the problem of manual putty taking based on operator estimates to semi-automatic with standardized and consistent mass through putty dispensers. The balanced armature isshown in Fig. 1.

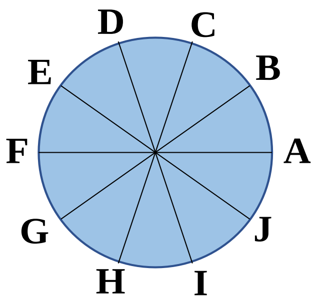

Fig. 1. The sides of the armature were balanced.

Fig. 1 shows the armature part where the putty was added. If the test value shows that the armature is not balanced at the B to C side, then putty will be added to the opposite side, which is the G to H side.

2.2 Design Process

The design was carried out using Shigley stages [16] to obtain the most appropriate design with structured steps. The process starts by identifying the need and making a decision on what to do about it. After several iterations, the process ends with a proposal to satisfy these requirements. Depending on the type of design task, multiple designs may be iterated from start to finish. We examine these steps in the overall process design in the following sub-sections [17].

The design process usually begins by identifying requirements. Because these needs may only be vague dissatisfaction, feelings of discomfort, or the feeling that something is wrong, acknowledging and expressing these needs is often a creative act. This is followed by the problem definition, namely, the process of determining the specifications of the object to be designed. Synthesis is the third step, which is carried out by connecting the system elements with the design concept that is owned. This is followed by an analysis and optimization of the design. An evaluation is then carried out and ends with the presentation stage. The final design of the tool is shown in Fig. 2.

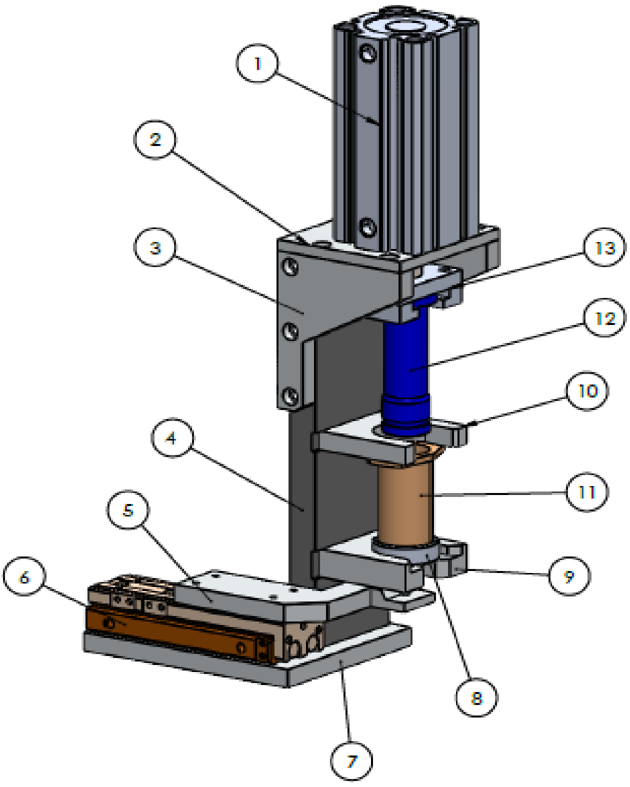

Fig. 2. Putty dispenser design.

Description of components of putty dispenser tool

1 Pneumatic cylinder (SSD2-ML-40-75-TOH)
2 Mount cylinder press
3 Guide cylinder lock
4 Stand jig
5 Load
6 Pneumatic cylinder (MXQ8-50-M9BL)
7 Base jig
8 Tube guide
9 Lower holder
10 Upper holder
11 Tube
12 Ejector
13 Guide ejector

2.3 Design Fabrication

The putty dispenser was manufactured byan automotive company using the following materials: (1) ASTM A36, which is used for the stand jig and base jig; (2) aluminum 5052 H32, which is the main material for its components in the cylinder press mount, tube holder, ejector guide, and cylinder lock guide; (3) nylon 101, which is used for the ejector; and (4) Polyphenylene Sulfide (PPS), which is used in the tube. The connection used in making the frame was a static nut and bolt connection.

