What's New in the ASME Y14.5 2009 Standard !

2009-07-31

Bill Tandler
With editorial contributions from
Evan Janeshewski and Ron Grube

Multi Metrics & *Smart*GD&T

1. Introduction

In March 2009 the ASME has released a new Y14.5 standard, the first since 1994, and there is much in it of great interest and benefit. In order to help potential users decide whether or not to adopt it, we attempt to cast some light on its most important novelties. To set the stage, we start with a definition of GD&T as a whole, in order to be sure we are all on the same page. Next we ask why a new standard might be interesting. Finally, we provide a brief overview of the contents of this evaluation before we go into detail.

What is GD&T? GD&T is a symbolic language with which to research, refine and finally encode the functions of each feature of a machine part by specifying permissible limits of imperfection to guarantee its operation, assemblability, manufacturability and inspectability. Whereas CAD is dedicated to communicating the geometry of a part, GD&T is dedicated to communicating its functional requirements.
.
Why do we need a "new" Standard? Standards always represent our best understanding of a topic at the time they are released. In most cases we keep learning as we go, and in the case of GD&T we have learned a lot since 1994. The many changes contained in Y14.5 2009 represent very useful advances and clarifications which will further empower the designer to fully and reliably express the desired functions of machine parts. In particular, they will result in significant benefits for Tolerance Stack-Up Analysis, for clear communication of manufacturing objectives, and for empowering coordinate metrology software. As we might suspect, however, not everything needing attention can be addressed in a new standard, and there are a few disappointments which also need to be logged.

Overview of the Most Important Changes: The most important changes in the 2009 Standard are presented in three groups. Click on any topic to go there directly and then hit the "Return" button to come back, or simply scroll through the entire article. In order to fully comprehend much of this overview, it is imperative to have a copy of the 2009 Standard at hand to study the figures referenced in the explanations, which limited space does not permit us to duplicate here.

2. New and refined Concept Definitions

   2a. Material Condition Modifiers
   2b. Geometric Tolerance Value Modifier Details
   2c. Material Boundary Modifier Details
   2d. Datum Feature Simulators
   2e. Datums
   2f. Actual Mating Envelopes

3. New and refined Tools

   3a. Datum (Feature Simulator) Translation Modifier: ►
   3b. Degrees of Constraint Modifiers: [u,v,w,x,y,z]
   3c. Explicit Datum Feature Simulator Size and Location Modifiers: [BSC] / [Ø15]

3d. Movable Datum Target (Simulator) Symbol
3e. Composite Feature Control Frames - Increased numbers of Tiers
3f. Datum Reference Frame Axis Identifiers: X[A,B,C], Y[A,B,C] and Z[A,B,C]
3g. Unequally Disposed Profile Modifier: (U)
3h. Non-Uniform Modifier: [NON-UNIFORM]
3i. ALL OVER Modifier: (())
3j. Continuous Feature Modifier: <CF>
3k. Independency Modifier: (I)
3l. The “True” Modifier: TRUE

4. Disappointments

4a. Loss of the RFS and RMB Modifier Symbols (S)
4b. Failure to Clean up or Eliminate the Concentricity & Symmetry Tools
4c. Failure to Clean up the Radius Tools
4d. Failure to Clarify the “Datum Feature Shift” Concept
4e. A Still only Partially Adequate Topic Index.
4f. Incomplete Explanation of the Functional Objectives of the “Geometric Tolerance Value” [Tolerance Zone Size] Modifier (L)
4g. Need to Eliminate the Term “Resultant Condition” and Refine the term “Virtual Condition”
4h. Inadequately Precise Definition of a Basic Dimension
4i. Need to Discontinue use of the Word “True”

2. New and Refined Nomenclature, Definitions & Effects

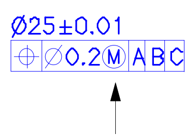
2a. Material Condition Modifiers - (S), (M) and (L)

What: Clarification of Concepts and Separation of the Modifiers into two Groups: “Geometric Tolerance Value” and “Material Boundary” Modifiers”, plus Elimination of the explicit Modifier (S).
Where: §2.8 pp.29 and §4.11.3 – 4.11.8 pp.59-63.
Objective: To clearly differentiate between the effects and use of these modifiers when applied to tolerance values versus datum features.
Ratings: Usefulness [high]

In order to significantly clarify their different effects, the 2009 Standard separates the material condition modifiers (S) [no longer defined], (M) and (L) into the two functional groups defined below: 1) “Geometric Tolerance Value” modifiers when associated with tolerance values, and 2) “Material Boundary” modifiers when associated with Datum Features.

Unfortunately, the 2009 Standard forbids explicit use of the symbol (S). For details, see Section 4.a).

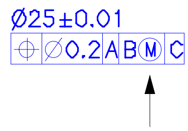
“Geometric Tolerance Value” Modifiers: These modifiers are associated with the tolerance value in a feature control frame, and fix or permit an increase in the size of a tolerance zone. They are decoded as follows when reading a Feature Control Frame:



- RFS = “Regardless of Feature Size” – the default modifier [no symbol]
- MMC = “at Maximum Material Condition” – symbol (M)
- LMC = “at Least Material condition” – symbol (L)

See Section 2.b of this document for clarification of their functional impact.

“Material Boundary” Modifiers: These modifiers are associated with the Datum Features referenced in a feature control frame, and determine the stabilizing or mobilizing impact of Datum Feature Simulators during the Datum Reference Frame establishment process. They are decoded as follows when reading a Feature Control Frame:



- RMB = “simulated Regardless of the Material Boundary” – the default modifier [no symbol]
- MMB = “simulated at the Virtual Maximum Material Boundary” – symbol (M)
- LMB = “simulated at the Virtual Least Material Boundary” – symbol (L)

See Section 2.c of this document for clarification of their functional impact.

