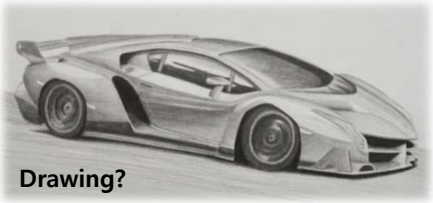
Advanced Solid Modelling

Guide to GD&T

DEPARTMENT OF MECHATRONICS

Prof. B. H. Kim



Drawing?

Design?

Drafting?

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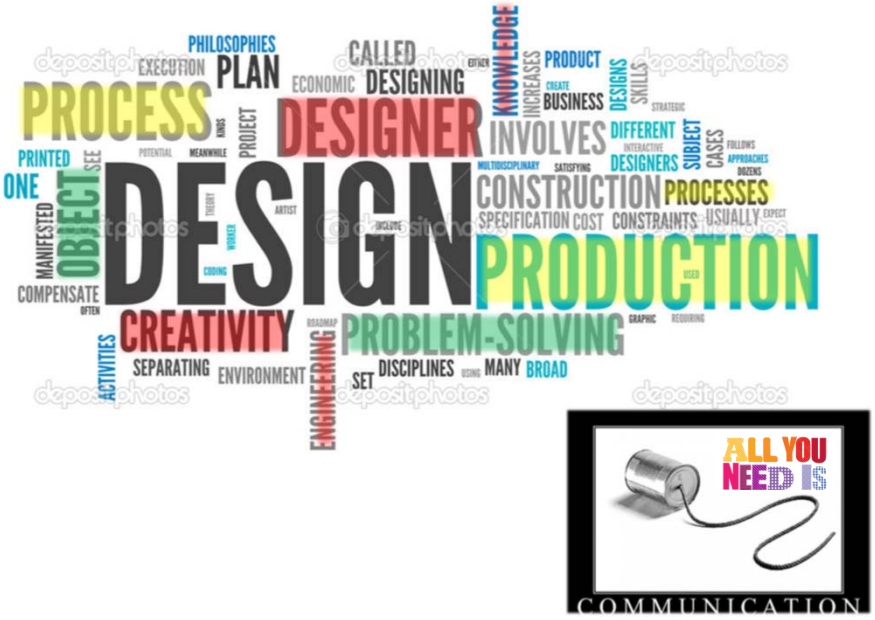

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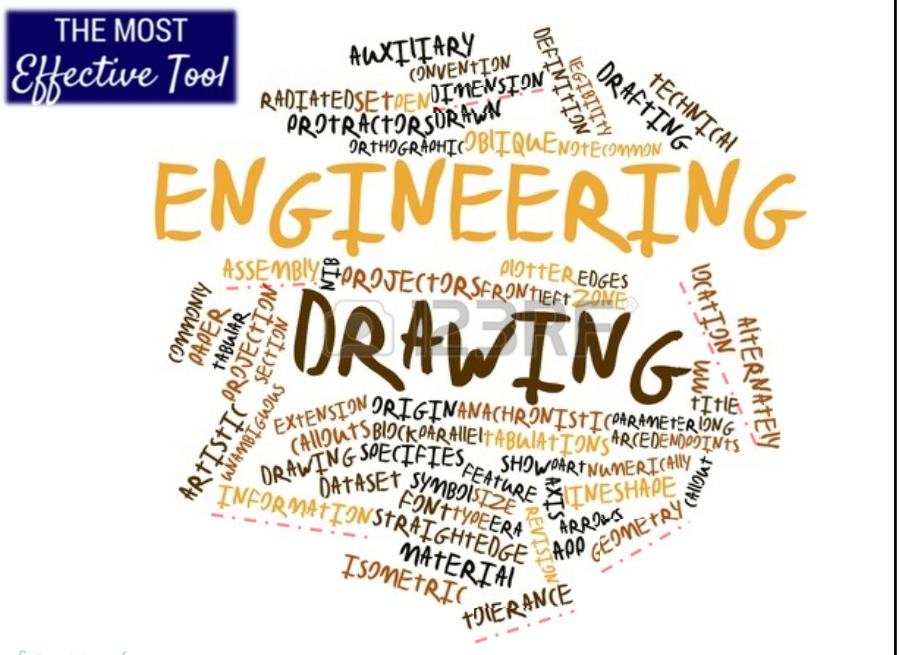

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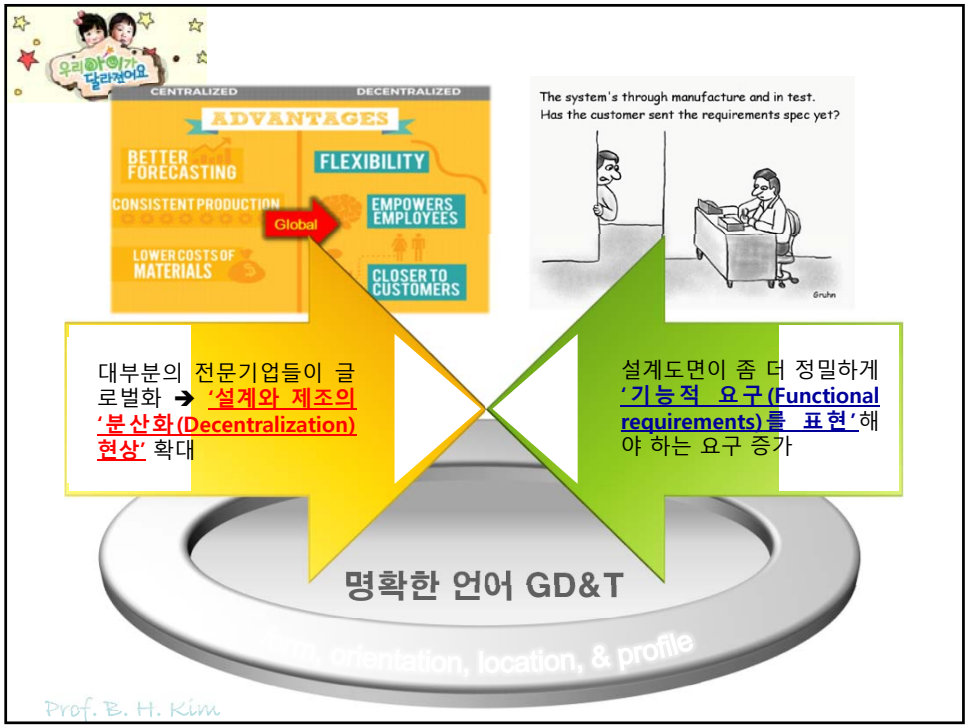
CENTRALIZED
DECENTRALIZED
ADVANTAGES
BETTER FORECASTING
FLEXIBILITY
CONSISTENT PRODUCTION
Global
EMPOWERS EMPLOYEES
LOWER COSTS OF MATERIALS
CLOSER TO CUSTOMERS
The system's through manufacture and in test.
Has the customer sent the requirements spec yet?
대부분의 전문기업들이 글로벌화 ➔ '설계와 제조의 '분산화(Decentralization) 현상' 확대
설계도면이 좀 더 정밀하게 '기능적 요구(Functional requirements)를 표현'해야 하는 요구 증가
명확한 언어 GD&T
orientation, location, & profile
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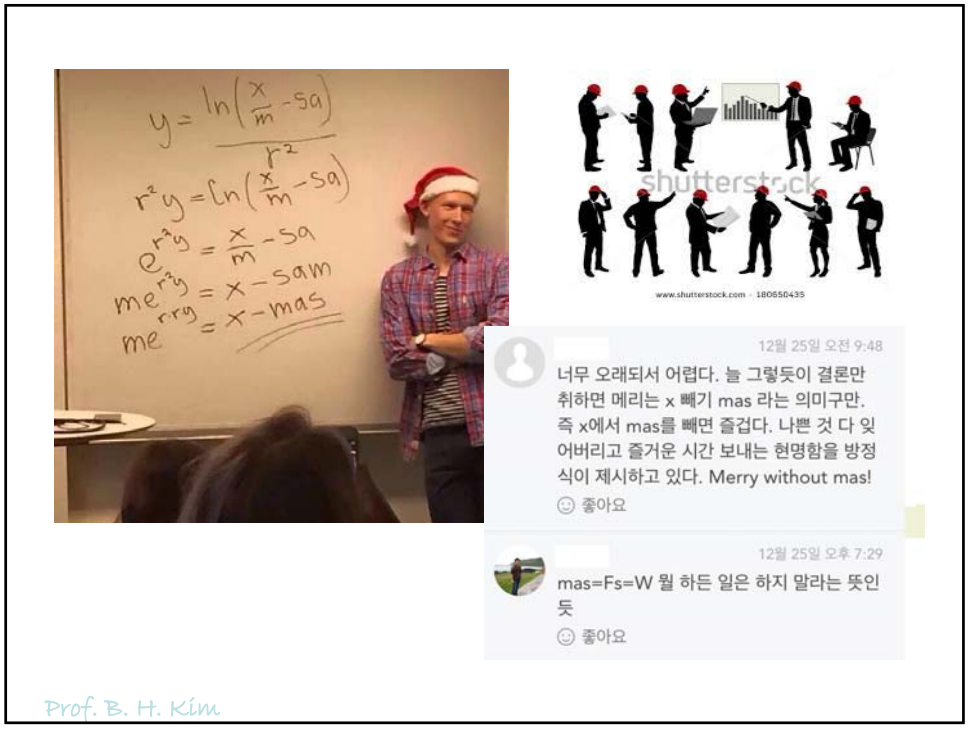
shutterstock
12월 25일 오전 9:48
너무 오래되서 어렵다. 늘 그렇듯이 결론만 취하면 메리는 x 빼기 mas 라는 의미구만. 즉 x에서 mas를 빼면 즐겁다. 나쁜 것 다 잊어버리고 즐거운 시간 보내는 현명함을 방정식이 제시하고 있다. Merry without mas!
좋아요
12월 25일 오후 7:29
mas=Fs=W 뭘 하든 일은 하지 말라는 뜻인 듯
좋아요
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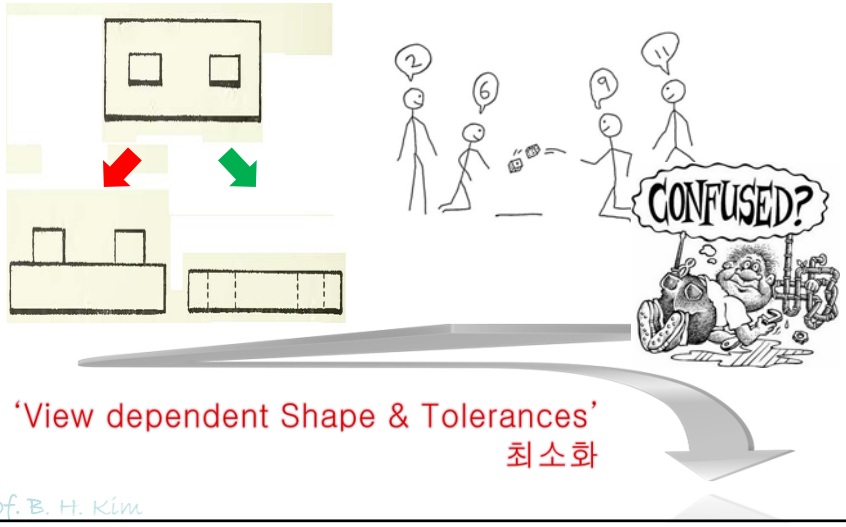
Drafting Golden Rules

- 도면정보는 설계-가공-측정 단계에서 **'이해 평등'** 해야 한다.



'View dependent Shape & Tolerances'
최소화

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Drafting Golden Rules

- 도면정보는 부품 또는 제품의 **'기능을 관통'** 해야 한다.

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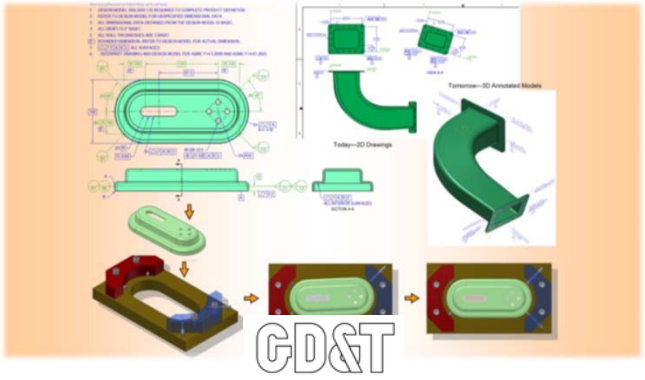

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Geometric Dimensioning & Tolerancing(GD&T) 기초

Ref. - ASME Y14.5-2009

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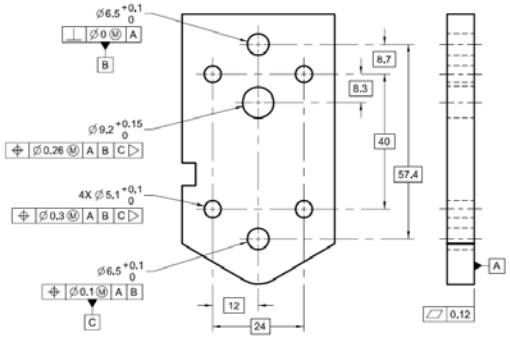
GD&T란?

- **[도면(Engineering Drawings)] 은 제조된 부품(Parts)의 크기(Size)와 형상(Shape) 을 서술한다.**
  - ✓ **공차(Tolerances)**는 크기에 영향을 주고,
  - ✓ **GD&T**는 형상에 영향을 준다. : *Manufacturing-oriented!!!*



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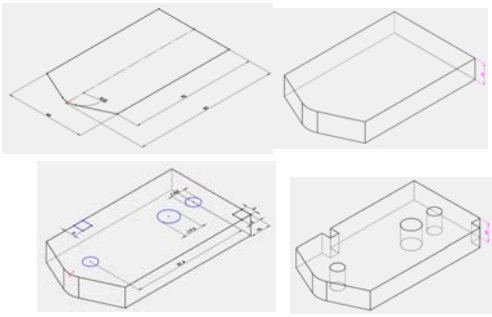
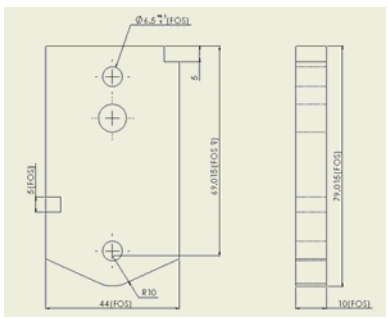
FOS(Feature of Size)

- **Feature of Size (FOS)**
  - ✓ 직경이나 두께 같은 형상의 치수
  - ✓ 원, 구, 두 상대요소, 평행면이 속한다. (*측정 가능 여부!!!*)
- **Example**





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Quiz 1

- 아래의 물체를 도면화하고 주요 공차를 기입하라.

-	+	+/- Tol	Description
			Totals

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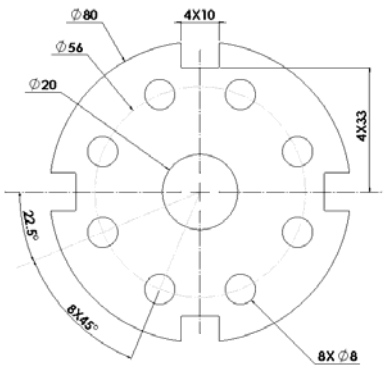
GD&T란?



- 치수는 정확하지만...
- 공차가 없어서!!!

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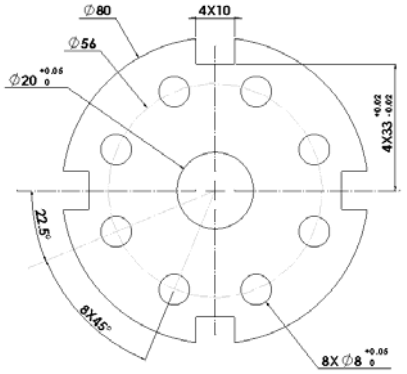
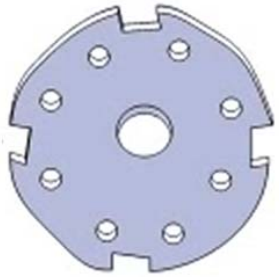
GD&T란?





- 치수공자는 주었지만...
- Bull's eye가 없어서!!!

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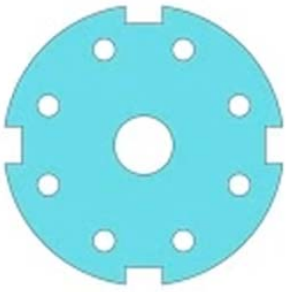
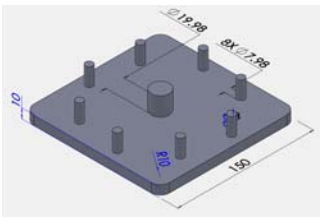
GD&T란?





- 명확한 GD&T!!!
- 효과적인 Gauging!!!

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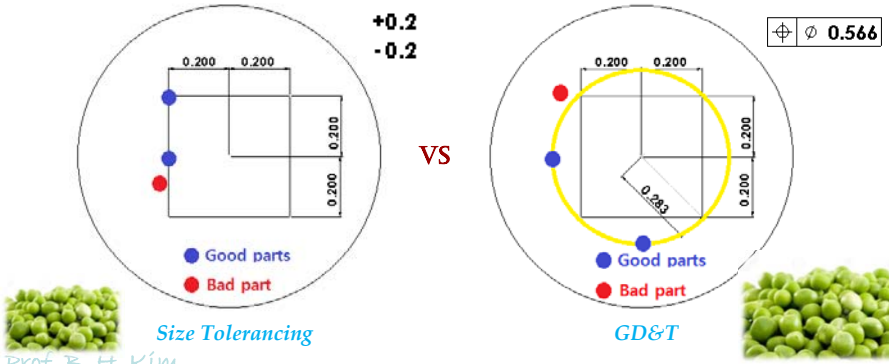
GD&T란?

