Measurement system stabilization impact on the work quality judgment

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This study focuses on the contribution of the Measurement System Analysis (MSA) in the automotive textile industry. Usually, to determine the quality of work and workers, correct indicators are required. So, it is essential to stabilize the measurement system providing these indicators. In this paper, the gage R&R was used to analyze three measurement systems. Using the indicators «repeatability» and «reproducibility», the source of variation was located for unstable systems. After the improvement plans application, measurement processes were reassessed. Once the systems were stabilized, the new measurement procedures were kept. To emphasize the contribution of this work, a comparative study between the measurement systems before and after stabilization was performed. The difference between the data resulting from the old and the new measurement systems confirmed that the stabilization influenced the judgment indicators. Thus, the measurement system stabilization strengthened the reliability of the extracted data and guaranteed a fair process's judgment.
***Key words**: Quality, Gage R&R, Indicators, Measurement System Analysis, Stabilization*

1. Introduction

Nowadays, to conquer the competition in term of quality, industries have to make the right decision in the right time. This decision depends on data accuracy and also their reliability scale. Despite the quality being a major concern for any sector, experts in manufacturing industries, express their anxiety about the measurement reliability which is used in decision making [1]. Quality data is an important basis to carry out quality analysis and diagnosis. It is obtained by the application of measurement system in measurement procedure. If the data is contaminated with errors, it could lead to wrong decisions. The ability to make right decisions depends on the availability of a measurement process, selecting the right measurement process and operating the measurement process in the correct manner. Understanding and managing "measurement error", generally called Measurement Systems Analysis (MSA), is an extremely important function in process improvement. Most of the quality problems in industries are solved by identifying and correcting inaccurate data and inaccurate measurement process. When the data quality is low, the benefits of a measurement system is also low, likewise when the data quality is high, the benefit is high too [2-4]. Measurement system, which is different from the traditional measurement instrument, consists of the measured part, measurement method, measurement process, measurement instrument, reference standards, and measurement environment. It means the entire measurement process. Because of various reasons, each element of measurement system is possible to bring variation and discreteness into the measurement results, and affect the measurement accuracy. In order to ensure the reliability of measurement system, it's necessary to analyze the measurement system so as to determine and control the variation sources [5, 6]. Measurement systems analysis assesses the adequacy of a measurement system for a given application. When measuring the output from a process, two sources of variation are considered: Part-to-part variation and Measurement system variation. If measurement system variation is large compared to part-to-part variation, the measurements may not provide useful information [7].

Before collecting the data from a process to check process mastery or capability, it is recommended to analyze the measurement system. This analysis is carried out to confirm that the measurement system discriminates adequately between parts and provides efficient and accurate data [8, 9]. In the apparel sector, the assessment of a product quality and labor competence is based on detected defects. Two types of defects are noted, aspect and measure defects. For the first one, the detection is visual and acquired from the experience. But for the second type, the controller relies on measurement systems that must be reliable to give correct results. Therefore, we aim in this work to stabilize measurement system in order to provide a valid database useful to judge compliance article and operator capability.

2. Materials and methods

This work was carried out in a company specialized in automotive textile products. This exporting company employs 25 persons with an annual production of 2 000 000 pieces. It makes technical items (security nets, straps, bracelets, gearbox covers…) for the automotive and transport industry to several brands (Mercedes Benz, Volkswagen, DAF…). This type of items requires a high quality level. In fact, its usage attached to human security expects alertness on its manufacturing quality.This work was achieved in a production line making seat belts for the lower bunk of semitrailer truck cabin (Fig.1).

