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STANDARDIZATION OF MEASUREMENT STRATEGIES IN COORDINATE METROLOGY IN THE AUTOMOTIVE SUPPLY CHAIN

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Abstract: The outsourcing in the automotive industry transferred the responsibility to produce products with quality to its supplier and, consequently, the definition and execution of the measurements in the supplied products. However, it is still frequent the occurrence of the conflicts between companies related to divergences in the dimensional tests. This problem is more critical in coordinate metrology, due to the many parameters in the measurement process. This paper describes a methodology developed for the standardization of measurement strategies to be used during the product development and its application in the supply chain of the Brazilian automotive industry.

Keywords: coordinate metrology, measurement strategies, supply chain.

1. INTRODUCTION

The intense outsourcing in the automotive industry in the last 20 years brought new challenges to the technical relationships between customers and suppliers. To adjust themselves to this new reality, the assembly plants have realized a complete reorganization of the supply chains and, consequently, of the relations and of the distribution of the responsibilities among the companies.

The product has been developed in an integrated way between customers and suppliers and, as a result, the assembly plants needed to establish methods to assure the quality of these supplied products.

During all the stages of the product life cycle, are generated deviations related to its quality. However, most of them are generated in the initial stages of product development and not only during the manufacturing process [1].

In the dimensional area these deviations in the quality of the product are particularly important, being a critical contractual requirement in the supply. In the companies where there is not an adequate definition of the measurement process by the suppliers and by the assembly plant, the deviations in the quality of the product will be probably detected only during the manufacturing process, causing many re-works.

It was observed in many Brazilian companies that the suppliers are responsible for defining the parameters of the measurements and reporting the results. Consequently, in many cases, there are divergences in the measurement results between suppliers and assembly plants (Figure 1), errors in the report and interpretation of the measurement results (Figure 2), use of inadequate measurement systems, errors in the interpretation of the specifications in the drawings and so on.

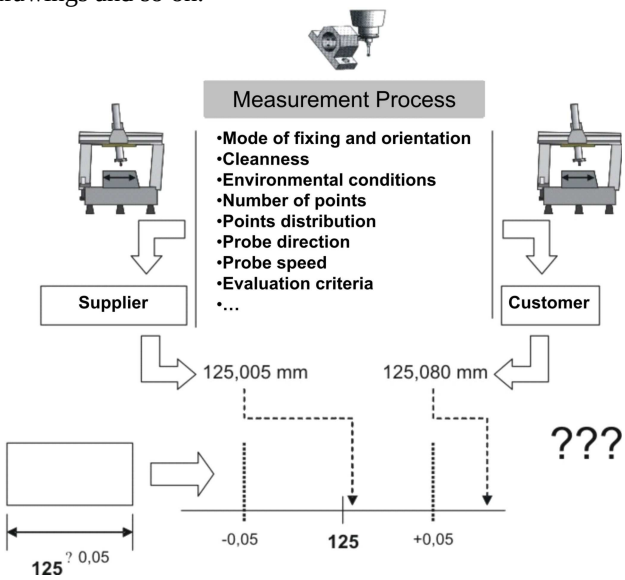

Figure 1: Different measurement strategies potentializes incompatibility between results

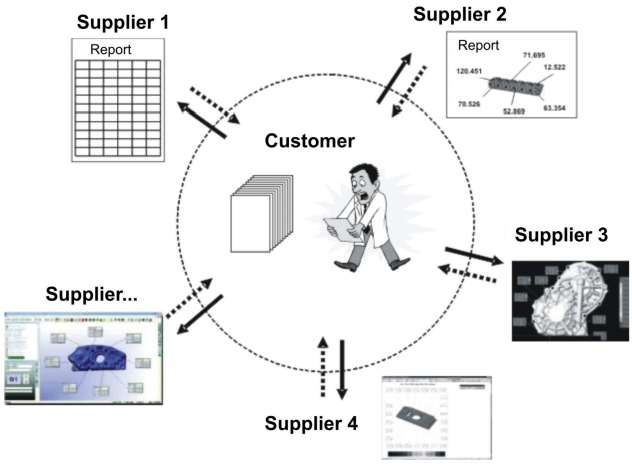

Figure 2: – Not standardized reports difficult the communication

These problems are more critical in the coordinate metrology, because of the many parameters that have to be defined in the measurement process. Currently, the coordinate metrology is the most used resource of measurement for the dimensional conformity evaluation in supply processes, due to its flexibility and universality [2], and this is also found in Brazil.

