All papers submitted for publishing to the RECENT® journal are subjected to the scientific review procedure.

The objective of scientific review is to ensure that all papers accepted for publishing meet the requirement of an adequate scientific level and provide original and significant contributions to the respective field.

The scientific review procedures practiced by the RECENT® journal are "*Expert Peer-Review*" (scientific review by experts, including the members of the Scientific Board of the journal) and "*Editorial Board Peer-Review*" (review, scientific included, by the members of the Editorial Board). All members of the Scientific Board and of the Technical Board of the journal are holders of PhD degrees, are members of the scientific community and experts in their respective fields of activity.

The complete scientific review procedure of submitted papers practiced by the RECENT® journal is available at http://www.recentonline.ro/PeerRew.htm.

RECENT®

REzultatele CErcetărilor Noastre Tehnice

Industrial Engineering Journal

Transilvania University of Brasov, Romania

Vol. 14 (2013), No. 4(40) **ISSN 1582 - 0246**

ICEEMS 2013
7th International Conference on Economic Engineering and Manufacturing Systems

- selected papers -

40

November 2013

CONTENTS

Vol. 14, no. 4(40), November, 2013

All papers submitted for publication to the RECENT® journal undergo a peer-review procedure.

The objective of peer review is to verify and endorse that all papers accepted for publication are of adequate scientific level and include original and significant contributions in their respective field.

The RECENT® journal provides *Expert Peer-Review*, including by members of the Scientific Panel as well as *Editorial Board Peer-Review* by the members of the Editorial Board. All members of the Scientific Panel and of the Technical Panel have PhDs, are members of the academic community and experts in their respective fields of activity.

The received papers undergo initial *Editorial Board Peer-Review* by the members of the Technical Panel of the RECENT® journal, conducted mainly by the scientific secretaries. Evaluation concerns with priority whether the paper matches the fields covered by the journal and meets its standards.

Complete scientific evaluation procedure is available at http://www.recentonline.ro/PeerRew.htm

Electronic version of RECENT® journal, ISSN 2065-4529, is available at www.recentonline.ro

CONTRIBUTIONS AT THE MODELLING DIMENSIONS OF THE GAUGES BY THE WEAR OF THIS AND BY THE NUMBER OF VERIFIED PIECES

Constantin BUZATU, Iulian Alexandru ORZAN
Transilvania University of Braşov, Romania

Abstract. Based on the information's about the values of the constructive parameters and of the tolerance fields provided by the actual projection standards of the gauges for the control of the cylindrical revolution pieces, both exterior and interior, in the paper it is presented the most adequate mathematical models for the constructive and technological parameters which interfere with the active dimension calculation of the gauges, as well as the method of how it can be optimized the projection methodology by taking in consideration the production batch and the prescribed tolerance field, till the gauge must be replaced. Furthermore, it is presented the adequate mathematical models of admissible wear field depend on the constructive parameters of the gauge and the verified piece.

Keywords: gauge, wear, projection, cylindrical piece, standards

1. Introduction

Gauges are instruments for control, used for limitative dimensional and geometrical control deviation of the machined surfaces, being high productive, economical, practical and have no need for highly trained operators, used in serial and mass production conditions.

From theoretical point of view, the shape of the control end of the gauge corresponds to the shape of the conjugate piece which is being verified that is cushion for boring, respectively for horseshoe gauge like in Figure 1.

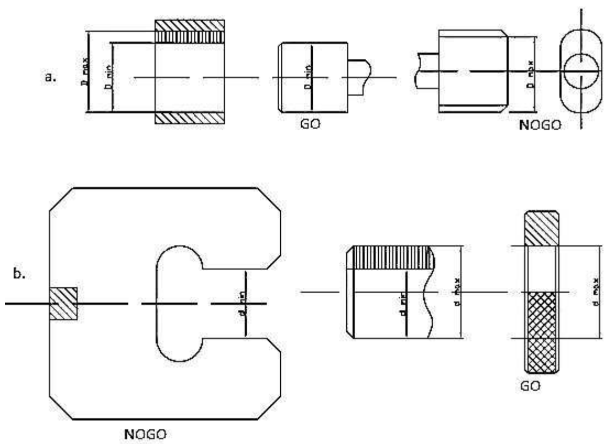

Figure 1.Gauges for smooth cylindrical pieces control
a- for boring; b- for horseshoe

In the actual standard ISO (STAS 8222-85) at the projection of the gauges for the active dimension "GO_{new}", "NOGO" and respectively "GO_{wear}", are taking in consideration only 3 factors: tolerance field of the verified piece, dimension of the piece and the tolerance field of the active part of the gauge which is defined based on experimental dates, rounded to integer value [1].

