Available online at: http://publikasi.mercubuana.ac.id/index.php/ijiem
IJIEM (Indonesian Journal of Industrial Engineering & Management)
ISSN (Print) : 2614-7327 ISSN (Online) : 2745-9063

Implementation of Measurement System Analysis to Reduce Measurement Process Failures on Part Reinf BK6

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ARTICLE INFORMATION

Article history:

Received: 27 April 2023
Revised: 30 May 2023
Accepted: 2 June 2023

Category: Research paper

Keywords:
ANOVA
Automotive part
MSA
Quality

DOI: 10.22441/ijiem.v4i2.20212

A B S T R A C T

This study aims to reduce the failure of the measurement process on Part Reinf BK6 in the automotive industry which prioritizes accuracy and precision in the process to maintain product quality and customer satisfaction. This study used the measurement system analysis (MSA) method to analyze the Gage R&R on a measurement system, with 2 operators and 10 parts measured with 3 repetitions. The MSA results before improvement showed a Total Gage R&R of 67.80% with a repeatability value of 0.98% and a reproducibility value of 66.82%. The result indicated that the measurement system needs to be improved because the Gage R&R is still above 30%. After improving the measurement process by adding the Go No Go pin as an additional tool, the MSA results show the Total Gage R&R value after the improvement is made to 10.11% with repeatability and reproducibility values of 10.11% and 0% respectively. Based on the results of the study, it can be concluded that the improvements made have a significant effect on the measurement system on Part Reinf BK6. This will improve accuracy and precision in the measurement process, maintain product quality, and increase customer satisfaction. Therefore, improving the measurement system is very important in the automotive industry.

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1. INTRODUCTION

In this global era, it is undeniable that every aspect of activity requires developments in industrial technology to deal with problems and production activity (Fu, 2022). The processing of an industrial material always uses sophisticated tools to speed up the process. With the development of science, knowledge in the field of industry will also increase, especially in the technology industry. In dealing with this, an effort is needed to improve human resources (HR) so that they can keep up with current developments (Chenoy et al., 2019; Pinthapataya, 2022). In addition, quality improvement based on customer demand is also a critical aspect of the manufacturing industry (Sumasto et al., 2022).

How to Cite: Sumasto, F., Nugroho, Y. A., Purwojatmiko, B. H., Wirandi, M., Imansuri, F., & Aisyah, S. (2023). Implementation of Measurement System Analysis to Reduce Measurement Process Failures on Part Reinf BK6. *IJIEM (Indonesian Journal of Industrial Engineering & Management)*, 4(2), 212-220. https://doi.org/10.22441/ijiem.v4i2.20212

In companies that produce automotive parts, an accurate measurement system is very important to ensure the quality of the products produced (Ming, 2016). Measurement errors can result in products that do not meet quality standards or can even endanger user safety. Measurement System Analysis (MSA) is a method for measuring the quality of a measurement system in quantitative measurement. MSA is used to ensure that the measurement system used can provide consistent and reliable measurement results. Therefore, MSA has become very important in the automotive industry to ensure that the measuring system used provides accurate and reliable results (Cepova et al., 2018; Wijanarko et al., 2022). In addition, MSA can also be used to evaluate and improve the measurement system used by companies to ensure the products produced meet established quality standards (Al-Refaie & Bata, 2010).

Several MSA methods that are commonly used include Gage R&R (Repeatability and Reproducibility), Linearity, Stability, and Bias (Al-Refaie & Bata, 2010; Jaiganesh et al., 2011; Saikaew, 2018; Setiawan & Rahardjo, 2013; Setyabudhi et al., 2021; Shao et al., 2019). These methods are used to evaluate the characteristics of measurement systems, such as accuracy, precision, and uniformity. In this study, the application of MSA using the ANOVA method is discussed in companies that produce automotive parts. This study is important because to guarantee product quality, optimizes production processes, reduces production costs and avoids rework, and increases customer trust. This study will explain the measurement system evaluation process that is carried out and how companies use the results of this evaluation to improve the measurement system used. The research will also discuss the benefits obtained by companies after implementing MSA.

