A Case Study on Measurement System Analysis (MSA) at Pump Company

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Abstract-*The paper is concerned with to find out various variations in Measurement System and factor contributing to variations. The various parameters i.e. linearity, bias, stability and GR&R studies helps in determining the performance of Measurement Systems. For this quantitative research, the data collection results were analysed by using Analytical methods as per the Measurement System analysis, reference manual 4th Edition to evaluate linearity, bias, gage repeatability and gage reproducibility. The data analysis indicated that the measurement system is working satisfactorily under the quality parameters.*

Keywords: Linearity, GR&R, Bias, Effectiveness Kappa, reproducibility, reliability etc.

1. INTRODUCTION

All measurement systems have error. The error may be so small as to be irrelevant or it may be so large that we cannot trust our data. Regardless, they all have error. This means that if we want to choose a gauge we can trust, we need to understand the extent of this error, and we can do that through Measurement System Analysis. Measurement System Analysis is a set of techniques that allow us to assess how much error is being introduced by the measurement system.

Measurement systems analysis is a designed experiment that mainly focus on identify the parts of variation. Just as processes that produce a product may vary, the process of obtaining measurements and data may have vary and produce defects. It evaluates the test process, measuring equipment's and the overall process of obtaining measurements to ensure the reliability of data used for analysis and to understand the effects of measurement error to take decisions about a product or process.

2. Literature Review

Farhad Kooshan [2] is designing the test in the form of three inspectors in the final control on one of important parameter to measure, with measurement, equipment capability (variable aspect), and a capability (attribute aspect).

[1], MSA defines data quality and error in terms of "bias," "reproducibility," "reliability," and "stability". Further, MSA provides procedures to measure each term, however the phrase Gauge Repeatability and Reproducibility Studies (GR&RS) has come to incorporate the procedures recommended for measurement of "bias," "reproducibility," and "reliability".

[3]Most purposes of the measurement system and capability studies are to ; (1) accurately determine how much of the total observed variability is due to the gauge; (2) accurately isolate the sources of variability in the system; and (3) assess whether the is capable, so the result of measurement system analysis (MSA) must be accurate as well.

According to the Measurement System Analysis (MSA) and the Gauge R&R technique [4], one can estimate that:

1. If we have R&R %< 10% then, the measurement system that we use is excellent.
2. If we have R&R %< 30% then, the measurement system that we use is moderate.
3. If we have R&R %> 30% then, the measurement system that we use is worthless.

MSA is not only to audit existing measurement systems, but also help us to selecting the most appropriate ones for a new measurement task. An anonymous quality thinker could not have been more right when he said, "You can't inspect quality into a product." Performing MSA and looking at the measurement systems with your eyes open, drives your organization from the 'inspection' mentality towards the 'process assurance' mentality.

The actual process variability is the variation due to the measurement system must be evaluated and separated from that of the process. As per data collected there are two types of measurements possible:

a) Attributes: Pass/Fail, Very low counts, good/ defectives

b) Variables: Data can be described on a continuous scale.

There are two sources influencing gauge precision and accuracy:

(a) Gauge error. When an inspector uses the same gauge to measure a product several times under the same conditions, then several different values of measurement may occur. This error, called repeatability, comes from the gauge itself.

(b) Inspector error. This error occurs when different inspectors measure a product under the same condition and is called reproducibility. This error occurs when inspectors do not get sufficient training or inspectors do not measure a product according to standard procedure. The variability comes from the inspectors.

A Measurement Systems Analysis considers the following:

- Selecting the correct measurement and approach.
- Assessing the measuring device.
- Assessing procedures and operators.
- Assessing any measurement interactions.
- The tooling and fixture that locates and orients the object under measurement.
- Calculating the measurement uncertainty of individual measurement equipment or overall measurement systems.
- Common tools and methods of measurement systems analysis include: calibration studies, components of variance, attribute gauge study, gauge R&R and others.

