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QUALITY CONTROL IN THE MEASUREMENT OF PARAMETERS OF ELECTRICAL CONNECTIONS ACCORDING TO BRAZILIAN STANDARD

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ABSTRACT

The Brazilian Standard of Plugs and Sockets for domestic use was created with the purpose of unify the electrical connections used inside the residences. In addition to giving consumers more security due to the new design, the proposed changes also lead to a reduction in the use of adapters and extensions. The standardization of the plugs and sockets has generated changes and a great adaptation in the electrical materials industries of the country. Production processes, quotas and quality control procedures had to be reformulated and revised. This work makes an analysis of the conformity of the dimensions of plugsand socketswith the information defined in the new Brazilian standards. In the methodology used are the use of measurement systems with coordinate measuring machine to verify parallelism and perpendicularity and the caliper and micrometer to check the measures of the pins, holes and others parameters. The results are confronted with the specifications of the current regulatory standard, where conflicts between the connections found in the retail market and the specifications defined in ABNT NBR 14136 v4 2013 are highlighted.

KEYWORDS:

Electrical Plugs and Sockets;
Tolerance;
Geometric Shift;
Uncertainty,in measurement;
ABNT NBR 14136 v4 2013.

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1. INTRODUCTION

Despite the technological advances, the design of a product is often one of the great problems of the industry being involved in its high costs. The project should address the

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steps of dimensional and geometric control in order to generate a product with the quality desired for the final customer. Most of the deviations in quality can be caused by inadequate specification of dimensional and geometric tolerances, manufacturing processes without statistical control and measurement error negligence with its uncertainty, etc. [4, 5, 11, 22].

The description of a phenomenon or process is only completely clear when its characteristics can be quantified and this quantification must be done by means of measurements [13]. The results of the measurements must be obtained reliably and for this, when reporting the result of a measurement, it must be accompanied by quantitative information that indicates the quality of the measurement so that anyone can understand and reproduce the result with reliability [8, 12, 14]. Quantitative indication of the quality of the measurement is what we call measurement uncertainty [3, 17].

In the industrial sector of materials for electrical installations (sockets, plugs, extensions, etc.), metrology acts in order to help the normalization of the dimensional parameters and the quality control of the finished product. Among these standards there is ABNT NBR 14136, which governs the standardization of plugs and sockets for domestic use. This standard should ensure that the electrical connections produced and used in the Brazilian territory follow guidelines or characteristics established to standardize the connections and maintain the safety of users [1].

Figure 1. Sockets outside the patterns of the standard ABNT NBR 14136. Font: the authors

Figure 1 shows an example of a plug found in a sample piece of an appliance in a national supermarket chain, where no type of technical specification regarding the plug is presented to the consumer. This is an example of a product's poor suitability for technical standards. The absence of a description of important characteristics in regulatory standards may also lead to the emergence of products that are unsuitable for use, which may directly affect consumer safety.

In this article, an evaluation of the dimensional parameters obtained in electrical connections (sockets and plugs) found in the Brazilian market is carried out according to the guidelines of ABNT NBR 14136 v4 2013. For this, the study makes use of different measurement systems in order to evaluate parameters dimensions such as diameter, distance between centers, parallelism and perpendicularity. The measurement uncertainty calculation techniques by GUM (Guide to the expression of uncertainy in measurement) are used to evaluate the quality of the dimensional parameters when comparing the values obtained with those specified in the standard [11].

2. RESEARCH METHOD

In the accomplishment of the work, assemblies formed by plugs and sockets of different manufacturers were acquired randomly. These sets were obtained in the Home Center of the region. The pieces were selected within the large batch of pieces of each manufacturer, available in the Home Center.

The parts that at the first handling presented slack or gross damage were discarded. In this context, three socket manufacturers, here called A, B and C, were selected for analysis, as well as four plugs, called X, Y and Z. Each manufacturer was represented by 3 samples, named 1, 2 and 3.

The work generated several significant data and table 1 groups the distribution of sockets and plugs taken into account to present the results of this research.