2. LITERATURE REVIEW

The accuracy of the data collected and the systems used to collect it can be ensured by an efficient MSA process (Aslam & Bantan, 2020; Ferreira et al., 2021; Saikaew, 2018; Shao et al., 2019). In the manufacturing process, proper data processing can stop the wastage of time, labor, and scrap. Many customers of large manufacturing companies started complaining about materials that did not match what they received at their facilities. Some complaints or product failures such as components failing to lock in place or failing to bond properly to create a flat surface. Then parts were produced out of specification, according to process audits. Operators have the duty and responsibility to carry out inspections according to established standards or procedures and by using appropriate measuring instruments. But there are still problems such as the measurement resolution is not enough to find components that are not suitable when measurements are taken.

Several previous studies have discussed the use of the implementation of MSA in the automotive sector, tools or instruments, and engine assessment. In the automotive sector (Cepova et al., 2018), the perceived variation from the manufacturing process is too large, a measurement system study is needed to determine whether improvement efforts should be made in the measurement process. Measurement system analysis is primarily carried out according to the methods offered by the Chrysler reference guidelines. In this research, the chosen method is the range and average method and the Honest GRR study. From this study, it can be concluded that the total variability with the averaging and range method will not give a value of 100. Apart from the partial variability component information, there is also information available regarding the process signal attenuation, measuring system attenuation, ability to detect shifts of 3 standards deviation by subgroup n=10, and ability to track process improvement or weakness. In the case of the MSA and Honest GRR studies, there is a battle over being the market leader for measurement systems studies.

In the field of tools and instruments (Budiantono et al., 2016), the object of the research in files product for tools. The product was chosen because the product that is produced the most besides files, one of which is the product in the category of drills-type cutting tools. Analysis of variance (ANOVA) shows that the drills test block factor, inspector factor, and interaction factor have a significant influence on the measurement results, and inspector 1, inspector 2, and inspector 3 have different abilities in providing measurement results. This is because the measurement data obtained is not good. In addition, it is necessary to increase the inspector's ability to carry out measurement inspections. Based on research in the field of tools and instruments, the implementation of MSA is needed to increase the reliability of the process.

In the field of machine assessment (Saikaew, 2018), if the variation in the measurement system is relatively small compared to the variation in the process, then the measurement system is considered capable of meeting the set quality standards. The R method was used to monitor process variation and assess the variability of the measurement system for cast dimensions in the foundry. Method R was used for the first time to evaluate the reliability performance of three mini-CNC lathes by considering different machine variations in the production of the same part and measuring the part diameter with the same gauge and the same inspector for the process and product. However, quantitative evaluation using the ANOVA method and testing the component of the variance hypothesis will be required to determine the exact repeatability or reproducibility to identify the differences precisely. The results of the analysis of R diameter of machine parts for evaluating engine performance can use ANOVA. The results of ANOVA and hypothesis testing show that there is a statistically significant difference in performance between the three CNC lathes for different parts. Based on the results of ANOVA and hypothesis testing, there is a statistically significant interaction between spare parts and the machine, which indicates that the dimensions of the parts and the measurement results by the inspector are highly dependent on the performance of the machine. This leads to the suggestion that periodic engine maintenance and appropriate corrective action is necessary to ensure the quality of engine parts.

3. RESEARCH METHOD

The research object used in this research is one of the products produced from the production process in an automotive company, namely Part Reinf BK6. The data used in this study is primary data from the measurement results of Part Reinf BK6 obtained at the Quality Control department of PT Takagi Sari Multi Prima. Measurements were carried out by two inspectors using a caliper to measure 10 parts with 3 replications. The parts to be measured are the hole dimensions totaling 4 points (Fig. 1).

