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About Geometrical Tolerancing Standards

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Abstract

Measurement techniques have advanced and the standards they are based on no longer correspond to them.The standards ISO/FDIS 1101:2000(E) and ISO/TR5460:1985 are analyzed from this point of view in the article below.Herein are highlighted the inconveniences of the evaluation of the dimensions, the use of Coordinate Measuring Machines (CMMs) for this purpose, the interpretation of the adjustments.At the end of the article proposals are made, at the conceptual level, for the corrections which should be made to improve these standardsity.
***Keywords**: dimensional control, tolerancing, Coordinate Measuring Machines (CMMs .*

1. Generalities

The main standards in force that define the theoretical framework for the evaluation of the geometrical deviations in form, orientation, position and beat, as well as the respective tolerances are:

- The international standard ISO/FDIS 1101:2000 (E)

"Geometrical specification of the product – Geometrical tolerance – Form, orientation, position and beat tolerances"

- The international standard ISO/TR 5460:1985 "' Geometrical tolerances – Form, orientation, position and beat tolerances – Guiding principles"

A deeper analysis of these standards shows that the theoretical framework they contain proves to be ambiguous, unclear and even inadequate from a mathematical and even physical point of view, leaving a whole range of implicit questions unanswered.

Under these circumstances, using the definitions, taken as such from the above-mentioned standards, as working instruments may lead to errors in the quantitative and qualitative errors of the geometrical deviations for the real surface, excluding at the same time the possibility of rigorously including this surface among the well-defined theoretical surfaces that limit it. We will exemplify below the statements made above by presenting concrete cases extracted from the above-mentioned standards.

2. Critical Comments on the International Standard ISO/FDIS 1101:2000

According to the standard ISO/FDIS 1101:2000 (E), for a cylindrical surface (without any specification whether it is an inner or an outer surface) the area of tolerance in cylindricity (fig. 2.1) is limited by two co-axial cylinders with a difference in radius equal to T, the cylindrical surface to be analyzed having to be between these two cylinders, with T being the value of the tolerance in cylindricity (a value equal to 0.1 in the example in fig. 2.2).

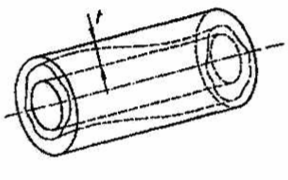


Fig. 2.1

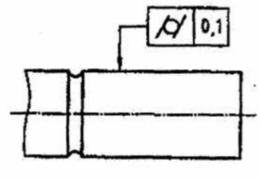
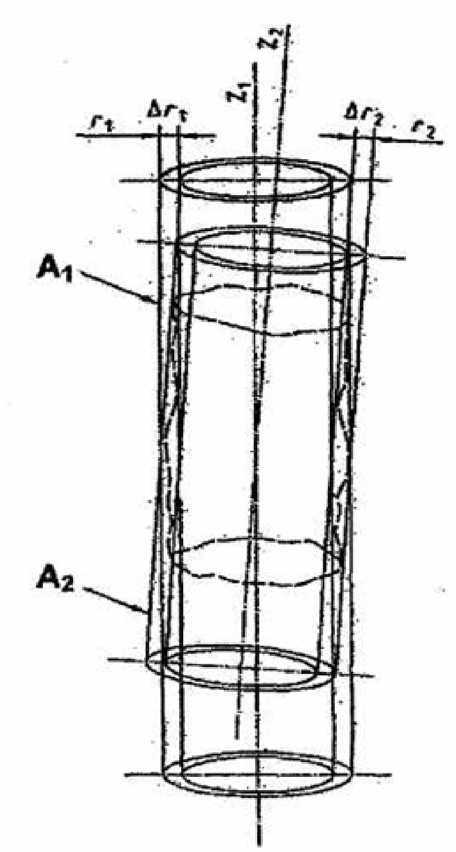


Fig. 2.2

At the same time, the standard shows that the cylindricity of a surface is considered correct if the respective surface is contained between two co-axial cylinders so that the difference between their radiuses is equal or smaller than the value of the specified tolerance "t".

