Analysis the measurement quality system of clearence tappet using measurement system analysis on motorcycle manufacturing company

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Abstract. A motorcycle manufacturing company on the K56S engine has a symptom that often occurs called noise tappet. The observations found that Symptom was caused by clearence or tappet gap that was not in accordance with the specified specifications. The gap measurement system uses filller which usually relies on the experience and feeling of the operator, so it is possible to produce an unsuitable gap measurement . This research will evaluate the measurement system of clearence tappet using Measurement system analysis (MSA) which includes stability, bias, linearity, repeatability & reproducibility. Based on data processing known that the measurement system has a stable process with a linearity level of 2.6% is acceptable. The measurement system has a biased problem with an average bias value of 0.054 mm (not acceptable) and from repeatability & reproducibility with a GRR% of ANOVA method of 49.98% that exceeds the acceptance criteria.
Keywords : Measurement System Analysis, Gage R&R, stability, Linearity, Bias

1. Introduction

Companies engaged in the motorcycle industry in Indonesia, especially in the motor sport engine type K56S, there is a symptom which is one of the causes of the most defects, namely noise tappet. Tappet noise is a symptom in the form of abnormal sounds coming from the inside of the machine which is detected at the firing station. According to previous research, the problem was due to the improper tappet setting and improper measures taken while setting the tappets on sub-assembly and main assembly stations [1]. Based on Symptom's observations, this is caused by clearence or tappet gaps that do not meet specified specifications. Clearence tappet is a gap between the rocker arm and the shim tappet and is a very small gap with a width of 0.14 mm - 0.27 mm. The gap measurement system uses a filler which tends to rely on the experience and feeling of the operator so that it is possible to produce a gap measurement that is not appropriate. Inaccurate and precise measurement of gaps causes the appearance of tappet noise and engine leaking symptoms that greatly affect the quality of the engine or product. Symptom noise tappet can cause engine noise [1]. This research was conducted to measure the accuracy of the measurement system and how to improve the accuracy and precision of the tappet clearence measurement system using Measurement system analysis (MSA), where with this method obtained the measurement system's accuracy level, the feasibility of the measurement system and other factors affecting the measurement system , which includes stability, bias, linearity, repeatability and reproducibility [2], [3], [4], [5], [6], [7], [8]. ISO / TS 16949 certification represents the

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essence of automotive quality system standards in all countries. Measurement System Analysis (MSA) is one of the five tools used in ISO / TS 16949 in addition to Advanced Product Quality Planning (APQP); Production Parts Approval Process (PPAP); Failure Mode and Effects Analysis (FMEA); and Statistical Process Control (SPC) [5], [9].

2. Method and materials

Measurement system analysis (MSA) identifies the components of variations in measurement. The purpose of MSA is to ensure that the measurement variance is relatively much smaller than the observed variance. MSA is an important prerequisite for data analysis. This is because inaccurate and / or precise measurement systems can cause wrong decisions [2], [10], [6], [11], [12]

2.1 Stability

Stability is the variation of the total measurements obtained with the measurement system on the same master or section when measuring a single characteristic over a certain time period. That is, stability is a change in bias over time.

Measurement analysis for process stability begins with measuring parts measured periodically (daily) then the measurement results are processed and an X chart & R control chart is formed. If there are no measurement results that come out of the upper or lower limit then it can be said that the measurement is stable. [2], [5], [12], [13], [14], [15], [16]. Making an $\bar{X}$ chart using the formula:

$$UCL = \bar{\bar{X}} + (A_2 * \bar{R}) \quad (1)$$

$$LCL = \bar{\bar{X}} - (A_2 * \bar{R}) \quad (2)$$

Making an R chart using the formula:

$$UCL = D_4 * \bar{R} \quad (3)$$

$$LCL = D_3 * \bar{R} \quad (4)$$

2.2 Bias

Bias is the difference between the reference value and the average of measurement observations on the same characteristics and parts. To determine whether the bias can be accepted using the hypothesis test H0 : bias = 0 and H1 : bias ≠ 0 and the formula used is as follows ; [2], [5], [14], [16].