Table 1. Distribution of sockets and plugs in the research

Type	**Producer**	**Samples**
Socket	Producer A	1A, 2A e 3A
Socket	Producer B	1B, 2B e 3B
Socket	Producer C	1C, 2C e 3C
Plug	Producer X	1X, 2X e 3X
Plug	Producer Y	1Y, 2Y e 3Y
Plug	Producer Z	1Z, 2Z e 3Z

All measurements were performed in an environment temperature controlled by a hygrometer, brand Cotrinic Technology and maintained at 20±1ºC. The dimensional parameters, defined in standard, were evaluated for the identification of the dimensions to be studied in the work. The selected quota dimensions were measured with calibrated instruments.

The instruments used for the measurement were a caliper (R = 0.02 mm) and a micrometer (R = 0.001 mm) both of the Mitutoyo brand and with certificate of calibration number 06501/15 and 06520/15, respectively.

A Mitutoyo coordinate measuring machine (R = 0.0005 mm) with calibration certificate 03206/13, located in the Mechanical Engineering department of UFPE, was also used. The measuring instruments were selected according to the tolerances presented in ABNT NBR 14136 v4 2013.

The drawings in figures 2, 3 and 4 show the layout of the selected dimensions for the evaluation of the sockets and plugs. The figures also present the tolerances defined in ABNT NBR 14136 v4 2013. Fifteen measurements were made for each of the selected dimensional parameters.

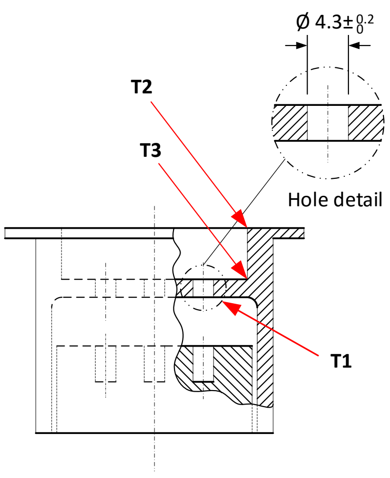

Figure 2. Quotas T1, T2 e T3 selected for the sockets - cuts views (Adapted from ABNT NBR 14136)

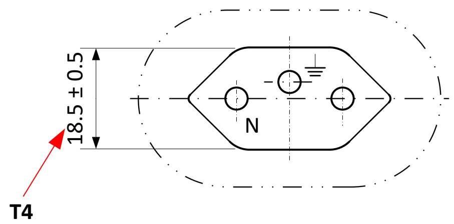

Figure 3. Quota T4 for the sockets - top view (Adapted ABNT NBR 14136).

Quotas T1 to T4 are related to the sockets and are described as: T1 - internal diameter of the hole, T2 - Largest opening of the socket measured at the top, T3 - Greater opening of the socket at the bottom, T4 - Lowe opening of the socket on the bottom.

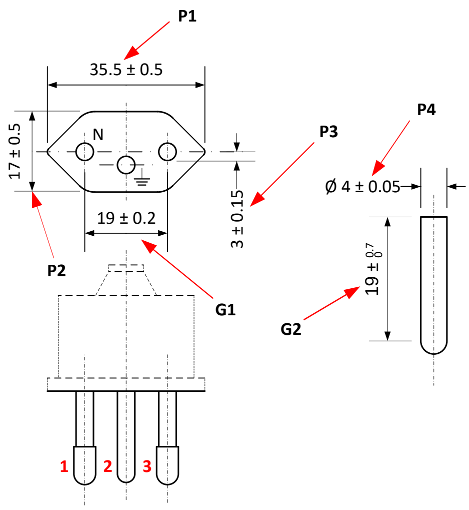

Figure 4. Dimensions P1, P2, P3, P4, G1 and G2 for the plugs (Adapted from ABNT NBR 14136).

