ANALYSIS OF MEASUREMENT SYSTEMS IN METAL-MECHANIC BUSINESS SECTOR

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Abstract: Three companies of metal-mechanic sector from Rondonópolis-MT were evaluated according MSA (Measurement System Analysis). The companies were assessed of their production control specifically checking measurements equipment and methods. The accuracy of their measurements and influences of measurement system were evaluated. Also it was taken data to check Repeatability and Reproducibility (R&R). As a result it is expected to observe the needs of investments in this sector, as in relation to technology as in training for the metrology activities responsible.

Keywords: Metrology, MSA, Metal-mechanic, Investment, Training

1. INTRODUCTION

The measurement process must consider not only the equipment but also the operator, the work environment and interference that may occur during activities of measurement. Thus, if the measurement system for quality control of a firm is not appropriate, the results can approve a product that not complies with the specification (non-compliant) or reject a product that meets specifications (compliant).

The correct choice of instrument for measurement, assessment of the operator, the evaluation of environmental and other concerns relating to the metrological quality control process are part of the process known as MSA [1] [9] (Measurement System Analysis), widespread in the automotive industry as the advent of QS-9000 [2], VDA [3] and ISO/TS 16949 [4]. From automotive sector suppliers the measurement system assessment in accordance with MSA requirements is an obligation stemming from ISO/TS 16949 [5] process and, thus, it is no longer a technological barrier.

1.1. Measuring System in Automotive Industry

Considering the large volume of products, its complexity and associated risks, the automotive industry seeks to be surrounded with care processes and quality management in addition to those usually permeate the usual controls in other industries. The quality management system based on ISO 9001 [5] [11] did not attend to the concerns of automakers. Thus, in 90 years the Big Three North American automakers: Chrysler, Ford and General Motors have joined forces to create a quality management standard, similar to the ISO 9001, but that was of particular characteristics of the automotive sector, calling it QS 9000 [6] [7].

Similarly comes a standard in the German automotive industry, originated from an agreement between the car makers Volkswagen, BMW and Mercedes, called VDA [3] (*Verband der Automobilindustrie*). And just as the French: Peugeot, Renault and Citroen have created EAQF [3] and Fiat in Italy created the AVSQ [3] [8]. The body ISO (International Organization for Standardization) intervened with these manufacturers and led the work, along with the newly created at the time IATF (International Automotive Task Force), which resulted in the formulation of a standard that could replace those specific to each country was entitled ISO/TS 16949, which also follows the basic rules of the ISO 9001, but adds the specific concerns of the automotive industry. The ISO/TS 16949 is in the version 2002 (now in the 2009 version in English, but has not be officially translated into Portuguese by ABNT).

Since the launch of QS 9000 manuals were created to support its implementation. These manuals establish tools for the quality management to:

- Production Part Approval Process (PPAP).
- Advanced Product Quality Planning (APQP)
- Statistical Process Control (SPC)
- Failure Mode and Effect Analysis (FMEA)
- Measurement Systems Analysis (MSA)

According to requirements of ISO/TS 16949:2002, it is not possible to acquire an aggregate a part for the supply chain of the automotive industry that is not appropriate to set out by the five manuals. The documentation of effectiveness of the actions of the supplier to the automotive industry in accordance with these five manual is translated in the form of an approval document part called PSW (Part Submission Warranty). The acceptance of the PSW means that the company is acquiring a piece only after examined the documentation attached to the PSW, which are: APQP,

FMEA, SPC and MSA, forming a single document called PPAP

1.2. Metrological Studies According MSA

The metrological studies of the Automotive Industry based in the MSA, provides analysis of five major errors, as follows: Repeatability, Reproducibility, Tendency, Linearity and Stability. These studies were part of a compendium of information that adds a document known as PPAP (Part Approval Process Planning). The PPAP is submitted to the assembly plant, where the supplier is straight (tear one) or the supplier of the assembly, when dealing with a supplier of bottom layer (tear two, tree, etc.).

The MSA can be understood and applied through its manual [1], which is edited and distributed by IAOB (International Automotive Oversights Bureau). In Brazil, the Portuguese version is published and distributed by the IQA (Institute of Automotive Quality).