This kind of projection is not taking in consideration other factors that can influence the technical-economic efficiency of the gauges utilization [3, 5]:

- number of the verified pieces, notated with N_p;
- dependence of the prescribed wear field in terms of the production rate;
- the influence of thermic and elastic deformations which the gauges tolerate during the control time, because of that the gauges must be verified often with the help of the anti-gauges.

Based on the standardized scheme of placing the tolerance filed of the active dimensions of the gauges presented in the Figure 2 it is possible to obtain border fit outside the ones that are prescribed, even if the probability is very low.

Because of this, in the next steps, it is presented an original important contribution at the projection of gauges which is taking in consideration the wear field and the production rate.

2. Contributions at the mathematical modelling of the constructive and precision parameters of gauges

Based on the existing information's from ISO standard (STAS 8222-85) about the constructive and precision parameters of the gauges, mathematical adapted with an specialized soft, and taking in consideration the mathematical model of the wear and thermic deformations fields obtained with the checking a sufficient large number of experimental information (*H*), were obtained the next unitary mathematical models adequate for gauges projection.

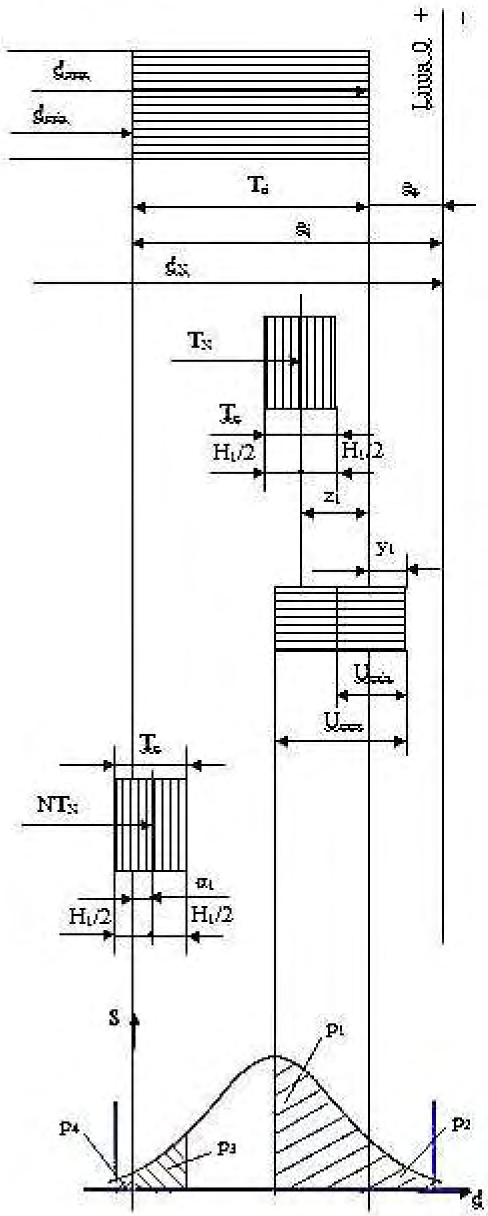

Figure 2. Placing scheme of the tolerance fields for the gauge projection

Fundamental tolerances *H*, H_1 used for the calculation of the execution tolerances at the gauges dimensions by taking in consideration the nominal dimension d^* of the verified piece (till 500 mm):

$$H, H_1(IT1) = 12.61\left(1.07 - e^{-0.0018 \cdot d^*}\right) \quad (1)$$

$$H, H_1(IT2) = 1.658 + 0.028 d^* - 2.103\left(d^*\right)^2 \quad (2)$$

$$H, H_1(IT3) = 2.528 + 0.041 d^* - 3.089\left(d^*\right)^2 \quad (3)$$

$$H, H_1(IT4) = \frac{3011.12 + 756.323\left(d^*\right)^{0.561}}{1280.785 + \left(d^*\right)^{0.561}} \quad (4)$$