Regarding the location of the axes of the two cylinders and the values of their radiuses, these should be chosen in such a way that the difference between the radiuses of the two cylinders has the smallest possible value



Presenting two cases, the first being two co-axial cylinders A_1 with the location of the axis z_1 and the difference of the radiuses Δr_1, and the second case being two co-axial cylinders A_2 having the location of the axis z_2 and the difference of the radiuses Δr_2 and $\Delta r_2 < \Delta r_1$, the standard considers z_2 as the correct location and the cylinders A_2, on condition that the cu difference of the radiuses $\Delta r_2 < t$ (fig. 2.3)

The standard does not mention anything about the way in which the two cylinders are determined, if they are the closest to the irregularities of the real surface, or whether there are areas where the irregularities exceed / go beyond the surfaces of the cylinders.

The above-mentioned uncertainties are generated by the fact that there is no rigorously mathematical method is used in the process, a method that, starting from the theoretical surface which is most appropriate for the real surface, should provide the co-axial cylinders between which the irregularities are placed and whose difference in radius should be minimum and, at the same time, should be smaller or equal to the value "t".

At the same time, in the case of the outer cylindrical surface, if we can admit that it is possible to establish a cylinder circumscribed to the peaks of the irregularities by using a series of successive measurements and trials, the question remains: How can the cylinder inscribed to the bottom of the irregularities be established by using the same methods?

The problem of evaluating the deviation from the cylindricity for the inner cylindrical surfaces is similar to those described above, with the only specification that in this situation we admit the possibility of establishing by successive measurements and trials the theoretical cylinder inscribed to the peaks of the irregularities, but having no possibility to establish here the theoretical cylinder circumscribed to the bottom of the irregularities.

For these two situations: the "bottom" theoretical cylinder for the outer cylindrical surface and the "bottom" theoretical cylinder for the inner cylindrical surface, the method of successive measurements and trials cannot provide rigorous results.

At the same time, the standard does not provide any method by which to determine the theoretical surface that is the closest, or, in other words, is most appropriate to the real surface that is to be analyzed (cylinder, cone etc.).

Because of the inherent machining errors due to the present-day level of technology, the resulting surface having form, orientation, position and beat deviations from the theoretically designed one, there will certainly be a totally different theoretical surface that is most appropriate to it, the latter being possibly a cylinder, but different from the one in the picture.

Knowledge of this cylinder allows the qualitative geometrical evaluation and the drawing of conclusions on the real form of the part and on its capability to carry out the function for which it was conceived / designed.

3. Critical Comments on the International Standard ISO/TR 5460:1985

In certain cases the basis of reference is constituted by a common axis of two separate bases of reference that can be established by inner or outer elements (inscribed, circumscribed or extensible).

The standard itself admits in these cases that the form and position deviations of the reference elements can influence the position of the common axis, which, obviously, has an influence on the tolerated elements.

In this case simulated reference elements are used that guide the real reference elements and, at the same time, their common axis constitutes / becomes a basis of reference.

The following figure (3.1) presents the case of two shaft-type reference elements guided by simulated reference elements, these being the smallest co-axial cylinders circumscribed to the reference elements.