DETAILS

Although the 2009 nomenclature changes for the individual modifiers provide substantial improvement by finally differentiating between their names in accordance with their different applicability, a last recommended step would be to rename their groups as follows, to provide a thoroughly visceral connection with their functions:

1) Current: “Geometric Tolerance Value” modifiers.
   Recommended: “Tolerance Zone Size” modifiers.

2) Current: “Material Boundary” modifiers.
   Recommended: “Tolerance Zone Mobility” modifiers.

The intrinsic purpose of Feature Control Frames is to define the shape and size of tolerance zones, and the coordinate systems relative to which they are to be oriented and located.

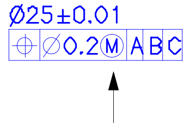
The impact of the newly named “Geometric Tolerance Value” modifiers is to specify whether a tolerance zone is to be fixed in size in the presence of the RFS modifier, or be free to expand in the presence of an MMC or LMC modifier. They are in fact “**Tolerance Zone Size**” modifiers. Why not call them that?

The impact of the newly named “Material Boundary” modifiers is to determine the permissible “mobility” of a Datum Reference Frame relative to a particular Datum Feature by specifying the behavior of its simulator. Whereas the RMB modifier “stabilizes” the Datum Reference Frame relative to the specified Datum Feature, the MMB modifier (M) “mobilizes” the frame, and the LMB modifier (L) “loosens” the frame relative to the specified Datum Feature. Since tolerance zones are attached to Datum Reference Frames by Basic dimensions, the impact of the “Material Boundary” modifiers is to either stabilize or mobilize the tolerance zones as well as the Datum Reference Frame relative to the Datum Features of the part, and therefore to encode whether mutual play between mating parts may or may not be taken advantage of during assembly. As a result, they are in fact “**Tolerance Zone Mobility**” modifiers. Why not call them that?

2b. “Geometric Tolerance Value” Modifier Details

Return

What: Clarification of the Method for Calculating “Bonus” Tolerance Values.
Where: §2.8.1 through §2.8.5 pp.29-31.
Objective: To clarify the process for determining of the effective size of a tolerance zone under the influence of the “Geometric Tolerance Value” modifiers (M) and (L)..
Ratings: Usefulness [high]



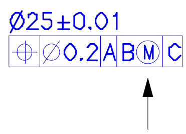
The methods for determining the effective size of a tolerance zone under the impact of an (M) or (L) modifier are clarified in the indicated paragraphs.

DETAILS

In particular, in the presence of the modifier (M), the specified tolerance increases by the absolute value of the difference between the MMC size of the feature and its unconstrained, in-space actual mating size, and in the presence of the modifier (L), the specified tolerance increases by the absolute value of the difference between the LMC size of the feature and its unconstrained, in-material actual mating size.

2c. "Material Boundary" Modifier Details

What: Expanded Applicability and Impact Clarification.
Where: §4.11.3 p.59 through §4.16 p.74. Figs. 4-29 through 4-32 pp.71-74
Objective: Refinement of Datum Reference Frame Establishment processes in the case of planar and non-enveloping Datum Features.
Ratings: usefulness [high]



In addition to common features of size, the 2009 Standard makes the RMB [no symbol], MMB (M) and LMB (L) "Material Boundary" modifiers applicable to location constrained, planar and non-enveloping, rotation constraining Datum Features, and thereby closes a significant "black hole" in all previous versions of the Standard. It does so by allowing the designer to use these modifiers to clearly differentiate between alternative functional objectives in ways not possible before. For details, see Y14.5 2009 Figures 4-29 through 4-32 on pp.71-74.

2d. Datum Feature Simulators

What: Concept Update (True Geometric Counterpart)..
Where: §1.3.17 p.3 + §4.5 & 4.6 p.53 + §4.11 through 4.17 pp.59-75.
Objective: To clarify the Datum Reference Frame establishment process.
Ratings: usefulness [high]

For purposes of defining the Datum Reference Frame establishment process, the 2009 Standard substitutes the concept of the Datum Feature Simulator – "a theoretically perfect, or physically almost perfect, inverse Datum Feature" – for the "True Geometric Counterpart" concept, allowing for a much more visceral understanding of the Datum Reference Frame establishment process.

DETAILS

In particular, a Datum Feature Simulator, whether theoretically perfect, or physically "almost" perfect, is now clearly understood as the entity:

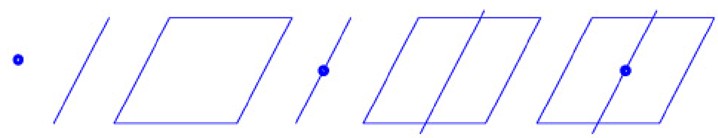
- from which we extract Datums,
- in which we first establish Datum Reference Frames, and

- with which we transfer Datum Reference Frames to actual parts by marrying their Datum Features to their simulators.

These concepts together with the new “Material Boundary” modifier terminology, significantly improve the comprehensibility of the Datum extraction and Datum Reference Frame establishment processes.

2e. Datums

What: Concept Clarification.
Where: Fig. 4-3 p.50 and §4.11 pp. 59-65.
Objectives: To improve users’ understanding of these concepts in order to ensure better implementation in Design and better application in manufacturing and coordinate metrology.
Ratings: usefulness [high]



The 2009 Standard significantly clarifies the concept of Datums showing for the first time that Datums are extracted from Datum Feature Simulators - not from Datum Features - that a Datum can be one of the six alternatives illustrated above, and exactly which Datum type a particular simulator defines. The new Standard further shows which degrees of freedom each Datum type constrains when acting as a primary Datum – see Fig. 4-3 p.50.