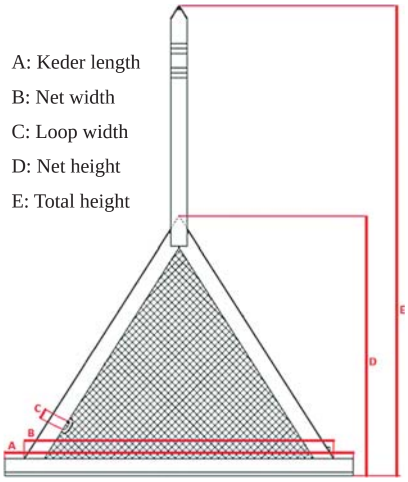

Fig.1 Sketch of seat belt with marked five measures

2.1. Measurement System Analysis (Gage R&R study)

The gage repeatability and reproducibility (R&R) study is a critical part of a successful process control system. It estimates how much the total process variation is caused by the measurement system. The measurement system variation consists in:

- Repeatability—variation due to the measuring device, or the variation observed when the same operator measures the same part repeatedly with the same device
- Reproducibility—variation due to the measuring system, or the variation observed when different operators measure the same part using the same device [2, 10, 11].

According to the Automotive Industry Action Group (AIAG) standards, if the gage R&R is less than 30%, the system is accepted. This means that the most of the variation is from the parts and not the measurement system. A gage R&R result of greater than 30% shows that the system is not acceptable and must be improved as the appraisers and equipment contribute to more than 30% of the system variation [12-14].

The testing form required three operators to measure 10 pieces in 3 times (trials) each [2]. The study was conducted so that each operator (one at a time) has chosen one of the pieces (selected randomly from the 10 pieces), and was asked to measure the piece using the "regular" measurement procedure for that product. The operator repeated this measurement process for the other 9 pieces, and then measured the same 10 pieces (in random order) for the second trial, then again for the third trial. This same study procedure was used for each operator. Calibrated instruments for measurements and software MINITAB for data analysis were used in this study.

2.2. Improvement and reassessment of the unacceptable measurement systems

For the unacceptable measurement system, the source of variation was deduced and the process was improved. The new system stabilization was verified by another gage R&R study.

2.3. Contribution of measurement systems stabilization

To focus on the analysis contribution, a comparative study of measurement systems before and after stabilization was conducted. The same 140 pieces were controlled before and after the processes improvement. The Defects Ratio, which is a judgment indicator of the manufacturing quality, was calculated before and after stabilization. Eventually, the lower this indicator is, the higher the quality of work and workforce is.

3. Results and disscusions

3.1. Gage R&R study

The MSA was done for the five measures A, B, C, D and E (Fig.1), but in this study only the three following measures are presented:

- A and C: The most important measures according to customer
- B: The measure having the higher customer claim rate.

Tab.1 Statistical results of the gage R&R study

Source	Percent study variation (%SV)		
	Measure A	Measure B	Measure C
Total Gage R&R	22.20	75.48	42.22
Repeatability	9.16	28.96	34.83
Reproducibility	20.22	69.70	23.86
Part-To-Part	97.50	65.60	90.65
Total Variation	100.00	100.00	100.00

Fig.2 Measurement method for measure A

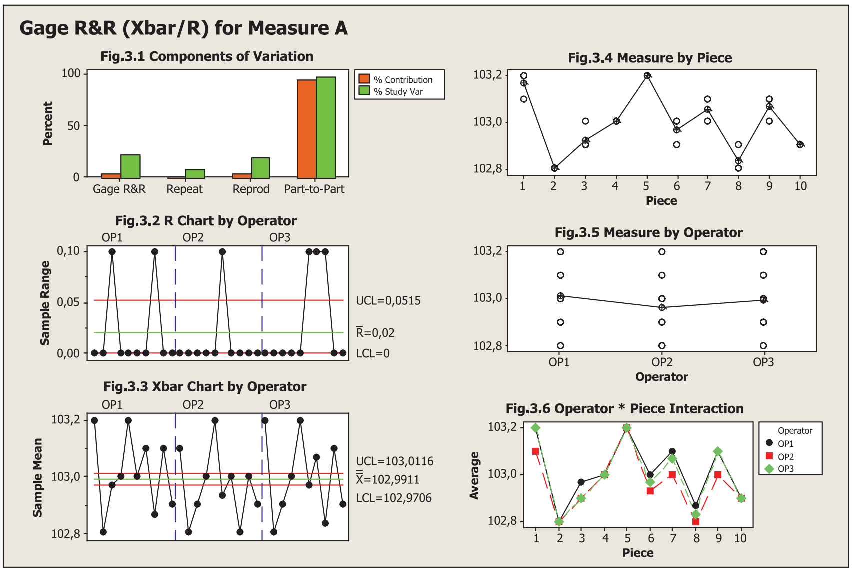

Fig.3 Gage R&R study for measure A

Generally, there are no problems noted in the measures D and E. The statistical results are given in the Tab.1.