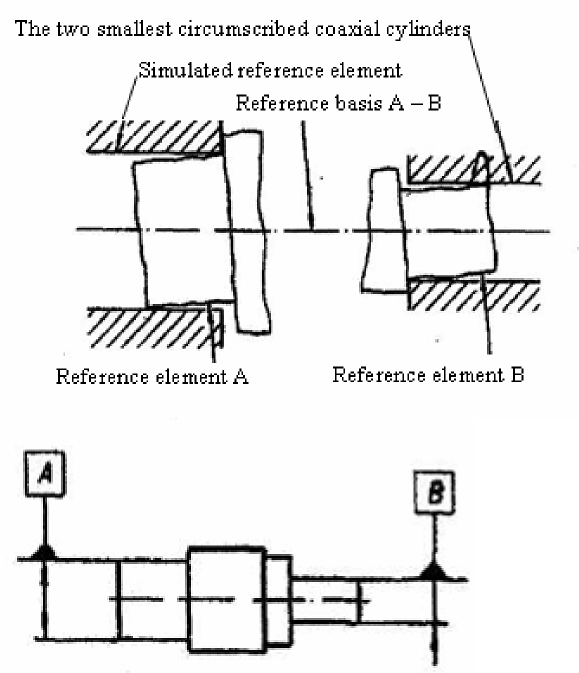


Fig. 3.1

The natural question arises about how the two smallest cylinders circumscribed to the two reference elements can be established and whether there is enough certainty that these cylinders are really the smallest.

Anyway, it is a considerable error to establish these cylinders with classical means of measurement.

At the same time, errors will occur from machining and alignment of the cylinder bore that materialize the two circumscribed cylinders, so it is quite improbable that they will have a common axis, their real axes being in fact different in position and orientation.

This fact adds additional errors to the measurement procedure which, cumulated with the ones mentioned above, increase the degree of uncertainty of the results

4. Conclusions on the Critical Comments

The result of everything presented so far is that, in determining the deviations in form, orientation, position and beat, according to the provisions of the standards in force, a series of errors are induced whose nature and size cannot be determined, and their influence on the results of the measurements and on the conclusions is large..

The factors generating these errors can be grouped in the following categories:

- The principles on the basis of which the verification is made.
- The participation of a reduced number of contact points in the measurements that are made; nothing is known about the rest of the points. The result of this is that the points taken into consideration cannot be defining for the surface being analyzed.
- The precision in execution of the devices for setting the part and of the measuring device, respectively.
- The precision in execution of the measuring apparatus itself.
- The position and the setting of the part and of the measuring device, respectively.
- The handling of the measuring device and the way it is positioned on the part.
- The size of the values indicated by the measuring device and their reading.
- The selection of the locations on the surface of the part where measurements are made. There is no control on whether they are representative (areas of maximum and minimum) and on their number (how many of them are defining for the surface being analyzed).

The form that is being analyzed is the one defined theoretically and not the real form obtained from manufacturing. The standards themselves admit the existence of certain errors in the results of the measurements, yet without defining and describing methods and principles for avoiding or diminishing.

5. Observations on the Way of Interpretation by Cmms Of The Cloud of Points Corresponding To An Analysed Surface

Using CMMs to collect points from the cloud corresponding to a surface and to interpret them has a series of advantages as compared to the classical measuring system; this has led to the more and more frequent use of CMMs, as well as to the improvement of the working mode that is characteristic to them.

In spite of this, there are a series of deficiencies in the current working mode of the CMMs that are presented below:

5.1. They do not communicate the definition of the error whose size they display.

E.g.: The machine indicates a 0.1 mm deviation from flatness, but we do not know what it represents exactly.

Every producer of CMMs can introduce their own definition of that deviation. This imposes the necessity for a standard to be drawn up that should define the type of error unequivocally and with mathematical substantiation.

5.2. They only tell qualitatively that as large a number as possible should be taken when investigating a surface, i.e. the bigger the number of points taken, the better the surface is evaluated.

But the machine cannot tell how big that number should be. Or which is the risk of investigating a smaller number of points. In other words, it cannot tell which the degree of reliability is when a certain number of points are analyzed.

5.3. They do not recognize whether the surface being analyzed is of the inner or outer type.

The machine gives the co-ordinates of the surface that passes through the center of the probe (this being a plane, a cylinder, a frustum of a cone etc.).

Yet, the real surface will be on one side of the center of the probe or on the other, the probing being made on an outer or inner contour, without any possibility to know exactly which surface it really is.