DETAILS

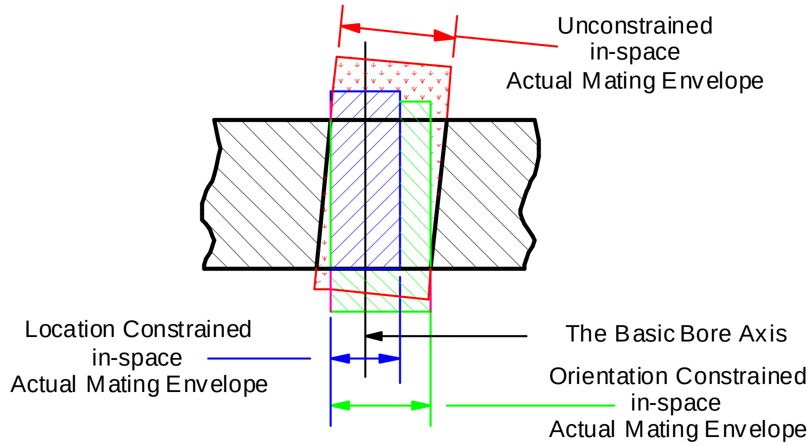
Unfortunately the new Standard fails to state the very simple general rule for extracting Datums from Datum Feature Simulators, namely: “Datums are the minimum integrated set of a single mathematical reference point, and/or axis, and/or plane which together fully characterize the orientation and location of a Datum Feature Simulator.” Thus there are six possible Datums: 1) a single point, 2) a single line, 3) a single plane, 4) a point on a line, 5) a line in a plane and 6) a point on a line in a plane. Although missing some important instances, these are clearly shown in Fig. 4-3 p. 50.

2f. Actual Mating Envelopes

What: Concept Clarifications.
Where: §1.3.25 and §1.3.26 pp. 4-5.
Objectives: To improve users’ understanding of these concepts in order to clarify their impact on manufacturing and coordinate metrology processes.
Ratings: usefulness [high]

The referenced paragraphs in the 2009 Standard clarify the concept of the “Actual Mating Envelope”, and make valuable contributions to inspection and manufacturing process control in spite of some terminology difficulties.

In fact, the “Actual Mating Envelope” of an actual physical feature is the effective “in-space”, or “in-material” envelope which just includes or excludes all the points on its surface under three different conditions: 1) unconstrained, 2) orientation constrained, or 3) location constrained. The terminology difficulties stem from the use of only two terms “unrelated” and “related” to refer to the three listed conditions, and are increased by the use of the term “minimum material”. The three in-space cases are illustrated in the figure below.



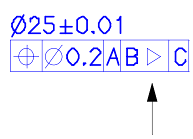
The Actual Mating Envelope concept has two major applications: 1) It is the basis for calculating a tolerance zone size bonus in the presence of the "Geometric Tolerance Value" modifiers (M) and (L). 2) It is the basis for determining the "Actual Mating Size" of a feature based on a size control under the impact of the Envelope Rule.

3. New Geometry Control Tools

DATUM REFERENCE FRAME ESTABLISHMENT

3a. Datum (Feature Simulator) Translation Modifier: ►. Return

What: Definition and Impact.of a new Datum Reference Frame Establishment Tool
Where: §3.3.26 p.44 & §4.11.10 p. 63, Fig. 4-19 p.64 & Fig. 4-32 p.74.
Objectives: To improve the Designer's ability to properly encode functional design objectives as they relate to mating part interactions.
Ratings: usefulness [high]

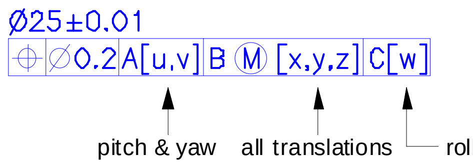


The new "Translation" modifier, which may be appended to a Datum Feature label in a Feature Control Frame, specifies that the associated Datum Feature Simulator (and its associated Datum) shall be free to translate toward or away from the primary axis or origin of a partially established Datum Reference Frame during the Datum Reference Frame constraining step. Availability of the "Translation" modifier allows the Designer to clearly distinguish between the function of a "clocking" Datum Feature and an "aligning" Datum Feature, namely between a feature which constrains rotational degrees of freedom by virtue of its location (clocking) and one which does so by virtue of its orientation (alignment).

Referring to Fig. 4-32 p.74 in the 2009 Standard, lack of a Translation modifier in alternative a) makes Datum Feature B a "clocking" Datum Feature, in other words, one whose orientation has no impact on roll constraint. The presence of a Translation modifier in alternative b) now makes Datum Feature B an "aligning" Datum Feature, in other words one whose orientation determines the alignment of the remaining axes of the Datum Reference Frame. Note: Both illustrations on the right in Fig. 4-32 are intended to represent a real part. Unfortunately the two bores are not "squiggly" and therefore do not look very real, but they are understood to be. Even more unfortunately the bore pattern in alternative b) is not rotated slightly clockwise as it must naturally be if the part in alternative b) is the same as that in a), which is absolutely the intent.

3b. Degrees of Constraint Modifiers: [u,v,w,x,y,z]

What: A new tool for explicit specification of the constraints for which each Datum Feature is responsible.
Where: §4.22 - §4.23 pp.81- 85, Fig. 4-45 p.83 & Fig. 4-46 p.84.
Objectives: To improve the Designer's ability to properly encode functional design objectives as they relate to mating part interactions.
Ratings: usefulness [high]



The 2009 Standard introduces a brand new tool which permits explicit specification of the degrees of freedom each Datum Feature is permitted to constrain. Not given a name in the Standard, but logically referred to as "Degrees of Constraint" modifiers, the bracketed lower case letters [u,v,w,x,y,z], when placed behind a Datum Feature label in a Feature Control Frame, serve to specify explicitly which degrees of freedom the Datum Feature is required and allowed to constrain.

