

FoDAMI

FORO DOCENTE DEL AREA MECANICA DE LAS INGENIERIAS



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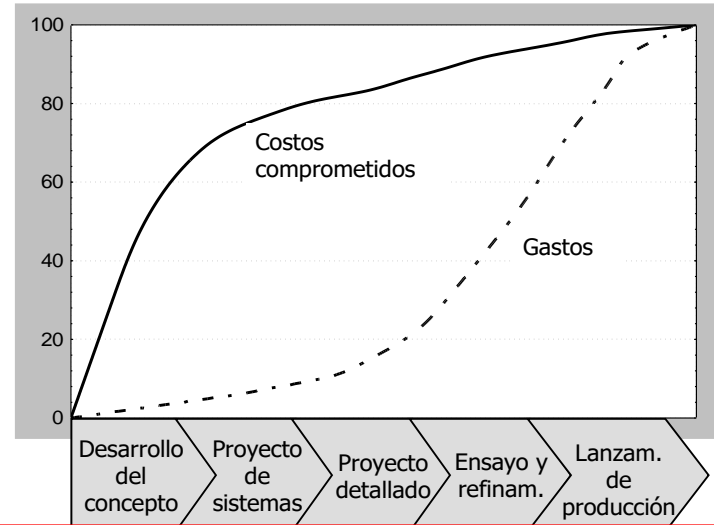
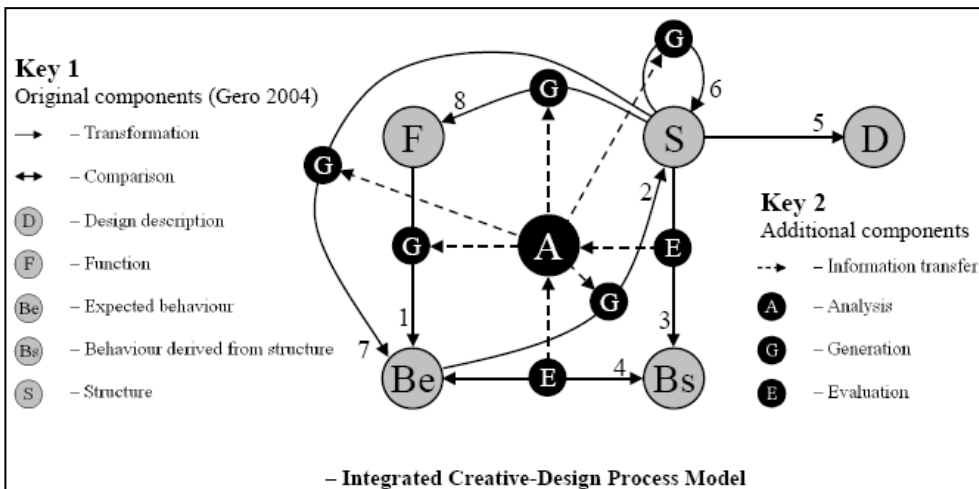
XXXIV REUNIÓN ACADÉMICO CIENTÍFICA DEL Fo.D.A.M.I.

19 Y 20 DE MAYO ESCUELA SUPERIOR
TÉCNICA DEL EJERCITO
“Gral.Div. Manuel Nicolás Savio”

**Complejidades e Incertidumbres asociadas al
diseño de Uniones Roscadas. Optimización
aplicando la normativa VDI 2230**

UNIONES ROSCADAS EN EL PROCESO DE DISEÑO DE MÁQUINAS

VISIÓN HOLÍSTICA



En el pasado reciente, los diseñadores empleaban el 75% de su tiempo, en trabajar sobre el diseño de detalle del producto.

