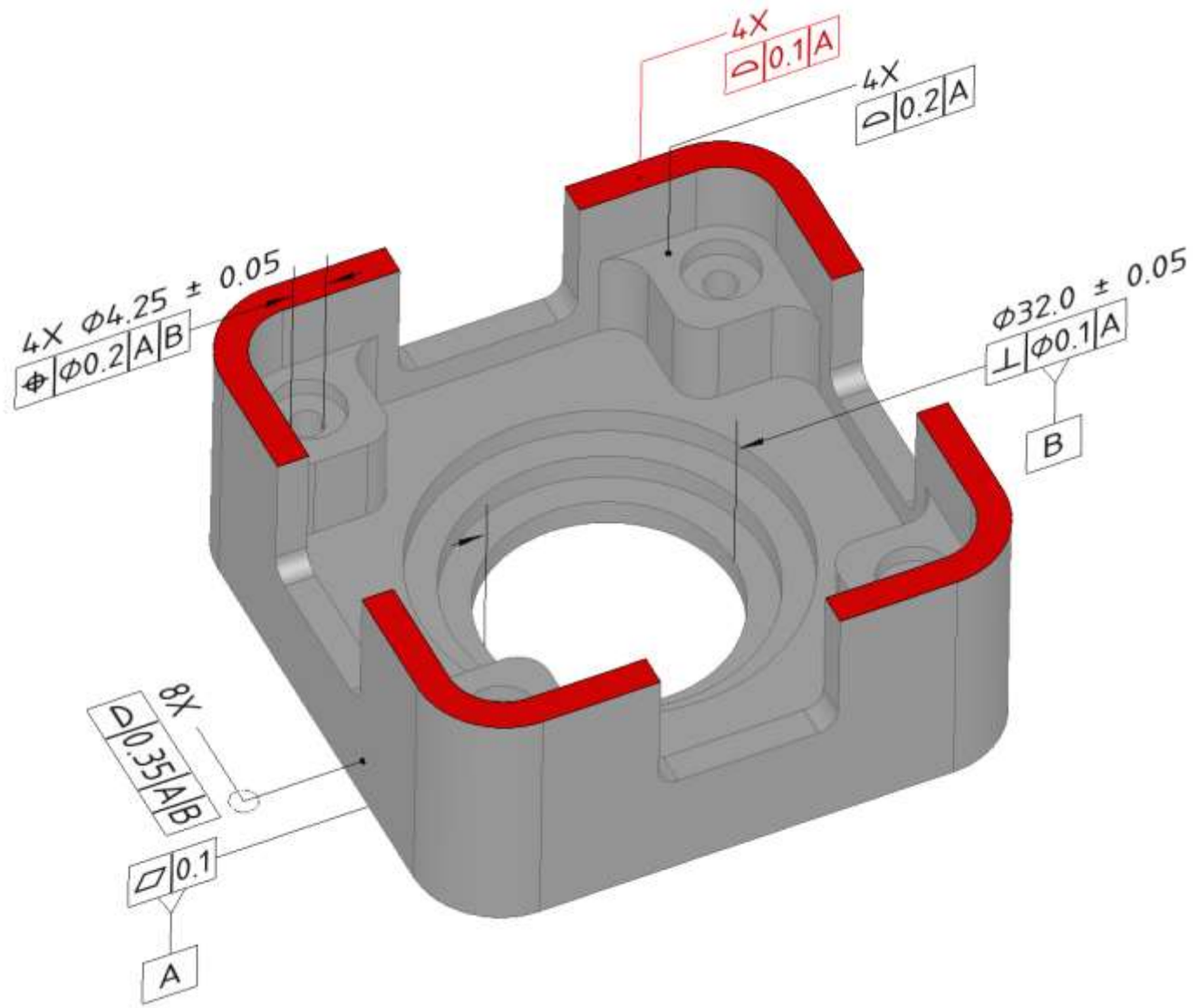
تلرانس و ابعاد هندسی مقدماتی

Geometric Dimensioning and Tolerancing (GD&T)



مدرس: داود قدس

مقدمه‌ای بر تلرانس هندسی

GD&T (Geometric Dimensioning and Tolerancing) یک زبان مهندسی بین‌المللی است که در زمینه نقشه‌های مهندسی مورد استفاده قرار می‌گیرد تا محصولات و آیتم‌های مختلف را به طور سه بعدی تشریح نماید.

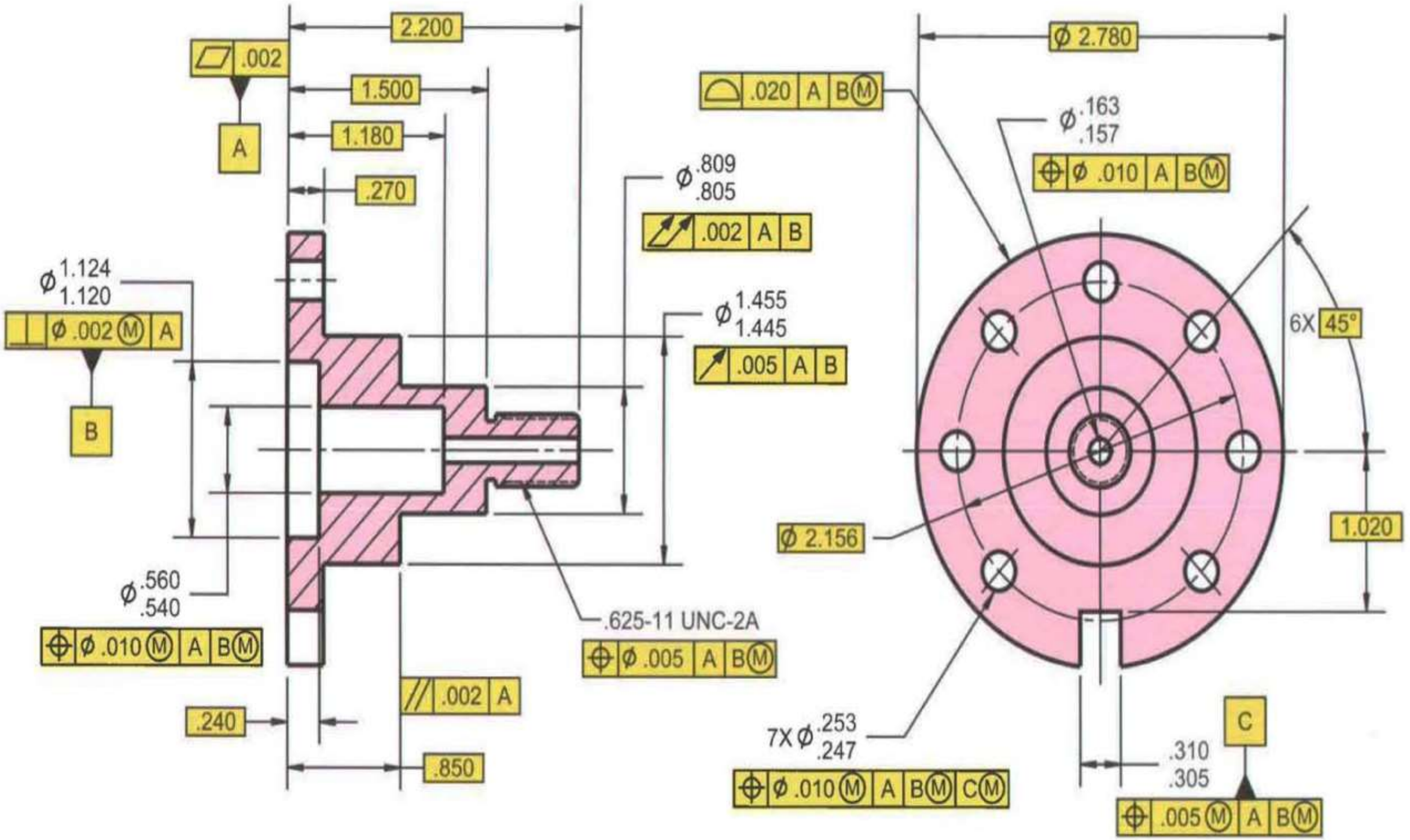
این زبان مهندسی از یک سری کاراکترها و عبارات شناخته شده استاندارد جهت تشریح محصول نهایی استفاده می‌کند.

این کاراکترها جهت نمایان کردن ترکیب یک محصول، تعریفی مختصر و واضح از آن، هدف طراحی را بیان می‌کنند.

GD&T یک زبان ریاضی دقیق و صریح است که فرم، جهت و مکان فیچرهای قسمتی از محصول را به صورت مناطق تلرانسی بیان می‌کند که نهایتاً این مناطق تلرانسی در یک سیستم مختصات کارتزین تشریح می‌گردند.

مدرس: داود قدس

نمونه ای از نقشه های GD&T



مدرس: داود قدس

نحوه نمایش دیتوم

Fig. 3-2 Datum Feature Symbol

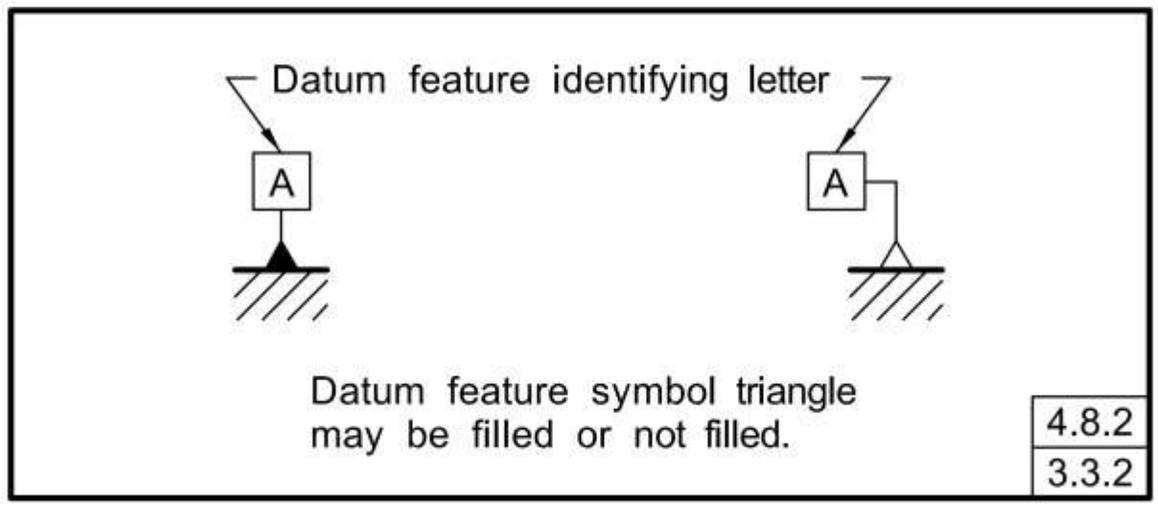
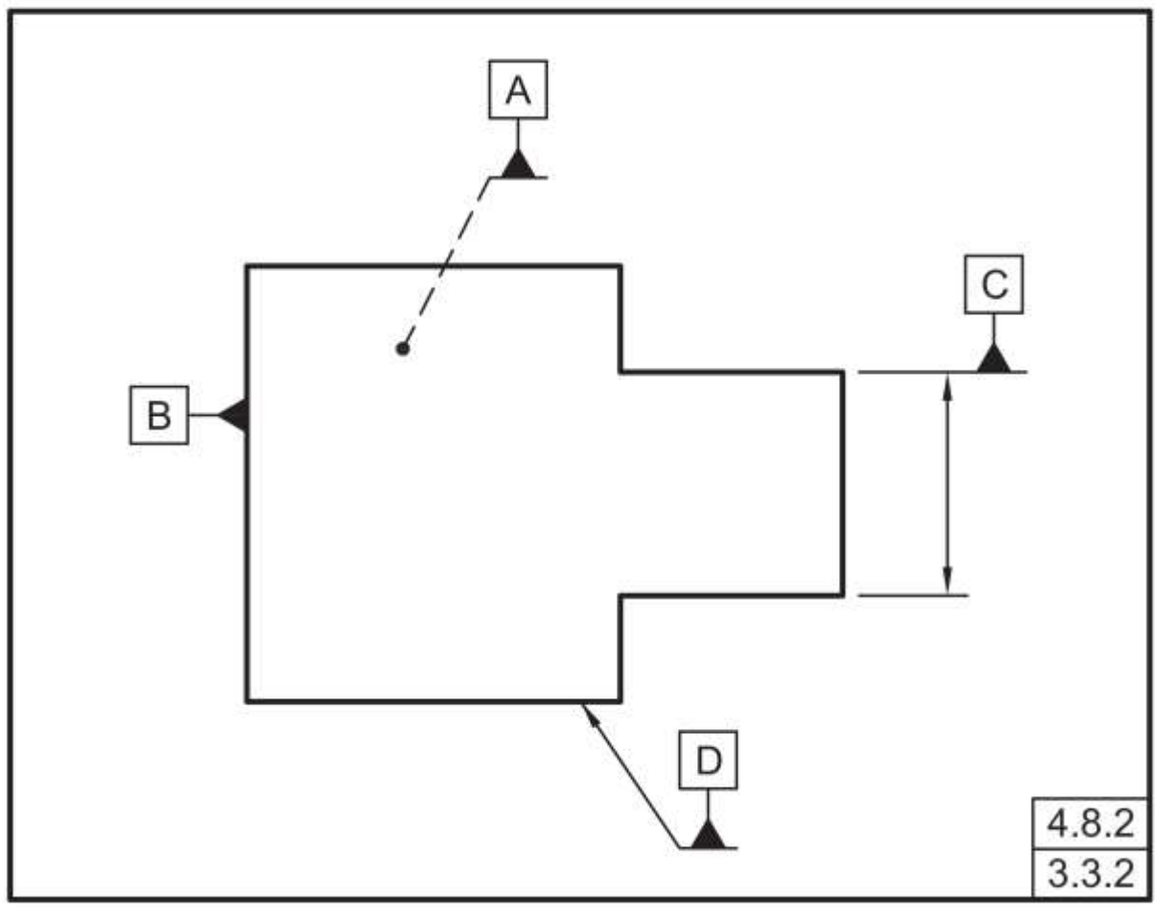
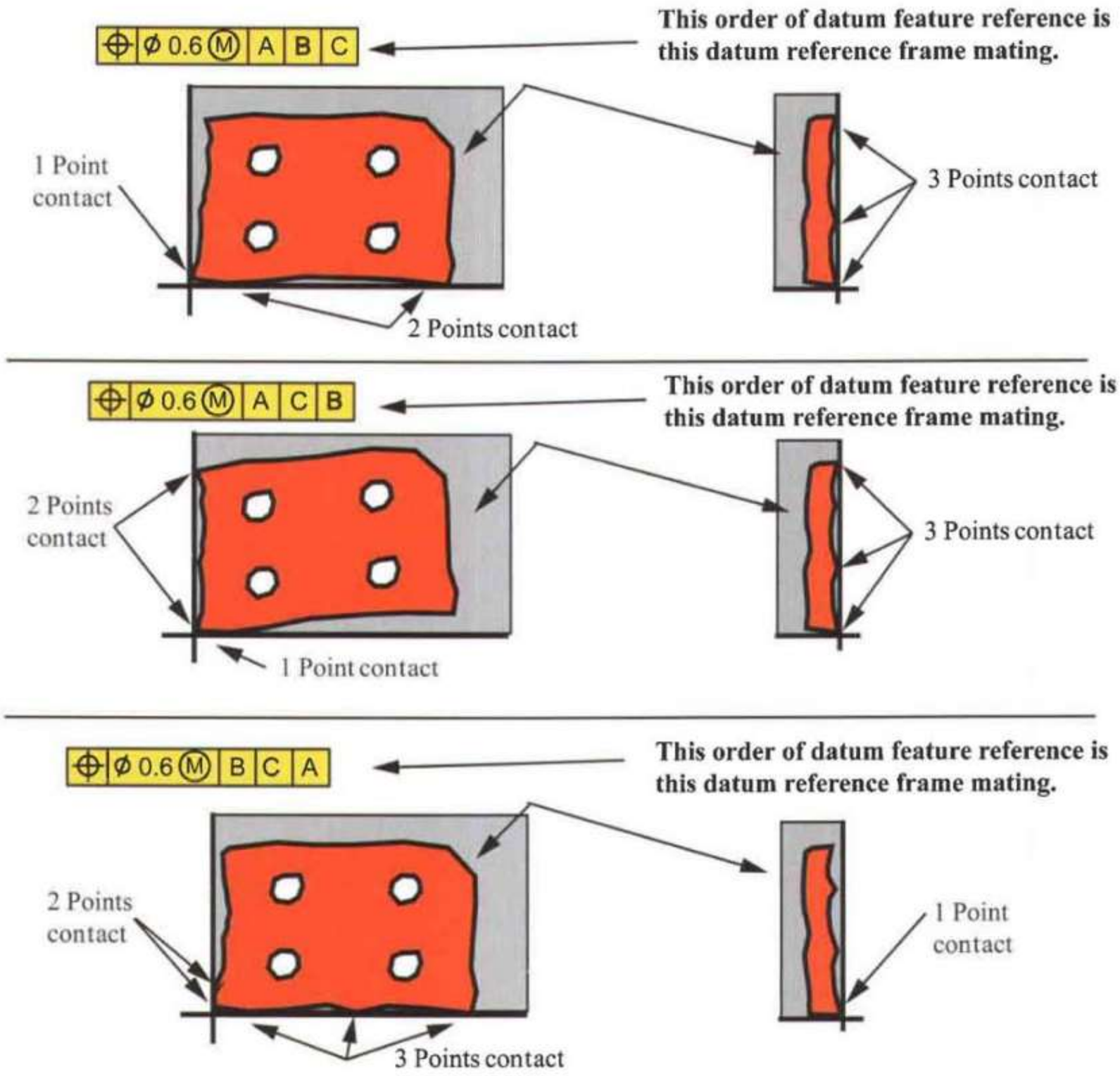


Fig. 3-3 Datum Feature Symbols on a Feature Surface and an Extension Line

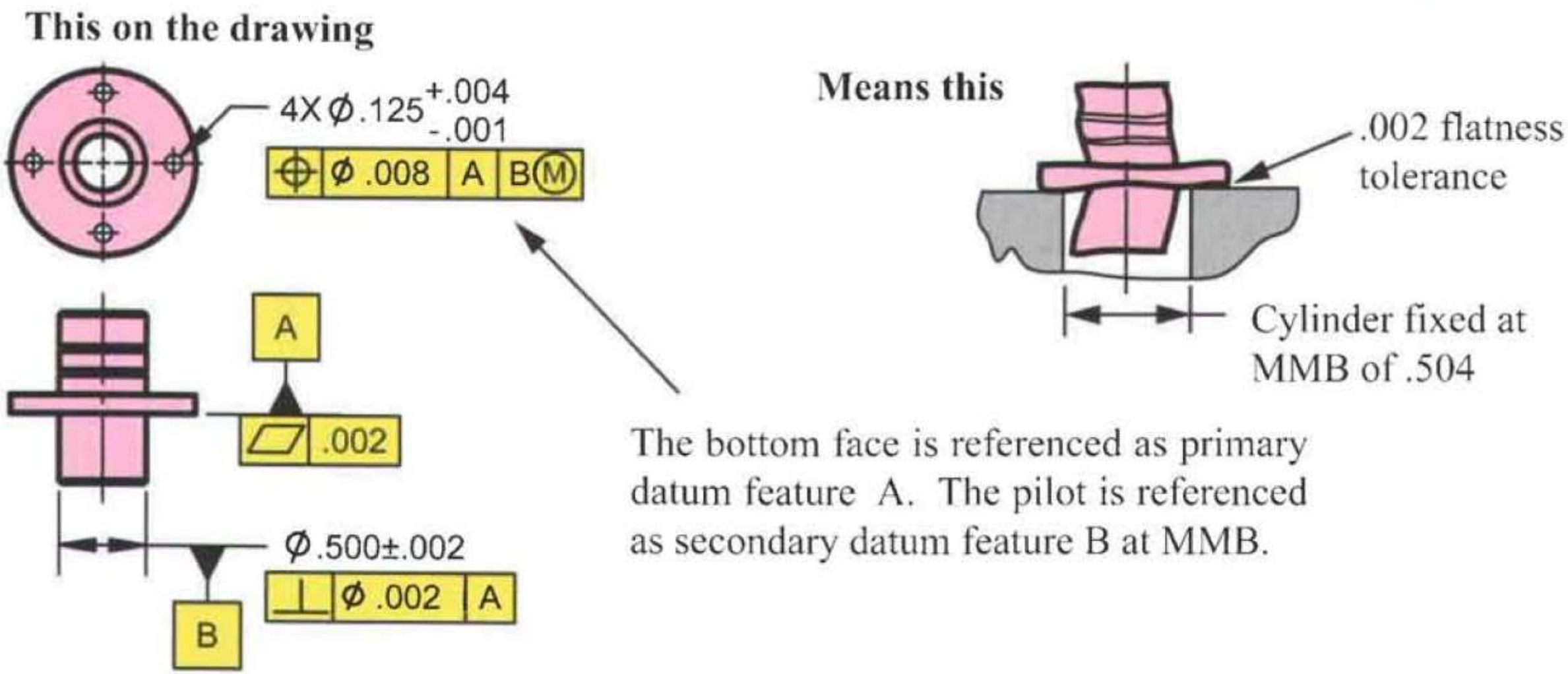


عملکرد ترتیب دیتوم‌ها



مدرس: داود قدس

ارتباط و اهمیت ترتیب دیتوم‌ها در جدول FCF



مدرس: داود قدس

ارتباط نوع ابزار و فرایند با کاراکترهای هندسی

Basic process	Geometric Tolerance Type			
	Parallelism	Perpendicularity	Concentricity	Angularity
Turning	0.01-0.02	0.02	0.005-0.01	0.01
Milling	0.01-0.02	0.02	-	0.01
Drilling	0.2	0.1	0.1	0.1
Boring	0.005	0.01	0.01	0.01
Grinding	0.001	0.001	0.002	0.002
Honing	0.0005	0.001	0.002	0.002
Super finishing	0.0005	0.001	0.002	0.002

مدرس: داود قدس

استانداردهای مرجع امریکایی

ASME Reference Standards

ASME Y14.5.1M-1994 (R2004), Mathematical Definition of Dimensioning and Tolerancing Principles
ASME Y14.5.2-2000 Certification of Geometric Dimensioning and Tolerancing Professionals
ASME Y14.41 - 2003 (R2008) Digital Product Definition Data Practices
ASME Y14.43 - 2003, (R2008) Dimensioning and Tolerancing Principles for Gages and Fixtures
ASME Y14.8-2009, Castings and Forgings
ANSI B4.2-1978 (R2004), Preferred Metric Limits and Fit
ANSI B4.1-1967 Preferred Limits and Fits for Cylindrical Parts
ASME Y13.38M-2007, Abbreviations
ASME Y14.100-2004, Engineering Drawing Practices
ASME Y14.3M-1994 (R2008), Multiview and Sectional View Drawings
ASME Y14.1M-2005, Drawing Sheet Size and Format
ASME Y14.2M-2008, Line Conventions and Lettering
ANSI/IEEE 268-1992,2 Metric Practice
IEEE/ASTM SI 10-2002 ERRATA 2005, Standard for Use of the International System of Units (SI) — The Modern Metric System
ASME B5.10-1994, Machine Tapers — Self Holding and Steep Taper Series
ASME B46.1-200, Surface Texture, Surface Roughness, Waviness, and Lay
ASME Y14.36M-1996, Surface Texture Symbols
ANSI B89.3.1-1972 (R2003), Measurement of Out-of-Roundness
ANSI B92.1-1996,1 Involute Splines and Inspection, Inch Version
ANSI B92.2M-1980,1 Metric Module, Involute Splines
ASME B94.11M-1993, Twist Drills
ANSI Y14.6-2001 (R2007), Screw Thread Representation
ANSI Y14.6aM-1981 (R1998), Screw Thread Representation (Metric Supplement)
ANSI Y14.7.1-1971 (R1998), Gear Drawing Standards — Part 1: For Spur, Helical, Double Helical, and Rack
ANSI Y14.7.2-1978 (R1999), Gear and Spline Dwg Standards - Pt 2: Bevel and Hypoid Gears
ANSI/ASME B1.2-1983, Gages and Gaging for Unified Inch Screw Threads
ANSI B4.4M-1981 (R1987), Inspection of Workpieces
ASME B89.7.2-1999 Dimensional Measurement Planning
ASME B89.7.3.1-2001 Guidelines for Decision Rules: Considering Measurements Uncertainty in Determining Conformance to Specifications
ANSI/ASME B89.6.2-1973 (R2003), Temperature and Humidity Environment for Dimensional Measurement
ANSI/ASME B94.6-1984 (R2003), Knurling

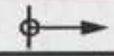
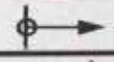
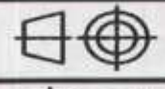
استانداردهای مرجع ایزو

ISO Reference Standards

ISO 1101-2004 Geometrical Product Specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out
ISO 1-1975, Standard reference temperature for industrial length measurements
ISO 286 Part 1, 1998, IS0 system of limits and fits -Bases of tolerances, deviations and fits
ISO 286 -Part 2, 2006, ISO system of limits and fits — Tables of standard tolerance grades and limit deviations for holes and shafts
ISO 1660:1987, Technical drawings — Dimensioning and tolerancing of profiles
ISO R 1938-1971, IS0 system of limits and fits, Part II : Inspection of plain workpieces
ISO 2692:—1), Geometrical Product Specification (GPS) — Geometrical tolerancing — Maximum Material Requirement (MMR) and Least Material Requirement (LMR)
ISO 2768-Part1 & 2, 1989, General tolerances -Tolerances for linear and angular dimensions without individual tolerance indications
ISO 5458:1998, Geometrical Product Specifications (GPS) — Geometrical tolerancing — Positional tolerancing
ISO 5459:1981, Technical drawings — Geometrical tolerancing — Datums and datum-systems for geometrical tolerances specifications, operators and uncertainties
ISO ISO/TR 5460-1985Technical drawings - Geometrical tolerancing -Tolerancing of form, orientation, location and run-out Verification principles and methods – Guidelines
ISO 8015:1985, Technical drawings — Fundamental tolerancing principle
ISO 10578:1992, Technical drawings — Tolerancing of orientation and location — Projected tolerance zone
ISO 10579:1993, Technical drawings — Dimensioning and tolerancing — Non-rigid parts
ISO/TS 12180-1:2003, Geometrical Product Specifications (GPS) — Cylindricity — Part 1: Vocabulary and parameters of cylindrical form
ISO/TS 12180-2:2003, Geometrical Product Specifications (GPS) — Cylindricity — Part 2: Specification operators
ISO/TS 12181-1:2003, Geometrical Product Specifications (GPS) — Roundness — Part 1: Vocabulary and parameters of roundness
ISO/TS 12181-2:2003, Geometrical Product Specifications (GPS) — Roundness — Part 2: Specification operators
ISO/TS 12780-1:2003, Geometrical Product Specifications (GPS) — Straightness — Part 1: Vocabulary and parameters of straightness
ISO/TS 12780-2:2003, Geometrical Product Specifications (GPS) — Straightness — Part 2: Specification operators
ISO/TS 12781-1:2003, Geometrical Product Specifications (GPS) — Flatness — Part 1: Vocabulary and parameters of flatness
ISO/TS 12781-2:2003, Geometrical Product Specifications (GPS) — Flatness — Part 2: Specification operators
ISO 14660-1:1999, Geometrical Product Specifications (GPS) — Geometrical features — Part 1: General terms and definitions
ISO 14660-2:1999, Geometrical Product Specifications (GPS) — Geometrical features — Part 2: Extracted median line of a cylinder, cone, extracted median surface, extracted local size feature
ISO/TS 17450-2:2002, Geometrical product specifications (GPS) — General concepts — Part 2: Basic tenets, specifications, operators and uncertainties

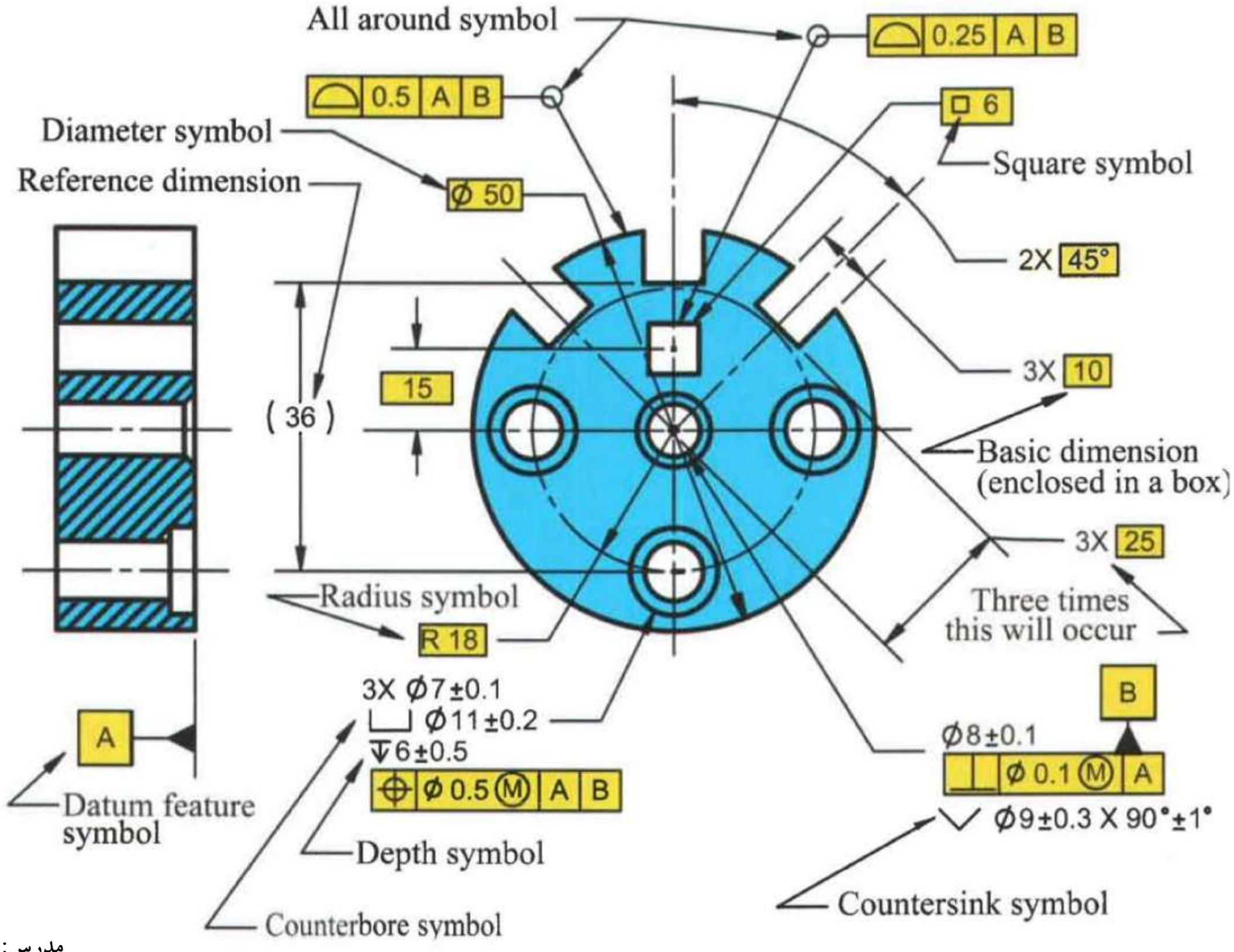
مدرس: داود قدس

جدول علائم و کاراکترها

	Term	Symbol ASME Y14.5	Symbol ISO
	Basic Dimension Theoretically Exact Dimension (ISO)	12	12
	Diameter	Ø	Ø
	Spherical Diameter	SØ	SØ
	Radius	R	R
	Controlled Radius	CR	None
	Spherical Radius	SR	SR
	Square	□	□
	Statistical Tolerance	ST	ST
	Reference Dimension	(12)	(12)
	Number of Places	3X	3X
	Counterbore	⌴	None
X	Spotface	SF	None
	Countersink	⌵	None
	Deep/Depth	↧	None
	Envelope Principle	None	Ⓔ
X	Independency Principle	Ⓘ	None
	Dimension not to Scale	23	23
	Arc Length	⌒23	⌒23
	Slope		
	Conical Taper		
X	Continuous Feature	CF	None
	Dimension Origin		
	First Angle Projection		
	Third Angle Projection		