2.4 Testing

Testing was conducted at an automotive company in Indonesia where the armature is being manufactured. There are two types of armatures:types A and B. Type A armature have bigger dimension than the type B armature. Type A armature have mass 92 mg balancing tolerance and type B armature have 102 mg mass balancing tolerance. Unfortunately the armature images cannot be published due to it’s confidentiality.

The data needed is data related to the balancing machine at the research location in the form of: (1) data cycle time balancing process for armature type A and armature type B before and after the putty dispenser, (2) data on the number of NG armature type A and armature type B before and after the putty dispenser and (3) putty mass test data given on type A and type B armatures.

3 Results and Discussion

3.1 Frame Strength Analysis

Strength analysis of the frame using Solidwork software was carried out on the part of the putty dispenser, which is considered critical because it directly supports the pressure exerted by the pneumatic cylinder and the load from the putty dispenser frame, namely, on the cylinder press mount part, bottom holder, and jig stand. The load applied to each part is a force (F) of 632 N, which comes from the maximum compressive capacity of the SSD2-ML-40-75-TOH cylinder and the mass of the putty dispenser frame.

3.1.1 Loading on Mount Cylinder Press

Fig.3shows the loading simulation ofthe cylinder press part mount. The loading results obtained with a maximum stress value of 17.206 N/mm^{2}under conditions that are still very safe when compared with the yield point of A5052 H32, which is 195 N/mm^2. The location of the maximum stress in the structure is shown in red in Fig. 3.

This simulation result is consistent with some studies [18], [19] where the A5052 H32 material proved to have very good corrosion resistance, formability, and ductility.

3.1.2 Loading on the Lower Holder

Fig. 4 shows the loading simulation of the lower part holder. The loading results obtained with a maximum stress value of 30.625 N/mm^2 in conditions that are still very safe when compared to the yield point of the A5052 H32 material, which is 195 N/mm^2.

This simulation result is also consistent with previous studies [20], [21]related to the A5052 H32 material, where the results showed that the A5052 H32 material had a higher bond strength.

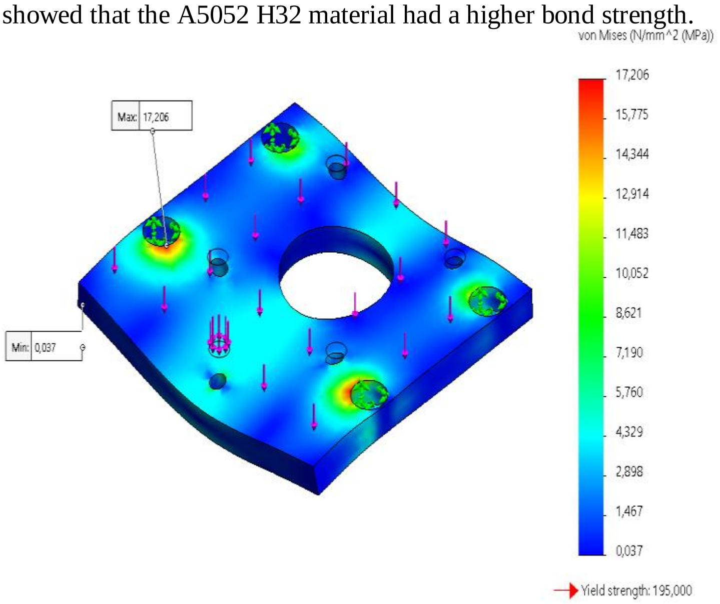

Fig. 3. Loading mount cylinder press.