Despite the measuring uncertainty of the coordinate measuring machines (CMM) is only a few micrometers, the differences in the measurement results of the same workpiece by different operators are considerably greater than the uncertainty specification of the CMM as stated by the manufacturer. [3]

The causes are not only in the measurement systems, but also in the measurement strategy defined for each measurement task and in the errors caused during the execution of the measurement. [3] The difficulty to define adequate measurement strategies occurs due to its dependence from the form deviations generated by the manufacturing processes, from the particularities of the measurement process and mainly from the operator skills.

To minimize all these problems and achieve the assurance of the dimensional quality of supplied products, two important points to be considered are the standardization and evaluation of the measurements between customers and suppliers and a correct communication of the results and information between them.

Currently, the Brazilian assembly plants are beginning the process of adapting themselves to this new reality, observing the application of some techniques and activities. However, all these efforts are still wide-ranging, and consist basically of a more detailed selection of the suppliers and the execution of more tests in the supplied products during the stages of the product development. The efforts related to the dimensional measurements, nevertheless are still deficient. Recommendations of how to define the parameters of the coordinate measurement process and a metrology support of the assembly plant are still deficient.

Thus, the standardization (recommendations) of measurement process among partners will be able to minimize in great amount the occurrence of these problems, bringing benefits as:

- Consistency among results;
- Reduction of the conflicts;
- More efficient and reliable measurements;
- Improvement in the relation among partners;
- More accurate and faster corrective actions;
- Quality Improvement of supplied products;
- Transference of knowledge between assembly plant and suppliers;
- Time reduction for the product development.

The standardization of the measurement reports, aiming to provide a more objective, accurate and faster communication among partners brings benefits as:

- Reduction of the interpretation errors;
- Easiness of communication among partners;
- More conclusive reports;
- More adequate and reliable dimensional analyses.

Motivated for this problem, this work proposes the development of a methodology for the standardization of coordinate measurement strategies to be used in all the automotive supply chain, to the support, evaluation and reliable in the dimensional test results.

With this methodology, the suppliers will define their measurements in an adequate and standardized way and all the parameters will be documented. Consequently, the analyses of the variations in the measurement results will be more reliable, and this will prevent imperfections in the measurements in some advanced stages of the product development.

2. PROPOSED METHOD

The methodology consists basically of a set of activities to be developed by the assembly plant and its suppliers during the stages of the product development. The general structure with the specific attributions of the assembly plant and the suppliers can be visualized in figure 3.

For the execution of the proposed methodology it is fundamental that a functional group is created with participants of different areas, such as product and process engineering, metrology, product development in the supplier and supplier participants. With this group the problems of communication will be minimized and will have a support among the companies.

The methodology was divided in the modules described in the following sections.

2.1Coordinate measurement strategies database

This module consists in disponibilizing coordinate measurement strategies recommendations to each measurement task to be used in the measurement processes of the suppliers and of the assembly plant.

Thus, these proposal recommendations by the assembly plant will be stored in a "database" that will be centralize the information.

The suppliers will have to consult the database to evaluate the suggested information and, if the strategies are suitable to its manufacturing and measurement processes, they will be able to use them. On the other hand, if its case is very particular, the supplier will have to define a new measurement strategy that will have to be approved by the assembly plant.

While new measurement strategies are being approved, the assembly plant will include them in the database, in order to increase the information and transfer the knowledge among companies. For this, it is necessary that the structure of the database is flexible, dynamic and expandable.