3. TYPES OF VARIATION STUDIED

For Variable Gage:-

Bias: - It is the difference between the observed average of measurements value and the reference value.

LCL<Bias<UCL at 95% confidence level

Linearity:-The change in bias over the normal operating range.

Repeatability:-It is variation in measurements made with single measuring equipment when used number of times by single appraiser while measuring the same parameter on the same part.

Reproducibility:-Variation in the average of the measurements made by not same appraisers again and again using the same gauge when measuring a parameter on one part.

GR&R or Gage R&R: - Gage repeatability and reproducibility: the combined estimate of measurement system repeatability and reproducibility.

For attribute Gage:-

Kappa: - This parameter help us to measure the agreement between the evaluations of two rates when both are rating the same object.

Effectiveness: - It is ratio of number of correct decisions to total opportunities for a decision.

4. METHODOLOGY

The following methods are used for calculate Parameters:

Table: I

Parameter's	Methods
Bias	Independent sample method.
Linearity	Graphical and Numerical Analysis.
GR&R	Average and Range Method.
Attribute R&R	Cross tab Method

a) Determining BIAS

Independent Sample Method:-

- Conducting the Study
- 1) Obtain a sample part and establish its reference value with master gauge. If master gauge is not available, select a production part that falls in the mid-range of the production measurements and assume it as the master sample for bias calculation.
- 2) Have a single appraiser measure the sample 10 times in the normal manner.
- Analysis of Results - **Numerical**
- 3) Compute the average of the n readings.
- 4) Compute the repeatability standard deviation (see also Gage Study, Range Method).
- 5) Determine the t statistic for the bias.
- 6) Bias is acceptable at α level if zero falls within the 1-α confidence bounds around the bias value.

b) Determining Linearity

Conducting the Study

Linearity can be evaluated using the following guidelines:

Objective: Find out the difference between the obtained value and a reference value using the same equipment over the entire measurement space.

Process:

1. Choose minimum five parts that cover the overall measurement space of the equipment.
2. Measure sample standards 15 to 25 times.
3. Calculate the average of the readings.
4. Calculate bias.
5. Plot reference values on x-y graph.
6. Calculate slope of the linear regression line.
7. Calculate linearity and percent linearity.
8. Calculate R2.

Analysis:

1. The closer the slope is to zero, the better the instrument.
2. R2 gives indication of how well the "best-fit" line accounts for variability in the x-y graph.

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c) Determining repeatability and reproducibility

The Variable Gage Study can be performed using a number of differing techniques. Such as:-Average and Range method (including the Control Chart method).

- **Objective:** Determine variation in a components of measurement using a single equipment that can be credited to the equipment itself, and to the entire system.
- **Process:**
  1. Generate random order for operators and parts to complete the run.
  2. We have consider 3 operator and 10 number of parts for determining GR&R.
  3. Repeat process for subsequent runs.
  4. Have operators take measurements.
- **Analysis:**
  5. Plot data.
  6. Use Average and Range method (analysis of variance) on data.
  7. Calculate total variance.
  8. Calculate % Contribution and determine if acceptable.
  9. Calculate % Contribution (R&R).
  10. Determine if %GR&R is acceptable.

d) Determine GR&R for Attribute Gage

- **Process:**
  1. Obtain a sample 50 and establish its reference value relative to a traceable standard.
  2. In this process 3 appraisers are measure each part at 3 times.
- **Analysis:**
  3. Find out the cross tables of two appraiser i.e. A*B, B*C, A*C.
  4. Determine the kappa value for each appraiser.
  5. With this new information develop another group of cross-tabulations comparing each appraiser to the reference decision. Also find kappa value for each appraiser against reference value.
  6. Then calculate the effectiveness of the measurement system.

$$kappa = \frac{p_o - p_e}{1 - p_e}$$

$$effectiveness = \frac{number\ of\ correct\ decisions}{total\ opportunities\ for\ a\ decision}$$