The quotas of P1 to P4, G1 and G2 are related to the plugs. P1 - Larger external width of plug, P2 - Smallest external width of plug, P3 - Length of pin to base of plug, P4 - Pin external diameter, G1 - Distance between centers of pins 1 and 3, G2 - Distance between centers between pins 2 and 3.

The ABNT NBR 14136 standard does not present criteria for geometric tolerance and the coordinate measuring machine was used to verify the geometric parameters of parallelism and perpendicularity that are not addressed in the standard. These criteria also take into account variations in the manufacturing process that cause shape shifts between the projected part and the actual one [7, 8, 9, 15, 16].

The coordinate measuring machine (MMC) was used to measure distance between centers, parallelism and perpendicularity between pins 1, 2 and 3. The pieces were fixed to the machine table where the entire measurement procedure was performed. In obtaining the quotas G1 and G2, the machine software performs an operation with the two diameters and a distance between pins 1 and 2 (G1) and 1 and 3 (G2). The perpendicularity was evaluated between the pins and their base of fixation and the parallelism was evaluated between the pins

The results of the measurements were treated for the dispersion of the values presented according to the statistical tests of Dixon, Chauvenet and Grubbs. These tests are considered acceptance criteria for measured values [6]. The outliers are data that present different behavior of the other data of the sample and can present errors, either by human failure or in the equipment during the data acquisition [2]. The detected outliers were removed from the measurement set. The statistical tests cited were evaluated using the Analysis software, developed by researchers from the Federal Institute of Pernambuco (IFPE). For the result of the measurements, the test that detected the greatest number of outliers was the one of Chauvenet, used in the calculations of measurement uncertainty [19, 21].

The GUM Workbench software version 2.4.1.384 from Metrodata GmbH was used to evaluate the measurement uncertainty. The GUM Workbench has an interface that allows the measurement uncertainty to be calculated using the ISO GUM method and simulation of Monte Carlo.

In order to evaluate the uncertainty, the factors measuring the repeatability, resolution and calibration of the measuring instrument were taken into account, according to the methodology developed by Oliveira et al., 2016 [20].

3. RESULTS AND ANALYSIS

3.1 Measurements with the Caliper and Micrometer

Results are summarized for ease of presentation. The uncertainty measures were compared with the tolerances established in ABNT NBR 14136.

Table 2 shows the results obtained by the measurements of the sockets of manufacturer A. Table 3 shows the results of the measurements made on the Y plug. The underlined values are the outliers, removed from the uncertainty calculation by the Chauvenet test. The parameter U, represents the measurement uncertainty.

T2 and T3 quotas, although present within the tolerance range defined in ABNT NBR 14136, present a difference when evaluating the top and bottom of the plug fitting area.

Table 2. Result of measurement for sockets manufacturer A samples 1A and 2A

	T1 (mm)		T2 (mm)		T3 (mm)		T4 (mm)	
---	1A	2A	1A	2A	1A	2A	1A	2A
1	4.40	4.48	37.26	37.24	37.00	37.14	18.42	18.44
2	4.44	4.50	37.18	37.22	37.06	37.16	18.44	18.50
3	4.40	4.48	37.26	37.20	37.06	37.16	18.42	18.44
4	4.38	4.44	37.18	37.20	37.04	37.10	18.46	18.44
5	4.44	4.46	37.20	37.18	37.08	37.10	18.48	18.42
6	4.42	4.48	37.18	37.20	37.00	37.12	18.44	18.44
7	4.40	4.48	37.20	37.24	37.06	37.16	18.44	18.48
8	4.42	4.48	37.18	37.22	37.06	37.10	18.42	18.46
9	4.40	4.50	37.20	37.26	37.00	37.16	18.42	18.44
10	4.42	4.50	37.22	37.26	37.02	37.16	18.46	18.44
11	4.46	4.48	37.20	37.24	37.00	37.10	18.44	18.44
12	4.44	4.46	37.18	37.22	37.02	37.14	18.48	18.46
13	4.40	4.46	37.20	37.22	37.00	37.16	18.44	18.48
14	4.42	4.48	37.20	37.20	37.00	37.14	18.42	18.44
15	4.40	4.48	37.16	37.20	37.02	37.12	18.48	18.44
Average	4.42	4.48	37.20	37.22	37.03	37.13	18.44	18.45