For the organization of the information stored in the database and easiness in its consult, a structure in tree form (Figure 4) was developed based on the work developed in [4]. In this way, the recommendations of the measurement strategies of each measurement task are structuralized by the characteristics of the geometric elements to be measured, defined from the tolerances specified in the project of the product.

Thus, to consult the index of the database, the user will have to define some parameters for each tolerance to be evaluated, such as:

- Direct or associate (association of elements measured directly) measurement;

- Physical and general characteristics of the geometric element to be measured;
- Characteristic to be evaluated in the element - tolerance.

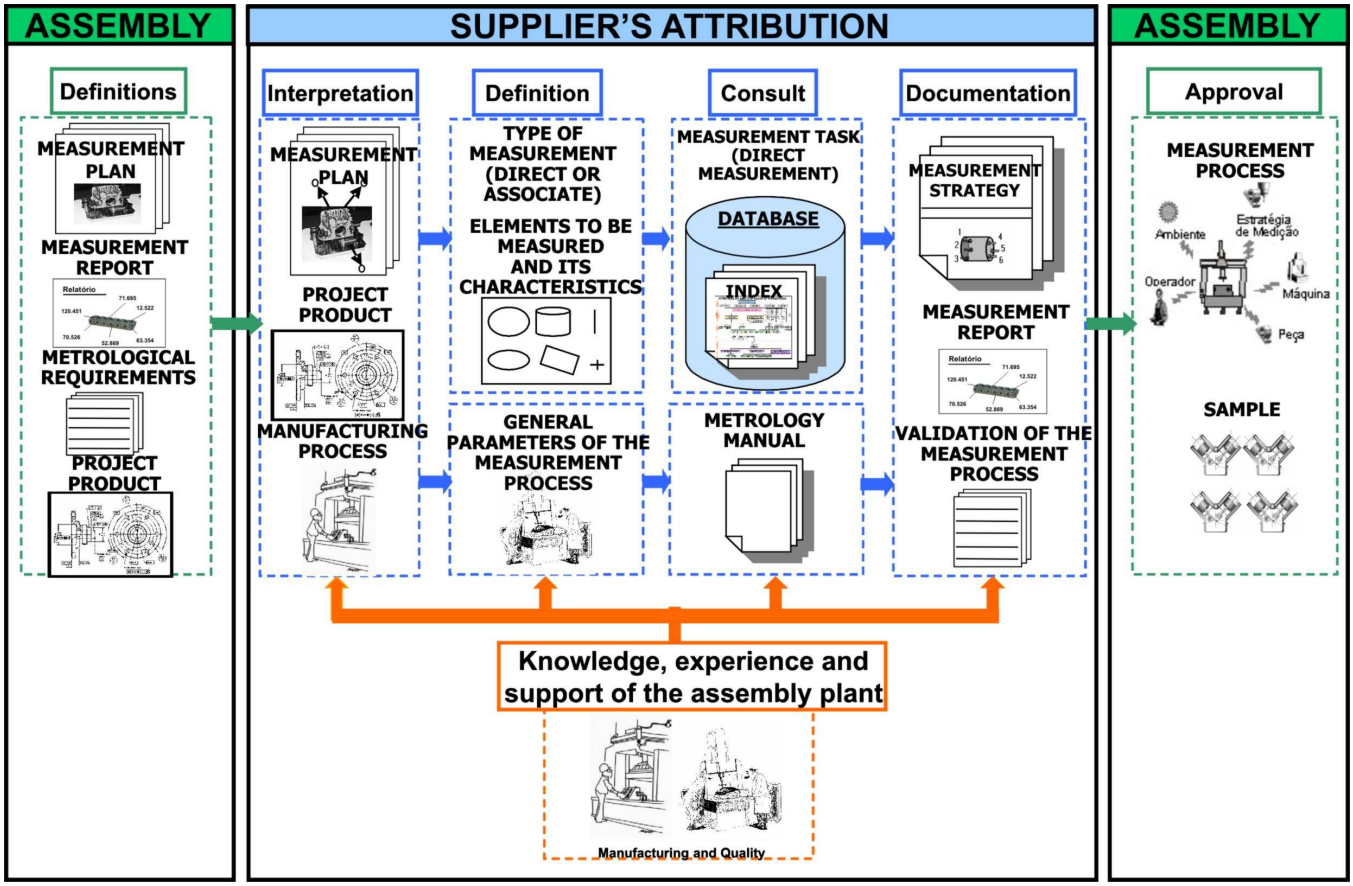

Figure 3: General structure of the proposed methodology

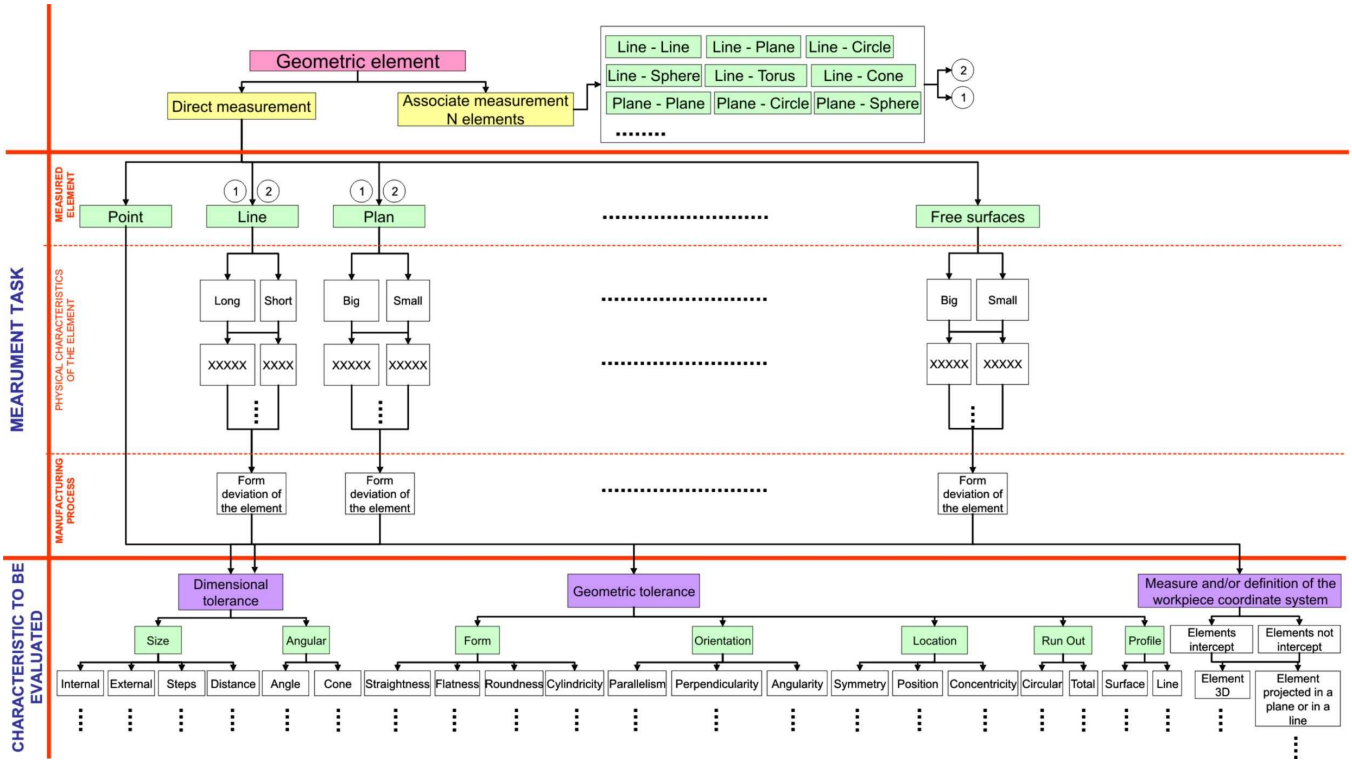

Figure 4: Index of the measurement strategy database

The concept of direct measurement was created because of the many cases where it is necessary to associate elements measured directly to evaluate a determinate characteristic. In the database there will be only recommendations of direct measurements. For the associate measurements, the user will have to specify the measurement strategy of each element and how its association was done.