- GD&T는 연관된 부품과의 기능과 조립을 고려한 치수기입 방법이다. (GD&T is a way to dimensioning that takes into account function and fit with related parts.)
  - GD&T는 더 정확한 치수기입(accurate dimensioning)과 느슨한 공차(looser tolerance)를 가능하게 한다.



Size Tolerancing GD&T

GD&T란?

- GD&T는 연관된 부품과의 기능과 조립을 고려한 치수기입 방법이다. (GD&T is a way to dimensioning that takes into account function and fit with related parts.)
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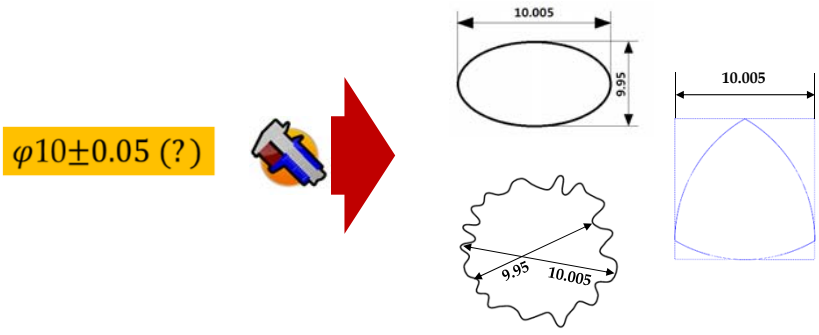

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GD&T 를 시작하기 전에…

- 모든 **치수(Dimension)**는 **공차(Tolerance)**를 가지고 있어야 한다
- 치수기입법(Dimensioning)과 공차할당(Tolerancing)을 통해 공칭 기하(Nominal geometry)와 허용편차(Allowable variation-마진)를 명확히 정의한다.
- 최종적인 부품을 정의하기 위한 **모든** 치수와 공차를 도면에 표기하여야 한다.
- 치수는 형상의 기능을 이해하기 쉽도록 기입되어야 한다.
- 가공법(manufacturing method)의 기입은 되도록 피한다.
- 치수와 공차 등의 가독성(readability)은 가능한 한 높인다.
- 공칭치수와 공차는 주변온도가 20°C일 경우이며, 그렇지 않은 경우 도면에 기술한다.
- 명확하게 기술되어 있지 않은 경우 모든 치수와 공차는 부품이 자유로운 상태(free state)에서의 값이다.
- 치수와 공차는 부품(형상)의 최대 길이, 폭, 깊이에 적용된다.

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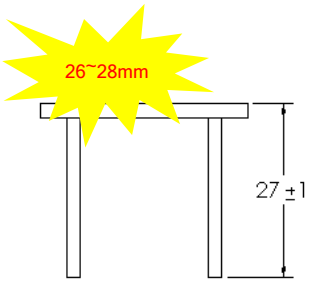
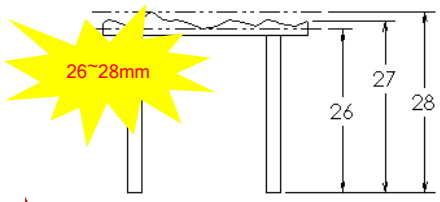
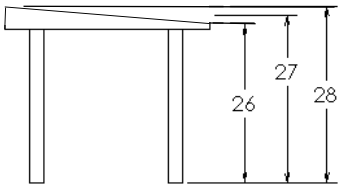
GD&T 를 시작하기 전에…



단순한 치수 공차

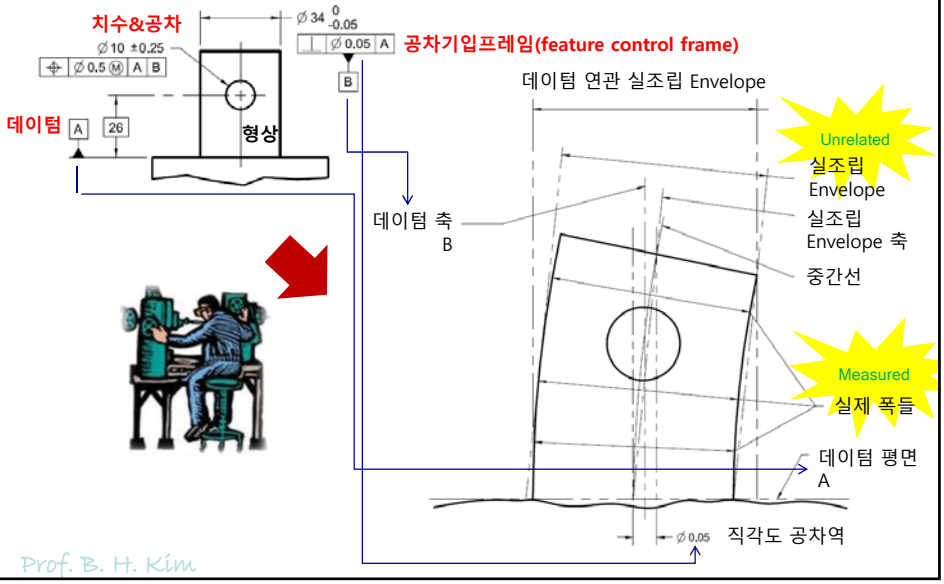


파상도를 고려하면…



편평도를 고려하면…

GD&T 를 시작하기 전에…



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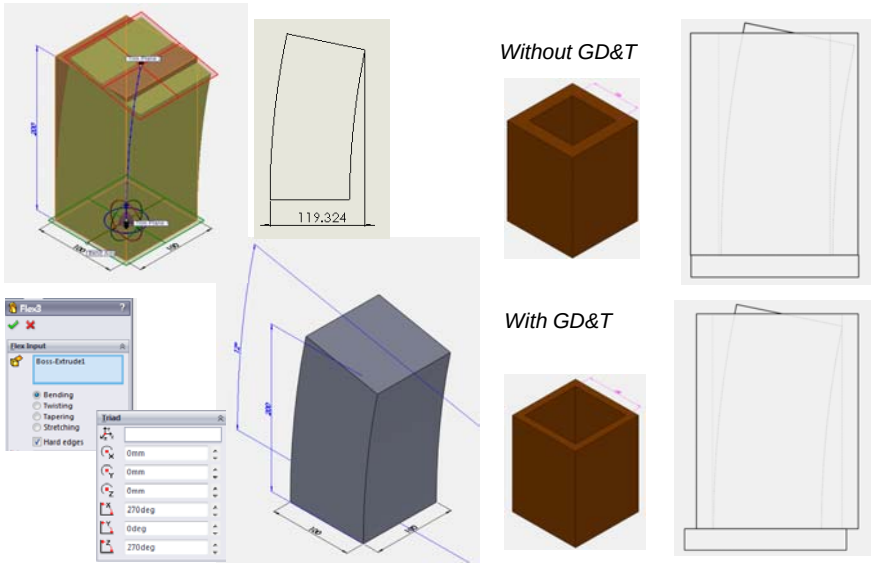
Example



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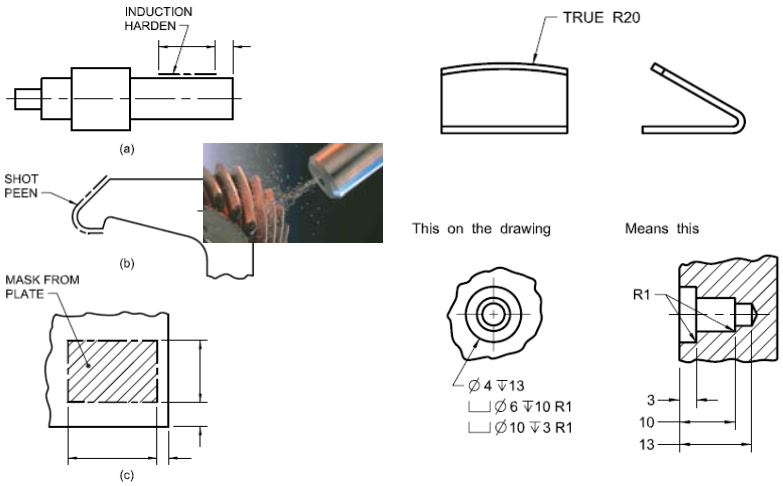
GD&T 를 시작하기 전에…

- Advanced Dimensioning



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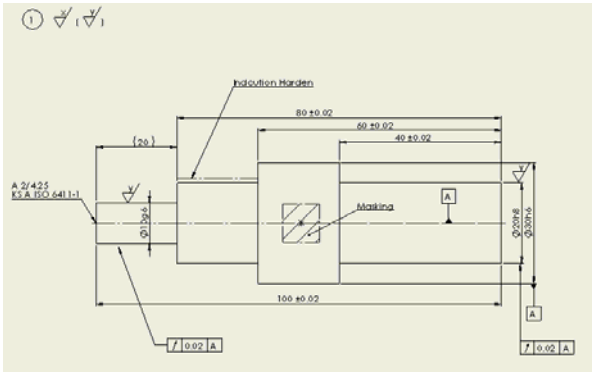

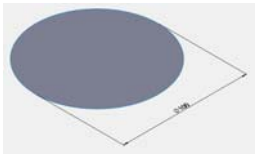

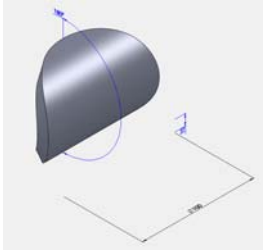

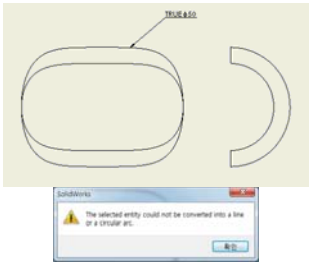

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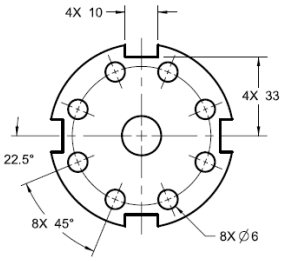
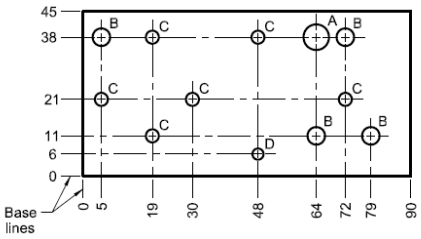
GD&T 를 시작하기 전에…

- Advanced Dimensioning





SIZE SYMBOL	A	B	C	D
HOLE Ø	7	4.8	3.6	3.1

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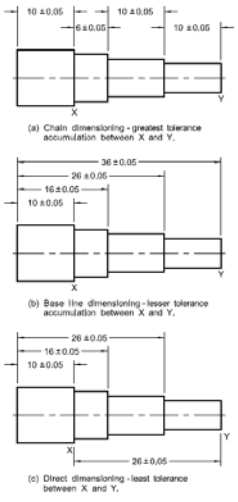
GD&T 를 시작하기 전에…

- 치수공차와 관련 원칙 – 치수기입 방식과 공차 누적

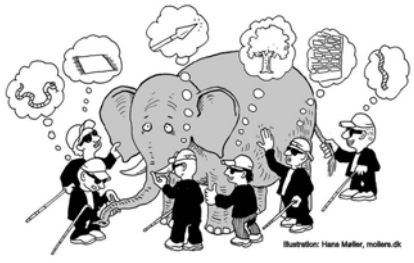


(a) 직렬치수기입법(Chain Dimensioning)
- X와 Y 사이의 누적공차는 ±0.15.

(b) 기선치수기입법(Base Line Dimensioning)
- X와 Y 사이의 누적공차는 ±0.1

.

(c) 직접치수기입법(Direct Dimensioning)
- X와 Y 사이의 공차는 ±0.05.



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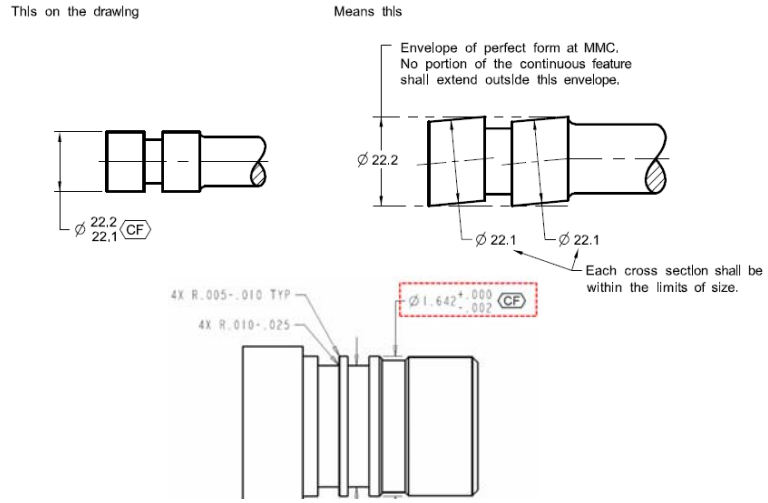
GD&T 를 시작하기 전에…

- 치수공차와 관련 원칙 – 연속 형상



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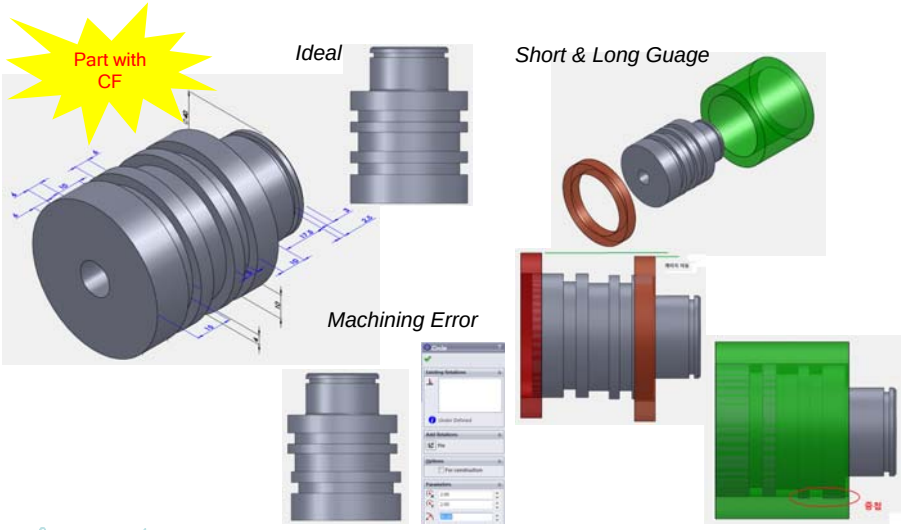
Example

- CF(Continuous Feature)



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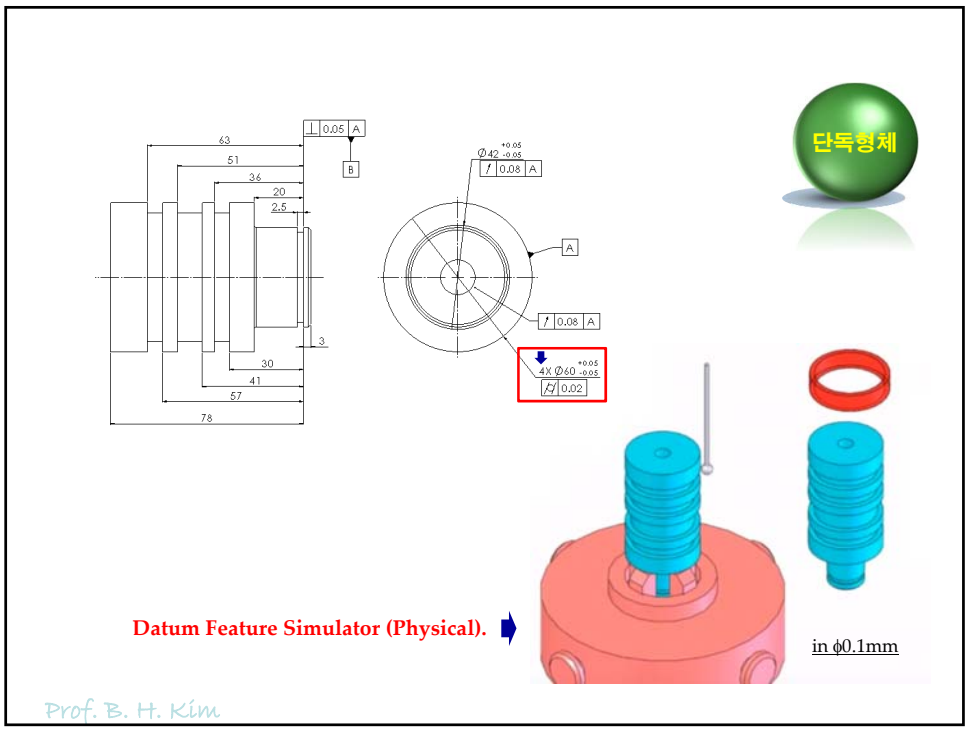
단독형체
63
51
36
20
2.5
3
30
41
57
78
0.05 A
B
Ø42 +0.05 -0.05
0.08 A
A
0.08 A
4X Ø60 +0.05 -0.05
0.02
Datum Feature Simulator (Physical).
in ϕ0.1mm
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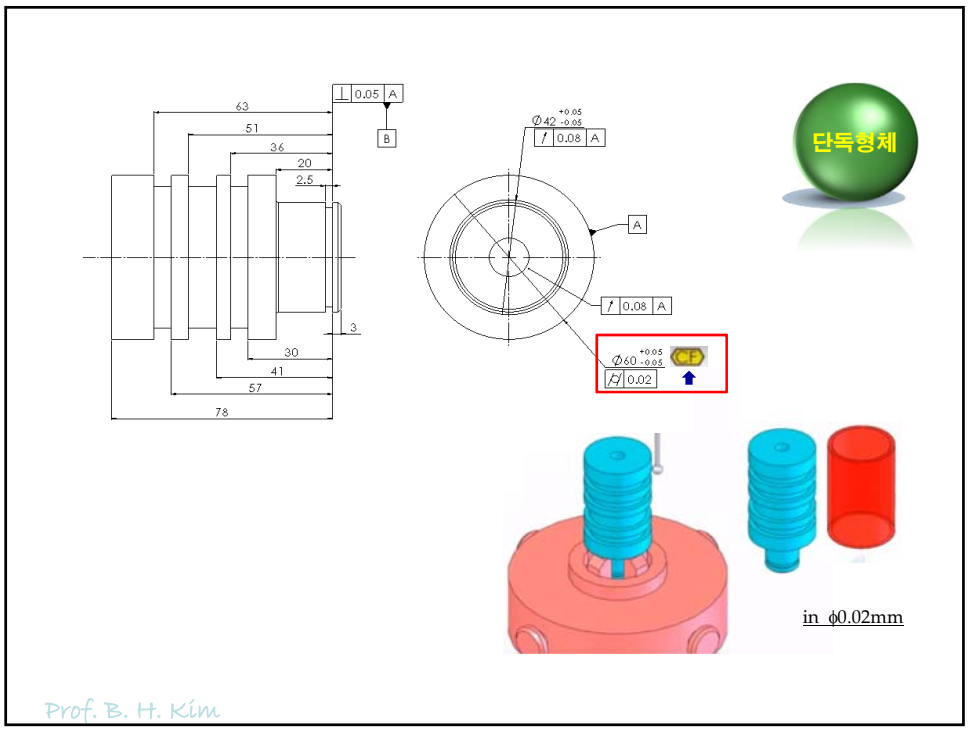
단독형체
63
51
36
20
2.5
3
30
41
57
78
0.05 A
B
Ø42 +0.05 -0.05
0.08 A
A
0.08 A
Ø60 +0.05 -0.05
0.02
in ϕ0.02mm
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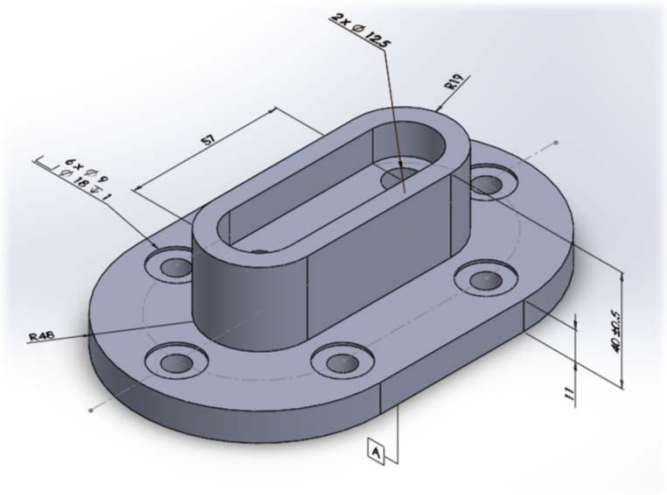
Model Based Definition