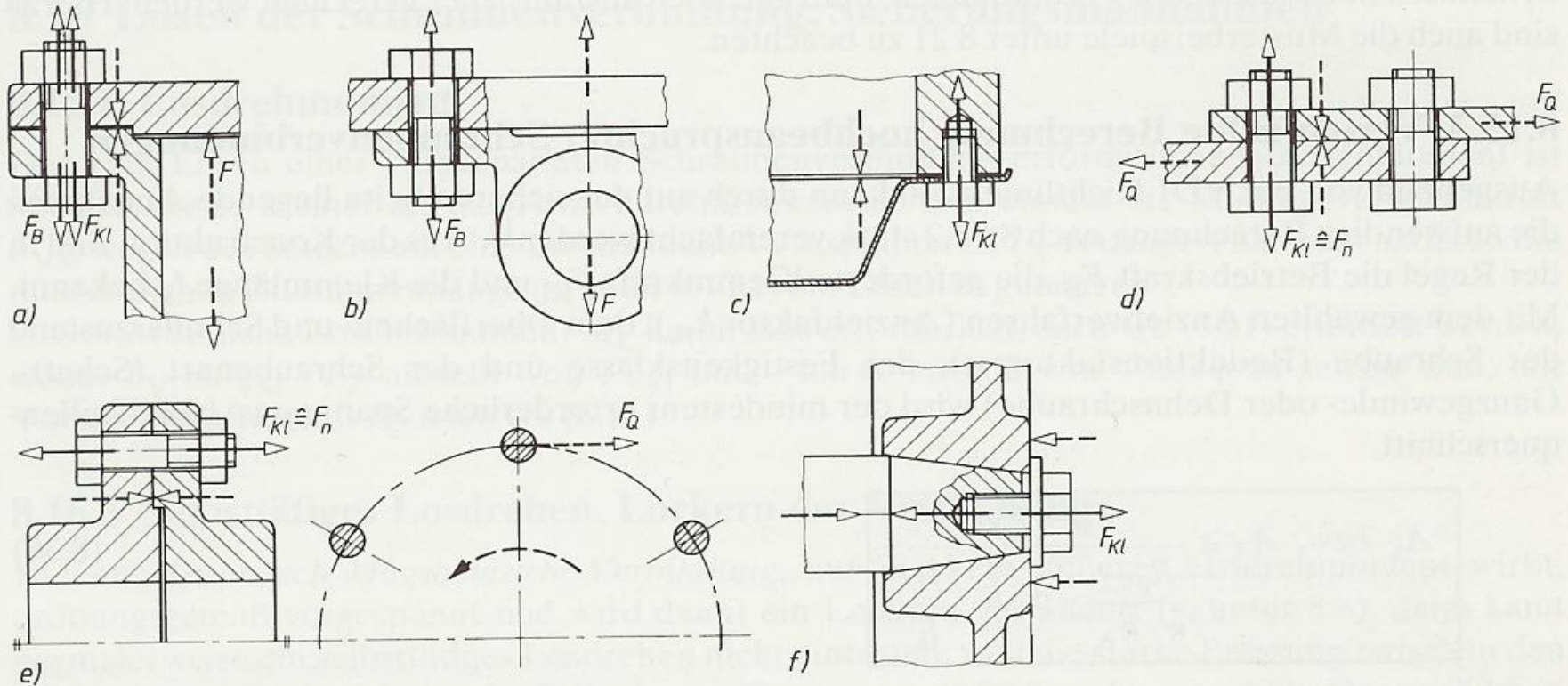
Actualmente emplean el 70% en desarrollar el concepto. No obstante muy buenos diseños, fallan por detalles.....Atención.....

En la Ingeniería de Detalle: Uniones Atornilladas vs Soldadas

Diseño Unión Roscada - Fases: Pre-diseño Procedimientos Clásicos – Optimización – Verificación Según Normativas. Enriquecer el proceso diseño inicial.....