After consulting the database, the user will have as a result, the recommendations of the measurement strategy for its measurement task.

These recommendations consist basically in a description of how the measurement will have to be executed, through the specification of some parameters considered important for the authors of this work. These parameters are the number and distribution of the measured points in the geometric element, the evaluation criteria, the filter used to smooth measuring data from continuous surface probing, the diameter of the probe tip, the size of the element and so on.

Another aspect also considered in the structure of the database is that the specific characteristics of each type of manufacturing process can influence, in a different way, the measurement process. For this, it was defined that the database will be categorized by the type of manufacturing process (figure 5). As a result, each supplier will have access only to the database referred to its manufacturing process.

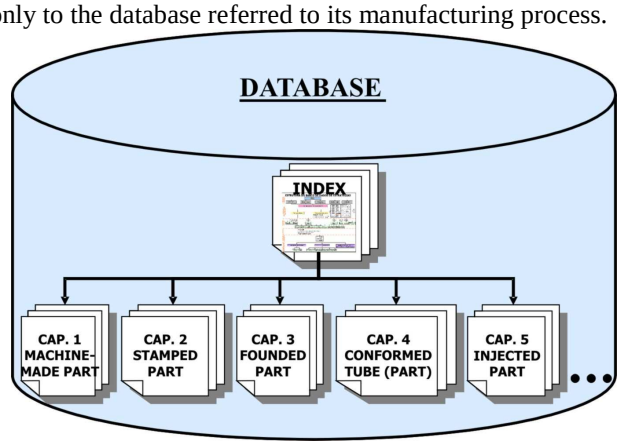

Figure 5: Database categorized by the type of the manufacturing process

2.2 Measurement Plan

It is a document with the goal to clearly define the metrology requirements to be demanded of the suppliers in all the stages of the product development and, consequently, minimize the incomplete estimates and assure the application of these requirements in the measurements. It must be defined by the functional group, based on the analysis of the project and the manufacturing process of the product and sent to the suppliers together with the drawing of the product, previous to the stage of selection of the supplier.

These requirements are constituted by the definition of the measurement resources to be used in the dimensional tests (to develop or not fixturing devices and control devices for the manufacturing process, measurement system, qualification of the operator), special considerations in the definition of the reference system (datums); definition of the tolerances and other parameters (functional elements) to be evaluated in each dimensional test and so on.

2.3 Measurement strategy document

It is a document to register all the parameters of the measurement process defined by the supplier, which allows a possible repetition of the measurement and facilitates the evaluation of the results.

Thus, this document will contain:

- Measurement system used;
- Mode of fixing and orientation of the part in the measurement system;
- Probe configurations;
- Specific parameters for each measurement task of the reference system;
- Specific parameters for each measurement task of each evaluated tolerance (code of the database or proposal of a new measurement strategy);
- Environmental conditions and so on.

Besides, this document will be the link of communication of the supplier with the assembly plant, that will contain information about the planning, the accompaniment and the analysis of the measurement process and, the evaluation of the supplied samples. It will be updated as soon as the analyses in the stages of the process of product development are realized.

After the definition of the measurement process is done by the supplier, it must be evaluated and approved by the assembly plant (initial evaluation, without the execution of the measurement), before the submission of the samples, in order to facilitate the evaluation of the measurement results of the samples submitted in the most advanced stages, when deadlines are shorter. In the stage of production of the supplied samples and the execution of the dimensional tests, the supplier will have to use the measurement process already defined and approved to perform its real validation.

