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Complementary writing of maximum and least material requirements, with an extension to complex surfaces

Bernard Anselmetti[a], Laurent Pierre[b,]*

[a] LURPA, ENS Cachan, Univ. Paris-Sud, Université Paris-Saclay, 94235 Cachan, France

* Corresponding author. Tel.: +33-1-47-40-29-97. *E-mail address:* laurent.pierre@ens-cachan.fr

Abstract

Maximum and least material requirements describe the strictly necessary fittability and accuracy functional requirements for an assembly involving connections with clearances. In the ISO 2692:2014 [1] dimensioning and tolerancing standard, the writing of this requirement violates the principle of independency and is limited to features of size. This paper proposes two complementary writings and several explanations for the application of the concepts. In order to make the definitions consistent with those of ISO 1101:2012 [2] standard, the requirements are defined by means of unilateral tolerance zones. For features of size, the dimension of the tolerance zone for the specified surface and for the reference is written directly between brackets in the specification. For all complex surfaces, the tolerance zone is defined by an offset surface of the nominal surface. The offset value is written between braces. The definitions of form, location and orientation specifications with these modifiers are given for simple elements and for a pattern of holes. Composite specifications, which associate orientation and location tolerance zones with respect to the same nominal, are defined. An example with flutter on a primary reference shows that it is no longer possible to use all the degrees of freedom to associate the subsequent references. The use of an orientation plane to deal with unidirectional chains of dimensions is defined. In terms of metrology, the characteristic to evaluate is the margin between the actual surface and the limit surface of the tolerance zone when the tolerance zone on the references is respected. This margin enables one, for example, to determine a capability.
Three applications present an assembly of a mechanism with clearances, a connection with a complex surface and a 3D chain of dimensions at least material which requires a composite specification.

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Keywords: ISO Standard, maximum/least material condition, functional tolerancing, composite specification,

1. Introduction

1.1. The context

In functional dimensioning, maximum or least material specifications should be used systematically for all connections with clearances because they define the strictly necessary requirements.

In practice, many designers are not familiar with the use of these specifications and many metrology computer programs are still unable to verify these specifications in perfect agreement with the definitions. One reason is probably the complexity of ISO 2692:2014 standard [1], which presents the concepts through the notion of virtual boundary along with very complex rules due to the violation of the principle of independency. Under very strict criteria, the dimension of the virtual boundary depends on the nominal diameter, the dimensional tolerance, the type of surface, the modifier and, possibly, the tolerance on the element of reference. Such information is very difficult to obtain in the numerical continuity context, especially for the calculation of 3D chains of dimensions and for metrology.

Figure 1, borrowed from figure A.13 of 2692:2014 standard, gives a schematic view of the rules for calculating the diameters of the virtual states on the toleranced element and the datum. Six values must be collected in four specifications.

The definition is limited to features of size, whereas many connections with clearances are created from more complex features.

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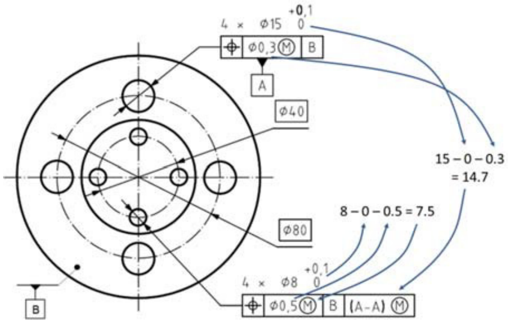

Figure 1 – Dimensions of the maximum material virtual states

Very often it is unnecessary to verify the local dimensions when the maximum or least material specifications are met.

This paper develops a more direct and complementary type of writing which satisfies the principle of independency and sets some rules for the application of the specifications.

1.2. The scientific context

The principle of maximum or least material specifications by virtual boundary are defined in ISO standards 2692 (1988) and in ASME standard (1994). This virtual boundaries are used as virtual gauges since the early 1990's by [3,4]. Robinson uses maximum material parts among assembly specifications, tolerance specifications and assembly tolerance analysis [5].

Some mathematical models can use the condition of the virtual boundary as T-maps [6], domains [7], analysis lines [8] and polytopes [9]. These different methods are applied to the tolerance analysis. Some papers confront these different methods [10,11]. Muthy uses simplex method for metrology [12]

Pairel and al. have exposed a conceptual model of “virtual fitting gauges” [13,14]. In this model, they can exploit maximum and least material requirement. They developed some algorithms implemented in a conventional software package for metrology. In [15,16], a presentation of the usability of this software is done in a pattern of holes.

Dantan and al. define the gauge with internal mobilities to limit the geometrical variations of the part [17]. The permissible geometrical variations are compared to the worst geometry of its environment. [18] use virtual gauges with internal mobilities to verify the maximum material and least material requirements.

Anselmetti uses these principles for functional tolerancing in assembling and for 3D tolerance stack-up [19].

2. Definition of the Ⓜ and Ⓛ tolerance zones

2.1. The tolerance zone for a cylinder

The new writing is simply to place in the specification the diameter of the virtual state of the specified surface and of datum. The meaning is exactly the same as classical writing Figure 1. This writing is new for ISO standard but is described in ASME Y14.5 2009 standard (section 4.1)

For a dimension, the diameter D of the tolerance zone is followed by Ⓜ or Ⓛ. For a specification, the diameter is placed between brackets after a Ø symbol. The unilateral tolerance zone is bounded by a cylinder of diameter D.

The maximum material tolerance zones are shown in figure 2:

- For a shaft, the tolerance zone is inside the cylinder of diameter D.
- For a hole, the tolerance zone is outside the cylinder of diameter D.

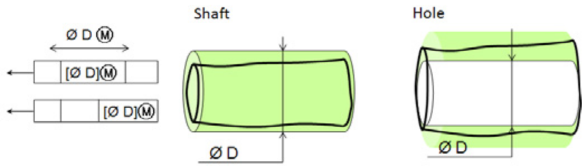

Figure 2 - The maximum material tolerance zone for a cylinder

The least material tolerance zones are shown in figure 3:

- For a shaft, the tolerance zone is outside the cylinder of diameter D.
- For a hole, the tolerance zone is inside the cylinder of diameter D.

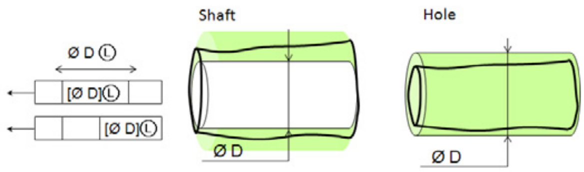

Figure 3 - The least material tolerance zone for a cylinder

2.2. Example

The maximum material is a means to guarantee the fittability of two parts by specifying a boundary between the elements (figure 4). The values of D and d must be chosen, depending on the desired minimum clearance, such that Min. clearance = D – d

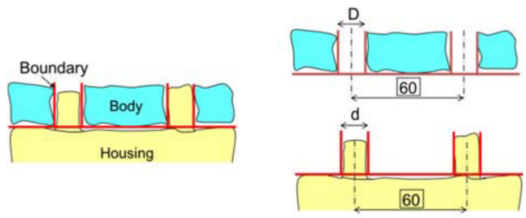

Figure 4 - Fittability with two pins

Using modifier Ⓜ, the writing on the drawing is immediate (figure 5).