مدرس: داود قدس

نمونه‌ای از نقشه‌های GD&T



مدرس: داود قدس

تفاوت شعاع و شعاع کنترل شده

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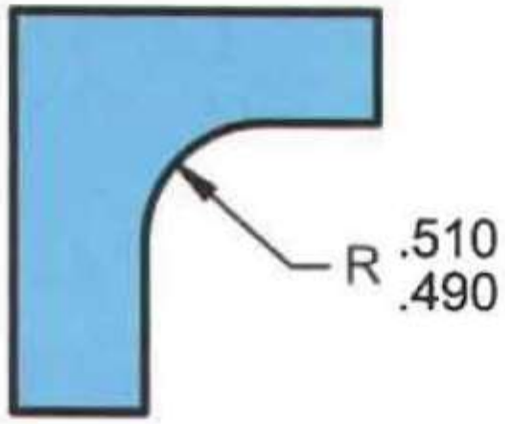
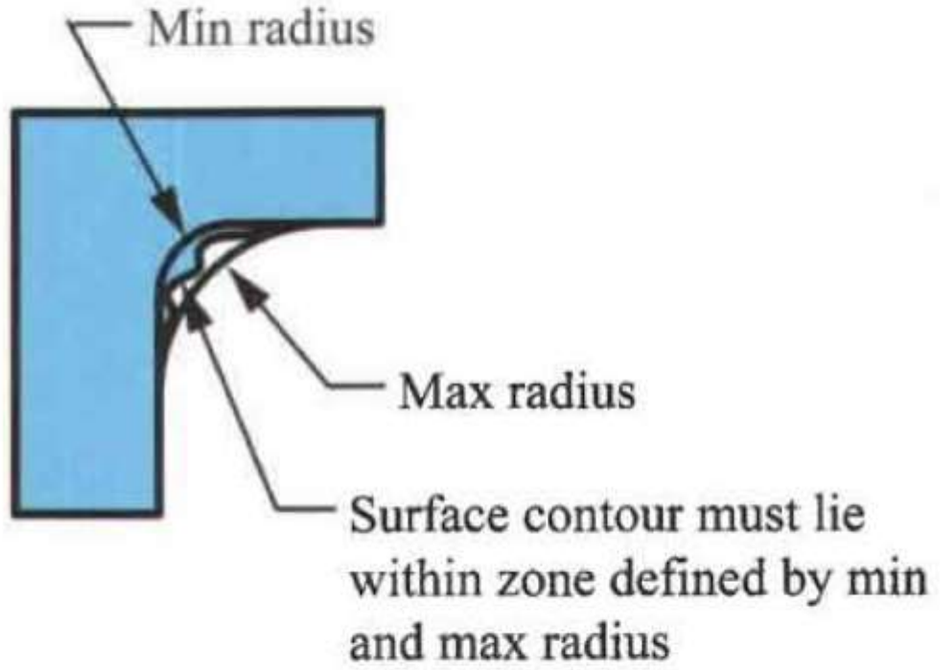
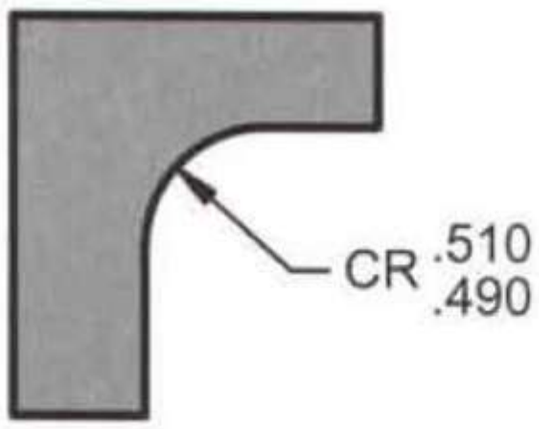
Means this

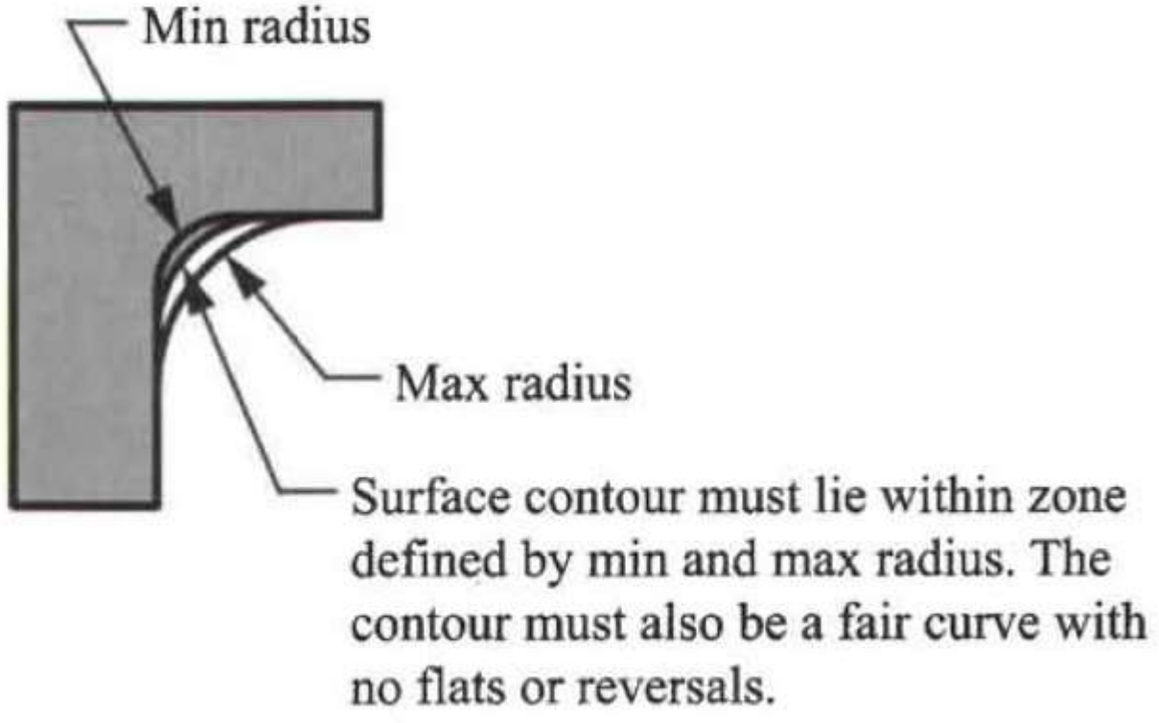
Radius





Controlled Radius





مدرس: داود قدس

تعریف بعد پایه

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Means this

Not this

مدرس: داود قدس

Geometric Characteristic Overview - ASME Y14.5-2009

Datums	Type of Tolerance	Geometric Characteristic	Symbol	2D or 3D	Controls		Applicability of Feature Modifiers	Applicability of Datum Modifiers	Control and Common Shape of Tolerance zones
					Axis or Center Plane	Surface			
Datums not Allowed	Form	Straightness of Line Elements	—	2D		X	No	NA	Surface line elements
		Straightness of an Axis	—	3D	X		Yes	NA	Axis
		Flatness of a Surface	▱	3D		X	No	NA	Surface
		Flatness of a Center Plane	▱	3D	X		Yes	NA	Center plane
		Circularity	○	2D		X	No	NA	Circular line elements
		Cylindricity	⌭	3D		X	No	NA	Surface
Datums Required	Orientation See note 3	Parallelism	//	3D	X	X	Yes, if features have size	Yes, if features have a boundary	
		Perpendicularity	⊥	3D	X	X	Yes, if features have size	Yes, if features have a boundary	
		Angularity	∠	3D	X	X	Yes, if features have size	Yes, if features have a boundary	
	Runout See note 1	Circular Runout	↗	2D		X	No	No	Circular line elements
		Total Runout	⌰	3D		X	No	No	Surface
Datums Required See note 2	Profile (Location of Surfaces)	Profile of a Line	⌒	2D		X	No	Yes, if features have a boundary	Line elements
		Profile of a Surface	⌓	3D		X	No	Yes, if features have a boundary	Surface
	Location of Features of size	Position	⌖	3D	X	See note 5	Yes	Yes, if features have a boundary	
		Concentricity	◎	3D	X	See note 4	No	No	Median Points
		Symmetry	⌯	3D	X	See note 4	No	No	Median Points

Notes:
1. Runout can control form, orientation, and location.
2. There are special cases where position and profile may not require datums.
3. Angularity symbol may be used for any orientation. Orientation tolerances by default are 3D, they can be made 2D by writing "LINE ELEMENTS" under the feature control frame.
4. Concentricity and Symmetry control opposing median points and are not commonly used.
5. Position can also locate a surface boundary.

مدرس: داود قدس

کاراکترهای تلرانس هندسی

پنج خانواده از کاراکترهای هندسی برای کنترل‌های خاص قابل دسته‌بندی می‌باشند:

۱- تلرانس‌های فرم

برای کنترل فرم یا شکل فیچرهای انفرادی و فیچرهای سایز به کار می‌روند. خانواده تلورانس‌های فرم شامل کاراکترهای زیر می‌باشند:

الف- راستی

ب- تختی

ج- گردی یا دایروی بودن

د- استوانه‌ای بودن

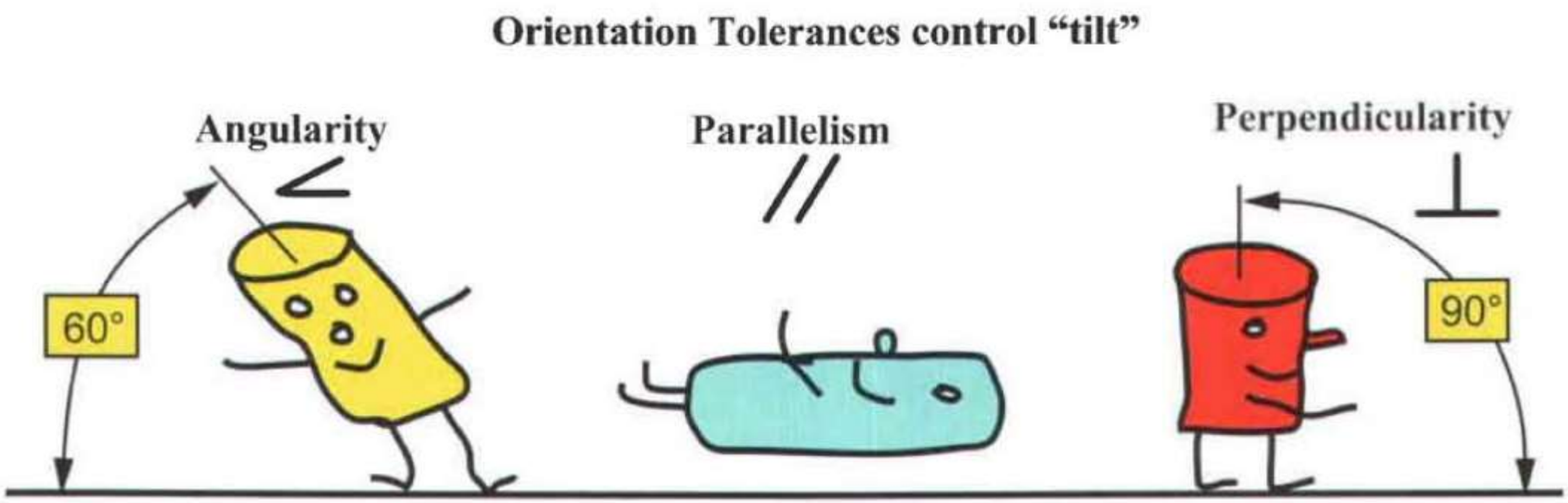
۲- تلرانس‌های جهت

تلرانس‌های جهت ارنباط بین یک فیچر با فیچر دیگر را بیان می‌کنند. بنابراین آنها همواره همراه با یک دیتوم بیان می‌شوند. این خانواده از تلرانس‌ها شامل کاراکترهای زیر می‌باشند:

الف- زاویه‌دار بودن

ب- تعامد

ج- توازی



مدرس: داود قدس

۳- تلرانس‌های پروفیل

تلرانس پروفیل برای شکل‌های غیر معمول مانند کانتورها به کار رفته و نیز می‌توانند جهت کنترل coplanarity (وجود بیش از یک صفحه در یک سطح) به کار روند.

این خانواده از تلرانس‌ها شامل کاراکترهای زیر می‌باشند:

۱- پروفیل خط

۲- پروفیل سطح

٤- تلرانس‌های لنگی

تلرانس‌های لنگی برای قطعات دورانی، به منظور کنترل هم‌محور بودن فیچرهای استوانه‌ای نسبت به یکدیگر و یا لنگی سطوح نهایی نسبت به محور دیتوم مورد استفاده قرار می‌گیرند.

این خانواده از تلرانس‌ها شامل کاراکترهای زیر می‌باشند:

۱- لنگی ساده

۲- لنگی مرکب

۵- تلرانس‌های مکانی

تلرانس‌های مکانی برای کنترل موقعیت مرکز فیچرهای سایز (مانند موقعیت محور سوراخ یا پین یا صفحه میانه شیار و یا نوارهای عمودی) استفاده می‌شوند.

خانواده تلرانس‌های مکانی شامل کاراکترهای زیر می‌باشند:

۱- موقعیت

۲- هم‌مرکزی

۳- تقارن

راستی در حالت دو بعدی

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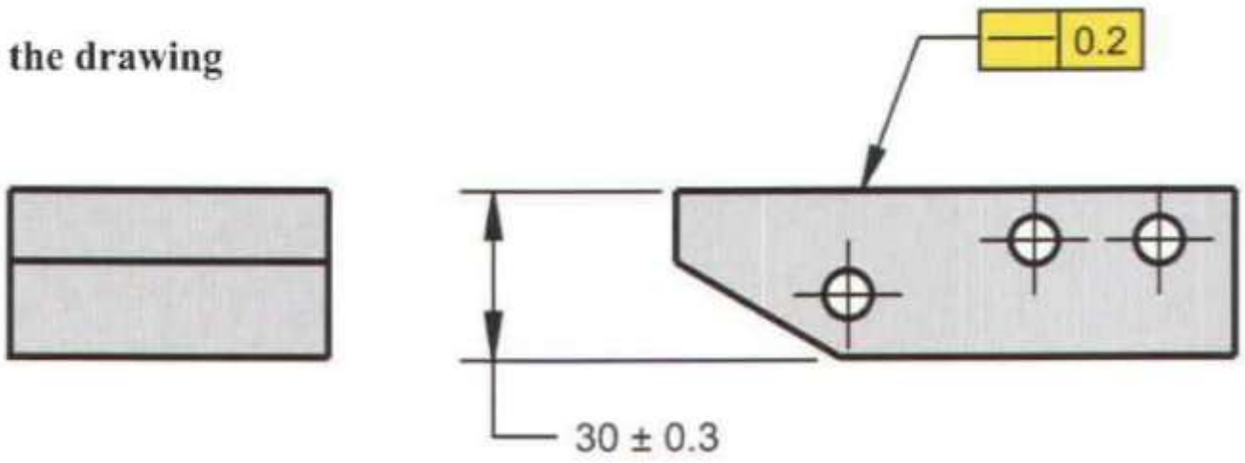
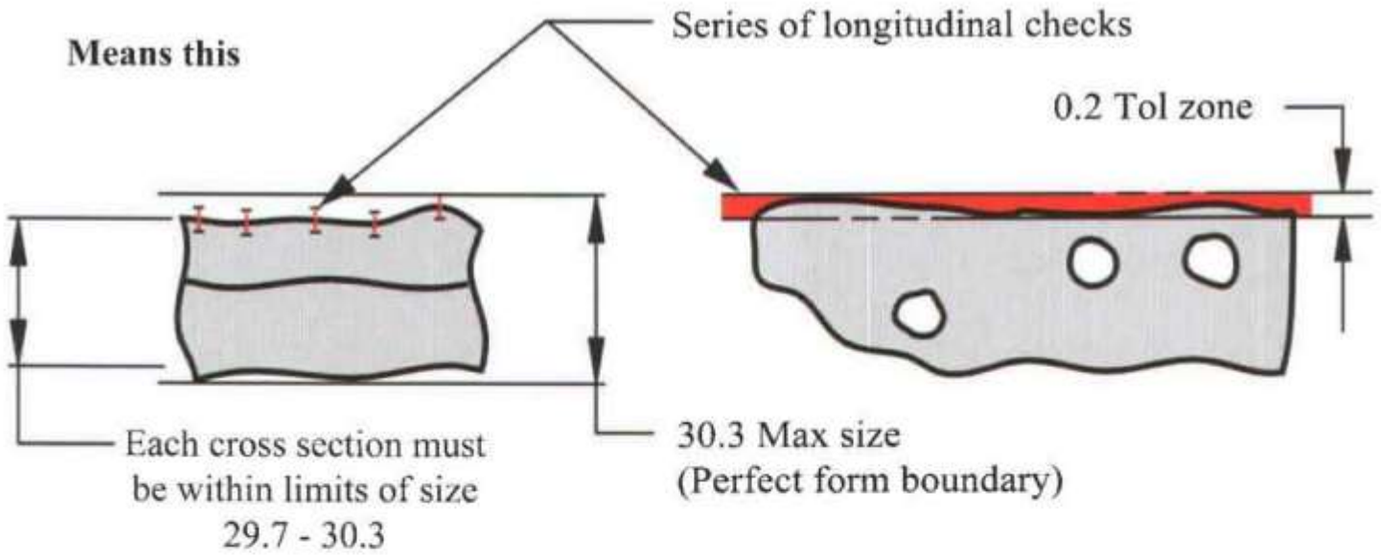
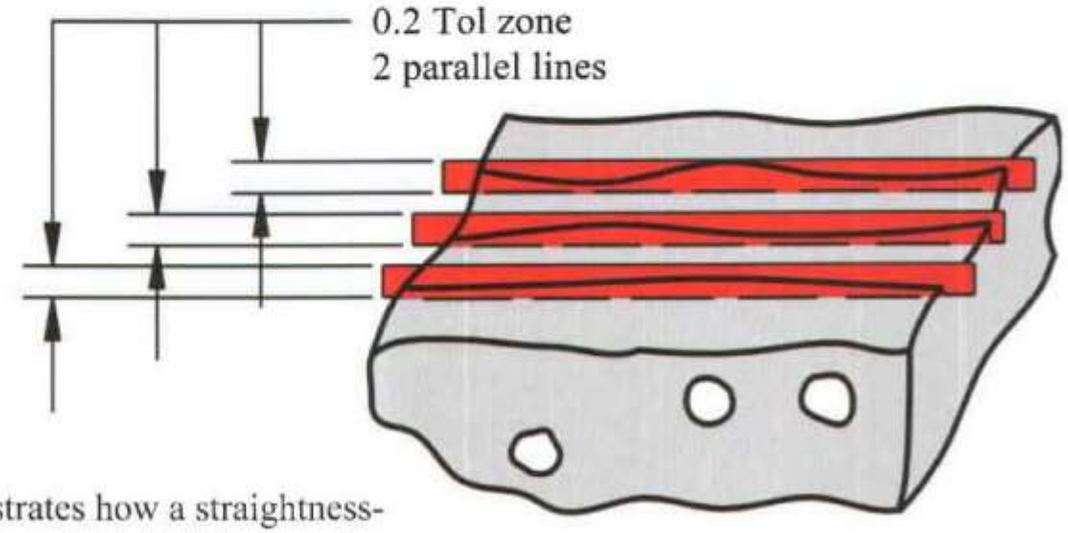


Means this





The figure to the right illustrates how a straightness-line elements specification controls the tolerance in a series of 2D line elements in the view shown.

مدرس: داود قدس

راستی در حالت دو بعدی

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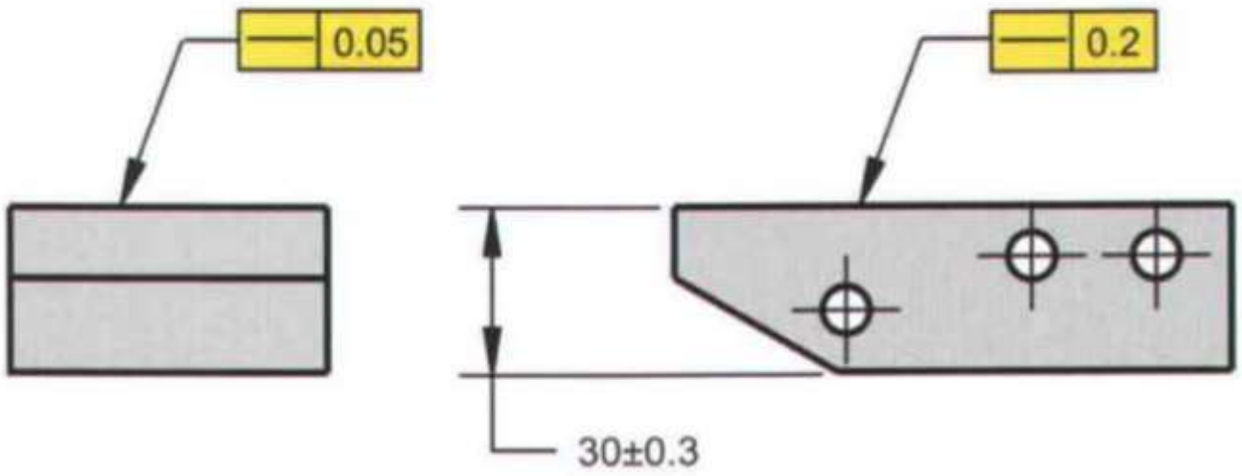

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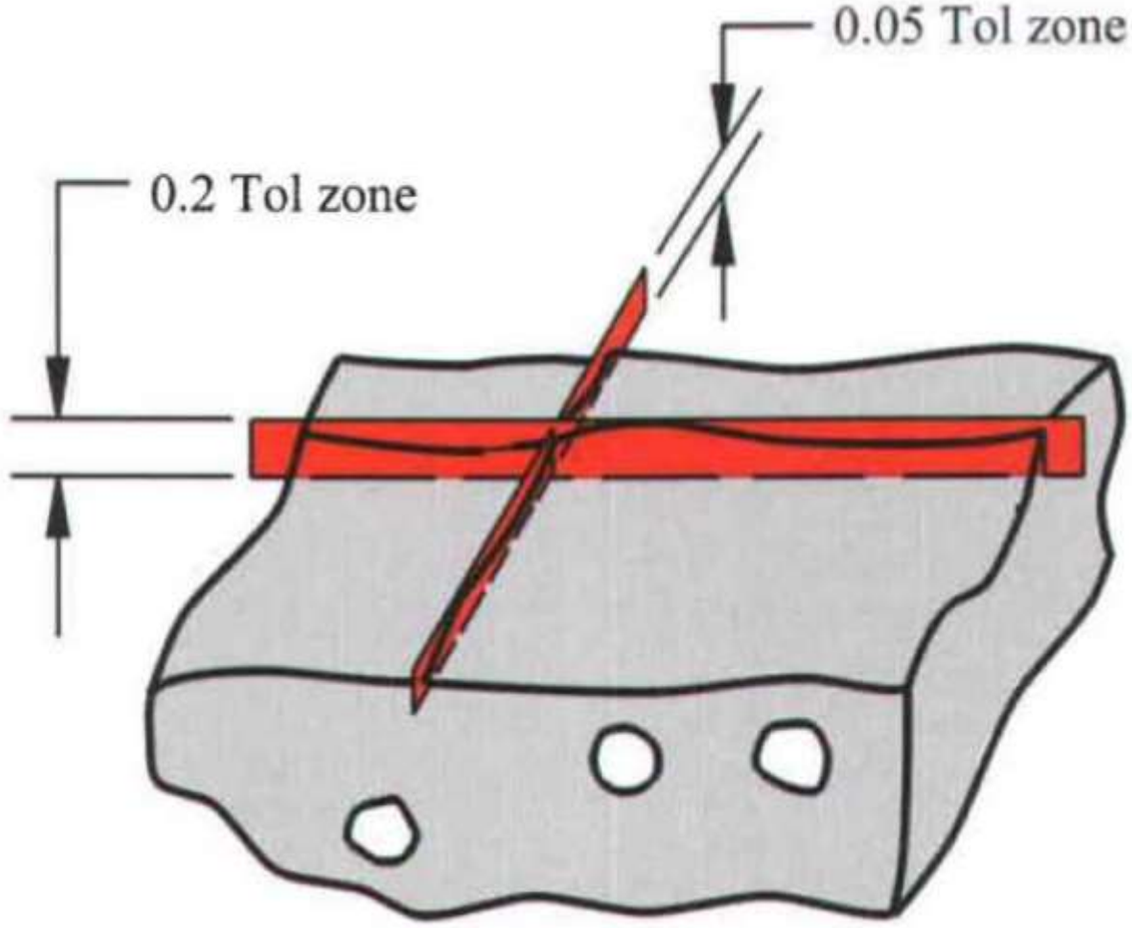

راستی در حالت سه بعدی

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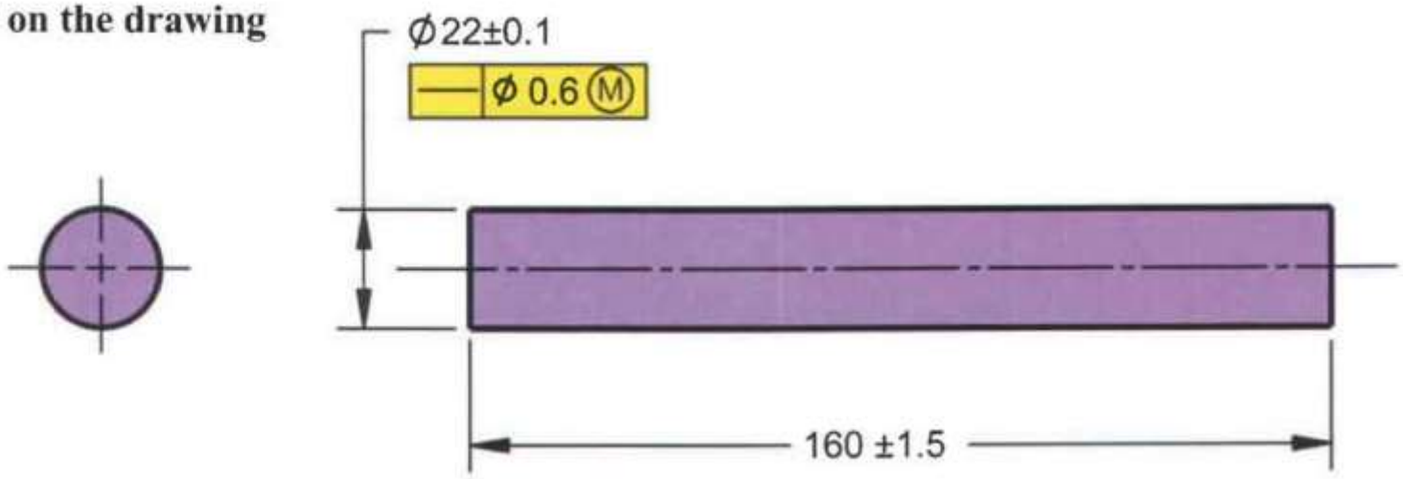
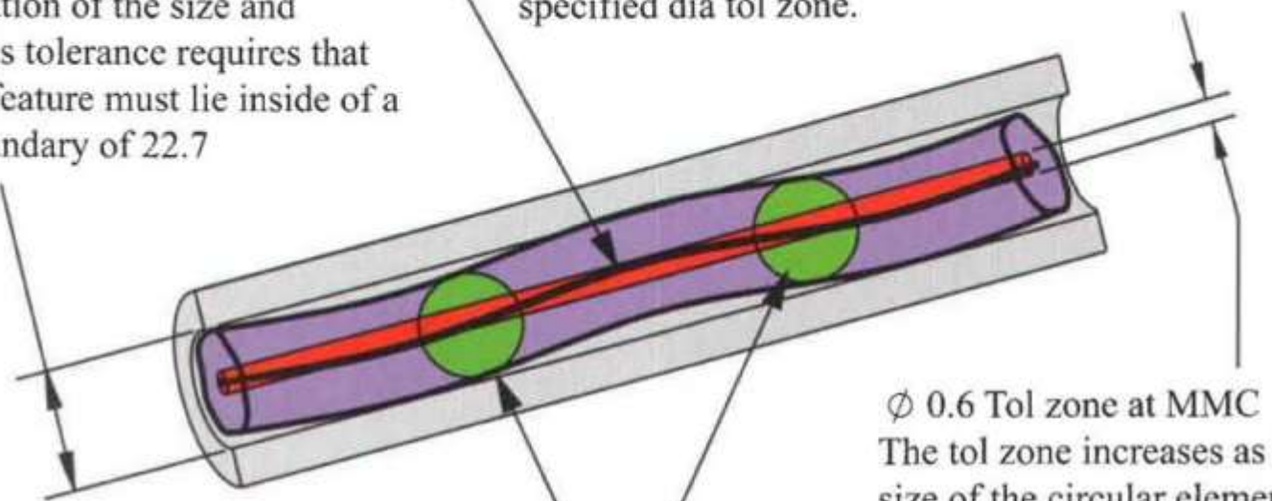


Means this

A combination of the size and straightness tolerance requires that the entire feature must lie inside of a virtual boundary of 22.7

The derived median line of the feature must lie within the specified dia tol zone.



