Profile Tolerancing: Proof of Compliance vs Process & Design Feedback

Presented at NACAM - October 8-9, 2012

Dr. Greg Hetland, President
International Institute of GD&T
www.iigdt.com
Business & Technology Constraints

Technology Challenges & Constraints
Miniaturization & Tolerance Truncation
• Cycle-time Competing with Precision Requirements

Business Challenges & Constraints
Decreasing Profit Margins
• Tolerances Decreasing - Bad Decisions Increasing

High-Risk Issue
Inability to represent functional intent through engineering drawings and specifications.
What do we control on a mechanical part?
(without getting down to Surface Roughness, Material Properties, Plating, etc.)

1. Size
   Form
   Orientation
   Location

ASME Y14.5-2009

Note: Surface Roughness is defined in ASME B46.1-1995

Is there a way to simplify this list of 4 items?
What is controlled on a mechanical part other than:

Surfaces & Axes

Profile controls Surface Geometries
Position controls derived Axes
Section 8.2 - Profile tolerances are used to define a tolerance zone to control form or combinations of size, form, orientation, and location of a feature(s) relative to a true profile. Depending on the design requirements, profile tolerance zones may or may not be related to datums. Where used as a refinement of size tolerance created by tolerated dimensions, the profile tolerance must be contained within the size limits.

Section 8.2.2 - The profile tolerance zone specifies a uniform or nonuniform tolerance boundary along the true profile within which the surface or single elements of the surface must lie.
What would your intent be?

Design Intent requires that “ALL” features simultaneously lie within their respective tolerance zones.

Four holes simply fit over four pins and the outside surfaces of the part (in the X/Y plane) do not mate up against other parts.

Unless otherwise specified all dimensions are BASIC and controlled by the CAD model.
Technology Challenges/Constraints
- Miniaturization & Tolerance Truncation
- Increased geometric complexity (complex curves)
- Cycle-time competing with precision requirements

Business Challenges/Constraints
- Industry profit margins are radically low
- Significant costs related to physical parameters
- Tolerances decreasing & bad decisions increasing

High Risk Issues
- Designers’ inability to represent functional intent (unambiguously) through engineering drawings and specifications
- Individuals in manufacturing, quality and supply-chain not trained adequately to interpret engineering drawings to optimally produce and deliver product
Dimensioning and Tolerancing

Engineering Drawing and Related Documentation Practices

AN INTERNATIONAL STANDARD

The American Society of Mechanical Engineers
This revision contains paragraphs that give stronger admonition than in the past that the fully defined drawing should be dimensioned using GD&T with limit dimensioning reserved primarily for features of size.
Dimensioning & Tolerancing Standards

Other National Standards
- CSA – Canadian Standards
- DIN – German Standards
- GB – Chinese Standards
- ISO – ISO Standards
- JIS – Japanese Standards
- UNI - Italian Standards
- Etc…… the list goes on

Caution: Other National Standards are not 100% equal to ASME Y14.5 Standard
∅ ⊕ ⊙ ≡ ∩ ∧ (just to highlight a few)
Profile

A profile tolerance specifies a uniform boundary along the true profile within which the elements of the surface must lie. Where a profile tolerance encompasses a sharp corner, the tolerance zone extends to the intersection of the boundary lines. See the figure below.

Since the intersecting surfaces may lie anywhere within the converging zone, the actual part contour could conceivably be rounded. If this is undesirable, the drawing must indicate the design requirements, such as by specifying the maximum radius.
Profile “ASME Y14.5” -vs- “ISO 1101”
Precision GD&T – Uniform Boundary

“Profile Tolerancing Controls Simple and Complex Geometries”
Simultaneous Requirement (Planar Datums)

Unless Otherwise Specified All Dimensions Controlled by the CAD Model and are Basic

Potential Problem with Datum’s B & C
Simultaneous Requirement (Planar Datums)
Simultaneous Requirement (Planar Datums)

Designers intent simply requires all features to simultaneously lie within their respective tolerancing zones in relationship to respective datum reference frame. This allows all features to expand or contract in size and/or be out of square to Datum A and/or be off location to datum B & C as long as they simultaneously lie within their respective tolerance zone.
Simultaneous Requirement (Planar Datums)

Problem: Negative Effects of Datum B & C (if part truly does not mate up against datum feature B & C) as part would be required to shift and mate up against B & C respectively. The resulting effect would be the part would lie outside the respective Profile Boundaries.
Simultaneous Requirement (Planar Datums)

Resulting Effects of Datum B & C would be that part would require to be shifted to mate up with B & C respectively and would result in the part lying outside Profile Boundaries and be Rejected.