$$H, H_1(IT5) = 3.005\left(d^*\right)^{0.3255} \quad (5)$$

$$H, H_1(IT6) = 4.763\left(d^*\right)^{0.3239} \quad (6)$$

$$H, H_1(IT7) = 7.592\left(d^*\right)^{0.3255} \quad (7)$$

Mathematical models of the constructive parameters *Z*, Z_1, *y*, y_1, α, α_1 by taking in consideration the verification dimension and the grade of precision for the verification piece (till 500mm) for the often utilized fit (IT6 ÷ IT12):

$$Z(IT6) = 1.7 + 0.0147 d^* - 3.068\left(d^*\right)^2 \quad (8)$$

$$Z(IT7) = Z_1(IT7) = 1.144\left(d^*\right)^{0.2979} \quad (9)$$

$$Z(IT8) = Z_1(IT8) = 1.6533\left(d^*\right)^{0.3322} \quad (10)$$

$$Z(IT9) = Z_1(IT9) = 3.8592\left(d^*\right)^{0.278} \quad (11)$$

$$Z(IT10) = Z_1(IT10) = \frac{167057 + 101603\left(d^*\right)^{0.7578}}{31820489 + \left(d^*\right)^{0.7578}} \quad (12)$$

$$Z(IT11) = Z_1(IT11) = 7.960\left(d^*\right)^{0.2671} \quad (13)$$

$$Z(IT12) = Z_1(IT12) = 8.018\left(d^*\right)^{0.2547} \quad (14)$$

$$y(IT6) = \frac{1}{1.033} - 0.1645 \ln\left(d^*\right) \quad (15)$$

$$y_1(IT6) = 1.0675\left(d^*\right)^{0.2606} \quad (16)$$

$$y(IT7) = y_1(IT7) = 1.0665\left(d^*\right)^{0.2606} \quad (17)$$

$$y(IT8) = y_1(IT8) = 2.4737\left(d^*\right)^{0.1558} \quad (18)$$

$$y(IT9 \div IT12) = y_1(IT9 \div IT12) = 0 \quad (19)$$

For the parameters α and α_1 the verification dimension is over 180 mm, and the mathematical models are:

$$\alpha(IT6) = \alpha_1(IT6) = \frac{-655.587 + 40.5786\left(d^*\right)^{0.592}}{182.267 + \left(d^*\right)^{0.592}} \quad (20)$$

$$\alpha(IT7) = \alpha_1(IT7) = \frac{-1031.26 + 41.1859\left(d^*\right)^{0.692}}{182.267 + \left(d^*\right)^{0.692}} \quad (21)$$

$$\alpha(IT8)=\alpha_1(IT8)=\frac{1649.666+15.421\left(d^*\right)^{0.92}}{17.645+\left(d^*\right)^{0.92}} \quad (22)$$

$$\alpha(IT9)=\alpha_1(IT9)=$$
$$=9.898-8.126\cdot e^{-8.83e^{-0.07}\left(d^*\right)^{2.399}} \quad (23)$$

$$\alpha(IT10)=\alpha_1(IT10)=$$
$$=\frac{-1671.402+128.701\left(d^*\right)^{0.61}}{224.923+\left(d^*\right)^{0.61}} \quad (24)$$

$$\alpha(IT11)=\alpha_1(IT11)=$$
$$=21.816-18.9e^{-3.008e^{-0.05}\left(d^*\right)^{1.816}} \quad (25)$$

$$\alpha(IT12)=\alpha_1(IT12)=$$
$$=\frac{-5162.348+205.929\left(d^*\right)^{0.692}}{182.267+\left(d^*\right)^{0.692}} \quad (26)$$

3. Mathematical models of the wear field of the gauges

In Figure 3 it is presented the tolerance filed scheme for the gauges and anti-gauges according to ISO (STAS 8222-85) corresponding to the cut out of the wear field outside the piece tolerance (the most common case).

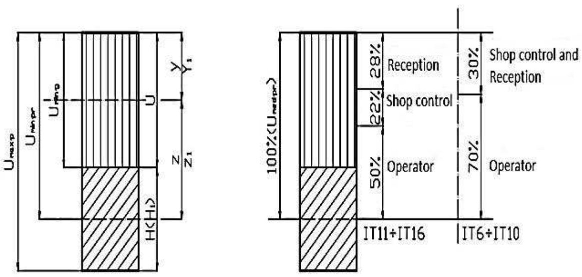

Figure 3. Wear fields of the gauges for the “GO” part and assignment of this on control types

Wear field U, estimated from the projection for all the dimensions “GO” in the new stage of the gauges, it is called also the minimal guaranteed wear U_{ming}. In the same time, it can be observed that it is possible also the variant in which the gauge can have a bigger wear field called the medium probability wear $U_{med.pr.}$ or a possible maximum one $U_{max.pos}$ like in Figure 3, by taking in consideration the final dimension of “GO”.