Measure A (Keder length):
103 ±0.2cm

Measurement method shows Fig.2. Place the piece in the template Keder. Note the measure (the tape measure is fixed on the template).

Fig.3 shows the following results:

- The gage R&R indicates that the measurement system accounts for less than 30% of the overall variation (22.20%). Therefore, this measurement system is acceptable. The difference in parts accounts for most of the variation (97.50%). Thus, it is a good measurement system. (Tab.1 and Fig.3.1)
- Some points fall above upper control limit (UCL). The operators are not consistently measuring the pieces (example: the repeatability error for pieces 3 and 8 are out of control for operator 1). (Fig.3.2)
- Many points are above or below the control limits. These results indicate that the system can discriminate between parts. (Fig.3.3)
- Averages vary enough so that differences between parts are clear. The operators are measuring consistently and adequately pieces 2, 4, 5 and 10. (Fig.3.4)
- The line is not parallel to the x-axis. The operators are measuring the parts differently, on average. Operator 2 seems getting smaller values than the operator 1 and operator 3. (Fig.3.5)
- Lines cross, an operator's ability to measure a part depends on which part is being measured (an interaction exists between operator and part). (Fig.3.6)

Consequently, the measurement method is kept. The actual measurement system can give reliable data.

Measure B (Net width):
91.7 ±1cm

Measurement method shows Fig.4. Place the piece on the table (the apex of triangle is in front of the operator). Attach the measure tape on the two ends of the net. Note the measure.

Fig.5 shows the following results:

- This measurement system is unacceptable (gage R&R>30%). The largest component of variation is measurement system variation.

Fig.4 Measurement method for measure B

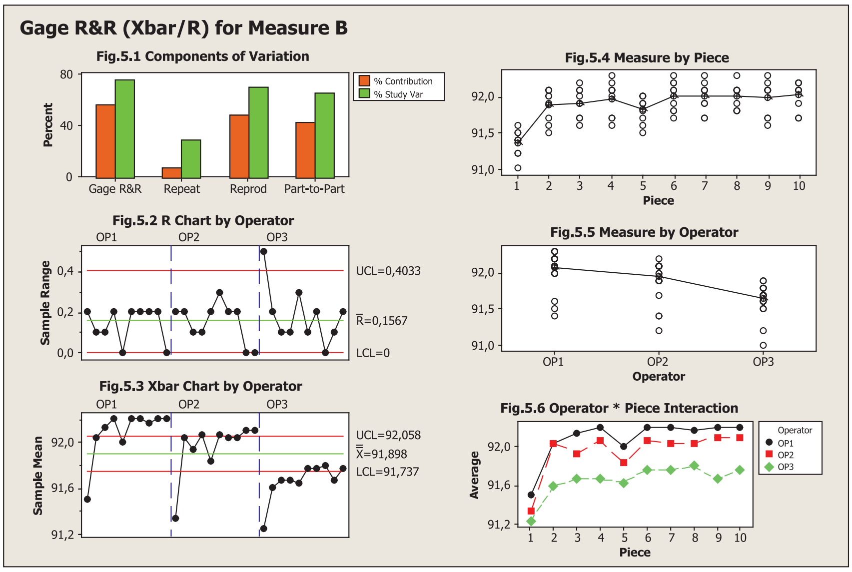

Fig.5 Gage R&R study for measure B

So, it is a bad measurement system. The measurement process is degraded by the reproducibility (69.70%) more than the repeatability (28.96%). Indeed, this can be explained that operators are inadequately trained on this measurement, or it is a bad measurement method that cannot be respected by them. (Tab.1 and Fig.5.1)

- Operators obtain the same values, except for operator 3 whose measures for piece 1 are varied. (Fig.5.2)
- Many points are above or below the control limits. These results indicate that the system can discriminate between parts. (Fig.5.3)
- Averages vary enough so that differences between parts are clear. (Fig.5.4)
- The line is not parallel to the x-axis. The operators are measuring the parts differently, on average. Operator 3 seems getting smaller values than the operator 1 and operator 2. (Fig.5.5)
- Operator 1 is measuring parts consistently higher than the other operators. (Fig.5.6)

For these reasons, the measurement method must be changed: the piece should be fixed in the template keder. Therefore, the keder will be stuck. The curve formed due to the keder flexibility will be eliminated. So, with this method the section to measure will be straight.