$$bias_i = x_i - reference\ value \quad (5)$$

$$\overline{bias} = \frac{\sum_{i=1}^{n} bias_i}{n} \quad (6)$$

$$\sigma_r = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1} \quad (7)$$

$$t_{bias} = \frac{\overline{bias}}{\sigma_b} \quad (8)$$

2.3 Linearity

The difference in bias over the expected operating (measurement) range of equipment is called linearity. The acceptance criteria for linearity were tested using graphical analysis and numerical analysis [2], [10], [11]. Making linearity charts using the formula:

$$\bar{y}_i = ax_i + b \quad (9)$$

$$a = \frac{\sum xy - \left(\frac{1}{gm}\right)\sum x \sum y}{\sum x^2 - \frac{1}{gm}(\sum x)^2} \quad (10)$$

$$b = \bar{y} - a\bar{x} \quad (11)$$

Numerical analysis can be done by testing the hypothesis H_0 :a = 0, H_1 :a ≠ 0 and H_0 :b = 0, H_1 :b ≠ 0 by testing using the formula:

$$t_a = \frac{|a|}{\left[\frac{s}{\sqrt{\sum (x_j - x)^2}}\right]} \leq t_{gm-2,1-\frac{\alpha}{2}} \quad (12)$$

$$t_b = \frac{|b|}{\left[\sqrt{\frac{1}{gm} + \frac{x^2}{\sum (x_i - x)^2}}\right] s} \leq t_{gm-2,1-\frac{\alpha}{2}} \quad (13)$$

2.4 ***Repeatability & Reproducibility***

Repeatability is a variation in measurements obtained from a measurement tool when used several times by an appraiser on measuring a characteristic on the same part. Reproducibility is defined as a variation on the average of measurements made by different appraisers using the same measuring instrument when measuring a characteristic on the same part. The results of the analysis of the combination of the level of repeatability and reproducibility of a measurement system are expressed in percentage of Gage Repeatability & Reproducibility (% GRR) [2], [4], [6], [7], [8], [10], [11], [14], [15], [16]. There are several methods in analyzing the GRR of the measurement system, namely the range method, average & range method and the ANOVA method ANOVA method using the Minitab program in processing data [13]. The range method uses the formula:

$$\bar{R} = \frac{\sum R_i}{n} \quad (14)$$

$$S = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1} \quad (15)$$

$$GRR = \frac{\bar{R}}{d_2} \quad (16)$$

$$\%GRR = 100\ x \left(\frac{GRR}{S}\right) \quad (17)$$

The Average & Range Method uses the formula:

$$\bar{X}_{DIFF} = \max \bar{X}_i - \min \bar{X}_i \quad (18)$$

$$K_1 = \frac{1}{d_2} \quad (19)$$

$$EV = \bar{\bar{R}}\ x\ K_1 \quad (20)$$

$$K_2 = \frac{1}{d_2} \quad (21)$$

$$AV = \sqrt{(\bar{X}_{DIFF}\ x\ K_2)^2 - \left(\frac{EV^2}{nr}\right)} \quad (22)$$

$$GRR = \sqrt{(EV)^2 + (AV)^2} \quad (23)$$

$$R_p = Min(Part\ Average) - Max(Part\ Average) \quad (24)$$

$$K_3 = \frac{1}{d_2} \quad (25)$$

$$PV = R_p \; x \; K_3 \quad (26)$$
$$TV = \sqrt{(GGR)^2 + (PV)^2} \quad (27)$$
$$\%PV = 100 \; x \left(\frac{PV}{TV}\right) \quad (28)$$
$$\%AV = 100 \; x \left(\frac{AV}{TV}\right) \quad (29)$$
$$\%EV = 100 \; x \left(\frac{EV}{TV}\right) \quad (30)$$
$$\%GGR = 100 \; x \left(\frac{GGR}{TV}\right) \quad (31)$$

3. Results and discussion

3.1 Stability Analysis & Acceptance

Measurement analysis for the stability of the process begins by measuring parts that are measured periodically then the measurement results are processed and formed $\bar{X}$ & R chart.