Also, in Figure 3 it is presented the way in which the medium wear filed is assigned between different operators which are using the gauges.

With the notations from Figure 2, it results the next possible relations of the wear field:

$$U_{\min.g}=y(y_1)+z(z_1)-\frac{H(H_1)}{2} \quad (27)$$

$$U_{med.pr}=y(y_1)+z(z_1) \quad (28)$$

$$U_{med.pos}=y(y_1)+z(z_1)+\frac{H(H_1)}{2} \quad (29)$$

For dimensions over 180 mm, in the equations (27)÷(29), it can be replaced y with $y' = y - \alpha$, respectively y_1 with $y_1' = y_1 + \alpha_1$.

Based on the information’s from STAS 8222-85, it were obtained the mathematical models of the wear fields by taking in consideration the tolerance level of the piece/ tolerance level of the gauge:

For IT6/IT2:

$$U_{\min.g}=\frac{1}{0.7281-0.193\ln d^*} \quad (30)$$

$$U_{\max.pos}=4.201+0.0368d^*-\frac{7.659}{\left(d^*\right)^2} \quad (31)$$

For IT7/IT3:

$$U_{\min.g}=1.3588\left(d^*\right)^{0.718} \quad (32)$$

$$U_{\max.pos}=\frac{3514.24+284.836\left(d^*\right)^{0.718}}{894.118+\left(d^*\right)^{0.718}} \quad (33)$$

For IT8/IT3:

$$U_{\min.g}=3.3572\left(d^*\right)^{0.2243} \quad (34)$$

$$U_{\max.pos}=4.7172\left(d^*\right)^{0.2599} \quad (35)$$

For IT9/IT3:

$$U_{\max.pos}=4.5742\left(d^*\right)^{0.2834} \quad (36)$$

For IT10/IT3:

$$U_{\max.pos}=\frac{13822.47+818.352\left(d^*\right)^{0.764}}{2170.649+\left(d^*\right)^{0.764}} \quad (37)$$

For IT11/IT5:

$$U_{\max.pos}=9.4228\left(d^*\right)^{0.2838} \quad (38)$$

For IT12/IT5:

$$U_{\max.pos}=13.5163+0.409d^*-0.002\left(d^*\right)^2+$$
$$+8.433e^{-0.06}\left(d^*\right)^3 \quad (39)$$

For IT13/ IT7:

$$U_{max.p} = 19.4669\left(d^*\right)^{0.2719} \quad (40)$$

For IT14/ IT7:

$$U_{max.p} = 3.147\left(d^* + 33.529\right)^{0.6536} \quad (41)$$

For IT15/ IT7:

$$U_{max.p} = 6.2941\left(d^* + 33.505\right)^{0.6105} \quad (42)$$

For IT16/ IT7:

$$U_{max.p} = 348.418e^{\frac{-\left(d^* - 460.86\right)^2}{122205.5}} \quad (43)$$

4. Contributions to the optimization of the gauges projection

Based on the experimental information's refinement about the variation of the wear field of the gauges "GO" part by taking in consideration the number of verified pieces and the dimension of the piece were obtained the mathematical models for the wear of the interior diameter gauge U_t and for the exterior diameter U_p:

For the interior diameter gauge with Φ19:

$$U_t = 12.7\left(1.5 - e^{-0.1135N_p}\right) \quad (44)$$

For the interior diameter gauge with Φ38:

$$U_t = 25.4\left(1.49 - e^{-0.1062N_p}\right) \quad (45)$$

For the interior diameter gauge with Φ48:

$$U_t = 32\left(1.5 - e^{-0.1221N_p}\right) \quad (46)$$

For the exterior diameter gauge with Φ25:

$$U_p = 13.78\left(1.5 - e^{-0.11N_p}\right) \quad (47)$$

For the exterior diameter gauge with Φ46:

$$U_p = 30.73\left(1.49 - e^{-0.1N_p}\right) \quad (48)$$

In relation with the number of verified pieces (the number of pieces verified is 1000), the mathematical models are:

$$U_t = 28.0709 + 99.73N_p - 124.7333N_p^2 \quad (49)$$

$$U_p = -2.5719 + 8.9225N_p - 0.3607N_p^2 \quad (50)$$

For a suggestive comparison, in Figure 4 it is presented the variation model of the wear for the interior and exterior diameter gauge.