The MSA deals not only to the measurement errors and its form, but also the management of the measurement system, with demands actions for the planning process metrological control through the acquisition of equipment, calibration, use and documentation.

2. RESEARCH METHODOLOGY

Three companies from the metal-mechanic sector of Rondonopolis-MT city were intentionally selected from a database of one hundred and fifty companies, which was part of a research conducted by UFMT in partnership with SEBRAE/MT on a project called Census of Metal Mechanics Sector Industries from Rondonópolis-MT.

Those companies that present the greatest amount of metrological equipment, number of measurements taken and been larger, were selected. Most of them do not have the characteristics to participate of this research then only three were selected.

There was set up a questionnaire with open and closed questions, aiming to identify which characteristics of the MSA are served by the metrological process of each of the companies surveyed. This part of the research was conduct as an assessment.

The measuring instruments were evaluated using standard blocks from Federal University of Mato Grosso (UFMT). The objective of this evaluation is to verify the dimensional measuring equipment conditions of the companies surveyed. Random pieces selected from the approved pats stock were again measured using measuring equipment calibrated from UFMT and the results were compared. There was conducted a metrological study according to MSA for each of the companies surveyed.

Finally, based on questionnaire data, the results of measurements in each of the companies surveyed and the results of analysis of measurement system in accordance with the requirements of the MSA, there were discussions, analysis and findings of this research work.

To evaluate the Repeatability was used the following equation (1):

$$R = average\left(\frac{\sigma}{tolerance}\right) \qquad (1)$$

The repeatability is evaluated considering both measures, with company's instrument and UFMT's instrument. The standard deviation of measures done in the same sample is compared to the tolerance.

To evaluate the reproducibility is using the equation (2):

$$R = \frac{\max . difference}{tolerance} \qquad (2)$$

3. CASE STUDIES

This survey was conducted through case studies in three companies in the metalworking, as follows:

Machining company that produces parts for companies located in South Mato Grosso State region.

Factory of grain storage systems that manufactures installs and provides maintenance for silos, elevators, conveyors and separators for grain (mostly soy and corn).

Factory of animal feed system for cattle and pig in the confinement system creation. The factory produces animal feed storage systems, conveyors, elevators and mixers.

For each case study it was assessed the general aspects of the company and measurements methods. The measurements were done using the factory's instruments and instruments from UFMT, which are calibrated.

3.1. Machining Company

The company has a staff of seven employees, all trained by the owner and also conducted courses in metrology by SENAI/MT. Is a reference in machining in the city and recognized as one of the companies that have greater dimensional control of produced parts.

One of its main products is a specifically screw for agricultural sector. Usually the design of the part is supplied by the customer, with the dimensions and tolerance. Thus, this screw was selected for the case study. Were analyzed screw length and diameter characteristics.

Assessment: The length is measured by caliper that is not calibrated. The diameter is measured by a micrometer, which is not calibrated also. The instruments are replaced when they have high wear observed visually. The company has no pattern blocks or other form of calibration assessment for the instruments as other instruments measuring more precise. The company do not hires calibration services because there is no provider of measuring instruments calibration in the city. Interviews were held with the operator that normally manufactures and controls the piece.

Measurement Method: The operator usually makes only one measurement of length and diameter at each assessment. Do not use an average of length measurements to consider variations of run-and and also does not mean diameters to verify circularity variations, but understands the need. He justified that the work is usually fast to fill orders which prevents a more careful measurement.

Environment: Measurement is done in workplace. There is not much care for the environment cleanliness. The measure equipments are stored in their boxes exception of the caliper. Operator does not make total hand hygiene to handle the equipment, only a palliative cleaning. There is no temperature control in the measurement environment and on hot days the temperature in the workplace reaches 35 ^{o}C.

Were evaluated the MSA characteristics: Repeatability, Reproducibility and Trend. There were no conduct analysis of linearity and stability. Each operator has done two measures of each sample.