Ø 0.6 Tol zone at MMC
The tol zone increases as the size of the circular elements departs from MMC

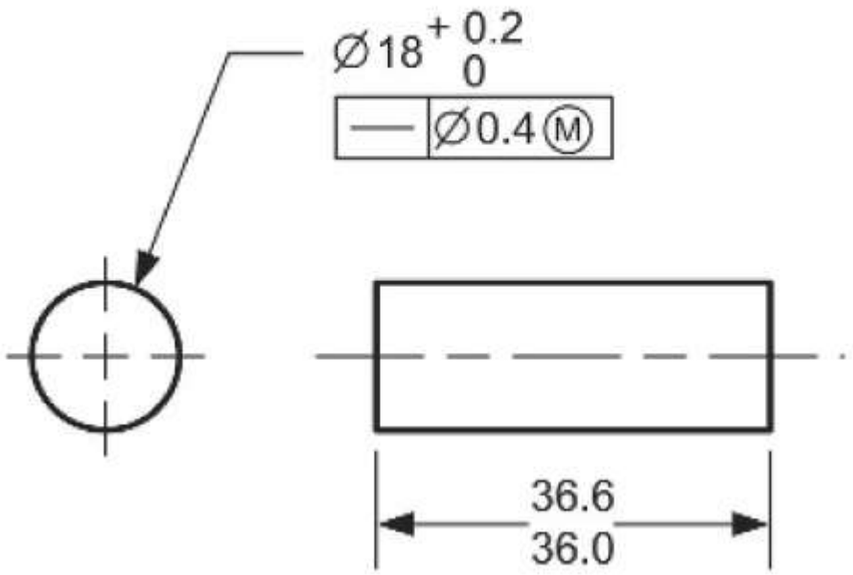
Straightness of an axis releases the perfect form at MMC requirement defined by Rule #1, but still requires each local cross-section to be within the 21.9/22.1 limits of size.

Feature Size	Tol Zone Size	Virtual
MMC Ø 22.1	Ø 0.6	
Ø 22.0	Ø 0.7	Ø 22.7
LMC Ø 21.9	Ø 0.8	

مدرس: داود قدس

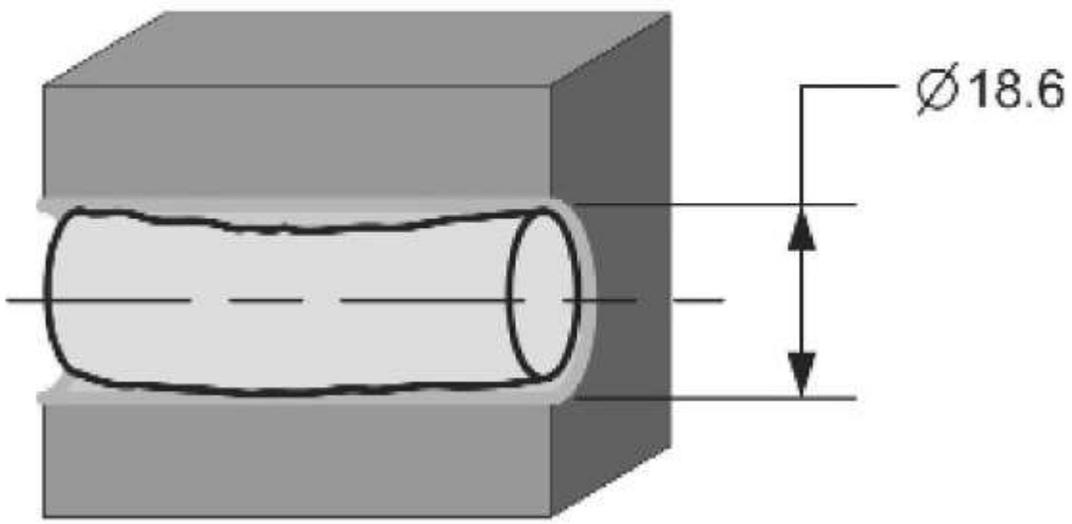
راستی در حالت سه بعدی

Drawing

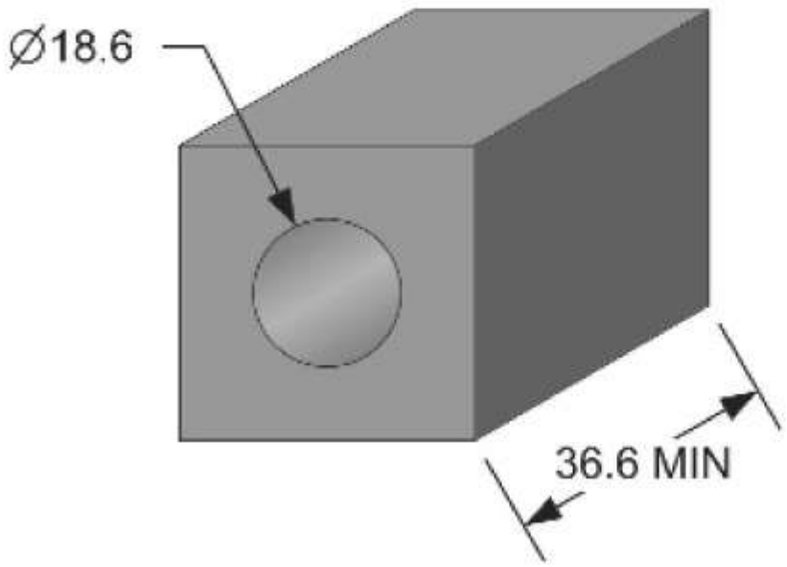


Part verification

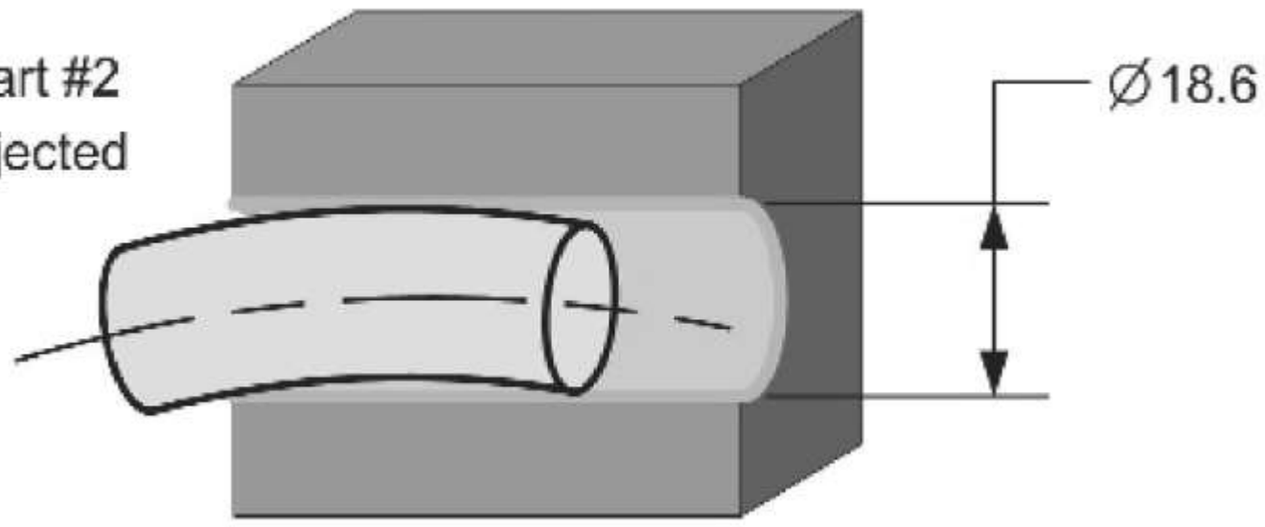
Part #1
accepted



Functional gage

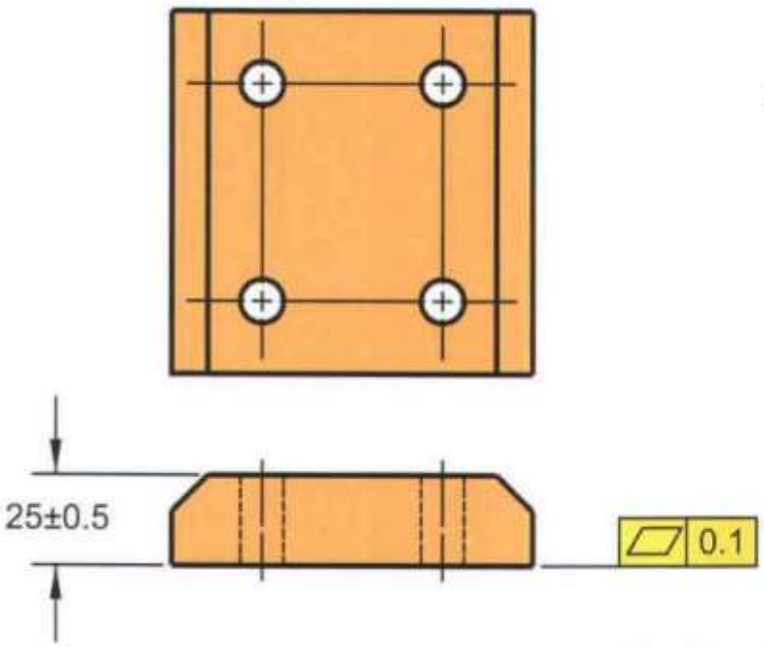


Part #2
rejected

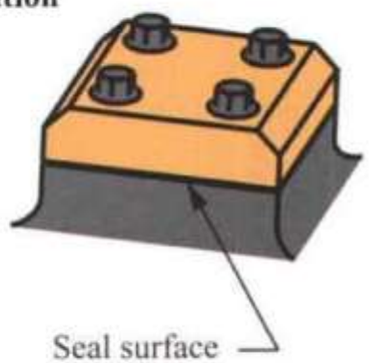


تختی

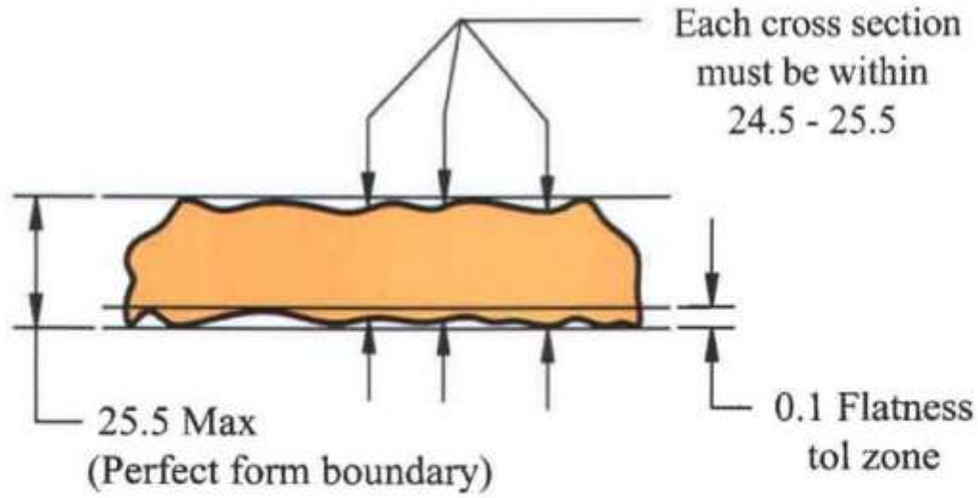
This on the drawing

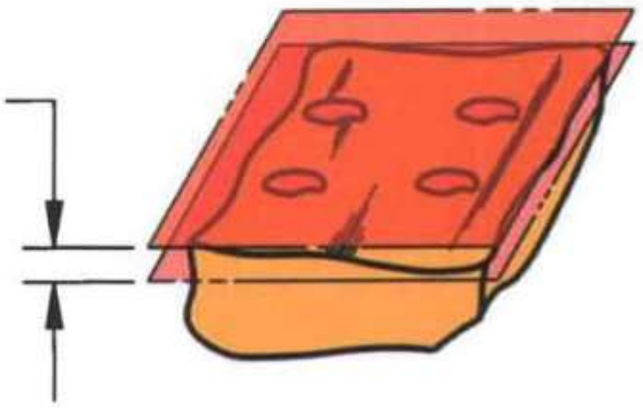


Application



Means this



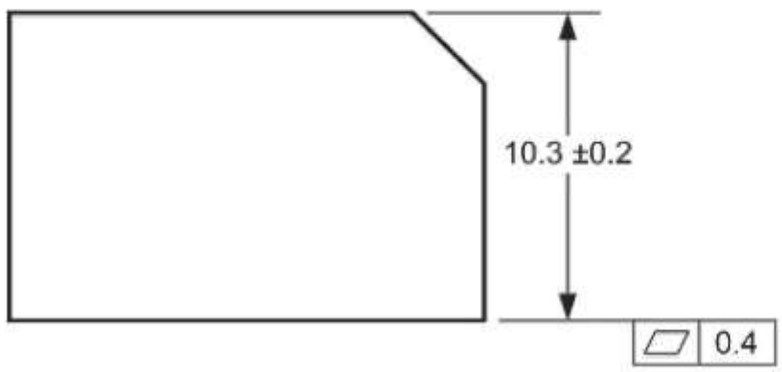


Flatness of a surface is a form tolerance and datums are not allowed. Since flatness controls the surface, the material condition modifiers MMC and LMC are not allowed.

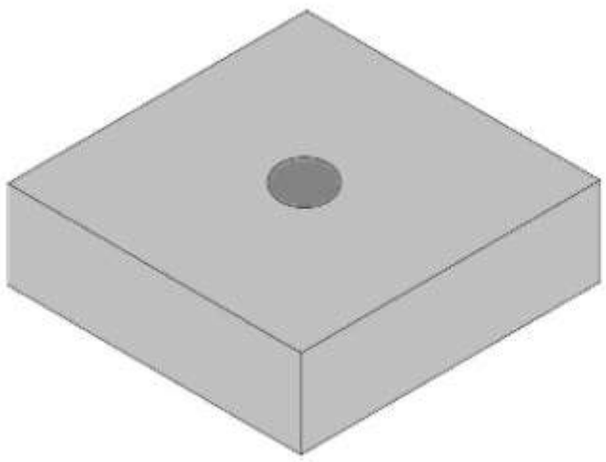
مدرس: داود قدس

تختی

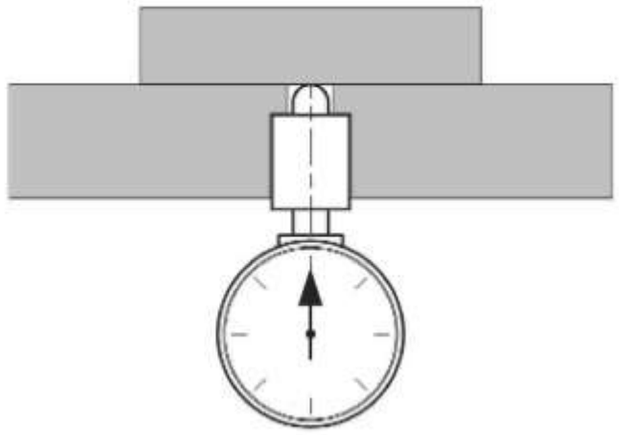
A Drawing



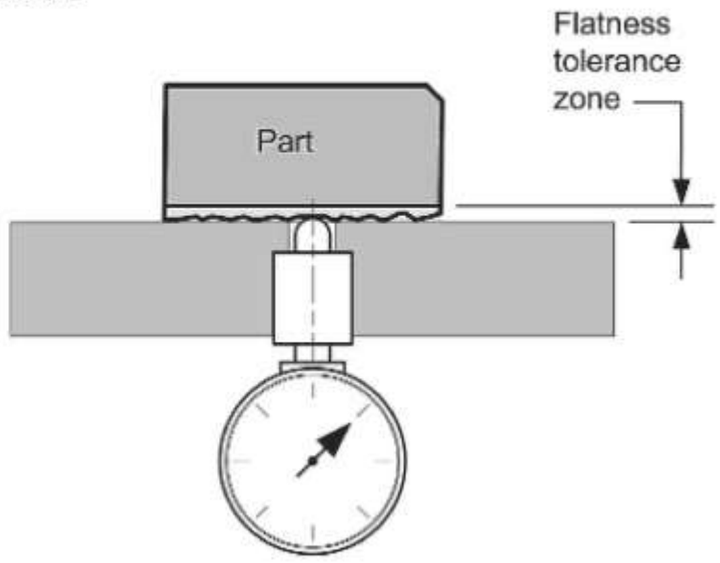
B Surface plate with small hole



C Dial indicator mounted to the surface plate and a gage plate is used to set the indicator to zero at the surface of the plate



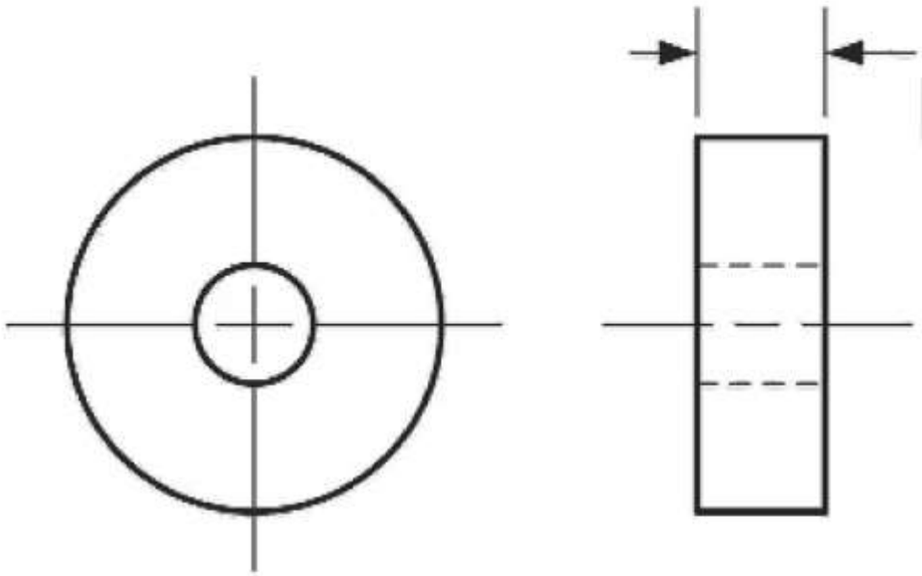
D The indicator reading is the flatness deviation of the surface



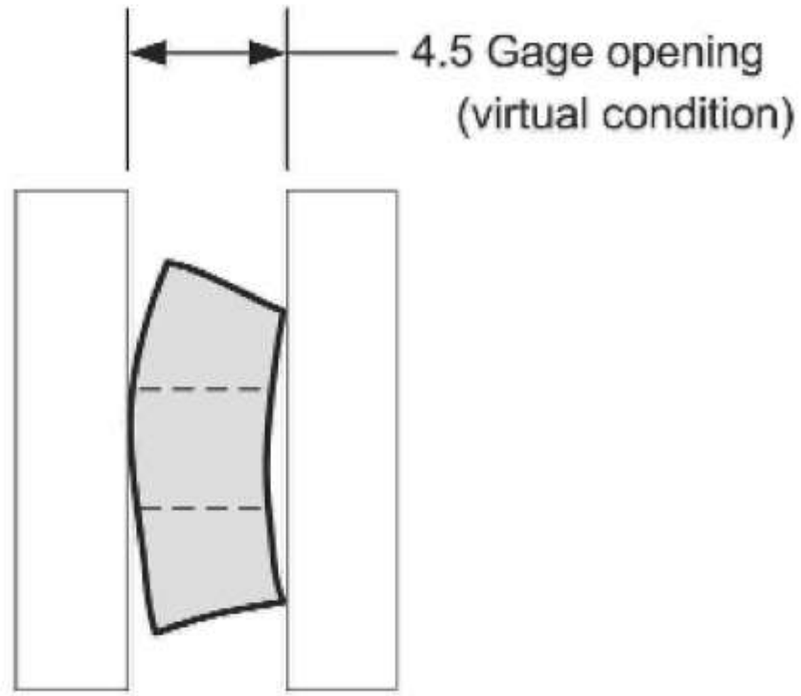
مدرس: داود قدس

تختی

Drawing



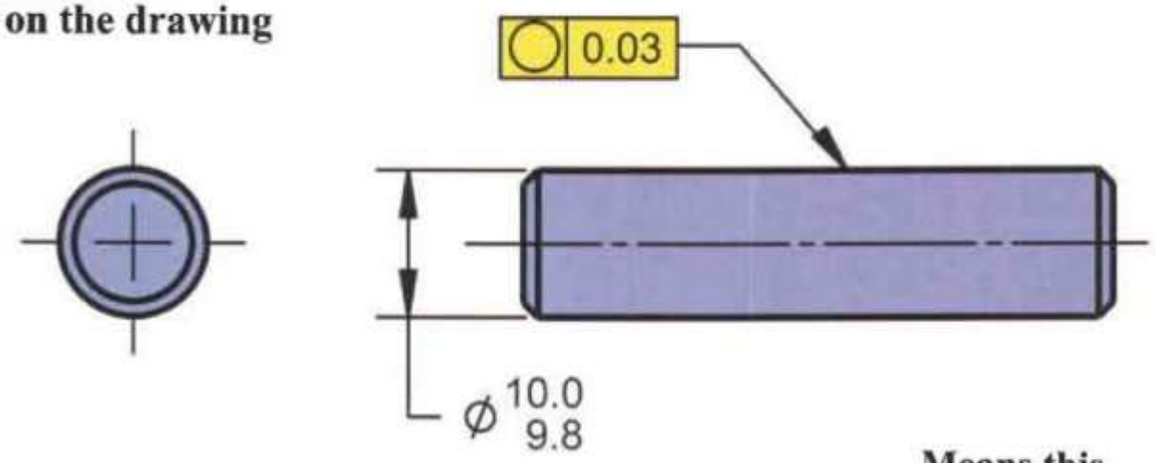
Verification



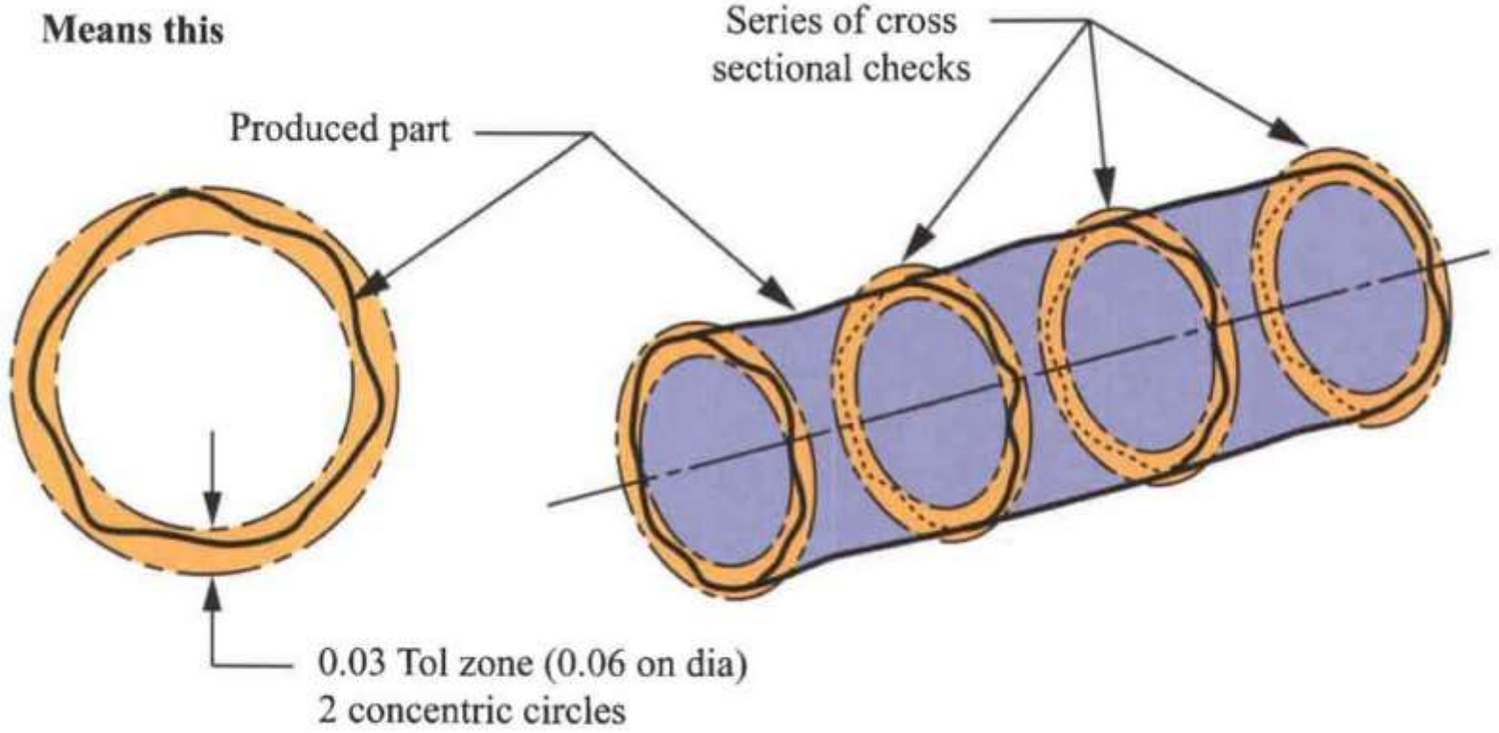
مدرس: داود قدس

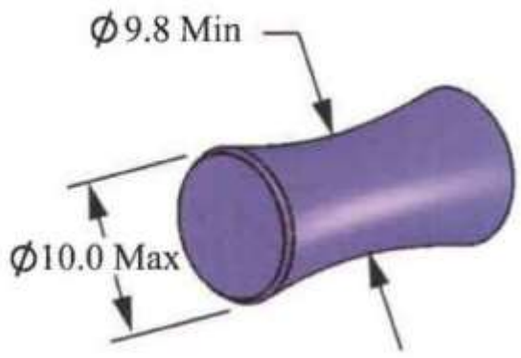
گردی

This on the drawing



Means this



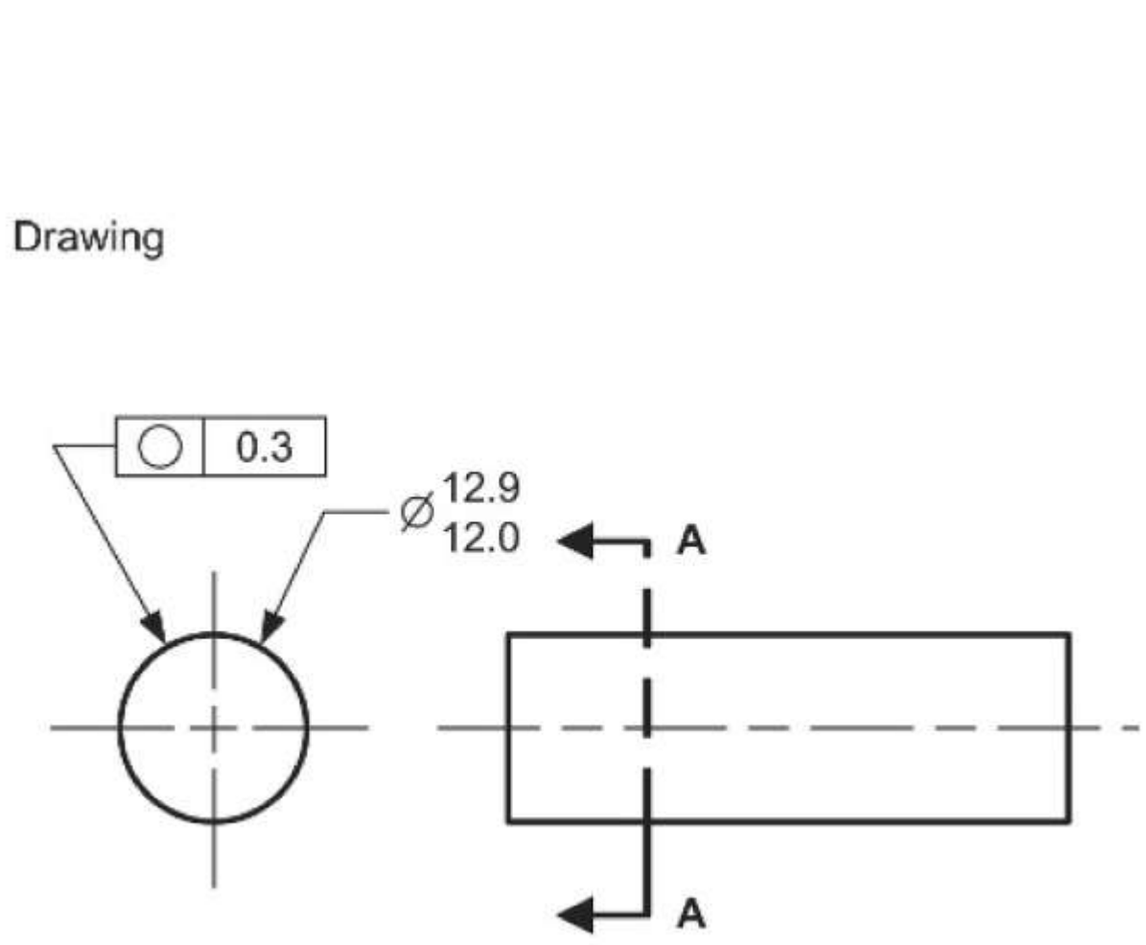


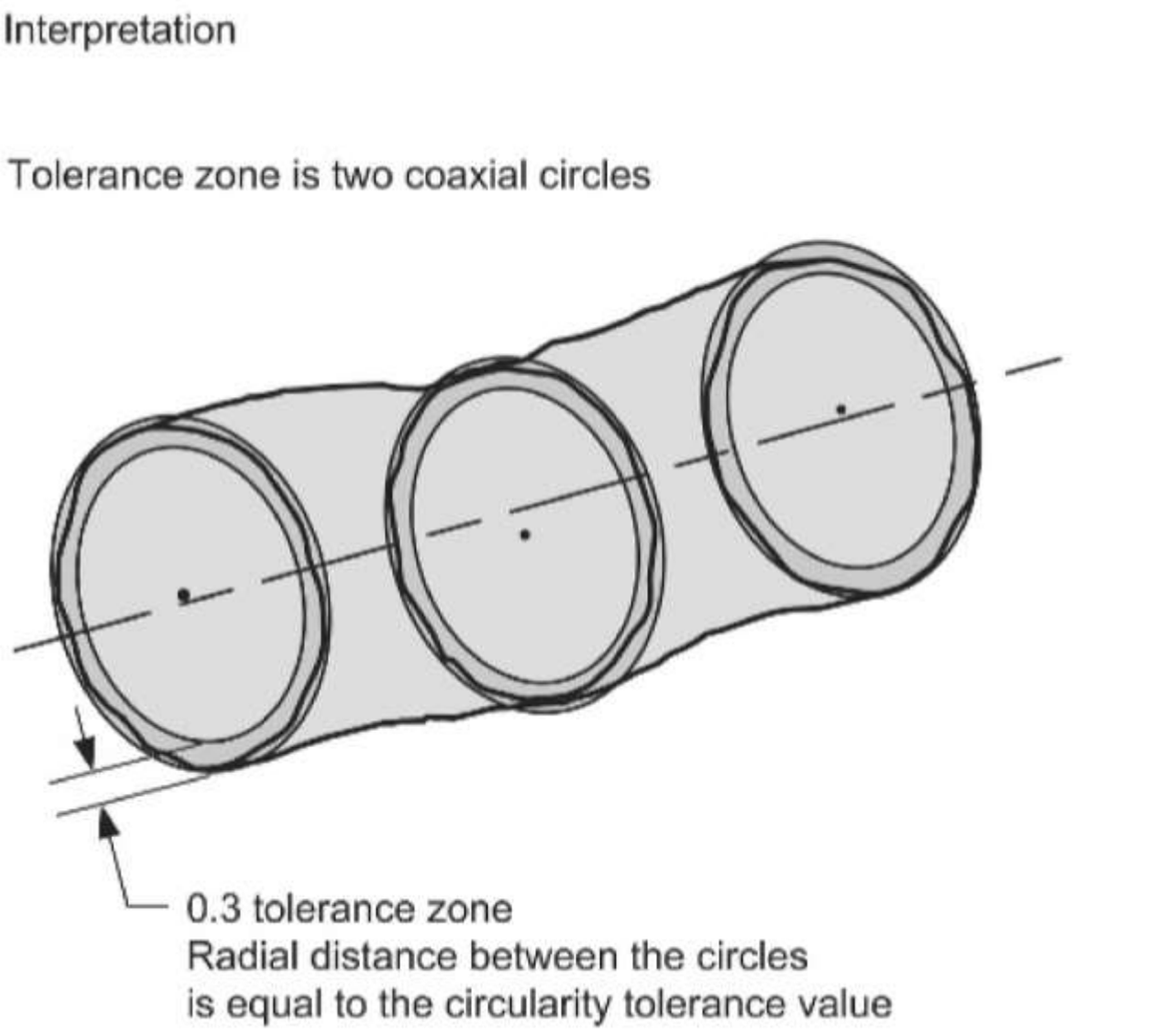
Circularity allows the shape of the feature to be waisted, barrelled, or tapered within the size tolerance. Circularity controls only the circular elements of the feature.