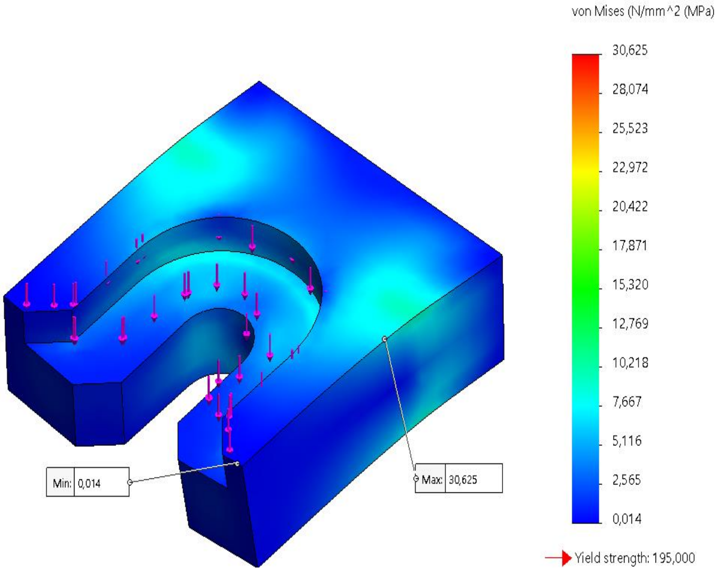

Fig. 4. Lower holder loading.

3.1.3 Loading on the Stand Jig

Fig. 5 shows the loading simulation of the stand jig part. Loading results were obtained with a maximum stress value of 4.795 N/mm^2. This condition is still very safe compared to the yield point of ASTM A36, which is 250,000 N/mm^2. During this loading, buckling also occurredat the center of the jig stand, which was where the maximum stress occurred. However, this is still within reasonable limits, because the loading that occurs is a static load rather than a shock load.

This simulation result is in line with another study [22] where a finite element method simulation was conducted between two materials, that is, ASTM A36 and JIS G3101. The study found that the ASTM A36 material exhibited better performance under static, dynamic, and shock loads.

3.2 Cycle Time and Productivity Analysis

Cycle time is the amount of time required to complete a task or process for making a product. The calculation of the cycle time makes it easy to identify the time required for the production process. This time can be used to determine a more efficient production method [23]. Data analysis was performed using the independent t-test. The choice of analysis of the independent t-test method was to scientifically identify the existence of a significant difference before and after the improvement in the putty dispenser tool. Table 1 shows the cycle time data analysis for armature type A and Table 2 shows the cycle time data analysis for armature type B.

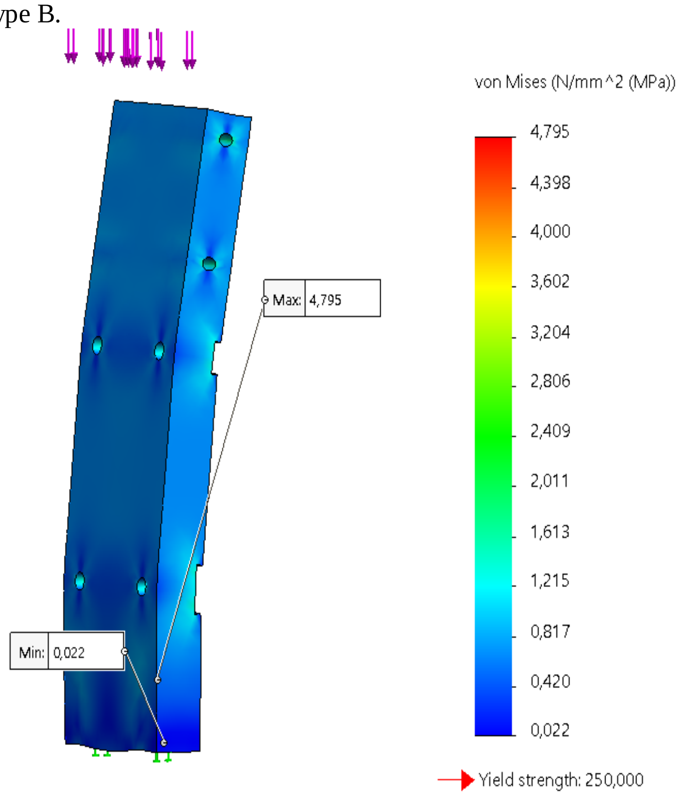

Fig. 5. Loading on the jig stand.

