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ISSUES RELATED TO THE DESIGN OF CONTROL DEVICES AND RANGE LIMIT RESTRICTIONS - CASE STUDY

Abstract: *The machine-building industry frequently uses device control equipment so this paper aims to clearly present some case studies with the help of which we will highlight their measurement and control uncertainty. The case of limiting gauges will be analyzed using the relations for the delineation of the total limit control error ΔLT by applying the generalized method. The general calculation relations and the unitary character of the methodology allow us to develop a mathematical model. The methodology and the general calculation relations facilitate the analysis of existing methods and means to find out to what extent they correspond to the real requirements, establishing the limits of their use from a technical and economic point of view. The specific weaknesses and limits of classical control equipment will be highlighted because they are important in the design, choice and determination of their use in control operations and technologies.*

Key words: *Design, quality, control devices, tolerances, uncertainty.*

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1. INTRODUCTION

The limiting gauges are considered indispensable for serial production due to their high productivity, construction simplicity and easy usage.

When analysing these gauges according to the Quality Concepts [1], [2], must be taken into account some deficiencies and disadvantages, such as: high price due to their very low manufacturing tolerances -about ten times lower than the tolerance of the part to be checked and their high specialisation. It is known that each parameter has to be checked needs two gauges, one of “Go” (T) type, and the other of “Not -Go” (NT) type.

On the basis of the study [3], [4], [5], [6], we draw attention that the specialised literature present only descriptively and functionally these devices without mentioning anything about the specific control uncertainty. We think that it is appropriate and beneficial to show this aspect, both for gauges, and other control devices [6], applying the generalised methodology and relations for determining total limit control error ΔL_T.

2. CASE STUDY: SPECIFIC UNCERTAINTY FOR THE INTERNAL GAUGES-BORE CONTROL INFORMATION

On the basis of specialised literature [6], when the gauge control is performed, error ΔL_T is:

$$\Delta L_T = f(\varepsilon_{cp}, \varepsilon_u, \varepsilon_{id}, \varepsilon_{FMG}, \varepsilon_{fmg}, \varepsilon_{dc}, \varepsilon_{de}, \delta_\tau, \delta_{\tau p}) \qquad (1)$$

The meaning of the component errors is:

ε_{cp} - error characteristic to the measurement (control) principle;

ε_u - error caused by wear;

ε_{id} - error caused by the dimensional imprecision;

ε_{FMG} - error caused by the imprecision of the macro-geometrical shape;

ε_{fmg} - error caused by the imprecision of the micro-geometrical shape;

ε_{dc} - error caused by contact deformations;

ε_{de}- error caused by elastic deformations;

δ_τ - error caused by temperature;

$\delta_{\tau p}$ - error caused by the part’s temperature.

When the bores are checked with limiting plug gauges (Figure 1), parts are considered accurate if part „*T*” passes and part „*NT*” does not. Without further details, we show the nominal dimensions d_{nomT}, $d_{nom\,NT}$, the manufacturing dimensions d_T and d_{NT} and the limit wear dimensions $d_{T\,uz}$, for the limiting control gauges of the bores with the diameter *D≤180mm*:

- For „*T*” gauge, according to Figure 1, it results in:

$$d_{nomT} = D_{\min} + z \qquad (2)$$

$$d_T = d_{nomT} \pm \frac{H}{2} = (D_{\min} + z) \pm \frac{H}{2} \qquad (3)$$

$$d_{Tuz} = D_{\min} - y \qquad (4)$$

- For „*NT*”gauge:

$$d_{nomNT} = D_{\max} \qquad (5)$$

$$d_{NT} = d_{nomNT} \pm \frac{H}{2} = D_{\max} \pm \frac{H}{2} \qquad (6)$$

where:

D_{min} and D_{max} – represent the admissive limiting dimensions prescribed for the bores to be checked;

z – represents the dimension surplus for wear;

y – is the wear limit;

H – represents the gauge manufacturing tolerance;

Z, *y* and *H* have standard values [6],[7].