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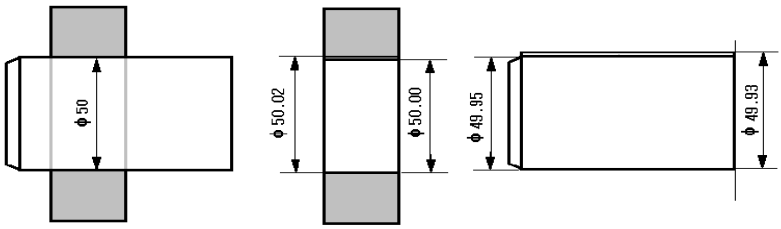
GD&T 기초

- 기본치수

- 기본치수 : 공칭치수(Nominal dimension)/50mm
- 영점(Zero line): 기준선(Reference line)
- 최대한계치수(Maximum limit of size): 홀/50.02mm-축/49.95mm
- 최소한계치수(Minimum limit of size): 홀/50.00mm-축/49.93mm

- 공차 = 최대한계치수 – 최소한계치수 (0.02)

- 윗치수 허용차(Upper deviation): 홀/0.02mm-축/-0.05mm
- 아랫치수 허용차(Lower deviation): 홀/0.0mm-축/-0.07mm



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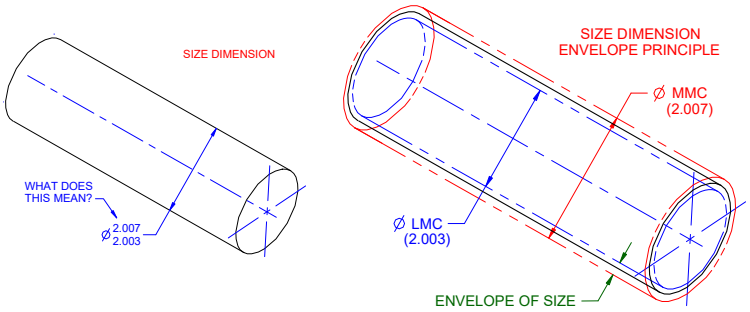
GD&T 기초– MMC/LMC

- 최대실체조건(MMC – Maximum Material Condition)
  - 주어진 한계치수에서 최대의 재료량을 포함하는 형체 크기(size feature).
    ☞ largest shaft and smallest hole.
- 최소실체조건(LMC – Least Material Condition)
  - 주어진 한계치수에서 최소의 재료량을 포함하는 형체 크기(size feature).
    ☞ smallest shaft and largest hole.



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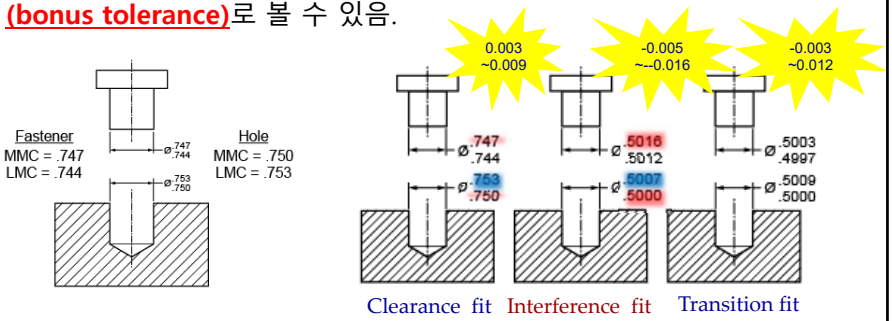
GD&T 기초– MMC/LMC

- 부품의 실체조건(material condition)은 GD&T의 활용에 매우 큰 영향을 미침.
- 많은 경우, 부품의 실체치수와 최대실체조건 간의 차는 **보너스공차 (bonus tolerance)**로 볼 수 있음.



* 실제 가공된 Fastener/Hole 치수 = 0.745″/0.752″ ➔ Clearance(간극) = 0.007″
☞ Fastener의 최대실체조건과 Hole의 최대실체조건의 상대적 치수가 Fit 상태를 결정

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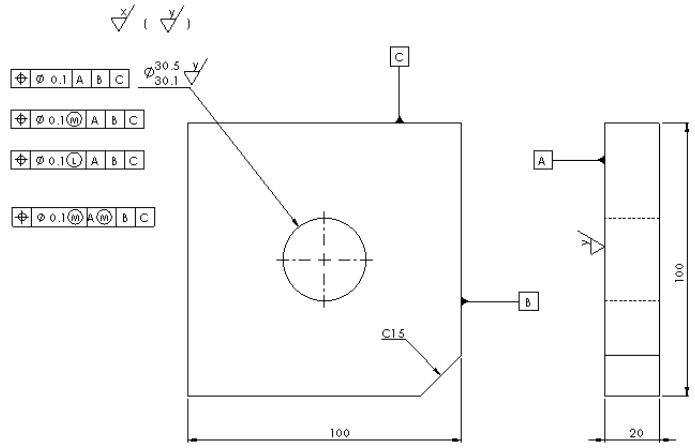
Exercise



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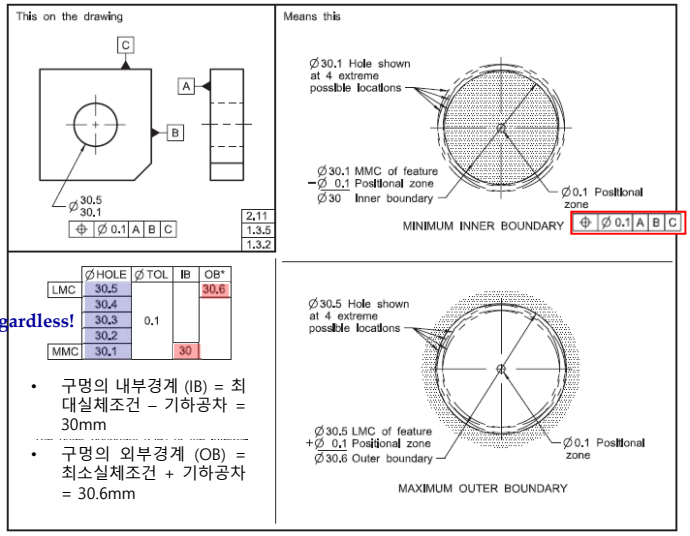
GD&T 기초- RFS



- 구멍의 내부경계 (IB) = 최대실체조건 – 기하공차 = 30mm
- 구멍의 외부경계 (OB) = 최소실체조건 + 기하공차 = 30.6mm

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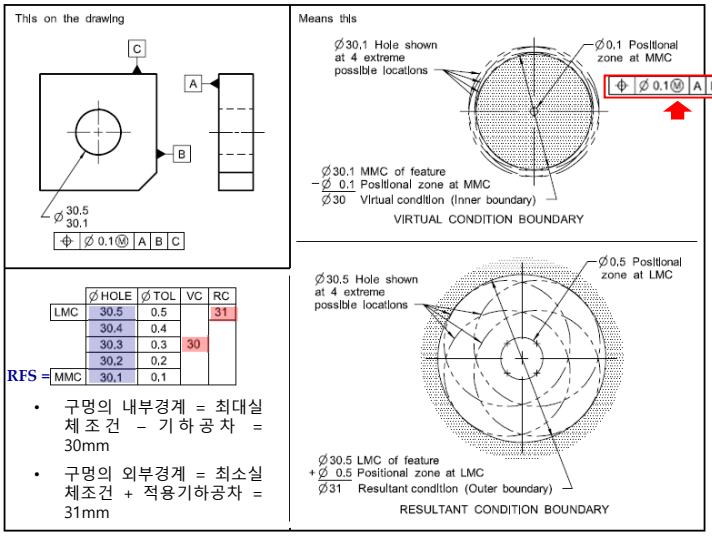
GD&T 기초- MMC



- 구멍의 내부경계 = 최대실체조건 – 기하공차 = 30mm
- 구멍의 외부경계 = 최소실체조건 + 적용기하공차 = 31mm

* VC: 기하공차만 고려; RC: 기하공차, 실체조건, 치수공차를 모두 고려

GD&T 기초- MMC

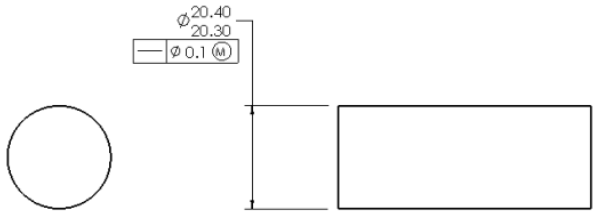
- 적용기하공차 = 보너스공차

Actual Mating Envelope	Geometric Tolerance Zone	Bonus Tolerance	Total Tolerance Zone
30.1(MMC/RFS)	0.1	0	0.1
30.2		0.1	0.2
30.3		0.2	0.3
30.4		0.3	0.4
30.5(LMC)		0.4	0.5

✓ 총 공차구역의 크기 = 기하공차 + 보너스 공차
∴ VC = 30.1 – 0.1 = ϕ30mm, RC = 30.5 + 0.5 = ϕ31mm

✓ 제조의 유연성(flexibility)를 제고하여 비용 절감이 가능

Virtual Condition



- MMC is Ø20.4 and a straightness tolerance 0.1 is specified at MMC. Which means that our extreme boundary is 20.5 and which is the virtual condition.
- It is a number that represents a worst-case combination of a feature's size along with its geometric tolerance.
- Virtual condition is extensively used by product designers to analyze mating parts, used by gauge manufactures to find the gauge dimensions and also used by product inspectors to check these extreme conditions.

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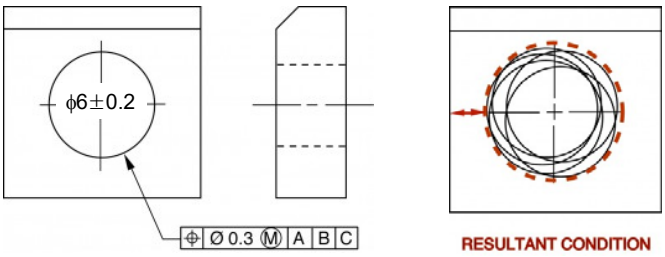
Resultant Condition



- The outside boundary created by the largest hole that is also off center.
- Resultant condition boundary is calculated as 'LMC + stated geometric tolerance + any bonus (6.2 + 0.3 + 0.4 = 6.9 mm.)'.
- This resultant condition is not of concern when dealing with assembly of holes and pins! At simple punching a hole on sheet metals, the concern now is that the hole's edge not be too close to the edge of the sheet metal.

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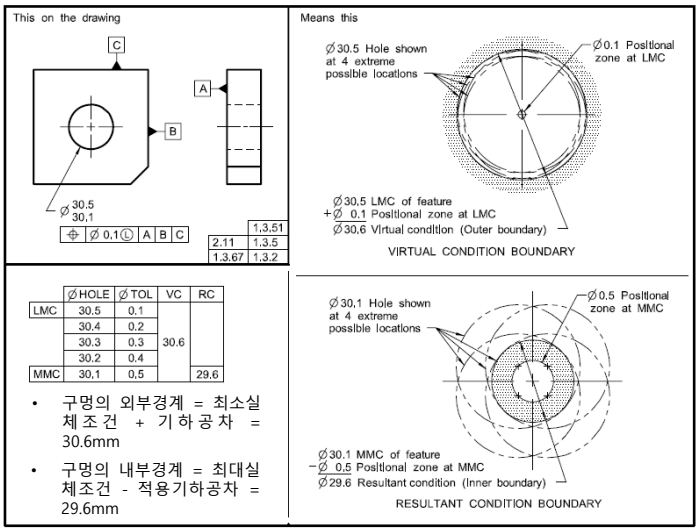
GD&T 기초- LMC



	Ø HOLE	Ø TOL	VC	RC
LMC	30.5	0.1	30.6	
	30.4	0.2		
	30.3	0.3		
	30.2	0.4		
MMC	30,1	0,5		29.6

- 구멍의 외부경계 = 최소실체조건 + 기하공차 = 30.6mm
- 구멍의 내부경계 = 최대실체조건 - 적용기하공차 = 29.6mm

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GD&T 기초- LMC

- 적용기하공차 = 보너스공차

Actual Mating Envelope	Geometric Tolerance Zone	Bonus Tolerance	Total Tolerance Zone
30.1(MMC/RFS)	0.1	0.4	0.5
30.2		0.3	0.4
30.3		0.2	0.3
30.4		0.1	0.2
30.5(LMC)		0	0.1

✓ 총 공차구역의 크기 = 기하공차 + 보너스 공차
∴ VC = 30.5 + 0.1 = ϕ30.6mm, RC = 30.1 – 0.5 = ϕ29.6mm
✓ 제조의 유연성(flexibility)를 제고하여 비용 절감이 가능

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GD&T 기초

구분	기호	공차의 종류		적용하는 형체	데이텀
모양공차		진직도		단독 형체	불필요
		평면도			
		진원도			
		원통도			
		윤곽도		단독 형체 관련 형체	
		윤곽도			
자세공차	//	MMC (최대실체 공차)적용	평행도	관련 형체	필요
	⊥		직각도		
	∠		경사도		
위치공차	⌖		위치도		
	◎	ONLY RFS (형세지수 무관계) 적용	동심도		
	=		대칭도		
흔들림 공차	↗		원주 흔들림		
	⌰		온 흔들림		

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Geometric Dimensioning & Tolerancing(GD&T) 응용기법

Ref. - ASME Y14.5-2009

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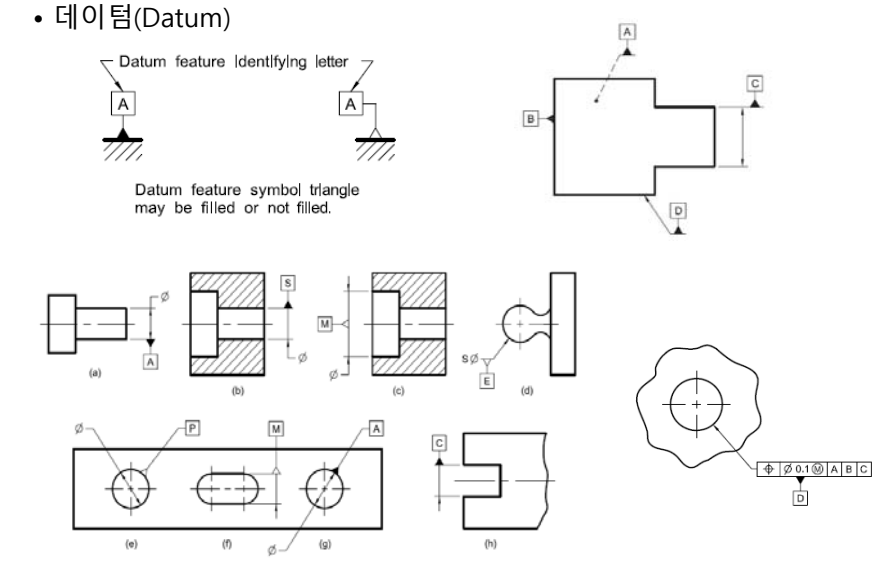
GD&T 활용

- 데이텀(Datum)



