1. Name the following Geometry Control Tools

1.1 Ø XX±0.XX “Diameter”
1.2 ←→ XX±0.XX “Width”
1.3 □ “Flatness”
1.4 ⊥ “Perpendicularity”
1.5 // “Parallelism”
1.6 ⊕ “Surface Profile”
1.7 ⊞ “Position”
1.8 XXX “Basic Dimension”
1.9 □A “Datum Feature Label”
1.10 ⊕ 0.5□□□A B C “Feature Control Frame”

2. At the left end of the lines below, enter the names of the four fundamental groups of geometric characteristics that describe the four things that can go wrong with machine part features. On the right, enter the symbols of the Y14.5 tools dedicated to each group.

   2.1 Size | Ø SØ ←→ SØ R SR CR
   2.2 Form | ↘ ↘ ↘ ↘ ↘
   2.3 Orientation | ↘ ↘ ↘
   2.4 Location | ⊕ ⊕ ⊕ ⊕ ⊕ ⊕ ⊕ ⊕ ⊕ ⊕

3. What geometric characteristics can the Surface Profile tool control?
   Every possible geometric characteristic covering Size, Form, Orientation and Location. Surface Profile is in fact the “Everything” tool.

4. What is the shape of every Surface Profile tolerance zone?
   Skin-like!

5. GD&T controls the imperfect real world with the help of a perfect imaginary world. Name some of the components of the perfect imaginary world of GD&T.

   5.1 Tolerance Zones
   5.2 Tolerance Values (the sizes of tolerance zones)
   5.3 Datums
   5.4 Datum Reference Frames
   5.5 Basic Dimensions

6. What are the only two purposes Basic dimensions serve?
   Basic dimensions serve to orient and locate 1) tolerance zones and 2) Datum Targets.

7. On a separate piece of paper, decode each of the following Feature Control Frames found in the drawing below, in order to make the stated requirements absolutely clear and avoid the dangers of “interpretation”:

   7.1 Working Plane
   Flatness requires all points on the considered surface to lie within a slab-like tolerance zone of thickness 0.2mm with no external constraints.

   7.2 Working Plane
   Perpendicularity requires all points on Datum Feature B to lie within a slab-like tolerance zone of thickness 0.2mm which is perpendicular to the base plane of a Datum Reference Frame established using Datum Feature A (namely Datum A), simulated rocking (Y14.5 2009 §4.11.2 p.59).

   7.3 Working Plane
   Position requires the bounded axis of the bore to lie within a cylindrical tolerance zone of diameter 0.5mm Regardless of Feature Size, which is oriented and located by Basic dimensions relative to a Datum Reference Frame established using Datum Feature A simulated rocking and Datum Feature B simulated rolling.

   7.4 Working Plane
   Surface Profile requires all points on the surface of the bore to lie within a cylindrical, skin-like (tube-like) tolerance zone of wall thickness 0.5mm which...
is oriented and located by Basic dimensions relative to a Datum Reference Frame established using Datum Feature A simulated rocking, Datum Feature B simulated rolling, and Datum Feature C simulated “stably” Regardless of its Material Boundary.

7.5 \[ \varnothing 0.05 \]

Cylindricity requires all points on the surface of the bore to lie within a tube-like tolerance zone of wall thickness 0.05mm which is free to expand and contract to accommodate changes in size, with no external constraints.

\[ \varnothing 20 \pm 1 \]

7.6 \[ \varnothing 0.5 \]

Position requires the bounded axis of the bore to lie within a cylindrical tolerance zone of diameter 0.5mm at Maximum Material Condition, expanding by the absolute value of the difference between the unconstrained Actual Mating Size and the Maximum Material Condition size of the bore as it departs from Maximum toward Least Material Condition, which is oriented and located by Basic dimensions relative to a Datum Reference Frame established using Datum Feature A simulated rocking, Datum Feature B simulated rolling, and Datum Feature C simulated “stably” Regardless of its Material Boundary.

8. Describe in words and draw in the shapes of the tolerance zones defined by the numbered Feature Control Frames. 1) Slab-like, 2) Slab-like, 3) Cylindrical, 4) Tube-like, 5) Tube-like, and 6) Cylindrical. See Figure 1. for sketches of the tolerance zones.

9. Referring to Feature Control Frame 8.6 in the figure above:

9.1 Provide a detailed name for the symbol (M) and compute the maximum permissible Position tolerance: (M) is a Maximum Material Condition “Tolerance Zone Size” modifier. The maximum permissible Position tolerance is 2.5 at LMC.