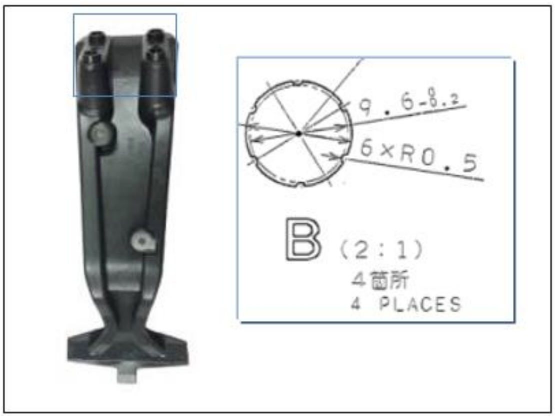

Fig. 1. Part Reinf BK6

The data that has been collected will be analyzed using MSA Type I and MSA Type II to evaluate the characteristics of the measurement system. The data that has been collected is processed and analyzed using Minitab® software (Huda & Islahudin, 2021; Mohamed & Davahran, 2006). Minitab® data processing with Gage R&R (Crossed) using ANOVA as the method of analysis. This analysis will include evaluating the variability of the measurement system, including repetitive and reproducible measurements, bias, linearity, and stability. The results of the analysis will be interpreted to determine whether the measurement system used can meet the set quality standards. If the measurement system does not meet the established quality standards, further evaluation will be carried out to determine the source of the error and the necessary corrective action. Assessment of the system is carried out by looking at the size of the GRR. The resulting Gage R&R percentage is used as a basis for accepting decision results from a measurement system. Guidelines for making decisions can be seen in Table 1.

Table 1. Border value of % GRR and NDC (Cepova et al., 2018; Down et al., 2010)

Value	Remarks
%GRR < 10%	Acceptable measuring system. The measuring system provides reliable information about process

	changes.
10% < %GRR < 30%	Conditionally acceptable measurement system. It can be used for several applications.
%GRR > 30%	Unacceptable measurement system. The measuring system does not provide reliable information about process changes.
ndc ≥ 5	Acceptable measuring system. The measuring system provides reliable information about process changes.
2 ≤ ndc ≤ 4	Generally unacceptable for estimating process parameters and indices since it only provides coarse estimates. Rejected measurement equipment - more sensitive equipment needs to be used.
ndc = 1	Unacceptable measurement system. The measuring system does not provide reliable information about process changes.

4. RESULT AND DISCUSSION

4.1. Analysis of Variance (ANOVA)

Analysis of variance is used to calculate the R&R gage value and find out the difference in the mean (average) of the two factors tested, namely the Part Reinf BK6 factor and the inspector factor whether it influences the dimensional measurement results. In the study, there were two operators and 10 types of parts with three replications (Table 2). Table 3 shows the results of the Two-Way ANOVA to find out the difference between the two factors, namely the inspector factor and the Part Reinf BK6 factor. In the study, there were two inspectors and 10 types of parts with three replications.

Table 2. Measurement data of 2 operators in 3 replications

Part	Operator 1			Operator 2		
	Rep-1	Rep-2	Rep-3	Rep-1	Rep-2	Rep-3
1	9.530	9.550	9.540	9.560	9.570	9.570
2	9.550	9.550	9.550	9.450	9.450	9.440
3	9.570	9.570	9.560	9.360	9.360	9.380
4	9.540	9.540	9.530	9.400	9.390	9.390
5	9.520	9.530	9.530	9.540	9.540	9.530
6	9.320	9.320	9.350	9.320	9.320	9.350
7	9.390	9.390	9.370	9.420	9.400	9.400
8	9.350	9.350	9.370	9.340	9.340	9.350
9	9.420	9.400	9.400	9.350	9.350	9.340
10	9.340	9.340	9.350	9.540	9.540	9.530