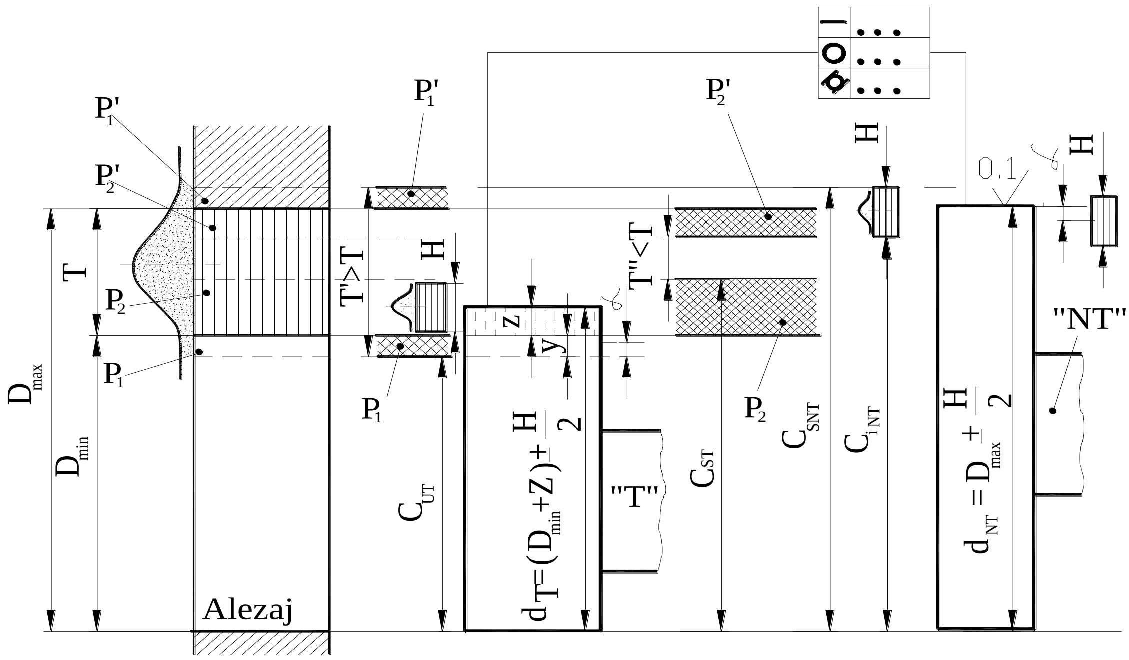

Figure 1 Showing the bore control uncertainty with internal gauges.

Next will mostly analyse explanation of the control uncertainty specific for these gauges. Thus, in order to analytically determine the error specific for the control principle ε_{cp}, we proceed the way presented hereafter.

In the case of gauges, we consider C_{UT} and C_{SNT} (Figure 1) disadvantageous ranges and there is the probability for the parts to be accepted within tolerance $T' > T$, which means some waste parts with dimensions in segments P_1 şi P'_1 will be accepted.

In this case, the beneficiary will be disadvantaged and, according to Taguchi principle, the society will suffer a loss [2], [3], [8].

In another disadvantaging situation, considering gauges with ranges C_{ST} and C_{INT} in Figure 1 we observe that when checked parts will be accepted within tolerance $T'' < T$. This means that the parts having values within the P_2 and P'_2 segments will be rejected, although they are correctly manufactured.

This will disadvantage the producer (the producer's risk), but the beneficiary's satisfaction increases on the account of the producer's economical losses [2], [8].

Probabilities $P_{1,\,2}$ and $P'_{1,\,2}$ for the mentioned risks can be determined [6], [7].

The control technologies have objectivity degree corresponding to the target if relation (7) is respected.

$$(P_1 + P_2 + P'_1 + P'_2) \leq (10 \ldots 20)\%T \tag{7}$$

If not, the control is not objective and, consequently, we must use other control means which have a limit measurement error compatible with the prescribed tolerance for the parts to be checked.

On the basis of what we presented for bore gauge control, the control uncertainty appears, being caused by the error characteristic for the principle (procedure) ε_{cpLs} at the superior limit. This principle can be determined using relation:

$$\varepsilon_{cpLs} = P'_1 + P'_2 = H \tag{8}$$

At the inferior limit of the tolerance for the part to be checked, the control uncertainty will depend on ε_{cpLi}:

$$\varepsilon_{cpLi} = P_1 + P_2 = z + y + 0.5H \tag{9}$$

The control principle error ε_{cp} will be determined according to the errors characteristic for the principle at the two limits L_i and L_s of tolerance T:

$$\varepsilon_{cp} = 1.5H + z + y \tag{10}$$

The chart in figure1 is valid for parts with dimensions below *180 mm*. If the parts' dimensions exceed *180 mm*, the P_1 and P'_1 probabilities will diminish with a value equal to α, named safety zone for compensating the measurement error . Specialised literature has standard values for the parameter α [6], [7].