DETAILS

The purpose of Datum Features is to reduce the rotational and translational degrees of freedom between two mating parts during an assembly process. Datum Features do this naturally in keeping with the "Rules of Natural Datum Reference Frame Establishment" partially extracted from the Y14.5 Standard and partially based on physical laws, as stated in Note 2. below. In some cases the natural processes need to be overridden to represent special functional requirements. Until the advent of the 2009 standard, the only available, but very limiting alternative was provided by the second and third tiers of a Composite Feature Control Frame, in which the referenced Datum Features are only permitted to constrain rotational degrees of freedom. With the advent of the 2009 standard, the designer can use the "Degrees of Constraint" modifiers (u,v,w,x,y,z) to specify exactly which degrees of freedom each Datum Feature may constrain. In fact these modifiers can be used in place of the second or third tier of a composite Feature Control Frame, which is highly recommended because of the broad lack of understanding of Composite Feature Control Frames. They can also be used across the board at all times, which, however, is not recommended due the benefits of not overcomplicating things.

Examples: In Fig. 4-45 p. 83, without the addition of the Degrees of Constraint modifiers [u,v,x,y], Datum Feature A would constrain translation along the Z axis, making Datum Feature B irrelevant. In Fig. 4-46 p.84, without the addition of the modifier [x,y], Datum Feature B would be required to constrain all the degrees of freedom of which it is capable, including roll [w], making Datum Feature C irrelevant.

Note 1: It is a physical fact – a natural law - that rotational constraints must be dealt with before translational constraints, thus rotation constraining modifiers must precede translation constraining modifiers in a Degrees of Constraint modifier, contrary to the unfortunate reverse specified in the 2009 Standard.

Note 2: Rules of Natural Datum Reference Frame Establishment:

1. Rule of Datum Feature Precedence (Y14.5M 1994 §4.4 p.52): Datum Features shall be used in the order in which they appear in the defining Feature Control Frame, reading from left to right.

2. Rule of Degrees of Constraint Precedence (*Smart*GD&T): Each Datum Feature shall constrain every rotational degree of freedom it can and may, before attempting to constrain any translational degrees of freedom.

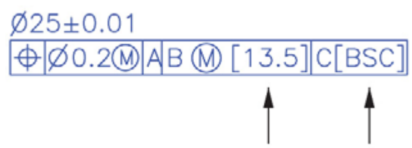
3. Rule of Non-Override (*Smart*GD&T): No Datum Feature may override

degrees of freedom partially or wholly constrained by higher precedence Datum Features.

4. Rule of Maximum Utilization (The Can-May-Must Rule) (*Smart*GD&T): If a Datum Feature can (is able to) and may (is permitted to) constrain a degree of freedom, it must.

3c. Explicit Datum Feature Simulator Size and Location Modifiers: [BSC] / [Ø15] / [20].

What: New tools are introduced to explicitly state the size or location of a Datum Feature Simulator.
Where §4.11.8 p.62, Fig. 4-31 p.73.
Objectives: To enable Designers to explicitly specify Datum Feature simulation requirements.
Ratings: usefulness [high]



These tools provide the ability to explicitly state the size of a Datum Feature Simulator of size, or the location of a planar Datum Feature Simulator.

DETAILS

There are three applicable cases:

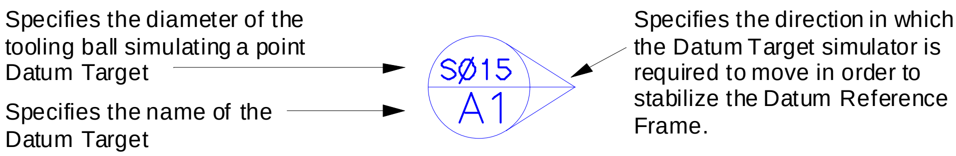
Datum Features of Size in the presence of an MMB or an LMB "Material Boundary" modifier and an explicit Datum Feature Simulator size modifier: If the Designer wishes to specify the size of a Datum Feature Simulator explicitly in order to speed the Feature Control Frame decoding process, or in order to impose a unique requirement, he can do so by placing the width (diameter) of the simulator in brackets following an MMB or an LMB "Material Boundary" modifier. See the EXAMPLE in §4.11.8 p.62.

Planar Datum Features in the presence of an MMB or an LMB "Material Boundary" modifier and an explicit Datum Feature Simulator location modifier: If the Designer wishes to specify the location of a planar Datum Feature Simulator explicitly in order to speed the Feature Control Frame decoding process, he can do so by placing the Basic location of the simulator in brackets following the "Material Boundary" modifier or a "Degrees of Constraint" modifier. See Fig. 4-31 c) p.73.

Planar Datum Features in the absence of any "Material Boundary" modifier and in the presence of a [BSC] Datum Feature Simulator location modifier : If the Designer wishes a planar Datum Feature Simulator to be located at the CAD defined location of its defining planar Datum Feature, he can do so by placing the letters [BSC] or [BASIC] in brackets following the Datum Feature Label or a "Degrees of Constraint" modifier. See Fig. 4-31 b) p.73.

3d. Movable Datum Target (Simulator) Symbol

What: A new tool is introduced to explicitly state translation requirements for Datum Target Simulators
Where: §3.3.27 p.44 & §4.24.6 p.85, Fig. 4-47 p.85 & Fig. 4-49 p.87
Objectives: To enable Designers to more clearly state Datum Target simulation requirements.
Ratings: usefulness [high]



This new symbol allows the Designer to explicitly specify that a particular Datum Target and its associated Simulator are not only free to move, but required to move when the part is inserted into the simulator set, and also the direction in which it must move in order to eliminate play between the part and the simulator.