9.2 Provide a detailed name for the symbol (S) and describe its impact on the Simulator for Datum Feature C: (S) is a Regardless of Material Boundary “Tolerance Zone Mobility” modifier which requires DRF[A,B,C(S)] to be “stable” relative to Datum Feature C. Note: Even though forbidden by the Y14.5 2009 Standard, the modifier (S) is made explicit here in order to make its presence obvious.

9.3 Draw in and label the axes of the Datum Reference Frame defined by the Datum Feature sequence A,B,C. See the Figure above.

9.4. Given that this feature is a bore and can suffer problems with its size, form, orientation and location, explain how only a size tool and a location tool are able to impose all the necessary controls: Due to default imposition of the Envelope Rule by the Y14.5 2009 Standard, which empowers the Rule of Size and Form (Rule #1), the Diameter tools control not only size but also Cylindricity, Roundness and Straightness.

10. Define a Datum Feature:
Datum Features are specially labeled, imperfect surfaces of real parts which serve to constrain rotational and translational degrees of freedom during assembly processes and contribute to the establishment of Datum Reference Frames.

11. Define a Datum Feature Simulator:
Datum Feature Simulators are “perfect” inverse Datum Features which serve as a bridge from the imperfect real world of physical parts to the perfect imaginary world of GD&T, 1) from which we extract Datums,. 2) in which we first establish DRFs and 3) with which we transfer DRFs to actual parts.

12. Define a Datum:
Datums are the minimum, mutually embedded set of a single, perfect imaginary point, and/or axis, and/or plane, which fully characterize the orientation and location of a Datum Feature Simulator, and serve to constrain the rotational and translational degrees of freedom of a “starter” coordinate system and turn it into a DRF.

13. Define a Datum Reference Frame:
A Datum Reference Frame is a Cartesian coordinate system established by a set of Datums extracted from a set of Datum Feature Simulators defined by a set of Datum Features listed in a Feature Control Frame. DRFs provide the means for orienting and locating tolerance zones with Basic dimensions.

14. Think carefully about the function of a rivet and the functions of each of its features. Then, on a separate piece of paper, recreate the drawing and use whatever Y14.5 tools you feel are appropriate to control its geometry and add some explanations for your choice of Datum Features and Geometry Control Tools. We’ll discuss various alternatives in the December column.

There is no “right” answer, but there are good and better answers, and almost every time we produce any answer, we recognize the possibilities for improvements. Thus, the GD&T “encoding” process is iterative. See the figure below for one approach and the explanations which follow.
Additional Features: Note the addition of three new features, which feature function analysis during the “encoding” process made clear were functionally valuable, especially the fillet at the base of the shank to reduce the chance of breaking off.

Datum Feature Selection: Although it would appear that the function of the shank of the rivet is to constrain “pitch” and “yaw” during the assembly process – thus making it the primary Datum Feature - its actual function is to simply clear the bore in the mating part as the force applied to the planar surface at the base of the head constrains “pitch” and “yaw”, making said planar surface the primary Datum Feature. The actual function of the shank is therefore to center the rivet in the mating bore, making it the secondary Datum Feature.

Controlling the Length of the Shank: Given three possibilities, namely 1) the “width” tool which does not apply because we are not dealing with a feature of size, 2) the Surface Profile tool referenced to A, or 3) the Dimension Origin tool, the latter was chosen fully effective and the most simple.

Controlling the size of the Rivet Head: Given three possibilities, namely a toleranced spherical radius, a toleranced spherical diameter and the Surface Profile tool, the latter was chosen as the easiest to assess metrologically, with no downside.

Tolerance Zone Size (Material Condition) modifier Selection for controlling the Perpendicularity of the Shank: The Tolerance Zone Size modifier (M) might have been chosen for the Perpendicularity control applied to the shank of the rivet in order to encode the “clearance function”, but the modifier (M) encourages the machine shop to aim for the Least Material Condition, leading to a thinner shank which makes it weaker and also permits a greater offset of the head relative to the bore in the mating part during the riveting process. Thus the modifier (S) was used instead.

Tolerance Zone Size (Material Condition) modifier Selection for controlling the Position of the Head: The Tolerance Zone Size modifier (L) was chosen for the Position control applied to the head of the rivet, because as the radius of the head departs from LMC (namely grows), the head may be further and further offset from the axis of the shank while still providing adequate overlap with the hole in the plates.

Tolerance Zone Mobility (Material Boundary) modifier Selection for Datum Feature B in the Position control applied to the Head: The Tolerance Zone Mobility modifier (L) was chosen for the Position control applied to the head of the rivet, because as the shank departs from LMC (grows), the head may be further and further offset from its axis while still providing adequate overlap with the hole in the plates.

Final Note: It seems outrageous to apply such “fancy” controls to a simple rivet, when meeting most of its requirements can be guaranteed by its manufacturing process, but it was fun even so.

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