مدرس: داود قدس

در این حالت بایستی قطعه را با استفاده از ۵ بلوک V شکل آزمایش نمود. بلوک V شکلی که اعداد حاصل از آن دارای مقادیر کمتر است بیانگر تعداد لبه قطعه است.

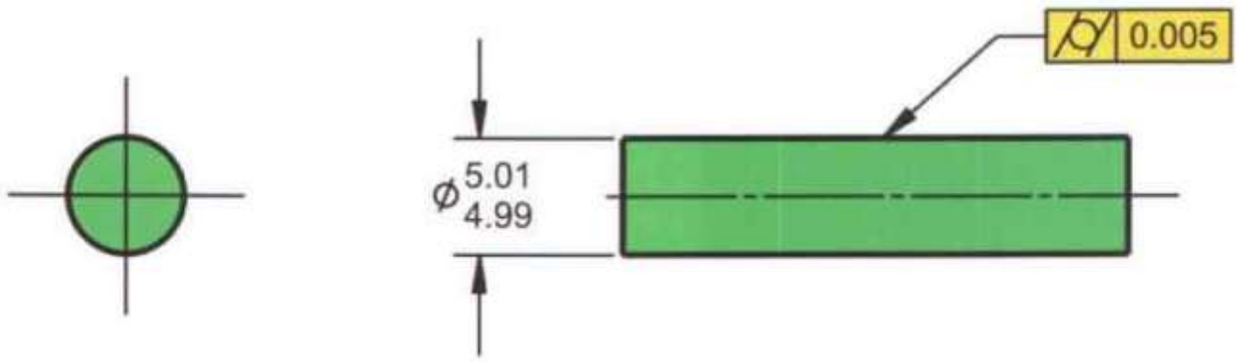
علت این که کمترین عدد انتخاب می‌شود این است که میزان هم محوری آن کمترین مقدار است.





استوانه‌ای بودن

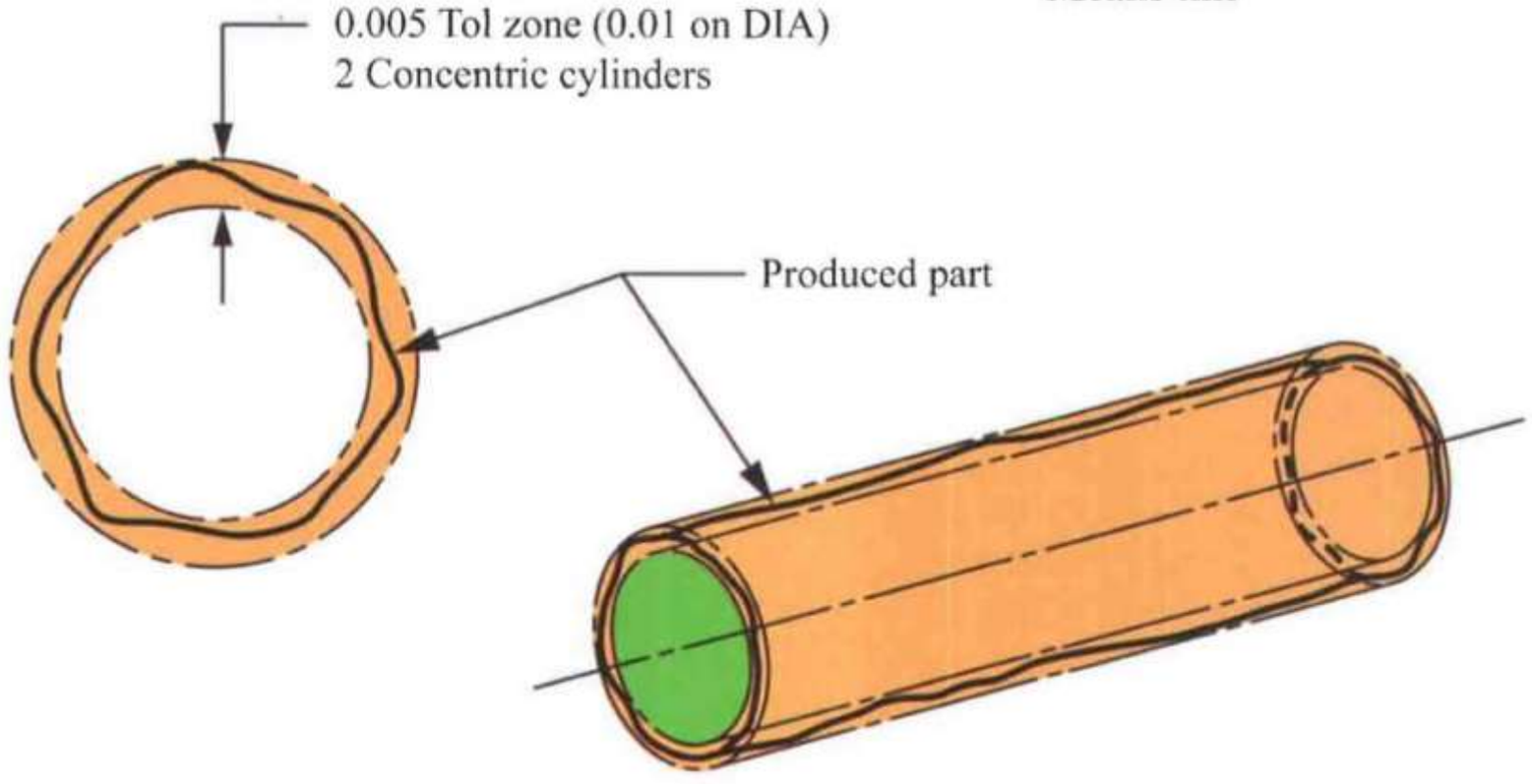
This on the drawing



Application

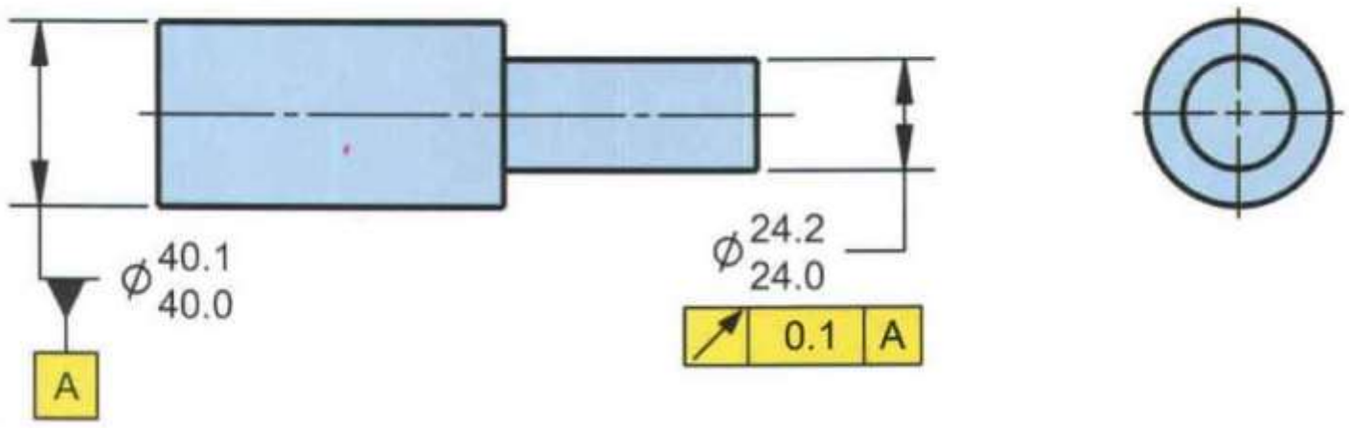
The size of the bearings can vary within a greater tolerance relative to the cylindricity.

Means this



لنگی ساده

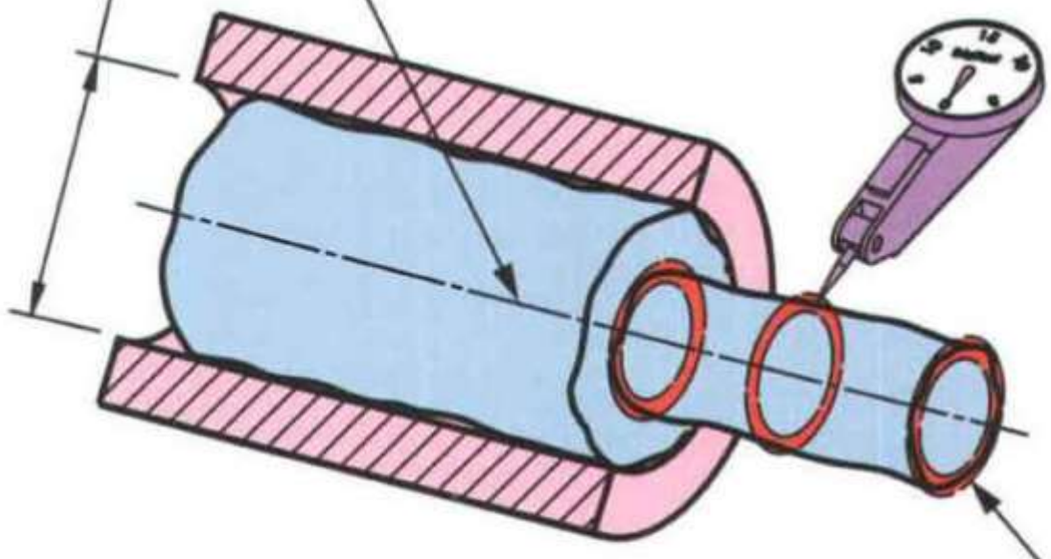
This on the drawing



Means this

The theoretical datum feature simulator is the smallest circumscribed cylinder that contacts the high points of the feature. Depending on the accuracy required, this may be practically simulated by a collet, chuck, vee block, etc.

Datum axis A is the axis of the datum feature simulator

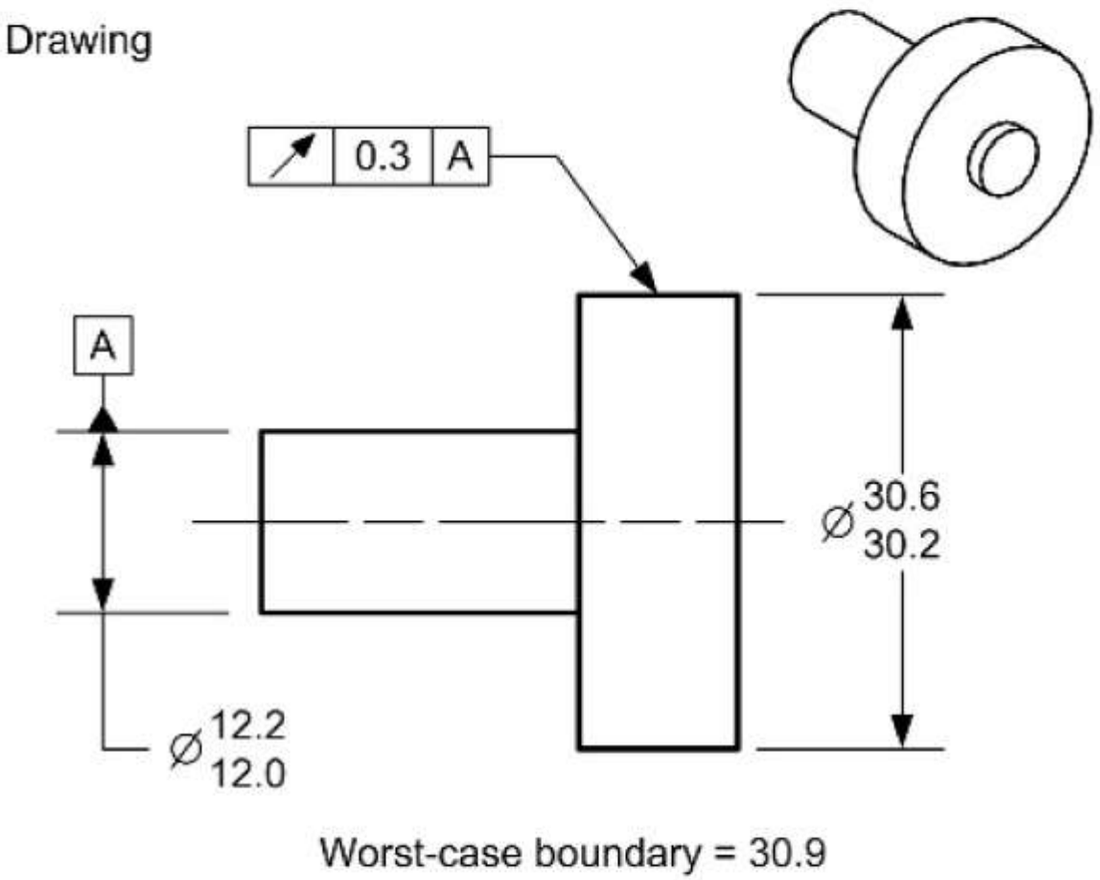


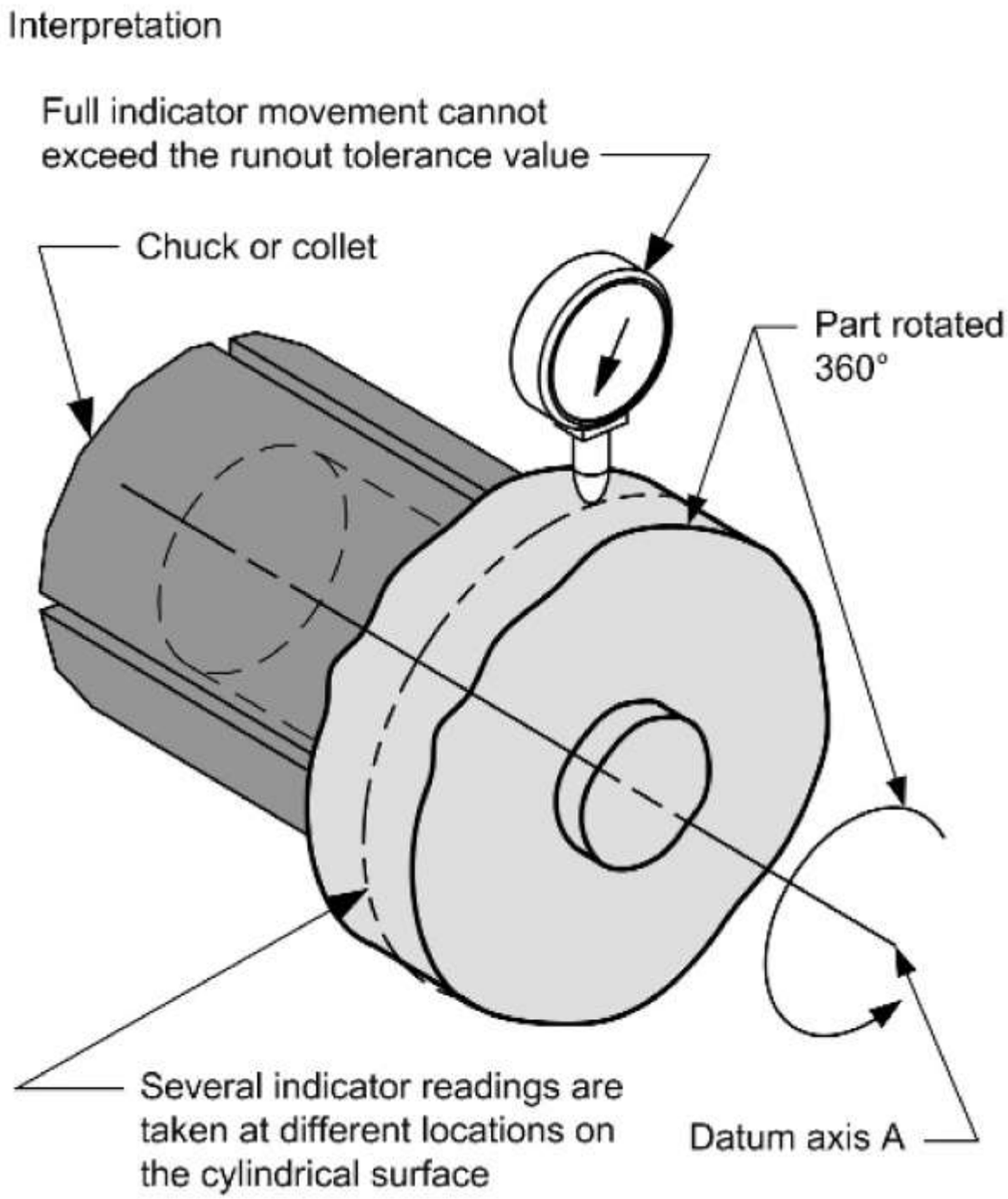
Circular runout is a 2D control and requires a series of circular cross-sectional checks of the surface.

This controls circularity, orientation, and location of the feature for a maximum of 0.1 full indicator movement. It does not control taper, straightness, or size. On this part, the outer boundary is 24.3. The inner boundary is 23.9.

Each circular element of the feature must lie between two circles, one having a radius of 0.1 larger than the other, perfectly concentric to the datum axis A. Additionally, the feature must be within the limits of size (24.0/24.2).

لنگی ساده

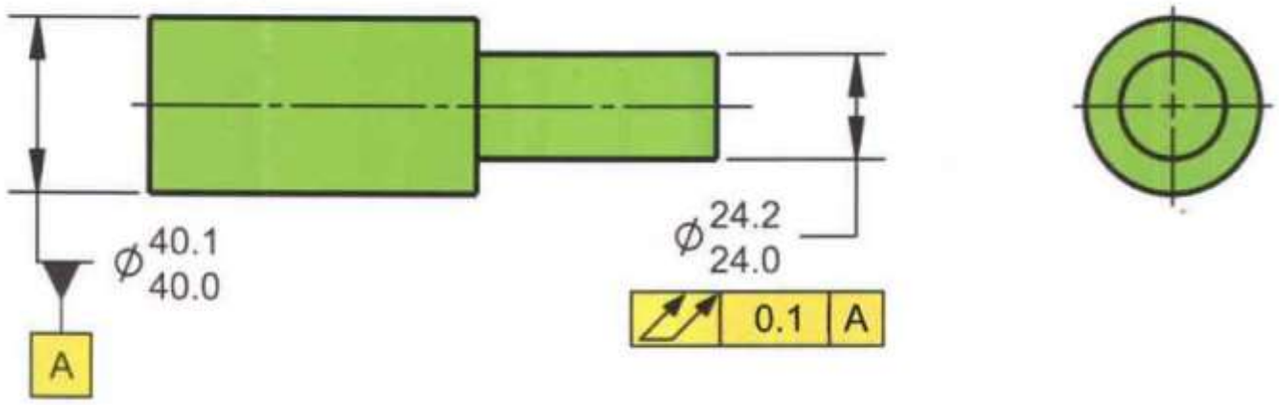




مدرس: داود قدس

لنگی مرکب

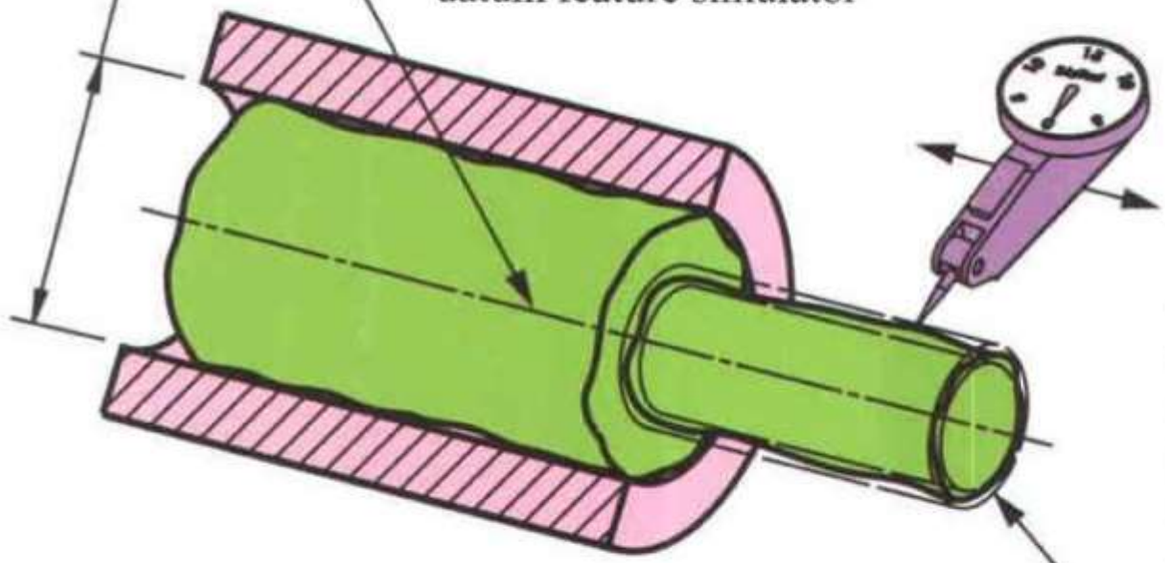
This on the drawing



Means this

The theoretical datum feature simulator is the smallest circumscribed cylinder that contacts the high points of the feature. Depending on the accuracy required, this may be practically simulated by a collet, chuck, vee block, etc.

Datum axis A is the axis of the datum feature simulator

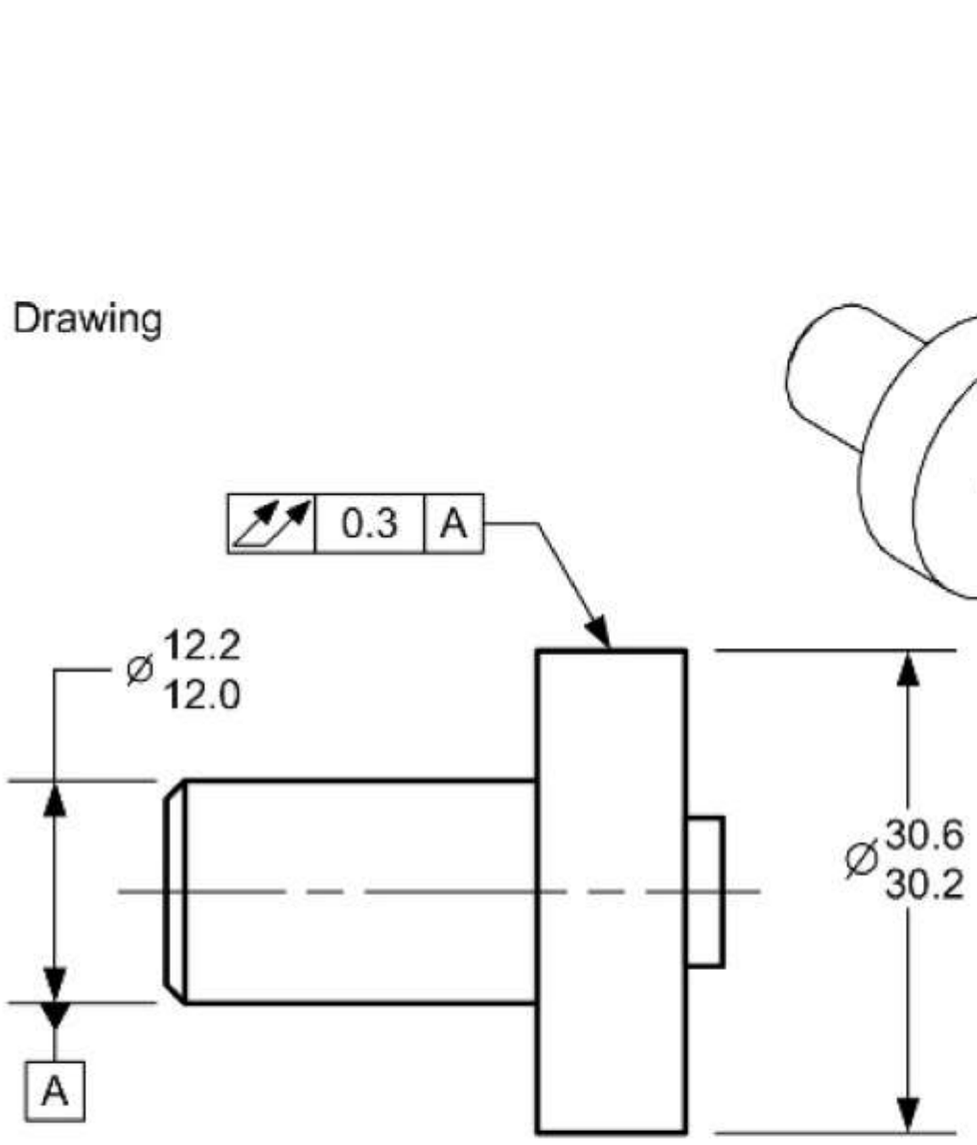


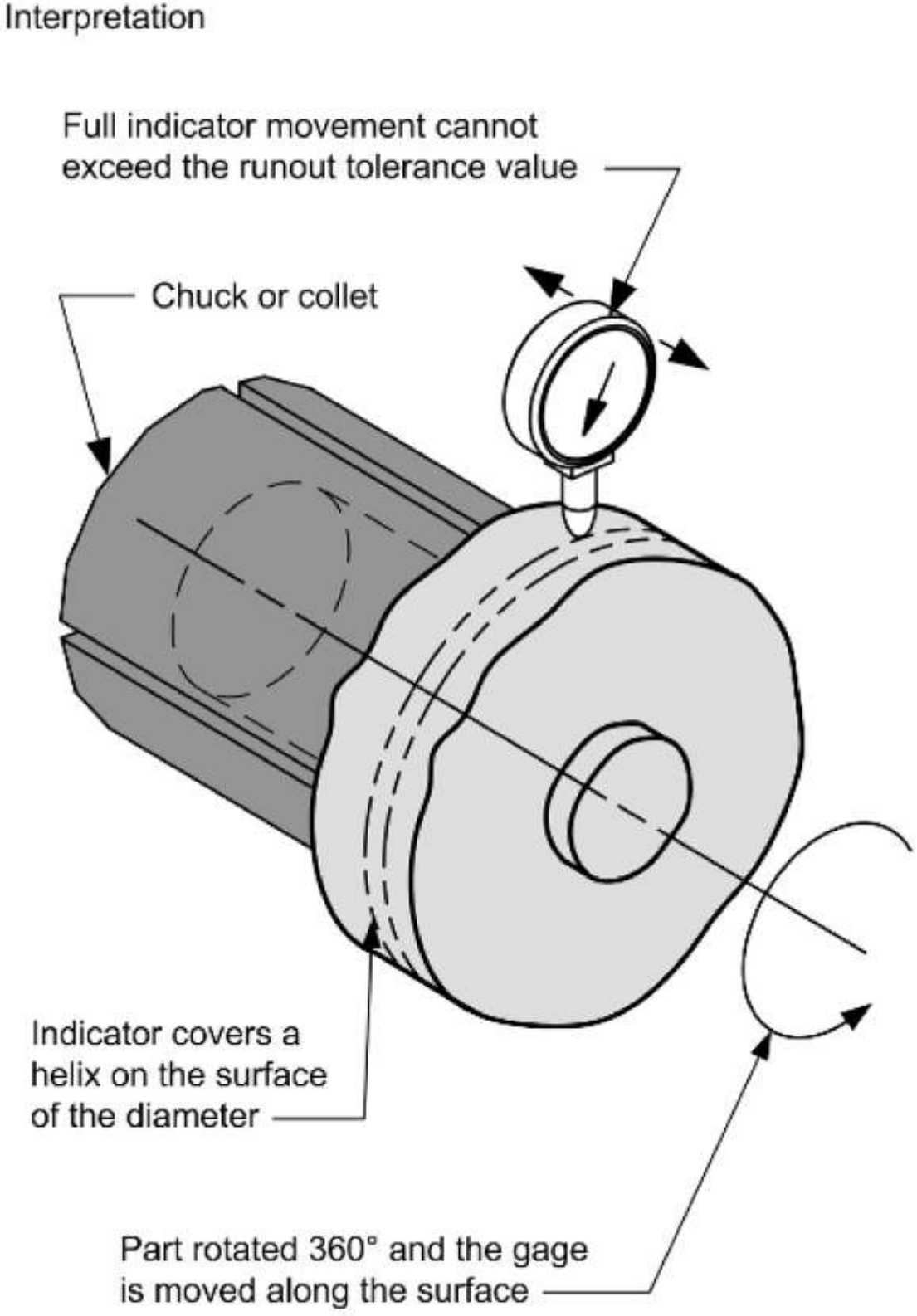
Total runout is a 3D control and requires a total sweep of the surface. This will control form, orientation, location, and taper (but not size) of the feature for a maximum of 0.1 full indicator movement (FIM). On this part, the outer boundary is 24.3. The inner boundary is 23.9.

The feature must lie between two cylinders, one having a radius of 0.1 larger than the other, perfectly concentric to the datum axis A. Additionally, the feature must be within the limits of size (24.0/24.2).