Table 3. The result of ANOVA

Source	DF	SS	MS	F
Parts	9	0.313307	0.0348119	1.959
Operators	1	0.010667	0.0106667	0.600
Parts * Operators	9	0.159933	0.0177704	205.043
Repeatability	40	0.003467	0.0000867	
Total	59	0.487373		

The F_0 value for the parts factor is 1,959 which is smaller than the F(0.05;9;40) value of 2.12, so it can be concluded that there is no effect of the parts on the parts measurement results. The F_0 value on the operator factor is 0.600 which is smaller than the F(0.05;1;40) value of 4.08, it can be concluded that there is no influence from the operator on the parts measurement results. The F_0 value on the interaction factor between parts and operators is 205,043 which is greater than the F(0.05;9;40) value of 2.12, it can be concluded that the interaction between parts and operators has a different effect on the measurement results. In two-way ANOVA, it explains that there are error assumptions that must be met, namely the assumptions are identical, independent, and normally distributed.

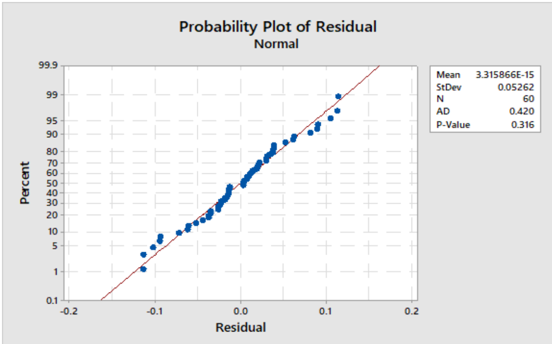

Fig. 2. Normal probability plot residual of measurement results

Fig. 2 shows the normal probability plot where the residuals do not spread and follow a straight line using the Anderson-Darling test with an AD value of 0.420 and a P-value > 0.05. Based on this, it can be concluded that normally distributed residuals can be fulfilled. Judging from the plot versus order (Fig. 3.), the residual points appear to be spread out so that it can be concluded that the independent residuals are met. In addition, identical residuals are also fulfilled based on the results of plots versus distributed fits (Fig. 4). Based on the results of the error assumption obtained, the data can be further analyzed using the gage R&R method.

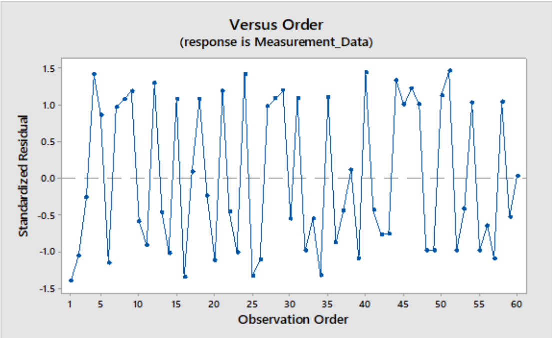

Fig. 3. Plot versus order of measurement results

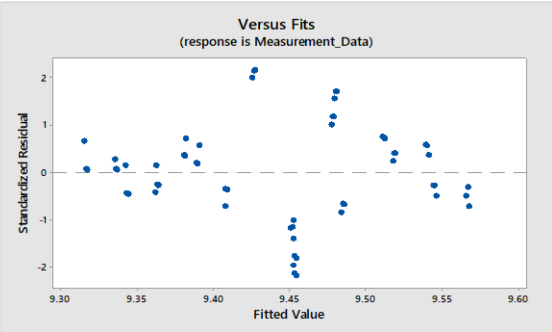

Fig. 4. Plot versus Fitted value from measurement results

4.2. Measurement System Analysis (MSA)

MSA is used to be able to validate a system, whether the measurement system has been able to measure consistently and accurately. MSA results can also show whether each factor affects on the measurement results. MSA can be analyzed using two measurement system approaches, namely MSA Type I and MSA Type II.