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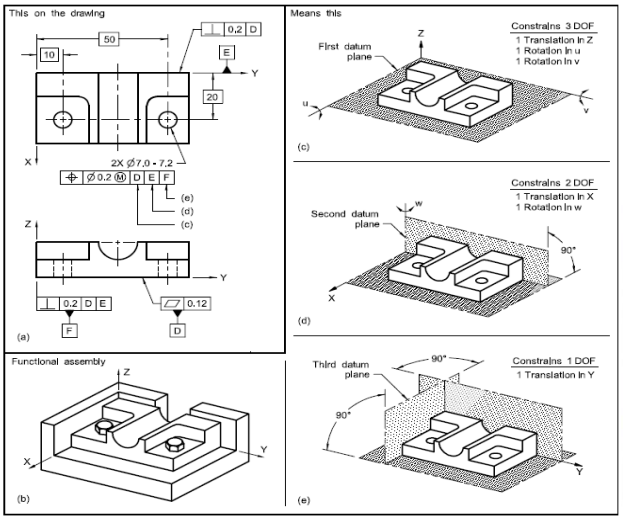
GD&T 활용

- 데이텀(Datum): 6자유도계의 구속(constraint) 시뮬레이터



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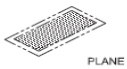
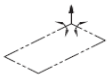
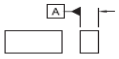
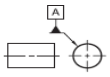
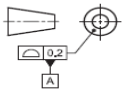
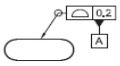
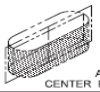
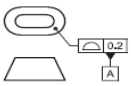
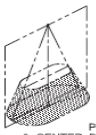
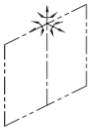
FEATURE TYPE	ON THE DRAWING	DATUM FEATURE	DATUM AND DATUM FEATURE SIMULATOR	DATUM AND CONSTRAINING DEGREES OF FREEDOM
PLANAR (a)			 PLANE	
WIDTH (b)			 CENTER PLANE	
SPHERICAL (c)			 POINT	
CYLINDRICAL (d)			 AXIS	
CONICAL (e)			 AXIS & POINT	
LINEAR EXTRUDED SHAPE (f)			 AXIS & CENTER PLANE	
COMPLEX (g)			 AXIS, POINT, & CENTER PLANE	

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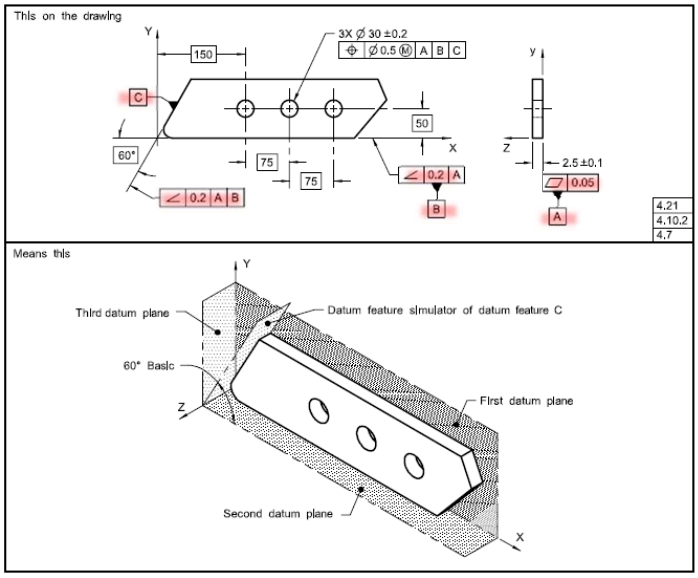

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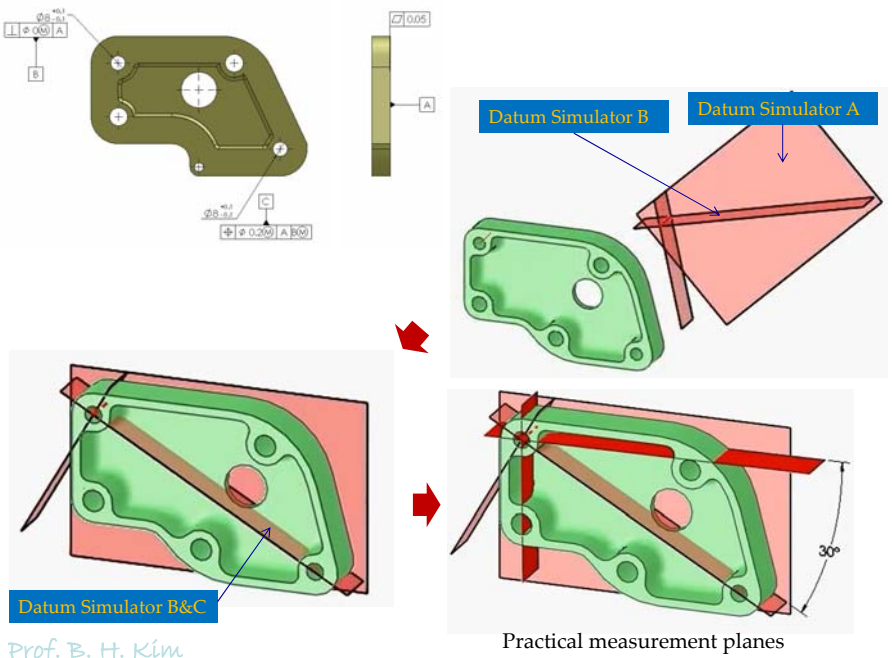

Practical measurement planes

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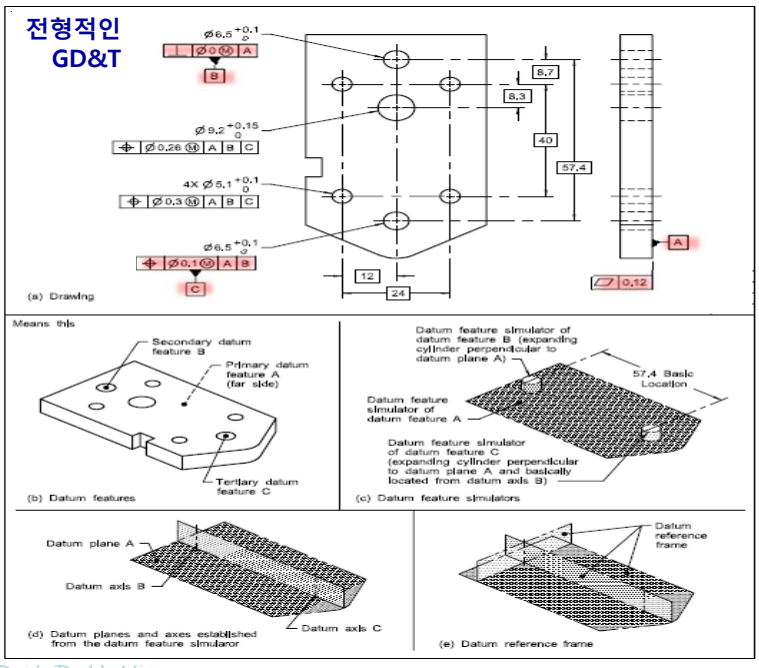

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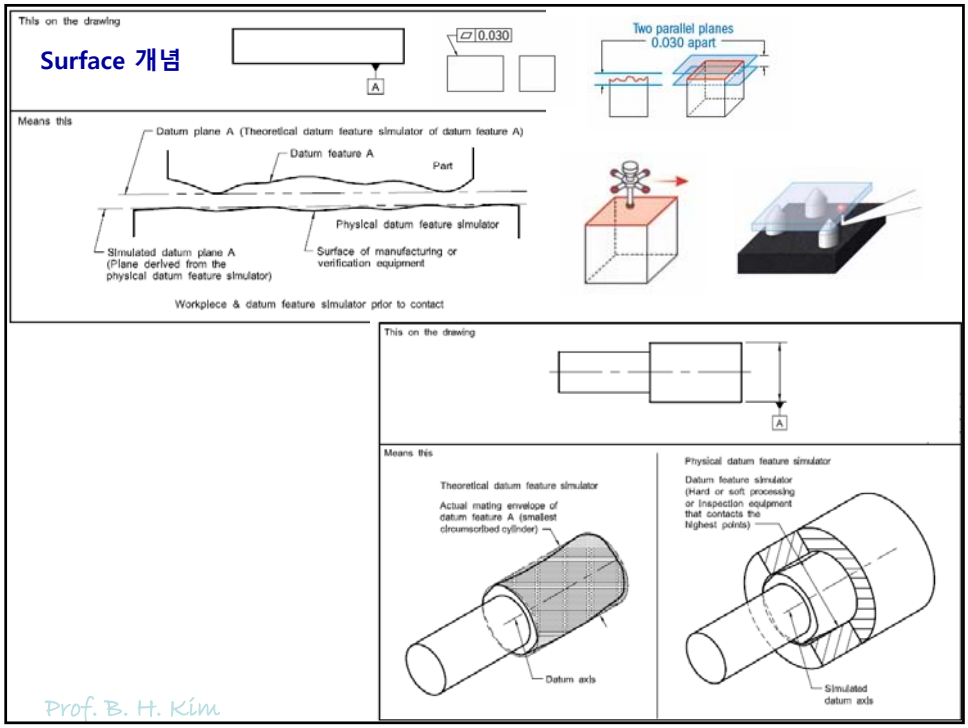

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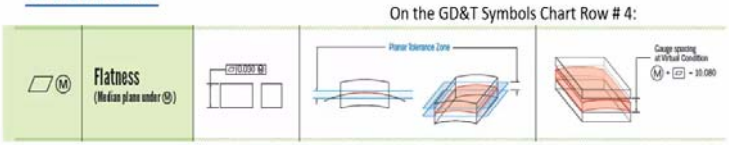
But…

Flatness (Feature of Size)

Flatness Symbol:

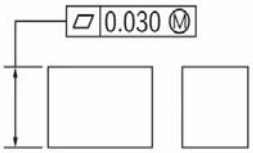
Overview

On the GD&T Symbols Chart Row # 4:



Relative to Datum: **NO**

MMC or LMC: **Yes**
(new in 2009 for a derived median plane)



For Flatness – it is important that the correct feature control frame placement is used to determine whether it is called on the surface or a feature of size.

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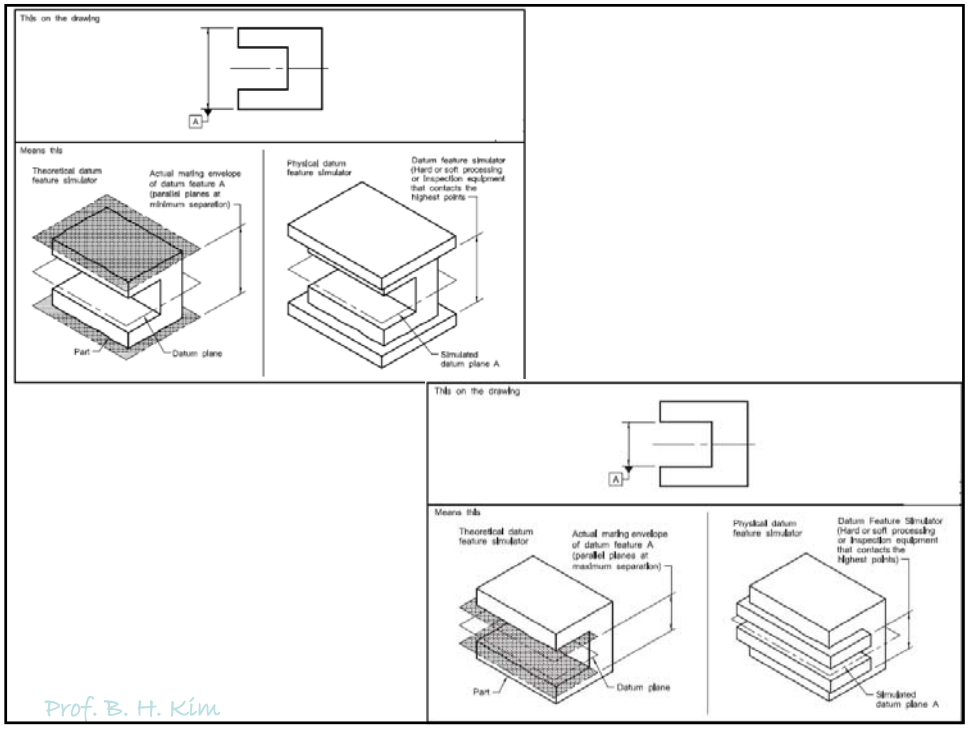

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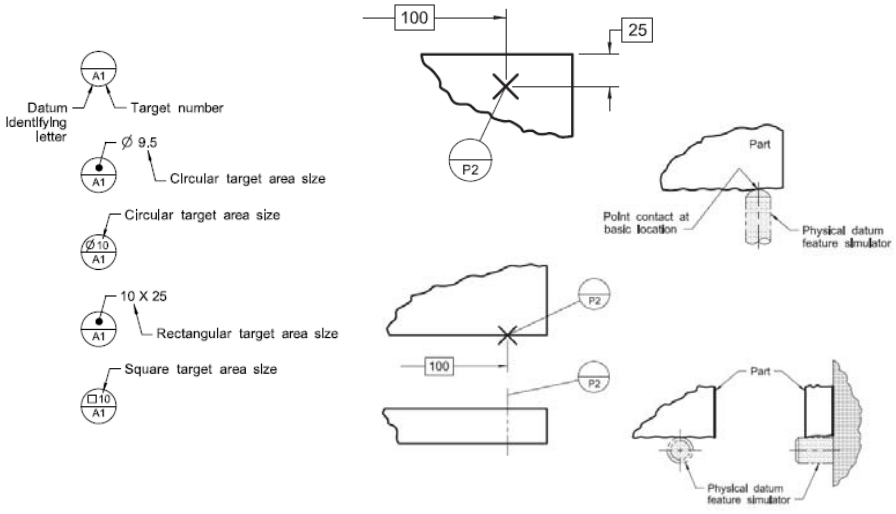
GD&T 활용

- 데이텀 타깃(Datum Target)



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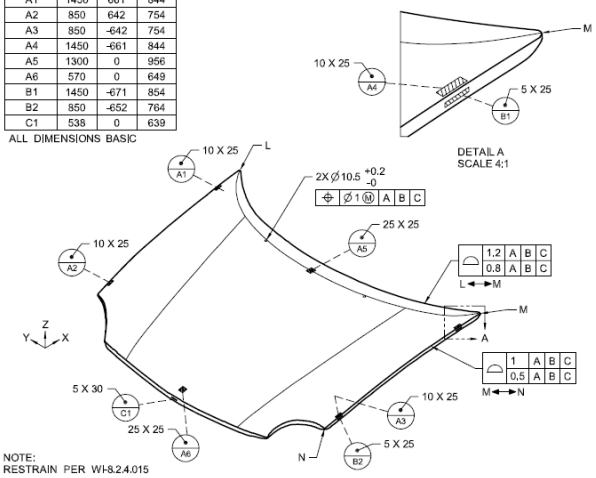
GD&T 활용

- 데이텀 타깃(Datum Target)

DATUM TARGET LOCATIONS			
TARGET	X	Y	Z
A1	1450	661	844
A2	850	642	754
A3	850	-642	754
A4	1450	-661	844
A5	1300	0	956
A6	570	0	649
B1	1450	-671	854
B2	850	-652	764
C1	538	0	639

ALL DIMENSIONS BASIC



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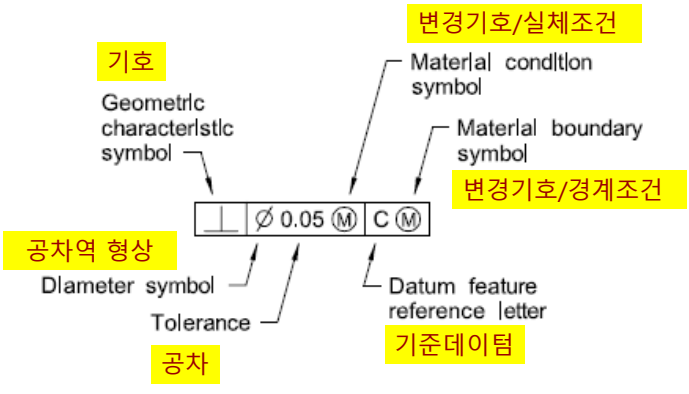
GD&T 활용

- 공차기입프레임(Feature Control Frame)



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GD&T 활용

- 주요 변경기호(Modifying symbol)

CF
Continuous Feature [ASME Y14.5-2009 Section 2.7.5] - The note CONTINUOUS FEATURE or the continuous feature symbol is used to identify a group of two or more features of size where there is a requirement that they be treated geometrically as a single feature of size. Although the definition only mentions features of size, there is an example of CF being applied to a pair of planar features.

Datum Feature - is the actual component feature used to establish a datum.

Datum Target - is a specified point, line, or area on a part that is used to establish the Datum Reference Plane for manufacturing and inspection operations.

Depth/Deep - is used to indicate that a dimension applies to the depth of a feature. This symbol precedes the depth value with no space in between.

Free State Variations - is a term used to describe distortion of a part after removal of forces applied during manufacture.

Least Material Condition (LMC) - implies that condition of a part feature of size wherein it contains the least (minimum) amount of material, examples, largest hole size and smallest shaft size. It is opposite to maximum material condition.

Maximum Material Condition (MMC)- is that condition of a part feature wherein it contains the maximum amount of material within the stated limits of size. That is: minimum hole size and maximum shaft size.

Projected Tolerance Zone - applies to a hole in which a pin, stud, screw, etc., is to be inserted. It controls the perpendicularity of the hole to the extent of the projection from the hole and as it relates to the mating part clearance. The projected tolerance zone extends above the surface of the part to the functional length of the pin, stud, and screw relative to its assembly with the mating part.

SR
Spherical Radius - precedes the value of a dimension or tolerance.

ST
Statistical Tolerance - is the assigning of tolerances to related components of an assembly on the basis of sound statistics (such as the assembly tolerance is equal to the square root of the sum of the squares of the individual tolerances). By applying statistical tolerancing, tolerances of individual components may be increased or clearances between mating parts may be reduced. The increased tolerance or improved fit may reduce manufacturing cost or improve the product's performance, but shall only be employed where the appropriate statistical process control will be used. Therefore, consideration should be given to specifying the required Cp and /or Cpk or other process performance indices.