Table 3. Result of measurements for the plugs of the manufacturer Y samples 1Y and 2Y

	P1 (mm)		P2 (mm)		P3 (mm)		P4 (mm)	
---	1Y	2Y	1Y	2Y	1Y	2Y	1Y	2Y
1	35.50	35.46	17.14	17.14	19,00	19.02	3.983	3.986
2	35.50	35.44	17.18	17.12	19.04	19.12	3.982	3.988
3	35.52	34.48	17.16	17.16	18.90	19.02	3.984	3.990
4	35.50	35.50	17.18	17.14	19,00	19,00	3.988	3.989
5	35.52	35.46	17.16	17.14	18.94	19,00	3.986	3.990
6	35.56	35.48	17.20	17.10	19,00	18.96	3.989	3.985
7	35.50	35.48	17.16	17.12	19,00	19.02	3.988	3.983
8	35.56	35.46	17.16	17.12	19,00	19.02	3.990	3.986
9	35.54	35.46	17.20	17.14	19,00	19.02	3.988	3.988
10	35.56	35.46	17.16	17.14	19,00	18.89	3.990	3.989
11	35.50	35.46	17.16	17.14	19,00	19,00	3.988	3.989
12	35.52	35.46	17.16	17.16	19.10	19,00	3.990	3.990
13	35.52	35.46	17.18	17.14	18.89	19,00	3.988	3.989
14	35.50	35.48	17.20	17.16	19,00	19,00	3.990	3.982
15	35.54	35.46	17.18	17.10	19.06	19.02	3.988	3.982
Average	35.52	35.46	17.17	17.13	19,00	19.01	3.988	3.987
U	±0.026	±0.024	±0.025	±0.025	±0.034	±0.025	±0.0018	±0.0019

Graphs of figures 5 to 8 present some results of the measurements made with the caliper. These graphs also record the lower limit, upper limit, as well as the nominal value of the tolerances recorded in ABNT NBR 14136 (see figures 2 to 4).

Figure 5 shows the measurements of T2 for manufacturers A, B and C, each with 3 parts. This graph shows that manufacturer C displays the measurements for the three parts with the closest proximity to the nominal value (37.0 mm). Manufacturer B shows almost all measured values outside the specified tolerance of the standard. Manufacturer A displays all values above the nominal value, but within the established tolerance.

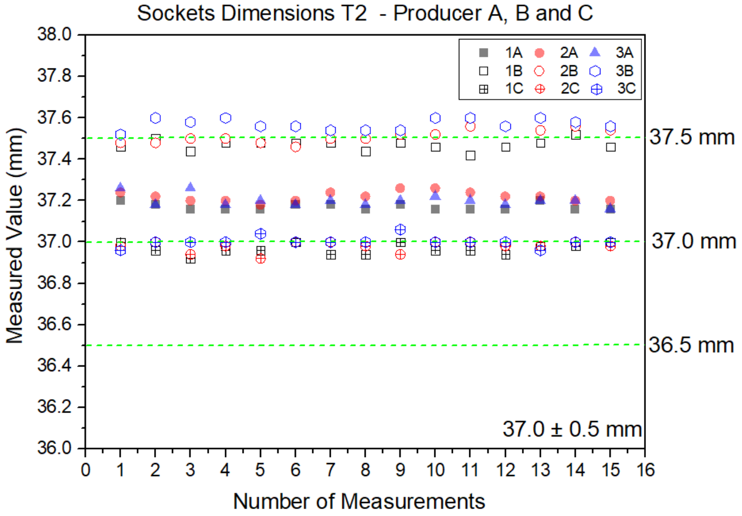

Figure 5. Quota T2 measured with caliper in the outlets of manufacturers A, B and C

Figure 6 shows the measurements of quota T4 for the three manufacturers, each with 3 pieces. In this figure, it is visualized that all the manufacturers present the measurements within the established in the norm, standing out the samples of the manufacturers A and C, that present values closer to the nominal value (18.5mm).