Measure C (Loop width):
3cm ±0.2cm

Measurement method shows Fig.6. Place the piece on the table (loop in front of the operator). Attach the measure tape on the two internal extremities of the loop. Note the measure

Fig.7 reveals the following results:

- This measurement system is unacceptable (gage R&R>30%). The largest component of variation is part-to-part variation (90.65%). Thus, it is a good measurement system. The measurement process is degraded by the repeatability (34.83%) more than the reproducibility (23.86%). Indeed, the repeatability of the operators is not optimal; this can be explained by an unsuitable instrument for the measuring section or a measure which does not allow being repeatable (imprecise positioning of the instrument). (Tab.1 and Fig.7.1)
- All the points fall within the control limits. Operators measure consistently the parts. (Fig.7.2)
- Many points are above or below the control limits. These results indicate that the system can discriminate between parts. (Fig7.3)

Fig.6 Measurement method for measure C

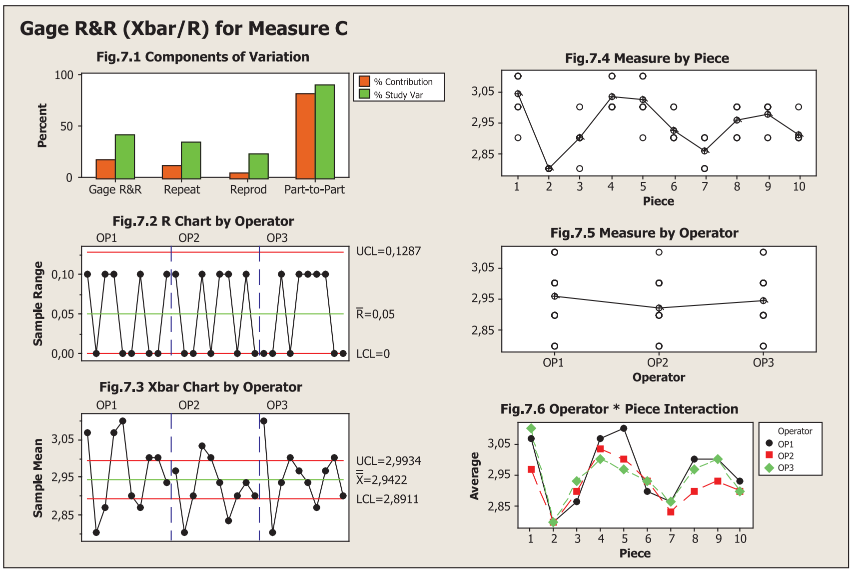

Fig.7 Gage R&R study for measure C

- Averages vary enough so that differences between parts are clear. The piece 2 represents the lowest variation. (Fig.7.4)
- The line is not parallel to the x-axis. The operators are measuring the parts differently, on average. Operator 2 seems getting smaller values than the operator 1 and operator 3. (Fig.7.5)
- Lines cross. An operator's ability to measure a part depends on which part is being measured. (Fig.7.6)

Hence, the measurement instrument must be changed. See its flexibility; the measure tape does not give precise measure. Thus, using a metal rule seems more appropriate for this small measure.

3.2. Gage R&R study for instable measurement systems

From the first gage R&R study, we concluded that the measurement systems of measures B and C are unacceptable. Thus, new methods, used in order to eliminate the source of variation and to improve the measurement process, are presented. We re-evaluated the new systems by another gage R&R study. The new statistical results are given in the Tab.2.

Measure B (Net width): 91.7 ±1cm

Improved measurement method shows Fig.8. Place the piece in the template Keder. Attach the measure tape measure on the two ends of the net. Note the measure.