Unless Otherwise Specified All Dimensions Controlled by the CAD Model and are Basic
Simultaneous Requirement (Mid-Plane Analysis)

Potential Problem with Datum’s B & C

Unless Otherwise Specified All Dimensions Controlled by the CAD Model and are Basic
Simultaneous Requirement (Mid-Plane Analysis)

Datum B and Datum C are the mid-planes between their respective features
Simultaneous Requirement (Mid-Plane Analysis)
Designers intent simply requires all features to simultaneously lie within their respective tolerancing zones in relationship to respective datum reference frame. This allows all features to expand or contract in size and/or be out of square to Datum A and/or be off location to datum B & C as long as they simultaneously lie within their respective tolerance zone.
Simultaneous Requirement (Mid-Plane Analysis)

Designers intent simply requires all features to simultaneously lie within their respective tolerancing zones in relationship to respective datum reference frame. This allows all features to expand or contract in size and/or be out of square to Datum A and/or be off location to datum B & C as long as they simultaneously lie within their respective tolerance zone.
Problem: Without the part being constrained to datums B & C the part lies within its respective tolerance zones. Negative Effects of Datum B & C would be that it would force the part to shift and potentially lie outside the respective Profile Boundaries.
Simultaneous Requirement (Mid-Plane Analysis)

Resulting Effects of Datum B & C would be that part would require to be shifted to mate up with B & C respectively and would result in the part lying outside Profile Boundaries and be Rejected.
Simultaneous Requirement

Unless Otherwise Specified All Dimensions Controlled by the CAD Model and are Basic

Simultaneous requirements come into play when “geometric controls use the same datums, in the same order of precedence, with the same datum feature modifiers.” All callouts under the simultaneous requirement must be evaluated at the same time.
Simultaneous Requirement

Derived Boundaries
Simultaneous Requirement

Designers intent simply requires all features to simultaneously lie within their respective tolerancing zones. This allows all features to expand or contract in size and/or be out of square to Datum A and/or be off location to each other as long as they simultaneously lie within their respective tolerance zone.
Paragraph 2.15.1 of ASME Y14.5M-1994 States: Radius Tolerance

“A radius symbol R creates a zone defined by two arcs (the minimum and maximum radii). The part surface must lie within this zone.”
Paragraph 1.8.2.1 of ASME Y14.5M-1994 States: Center of Radius

“Where a dimension is given to the center of a radius, a small cross is drawn at the center. Extension lines and dimension lines are used to locate the center.
Specifying small arc radii for size using linear tolerancing and location using position tolerancing is a less than optimum way of specifying design requirements as they do not represent the designers true intent which is simply to have all the surface geometries lie within a uniform boundary which can only be done using Profile. In addition, they are major problems with the analytical methods which in each case have large sensitivities and have negative impacts for proving compliance with specification requirements and provide less than adequate feedback to manufacturing to use for process optimization. The following shows analysis of a dataset that would reject the part for size and position. The same dataset is used on the next page for analysis using profile.
The same part from the previous page was re-defined using profile and the same dataset was used for analysis using a minimum zone fit which proves all the measured points comfortably lie within the desired tolerance zone.
Minimum Zone Fit is proper fit for Proof of compliance but is difficult for manufacturing to use to determine process optimization.

Least Squares Fit (Best Fit) is “NOT” the proper fit for proof of compliance but in many cases provides fabulous graphical feedback to manufacturing to use for process optimization.
Minimum Zone Fit is proper fit for Proof of compliance but is difficult for manufacturing to use to determine process optimization.

Least Squares Fit (Best Fit) is “NOT” the proper fit for proof of compliance but in many cases provides fabulous graphical feedback to manufacturing to use for process optimization.
The above engineering drawing example depicts profile tolerancing of all 3D surfaces being fully defined with three explicit profile of a surface callouts per the ASME Y14.41-2003 Standard.
3D Analysis of all Surfaces Simultaneously
“Quality Transformation”

1. Turn engineering efforts into a science and eliminate redundant and inefficient development initiatives

2. Gain a thorough understanding of the constraints & implications to critical functional characteristics

3. Utilize this core knowledge to optimize leading-edge processes which meet or exceed market needs and use to your advantage to determine and optimize the vital few development needs

(Appplies To: Product, Tooling, Equipment, Design, Process and Measurement)

“Find the waste… Get rid of it… Keep it gone… Do it right the first time”

Foundation for Effective Communication
GD&T Applies to all Disciplines

- Executives
  - Engineers
    - Sales/Applications
  - Customers
  - Administration
  - Manufacturing
    - Machine Operators
    - Process Technicians
    - Process Engineers
  - Quality/Measurement
    - Measurement Technicians
    - Measurement Engineers
    - Quality-Technicians
    - Quality-Engineers
    - Inspectors
  - Design
    - Drafters
    - Designers
    - Engineers
  - Tool Room
    - Machine Operators
    - Machinists
    - Tool Makers

- Executives
  - Executives
  - Administration
  - Manufacturing
  - Quality/Measurement
  - Design
  - Tool Room

- Precision GD&T
  - Metrology
  - Design
  - Manufacturing
Thank you

For Information on In-House or Public Seminars and Products

www.iigdt.com