Tangent Plane - indicating a tangent plane is shown. The symbol is placed in the feature control frame following the stated tolerance.

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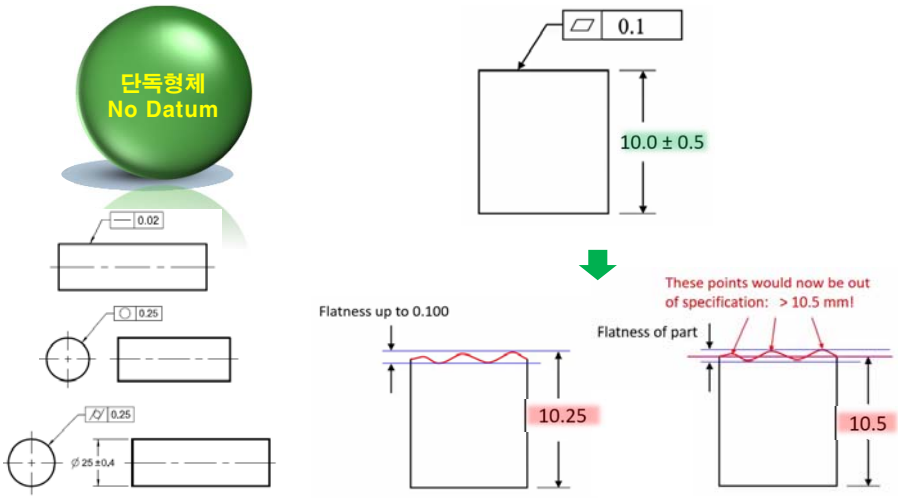
GD&T 활용

- 형상공차(Tolerance of form) – 편평도(Flatness)



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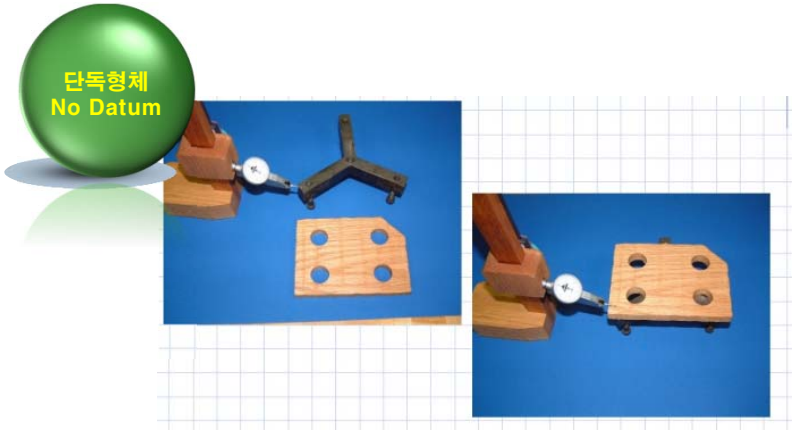
GD&T 활용

- 형상공차(Tolerance of form) – 편평도(Flatness)



✓ 출처: http://www.slideshare.net/Pinnacleconsultancy/gdt-13337846

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GD&T 활용

- 형상공차(Tolerance of form) – 편평도(Flatness)

✓ 출처: https://www.youtube.com/watch?v=naXOpoRb-ws

Prof. B. H. Kim

GD&T 활용

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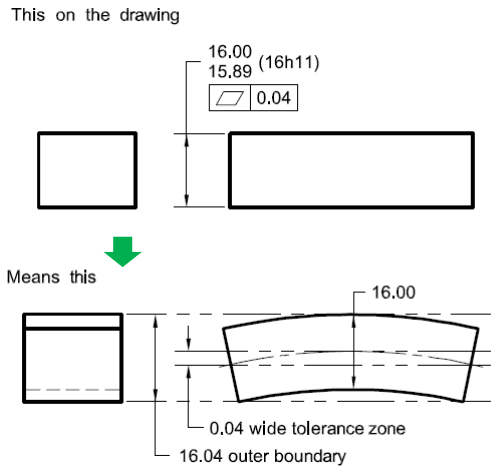

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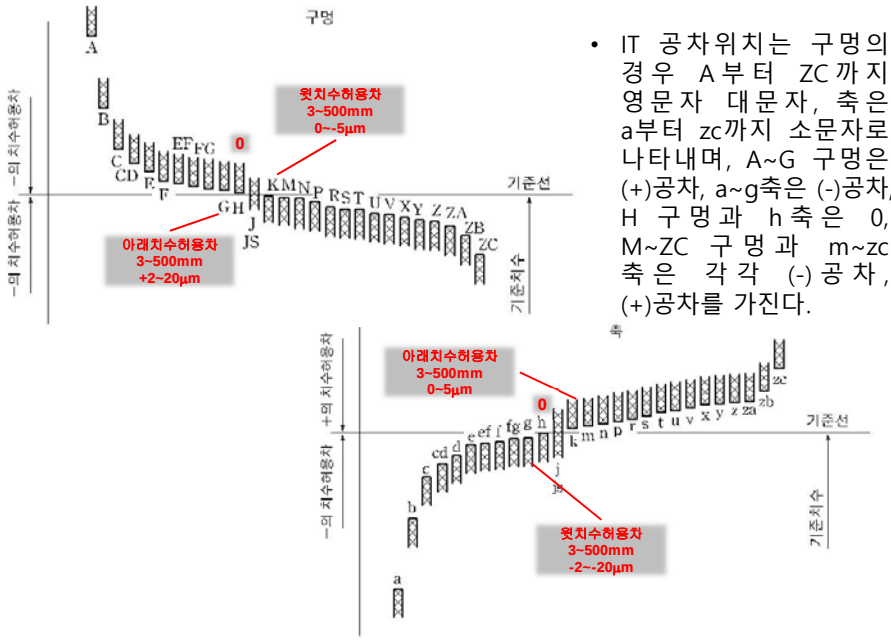

- IT 공차위치는 구멍의 경우 A부터 ZC까지 영문자 대문자, 축은 a부터 zc까지 소문자로 나타내며, A~G 구멍은 (+)공차, a~g축은 (-)공차, H 구멍과 h축은 0, M~ZC 구멍과 m~zc 축은 각각 (-)공차, (+)공차를 가진다.

Prof. B. H. Kim

IT공차 등급

IT01부터 ~ IT18까지 20등급으로 구분합니다. (KS B 0401)
단위 μm : 0.001mm

기준 치수 (mm)		IT 공차등급																		
		01	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
초과	이하	기본 공차의 수치(μm)													기본 공차의 수치(μm)						
-	3	0.3	0.5	0.8	1.2	2	3	4	6	10	14	25	40	60	0.10	0.14	0.26	0.40	0.60	1.00	1.40
3	6	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	0.12	0.18	0.30	0.48	0.75	1.20	1.80
6	10	0.4	0.6	1	1.5	2.5	4	6	9	15	22	36	58	90	0.15	0.22	0.36	0.58	0.90	1.50	2.20
10	18	0.5	0.8	1.2	2	3	5	8	11	18	27	43	70	110	0.18	0.27	0.43	0.70	1.10	1.80	2.70
18	30	0.6	1.0	1.5	2.5	4	6	9	13	21	33	52	84	130	0.21	0.33	0.52	0.84	1.30	2.10	3.30
30	50	0.6	1.0	1.5	2.5	4	7	11	16	25	39	62	100	160	0.25	0.39	0.62	1.00	1.60	2.50	3.90
50	80	0.8	1.2	2	3	5	8	13	19	30	46	74	120	190	0.30	0.46	0.74	1.20	1.90	3.00	4.60
80	120	1.0	1.5	2.5	4	6	10	15	22	35	54	87	140	220	0.35	0.54	0.87	1.40	2.20	3.50	5.40
120	180	1.2	2.0	3.5	5	8	12	18	25	40	63	100	160	250	0.40	0.63	1.00	1.60	2.50	4.00	6.30
180	250	2.0	3.0	4.5	7	10	14	20	29	46	72	115	185	290	0.46	0.72	1.15	1.85	2.90	4.60	7.60
250	315	2.5	4.0	6	8	12	16	23	32	52	81	130	210	320	0.52	0.81	1.30	2.10	3.20	5.20	8.10
315	400	3.0	5.0	7	9	13	18	25	36	57	89	140	230	360	0.57	0.89	1.40	2.30	3.60	5.70	8.90

$i=0.45\times\sqrt[3]{D}+0.001\times D(\mu m)$ · · · · · · · 500㎜이하의 경우

단, D : 각 치수구분의 양쪽 한계치수 D1, D2의 기하평균값

$D=\sqrt{D_1\times D_2}$

IT 공차 등급과 단위수

공차등급	IT 5	IT 6	IT 7	IT 8	IT 9	IT 10
공차단위의 수	7	10	16	25	40	64

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GD&T 활용

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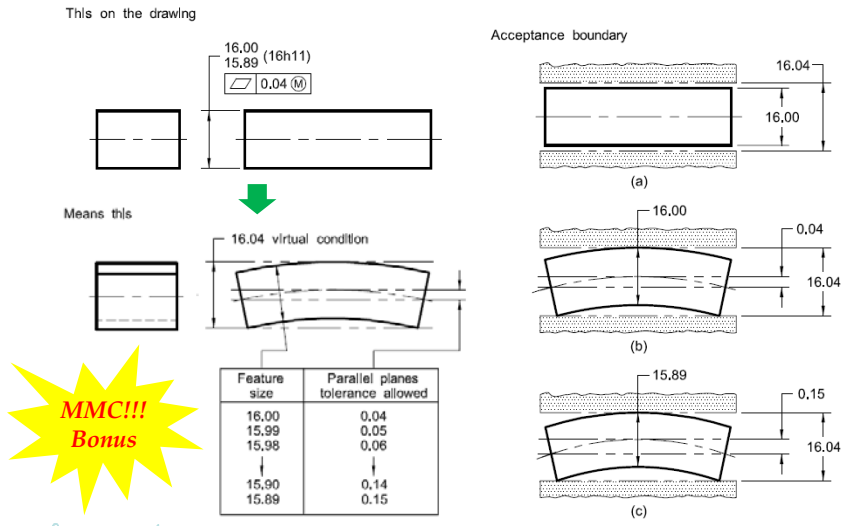

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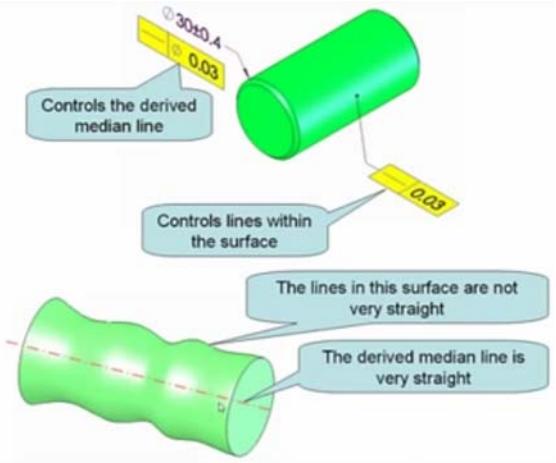
GD&T 활용

• 형상공차(Tolerance of form) – 진직도 (Straightness)



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GD&T 활용

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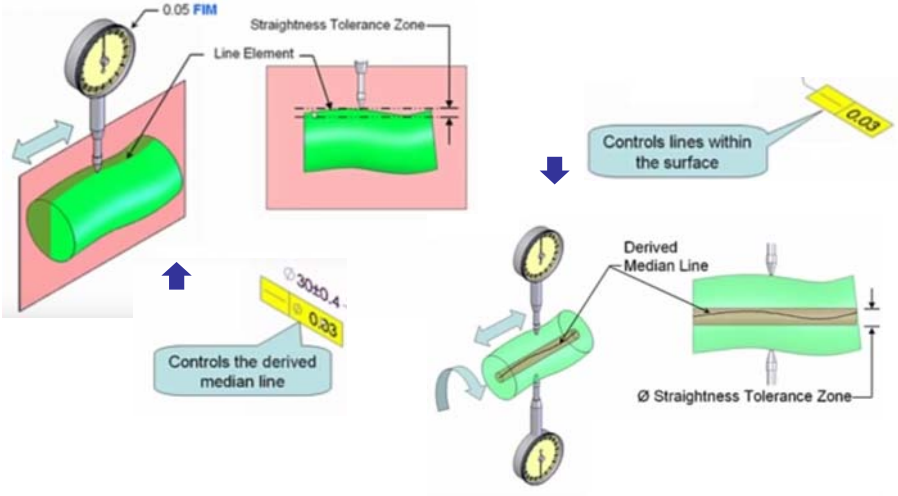

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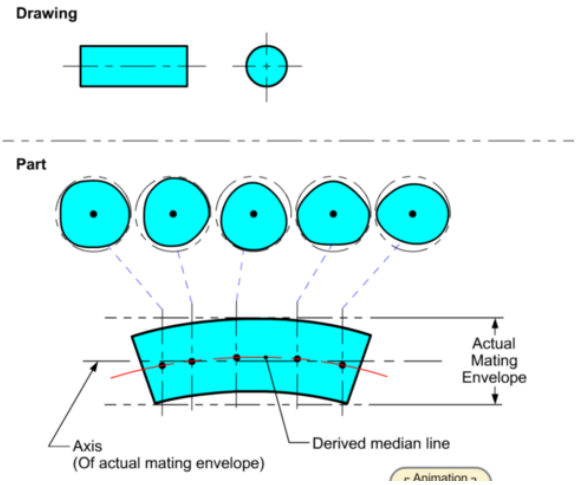
GD&T 활용



From https://quizlet.com/215035942/7-gdt-straightness-flash-cards/

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GD&T 활용

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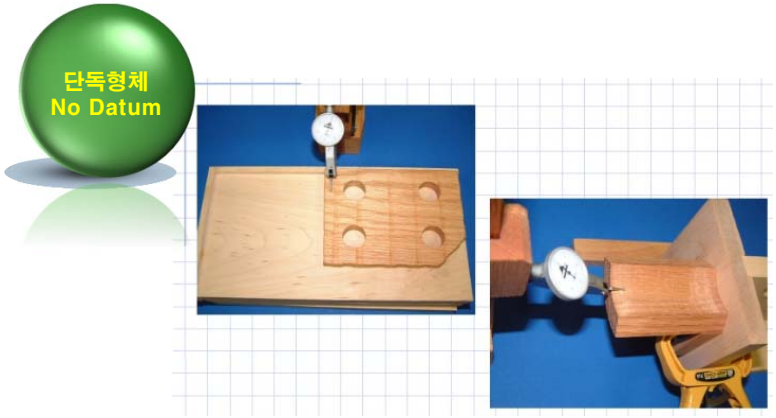

출처: http://www.slideshare.net/Pinnacleconsultancy/gdt-13337846

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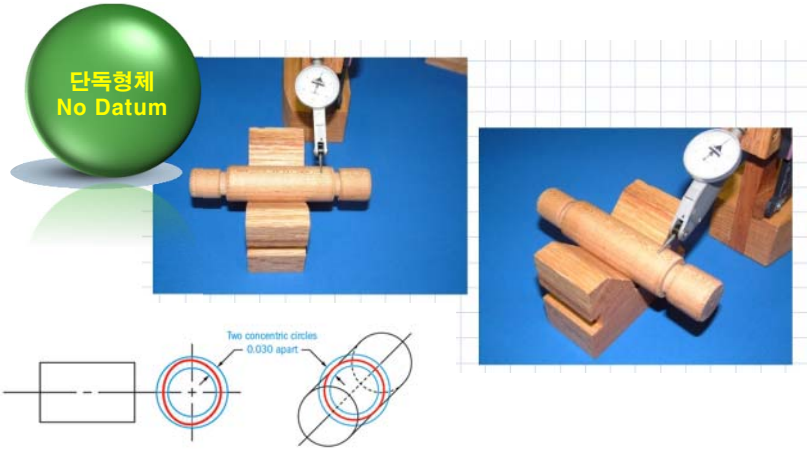
GD&T 활용

- 형상공차(Tolerance of form) – 진원도 (Circularity)



출처: http://www.slideshare.net/Pinnacleconsultancy/gdt-13337846
https://www.gdandtbasics.com/circularity/

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GD&T 활용

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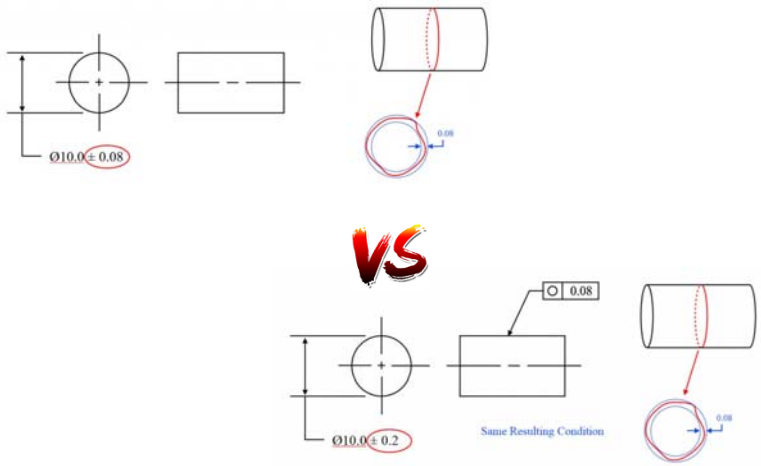