1) MSA Type I

Table 4 shows that the value of Cg is 0.86 and Cgk is 0.28 for the observational variables. The tolerance value that is affected by variations in the measurement system can be seen from the Cg value, while the tolerance value is influenced by the measurement system and can be seen from the Cgk value. These two indexes of ability are less than the commonly used benchmark value, which is 1.33, so it can be concluded that the measurement system is inadequate and needs to be improved.

Table 4. Gage R&R type I

	Part Reinf BK6
Cg	0.86
Cgk	0.28
%Var (Repeatability)	5.8%
%Var (Repeatability and Bias)	18.02%
(P-value)	0.000
Tolerance (BK6)	94
Reference (BK6)	96

2) MSA Type II

MSA type II is used to estimate the process variation caused by the measuring system. This analysis provides a comparison value between the variation of the measurement system with the total process variation. ANOVA is used in MSA type II to make decisions about whether or not a measurement system condition is acceptable. Table 5 shows the variation component value of 67.80%. The total R&R gage value is greater than 9% and greater than 30%, so it can be concluded that the measurement system is unacceptable. In addition, seen from the repeatability and reproducibility variance component values of 0.98% and 66.82%, respectively. This explains that the error variance of the measurement results caused by the measuring instrument contributed 0.98% and the error variance caused by the operator and interaction was 66.82%. A number of distinct categories value of 1 is also obtained where the value is less than 5, so it can be said that the measurement system used is unacceptable.

Table 5. Gage R&R type II

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0059812	67.80

Repeatability	0.0000867	0.98
Reproducibility	0.0058946	66.82
Operators	0.0000000	0.00
Operators*Parts	0.0058946	66.82
Part-To-Part	0.0028402	32.20
Total Variation	0.0088215	100.00

Number of Distinct Categories = 1

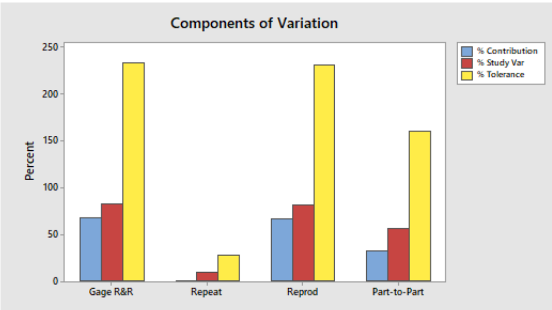

Fig. 5. Gage R&R graph of component variations

Figure 5 shows a visual representation of the gage R&R analysis results. The measurement system is said to be good if the largest component of the variation is part to part and vice versa, the measurement system needs to be improved. Visually, the measurement system needs to be improved, which shows the high "% contribution" of the R&R gage variance. This is due to the large variation of repeatability and reproducibility variances. In addition, the part to part “% study variance” is also high, so it can be concluded that the measurement system is unacceptable.

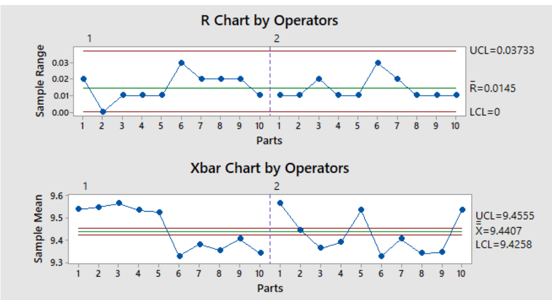

Fig. 6. R chart and Xbar chart of operators

Based on Fig. 6 it is known that the R chart where the plots between operator 1 and operator 2 have different patterns. This indicates that the operator produces a large measurement variance. Based on the Xbar chart, the graph obtained from the mean of each Part Reinf BK6 measurement result and the center line is the overall average for all Part Reinf BK6. The large number of plots that are outside the control limits illustrates that the reproducibility value (operators and interactions) gives a large variance value (Fig. 7).