Table 1. Cycle time data analysis for type A armature

Variable	Before improvement value	After improvement value
Mean	52.37	33.41
Variance	0.83	1.42
Observations	49	49
Hypothesized mean difference	0	
df	90	
T Stat	88.32	
P (T<=) one-tail	1.56E-89	
T Critical one-tail	1.66	
P (T<=) two-tail	3.14E-89	
T Critical two-tail	1.98	

Table 2. Cycle time data analysis for type B armature

Variable	Before improvement value	After improvement value
Mean	52.47	35.6
Variance	1.71	0.92
Observations	49	49
Hypothesized mean difference	0	
df	88	
T Stat	72.89	
P (T<=) one-tail	9.058E-81	
T Critical one-tail	1.66	
P (T<=) two-tail	1.811E-80	
T Critical two-tail	1.98	

To test the significance of this time variable, an independent t-testwas used to determine the effect of differences in cycle time results on the armature balancing process before and after improvement using a 95% confidence level and a standard error value of 5% for t table n-1 (n = 49). This hypothesis was formulated as follows:

Ho: There is no significant difference in the cycle time of the armature balancing process before and after the putty dispenser.
Ha: There is a real difference in the cycle times of the armature balancing process before and after the putty dispenser.

With indications: If t count > t table, then Ho is rejected, meaning that it is significantly different, or if - t count < - t table, then Ho is rejected, meaning it is significantly different. The results of the t-testare shown in Fig. 6.

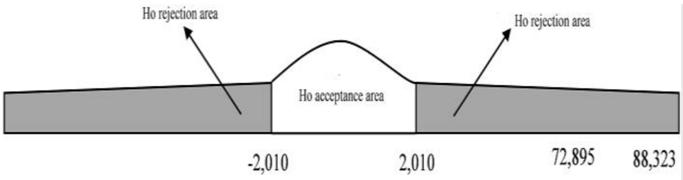

Fig. 6. Independent T-test curve for cycle time.

The results of the analysis show that t count > t table, so Ho is rejected and Ha is accepted, meaning the hypothesis that the putty dispenser affects the cycle time reduction of the armature balancing process. Fig. 7 shows the cycle time data for armature type A, and Fig. 8 shows the cycle time data for armature type B before and after the putty dispenser.

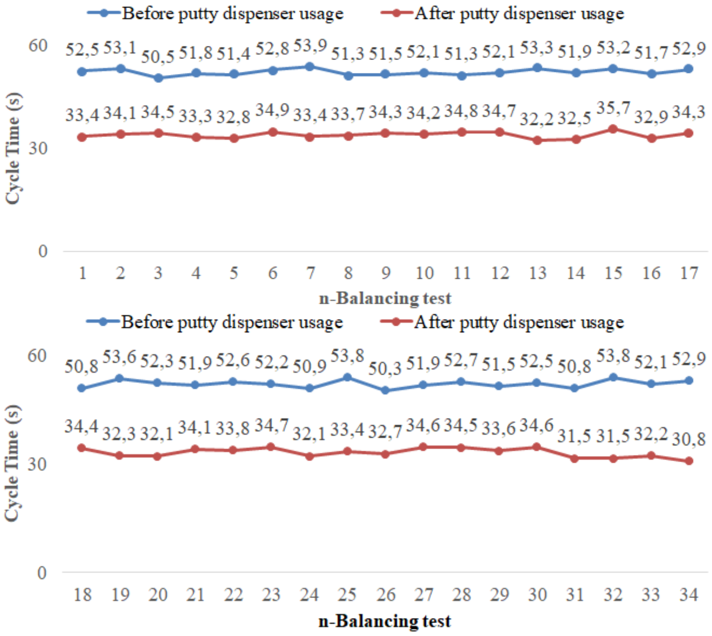

Fig. 7. Type A armature cycle time diagram.