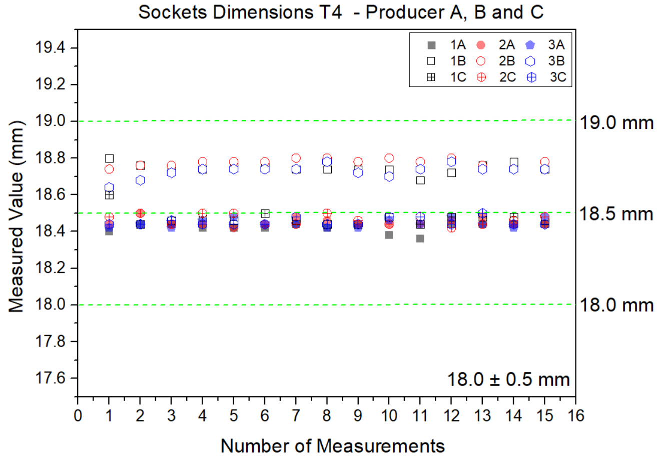

Figure 6. Quota T4 measured with caliper at sockets of manufacturers A, B and C

Figure 7 shows the measurements of the P1 dimension for the three manufacturers, each with 3 pieces. In this figure it is possible to identify that all measurements performed are within the tolerance standard established in the standard. In this figure stand out the parts 1 and 2 of the manufacturer Y, which are closer to the nominal value.

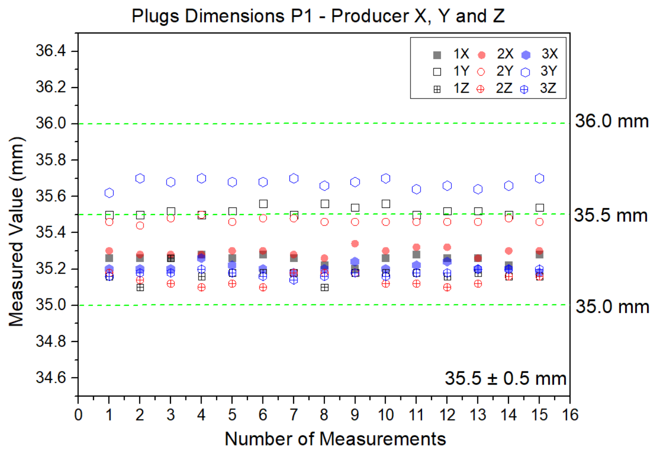

Figure 7. Dimension P1 measured with caliper in the plugs of manufacturers X, Y and Z

Figure 8 shows the dimensions of quota P3, the height of the pin in the plug, for the parts of the three manufacturers. Quota P3 is one of the few listed in the standard, whose lower limit is the nominal value itself. The tolerance for quota P3 is mm and the measurements shown in the graph of figure 3.4 indicate that all manufacturers have parts with deviations from the nominal value

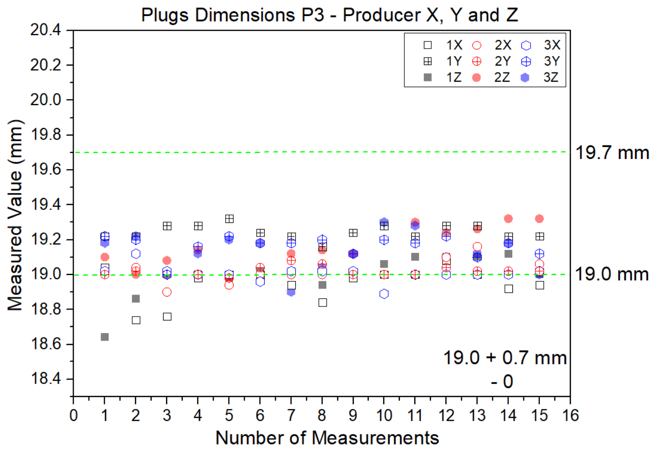

Figure 8. Quota P3 measured with caliper in the plugs of manufacturers X, Y and Z.

