



# CMMs and GD&T

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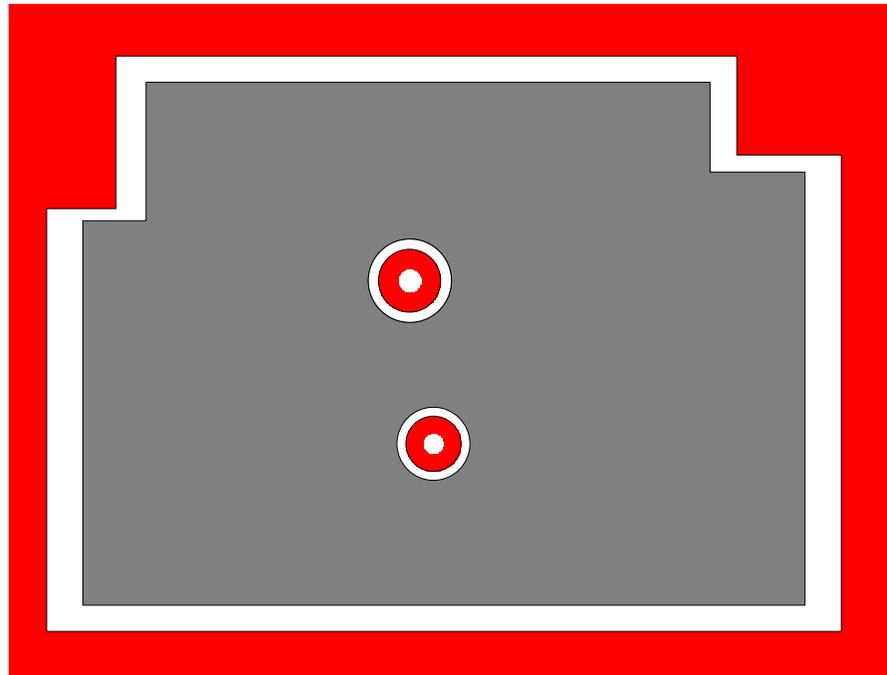
# The History of Tolerancing (abbreviated)

- Initially there was linear +/- tolerancing
  - did not capture geometric relationships
  - did not assure assemblability
- Then came Geometrical Dimensioning and Tolerancing
  - Standardized in ANSI/ASME Y14.5 and ISO 1101
  - captures geometric relationships
  - ensures assemblability



# The Scope of GD&T

- Claims to cover part function
  - But the only function covered is assembly

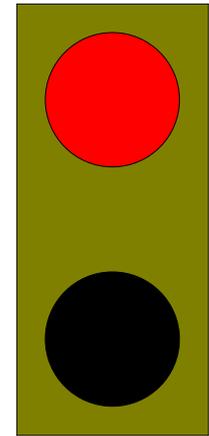
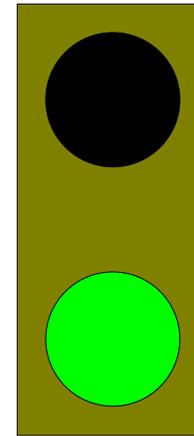




# Philosophies of GD&T

- Only concerned with Pass or Fail

- An actual value is only defined for simple call-outs
  - such as form deviation



- For features referenced to datums all features must be considered simultaneously to determine pass or fail
  - Actual value is not defined and non-existent



# What GD&T Does Well

- Tolerancing for assembly
  - Properly used GD&T can ensure assemblability
- Interference avoidance
  - GD&T controls the extreme points in features
- Enable tolerance stackup calculations
  - By capturing geometrical relationships



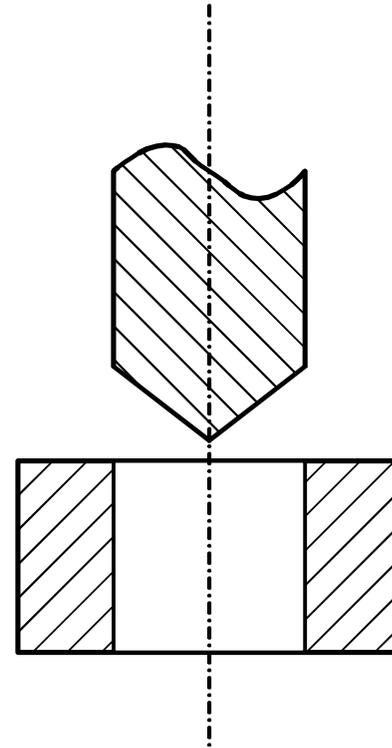
# What GD&T does not do well

- Sealing interfaces
- Interference fits
- Adaptable (non-stiff) parts
- Hydrodynamic interfaces
- Roller bearings