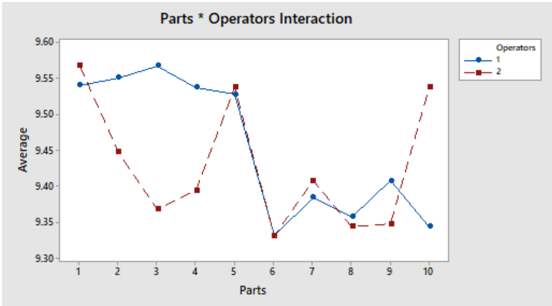

Fig. 7. Graph of interaction between part and operator

4.3. Improvement

Based on the results that have been obtained from the MSA method, improvements can be made by making changes to the inspection standard data for the measurement process and adding standard checkpoints using a go no go pin jig to make it easier for the operator to check the hole area (Figure 8.). Naming Go or No Go is to indicate the measurement results of the tool using a comparison tool. Where is the meaning of the word "GO" if the measurement results show that the dimensions of the object are within the tolerance area, the product is said to have met the standard (GO), whereas if the measurement results are outside the tolerance limit, it means not good or (NO GO). In a check of Part Reinf BK6 has been added using the “Go No Go” pin.

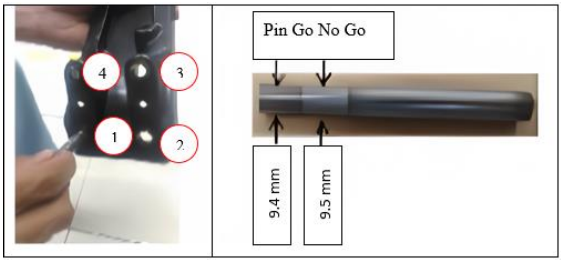

Fig. 8. Standard checkpoint Pin Go No Go

4.4. Analysis of Improvement Results

The results of improvements are measured to determine the level of success and results of the improvements that have been made. Total gage R&R compared before and after a process improvement. Based on the results of observations after improvement, measurement data was obtained using the Go no Go pin by two operators with ten Part Reinf BK6 and three replications were carried out (Table 6.). MSA Type II analysis was performed using Two-Way ANOVA and yielded a total R&R gage of 10.11% with repeatability and reproducibility of 10.11% and 0%, respectively (Table 7).

Table 6. Measurement data for 2 operators in 3 times of replication after improvement

Part	Operator 1			Operator 2		
	Rep-1	Rep-2	Rep-3	Rep-1	Rep-2	Rep-3
1	9.500	9.500	9.500	9.500	9.500	9.500
2	9.500	9.400	9.400	9.400	9.400	9.400
3	9.500	9.500	9.500	9.500	9.500	9.500
4	9.500	9.500	9.500	9.500	9.500	9.500
5	9.500	9.500	9.500	9.500	9.500	9.500
6	9.500	9.500	9.500	9.500	9.500	9.500
7	9.400	9.400	9.400	9.400	9.400	9.400
8	9.500	9.500	9.500	9.500	9.500	9.500
9	9.500	9.500	9.500	9.500	9.500	9.500
10	9.500	9.500	9.500	9.500	9.500	9.500

Table 7. Gage R&R type II

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0001667	10.11
Repeatability	0.0001667	10.11
Reproducibility	0	0
Operators	0	0
Operators*Parts	0.0014815	89.89
Part-To-Part	0.0016481	100
Total Variation	0.0001667	10.11
Number of Distinct Categories = 4		

The total R&R gage value is greater than 9% but less than 30%, so it can be concluded that the measurement system may be acceptable based on the gage cost. In addition, judging from the repeatability and reproducibility variance component values of 10.11% and 0%, respectively. This explains that the error variance of the measurement results caused by the measuring instrument contributes 10.11% and the error variance caused by the operator and interaction is 0%. A number of distinct categories value of 4 was also obtained where the value was less than 5, so that it can be said that the measurement system carried out still has deficiencies, namely it cannot detect differences between several parts. However, increasing the precision of the measurer increases the value of the number of distinct categories.