2.4 Measurement report

This module proposes a definition of a standardized model of measurement report to be used by all involved. It also proposes mechanisms that facilitate its generation.

The measurement reports must contain the necessary information in an objective form, in a format that will allow a fast and an easy way to interpret dimensional conformity of the product, without generating doubts. The report format cannot be disentailed of the possibilities of the software used for this purpose. Preferably, all the process has to be fast and automatized, to prevent errors in the write and alterations in its format.

It is necessary that the assembly plant informs the tools that will generate the measurement reports or define the tool that shall be used by all suppliers.

2.5 Validation of the measurement process

It is a study that will have to be performed by the supplier, for the operational (time, easiness and cost) and metrological validation (compare the variability of the measurement process with the manufacturing process or the specification limits) of its measurement process. Its objective is to increase the reliability of the measurements

and, it is important that the suppliers have the conscious about its importance.

There are diverse studies and standards for the metrological validation of the measurement process; however its objectives and evaluated parameters are different. In this direction, studies of metrology conformity based on the estimate of the uncertainty according to ISO Guide [5], and studies of statistics capacity of measurement systems are indicated [6]. The assembly plant will be able to specify some specific study to the suppliers or to let the choice for the supplier.

Free from the executed study, it is important that will shows a complete knowledge about the measurement process, and when possible, the identification and the quantification of the uncertainty sources. Moreover, the results of these studies must be registered and sent to the assembly plant to evaluate them.

It must be realized by the supplier together with the dimensional tests in its sample, considering the measurement process already pre-approved by the assembly plant. If the results of this validation are not satisfactory, the causes will have to be evaluated and the necessary parameters will have to be modified. However, it is essential that the assembly plant realizes a new analyze in the measurement process, based then on the real data of the measurements.

After the validation of the measurement process by the supplier and its approval by the assembly plant, the supplier will have to use it in the other dimensional tests to be realized in the further stages of the product development.

2.6 Metrology manual

Its objective is to level the knowledge referred to the development and to assure the quality of the product among the assembly plants and its suppliers. It will have to contain theoretical and practical concepts for the definition and the execution of the measurement process in an adequate way.

It will have to be supplied by the assembly plant and to be available to be consulted.

With the explanation of the main modules of this methodology, its implantation consists basically on the creation, consult and use of the proposed documents by the assembly plant and the suppliers, each one in its more adjusted stage of the process of product development, in order to guarantee the considered benefits.

Thus, with the definition of the measurement process based on these 6 modules, with the metrology support of the assembly plant and the joint effort of the functional group, the assembly plant will have more reliability and easiness in the evaluation of the measurement results of supplied products and will only repeat the measurement of the supplied sample in its installations for critical cases.

3. APPLICATION OF THE PROPOSED METHOD

For the validation and improvement of the proposed methodology, it was applied in an assembly plant and in a supplier company (aluminum casting and machining), both in Brazil.

From the mapping of the current reality in these companies, the application of methodology was considered of immense validity for the work, due to presence of diverse items that were evaluated and included in the development of this methodology, increasing the probability to verify its practical behavior and to realize the necessary validations and improvements.

Some of the problems observed in the dimensional tests of this supply chain are:

- Lack of involvement of the metrology area with the supplier;
- Lack of definition of the metrology requirements to be developed by the supplier;
- Incomplete estimates in the metrology items;
- Problems in the project of the product;
- Lack of information in the measurement report;
- Lack of knowledge of how the measurement of the supplier was realized;
- Repetition of the measurement of the supplied sample by the assembly plant.

Therefore, to apply the proposed methodology in this supply chain, some points of the organizational configuration of the assembly plant were modified:

- Generation of a functional group, responsible for the supplied product development;
- Participation of the metrology area in the beginning of the product development, in order to critically analyze the project of the product and to define the metrology requirements to be fulfilled by the supplier in its measurement process;
- Metrology support during the stages of the methodology. The metrology area has to deal directly with the supplier.