From results shown in Tab.2 and Fig.9 that this measurement system is acceptable (15.26%). Previously, the measurement process was degraded by the reproducibility (69.70%). When we changed the measurement method, this indicator decreases (4.66%). This new method allows fixing the piece in the template. So, it reduces the operator intervention in the measurement method, which is in favor of stability. Gage R&R drops

Tab.2 Statistical results of the gage R&R study (after improvement)

Source	Percent study variation (%SV)	
	Measure B	Measure C
Total Gage R&R	15.26	4.16
Repeatability	14.53	0.00
Reproducibility	4.66	4.16
Part-To-Part	98.83	99.91
Total Variation	100.00	100.00

from 75.48% to 15.26%, confirming that the curve formed because of the keder flexibility is the source of the measurement system variation.

Measure C (Loop width): 3cm ±0.2cm

Improved measurement method shows Fig.10. Place the piece on the table (loop in front of the operator). Measure the loop width using a metal ruler.

Tab.2 and Fig.11 demonstrate clearly that this measurement system is acceptable (4.16%). Previously, the measurement process was degraded by the Repeatability (34.83%). The use of a metal ruler makes the problem disappear and the Repeatability becomes 0%. Gage R&R drops from 42.22% to 4.16%. This, confirm that the measure tape was not appropriate for this measuring section.

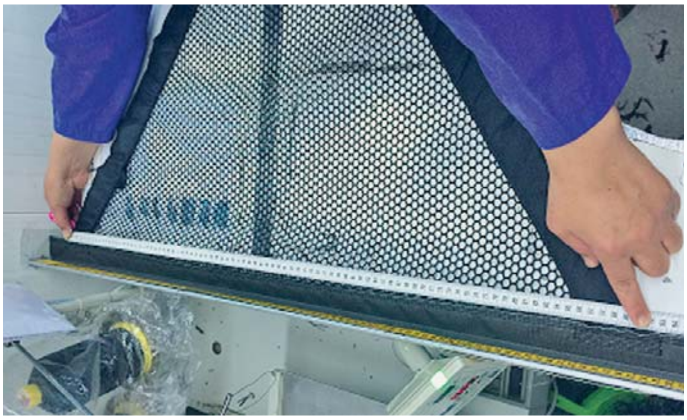

Fig.8 Improved measurement method for measure B

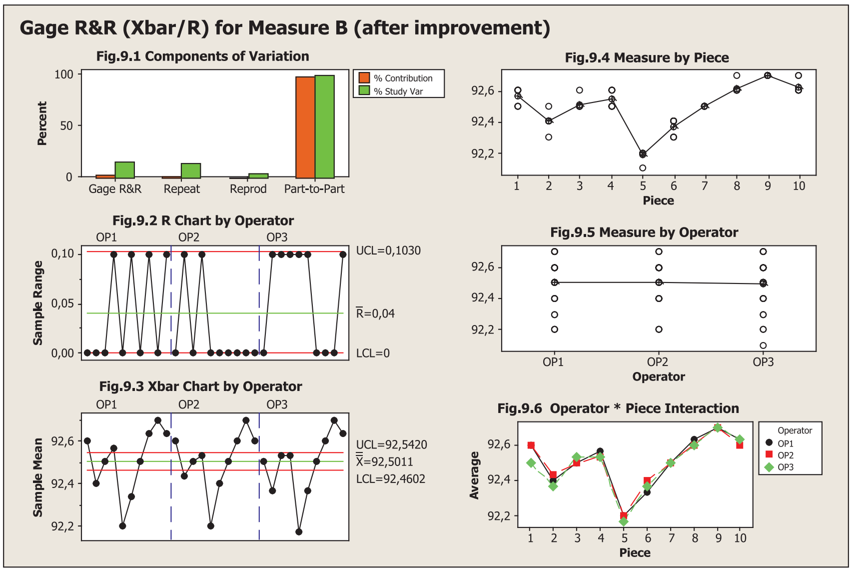

Fig.9 Gage R&R study for measure B (after improvement)

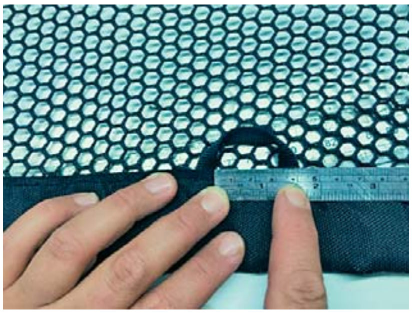

Fig.10 Improved measurement method for measure C

with the new procedure created for the improvements. The control results are indicated in Tab.3.