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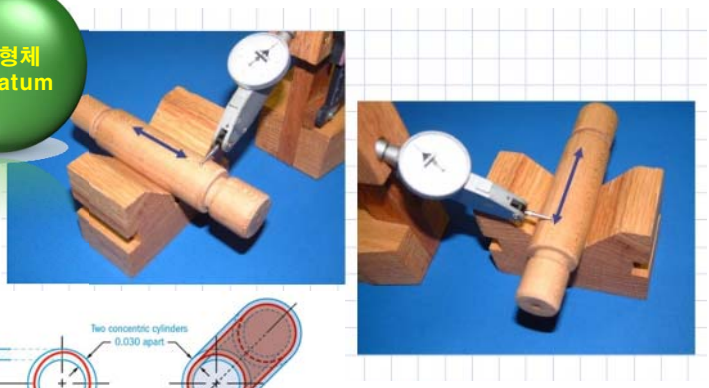
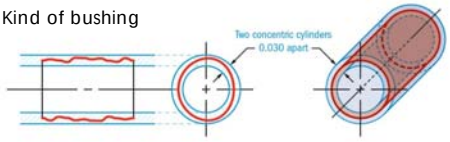
GD&T 활용

• 형상공차(Tolerance of form) – 원통도 (Cylindricity)



Kind of bushing



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https://www.gdandtbasics.com/?s=++cylindricity

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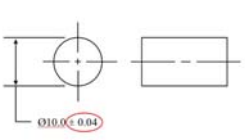
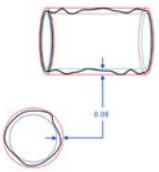
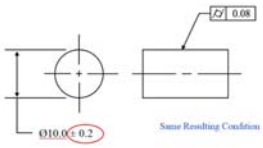
GD&T 활용

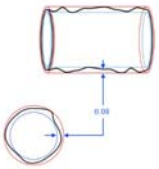
• 형상공차(Tolerance of form) – 원통도 (Cylindricity)





VS





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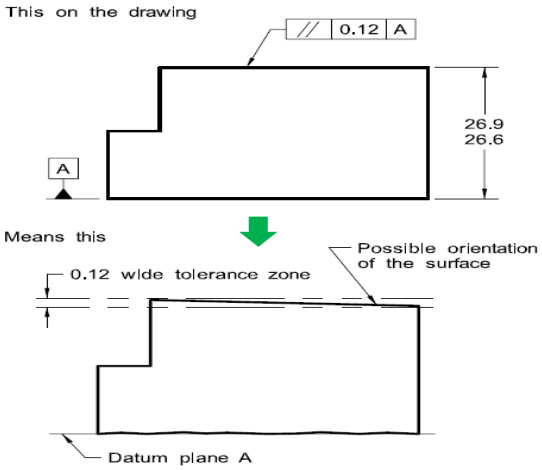
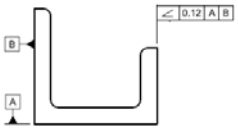
GD&T 활용

- 자세공차(Tolerance of Orientation) – 평행도(parallelism)





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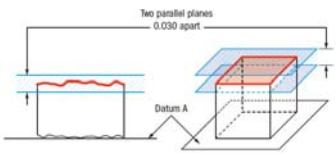

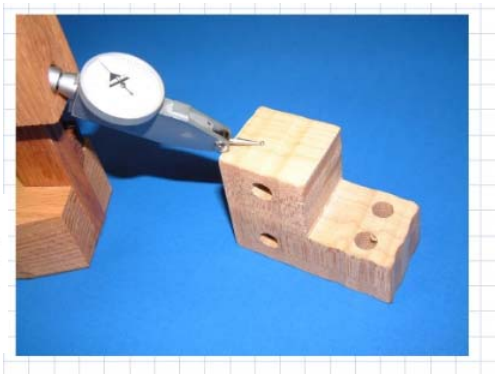

출처: http://www.slideshare.net/Pinnacleconsultancy/gdt-13337846

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GD&T 활용

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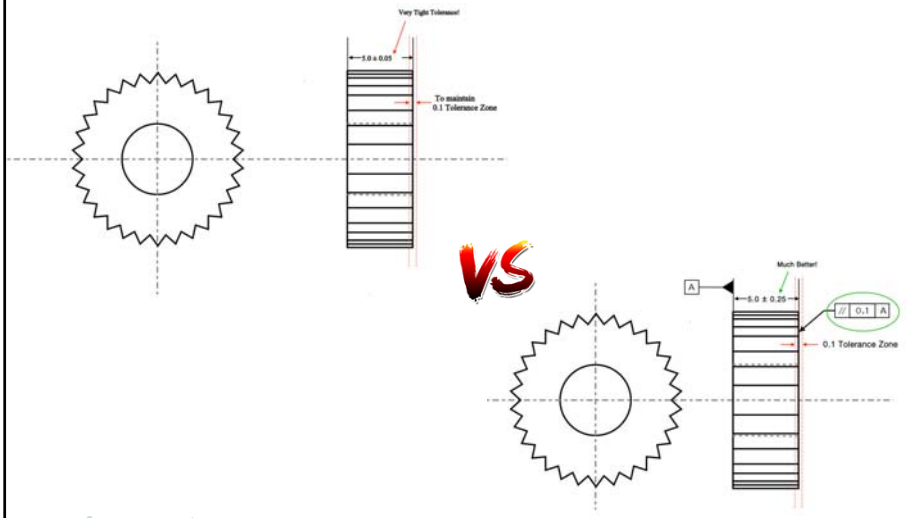

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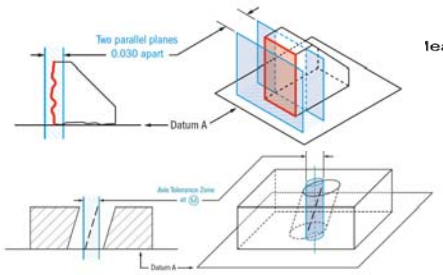
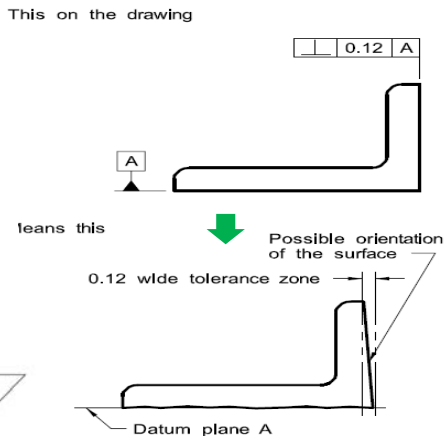
GD&T 활용

- 자세공차(Tolerance of Orientation) – 직각도(Perpendicularity)





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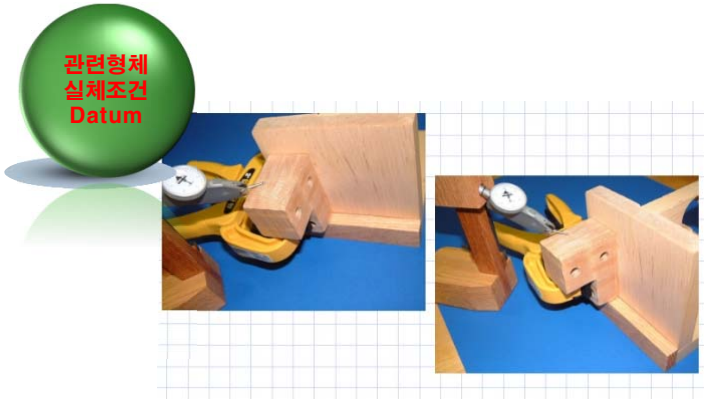

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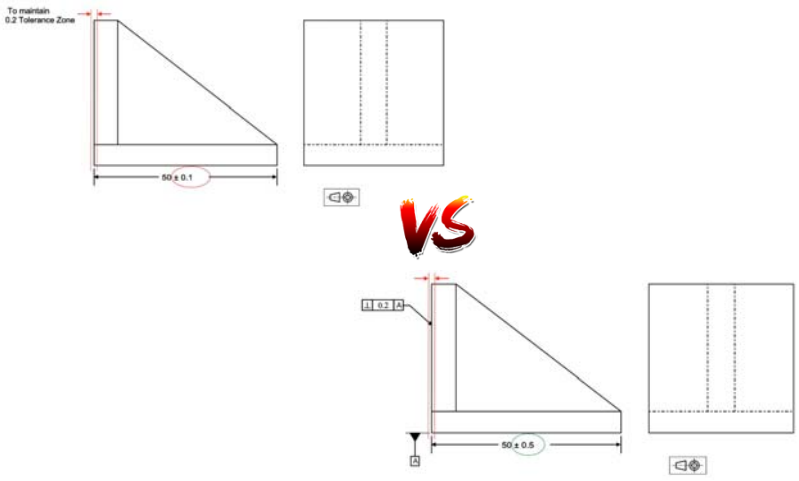

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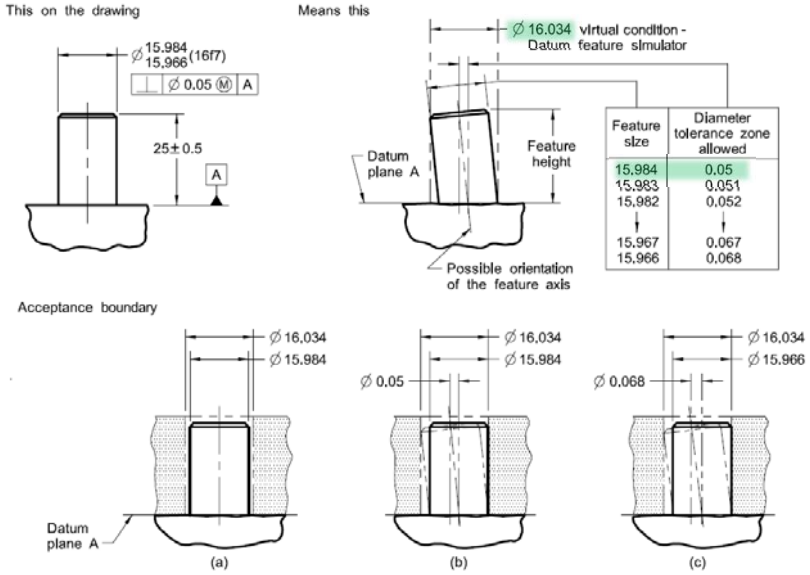
- 축 f의 윗치수 허용차: 0.016mm ➔ ϕ16의 IT7등급의 기본공차 : 0.018mm
  ➔ 결과적인 가공치수 ; -0.016~-0.034mm



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IT공차 등급

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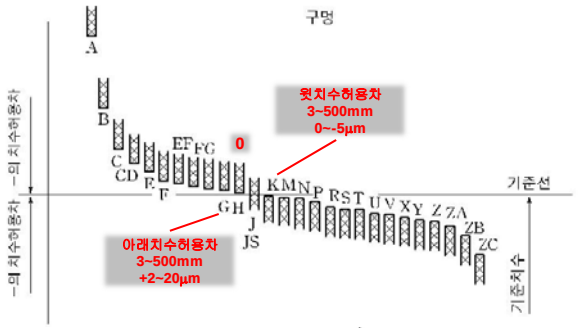

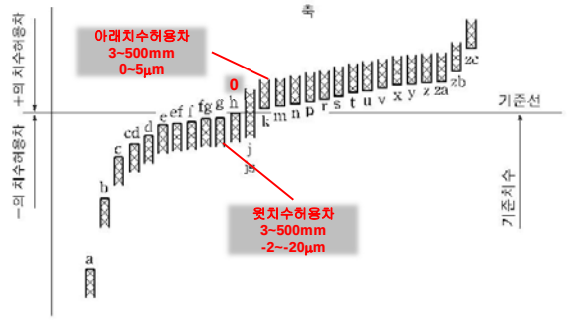

- IT 공차위치는 구멍의 경우 A부터 ZC까지 영문자 대문자, 축은 a부터 zc까지 소문자로 나타내며, A~G 구멍은 (+)공차, a~g축은 (-)공차, H 구멍과 h축은 0, M~ZC 구멍과 m~zc 축은 각각 (-)공차, (+)공차를 가진다.

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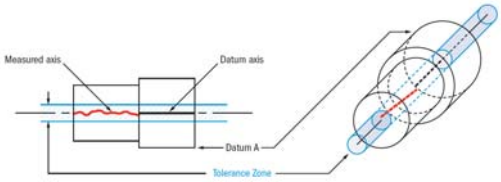
GD&T 활용

- 형상공차(Tolerance of form) – 동심도 (Concentricity)



출처: http://www.slideshare.net/Pinnacleconsultancy/gdt-13337846

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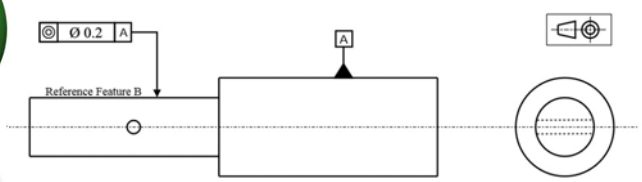
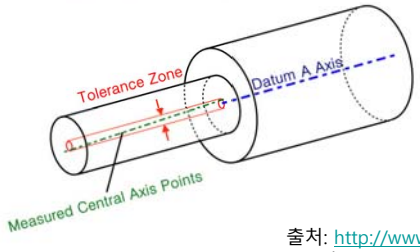
GD&T 활용

• 형상공차(Tolerance of form) – 동심도 (Concentricity)





Avoid Concentricity!!!

- ✓ **A good replacement for concentricity is runout**

출처: http://www.slideshare.net/Pinnacleconsultancy/gdt-13337846
https://www.gdandtbasics.com/concentricity/

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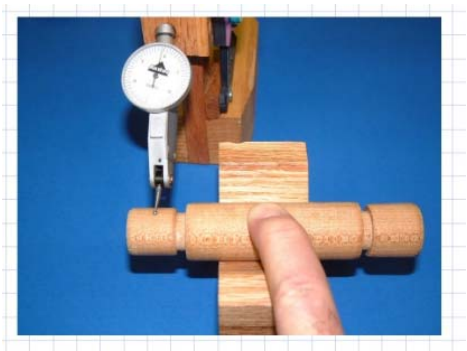
GD&T 활용

• 형상공차(Tolerance of form) – 흔들림 (Circular Runout)



출처: http://www.slideshare.net/Pinnacleconsultancy/gdt-13337846
https://www.gdandtbasics.com/runout/

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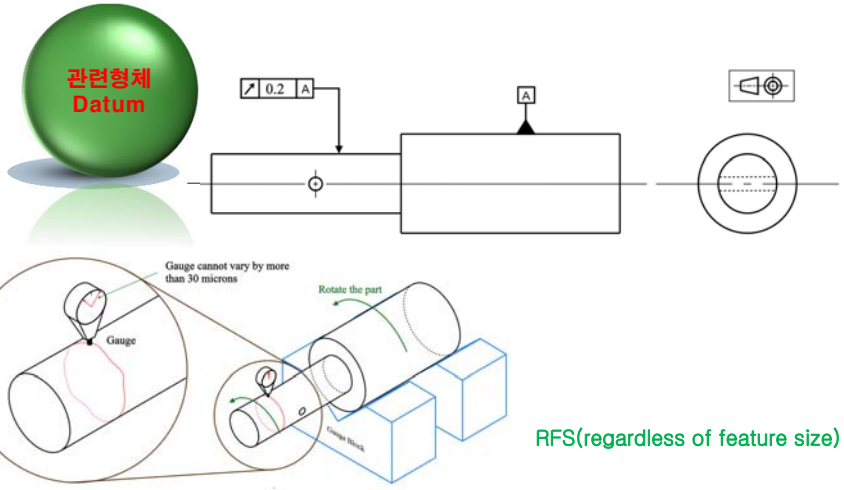
GD&T 활용

• 형상공차(Tolerance of form) – 흔들림 (Circular Runout)



RFS(regardless of feature size)

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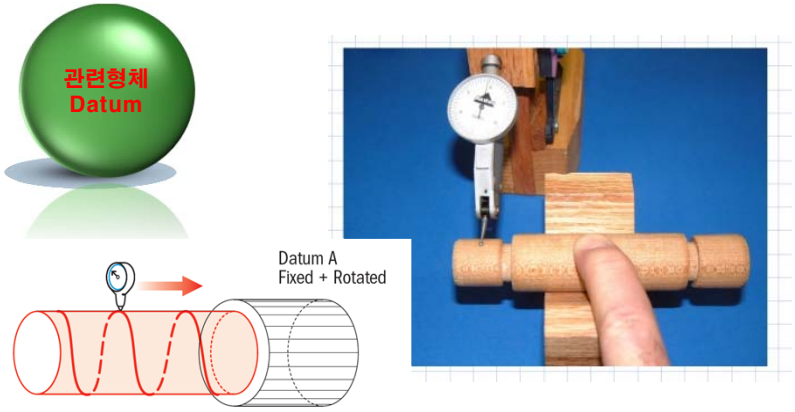
GD&T 활용

• 형상공차(Tolerance of form) – 흔들림 (Total Runout)



출처: http://www.slideshare.net/Pinnacleconsultancy/gdt-13337846
https://www.gdandtbasics.com/runout/

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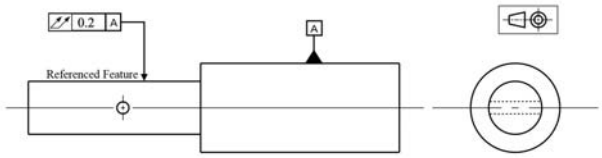
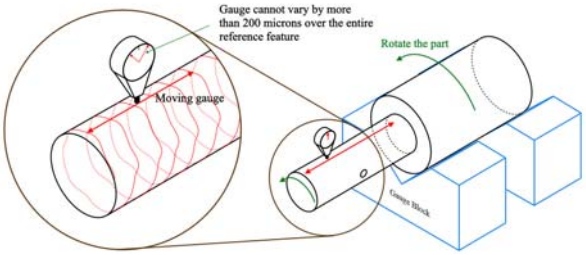
GD&T 활용

• 형상공차(Tolerance of form) – 흔들림 (Total Runout)





RFS(regardless of feature size)

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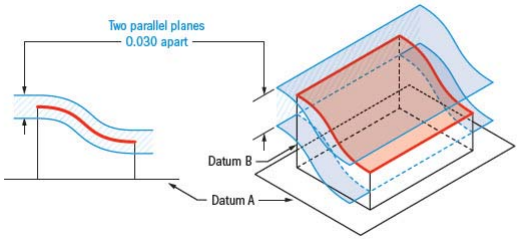
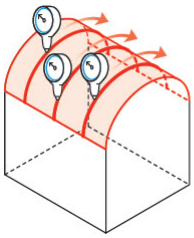
GD&T 활용

• 형상공차(Tolerance of form) – 윤곽도 (Profile of a Surface)





Gauge must follow true profile.