Table 1. Stability Study Data

Appraiser A	Trial (*Reference value* = 0,163 mm)					$\bar{X}$	Range
Trial Date	1	2	3	4	5		
5/9/2017	0,16	0,16	0,17	0,16	0,16		
7/9/2017	0,15	0,17	0,16	0,17	0,16		
12/9/2017	0,17	0,16	0,16	0,16	0,16		
14/9/2017	0,16	0,16	0,17	0,16	0,17		
19/9/2017	0,15	0,16	0,16	0,16	0,17		
			$\bar{\bar{X}}$ & [illegible]				

Table 2. Bias Study Data

No	Data (X_i)	Bias	$(x_i - \bar{x})^2$	No	Data (X_i)	Bias	$(x_i - \bar{x})^2$
1	0,16	0,003	0,000009	9	0,16	0,003	0,000009
2	0,15	0,013	0,000169	10	0,16	0,003	0,000009
3	0,17	0,007	0,000049	11	0,17	0,007	0,000049
4	0,16	0,003	0,000009	12	0,16	0,003	0,000009
5	0,15	0,013	0,000169	13	0,16	0,003	0,000009
6	0,16	0,003	0,000009	14	0,17	0,007	0,000049
7	0,17	0,007	0,000049	15	0,16	0,003	0,000009
8	0,16	0,003	0,000009		Mean	0,0054	0,000615

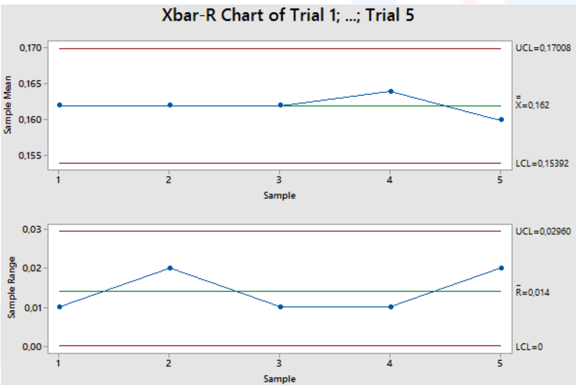

Figure 1. $\bar{X}$ & R *chart*

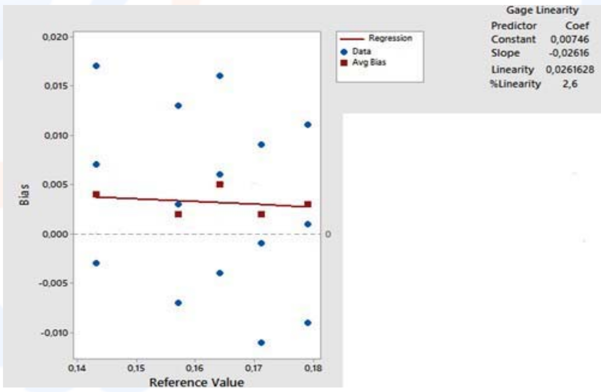

Figure 2. Grafik *Linearity*

Table 3. Range Method Study Data

Part	*Appraiser A*	*Appraiser B*	Range (A,B)
1	0,17	0,17	0
2	0,14	0,15	0,01
3	0,16	0,18	0,02
4	0,16	0,16	0
5	0,16	0,15	0,01

Table 4. Linearity Study Data

	Part	**1**	**2**	**3**	**4**	**5**
	Reference value	**0,143**	**0,157**	**0,164**	**0,171**	**0,179**
TRIAL	1	0,15	0,16	0,18	0,18	0,18
	2	0,15	0,16	0,17	0,17	0,19
	3	0,15	0,16	0,17	0,17	0,18
	4	0,14	0,15	0,16	0,17	0,18
	5	0,14	0,17	0,16	0,18	0,18
	6	0,14	0,16	0,18	0,16	0,19
	7	0,15	0,15	0,16	0,18	0,18
	8	0,15	0,16	0,17	0,18	0,19
	9	0,14	0,17	0,17	0,17	0,18
	10	0,16	0,15	0,17	0,17	0,17