3.2 Measurements with Coordinate Measuring Machine

According to the principle of independence, a linear quota and its tolerance limit only the aspect of the size of a geometric element, but not its geometrical shape deviations [23]. To evaluate the geometric deviations of parallelism and perpendicularity between pins 1 and 2 and between pins 1 and 3 of the plugs an MMC is used. This machine is also used to measure the distance between centers of pins 1, 2 and 3 (quotas G1 and G2).

Tables 4 and 5 show the results of the measured parameters for a part of the plug manufacturers X and Y. The table shows the distances between centers of the pins, measurement uncertainty, besides the geometric deviations of parallelism and perpendicularity.

Table 4. Measurement result for X-plugs with Coordinate Measuring Machine.

Measures	G2	G1	Parallelism		Perpendicularity		
mm	1-2	1-3	1-2	1-3	1	2	3
1	3.2799	18.4711	0.1390	0.6723	0.2853	0.2685	0.3364
2	2.6958	18.5797	0.1224	0.7222	0.2694	0.2760	0.2181
3	2.8003	18.7241	0.0962	0.6655	0.2357	0.2707	0.3668
Average	2.7049	18.5916	0.1192	0.6867	0.2635	0.2717	0.3071
U	0.2400	0.3300	0.0560	0.0870	0.0660	0.0100	0.2100

Table 5. Measurements result for Y-plugs with Coordinate Measuring Machine.

Measures	G2	G1	Parallelism		Perpendicularity		
mm	1-2	1-3	1-2	1-3	1	2	3
1	3.2799	19.6473	0.0377	0.5763	0.1746	0.1071	0.3035
2	3.1908	19.5350	0.0124	0.4833	0.1525	0.1046	0.2547
3	3.1223	19.4503	0.0055	0.4864	0.1488	0.1061	0.2607
Average	3.1977	19.5442	0.0185	0.5153	0.1586	0.1059	0.2730
U	0.2100	0.2600	0.0440	0.095	0.0370	0.0027	0.0700

In tables 4 and 5, it is observed that there is a variation between the measured values for G1 and G2 quotas and also deviations of parallelism and perpendicularity. Quota G1, for example, presents values with differences of more than 0.253 mm (table 4). The parameters parallelism and perpendicularity indicate that there is a deviation between pins 1, 2 and 3. Depending on the intensity of these deviations, problems may arise regarding the inadequate interaction between the socket and the plug. These problems hinder the use of these elements, causing bad contact between the parts, generating sparks and may even cause short circuits and leakage of electric current.

Figure 9 shows the measured data for the distance parameters between the centers of pins 1 and 2 (quota G1). The graph also shows, with dashed lines and in green color, the limits of the tolerance defined in standard. In this case, the graph shows that most of the pins are out of tolerance of the standard (19.0 ± 0.2 mm).

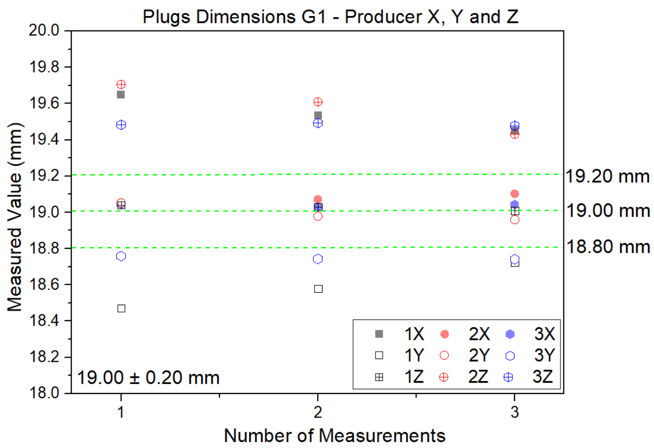

Figure 9. Quota G1 measured with MMC for the X, Y and Z plugs manufactures.