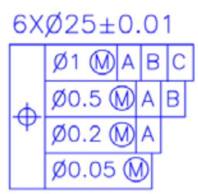
DETAILS

Just like Datum Feature Simulators, Datum Target Simulators are the source of Datums and also form the "almost" perfect world in which Datum Reference Frames are first established. In the case of non-rigid parts, Datum Target Simulators usually serve to constrain the features of the part during assembly and inspection operations and must therefore be fixed in location. In the case of rigid parts, where simulators work together to not only establish a Datum Reference Frame, but must also stabilize the part relative to the Datum Reference Frame for manufacturing purposes, the simulators must often be adjusted to compensate for Datum Feature size, orientation or location problems. It is under these conditions that the newly defined "Movable Datum Target" symbol enables a clear statement on the part of the designer as to the preferred method of achieving stability.

Thus, although the symbol is understood to permit a Datum Target to move, the functional result is obtained by moving the associated Datum Target Simulator.

3e. Composite Feature Control Frames - Increased numbers of Tiers. Return

What: The full power of the Composite Feature Control frame is made available.
Where: §7.5.1 pp.127-139. Figs. 7-38 through 7-55.
Objectives: To expand the power of the Composite Feature Control Frame.
Ratings: usefulness [high]

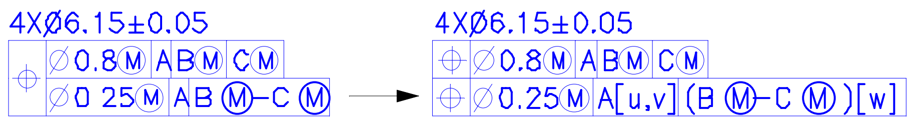


The 1994 Standard dedicated forty pages (93-133) to explaining the difference between compound Feature Control Frames (in which the Geometry Control Tool is used twice) and Composite Feature Control Frames (in which the Geometry Control Tool is shared twice), but failed to state the Rule of Composite Feature Control Frames, and limited the number of tiers to two. The 2009 Standard states the rule (§7.5.1.8 p135), also expands the applicability to a third tier referencing only one Datum Feature, and even allows a fourth tier referencing no Datum Feature.

DETAILS

The 2009 Standard finally generalizes the Composite Feature Control Frame tool to permit up to a total of four tiers, and, although well hidden, actually states the Rule of Composite Feature Control Frames (§7.5.1.8 p135) namely: "The datum features referenced in the second and all lower tiers of a composite feature control frame may only constrain rotational degrees of freedom".

However, if the Datum Features in the second and all lower tiers may only constrain rotational degrees of freedom, the 2009 Standard (see Fig. 7-42 p.138) has failed to correct an error in the 1994 Standard (see Fig.. 5-25 p.122) where datum features B and C are left in individual compartments in the second tier, but must in fact be referenced as composite, namely [B-C], in order to perform their function. This is true, because B, as a stand-alone Datum Feature, can only constrain the first two degrees of rotational freedom which A has already constrained, and therefore serves no purpose. C on the other hand, as a stand-alone, can, may and must constrain roll, but must do so on its own, instead of working in conjunction with B as it does in the first tier and must therefore continue to do. The following alternative Feature Control Frames properly encode the functional requirement:



Using a Composite Feature Control Frame.

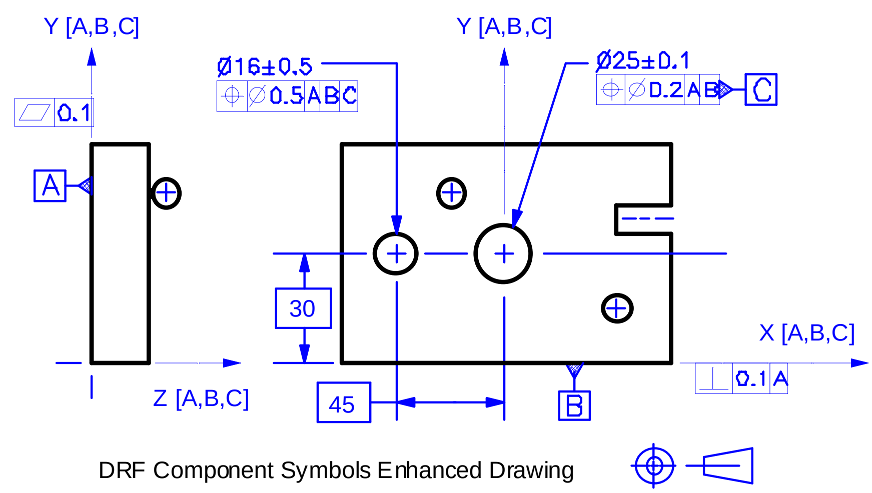
Using Degrees of Constraint Modifiers

Finally, the new Standard fails to demonstrate that the Composite Feature Control frame can be replaced using the newly introduced Degrees of Constraint modifiers (u,v,w,x,y,z), namely by following the first Datum Feature label with the modifier [u,v] and the second with the modifier [w].

DATUM REFERENCE FRAME AXIS LABELING

3f. Datum Reference Frame Axis Identifiers: X, Y and Z, or X[A,B,C], Y[A,B,C] and Z[A,B,C]. Return

What: New tools empower the design group to explicitly represent Datum Reference Frames in CAD models and Drawings.
Where: §4.21 p.79 Fig. 4-7 p. 52 & Fig. 4-43 p.82.
Objectives: 1) To accelerate the decoding of Feature Control Frames by visually displaying Datum reference Frame axes in CAD models and drawings. 2) To standardize coordinate measuring machine data reporting.
Ratings: usefulness [high]



DRF Component Symbols Enhanced Drawing

The 2009 Standard finally introduces the concept of a "coordinate system", stating that a Datum Reference Frame is in fact a coordinate system and moreover by default, a right handed coordinate system. It also enables the insertion of coordinate system axes into CAD models and drawings using X, Y and Z axis labels. In addition, and equally importantly, the new Standard provides the means to identify the Datum Features responsible for defining a particular coordinate system by allowing the addition of a bracketed list of Datum Features to the label: X[A,B,C].