The case study was divided in five stages:

- 1st Executed in the assembly plant: selection of the part, analysis of its project, definition of the measurement requirements to be followed by the supplier, definition of recommendations of measurement strategies to be included in the database by the assembly plant (initial recommendations) and definition of the model of the measurement report;
- 2nd Executed in the supplier plant: definition and documentation of the measurement process parameters through the database and the operator's knowledge,
- 3rd Executed in the assembly plant: analysis of the measurement process defined by the supplier (document) and its approval;
- 4nd Executed in the supplier plant: execution of the measurement using the measurement process already approved, realization of the validation study and generation of the measurement report;
- 5rd Executed in the assembly plant: measurement of the part (choice of the assembly plant), comparison and evaluation of the results, approval of the measurement of the supplier and update of the information in the database.

4. RESULTS AND DISCUSSION

The application of methodology in the case study clearly evidenced the transference of knowledge among the companies, where the supplier proposed some useful considerations of the manufacturing processes, that had been enclosed in the database, and the assembly plant contributed with general recommendations for the execution of the measurement, analysis of the measurement system and the influence sources.

Another topic that brought a favorable result was the involvement of the metrology area of the assembly plant with the supplier during the diverse stages of methodology, having a closer relationship and facilitating the exchange of information and solution of the doubts.

Some recommendations of measurement strategies present in the data base (proposed by the assembly plant) was improved after of the realization of the case study. This illustrates the responsibility in defining and evaluating the measurement strategies, and the necessity to have a dynamic structure to store the information in the database and to divulge its updates.

It was evident also that the success of the methodology depends fundamentally on the involved people in the process that must be eager to realize a process of assurance of the quality of the product in a precise form.

Therefore, the main advantages of the proposed methodology are:

- Earlier identification of the problems and inconsistencies in the project of the product;
- Adequate definition of the product reference system (datum) realized by a functional group that has knowledge about the whole product and manufacturing process;
- Elimination of the incomplete supplier's estimates in the metrology requisites;
- Definition and documentation of the adequate measurement strategy to the mensurand and approved by the assembly plant, before the submission of the samples;
- Standardization of the report of results;
- Recommendations of measurement strategies defined by the assembly plant, which will have the particularities of the supplier process;
- Minimization of errors in the measurement results;
- Exchange of knowledge among companies;
- Reduction of the supplier sample approval time;
- The assembly plant's metrology support brings more confidence to the suppliers.

5. CONCLUSIONS

During the development of this work, it was clearly distinguished the moment of the reorganization that the automotive industry is passing, and consequently, the existence of the many technical conflicts, amongst other factors, for the incompatibility of the diagnostic of conformity of the products.

In fact, to reach the solution of these diverse problems evidenced in the stages of development of a product, it was necessary to develop a methodology to accompanied all these stages since the initial moment, where not even occurred the selection of the supplier, so that the metrology area already could include its considerations in the project of the product and define the metrology requirements to be developed by the suppliers.

In addition, the methodology also proposes the standardization of the coordinate measurement strategies to be used by the suppliers and by the assembly plants. This way, it must be included all the parameters considered important to an adequate measurement. These parameters are stored in a database, with a flexible structure that can be adapted to the particularities of each company.

However, the use of the proposed methodology, whose objective is to intensify the studies during the product development, is not enough. It is necessary to continue the assurance the quality of the product through the application of tools that control its manufacturing process, as for example, the application of statistical process control.

Therefore, it is essential to realize an adequate effort in the measurement tasks in both stages. In the stage of product development, it is necessary high accuracy in the measurements, because the measurement errors produced will be frozen and the quality of the product will be inferior to the level established. This is the focus of the proposed methodology in this work.

However, for the stage of production of the product it is essential the continuity of the quality control of the supplied product, through the control of the process, activity that must also have an accompaniment and support of the assembly plant.

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