Error ε_{cp} determined by relation (10) can be decreased if we decrease the H, y and z components, which will lead to increasing costs for performing and using these control means.

Error ε_u can be diminished by the correct prescription of the material, thermo-chemical treatments, correct maintenance and usage of gauges.

Errors ε_{id}, ε_{FMG}, ε_{fmg}, can be diminished by prescription the dimensional and shape precision, and also by manufacturing within the prescribed parameters. Errors ε_{dc} can be diminished by the correct usage of the gauge during checking. Errors δ_τ and $\delta_{\tau p}$ can be diminished by equalising the temperatures for the control means and the parts to be checked, and also providing the gauges with thermo-isolating handles.

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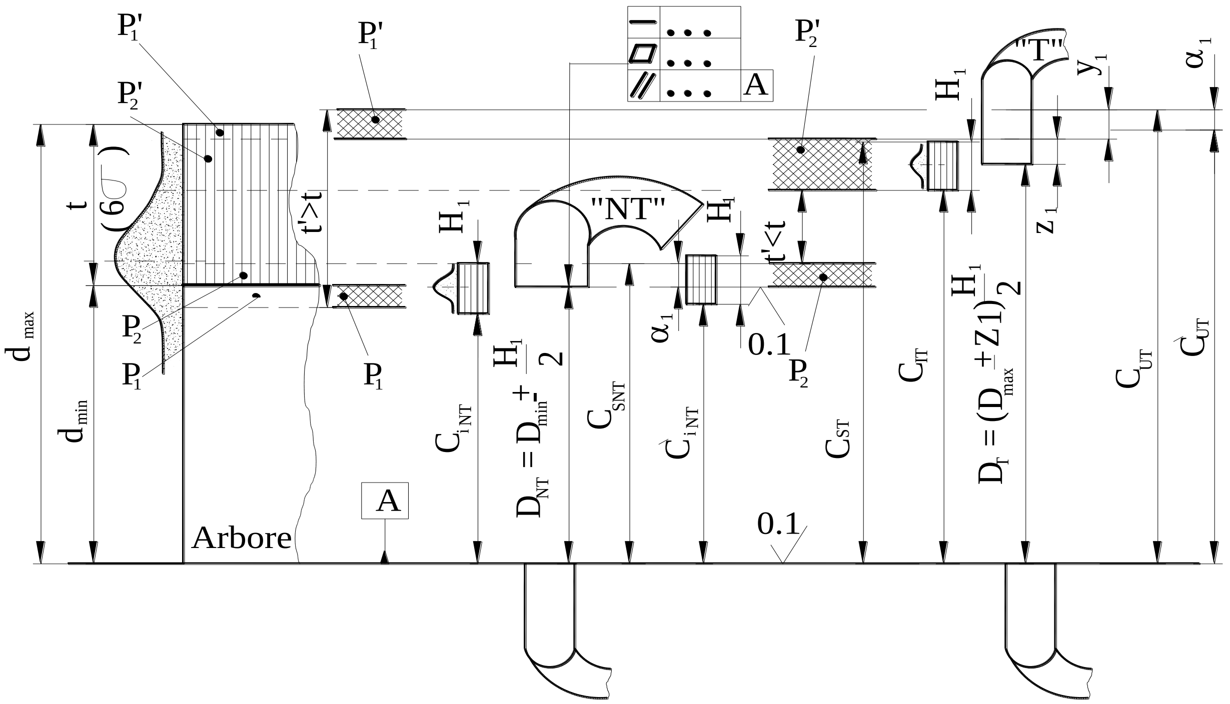

Figure 2 Showing the shaft control uncertainty with external gauges.

3. CASE STUDY: SPECIFIC UNCERTAINTY FOR THE EXTERNAL GAUGES - SHAFT CONTROL

These external gauges with “horse shoe” shape (Figure 2) have a more complex shape and the same advantages and disadvantages as the internal gauges. The error ΔL_T will have the same formula as relation (1).