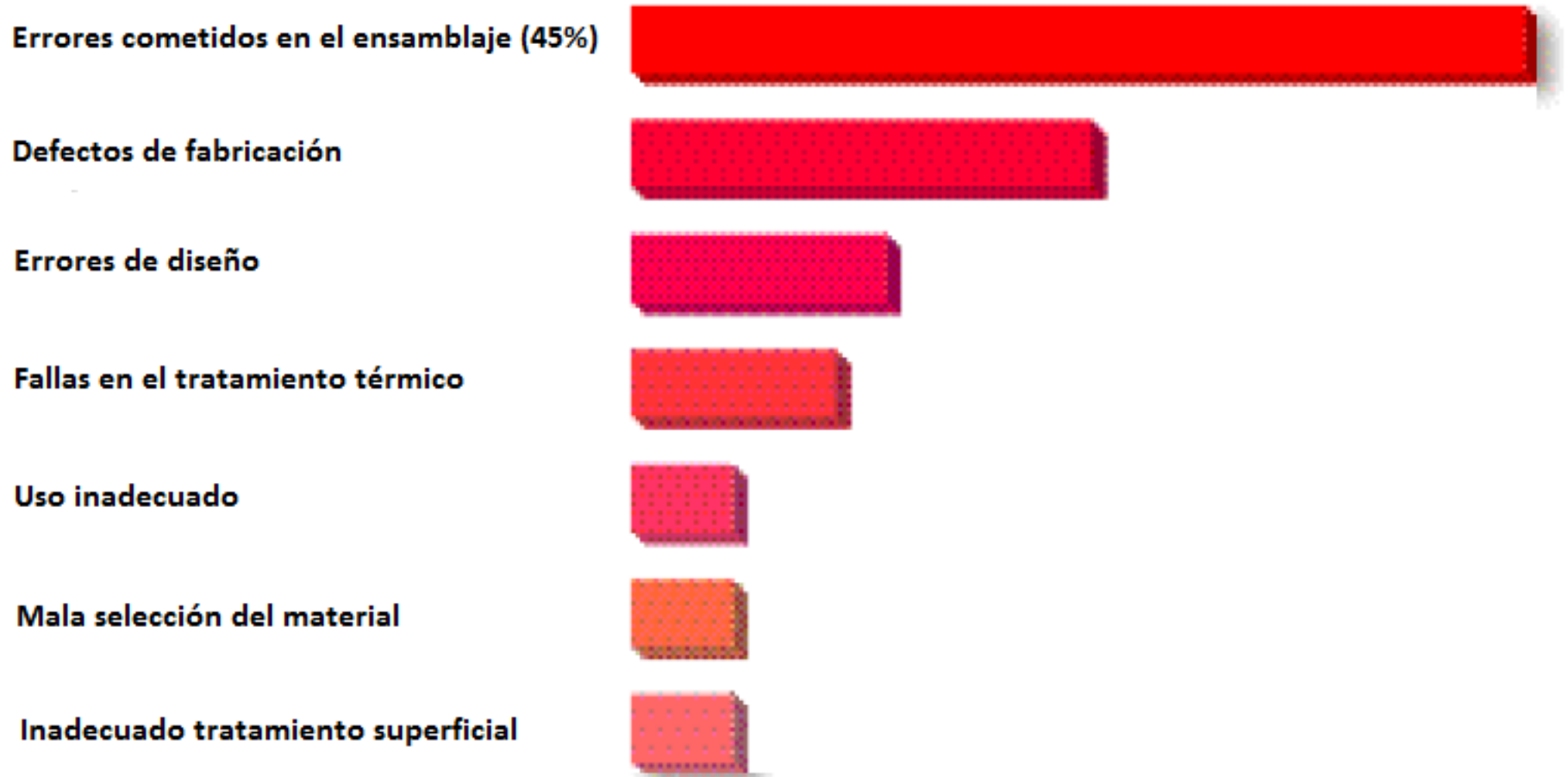
UNIONES ROSCADAS - ATORNILLADAS PRETENSADAS