DETAILS

There are huge benefits:

1) We now have the means to clearly communicate the impact of the Datum Features referenced in a Feature Control Frame by making the coordinate system they define visible.

2) By clearly specifying the axes of a Datum Reference Frame relative to the geometry of the part, we have the extremely valuable benefit of being able to ensure that coordinate metrology results produced by different parties are fully reconcilable - the x,y location of a bore in one report cannot turn up as a y,z location in another.

Note: The standard fails to comment on how to display the axes of partially mobile Datum Reference Frames, namely ones which retain substantial rotational or translational degrees of freedom. This will ultimately have to be dealt with as well. In the 3D CAD world this could be handled by animation.

SURFACE PROFILE CONTROL

3g. Unequally Disposed Profile Modifier: (U).

Return

What: The ability is provided to specify unequally disposed Surface Profile tolerance zones without resort to graphic methods.
Where §8.3.1.1 & 8.3.1.2 and Figs. 8-1 through 8-4 p.159-161 & Fig. 8-25 p. 177
Objectives: To enable the specification of unequally disposed Surface Profile tolerance zones to be captured in code rather than merely visually in a drawing.
Ratings: usefulness [high] implementation [extremely poor]

⌓	0.3 Ⓤ 0.3	A	B	C

Although not as clearly stated in the 2009 Standard as one might like, the default condition of a Surface Profile tolerance zone is that it be equally bilaterally distributed about the Basic (True) surface of the controlled feature as shown in Fig. 8-4 a) p.161.

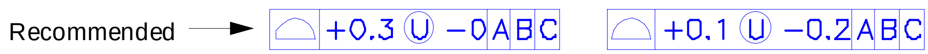
When there are reasons to specify a unilateral or an unequal bilateral Surface Profile tolerance zone, the 1994 standard only made it possible to do so visually in a drawing – see Figs. 8-4 a) - d) p.161. The 2009 Standard however, provides symbolic means for doing so using the "Unequally Disposed Profile" modifier (U) as also shown in Figs. 8-4 a) - d) p.161. Unfortunately, the method chosen to do so makes it difficult for users to "decode".

DETAILS

Y14.5 2009 Implementation of the Modifier (U): As set forth in §8.3.1.2 p.159 and illustrated in the first set of Feature Control Frames below, when the modifier (U) is specified, the tolerance value preceding the (U) in the Feature Control Frame represents the total Surface Profile tolerance, and the value following the (U) represents the portion of the tolerance zone which lies on the in-space side of the Basic surface. As illustrated in accordance with the Y14.5 2009 specification, in the first instance, the total tolerance is 0.3 mm and the tolerance zone is unilaterally in-space. In the second case, the total tolerance is again 0.3 mm, but only 0.1 mm is in-space.

Y14.5 2009 ⟶ | ⌓ | 0.3 Ⓤ 0.3 | A | B | C | | ⌓ | 0.3 Ⓤ 0.1 | A | B | C |

A Possible Alternative Implementation of the Modifier (U): As can easily be made part of a corporate modification of the Standard, the following alternative is suggested for consideration, namely that the tolerance value preceding the (U) represent the in-space portion of the tolerance zone and be preceded by a "+" sign to emphasize the fact, and that the value following the (U) represent the in-material portion of the tolerance zone and be preceded by a "-" sign to emphasize the fact. Since deviations in-space and in-material must be independently reported anyway, this method represents a far more functional, and far more easily decoded alternative. These two instances above are reformatted here:



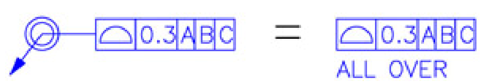
3h. Non-Uniform Modifier: [NON-UNIFORM].

What: A new tool enables clear, Feature Control Frame based referral to non-uniform Surface Profile tolerance zones.
Where: §8.3.2 p.161 Figs. 8-9 through 8-11 p.164.
Objectives: To bring attention to and enable separate specification of variable thickness and potentially unequally disposed Surface Profile tolerance zones.
Ratings: usefulness [high]

When the Surface Profile tolerance appropriate for one portion of a feature is not appropriate for another portion, but each tolerance value is to remain constant, both the 1994 and the 2009 Standard recommend using multiple Feature Control Frames together with "Between" modifiers, i.e. a↔b, to control each portion. However, whereas the 1994Standard provided no method for specifying a Surface Profile tolerance zone of variable thickness, the 2009 Standard does, using the [NON-UNIFORM] modifier in place of a tolerance value to direct the attention of the user to phantom line tolerance zone specifications on the drawing or to data contained in the 3D CAD model.

3i. ALL OVER Modifier: (()).

What: A new graphic symbol can now be used in place of a note.
Where §3.3.25 p.44 + §8.3.1.6 p. 161 Fig. 8-8 p.163.
Objectives: To replace a note with a symbol.
Ratings: usefulness [questionable]

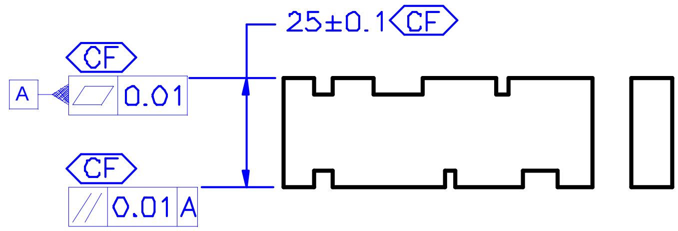


The 2009 Standard allows use of a newly introduced symbol to represent an ALL OVER Surface Profile requirement as shown in the drawing above, and includes a leader. Because the concept of ALL OVER does not apply to any particular feature of a part, but to all not otherwise controlled features, a leader seems unnecessary. Thus a stand-alone Feature Control Frame with the words ALL OVER may well remain the common implementation and is fortunately still permitted.

SIZE CONTROL

3j. Continuous Feature Modifier: <CF>.