Profile is usually measured with a CMM.

RFS(regardless of feature size)

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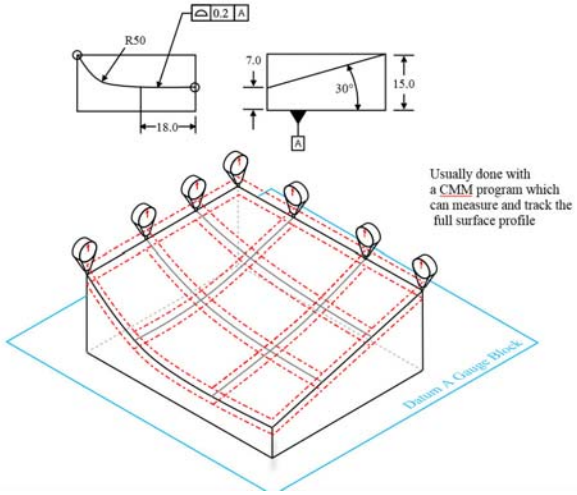
GD&T 활용

• 형상공차(Tolerance of form) – 윤곽도 (Profile of a Surface)



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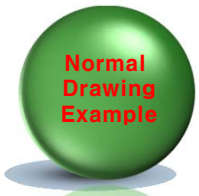
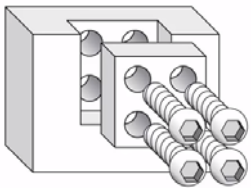
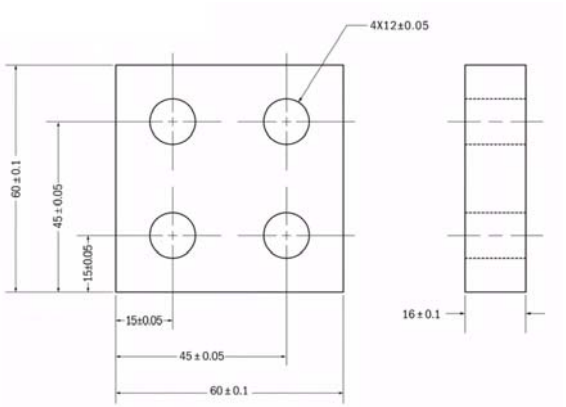
GD&T 활용

• 위치공차(Tolerance of Location) – 위치공차(Position Tolerance)







출처: https://www.gdandtbasics.com/true-position/

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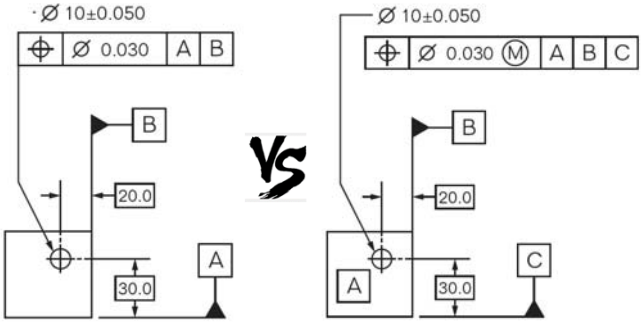
GD&T 활용

- 위치공차(Tolerance of Location) – 위치공차(Position Tolerance)



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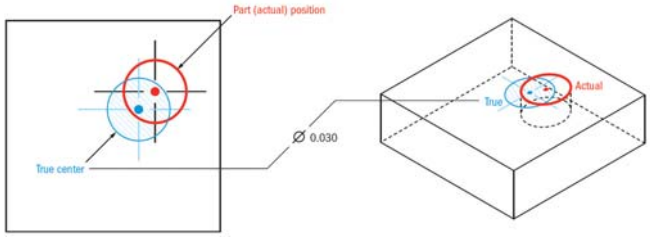
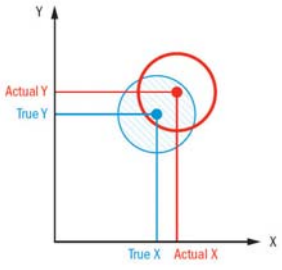
GD&T 활용

- 위치공차(Tolerance of Location) – 위치공차(Position Tolerance)





Measure X and Y location
and compare to the true position.

$$2 \cdot \sqrt{(\text{Actual X} - \text{True X})^2 + (\text{Actual Y} - \text{True Y})^2}$$

This formula must be less than
the ⌀ True Position tolerance

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GD&T 활용

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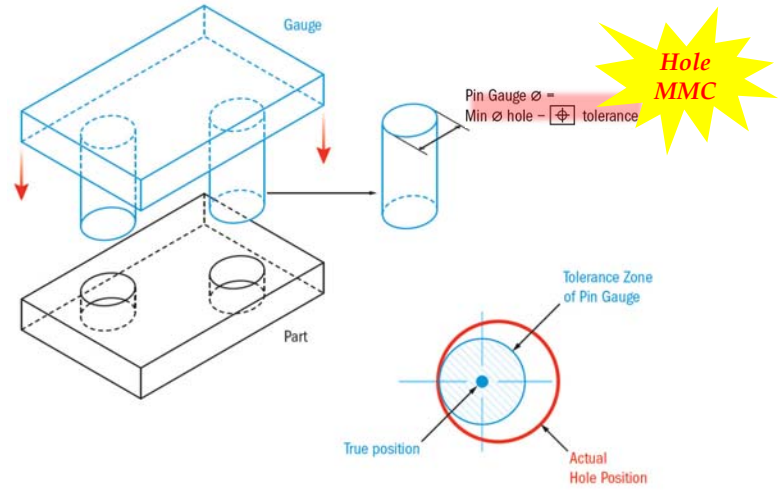

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GD&T 활용

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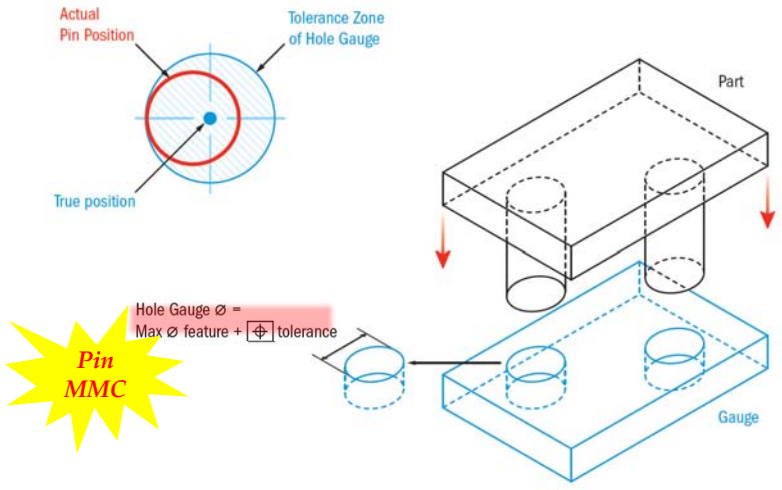

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GD&T 활용

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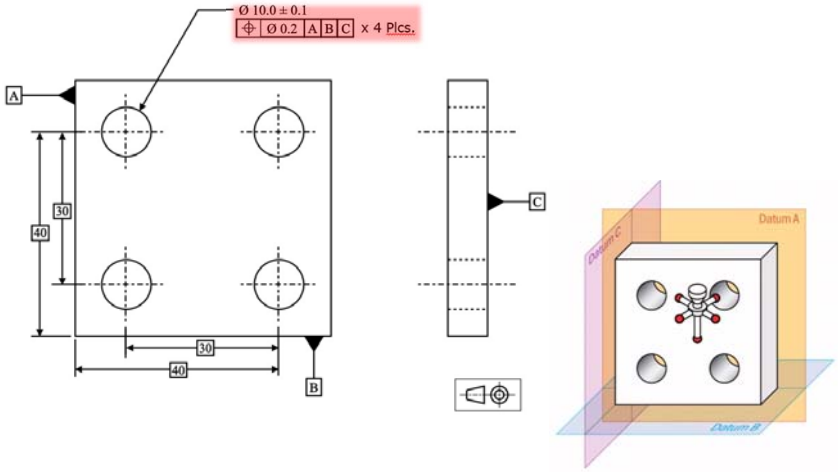

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GD&T 활용

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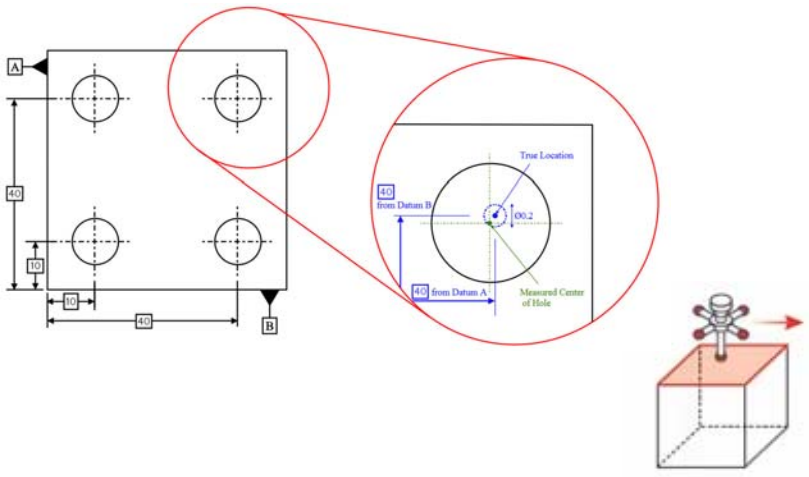

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GD&T 활용

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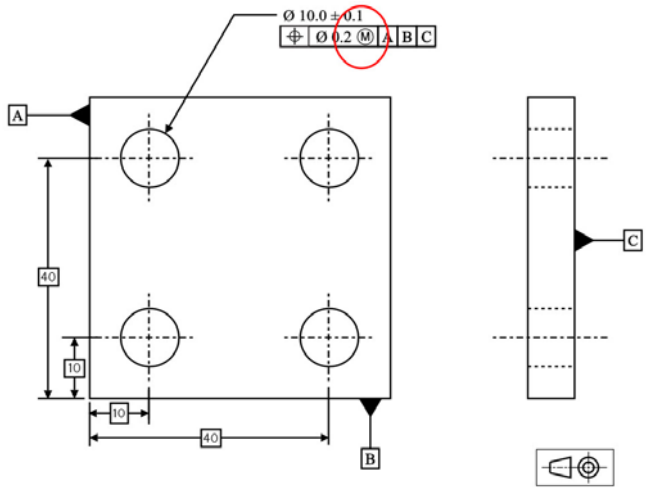

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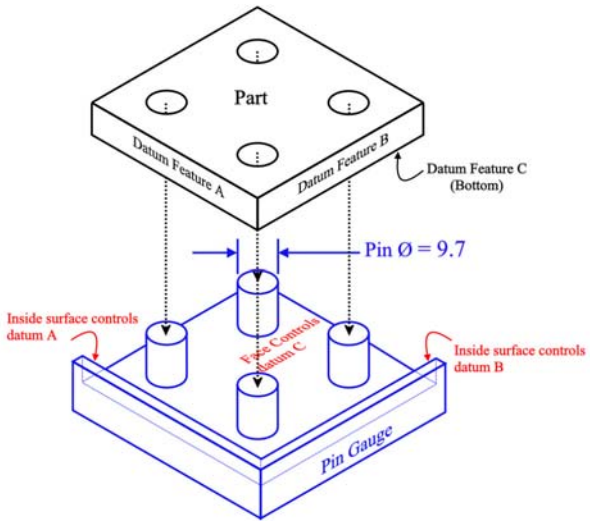
GD&T 활용

- 위치공차(Tolerance of Location) – 위치공차(Position Tolerance)



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GD&T 활용

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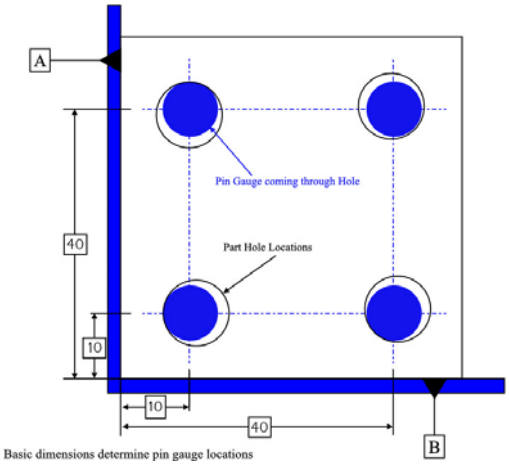

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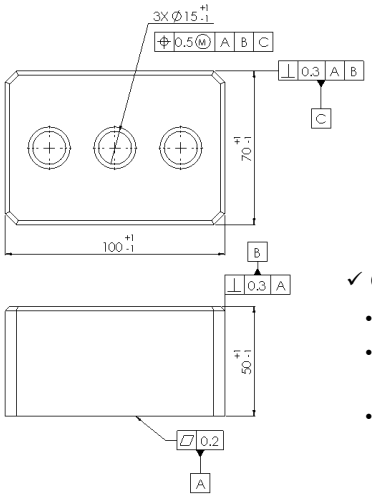
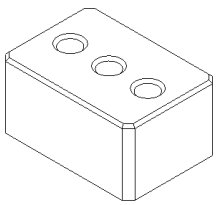
GD&T 활용

• 위치공차(Tolerance of Location) 정리





✓ GD&T Decoding

- FOS: 6개(홀, 너비, 폭, 높이) : 측정 대상
- 데이텀: 3개(편평도 1, 직각도 2)

➔ 실용데이텀(Datum Simulator) 사용 부품 구속

- 연관(조립) 기하공차: 3개의 홀 (위치공차)

➔ True Position, 최대실체조건 ($\phi 15-1=\phi 14$)

➔ 멀티플러그 게이지 사용 검사

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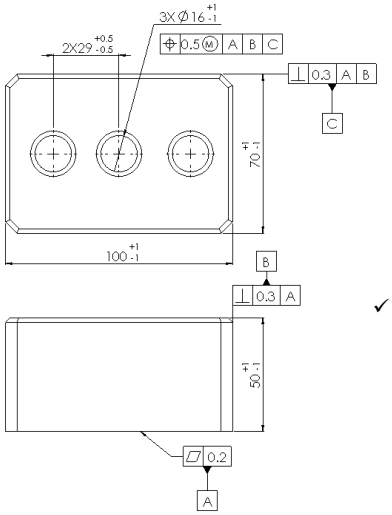
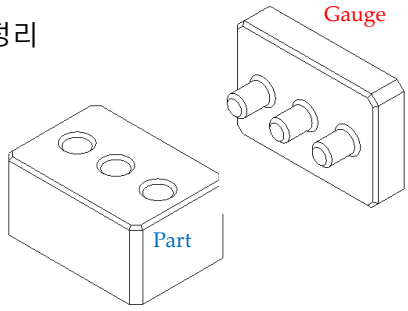
GD&T 활용

• 위치공차(Tolerance of Location) 정리





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  - ➔ 실용데이텀(Datum Simulator) 사용 부품 구속
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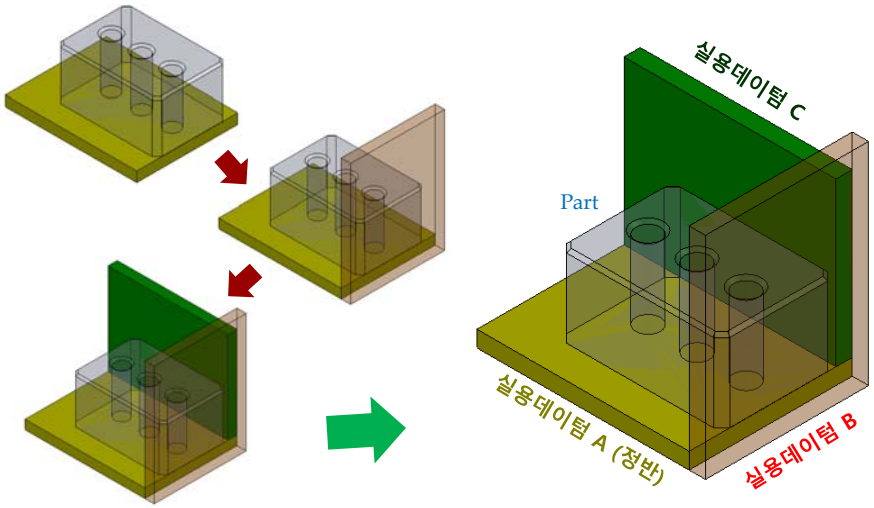
GD&T 활용

• 위치공차(Tolerance of Location) 정리



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GD&T 활용

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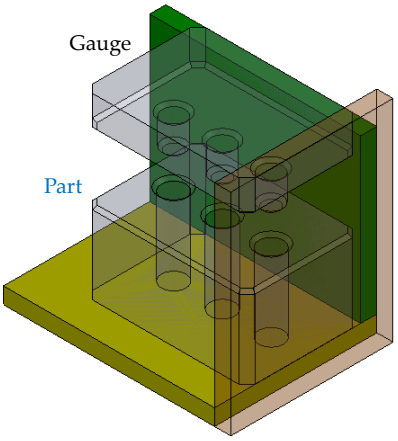

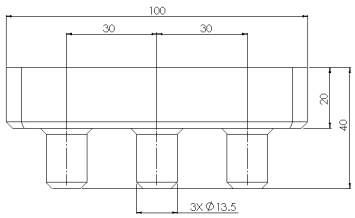

✓ Gauge는 검사용으로 정밀하게 가공
➔ 상하수직운동 정밀도 확보

✓ 핀(플러그) 직경은 최대실체조건을 고려하여 ϕ15(공칭치수) – ϕ1(치수공차) – ϕ0.5(기하공차) = ϕ13.5로 제작 (Virtual Condition, 가상조건)