# Sealing Interfaces

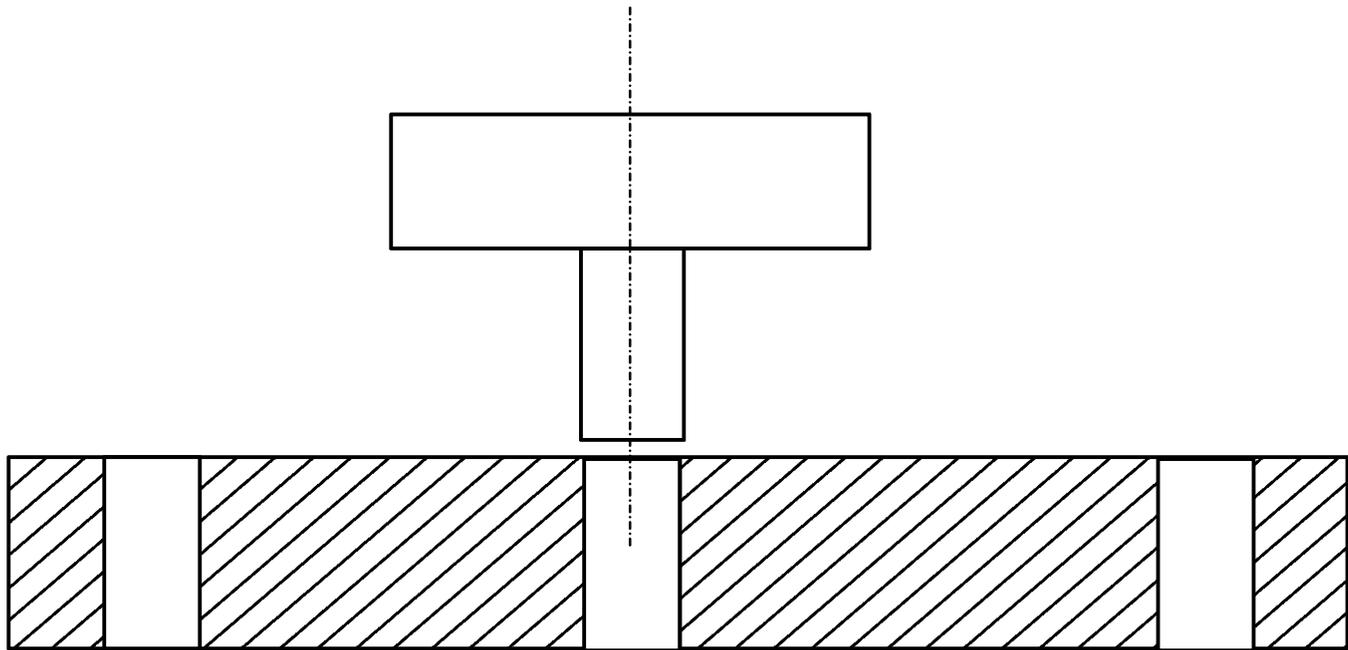
- Fuel Injectors
  - Ensure sealing
  - Avoid scuffing