مدرس: داود قدس

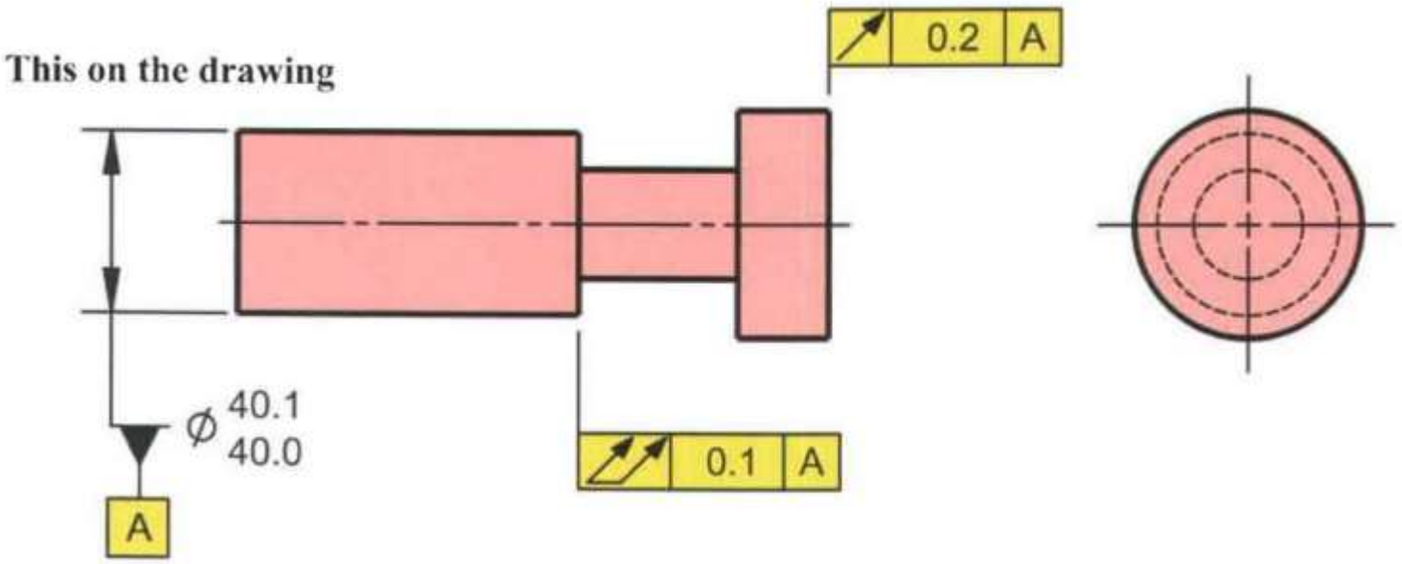
لنگی مرکب

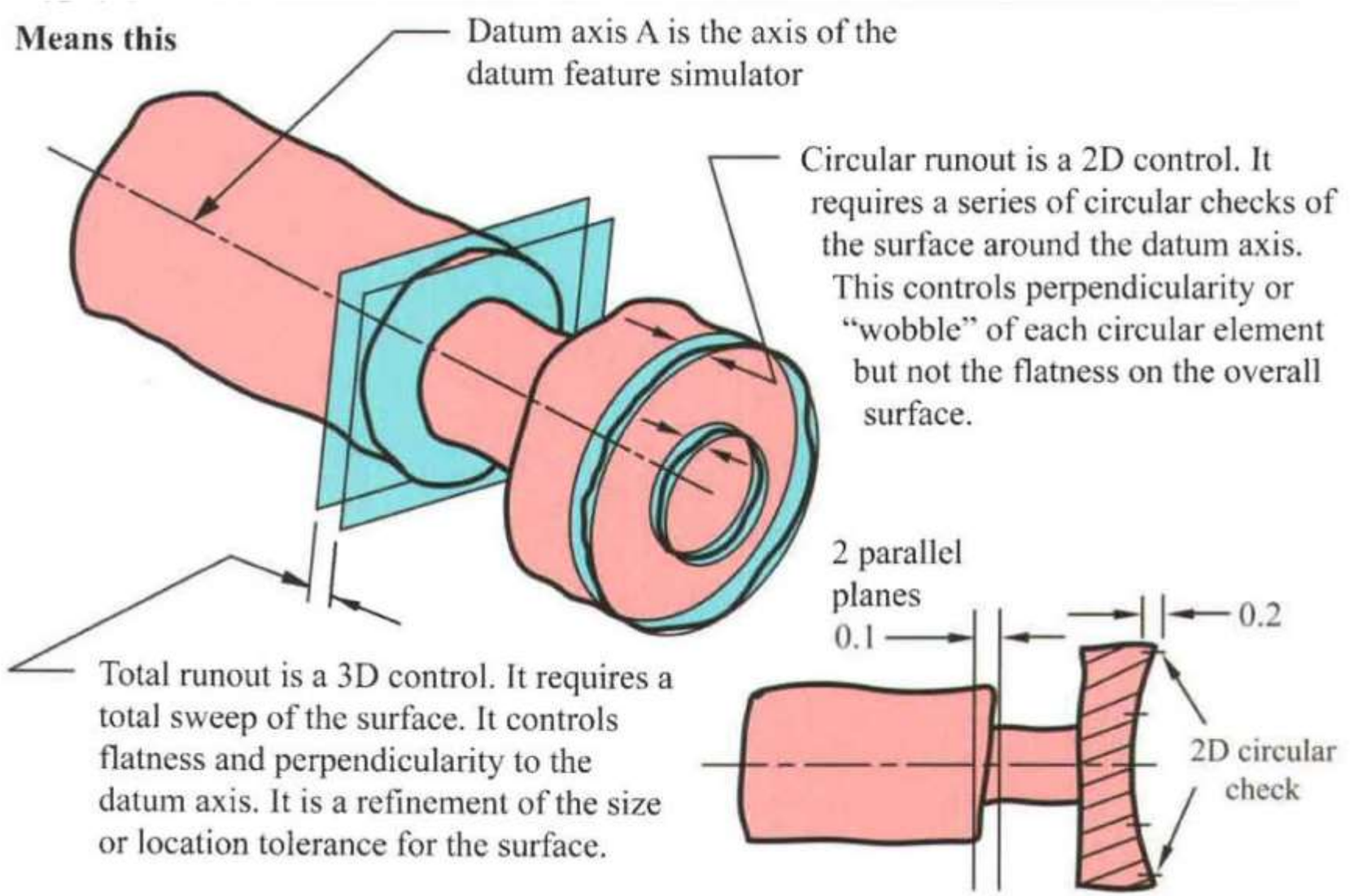




مدرس: داود قدس

لنگی ساده و مرکب روی پیشانی

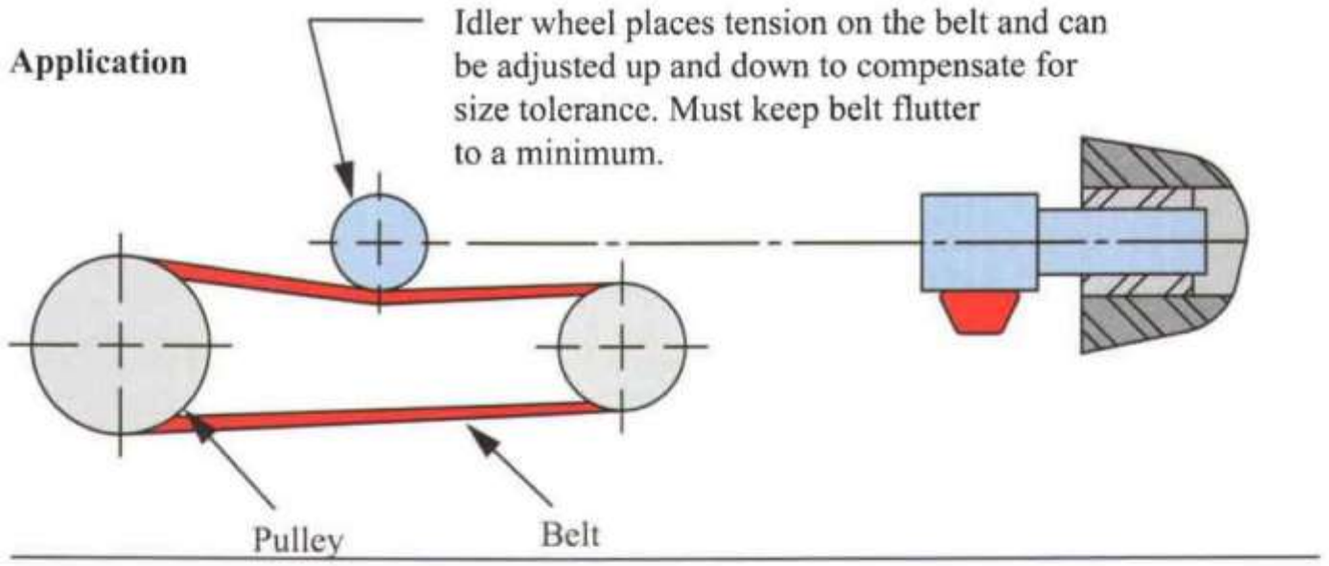




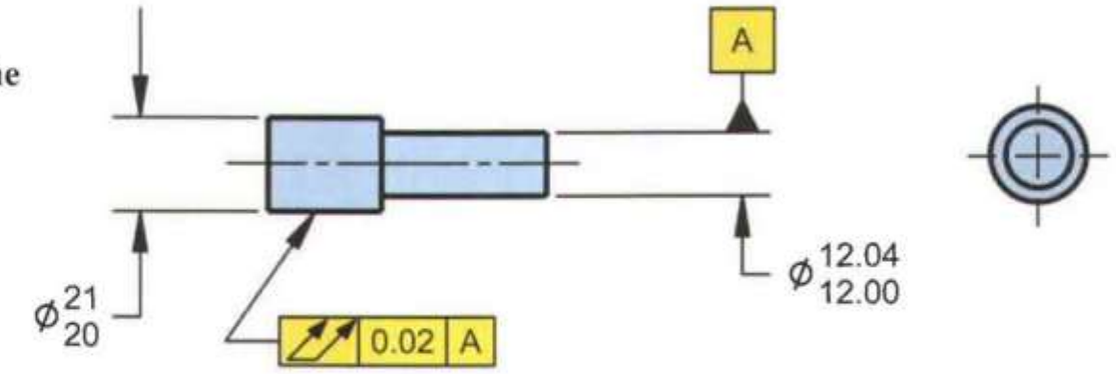
مدرس: داود قدس

Runout - Coaxial Application

Application

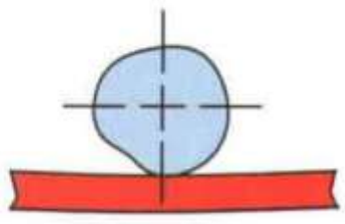


This on the drawing

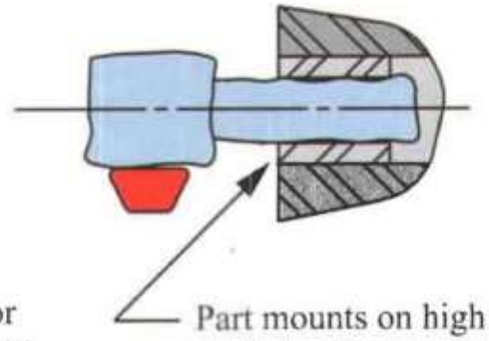


Produced part in assembly

Runout Is A Surface To An Axis Control



The belt rides on the feature surface. A runout tolerance was selected because the combined error of form, orientation, and location of the feature will contribute to the belt "flutter." The size of the feature has no impact because the idler wheel may be adjusted.

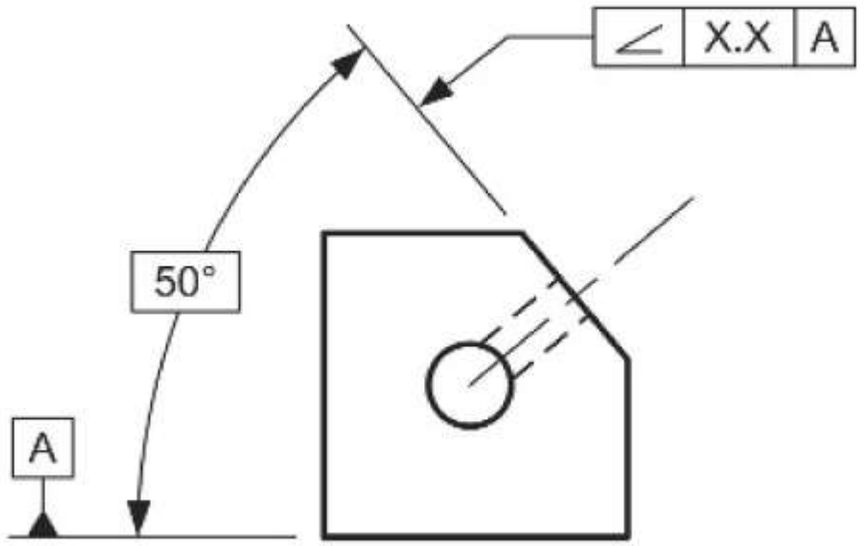


Part mounts on high points of the shaft (mating size). This diameter is established as datum feature A.