✓ 측정오차는 어쩔 수 없음...
➔ 보너스공차로 어느 정도 상쇄

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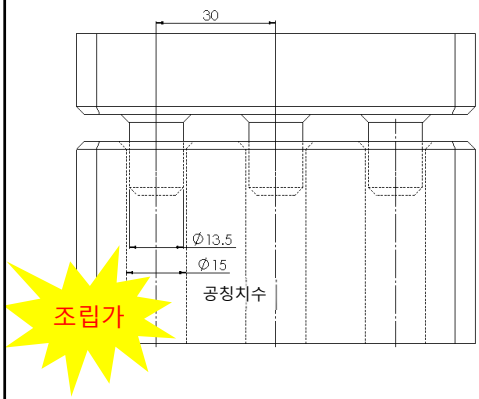
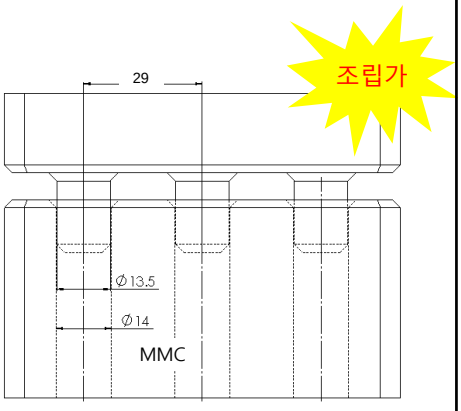
GD&T 활용

- 위치공차(Tolerance of Location) 정리





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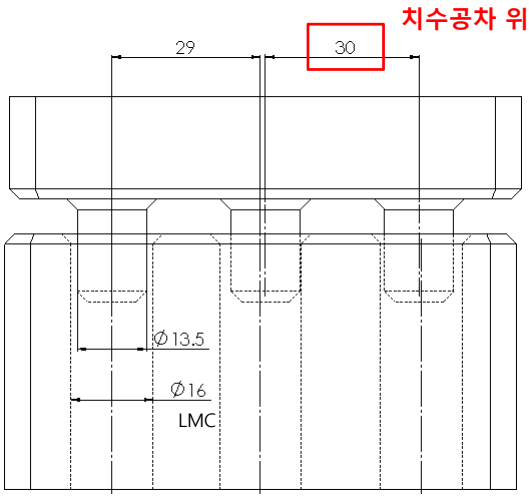
- 위치공차(Tolerance of Location) 정리



✓ 홀 간의 간격이 치수공차를 위반하였으나 보너스 공차로 인해 조립 가능

✓ 불량으로 판단될 제품이 양품으로 변경되어 수율 향상

✓ 제조비용 감소와 제작자의 부담 경감

✓ 측정오차의 상쇄효과 등을 가져옴

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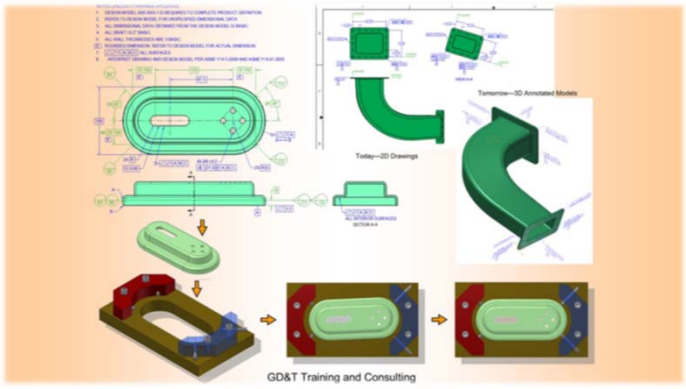

More Examples

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MBD & Costing

SOLIDWORKS MBD

Integrated Communication of PMI

- Capture 3D View — 3D Views
- Model Break View — Model Break View
- Dynamic Annotation Views — Dynamic Annotation Views
- Publish to 3D PDF — Publish to 3D PDF
- 3D PDF Template Editor — 3D PDF Template Editor

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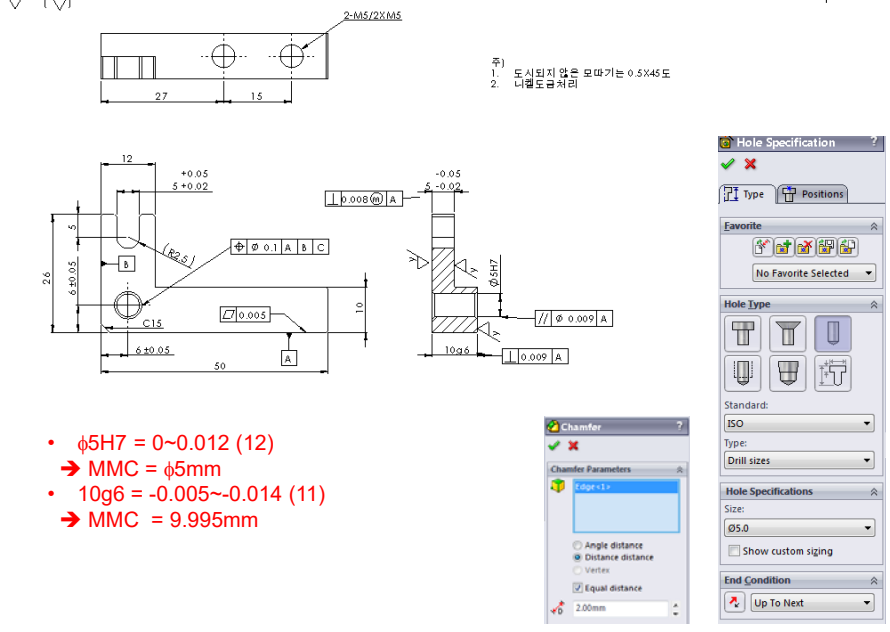
핑거 - 243p



- ϕ5H7 = 0~0.012 (12)
  ➔ MMC = ϕ5mm
- 10g6 = -0.005~-0.014 (11)
  ➔ MMC = 9.995mm

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KS B 0204

공칭 (D)	스레드.	볼트 직경			볼트 머리	볼트 너트	
크기	피치	주요 (D) 최대 - 최소	마이너 (D_3) 최대 - 최소	피치 직경 (D_2) 최대 - 최소	두께운 (ZB)	액세서리 / 연립 (A / F) 최대 - 최소	액세서리. / 옥수수 (A / C)
M3	0.5	2980 - 2874	2,439 -2,272	2655 - 2580	2125	5,50 - 5,38	6,40
M4	0,7	3978 - 3838	3220 - 3002	3523 - 3433	2925	7,00 - 6,85	8,10
M5	0.8	4976 - 4826	3869 - 4110	4456 - 4361	3650	8,00 - 7,85	9,20
M6	1,0	5974 - 5794	4891 - 4596	5324 - 5212	4150	10,00 - 9,78	11,50
M8	1,25	7972 - 7760	6272 - 6619	7160 - 7042	5650	13,00 - 12,73	15,00
M10	1,5	9968 - 9732	8344 - 7938	8994 - 8862	7180	17,00 - 16,73	19,60
M12	1,75	11966 - 11701	10072 - 9601	10829 - 10679	8180	19,00 - 18,67	22,10
M16	2,0	15962 - 15682	13797 - 13271	14663 - 14503	10180	24,00 - 23,67	27,70
M20	2,5	19958 - 19623	17252 - 16624	18334 - 18164	13215	30,00 - 29,67	34,60
M24	3,0	23952 - 23577	20701 - 19955	22003 - 21803	15215	36,00 - 35,58	41,60
M30	3,50	29947 - 29522	26158 - 25306	27674 - 27462	19260	46,00 - 45,38	53,1
M36	4,00	35940 - 35465	31610 - 30654	33342 - 33118	23260	55,00 - 54,26	63,5

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IT공차 등급

IT01부터 ~ IT18까지 20등급으로 구분합니다. (KS B 0401)

단위 μm : 0.001mm

기준 치수 (mm)		IT 공차등급																		
		01	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
초과	이하	기본 공차의 수치(μm)													기본 공차의 수치(μm)						
-	3	0.3	0.5	0.8	1.2	2	3	4	6	10	14	25	40	60	0.10	0.14	0.26	0.40	0.60	1.00	1.40
3	6	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	0.12	0.18	0.30	0.48	0.75	1.20	1.80
6	10	0.4	0.6	1	1.5	2.5	4	6	9	15	22	36	58	90	0.15	0.22	0.36	0.58	0.90	1.50	2.20
10	18	0.5	0.8	1.2	2	3	5	8	11	18	27	43	70	110	0.18	0.27	0.43	0.70	1.10	1.80	2.70
18	30	0.6	1.0	1.5	2.5	4	6	9	13	21	33	52	84	130	0.21	0.33	0.52	0.84	1.30	2.10	3.30
30	50	0.6	1.0	1.5	2.5	4	7	11	16	25	39	62	100	160	0.25	0.39	0.62	1.00	1.60	2.50	3.90
50	80	0.8	1.2	2	3	5	8	13	19	30	46	74	120	190	0.30	0.46	0.74	1.20	1.90	3.00	4.60
80	120	1.0	1.5	2.5	4	6	10	15	22	35	54	87	140	220	0.35	0.54	0.87	1.40	2.20	3.50	5.40
120	180	1.2	2.0	3.5	5	8	12	18	25	40	63	100	160	250	0.40	0.63	1.00	1.60	2.50	4.00	6.30
180	250	2.0	3.0	4.5	7	10	14	20	29	46	72	115	185	290	0.46	0.72	1.15	1.85	2.90	4.60	7.60
250	315	2.5	4.0	6	8	12	16	23	32	52	81	130	210	320	0.52	0.81	1.30	2.10	3.20	5.20	8.10
315	400	3.0	5.0	7	9	13	18	25	36	57	89	140	230	360	0.57	0.89	1.40	2.30	3.60	5.70	8.90

$i=0.45\times\sqrt[3]{D}+0.001\times D(\mu m)$ · · · · · · · 500mm이하의 경우

단, D : 각 치수구분의 양쪽 한계치수 D1, D2의 기하평균값

$D=\sqrt{D_1\times D_2}$

IT 공차 등급과 단위수

공 차 등 급	IT 5	IT 6	IT 7	IT 8	IT 9	IT 10
공차단위의 수	7	10	16	25	40	64

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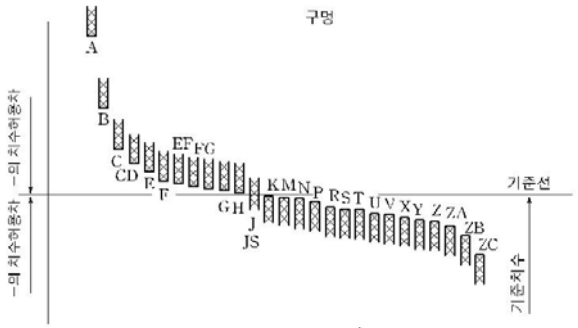

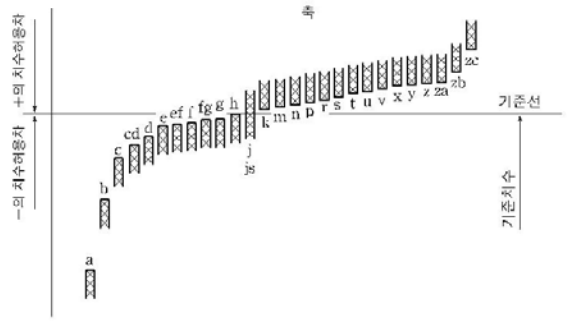

- IT 공차위치는 구멍의 경우 A부터 ZC까지 영문자 대문자, 축은 a부터 zc까지 소문자로 나타내며, A~G 구멍은 (+)공차, a~g축은 (-)공차, H 구멍과 h축은 0, M~ZC 구멍과 m~zc 축은 각각 (-)공차, (+)공차를 가진다.

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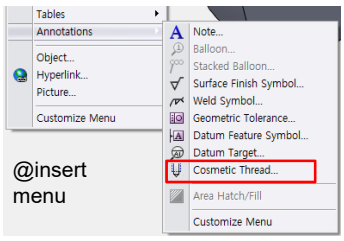

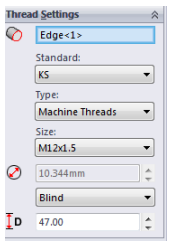

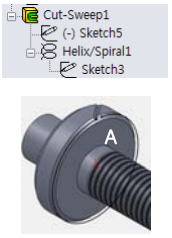

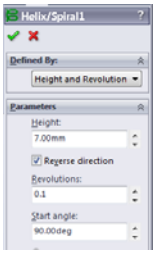

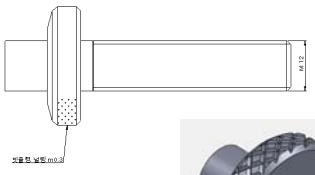

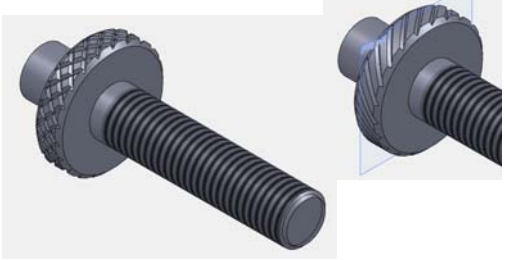

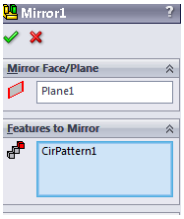

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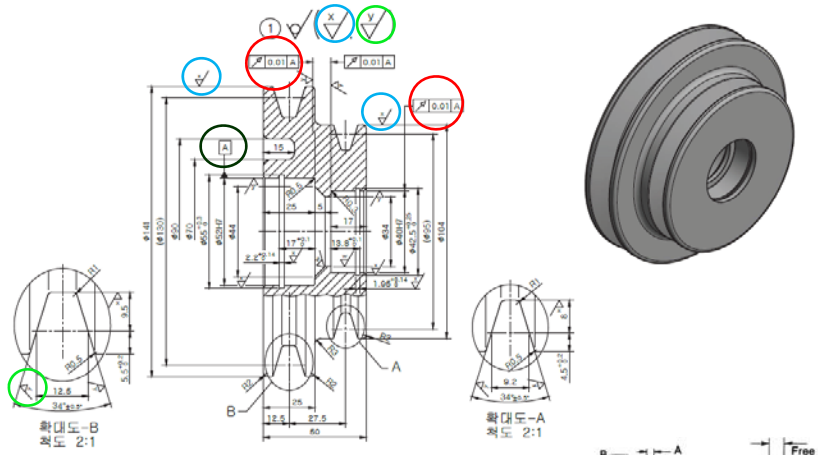
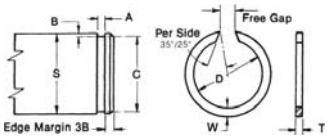
- w: 25~100
- x: 6.3~25
- y: 0.8~6.3
- Z: 0.1~0.8

V Belt Pulley





주 석 ▶ 도시되고 지시하지 않은 모따기 1X45°

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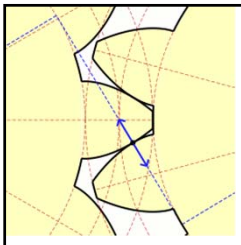
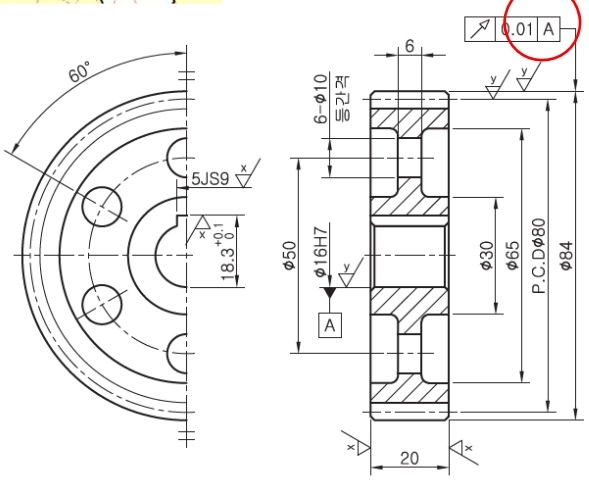
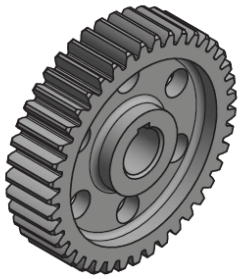
Spur Gear



③ $\sqrt{y}$ ($\sqrt{y}$ x , $\sqrt{y}$)

주) 기어 치부 열처리 HRC50±2

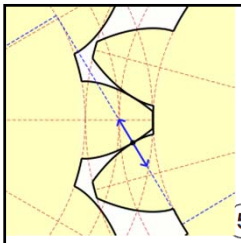




스 퍼 기 어		
기어치형		표준
공 구	치형	보통이
	모듈	2
	압력각	20°
잇수		41
피치원지름		□84
전체이높이		4.5
다듬질방법		호브절삭
정밀도		KS B ISO 1328-1,4급

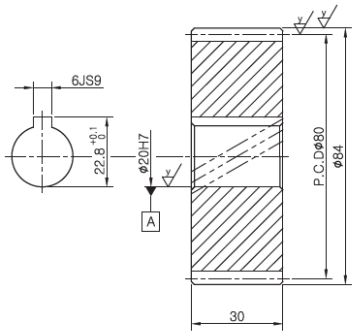
= PCD/m = 40
= PCD = 80
= 2.25Xm

Helical Gear



5 x y

주. 전체열처리 HRC 50 ±2



헬 리 컬 기 어		
기어치형		표준
치형기준단면		치직각
공구	치형	보통이
	모듈	2
	압력각	20°
비틀림 각		30°
비틀림 방향		우
잇수		40
피치원지름		□80
전체이높이		4.5
다듬질방법		호 브 절 삭
정밀도		KS B ISO 1328-1,3급

주 석 ▶ 도시되고 지시하지 않은 모따기 1X45 °