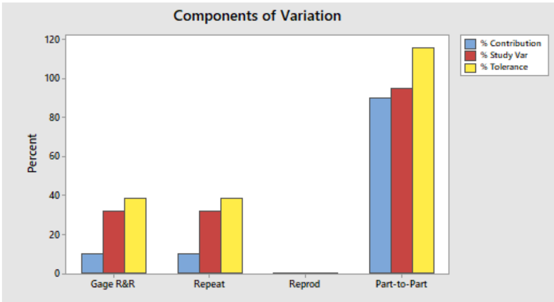

Fig. 9. Gage R&R graph of component variation after improvement

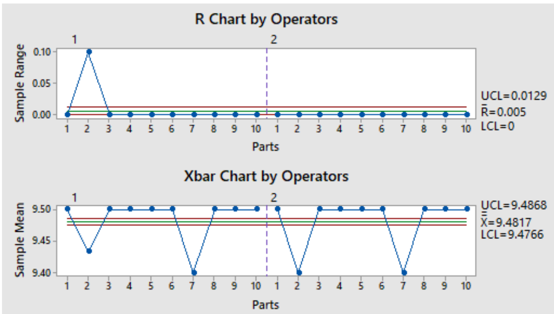

Fig. 10. R chart and Xbar chart of operators after improvement

Based on the visual description of the R&R gage analysis results (Fig. 9.). The improvement result measurement system can be said to be good because the components of the variation are part to part. Based on Figure 10, it is known that the R chart where the plots between operator 1 and operator 2 have almost the same pattern. This indicates that the operator produces a relatively low measurement variance. Based on the Xbar chart, the graph obtained from the mean of each Part Reinf BK6 measurement result and the center line is the overall average for all Part Reinf BK6. The large number of plots that are outside the control limits illustrates that the process is still not good even though overall the improvement results have had a significant impact as seen from the aligned interaction graph (Fig. 11.). To improve a good measurement system, action is needed to stabilize the process by scheduling calibration from the Go no Go pin and making continuous improvements.

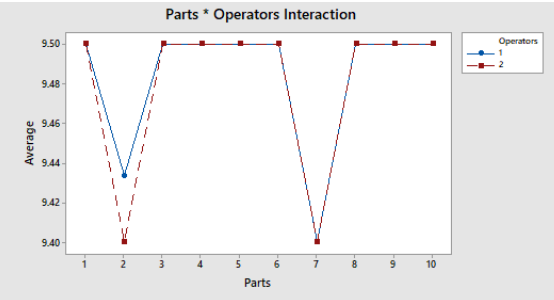

Fig. 11. Graph of Interaction after improvement

5. CONCLUSION

This study proposes the use of MSA to evaluate the performance of measurements on Parf Reinf BK6 which were randomly selected from operator performance for 10 parts which were measured with 3 replications. The MSA results from the GR&R study on the process before improvement obtained a Total Gage R&R of 67.80% with a repeatability value of 0.98% and a reproducibility value of 66.82%. These results indicate that the measurement system must receive improved treatment because the Gage R&R value is still above 30%. Improvement of the measurement system is carried out by improving the measurement process by adding a tool in the form of a Go No Go pin. The results of the improvement show that the Total Gage R&R value after improvement is 10.11% with a repeatability value of 10.11% and a reproducibility value of 0%. Based on the improved results, there was a decrease in the Total Gage R&R value of 57.69% and the Gage R&R value was below 30% although it was still not below 10%. Based on this, it can be concluded that the improvements made have a significant impact on improving the measurement system on Part Reinf BK6. This research was conducted by directly focusing on related objects. For further research, it is expected to be able to analyze the urgency of the risks or impacts that arise first so that they can have an impact on the system of an industry.

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