The main disadvantage of checking with these gauges consists in the fact that, like in the other case, some parts situated outside the prescribed tolerance *t* can be accepted - parts having dimensions within P_1 and P'_1, and tolerance $t'>t$.

This phenomenon appears when using gauges with ranges C_{INT} and C_{UT} (Figure 2).

At the same time, if we use gauges with ranges C_{SNT} and C_{IT}, they will accept only the parts having dimensions within tolerance $t'' < t$. This means some accurate parts will be rejected, because they have dimensions within segments P_2 and P'_2, which disadvantages the producer and advantages the client, with all the positive and negative aspects which accompany this phenomenon [3], [4].

Probabilities P_1, P_2, P'_1, and P'_2 can be calculated the same way as in the case of bore control.

For gauges having dimensions over *180 mm*, segments P_1 and P'_1 and, implicitly, tolerance t' decrease by $2\alpha_1$ (Figure 2).

Like gauges for bore control, limiting gauges for shaft control have the error characteristic for the principle at the superior limit:

$$\varepsilon_{CpLs} = P'_1 + P'_2 = 0.5H_1 + z_1 + y_1 \qquad (11)$$

and, respectively, at the inferior limit:

$$\varepsilon_{CpLi} = P_1 + P_2 = H_1 \qquad (12)$$

Error ε_{cp} will be:

$$\varepsilon_{Cp} = f(\varepsilon_{CpLi}, \varepsilon_{CpLs}) = 1.5H_1 + z_1 + y_1 \qquad (13)$$

In case it is difficult to evaluate the other component errors in relations (1) we can limit ourselves to errors ε_{cp} determined by using the relations (10) and (13), on condition they do not exceed *10 ... 15%* of the tolerance prescribed for the part to be checked.

Increasing flexibility of use and control precision by using the limiting gauges is possible by designing a construction based on the principle of precise assembling (*AS*), treated in a separate papers [4], [5], [6].

For error ε_{de} we anticipate from the project stage a dimension corresponding to the gauge body and having the rigidity corresponding to the target. At the same time, we must correctly use the gauges, avoiding too big forces. For the other error types, the partial or total elimination measurements are the same as for bore control gauges.

We observe the same deficiencies concerning uncertainty control also in case of gauges for checking the distance between the bores’ shafts. We must calculate ΔL_T [6], [7] and take the same measures as for gauges presented in this paper.

4. CONCLUSIONS

When an inadmissibly high error is present, the control of the manufacturing precision has no objectivity and, consequently, there is the risk of either accepting some parts which exceed tolerance *t* –"the beneficiary's risk" phenomenon, or rejecting some parts which, in reality, are correctly manufactured –"the producer's risk" phenomenon, without the operator realising this phenomenon, which, according to the present concepts concerning quality, will have disadvantaging technical and economical consequences and also will damage the producer's image.

The risks arising from the measurement uncertainty characteristic for the control means must be judicially analysed in order to take the necessary measure.

The measurement uncertainty must be an important factor in designing and conception of control technologies and in conception of control equipments in general; Δ_{LT} must be taken into account when performing Concurrent Engineering analyses - QFD analysis [1], [2], [8], [9]. Δ_{LT} must be considered as generating rejections and/or supplementary expenses or losses for the company.

The general methodology and the general relations for calculating error ΔLt make possible the rational interpretation of all the phenomena which appear during the control process, thus laying the theoretical foundations for conception, choosing and correct destination of control equipments.

Methodology and general calculus relations make it easier to analyse the existing methods and means to find out to what extent they correspond to actual requirement, establishing their usage limits from technical and economical point of view.

The unitary character of methodology and generalised calculus relations allows us to draw up a program (mathematical model) which is adequate for computer operations, having corresponding economical consequences.

Theoretical and applicative argument of uncertainty of measurement and control for control means widely used so that it can be created a solid data base concerning the errors, which appear during control and measurement processes. This data base will allow designing new control technologies and equipments which will minimize or even eliminate the components of the total measurement and control error Δ_{LT}.

We are sure that if you read the instructions carefully and prepare the paper exactly according to the instructions, you will have the satisfaction of a good published paper.

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