Where
p_o= the sum of the observed proportion in the diagonal cell
p_s= the sum of the expected proportion in the diagonal cells

5. DATA COLLECTION & DATA ANALYSIS

- Data collection & analysis of GR&R

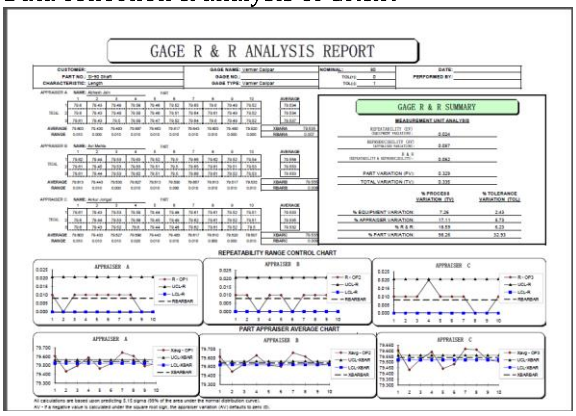
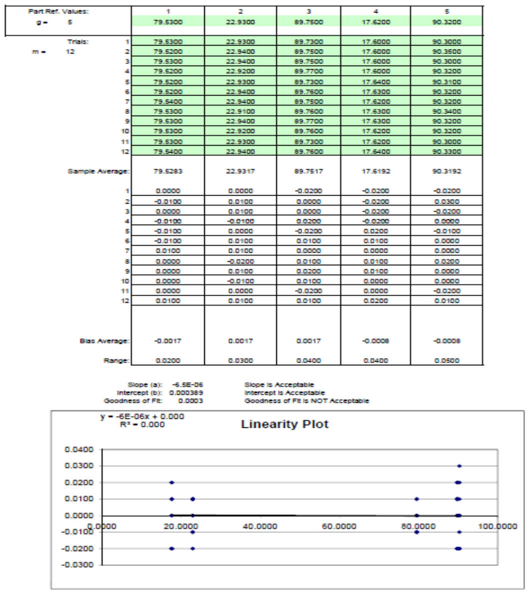


Figure 5.1 [GR&R data collection and Analysis sheet]

- Data collection & analysis of Linearity



		1	2	3	4	5
Part Ref. Values: g = 5		79.5300	22.9300	89.7500	17.6200	90.3200
Trials: m = 12	1	79.5300	22.9300	89.7300	17.6000	90.3000
	2	79.5200	22.9400	89.7500	17.6000	90.3500
	3	79.5300	22.9400	89.7500	17.6000	90.3000
	4	79.5200	22.9200	89.7700	17.6000	90.3200
	5	79.5200	22.9300	89.7300	17.6400	90.3100
	6	79.5200	22.9400	89.7600	17.6300	90.3200
	7	79.5400	22.9400	89.7500	17.6200	90.3200
	8	79.5300	22.9100	89.7600	17.6300	90.3400
	9	79.5300	22.9400	89.7700	17.6300	90.3200
	10	79.5300	22.9200	89.7600	17.6200	90.3200
	11	79.5300	22.9300	89.7300	17.6200	90.3000
	12	79.5400	22.9400	89.7600	17.6400	90.3300
Sample Average:		79.5283	22.9317	89.7517	17.6192	90.3192
	1	0.0000	0.0000	-0.0200	-0.0200	-0.0200
	2	-0.0100	0.0100	0.0000	-0.0200	0.0300
	3	0.0000	0.0100	0.0000	-0.0200	-0.0200
	4	-0.0100	-0.0100	0.0200	-0.0200	0.0000
	5	-0.0100	0.0000	-0.0200	0.0200	-0.0100
	6	-0.0100	0.0100	0.0100	0.0100	0.0000
	7	0.0100	0.0100	0.0000	0.0000	0.0000
	8	0.0000	-0.0200	0.0100	0.0100	0.0200
	9	0.0000	0.0100	0.0200	0.0100	0.0000
	10	0.0000	-0.0100	0.0100	0.0000	0.0000
	11	0.0000	0.0000	-0.0200	0.0000	-0.0200
	12	0.0100	0.0100	0.0100	0.0200	0.0100
Bias Average:		-0.0017	0.0017	0.0017	-0.0008	-0.0008
Range:		0.0200	0.0300	0.0400	0.0400	0.0500