From the control chart there is no point that comes out of the upper or lower control lines on the $\bar{X}$ & R chart. Therefore it can be concluded that the measurement system observed is statistically stable and acceptable [2]

3.2 Bias Analysis & Acceptance

From the calculation results obtained t_{bias} of 476.0935626 and t_{table} of 1.761, then obtained t_{bias}> t_{table} (476.0935626> 1.761) and produce conclusions H0 is rejected and H1 is accepted. From the results of the hypothesis test it can be concluded that the measurement system with a 95% confidence interval ($\alpha = 0.05$) the bias created by the measurement system measurement results is not equal to zero or in other words the bias created cannot be tolerated and does not pass the t_{test}. It is also known that the measurement system produces an average deviation or bias of 0.0054 mm from the reference value.

3.3 Linearity Analysis & Acceptanc

From Figure 2 above it is known that the linearity percentage of 2.6 is almost parallel to the bias line = 0. This shows the linearity size of 2.6% has a very minimal linearity of the entire process variation. So that it can be said based on graphical analysis considered acceptable. Based on numerical analysis with the hypothesis, t_a value is smaller than t_{table} ($0.1242 \leq 2.0106$) so H0 : a = 0 is accepted, so the tappet clearence measurement system is considered acceptable in terms of linearity and can be said to have the same bias for all reference values . To strengthen linearity acceptance, further hypothesis testing is also performed by testing t_b. From the calculation of nilait_b of 0.0444583 and t_{table} value of 2.0106. The value of t_b is smaller than t_{table} ($0.0444583 \leq 2.0106$) then H0 (b = 0) is accepted. The results of testing the hypothesis reinforce that the tappet clearence measurement system has minimal linearity and is said to be acceptable in the linearity study test.

3.4 Repeatability & Reproducibility Analysis & Acceptance

3.4.1 Range Method

Based on the calculation of% GRR using the Range Method, obtained% GRR of 59.3%. Based on the criteria made by the Automotive Industry Action Group (AIAG), the value exceeds 30% and enters the third criterion, which means the measurement system is deemed unfit for use. Efforts are needed to improve the measurement system.

3.4.2 Average & Range Method

Based on calculations obtained% GGR of 51.0165% with the breakdown percentage repeatability (% EV) of 35.442% and the percentage of reproducibility (% AV) of 36.7%. Repeatability represents variance in measurements when the same operator measures the same part several times, while reproducibility represents variance in a measurement when different operators measure the same part. The value of% GGR obtained exceeds 30% which means that according to the Automotive Industry Action Group (AIAG) the measurement system is considered unfit for use and an increase is needed to improve the measurement system.

3.4.3 ANOVA *Method*

Based on the analysis conducted using the ANOVA method it is known that the p-value of PartNum is 0.001. This value is smaller than the alpha value of 0.05, so it can be concluded that the differences between parts significantly influence the measurement results, which is good because in this study the parts used are different parts that represent variations in the process. The p-value of the operator is 0.009 which is also below 0.05, so the difference in the operator's measurement has a significant effect on the measurement results of the clearence tappet. This means that different operators will produce different measurement results. Whereas in PartNum * Operator, the p-value is 0.662 which means that the interaction between part and operator does not significantly influence the measurement results.

Based on Table 5 it is known that repeatability and reproducibility cause deviations up to 0.0091793 mm (almost reaching 0.01 mm). This value is very high, considering the tappet clearence measurement is in the range of 0.14 mm to 0.18 mm. For example, measurements were taken with a yield of 0.16 mm. With such a level of deviation, it is possible to create incorrect measurement results, with the possibility that the actual results are above or below 0.1 mm from the actual results.

From the above results it is concluded that the measurement system is not feasible to use because it has a% GRR value of 49.98%, where the percentage is greater than 30% which means that according to the Automotive Industry Action Group (AIAG) the measurement system is considered unfit for use and an increase in to improve the measurement system.