Based on Fig. 7, the armature balancing process data cycle time for armature type A before improvement has an average cycle time of 52.37s and after improvement, the average cycle time value decreased to 33.41s. In Fig. 8, the armature balancing process data cycle time for armature type B before improvement has an average cycle time of 52.43s and after improvement, the average cycle time value decreased to 35.59s. Calculation of the percentage reduction in cycle time usingEq. 1– Eq. 3[24], CT before denotes the cycle time value before putty dispense usage, CT after denotes the cycle time value after putty dispense usage, and ΔCT denotes the cycle time percentage.

$$\text{CT before} = (52.37\text{ s} + 52.43\text{ s})/2 = 52.4\text{ s} \quad (1)$$

$$\text{CT after} = (33.41\text{ s} + 35.59\text{ s})/2 = 34.5\text{ s} \quad (2)$$

$$\Delta\text{CT}(\%) = \frac{52.4\text{s} - 34.5\text{s}}{52.4\text{s}} = 34.16\% \quad (3)$$

Based onthe cycle time analysis, it is known that the average cycle time before data is 52.4s ≈ 0.873 min, and the average cycle time after is 34.5s ≈ 0.575 min. The working time applied at the research location was 9 h a day with 1 hour rest time, so the production work time was 8 h a day. The results of the calculation of production capacity are as follows: production capacity before the putty dispenser, shown in Eq. 4– Eq. 5, where PC denotes the production capacity.

$$\text{PC} = \frac{\text{Production time work}}{\text{CT}} \quad (4)$$

$$\text{PC} = \frac{480}{0.873} = 550 \text{ pieces} \quad (5)$$

The production capacity after the putty dispenser, shown in Eq. 6.

$$\text{PC} = \frac{480}{0.575} = 835 \text{ pieces} \quad (6)$$

A process can be said to experience an increase in productivity, one of which is if input remains constant and output increases, so that the productivity increase can be calculated in the armature balancing process based on production capacity analysis based on Eq. 7– Eq. 8.

$$\%\text{Productivity} = \frac{\text{PCa} - \text{PCb}}{\text{PCa}} \times 100\% \quad (7)$$

$$\%\text{Productivity} = \frac{835 - 550}{835} \times 100\% = 34.13\% \quad (8)$$

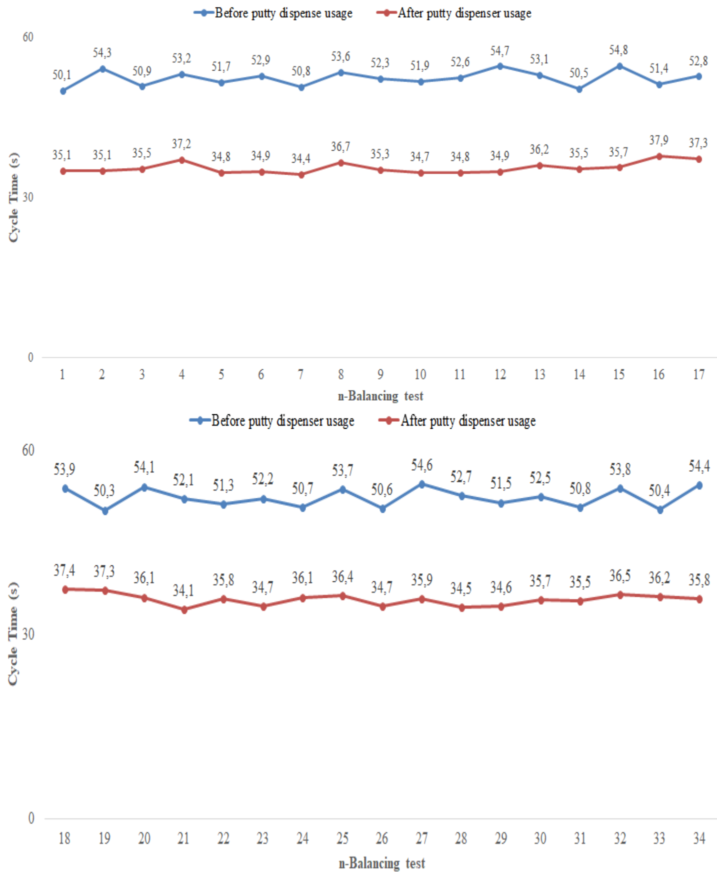

Fig. 8. Type B armature cycle time data.