Figure 10 shows the measured data for the distance parameters between the centers of pins 1 and 3 (quota G2), revealing that most of the pins are outside the tolerance of the standard (3.00 ± 0.15 mm). In this case, all the manufacturers presented parts in disagreement with the current norm.

3.3 Measured Values x ABNT Standard

From the results presented, it can be seen that some quotas were within the tolerances allowed in the regulatory standard and this can be observed when evaluating, for example, the T1 quota (see tables 2 and 3), whose measurements presented values of 4.42 ± 0.026 mm and 4.48 ± 0.024 mm for parts 1A and 2A, respectively. These data confirm that the values are within the $4{,}3^{+0{,}2}_{-0{,}0}$ mm range required by the standard. It has also been observed that many manufacturers present altered dimensions of plugs, plugs and adapters of electrical systems, disregarding the parameters of current norm ABNT NBR 14136, as is the case observed for quotas T2, P3, G1 and G2.

Although most of the values were within the tolerance ranges specified in ABNT NBR 14136, when evaluating the results of measurements of T2 and T4 quotas for the sockets and quotas P1 and P2 for the plugs, it was observed that the interaction between them caused a maximum clearance of 2.00 mm. This gap also exists within the norm. In this case, taking the upper limit of the quota T2 (37.0 ± 0.5 mm), that is, 37.5 mm and the lower limit of the quota P1 (35.5 ± 0.5 mm) 35.0 mm, a maximum difference of 2.50 mm is identified, when the nominal difference specified in standard would be 1.50 mm. This difference results in the gaps between the sockets and plugs and can generate heating of the elements, the interruption of energy of the equipment and in extreme cases, cause short circuits due to the mobility of the assembly.

Although in the experiments carried out, geometric deviations of parallelism and perpendicularity were found, it is not possible to make any type of comparison with the norm, since the standard does not make any type of comment regarding these deviations nor their tolerances.

4. CONCLUSION

It is known that the ABNT NBR 14136 standard alone can not solve all problems related to differences in voltages, electric current and frequency of the electricity grid in Brazil, but it is also verified as a result of the results that the ABNT standard has not been respected in any way to ensure the safety of users of home appliances in the country. Not all hazards involved with the divergences are known, but there are numerous errors observed in sockets, plugs and adapters found in the market.

The selected sockets and plugs had several non-standard dimensions specified in ABNT NBR 14136 v4 2013, where high clearances were identified between T2 and P1 quotas and between T4 and P2 quotas, reaching maximum clearance values of 2.50 mm. The gaps observed at the connection between the plug and the socket may cause heating or short circuit in extreme cases.

The distances between center of pins 1, 2 and 3, measured with the coordinate measuring machine, presented results outside the specifications of the standard. The analysis of these pins also allowed the identification of geometric deviations of parallelism and perpendicularity. These deviations are not addressed by the standard. It is necessary to include the geometric deviations of parallelism and perpendicularity as complementary information in the standards of plugs and electrical sockets of the new Brazilian standard, since values of parallelism and perpendicularity can cause problems such as, coarse gaps, lack of entroment between the parts, leakage current and short circuits.

It is very important that manufacturers of electrical connections fully comply with the standards established by ABNT.

REFERENCES

[1] Associação Braszileira de Normas Técnicas 2013 ABNT NBR 14136: Plugues e tomadas para uso doméstico e análogo até 20 A/250 V em corrente alternada – Padronização V.4.