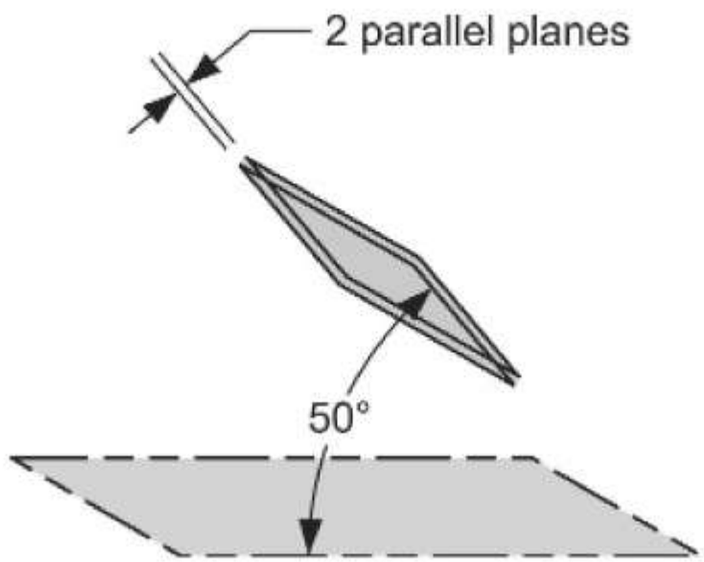
مدرس: داود قدس

زاویه‌دار بودن

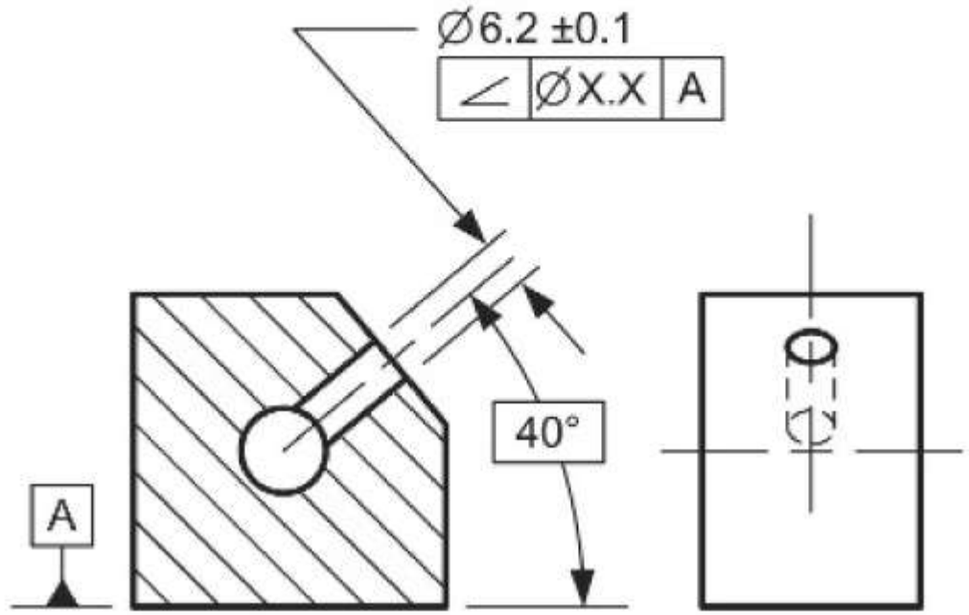
Specified with no modifier



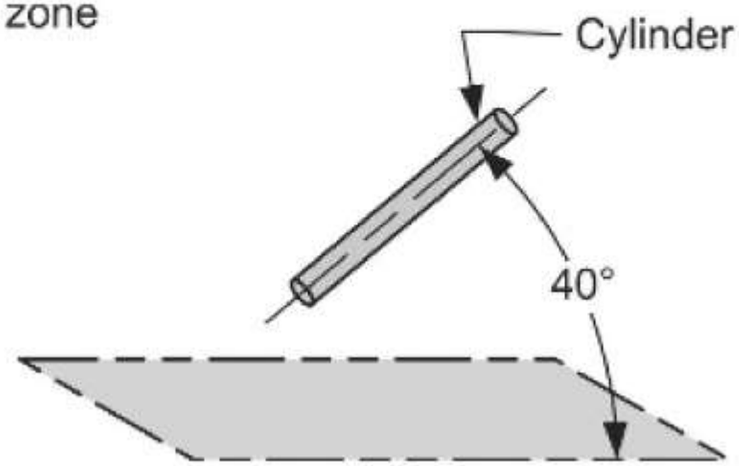
Tolerance zone



Specified with the diameter symbol modifier



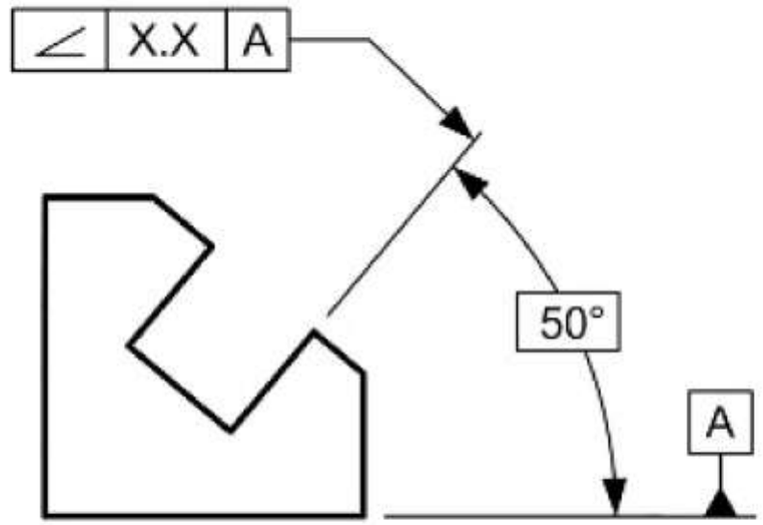
Tolerance zone



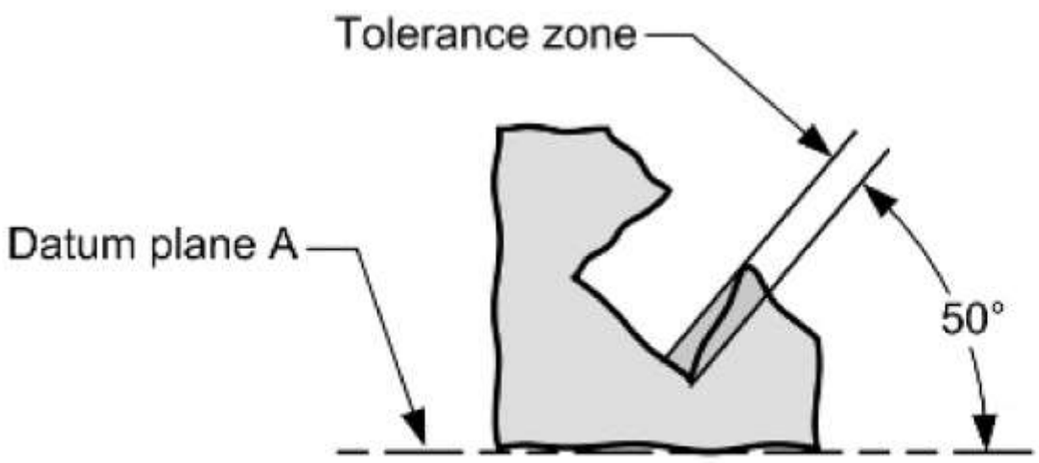
مدرس: داود قدس

زاویه‌دار بودن

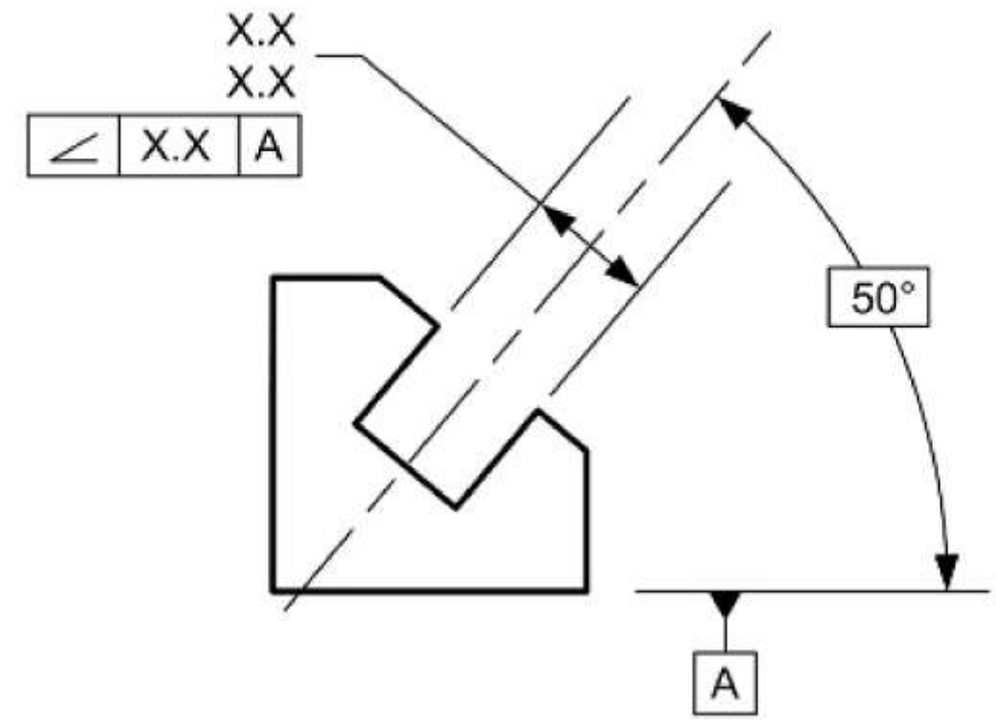
Application



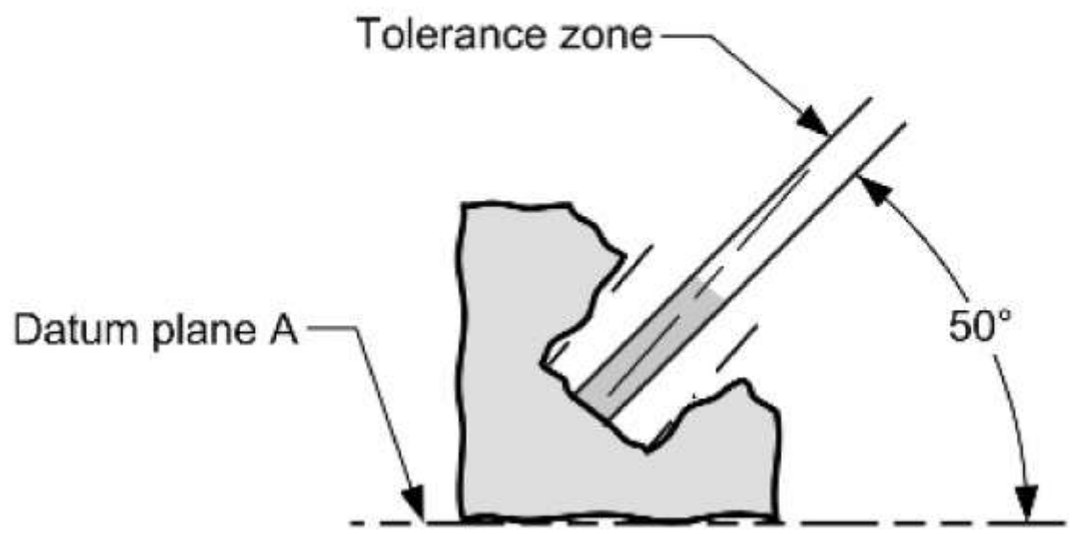
Tolerance zone



Application

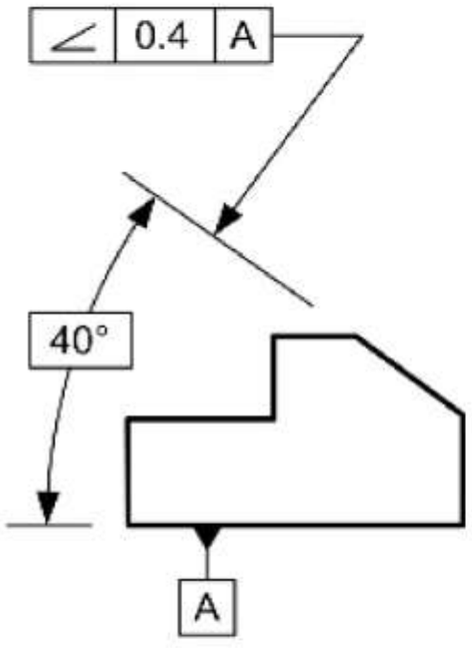


Tolerance zone

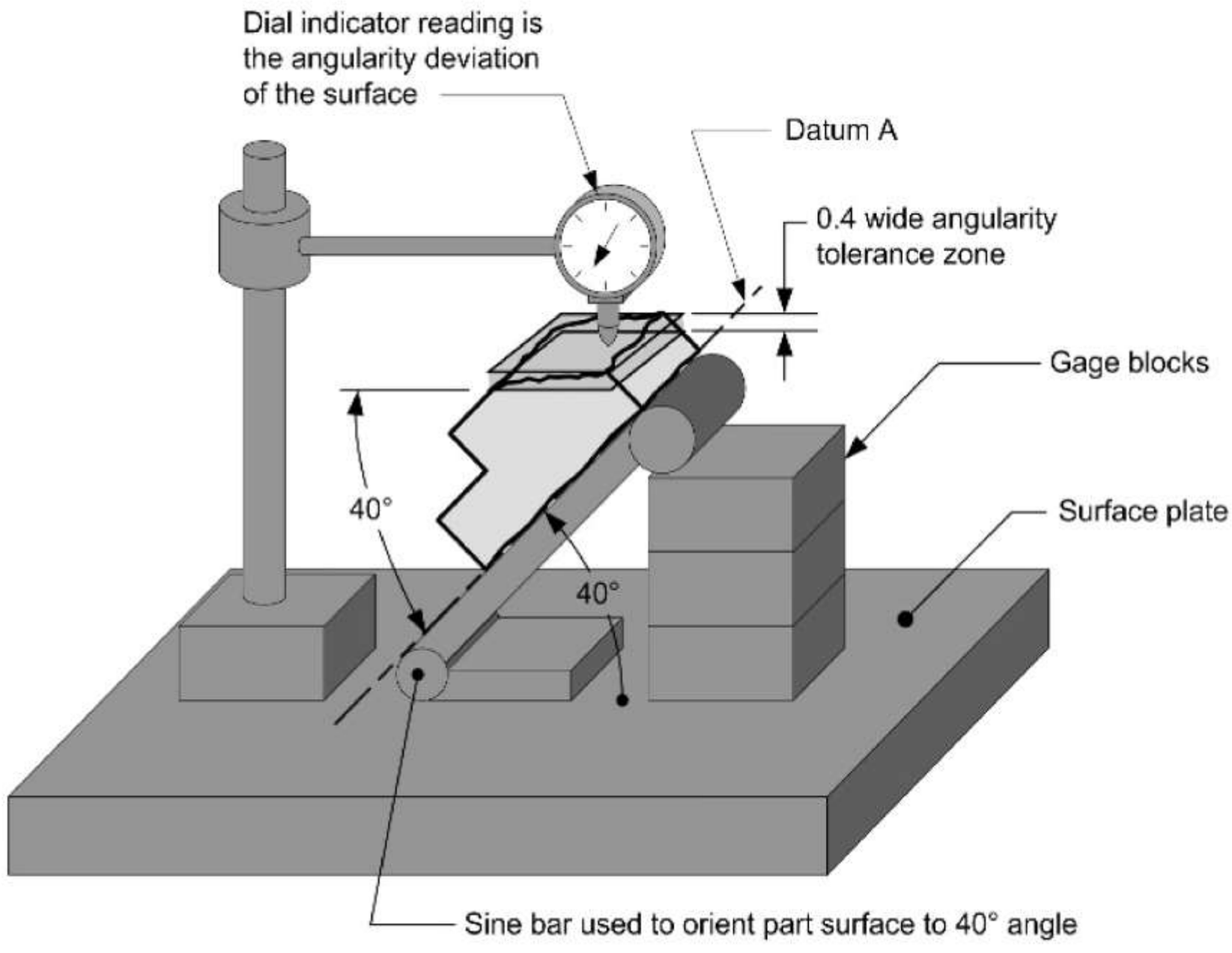


زاویه‌دار بودن

Drawing



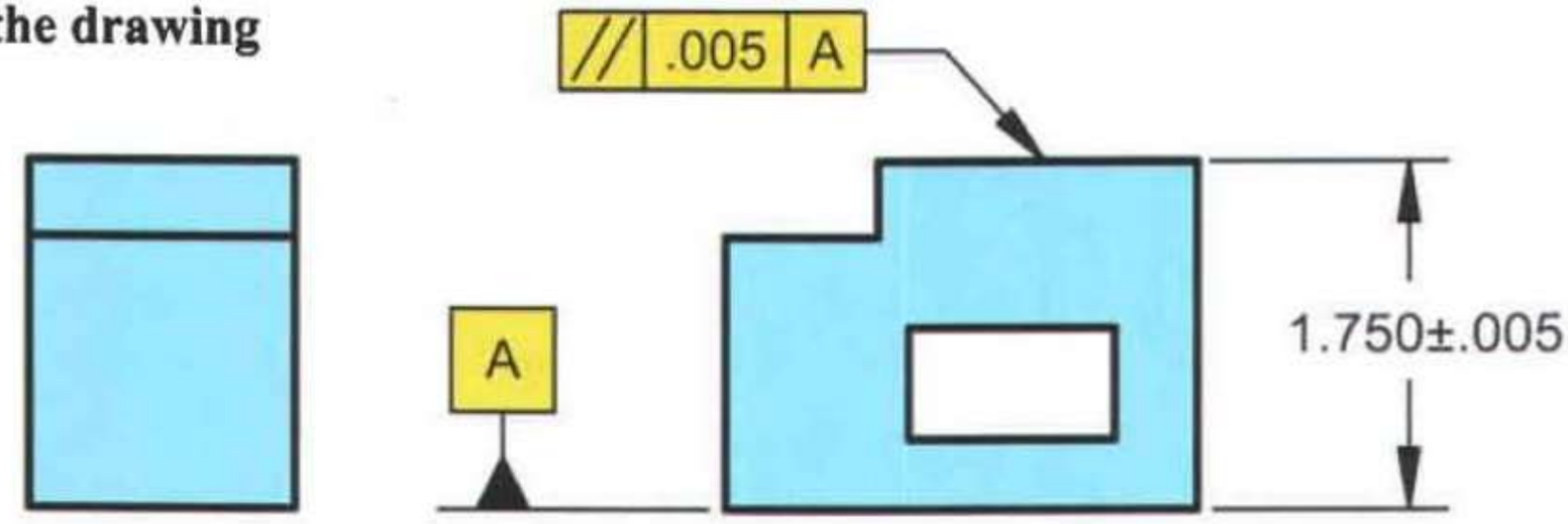
Inspection



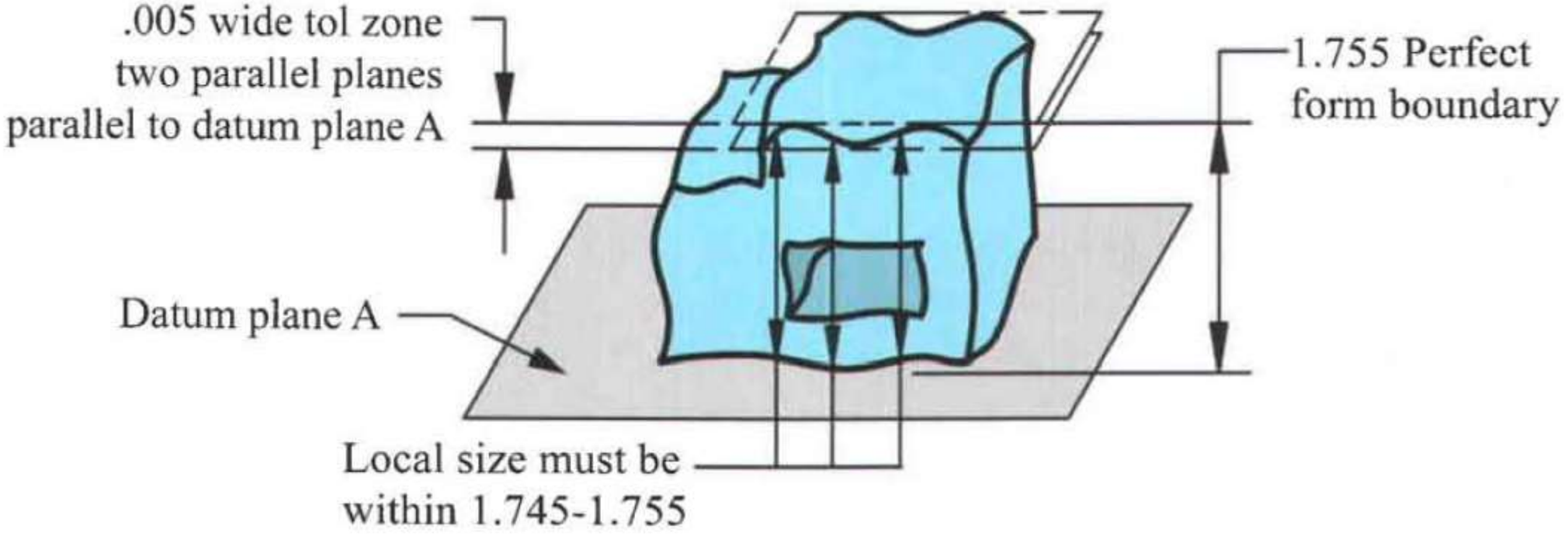
مدرس: داود قدس

توازی

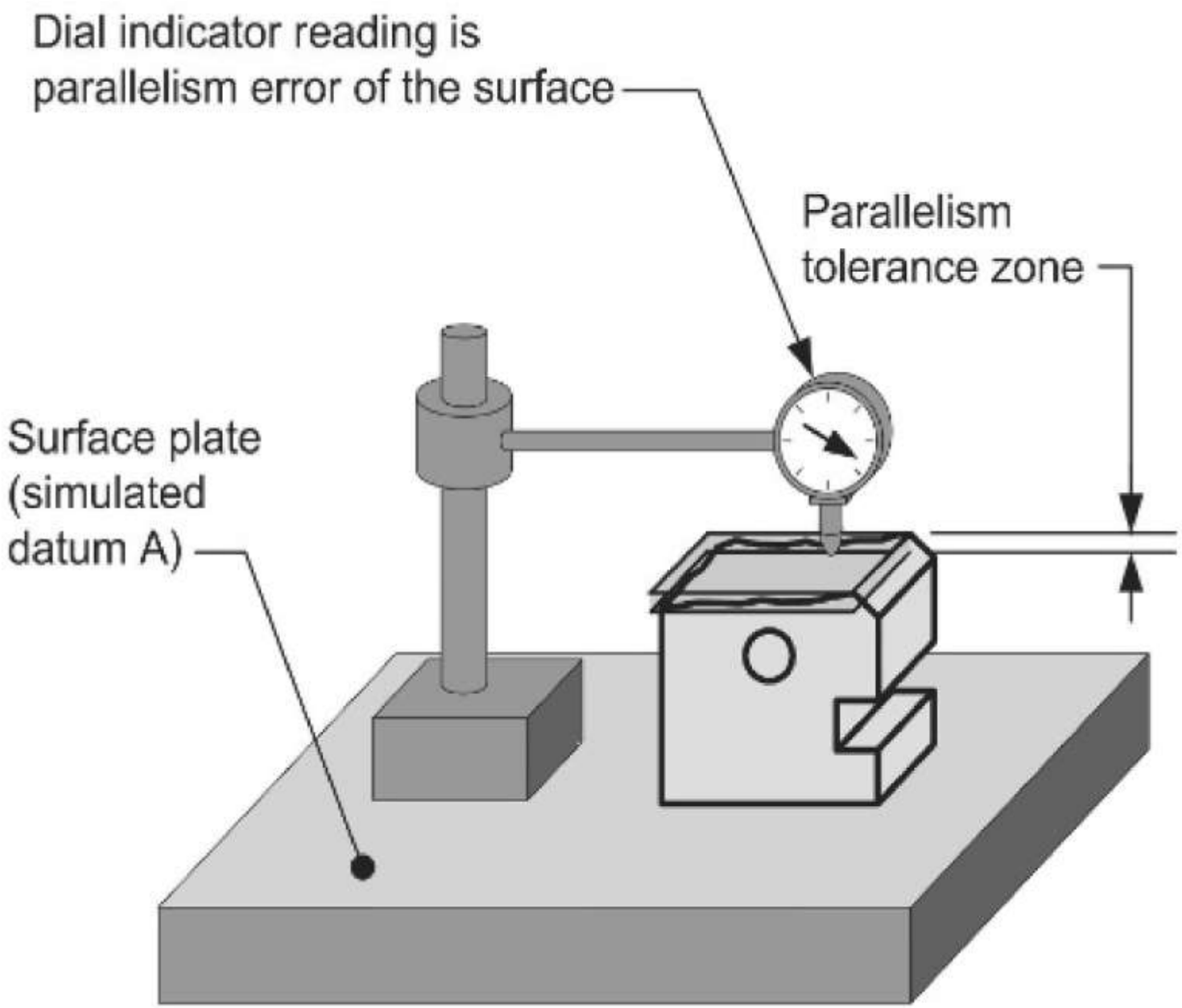
This on the drawing



Means this



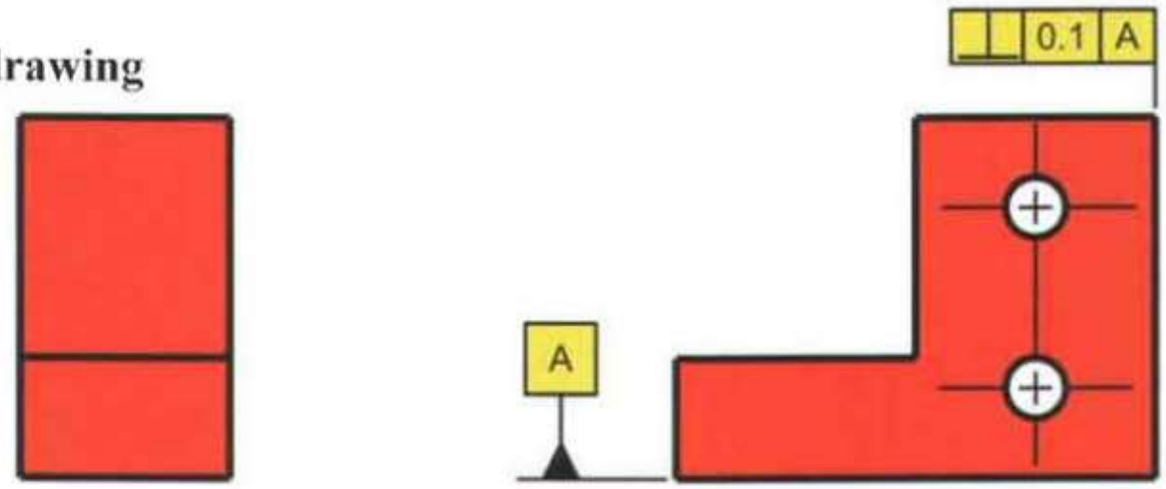
توازی



مدرس: داود قدس

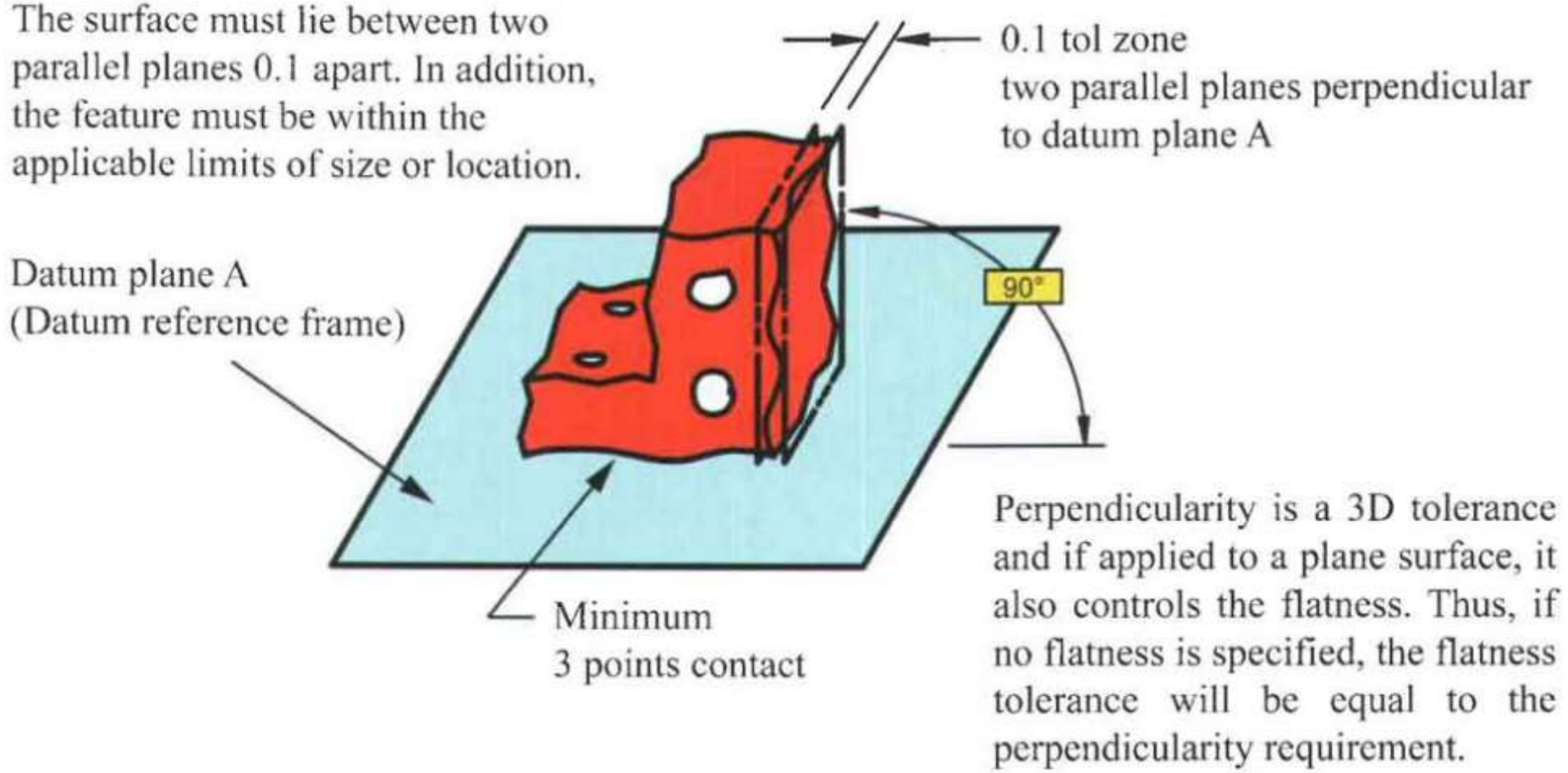
تعامد

This on the drawing



Means this

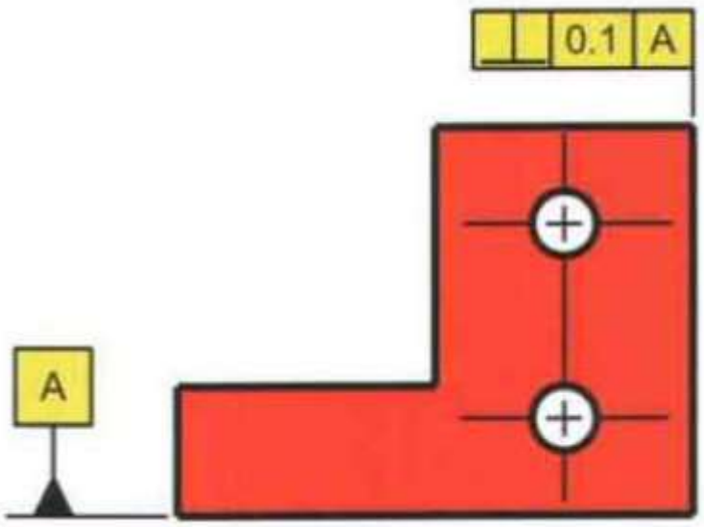
The surface must lie between two parallel planes 0.1 apart. In addition, the feature must be within the applicable limits of size or location.

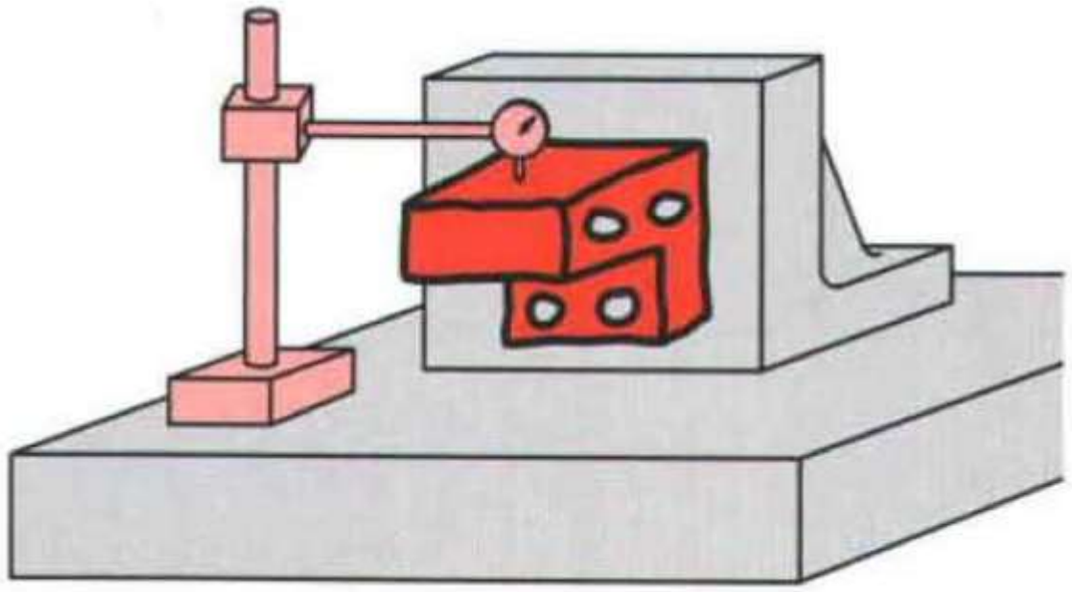


Perpendicularity is a 3D tolerance and if applied to a plane surface, it also controls the flatness. Thus, if no flatness is specified, the flatness tolerance will be equal to the perpendicularity requirement.

تعامد

This on the drawing



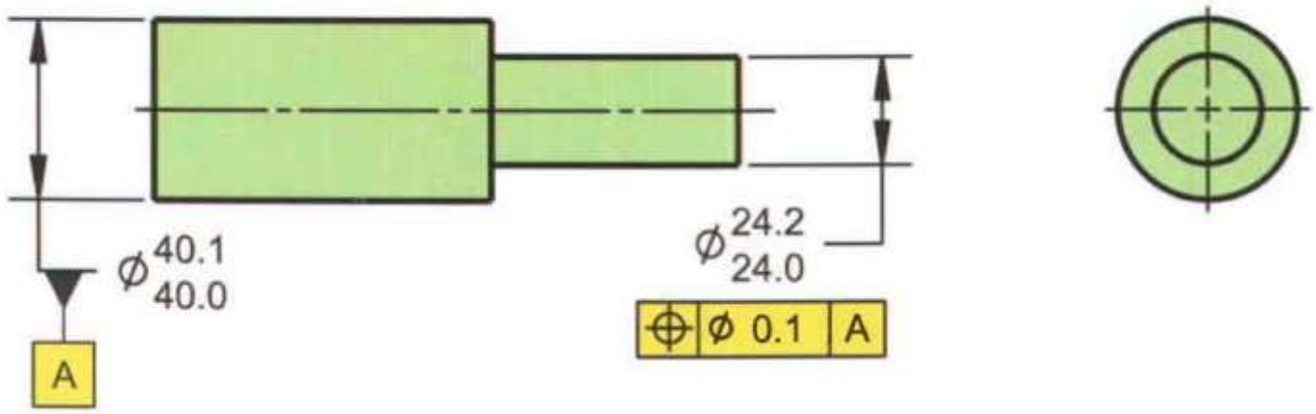


Sample Inspection

The part is mounted on datum feature A and the surface to be verified is leveled. The full indicator movement must not exceed 0.1.

موقعیت

This on the drawing



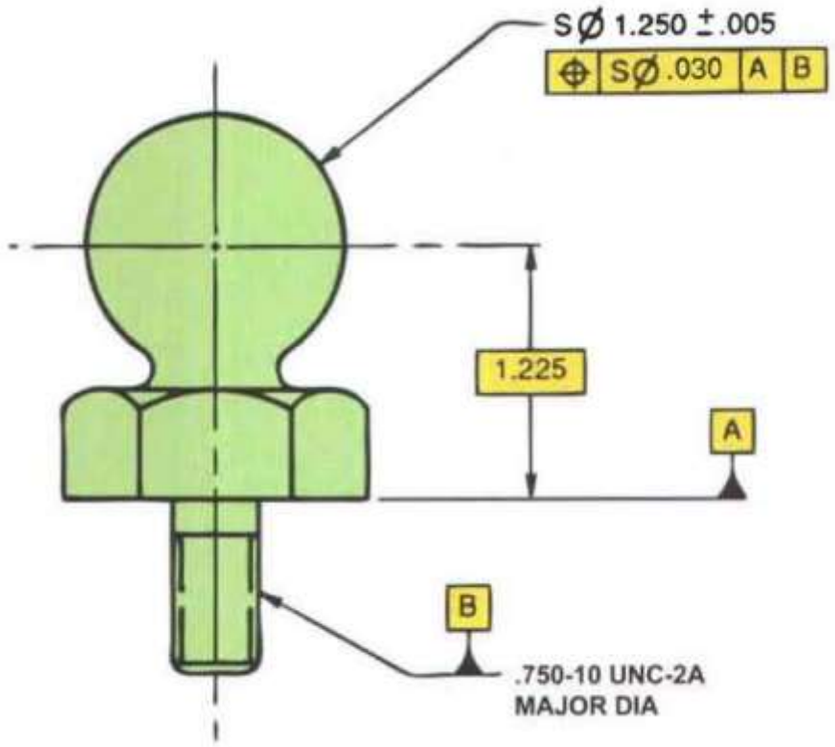
Means this

The theoretical datum feature simulator is the smallest circumscribed cylinder that contacts the high points of the feature. Depending on the accuracy required, this may be practically simulated by a collet, chuck, vee block, etc.

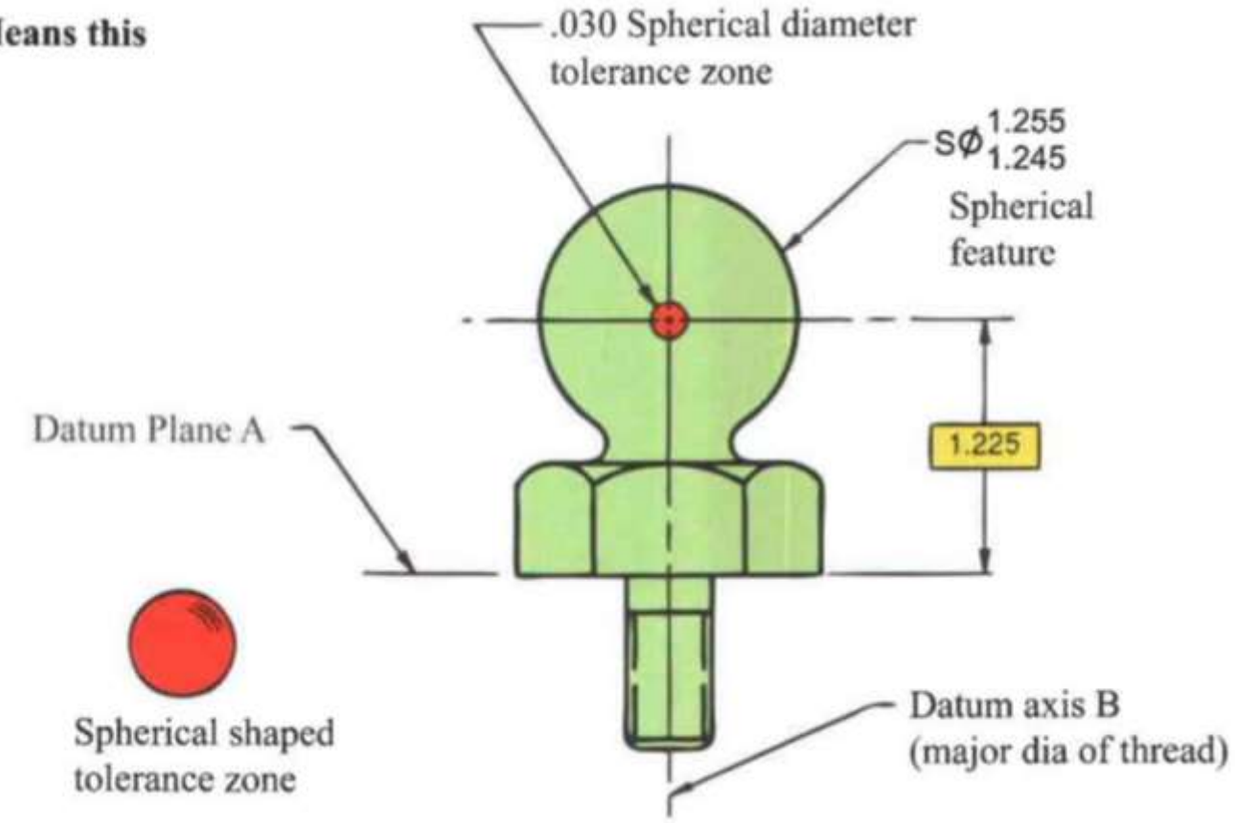
The axis of the actual mating envelope cylinder around the feature must lie within the cylindrical tolerance zone. The cylindrical tolerance zone is concentric with the datum axis. In addition, the feature must be within the limits of size.