Table 5. *Gage Evaluation*

Source	StdDev (SD)	Study Var (6 x SD)	% Study Var (%SV)
Total Gage R&R	0,0091793	0,055076	49,98
Repeatability	0,0066039	0,039623	35,96
Reproducibility	0,0063756	0,038254	34,72
Operator	0,0063756	0,038254	34,72
Part-To-Part	0,0159063	0,095438	86,61
Total Variation	0,0183649	0,110189	100,00

Table 6. ANOVA Processing Result*s*

Source	p-value
Operator Work Experience	0,040
Measurement Time	0,198
Filler Type	0,661
Operator Work Experience * Measurement Time	0,661
Operator Work Experience * Filler Type	0,661
Measurement Time * Filler Type	0,661
Operator Work Experience * Measurement Time * Filler Type	0,661

3.5 Analysis of Factors Affecting the Clearence Tappet Measurement System

Factors and their interactions that affect the accuracy of the tappet clearence measurement system are obtained by brainstorming. Factors collected were operator work experience (F1), measurement time (F2), type of filler (F3), use of gloves (F4) and room temperature (F5). Each respondent measured the level of Consistency Ratio (CR) to determine whether the data used for pairwise comparison was consistent and valid. Based on the analysis results it was found that each respondent has a consistent pairwise comparison. From pairwise comparison respondents were then combined each value using the geometric mean. The inter-factor values obtained from the geometric mean are then used for combined pairwise comparison data. Judging from the normalized vector eigenvalues, the most dominant factor weights are operator work experience, measurement time and filler type. Then the three factors are then carried out experiments to see the effect on measurement accuracy. The work experience of the operator (F1) consists of 2 levels, namely 6 months and 30 months work experience, the measurement time (F2) consists of the initial shift measurement time of 7.30 and towards the end of the shift at 15.30 while the type of filler (F3) used is unit filler and fan filler. The measurement data is then entered into the Minitab program and obtained with ANOVA. ANOVA results can be seen in Figure 6. Based on Figure 6 it is known that differences in operator experience significantly influence the measurement accuracy because the P-value <0.05 while the measurement time, type of filler, and the interaction between the three do not significantly influence the measurement accuracy due to P- value> 0.05.

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4. Conclusion

The conclusion obtained from this study is that the measurement system has the characteristics of having a stable process, with an average bias of 0.0054 mm,% linearity of 2.6%, which means the measurement system has the same bias for each process variation and has% GGR of 59.3% with the Range Method, 51.0165% with the Average & Range Method, and 49.98% with the ANOVA Method. Overall, the tappet clearence measurement system has a good level of precision, this can be seen from good stability and linearity. Large average bias reflects inaccuracies in the measurement system.

Acceptance criteria in terms of stability, the measurement system is concluded acceptable because there is no point that comes out of the upper or lower control lines on the $\bar{X}$ & R chart. In terms of bias, the measurement system was concluded to be unacceptable because it did not pass the hypothesis test H0 : bias = 0 and H1 : bias ≠ 0 with t values exceeding t table (476.0935626> 1.761). In terms of linearity, the measurement system is concluded acceptable because it has a low linearity value (2.6%) and the forecasting line is almost parallel to the bias line = 0 and passed in the t_{test} where t_{table} (0.1242 ≤ 2.0106) and tb ≤ t table (0.0444583 ≤ 2.0106). In terms of repeatability and reproducibility, the measurement system is concluded to be unacceptable because it has a% GGR value that exceeds 30% both from the Range Method, Average & Range Method and ANOVA Method. Differences in operator experience have a significant effect on the accuracy of measurements with operators who have more experience resulting in more accurate measurements while measurement time, filler type, and interactions between the three do not significantly influence the measurement accuracy. The recommendation to improve the quality of the tappet clearence measurement system is to use fillers with a higher level of accuracy, conduct trials and training for all operators who are tasked with measuring the clearness of the tappet in order to equalize feelings in measuring, and to periodically replace filler.

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