This kind of mathematical models allows it to adopt from the projection stage the optimal values of the constructive parameters Z, Z_1, y, y_1, in terms of the production plan, in this way it is possible to decrease at minimum the number of good pieces that considered scrap, respectively the number of scrap pieces considered good, if the gauges dimensions are fixed with the actual projection methodology.

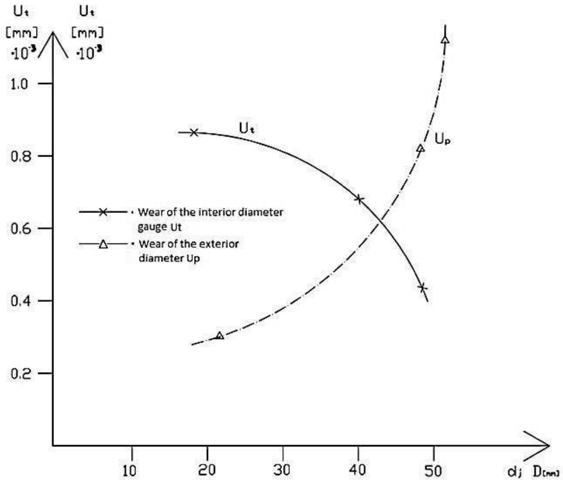

Figure 4. Experimental variation of wear for the interior diameter gauge U_t and exterior diameter gauge U_p in terms of each dimension
(*d* - interior gauge dimension; *D* - exterior gauge dimension)

5. Conclusions

Based on the information's presented in this paper it can be concluded the following:

1. In the conditions in which both the supplier and the client are interested to assure a higher quality (if it is possible with zero defects or total quality), the actual method of gauges projection must be improved, by taking in consideration both the number of the pieces that will be verified and the percentage of pieces accepted as scrap.

2. Because of the improved methods and manufacturing technologies, it is possible to decrease more and more the execution fields of the gauges and on this way to optimal place those in relation with tolerance field of the verified piece, and to study to obtain an efficient control from the point of verification precision.

3. It can be easily deduced frim Figure 4 that the wear of the exterior diameter gauge is with approximate 20 times bigger than then one for the interior diameter gauge for the same nominal value and the same number of verified pieces, from it can concluded that the production plan is a key factor in the projection of gauges, especially from the point of economic factors.

4. The optimization of gauges projection can also take in consideration the thermic or elastic deformations over the quality of the control, if this is performed in environment where the temperature is different from 20 °C, for which are valid the mathematical models presented in the relations (8)÷(26), when the control errors can became considerable [4], this fact is imposing the equalization of the temperature between the piece and the gauge by cooling with casting plates, emulsions, or the control to be performed in spaces with constant temperature.

5. The distinct form of the modelling relations of the parameters Z, Z_1, which are a characteristic of the wear filed of the gauges is imposing for the future a closer analyse of models in order to adapt the ones which are more closely to the one that are experimental determinate, in this way the relations (30)÷(43) will have a unite mathematical form.

References

1. Cosma, D., Buzatu, C. (2000) *Tolerante şi control dimensional* (*Tolerances and dimensional control*). CIT, ISBN 973-99051-3-78, Brasov, Romania (in Romanian)
2. Lepădătescu, B., Mihali, M. (2007) *Tolerances and Dimensional Control*. Transilvania University of Brasov, ISBN 978-973-635-768-8, Romania
3. Buzatu, C., Popescu, M. (2003) *Considerations Concerning Optimization of the Gauge Designing for the External Cylindrical Components*. Proceedings of the first international Conference on Challenges in Higher Education and Research in the 21st Century, Technical University of Sofia, ISBN 954-140-580-9, p. 152-153
4. Amza, G. (2001) *Tratat de tehnologia materialelor* (*Materials technology treaty*). Romanian Academy Publisher, ISBN 973-27-0910-3, Bucureşti, Romania (in Romanian)
5. Buzatu, C., Orzan, I.A. (2013) *Contributions at the Standardization Efficiency of the Limitative Inspection Tools Design of Geometrical-Dimensional Precision of the Pieces*. Proceedings in the Standardizations and Related Activities – A Means of International and Balkan Collaboration, ISBN 978-619-167-048-2, p. 108-113, Technical University of Sofia, Bulgaria