موقعیت

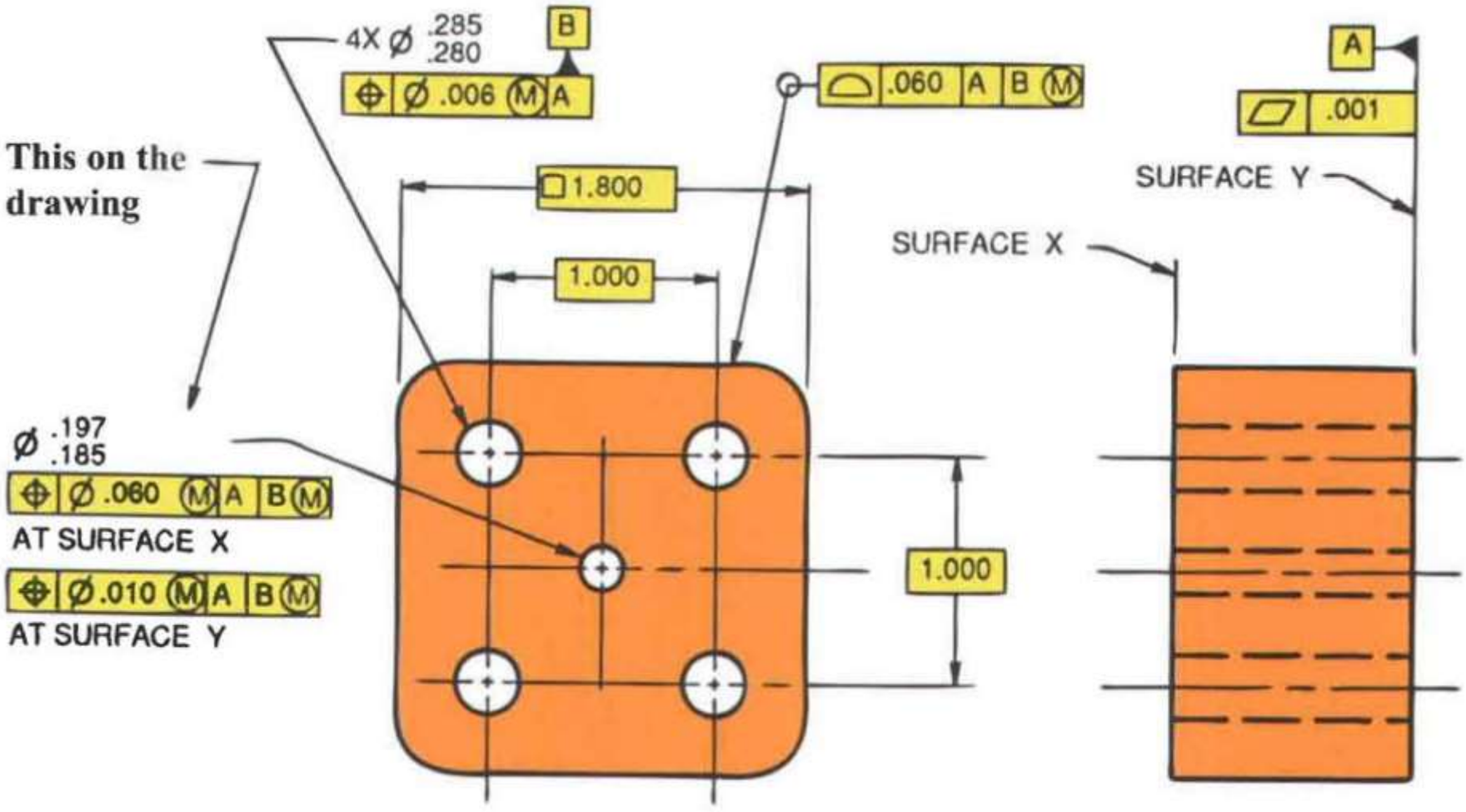
This on the drawing



Means this

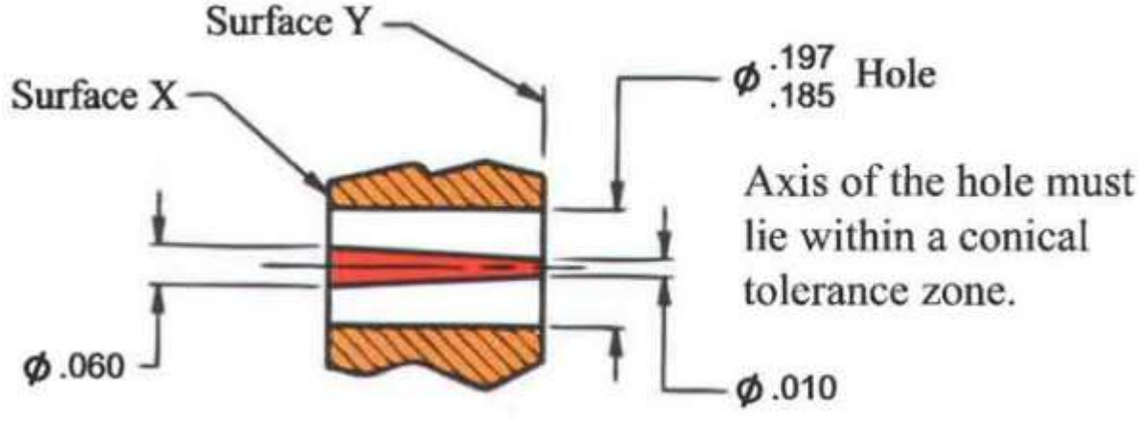


موقعیت



Means This

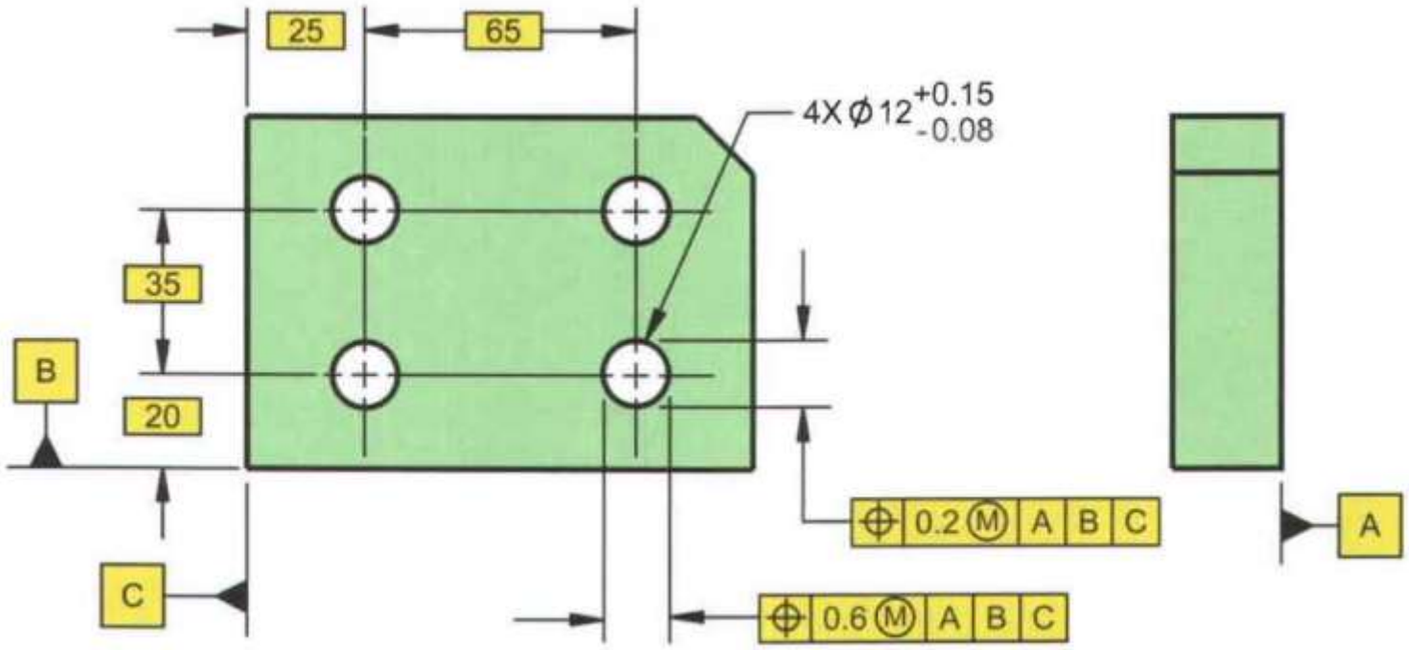
Conical shaped tolerance zone



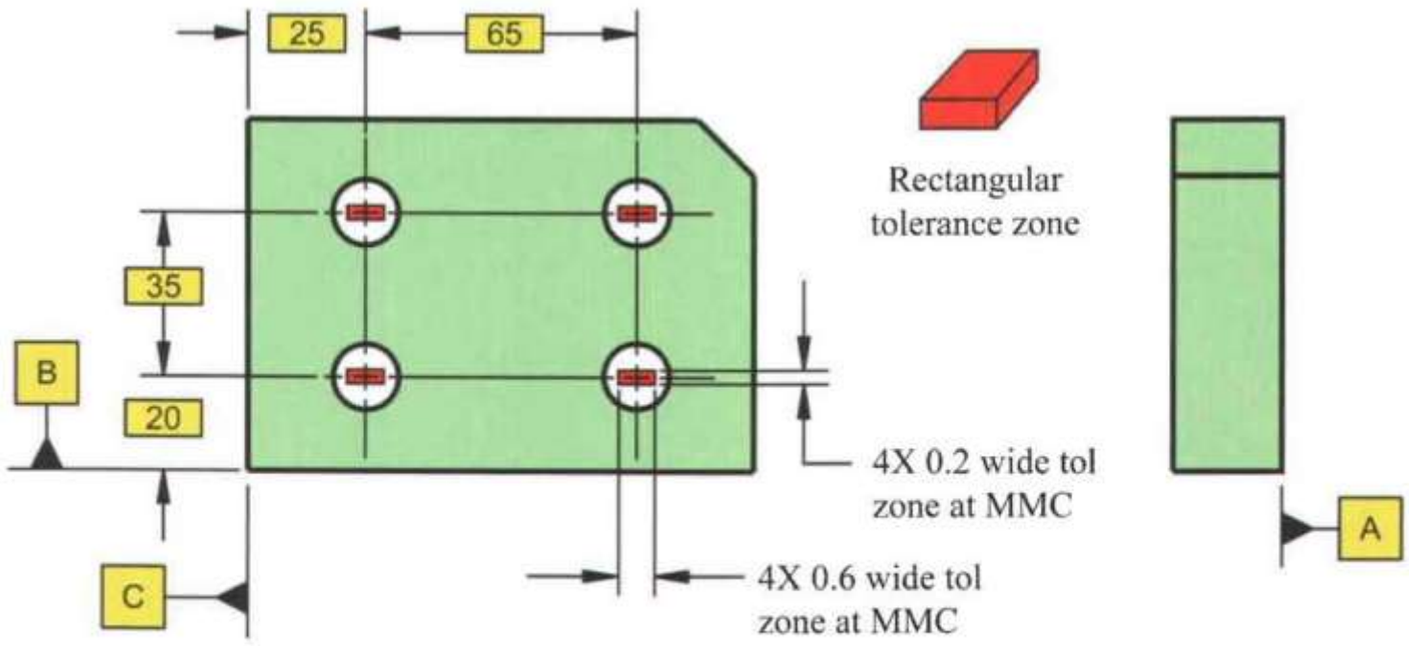
مدرس: داود قدس

موقعیت

This on the drawing



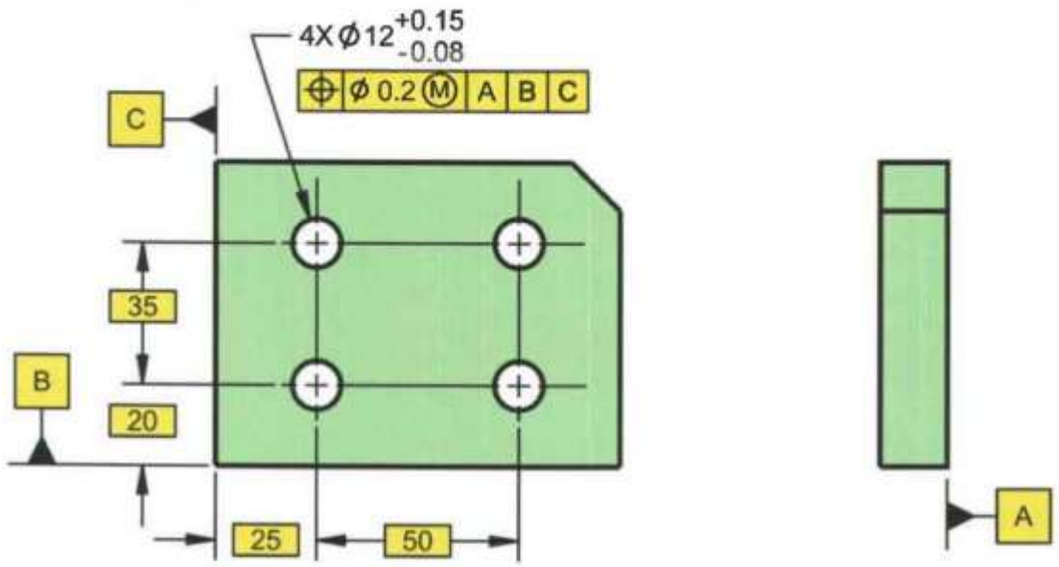
Means this



The axes of the holes must lie within the 0.2 X 0.6 rectangular tolerance zones basically located to the specified datum reference frame.

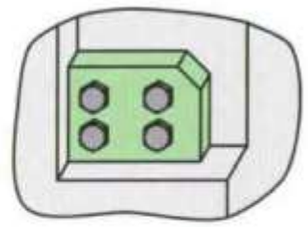
موقعیت

This on the drawing

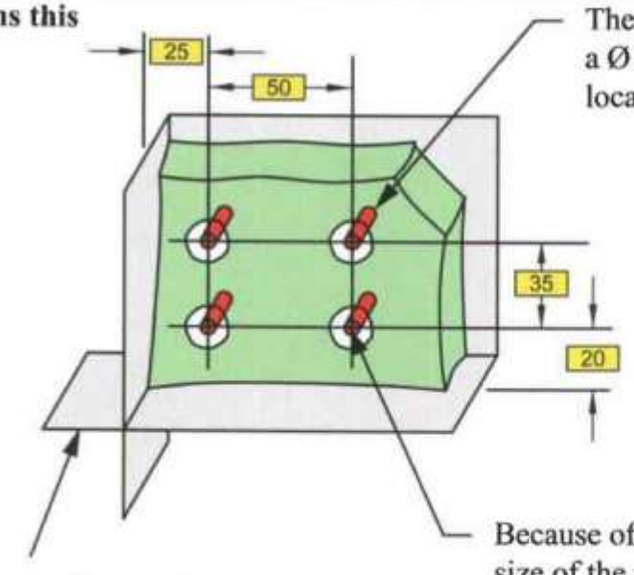


Application

Part mounts in assembly on surfaces shown. The holes provide clearance for the bolts.



Means this



The axis of the hole must lie within a Ø 0.2 tol zone at MMC basically located and oriented to the DRF.

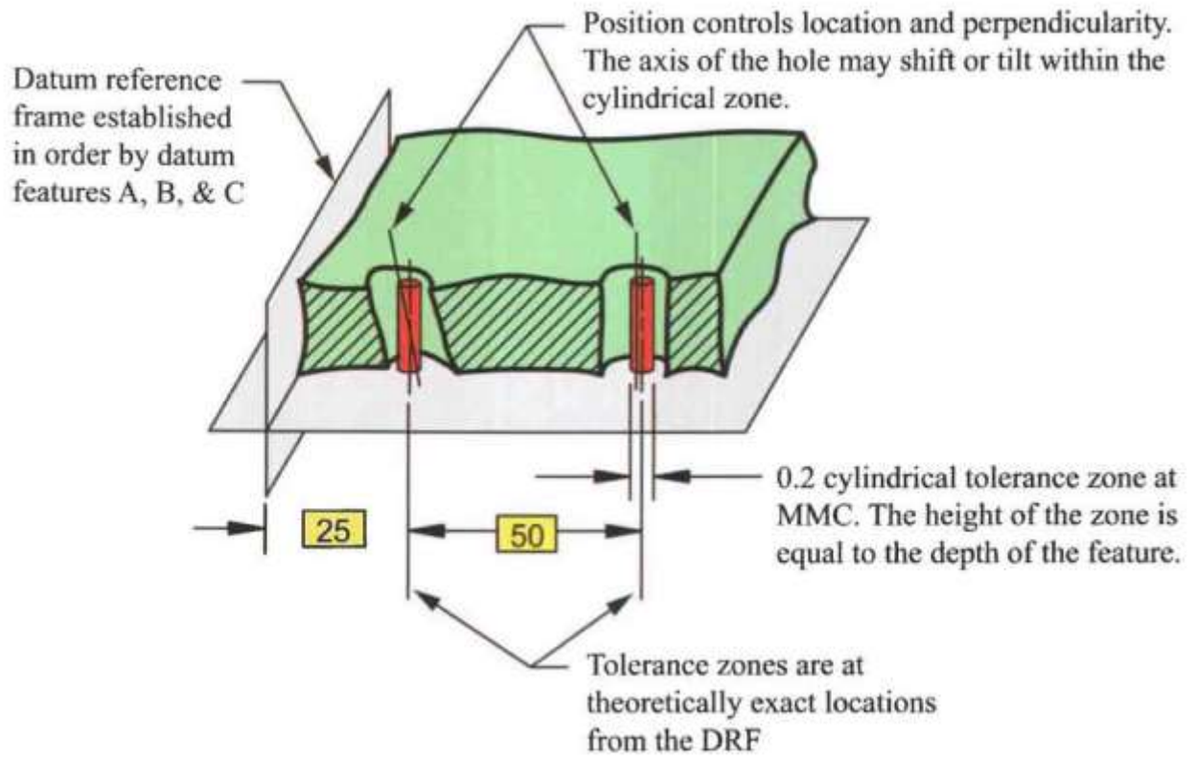
Feature Size	Tol Zone Size
MMC Ø 11.92	Ø 0.20
Ø 11.94	Ø 0.22
Ø 11.96	Ø 0.24
↓	↓
Ø 12.13	Ø 0.41
LMC Ø 12.15	Ø 0.43

Because of the MMC modifier, the size of the positional tol zone depends on the size of the holes. See chart.

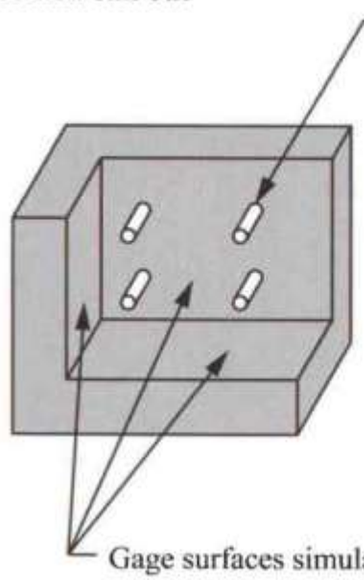
Datum reference frame is established on the part in order by datum features A, B, & C

مدرس: داود قدس

موقعیت



Functional gage for position call out

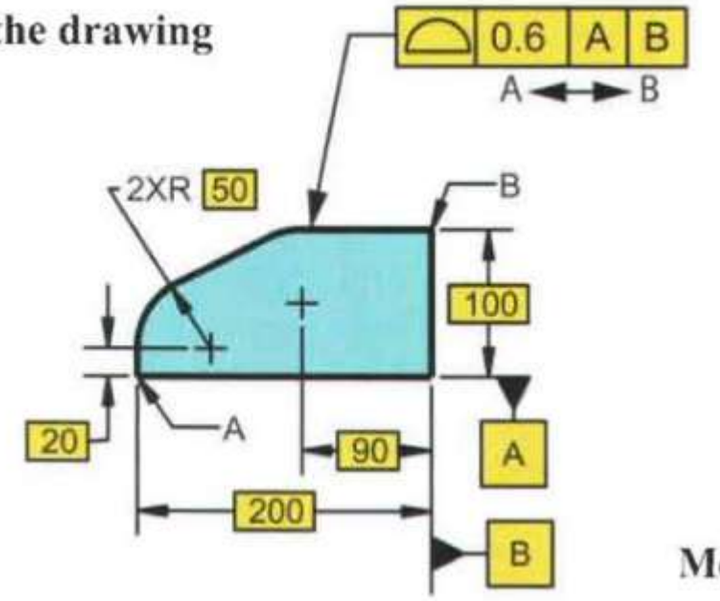


A functional gage is a good tool for understanding a position requirement at MMC. The gage pins can be thought of as 3D solids at a basic location that the holes must clear.

Position can be checked by other methods also. See Position Verification, unit 4, for more information on how to verify the position requirement.

پروفیل

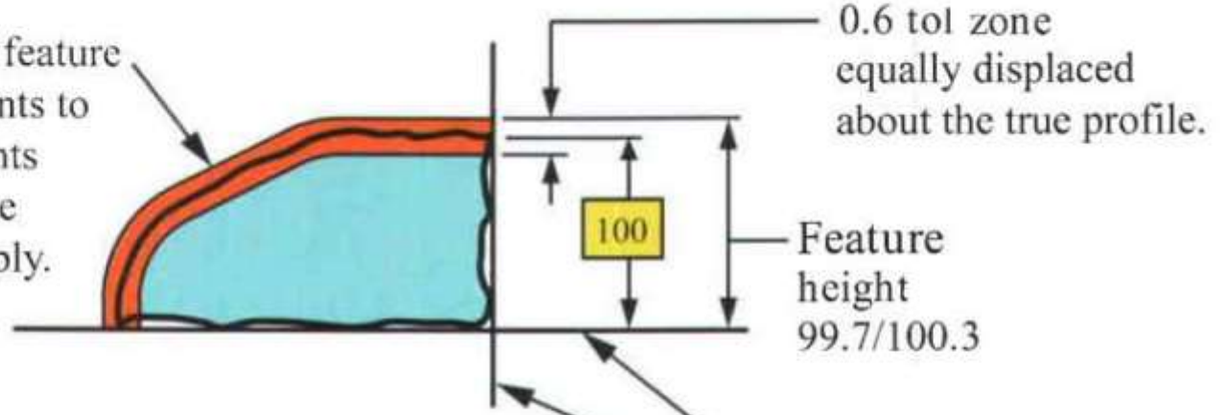
This on the drawing



Means this

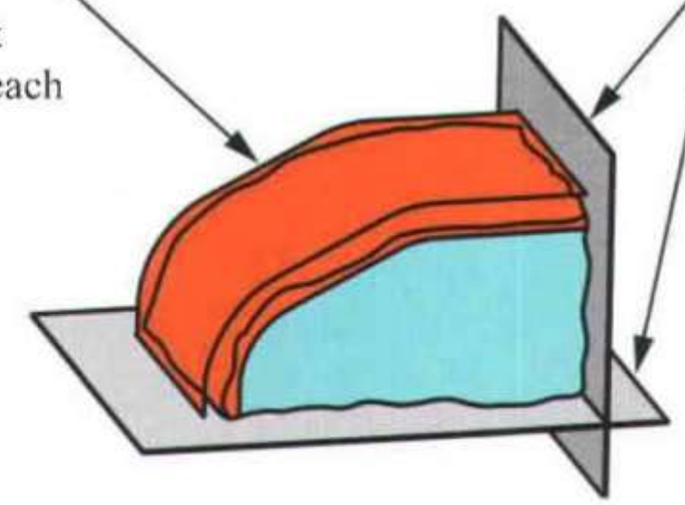
The arrow on the feature control frame points to area between points A and B where the tolerance is to apply.

2D View



Three dimensional 0.6 wide tolerance zone equally disposed about the true profile or 0.3 each side.

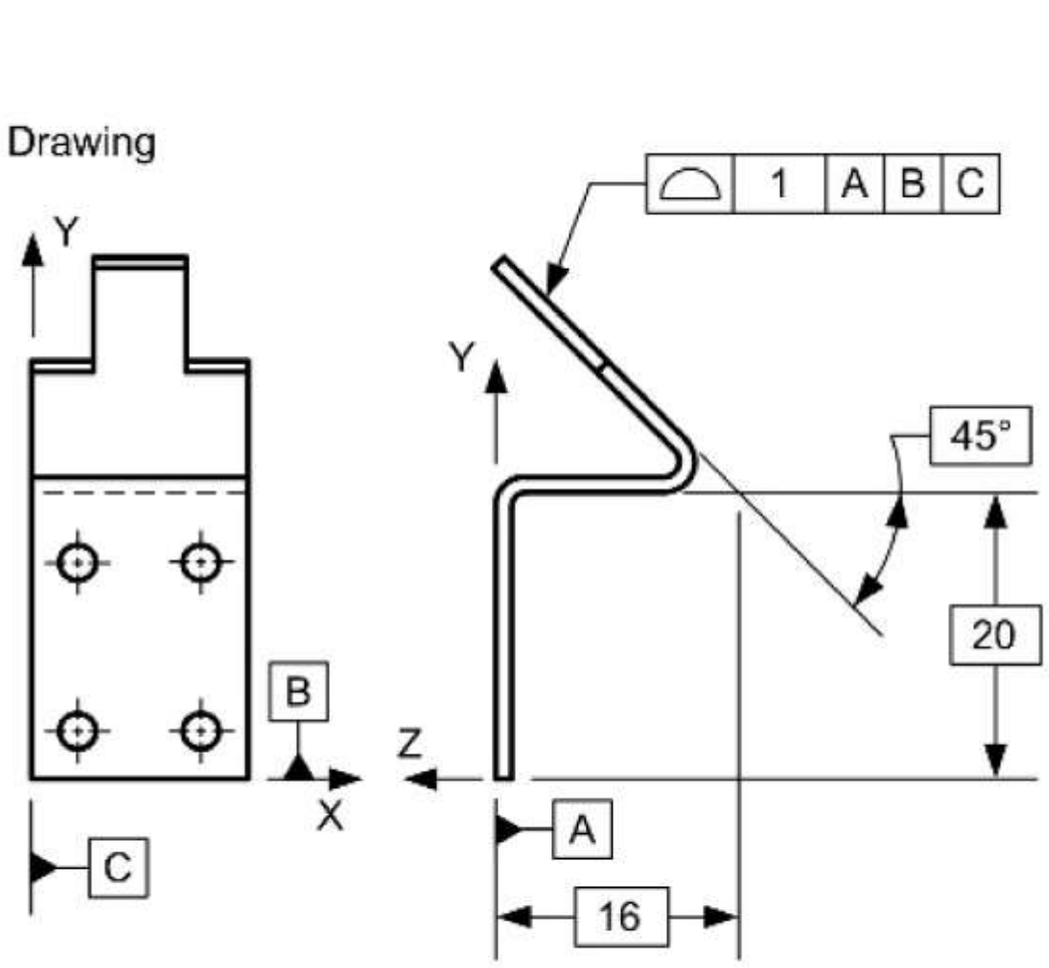
3D View

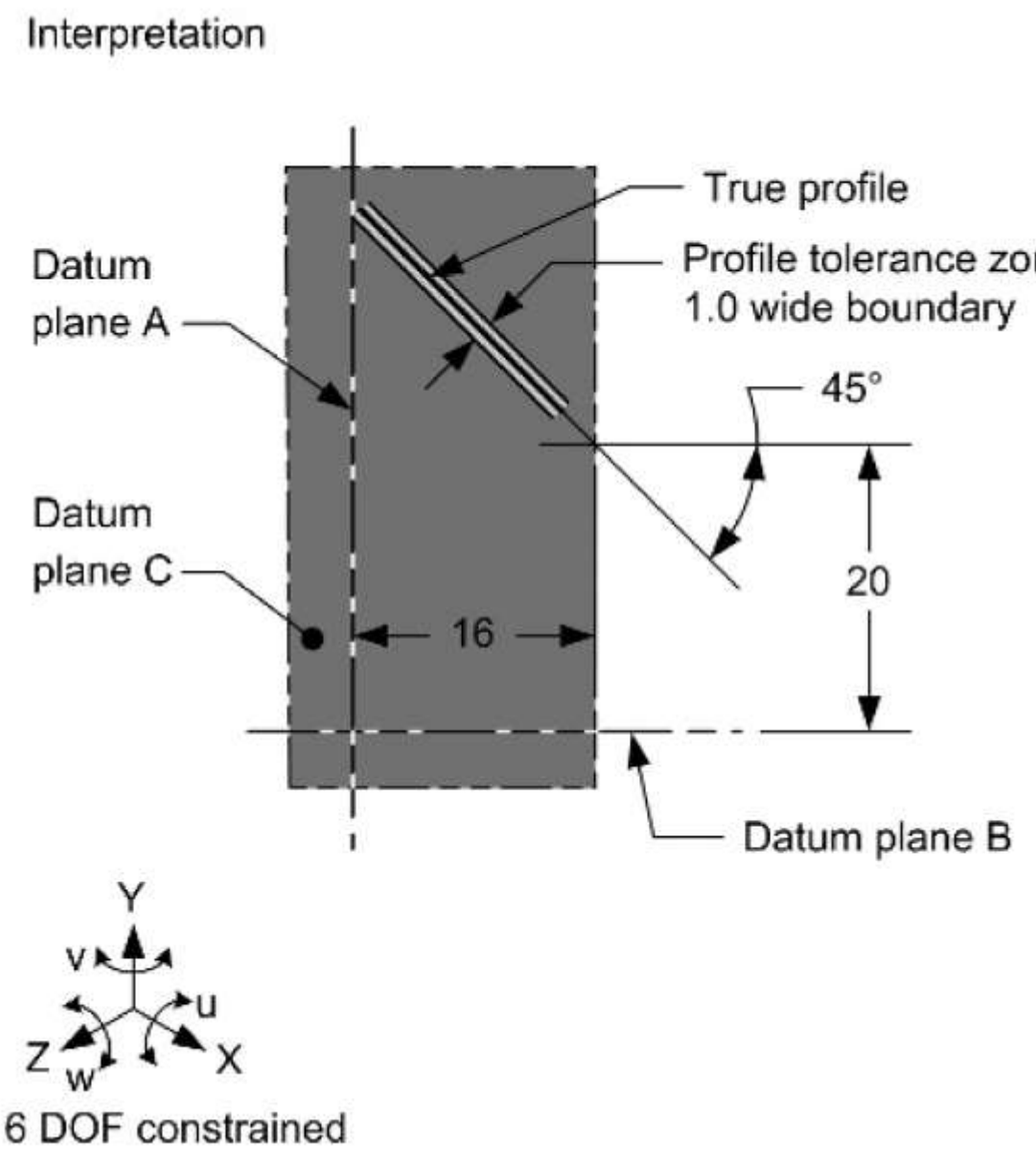


Datum reference frame established in order by datum features A and B.

مدرس: داود قدس

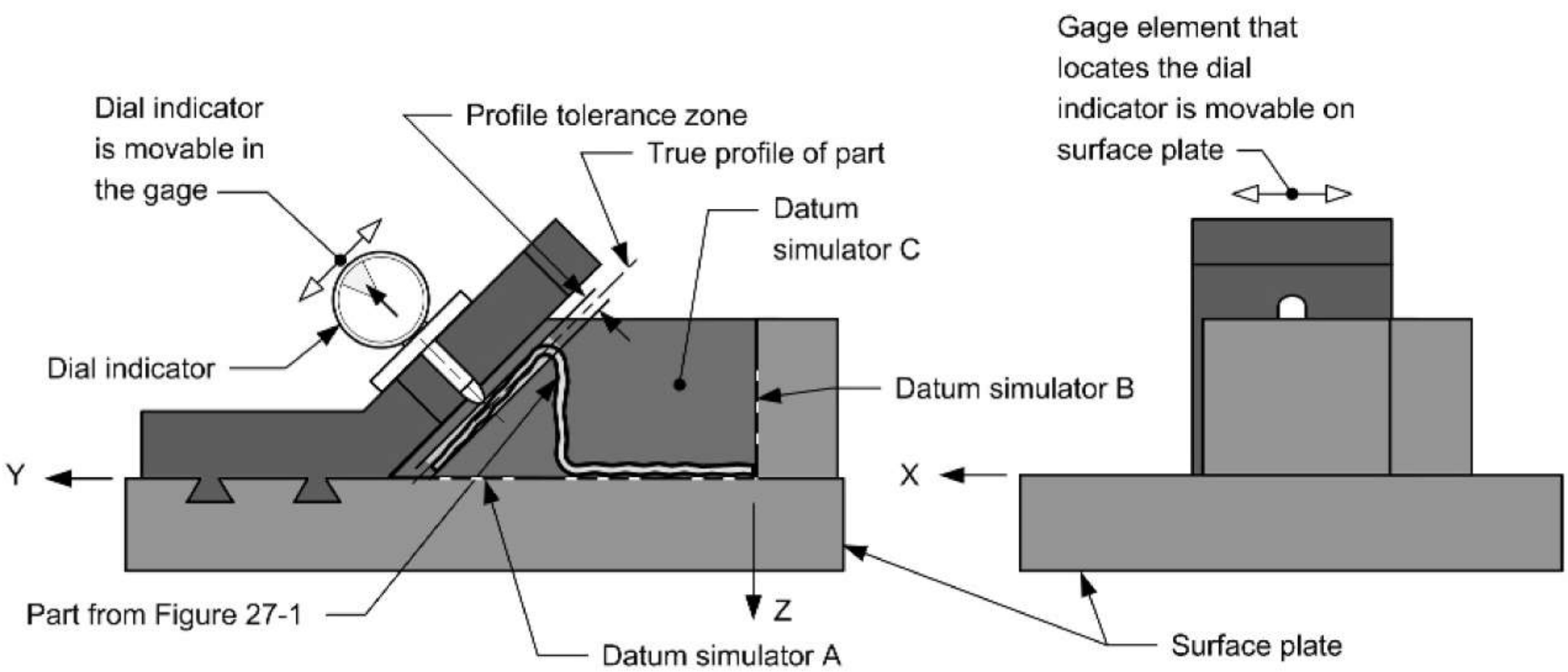
پروفیل





مدرس: داود قدس

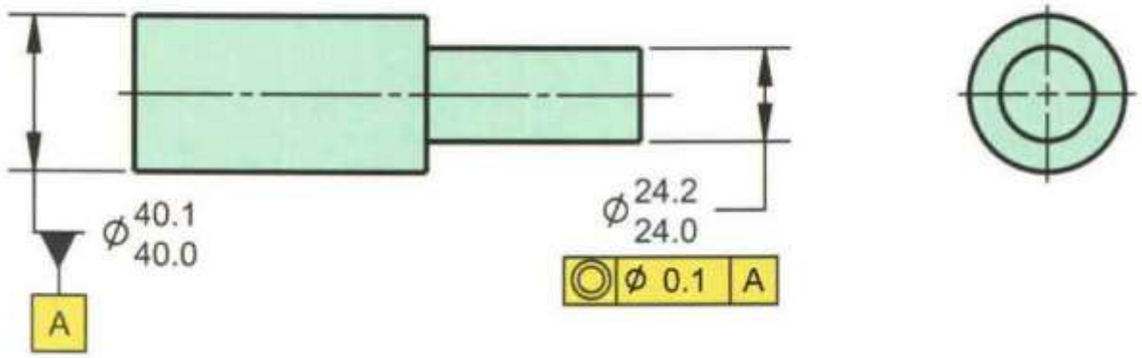
پروفیل



مدرس: داود قدس

هم مرکزی

This on the drawing



Means this

The theoretical datum feature simulator is the smallest circumscribed cylinder that contacts the high points of the feature. Depending on the accuracy required, this may be practically simulated by a collet, chuck, vee block, etc.

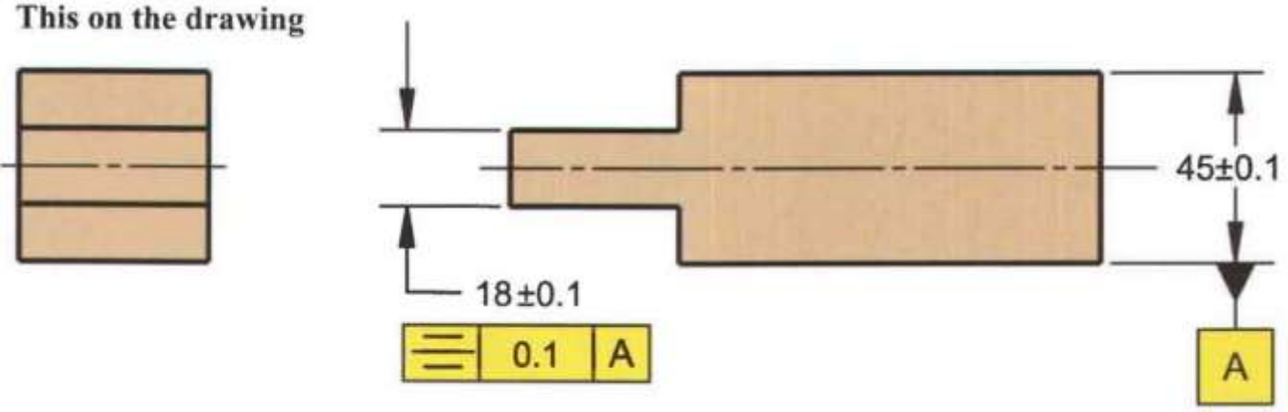
Datum axis A is the axis of the datum feature simulator

Concentricity is a 3D control. The "cloud" of opposing median points must fall within the cylindrical tolerance zone.

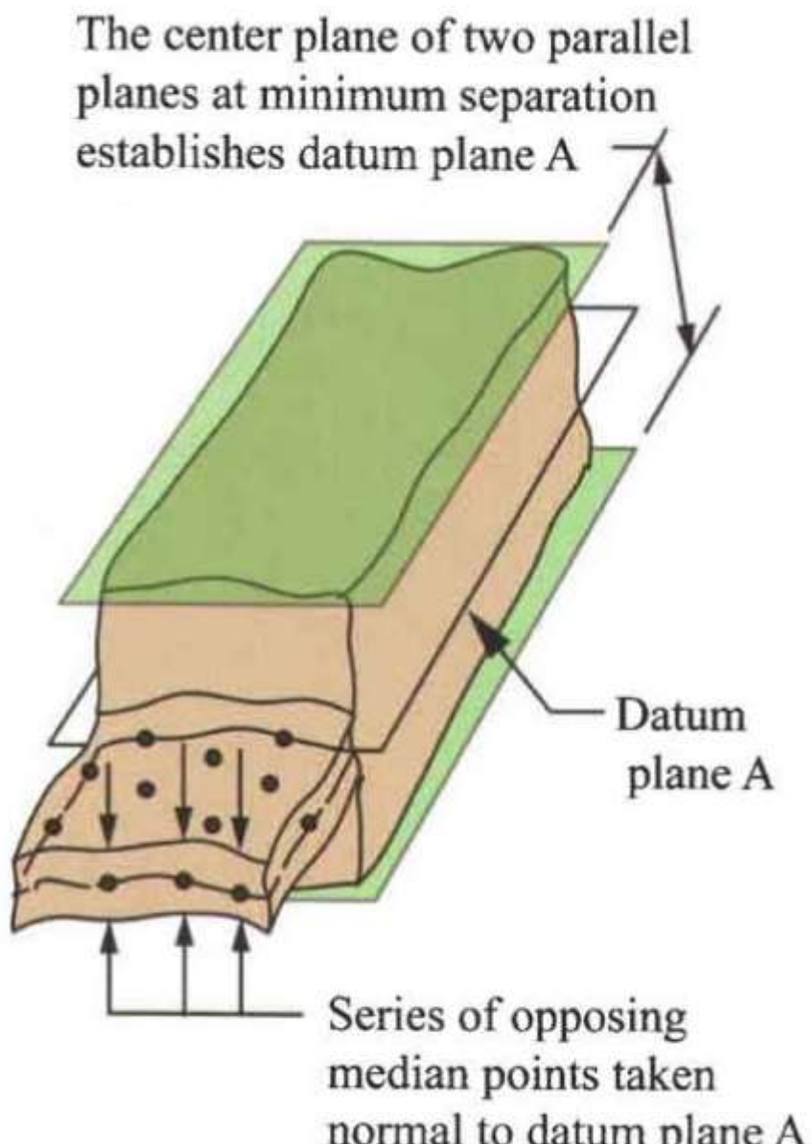
The median points of all diametrically opposed elements of the feature must lie within a 0.1 cylindrical tolerance zone. This tolerance zone is concentric with the datum axis. In addition, the feature must be within the limits of size.