What: A new symbol is provided with which to explicitly turn what might be individual features into a single (continuous) feature.
Where §2.7.5 p.29 Figs. 2-8 through 2-10 pp29-30.
Objectives: To specify that a group of identical, coaxial, co-midplanar or co-planar (?) features are to be dealt with as a single feature.
Ratings: usefulness [high] – applicability [seems to require further clarification]



This is a particularly useful, well conceived tool, but as presented appears only to be applicable to features of size (slab, slots, cylinders and spheres). It would seem natural that it be applicable to nominally coplanar, planar surfaces as well, as shown in the figure above. One must hope this is the case and that it will be clarified by the Committee in good time.

3k. Independency Modifier: (I).

What: A new graphic symbol is provided to break the Envelope Rule where functionally appropriate, and eliminate the need for a note.
Where §2.7.3 p.28 Fig. 2-7 p.28.
Objectives: To replace a note with a symbol.
Ratings: usefulness [high]

Ø25±0.01 (I)

Almost no one who uses any version of the Y14.5 Standard realizes that there is such a thing as an "Envelope Rule", or the absolute necessity of the rule in order 1) to guarantee the assemblability of mating features of size, and 2) to enable the use of the "Geometric Tolerance Value" and "Material Boundary" modifiers (M) and (L). If people are aware of the rule, they realize that there are also occasions when it doesn't apply, in particular for controlling the diameter of a garden hose. In the past, one would have had to add the words "PERFECT FORM AT MMC NOT REQD" to the size control in order to say so. The addition of the "Independency" modifier (I) is most welcome as a much more efficient way to accomplish the same thing, where we understand that "independent" means "independent of the Envelope Rule".

3l. The "True" Modifier: TRUE.

What: A note is added to make clear that a size dimension applied to a feature which appears skewed in a 2D drawing, in fact applies to the 3D feature.
Where: §1.8.2.3 p.14 & Fig. 4-28 p. 70
Objectives: To clarify a potentially confusing situation.
Ratings: usefulness [low] applicability [extremely rare]

Ø25±0.01 TRUE

This tool applies only to 2D representations (drawings) on non-normally oriented bores, slabs and slots, and is merely a clarifying convenience of probably little consequence. See also section 4.i.

4. Disappointments

Nothing is perfect, and there is always room for improvement. And different folks like different strokes. The following are therefore merely potentially interesting concerns, on which it seems some light should be cast.

4a. Loss of the RFS and RMB Modifier Symbols (S) Return

There are strong reasons to continue to allow the use of the (S) symbol. Reason 1): The more explicit the code, the more quickly it can be comprehended and its impact understood. If the controlled feature component is a symmetry component, a "Geometric Tolerance Value" [Tolerance Zone Size] modifier is automatically applicable. If a Datum Feature is a feature of size, or a location constrained planar surface, a "Material Boundary" [Tolerance Zone Mobility] modifier is automatically applicable. If there are no explicit modifiers present in these cases, the user remains uninformed as to the nature of the feature and must research the CAD model or the drawing in order to discover whether an RFS or an RMB modifier is applicable and make sure everything is in good order. Reason 2): If an (S) modifier is implied by default, but no modifier is present, the designer himself must wonder, upon reviewing the drawing, whether he considered the (M) and (L) alternatives, and must reconsider the problem to be sure the choice of (S) [oops!] is right. If explicit (S)'s are present, he is immediately informed on all counts, and can feel reasonably comfortable that they were intentionally chosen and need not be researched again.

Recommendation: It is strongly recommended that companies consider imposing the explicit use of the (S) modifier and make this deviation from the Y14.5 2009 Standard part of their corporate standard.

4b. Failure to Clean up or eliminate the Concentricity & Symmetry Tools Return

These tools should be special cases of the Position tool, but are defined such as to make them essentially useless and certainly confusing. The controlled feature component in the case of the Y14.5 defined Concentricity tool is the collection of "opposed point mid-points" which would be extracted from the surface of a bore or shaft by "dueling indicators" (a marvelous Jim Meadows term), leading to Actual values which confuse location offsets with form errors, but only sometimes. The controlled feature component in the case of the Y14.5 defined Symmetry tool is the median plane of a slab or a slot and that's all. In spite of these definitions, 99% of all CMM software systems treat both tools as if they were the Position tool, and report on axes and mid-planes. Furthermore, in the ISO 1101 Standard, both tools are in fact special cases of the Position tool. Arguments about this have been going on for some twenty years. It is time.

4c. Failure to Clean up the Radius Tools Return

In accordance with the Y14.5 1994 and 2009 Standards, both the Radius and the Controlled Radius tools define completely nonsensical, crescent shaped tolerance zones which tend to a tolerance of zero at the extremes and become ever more useless as the subtended angle increases above 90°. In order to fulfill its functional requirements, the tolerance zone should be defined as "circular ribbon-like" with the requirement that the plane containing it be perpendicular to the bounding feature surfaces, and that its circular mid-line be tangent to those surfaces. This is how radius requirements are generally assessed and reported in coordinate metrology software.