Figure 5.2 [Linearity data collection and Analysis sheet]

6. RESULT & DISCUSSION

The main aim of this paper was to find out various variation in measurement system

- The Bias of all Variable Gauges were found to be in control limits.

Table: II

	Bias	95% confidence level of the bias i.e. (lower <zero<upper)	
		Lower	Upper
Vernier caliper	0.009	-0.00408	0.00178
Micro meter	0.008	-0.00508	0.00108
Dial Gauge	0.0007	-0.000613	0.0000132
Air Gauge	0.00053	-0.000256	0.000056

- The linearity of all variable gauge were found to be in limits i.e. ta & t_b were found to be less the critical value of t for 95% level of confidence.

Table: III

	95% confidence level of the t = 2.0172	
	t_a<t	t_b<t
Vernier caliper	-0.12768	0.1121
Micro meter	-0.55263	1.98909
Dial Gauge	-1.43198	0.2041
Air Gauge	-1.00044	1.04045

- The variation in air gauge and Dial Gauge were found to be within Standard limits, but the variation of Vernier Caliper & Micrometre were found to be out of limits. So after suggestions on appraiser variation improvement i.e. by providing proper training & Equipment Variation improvement i.e. by new Calibration of equipment ,the total variation of equipment's were reduced.

Table: IV

	AV (%)	EV (%)	GR&R (%)
Vernier caliper	17.308	7.129	18.718
Micro meter	7.101	15.049	16.64
Dial Gauge	1.2851	7.6174	7.7476
Air Gauge	2.69	5.33	5.96

After improvement:-

Table: V

	AV (%)	EV (%)	GR&R (%)
Vernier caliper	6.123	6.79	9.1444
Micro meter	5.134	8.027	9.5235

- Effectiveness of attribute gauges were found to be within the acceptable limits.

Plug gauge:-

Table: VI

	Effectiveness (%)	Miss Rate (%)	False alarm Rate (%)
Appraiser1	92	2	0
Appraiser2	90.	2.56	0
Appraiser3	92	2.22	0

Ring gauge:-

Table: VII

	Effectiveness (%)	Miss Rate (%)	False alarm Rate (%)
Appraiser1	88	4.78	0.76
Appraiser2	88	4.78	1.52
Appraiser3	86	2.78	1.52

7. CONCLUSION

In this paper, we conduct various study for calculate variation in measurement system. The various studies are Bias, Linearity, GR&R and Attribute R&R. The study conduct on three variable gauge such as Vernier caliper, Air gauge, Micro meter, Dial gauge and two attribute gauge such as Ring gauge, Plug gauge. The method use for calculation of Bias Independent sample method, For Linearity Graphical and Numerical Analysis, For GR&R Average and Range Method and for Attribute R&R Cross tab Method is used. For the GR&R study we calculate Part variation, Appraiser variation and Equipment variation. In between the study we find the two equipment's was acceptable but they need some improvement. These equipment's are Vernier caliper and Micro meter. After the improvement we again calculate GR&R than system becomes under acceptable. After improvement percentage of GR&R reduce almost 50% as result show in above section. The improvement done for make system is acceptable are:

- Proper training may be given to the worker to reduce the percentage GR&R; i.e. appraiser variation is reduced because of improved method.
- Ergonomics of working space may be improved to avoid the variation in measurement system because of stress introduced to worker; such as use of adjustable chair or use of tables with appropriate height and increase in the work space area of gauge and material or job.

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