Table 1. Specification

Characteristic	Length	Diameter
Target Measure (mm)	22,225	20,000
Tolerance (mm)	0,400	0,200

Table 2. Factory's Caliper

Characteristic	Length			
Operator	Operator 01		Operator 02	
Piece Evaluated	A	B	A	B
Measure 01 (mm)	22,180	22,180	22,110	22,110
Measure 02 (mm)	22,140	22,140	22,110	22,110

Table 3. UFMT's Caliper

Characteristic	Length			
Operator	Operator 01		Operator 02	
Piece Evaluated	A	B	A	B
Measure 01 (mm)	22,200	22,200	22,200	22,200
Measure 02 (mm)	22,200	22,200	22,200	22,200

Table 4. Factory's Micrometer

Characteristic	Diameter			
Operator	Operator 01		Operator 02	
Piece Evaluated	A	B	A	B
Measure 01 (mm)	19,640	19,220	19,000	19,800
Measure 02 (mm)	19,640	19,220	19,000	19,800

Table 5. UFMT's Micrometer

Characteristic	Diameter			
Operator	Operator 01		Operator 02	
Piece Evaluated	A	B	A	B
Measure 01 (mm)	19,850	19,350	19,200	19,200
Measure 02 (mm)	19,800	19,350	18,900	19,200

Table 6. MSA Summary - Caliper

Characteristic / Operator	Operator 01	Operator 02
Repeatability	3,98%	13,26%
Reproducibility	193,8%	

Table 7. MSA Summary - Micrometer

Characteristic / Operator	Operator 01	Operator 02
Repeatability	3,54%	0,00%
Reproducibility	75,0%	

3.2. Factory of grain storage systems

This company manufactures grain storage systems from load receipt to the discharge been hoppers, conveyors, bucket elevators, separation systems and pipes. The company has a staff of 20 employees and only one has a metrology course performed at SENAI / MT. However, operators not trained often perform activities for measuring parts approval.

This is the largest company in this sector in the city of Rondonópolis and serves virtually every major grain producers. As their product line is diverse it was chosen a product that was being produced in large quantities in the week that was conducted the case study.

The product design is performed by the company itself, which despite having no mechanical engineers in its workforce, sporadic buying services for evaluation of the projects and signing of these ARTs.

Assessment: The product selected was a splicing stringer, used as part of the pipe passage for transporting the grain from hopper to the silo and also between the tabs and in the discharge. The characteristic length was evaluated. The operator used a caliper to perform such measurement, but said that normally use a tape measure. The length tolerance reported in the design of the part is ± 0.5 mm. When questioned the ability to measure such tolerance with a tape operator could not answer.

Measurement Method: During the research the operator used a caliper, but according to him during normal working days tape is used. No calibration is carried out of the caliper or any comparison with more accurate measuring instrument. Instrument is replaced when presents visual signs of wear. Usually each operator performs a measurement on the stage of production runs, but there is no quality control of the finished part.

Environment: Measurement is performed on the job, there is no very careful with the cleaning of hands, equipment and environment. Some equipment (such as the caliper) are stored in their proper boxes, others (like tape) do not have this care. There is no temperature control, the roof is of zinc and on hot days the temperature reaches 35 ^{o}C.

To present this research is shown the summary evaluation of second and third case studies. The analyze equation are the same showed in case first study.

Table 8. MSA - Factory of grain storage systems

Characteristic / Operator	Operator 01	Operator 02
Repeatability	127,28%	141,42%
Reproducibility	36,67%	

3.3. Factory of animal feed system

This company produces systems for animal feed, as the market leader providing mechanical and civil construction projects for cattle and pig in confinement system creation.

This is the largest company of this sector in the city of Rondonópolis and serves almost every large farmer of cattle and pig. Each project is undertaken specifically for customers, according to the budget and project characteristics.

The product design is performed by the company, which has a mechanical engineer in their staff and a trainee mechanical engineering. The civil works projects are carried out by engineers from the matrix, which is located in the of Santa Catarina State.