# Interference Fits

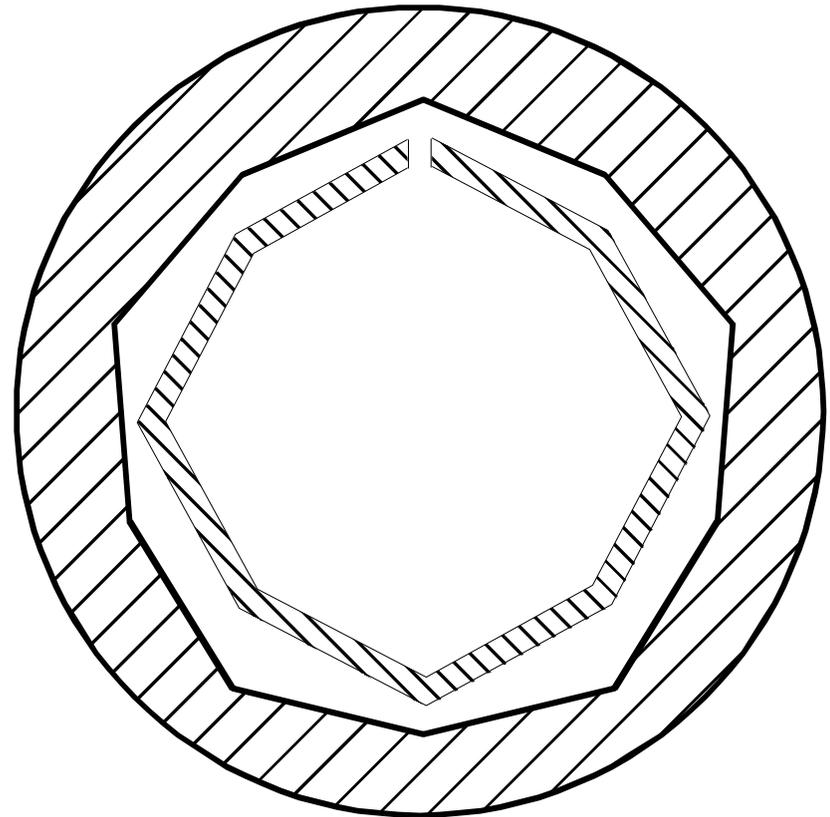
- Controlling the location of a pin pressed in a hole





# Adaptable (non-stiff) Parts

- Piston rings in liners
  - Ring can adapt to long undulations in liner
    - but not to short undulations





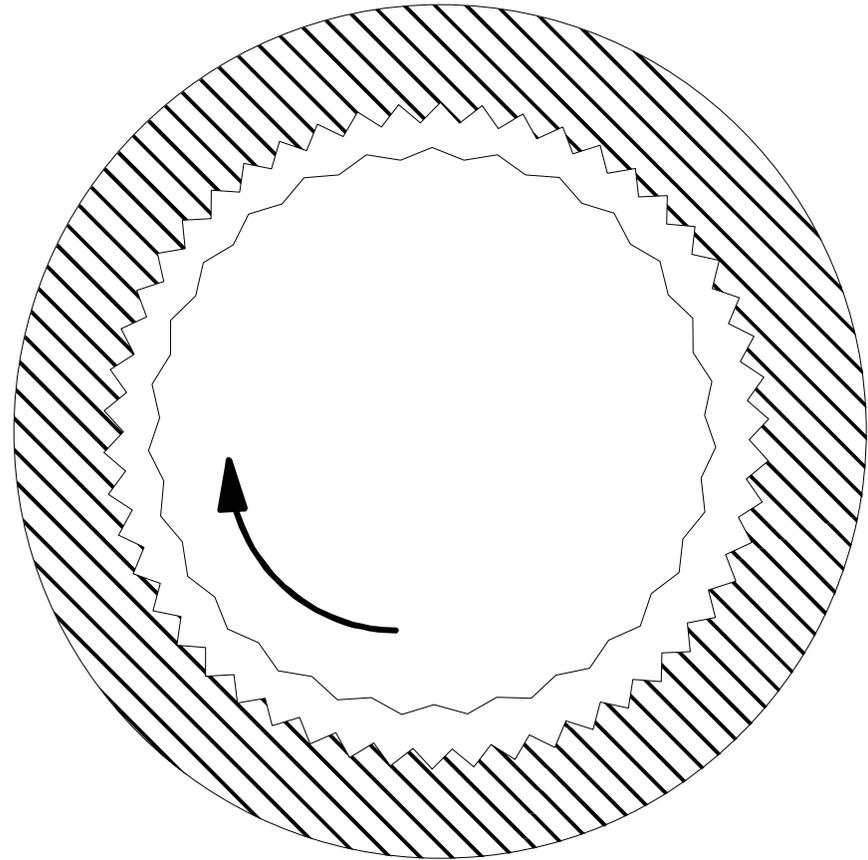
# Hydrodynamic Interfaces

- Sliding bearings

- Contact is avoided by:

- Oil film
    - Elastic deformation

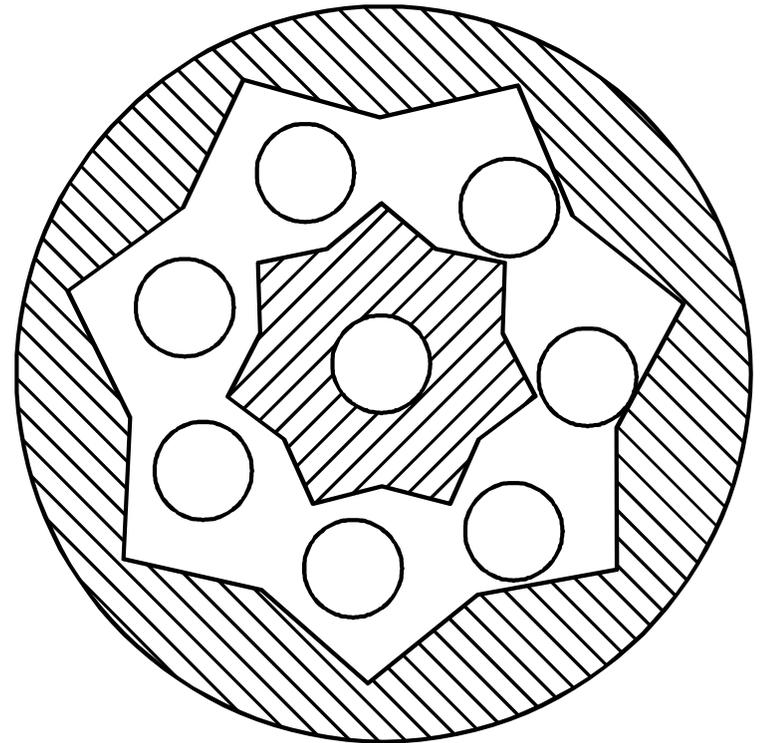
- Some form errors can be tolerated others cannot





# Roller bearings

- Lobing relative to number of rollers
  - Vibration
  - Noise
  - Longevity





# So What About CMMs?

- CMMs (or other discrete point measuring machines) can characterize all these examples
  - By mapping the surface
  - By breaking the surface down into various wavelength components
  - By finding average substitute features



# The Cost of Tolerances

- Cheap:

- Stationary, non-interference fit

- Expensive:

- Bearing
  - Roller
  - Sliding
- Seal
- Piston/Liner



# CMMs and GD&T

- CMMs can only measure discrete points
  - usually the operator only takes very few points
    - e.g. 5-10 points to describe a hole
- CMMs usually use least squares algorithms to find substitute features
  - these are used to represent the real features
- This is not in accordance with the definitions given in GD&T standards



# So Why Do We Use CMMs?

- GD&T is only aimed at the pass/fail decision
- Measurement data is needed for several other purposes
  - Calibration
  - Tolerance development
  - Process control
  - Process capability
- CMMs can provide variable data for these purposes



# What do CMMs do well?

- CMMs work best, when several points are averaged in a result, such as:
  - Position
    - e.g. of the center of a hole
  - Distance
    - e.g. between hole centers or from a hole center to a plane
  - Orientation
    - e.g. angle between two planes



# What are CMMs not good at?

- CMMs do not work very well for measurements, where the result is dependent on a single point, such as:
  - Form measurement
    - e.g. roundness of a hole
  - Finding datums based on extreme points