4d. Failure to Clarify "Datum Feature Shift" Concept Return

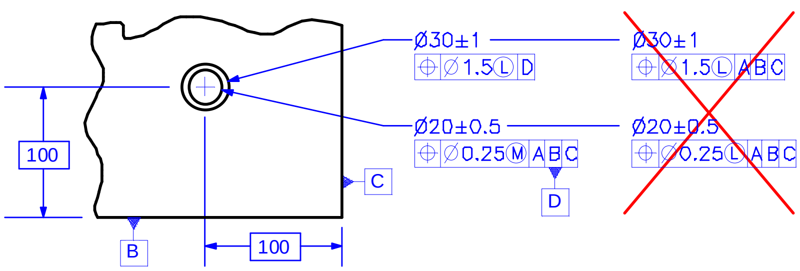
The term currently used to describe the impact of the "Material Boundary" modifiers MMB and LMB is "Datum Feature Shift" or "Datum Feature Displacement". See §4.11.9 p. 63. However, these modifiers do not lead to Datum Feature shift or displacement. Instead they lead to residual "mobilization" of the Datum Reference Frame - and therefore tolerance zone – relative to the specified Datum Feature, which can be purely translational, purely rotational or a combination of both, and in all but certain very special cases, there is no assignable numerical value. By contrast the "Material Boundary" modifier RMB leads to Datum Reference Frame "stability" relative to the specified Datum Feature. The words "Datum Feature Shift or Displacement" are therefore dangerously misleading and the cause of broad misunderstanding and misuse of the MMB and LMB modifiers. Recommended preferred nomenclature: "DRF Mobility" & "Tolerance Zone Mobility".

4e. A Still only Partially Adequate Topic Index.

Although the Index in the 2009 Standard is 10X better than in the 1994 Standard, there are many missing items, and NO PAGE NUMBERS. Someday.

4f. Incomplete Explanation of the Functional Objectives of the "Geometric Tolerance Value" [Tolerance Zone Size] Modifier (L). [§7.3.5.1 p.114 & Fig. 7-13 p.115]

Every "Geometric Tolerance Value" [Tolerance Zone Size] modifier encodes a particular feature function: (S) [whose symbol is now forbidden] encodes the "aiming" and "centering" functions. (M) encodes the "clearance" function, whereas (L) encodes a total of three functions: the "interference", the "overlap" and the "wall preservation" functions. Both the 1994 and 2009 standards fail to mention the first two of these functions, and at least in the application illustrated in Fig. 7-13 p.115, inappropriately recommend the use of (L). In particular, since the bore either serves an aiming function - requiring an RFS modifier - or a clearance function - requiring an MMC modifier - it should certainly not be referenced at LMC. On the other hand, the location of the external diameter does impact wall thickness, and is therefore appropriately given an LMC modifier, but which only makes sense when referenced to the bore – Datum Feature D - rather than to Datum Features A, B and C. The approach found in the 2009 Standard as well as the recommended alternative are shown in the illustration below:



4g. Need to Eliminate the Term "Resultant Condition" [§1.3.51 p.7] and Refine the Term "Virtual Condition" [§1.3.67 p.7] with the Terms "Virtual MM Boundary" and "Virtual LM Boundary".

The 1994 and 2009 Standards identify the two possible alternative, extreme conditions of a feature as either Virtual or Resultant. They also invert their applicability when the "Geometric Tolerance Value" modifier changes from (M) to (L). In fact, both extreme conditions are "virtual", namely are simply due to the combined effects of all the imposed requirements taken either in-space or in-material, regardless of the imposed modifier. The term "virtual" thus applies to two imaginary boundaries, one of which is in-space and is never completely filled with material, and the other of which is in-material and is never completely empty of material, both of which are impacted by the presence of an (M), an (L) or an implied (S) modifier. Thus both extremes represent "virtual" boundaries, and there is no need for the confusing word "resultant", given the wonderful new terms MMB (Maximum Material Boundary) and LMB (Least Material Boundary), which now allow us to refer to a Virtual MMB and a Virtual LMB to describe all possible alternatives. There are in fact six potential "virtual" conditions of a feature: 1) the unconstrained MMB, 2) the orientation constrained MMB, 3) the location constrained MMB, 4) the unconstrained LMB, 5) the orientation constrained LMB, and 6) the location constrained LMB, depending on the controls imposed on a feature.

4h. Inadequately Precise Definition of a Basic Dimension [§1.3.23 p.3]

The 2009 Standard defines a Basic dimension as "a theoretically exact dimension". However, all nominal dimensions and all tolerance values are also "theoretically exact", namely they are all followed by an infinite number of zeros - end of story. The functional definition of Basic dimensions is that they serve two and only two purposes, namely 1) to orient and locate tolerance zones relative to one another and relative to potentially imposed Datum Reference Frames, and 2) to mutually orient and locate Datum Targets, Datum Target Simulators and Datum Feature Simulators, end of story. It might also be helpful to state explicitly, that Basic dimensions shall always be fixed, other than for special purposes in the presence of a Datum Feature Simulator Translation modifier ►, or a Movable Datum Target symbol.

4i. Need to Discontinue use of the Word "True" Return

The use of the word "TRUE" is regrettable in that it continues the tradition of the terms "True Position" and "True Profile" which would much more appropriately be called "Basic Position" and "Basic Profile" to refer to the Basic dimensions which define the orientation and location of the associated tolerance zones. In the application at hand, surely the word NORMAL would even more clearly specify that the dimension applied only when taken normal, i.e. perpendicular, to the axis or mid-plane of the feature. Note: Use of the word "True" is additionally regrettable in that the Y14.5 standard refers to a CAD defined "perfect" dimension, whereas the long established meaning in the world of metrology is to represent the unknowable "actual" size, orientation or location of a real feature in a real part, in contrast with its "measured" dimension.

END

Multi Metrics & *Smart*GD&T

Multi Metrics, Inc., established in 1975, is the home of ***Smart*GD&T**, a rule based approach to implementing the ASME Y14.5M 1994 and ASME Y14.5 2009 Standards which makes it possible to replace the "decoration" of CAD models and drawings for later "interpretation" with strict "encoding" and "decoding". The "encoding" process is the rule based specification of permissible limits of imperfection which allow efficient manufacturing, and reliable coordinate metrology, and which guarantee assembly and operation prior to drawing release. The "decoding" process is the rule based conversion of GD&T code into reliable TSUPA™ (Tolerance Stack-Up Analysis), into reliable manufacturing processes, and into uniquely defined metrology processes. For more information, visit

www.multimetrics.com

Return