Assessment: The product selected was the axis of the elevator shaft, because it is a product belonging to almost all projects undertaken by the company and has an almost constant production. The measured characteristic was the axis diameter of the elevator shaft with specification of ± 0.011 mm. The measuring instrument used to assess this characteristic is a micrometer

Measurement Method: The operator uses a not calibrated micrometer for the measurement. The processes responsible engineer inform that there are no businesses in town that provide calibration services, but he understands this need. The diameter is measured four times to evaluate circularity error. The average of the measurements is considered as a measure of the piece. There are no statistical studies of process variation for possible fixes. The operators have course of machining but did not perform specifically metrology courses. Their learning was by on the job experience at the plant.

Environment: Measurement is done besides the job post. There is not much care for the maintenance of environment cleanliness. But the measuring equipment is stored in their boxes, with the exception of the caliper. Operator does not make total hand hygiene to handle the equipment, only a palliative cleaning. There is no temperature control, the roof is of zinc and on hot days the temperature reaches 35 ºC.

Table 9. MSA - Factory of animal feed system

Characteristic / Operator	Operator 01	Operator 02
Repeatability	48,21%	15,2%
Reproducibility	17,16%	

4. CONCLUSION

The case studies although not characterize a statistical sampling, are significant because of the importance of these enterprises in the economic scenario of Rondonopolis City and southern Mato Grosso State.

How companies are considered the most modern in its segment, it can be concluded on a preliminary basis:

a) The measuring equipment used are not calibrated, mainly because there is a company that provides this service in the region and was possible to evaluate that the equipment have significant measurement errors.
b) The employs in charge of metrological assessments do not have the proper training for this role, performing measurements on a non-proper way.
c) Are not conducted statistical studies of metrological data for preventive and corrective actions for the process
d) There is a high repeatability error of the metrology operators evaluated, which can impact the final evaluation of the products (approved non-conforming parts or otherwise).
e) There is a high reproducibility error among metrology operators evaluated.

4.2. Recommendations

It is recommended that there is a global action of training for operators involved in metrology for the firms in the South of Mato Grosso State region as well as to the establishment of a process of calibration services for these companies, which can be performed by UFMT in partnership with Mato Grosso State Government.

4.5. Research Continuation

For research continuation it is suggests that other forms of metrological evaluation to be checked, as testing the hardness in the steel plates shipments receipt and evaluation of screw torque assemblies of manufactured products.

REFERENCES

[1] MSA "Measurement System Analysis", 3rd Edition, IAOB, 2002.

[2] J. C. S. Gonzales,P. A. C. Miguel, "Uma contribuição à interpretação da QS 9000", ENEGEP, 1998

[3] M. G. Rebelato, D. C. Ferreira, A.M. Rodrigues, "*Estudo dos resultados da aplicação da auditoria de processo em uma montadora automobilística*", XXVI ENEGEP - Fortaleza, CE, Brasil, 9 a 11 de Outubro de 2006

[4] ISO/TS 16949:2002. "*Requisitos particulares para a aplicação da norma ISO 9001: 2000 para peças de produção e de reposição na indústria automotiva*", InternationalOrganization for Standardization, 2002

[5] C. R.Heckert, P. G.Francischini, R. G. Rotondaro, "*QS-9000: A ISO já não é o bastante*", Revista Produção, Belo Horizonte, Vol 8, N' 1, p.5-16, Jul.1998

[6] C. R.Heckert, E. R. Chaves, "*A implantação da QS-9000 na Fundição Osasco Ford BrasilLltda*", QualityProgress, January, p.23-28, 1996.

[7] J. C. S. Gonzalez, P.A.C. Miguel, "*Casos de Implantação da QS 9000 em Empresas no Brasil"*, Revista PRODUÇÃO, v. 11 n. 2, abril de 2002

[8] Norma NIT-DICOR-027, "*Critérios adicionais para o credenciamento de organismos de certificação de sistemas AVSQ´94*", INMETRO, 2002.

[9] R. F. Silva,"*A importância dos estudos de MSA nas organizações*", Revista Qualypro,2007

[10] S. F.Beckert, E. P.Paladini,"*A abrangência do gerenciamento metrológico nas empresas*", XXVI ENEGEP - Fortaleza, CE, Brasil, 9 a 11 de Outubro de 2006

[11] NBR/ISO 9001:2008"*Sistema de Gestão da Qualidade*", ABNT, 2008. .