EJEMPLOS



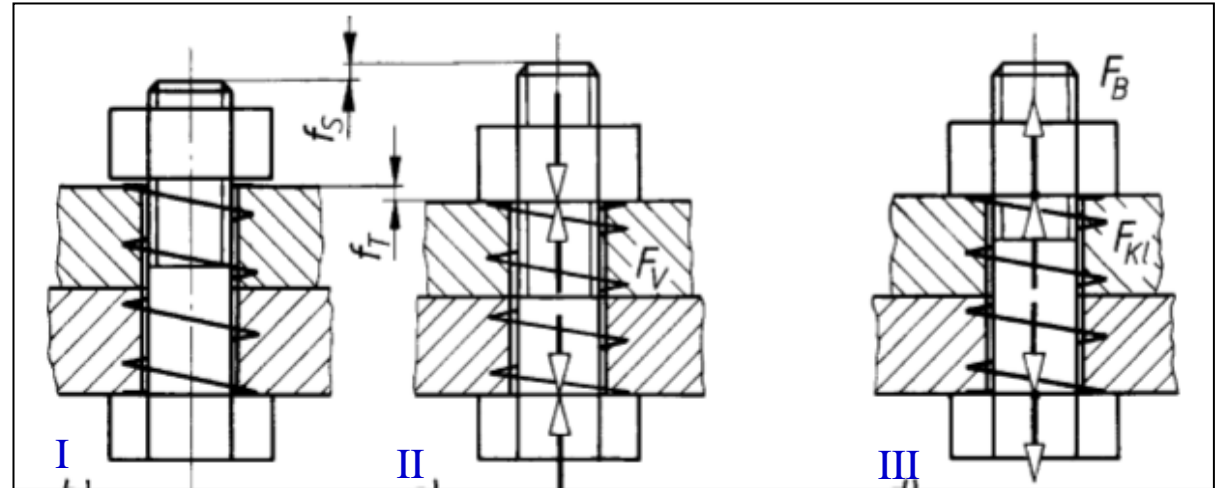
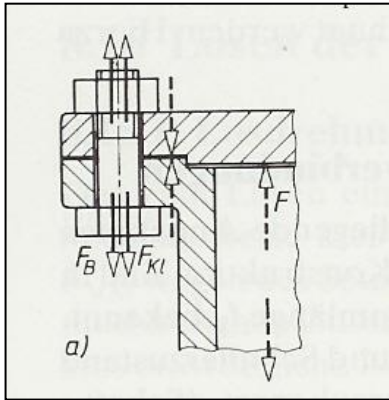
- Diversidad
- Complejidad ... Simplificaciones en la Ingeniería Básica
- Confiabilidad

Causas primarias de falla por fatiga de las uniones atornilladas



En una primer y generalizada simplificación.....

DIRECCIÓN DE CARGA Y EJE DEL TORNILLO COLINEALES Y COINCIDENTES CON EL BARICENTRO DE LOS ELEMENTOS A UNIR



SE PUEDEN OBSERVAR LAS TRES CONDICIONES DE UNA UNIÓN TÍPICA:

I) INICIAL SIN PRETENSIÓN.

II) CON PRETENSIÓN.

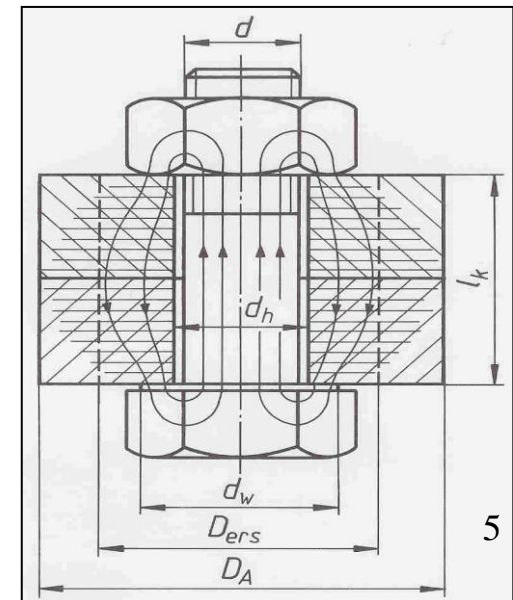
III) CON CARGA EXTERIOR.