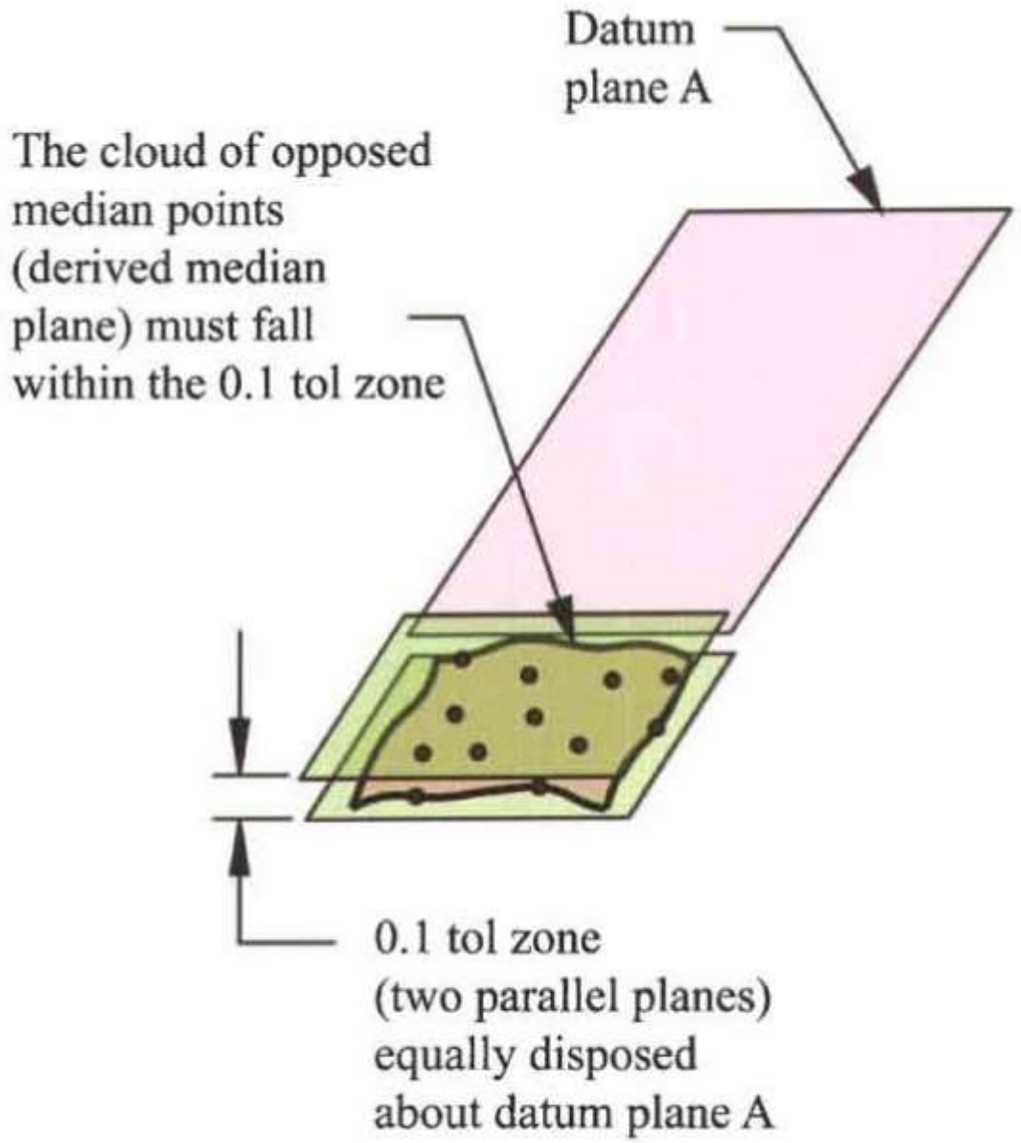
تقارن

This on the drawing



Means this

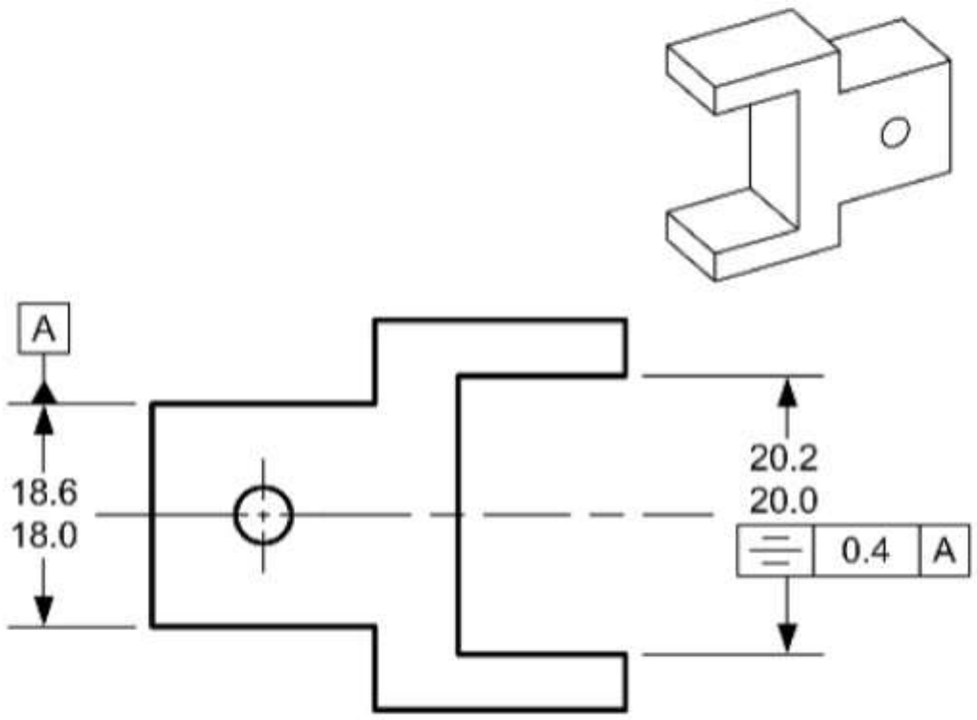




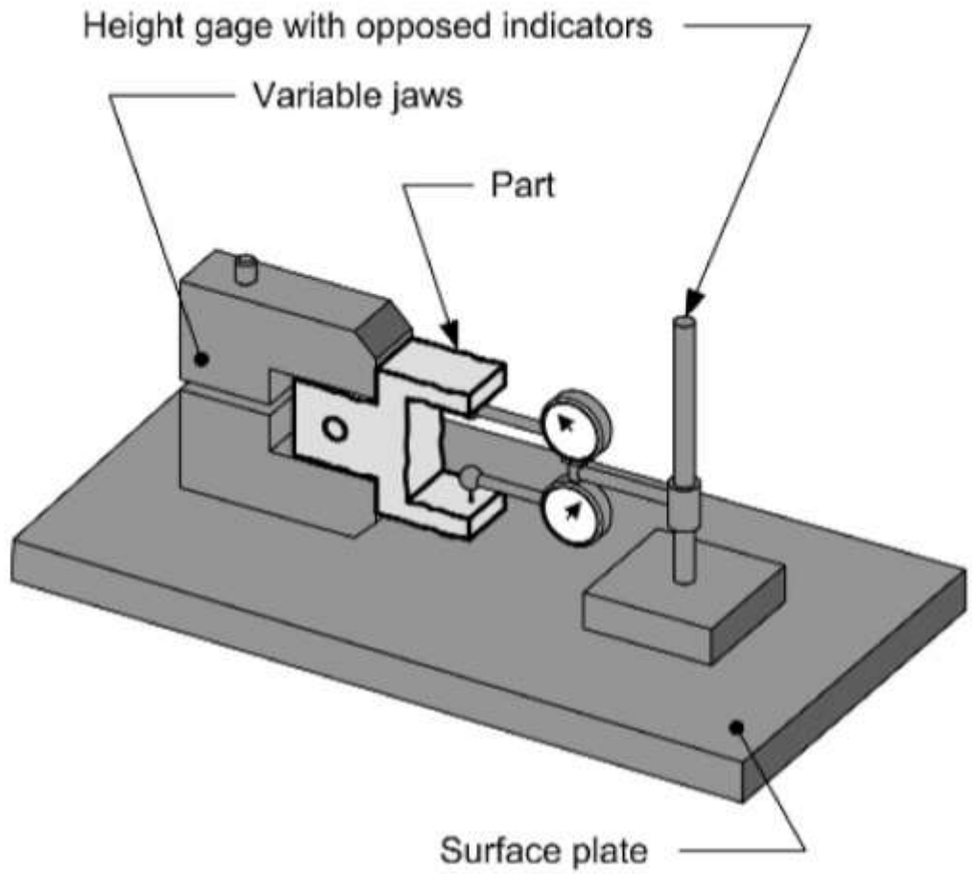
مدرس: داود قدس

تقارن

Drawing

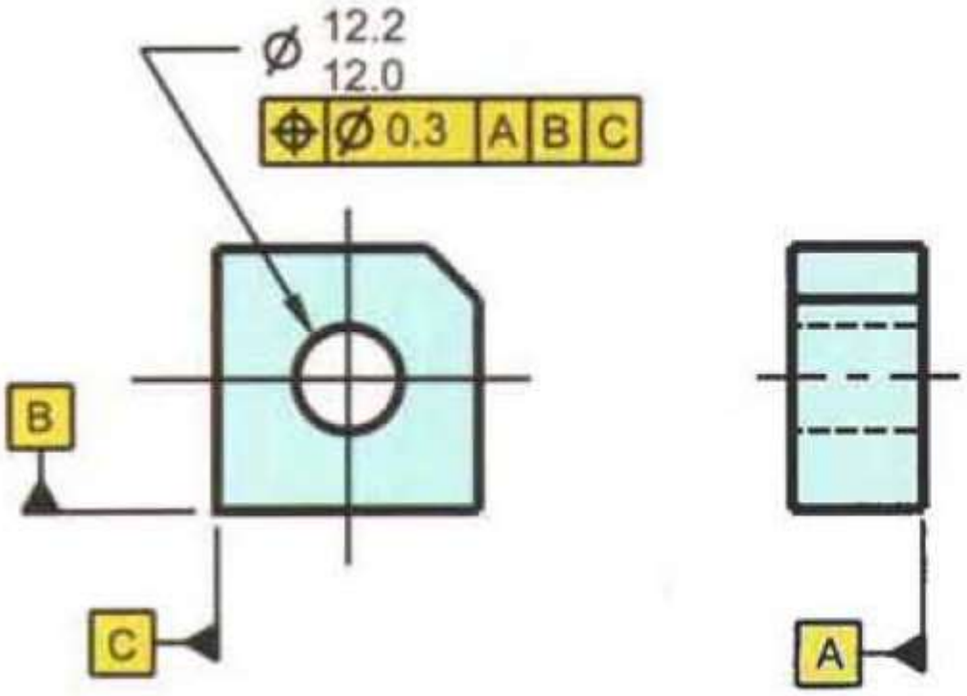


Inspection setup

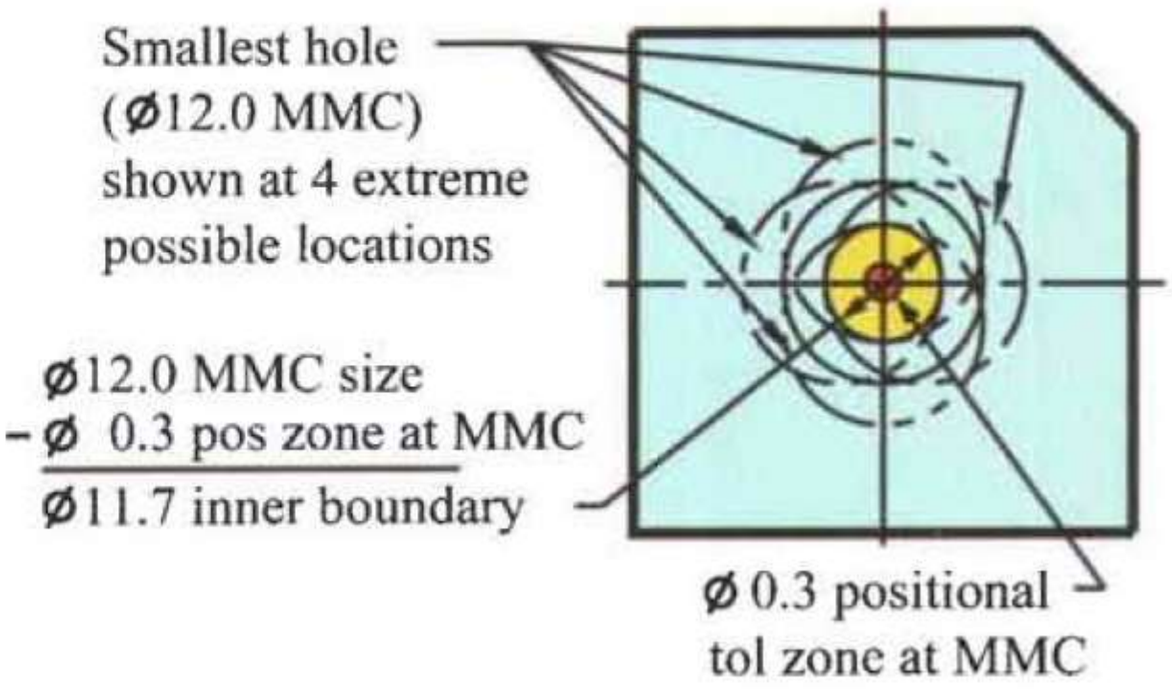


1. Center the indicators to the datum center plane
2. Zero the indicators to the nominal distance from the datum center plane
3. Measure the deviation of the opposed points from the datum center plane
4. Calculate the distance of the median point from the datum center plane (see Figure 25-12)
5. Repeat steps 1 thru 4 if necessary

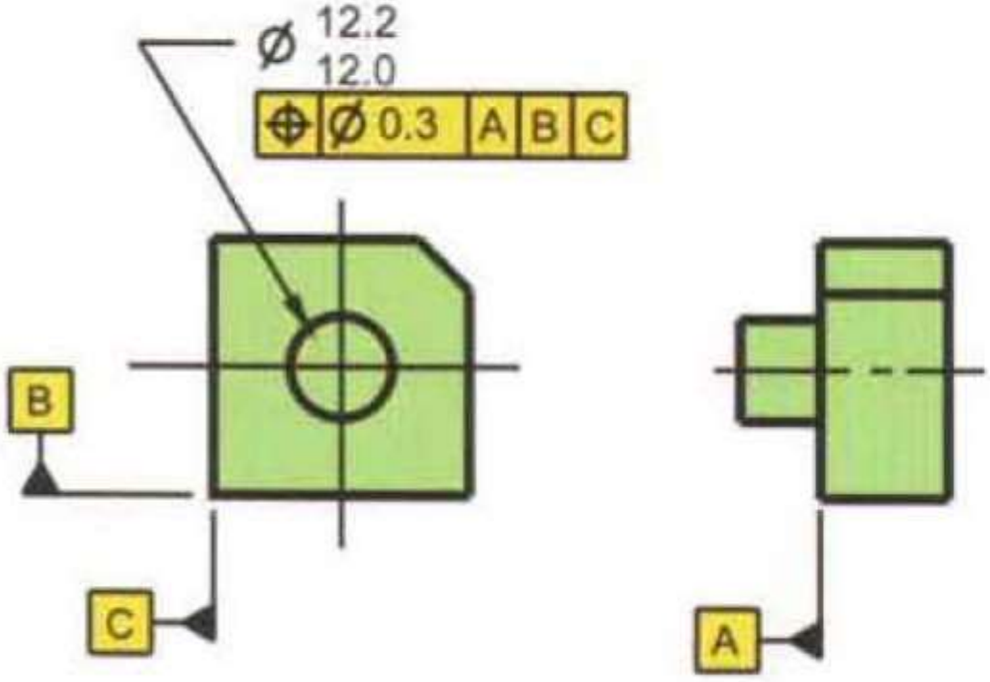
Internal Feature



Maximum Material Boundary (MMB)
is the Inner Boundary (IB) on a hole.



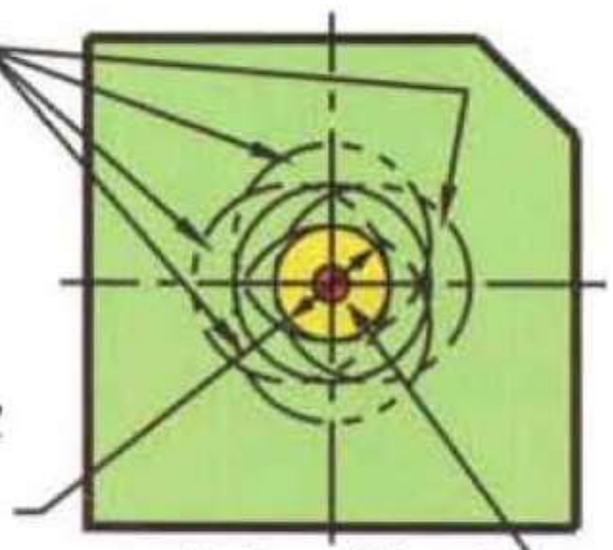
External Feature

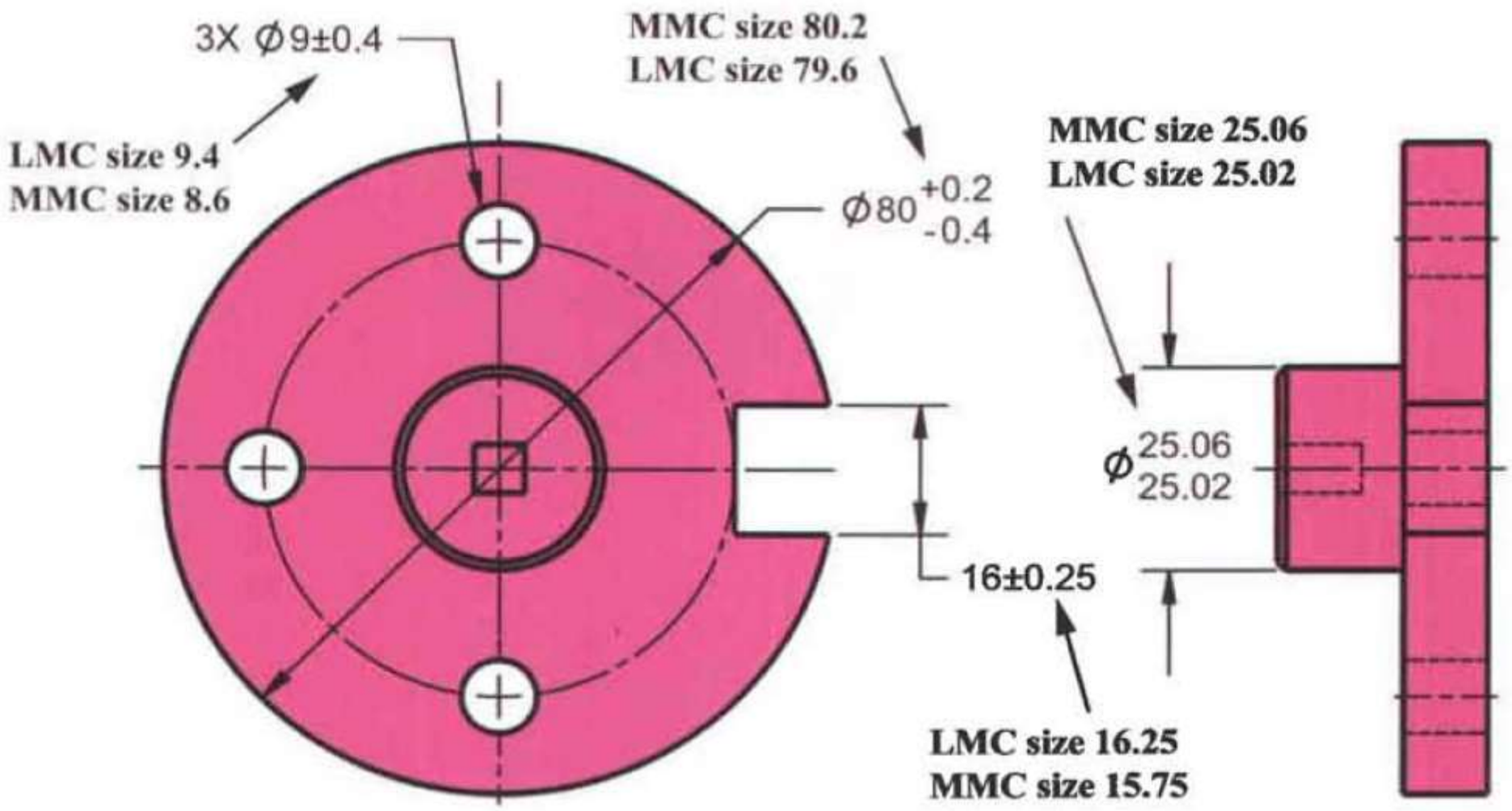


Least Material Boundary (LMB)
is the Inner Boundary (IB) on a pin.

Smallest pin
(Ø12.0 LMC)
shown at 4 extreme
possible locations

Ø12.0 LMC size
– Ø 0.3 pos zone at LMC
Ø11.7 inner boundary



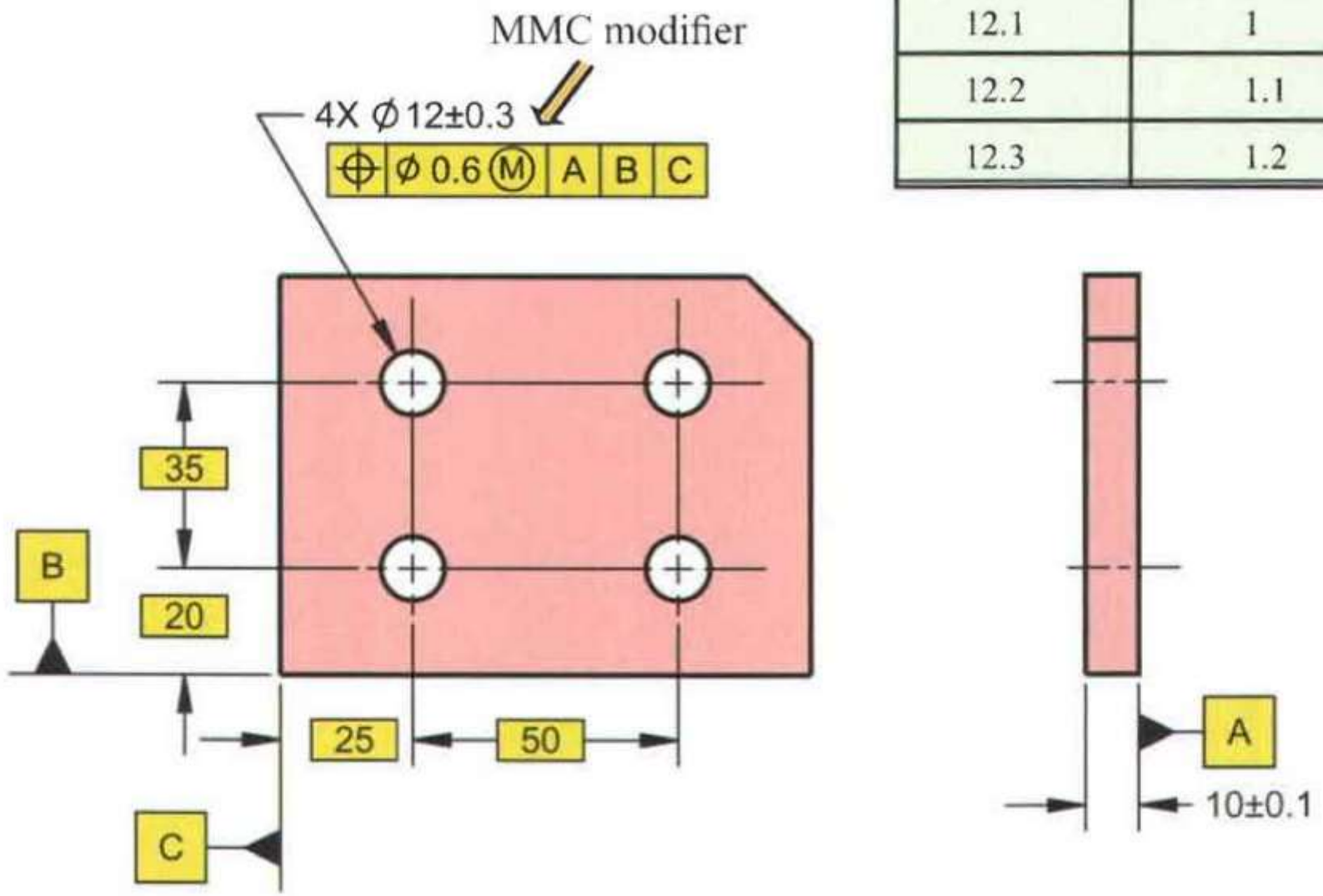


مدرس: داود قدس

Position tolerance modified at MMC

The MMC modifier in the feature control frame invokes the MMC concept and allows additional position tolerance as the features depart from their MMC. See table.

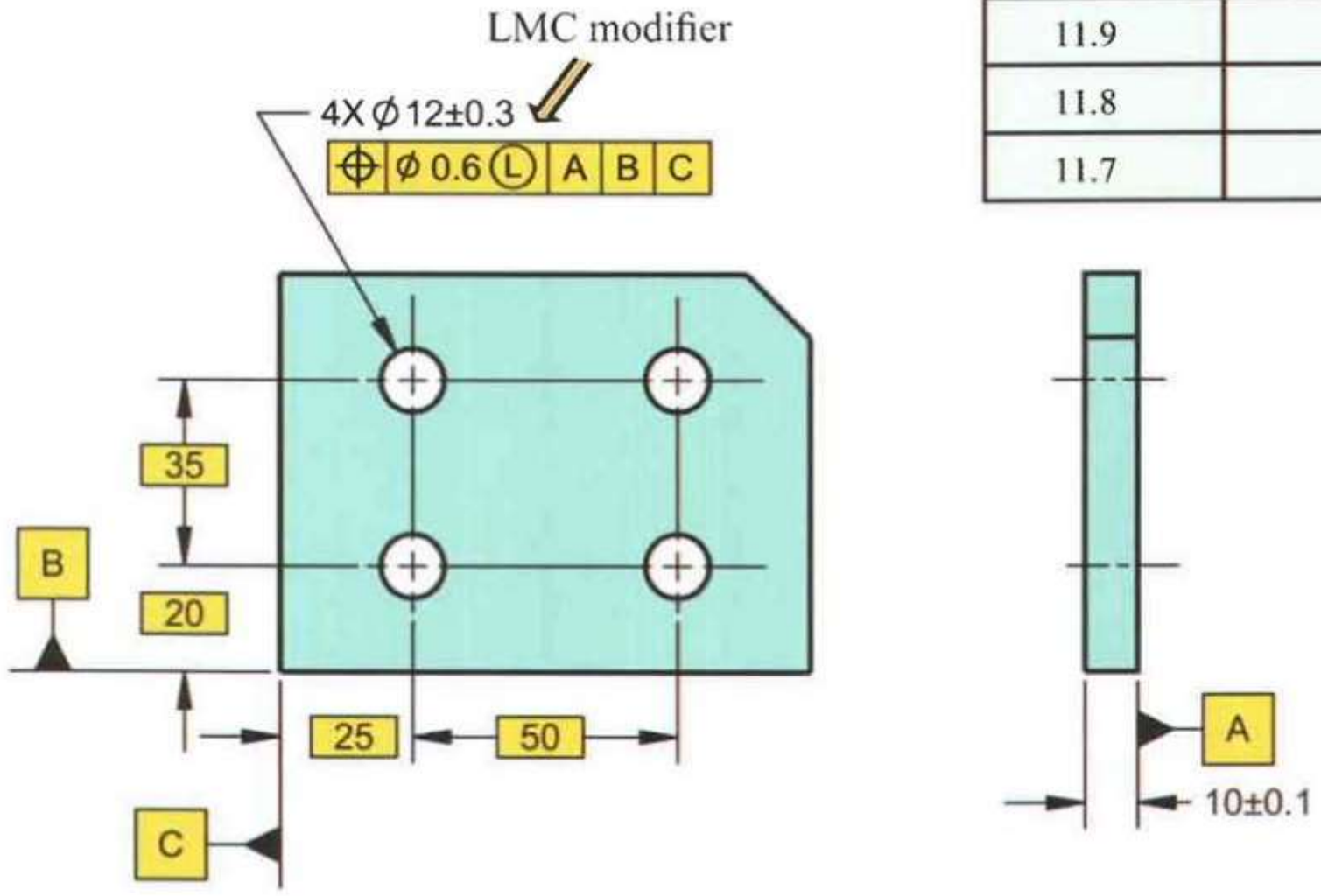
Diameter Feature Size	Diameter Position Tolerance Allowed
11.7	0.6
11.8	0.7
11.9	0.8
12	0.9
12.1	1
12.2	1.1
12.3	1.2



Position tolerance modified at LMC

The LMC modifier in the feature control frame invokes the LMC concept and allows additional position tolerance as the features depart from their LMC. See table.

Diameter Feature Size	Diameter Position Tolerance Allowed
12.3	0.6
12.2	0.7
12.1	0.8
12	0.9
11.9	1
11.8	1.1
11.7	1.2



مدرس: داود قدس

Position tolerance modified at RFS

The implied RFS modifier in the feature control frame invokes the RFS concept and requires the features to be positioned with a 0.6 diameter tolerance zone regardless of the feature size. See table.

Diameter Feature Size	Diameter Position Tolerance Allowed
11.7	0.6
11.8	0.6
11.9	0.6
12	0.6
12.1	0.6
12.2	0.6
12.3	0.6