For measure B, the defects ratio increased from 0% to 2.85% (Tab.3). Therefore, the new measurement system detected more defects than the old one. These defects were forgiven by the unstable measurement system. The old system allowed the transfer of defective pieces to the customer.

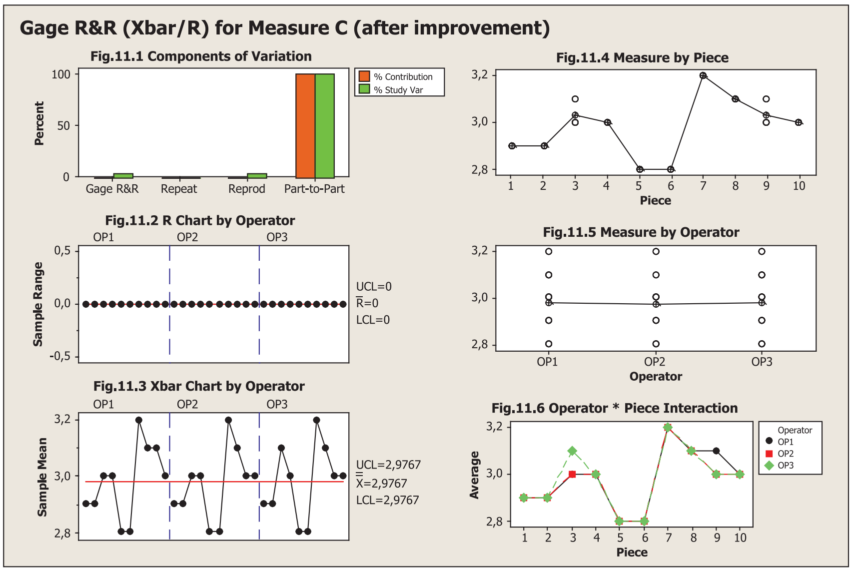

Fig.11 Gage R&R study for measure C (after improvement)

3.3. Contribution of measurement systems stabilization

To show the importance of the measurement system stabilization, a comparative study between the old and the new measurement process was conducted. Indeed, for the two measures “Net width” and “Loop width”, 140 pieces were controlled two times. The first control was with the regular procedure and the second one was

Tab.3 Defects ratio before-after improvement

	Defects Ratio (%)	
	Measure B	Measure C
Before improvement	0	5
After improvement	2.85	3.57

This well explains the high claim rate for this measure.

For measure C, the defects ratio dropped from 5% to 3.57%. Thus, the new measurement system eliminated defects non-existent in reality. These defects have been caused by the unstable measurement system. Compliant pieces have been condemned by the unstable measurement system, which caused waste of time, matter and energy.

Unstable measurement system is an unreliable system. Indeed, it cause customer dissatisfaction so a loss of image for the company. It can generates also a productivity decrease so a financial loss. In addition, it doesn’t allow a fair judgment in the workers’ capability because the competence assessment is erroneous by false data.

4. Conclusion

In this paper, a Measurement System Analysis (MSA) was conducted. Owing to the indicator “Total Gage R&R”, this work allowed knowing if the measurement systems were acceptable or not. Thus, for inacceptable systems, the anomalies were identified thanks to the indicators “repeatability” and “reproducibility. Improvement plans were proposed and the systems were re-evaluated. After stabilizing the inacceptable measurement processes, 140 pieces were controlled by the old and the improved systems. The results showed that instable measurement systems could provide wrong data either by eliminating existing defects or by adding non-existent ones. Thus, if the measurement system variation is important, it becomes useless to judge the process. This variation coming from measurement instrument, operator performing the measurement or measurement method disrupts the results. So, to judge objectively the process in terms of parts compliance and workforce competence, stabilizing the measurement systems is required.

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