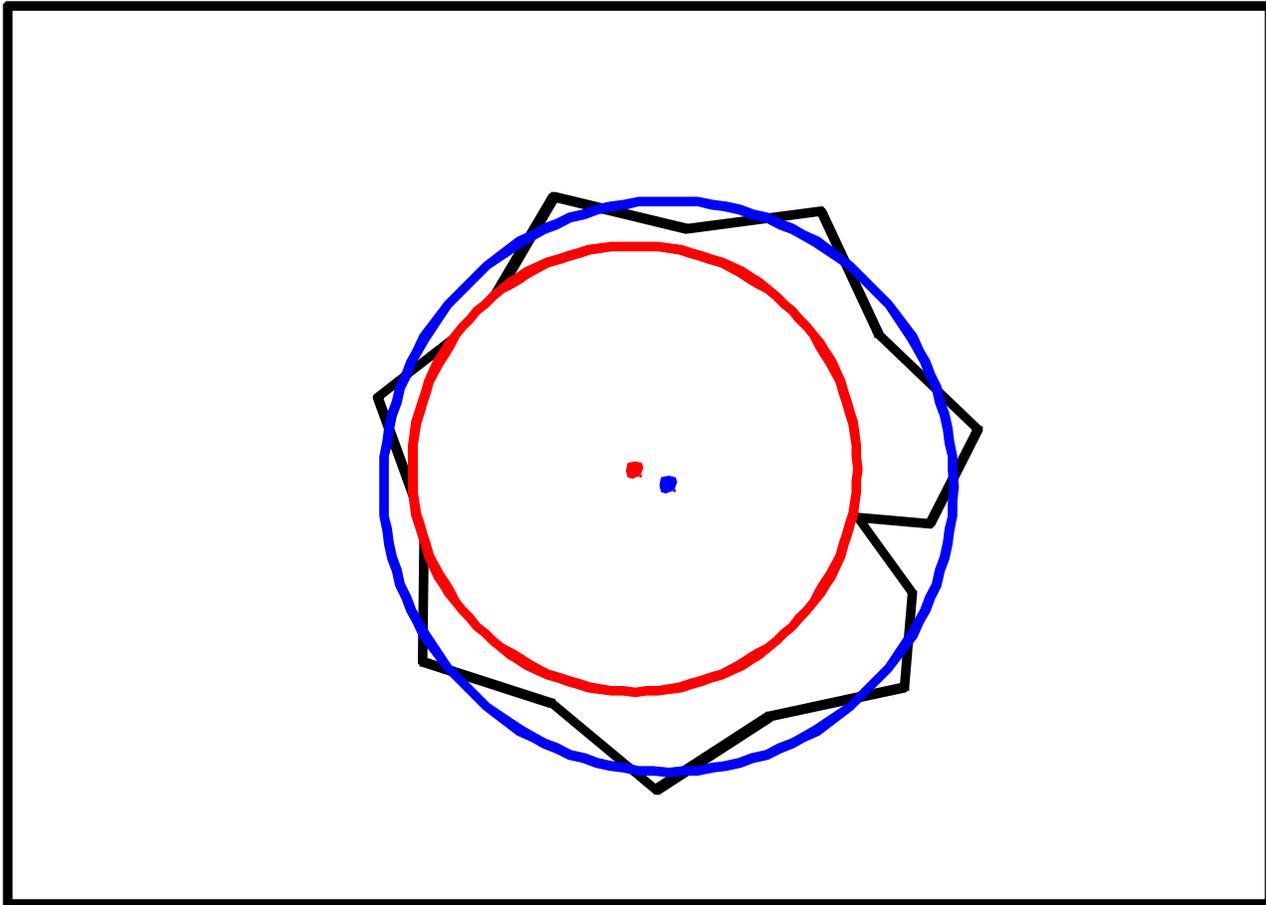


# Process Control (Feed Back Loop)

- What information is needed?
  - Position(s)
  - Distance(s)
  - Actual values
  - Individual features
- What is good control data?
  - Based on stable algorithms
    - not sensitive to single point deviations



# Process Control Data





# Conclusions I

- CMMs are very useful tools
  - Even though they do not measure in accordance with GD&T
    - Often the difference can be expressed as an uncertainty
  - CMMs can provide useful information for
    - Calibration
    - Tolerance development
    - Process control



# Conclusions II

## (The Future of Tolerancing)

- GD&T needs further development
  - Handling other functions than fit
    - There is work going on in ISO in this direction
  - Next generation GD&T will be a much richer language enabling designers to express functional requirements more precisely
- CMMs will handle many of these functions better than they handle current GD&T
  - because these functions are not based on extreme points