3.3 Quality Analysis

Quality analysis is assessed based on two aspects: first, based on the number of repetitions (NG) performed when adding putty mass, in the sense that the fewer repetitions, the better the quality; second, based on a consistent and standard putty mass imparted to the armature. Based on the data of the armature balancing process, the %NG reduction can be calculated using Eq.9–10for armature type A, and Eq. 11-12 for armature type B.

$$\%\ \text{NG} = \frac{\text{NGb} - \text{NGa}}{\text{NGb}} \times 100\% \quad (9)$$

$$\%\ \text{NG} = \frac{17 - 12}{17} \times 100\% = 29.41\% \quad (10)$$

$$\% \text{ NG} = \frac{29-13}{29} \times 100\% = 55.17\% \qquad (11)$$

$$\% \text{ NG} = \frac{29.41+55.17}{2} = 42.29\% \qquad (12)$$

Before the putty mass improvement was carried out, it had not been standardized; therefore, during the process of creating the tool, the author collected data on the putty mass, which would be used as a quality standard in the operation of the putty dispenser tool. An analysis of the quality data for the type A armature is shown in Fig. 9, and for the type B armature is shown in Fig. 10.

Fig. 9. Diagram of the mass quality test for the TypeA putty armature.

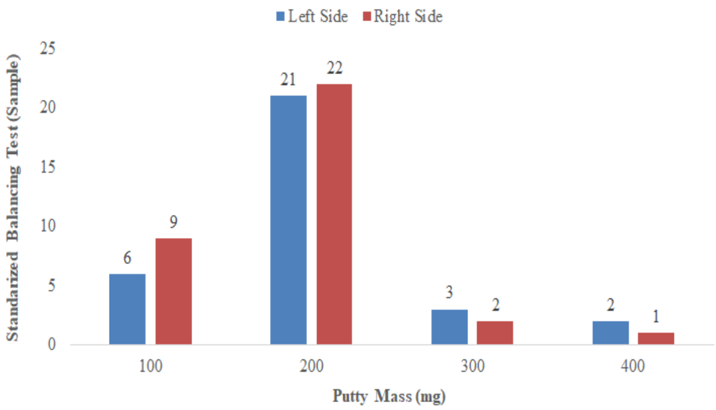

Fig. 10. Diagram of mass quality test for putty armature type B.

Based on the results of the analysis of the mass value of the putty that appears most often (mode), the final result is that the output quality standard for putty mass in the putty dispenser is 100 mg for armature type A and 200 mg for armature type B, with details of the imbalance values in Table 3.

Table 3. Parameters for giving putty based on the imbalance value

Unbalance value (mg)	Putty mass addition (mg)
102 – 170	100
171 – 239	200
240 – 301	300
302 – 401	400

4 Conclusion

This study aimed to analyze the putty addition quality and productivity of putty dispensers as a solution tothe armature balancing test industrial case study. The putty dispenser design and tool have been successfully applied in armature balancing tests as a quality control method for automotive companies. The research conducted has succeeded in creating a putty dispenser design and analyzing the influence of the tool on the armature balancing process. The frame used by the putty dispenser was proven to be safe by loading simulations carried out usingSolidworks software. Tests carried out 100 times consisting of armature type A and armature type B showed a decrease in cycle time before and after the presence of the tool with a percentage of 34.16% from 52.4s to 34.5s, an increase in productivity of 34.13%, and an increase in quality through the aspect of decreasing %NG by 42.29% and the standard and constant putty mass is 100 mg for armature type A and 200 mg for armature type B. This research result is consistent with that of a previous study [25], where cycle time optimization led to an increase in productivity.

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