[2] Ben-Gal, I Outlier detection, In: Maimon O. and Rockach L. (Eds.) 2005 Data Mining and Knowledge Discovery Handbook: A Complete Guide for Practitioners and Researchers. Kluwer Academic Publishers

[3] Couto P R G, Damasceno J C, Oliveira S P, 2013 Monte Carlo Simulations Applied to Uncertainty in Measurement. In:. InTech [S.l.]: cap. 2, p. 27 – 51

[4] Donatelli D, Konrath C, 2005 Simulação de Monte Carlo na avaliação de incertezas de medição. Revista de Ciência e Tecnologia, v. 13, n. 25/26, p. 5 – 15

[5] Donatelli D, Gonçalves A, Schneider A, 2005 Metrologia Geométrica na Indústria: Tendências e Desafios. In: O Futuro da Indústria: a Importância da Metrologia para o Desenvolvimento Industrial p. 9-28

[6] Ellison R, Barwick J, Farrant D, 2009 Practical Statistics for the Analytical Scientist. A Bench Guide. 2nd. Edition

[7] Feng C, Hopp H, 1991 A Review of Current Geometric Tolerancing Theories and Inspection data Analysis Algorithms, NISTIR 4509, National Institute of Standards and Technology, USA

[8] Grossi A, 2008 Metodologia para Avaliação de Incerteza na Medição de Propriedades Termofísicas pelo Método Flash Laser: Método de Monte Carlo aplicado a Modelos Dinâmicos de Saída Multivariável. Tese (Doutorado) — Universidade Federal de Minas Gerais

[9] Heping E, Xiangqian J, 2009 Evaluation and management procedure of measurement uncertainty in new generation geometrical product specification (GPS). Measurement 42, p. 654 – 660

[10] International Organization for Standardization 2008 ISO/TC 213: Dimensional and geometrical product specifications and verification – Business Plan. Executive Summary. Version: 5 Draft, 14p.

[11] ISO GUM, Avaliação de dados de Medição - Guia para a Expressão de Incerteza de Medição, 1ª edição brasileira. 2008.

[12] JCGM 2012 Evaluation of measurement data – The role of measurement uncertainty in conformity assessment

[13] JR. G, Souza R, 2008 Fundamentos de Metrologia Científica e Industrial. [S.l.]: Manole

[14] Junior G, 2014 Cálculo de incerteza de medições Unesp

[15] Kandikjana T, Shah J, Davidson K, 2001 A Mechanism for Validating Dimensioning and Tolerancing Schemes in CAD Systems, Computer-Aided Design, v. 33, p. 721-73

[16] Mavroidis C, Gatla K, 2002 A Review of Tolerance Analysis of Mechanical Assemblies, First year Report and Second Year Research Proposal, Department of Mechanical and Aerospace Engineering, Rutgers University, University of New Jersey

[17] Mathiesen O, 1997 Uncertainty of Measurement – understand the GUM. Advanced School of Metrology: Evaluation of Uncertainty of Measurement, Programa RH Metrologia, Angra dos Reis RJ

[18] MEYER R, 2007 Measurement uncertainty. Journal of Chromatography A, p. 15–24

[19] Nogueira M, Santos L, Oliveira J, Guimarães P, 2013 Desenvolvimento do Programa Computacional Analysis para Detecção de Outliers. Revista CIENTEC, Vol. 5, n. 2; pp. 40 – 49, Recife

[20] Oliveira C, Oliveira J, Bandeira M, Guedes G, Guimaraes P, Araújo R, Rolim T, 2016 Metodologia para Medição de Tomadas e Plugues de Acordo com o Novo Padrão Brasileiro Congresso Nacional de Engenharia Mecânica – CONEM

[21] Oliveira J, Silva N, Oliveira E, Xavier A, Cardoso L, Arão, W, Santos H, 2014 SQUAL – Sistema de Suporte à Qualidade. Manual do usuário. Instituto Federal de Pernambuco, Recife

[22] Page T, 2015 Study into the use of Tolerance Analysis in the Mechanical Design of Medical Devices. International Journal of Design Engineering, 6(2), pp.116-139

[23] Wandeck M, Sousa A, 2008 Análise Funcional e Metrológica dos Princípios de Taylor e da Independência na Especificação e Controle Geométrico de Produtos. 1º Congresso Internacioanal de Metrologia Mecânica – I CIMMEC. Rio de Janeiro