6. Observations on the Present-Day Concept of Evaluation of Adjustments

6.1. In the case of two parts that form a pressure adjustment, because of the irregular forms of the surfaces in contact and because of the dimensional deviations different for various sections, the character of the adjustment will change for two different positions in which the parts are set.

It is quite possible that, for one or several positions, the adjustment becomes loose.

So, the evaluation of the adjustment according to the nominal forms known beforehand is less than exact.

The situation is also similar for the loose adjustments.

6.2. The real looseness, the real pressure is in fact the difference in relief between the two surfaces.

The evaluation of the adjustment should be made by comparing the real surfaces taking into account their relief.

6.3. The replacement of the cloud of points with the theoretical surfaces is not relevant. What should be made is the quantification of the distances between the relief of the two surfaces and the theoretical interpretation of the results from the point of view of the character of the adjustment.

7. Proposals Refering to the Next Edition of the Standards ISO/FDIS 1101:2000 (E) and ISO/TR 5460:1985

As a consequence of the aspects presented above, the following problems are proposed to be solved:

7.1. The drawing up of a proposal for a standard that should define errors more correctly based on the mathematical interpretation of the cloud of points corresponding to a real surface of the part.

7.2. The theoretical drawing up of an automatic system for the recognition of the surfaces and of their character by the CMM, as compared to the present system in which the CMM requests information about the type and position of the real surface it measures.

7.3. The evaluation of the character of form and counter-form for the parts that form adjustments, i.e. the character of the real adjustment and not of the virtual adjustment formed by the theoretical defining surfaces of the parts.

7.4. The identification of the adjustment (loose or pressure) based on the analysis of the two clouds of points of the real surfaces.

7.5. The establishment of adjustment tolerances and the use of these tolerances for the evaluation of the adjustment instead of the surface tolerances that are used at present.

7.6. A new generation of standards that should use a totally different approach of the problem, the so-called "next generation", with a conceptually new reconstruction of the new system based on new theoretical foundations.

7.7. A new generation of standards regarding the dimensional control of mechanical components.

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Zusammenfassung

Die Messtechniken sind fortgeschritten und die Standarde, auf welchen diese beruhen, werden zur zeit nicht mehr entsprechend. Aus diesen Standpunkt werden im Beitrag die Standarde ISO/FDIS:2000(E) sowie ISO/TR5460:1985 untersucht. Es werden hervorgehoben die Mängel bezüglich der Massbewertung, der Benutzung von Messmaschinen auf Koordinaten (MK) zur Massbewertung sowie die Mängel bezüglich der Auslegung von Verbindungen. Am Ende des Beitrages werden auf der Konzeptebene die Verbesserungen vorgeschlagen, die diesen Standarden angebracht werden müssten.

Résumé

Les techniques de mesurage ont avancé et les standards sur lesquels elles se fondent ne correspondent plus aux réalités actuelles. De ce point de vue, on analyse dans l'article les standards ISO/FDIS:2000(E) et ISO/TR5460:1985. On met en évidence les inconvénients liés à l'évaluation des dimensions, à l'utilisation des Machines à Mesurer sur Coordonées (MMC) afin d'évaluer les dimensions et ceux liés à l'intérpretation des raccordements. À la fin de l'article, on propose au niveau conceptuel les améliorations qui devraient être apportées à ces standards.

Rezumat

Tehnicile de măsurare au avansat şi standardele care stau la baza acestora nu mai corespund. În articol se analizează din acest punct de vedere standardele ISO/FDIS:2000(E) şi ISO/TR5460:1985. Se pun în evidenţă neajunsurile legate de evaluarea dimensiunilor, de utilizarea Maşinilor de Măsurat în Coordonate (CMMs) pentru evaluarea dimensiunilor, interpretarea ajustajelor. În finalul articolului se propun la nivel conceptual corecţiile ce ar trebui aduse acestor standarde.