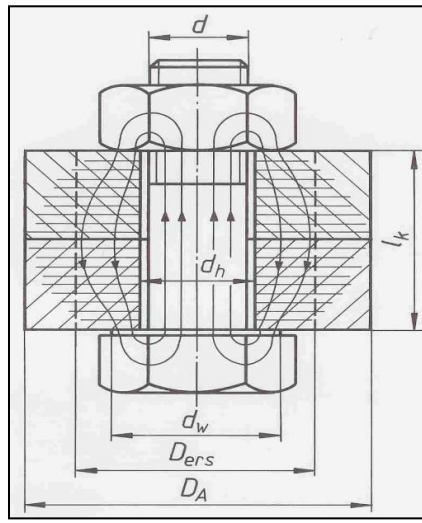
POR EFECTO DE LA FUERZA DE PRETENSIÓN “ F_v ”:

• TORNILLO: ALARGAMIENTO “ f_s ”.

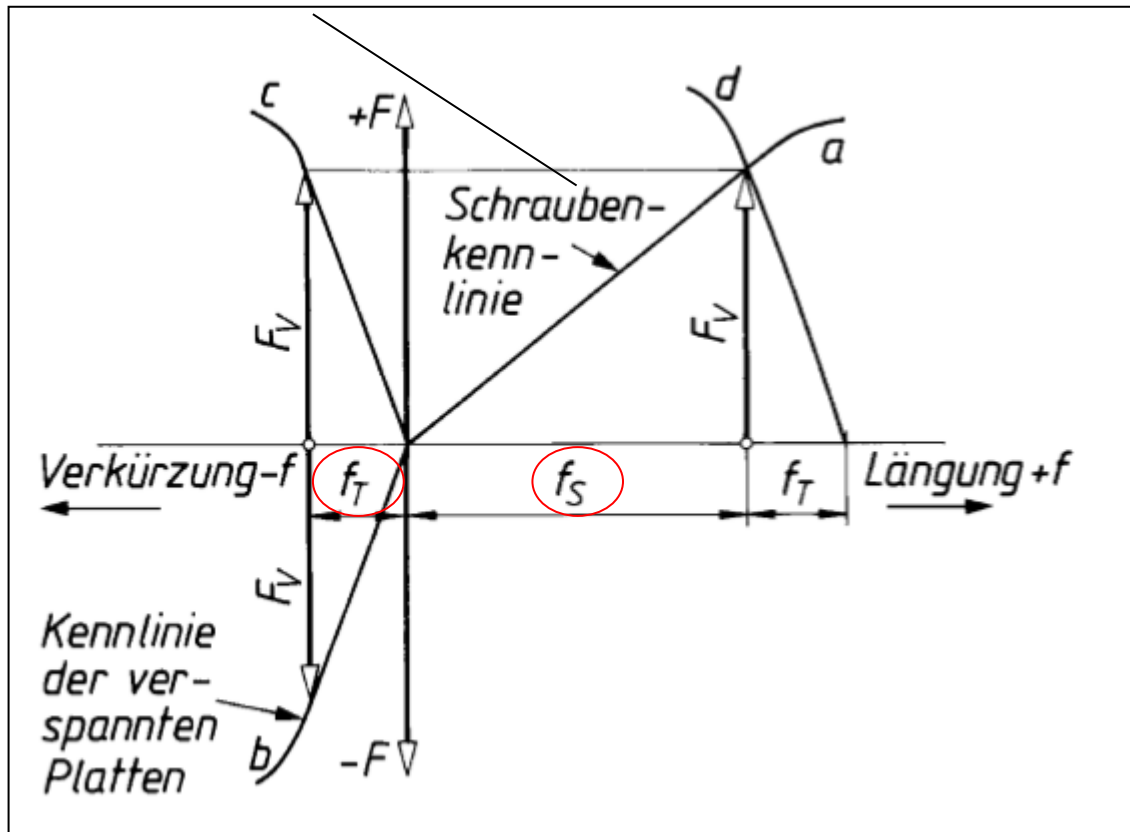
• JUNTA: ACORTAMIENTO “ f_t ”.

TORNILLO SOMETIDO A TRACCIÓN
ELEMENTOS A UNIR A COMPRESIÓN





Tornillo



Placas - Junta

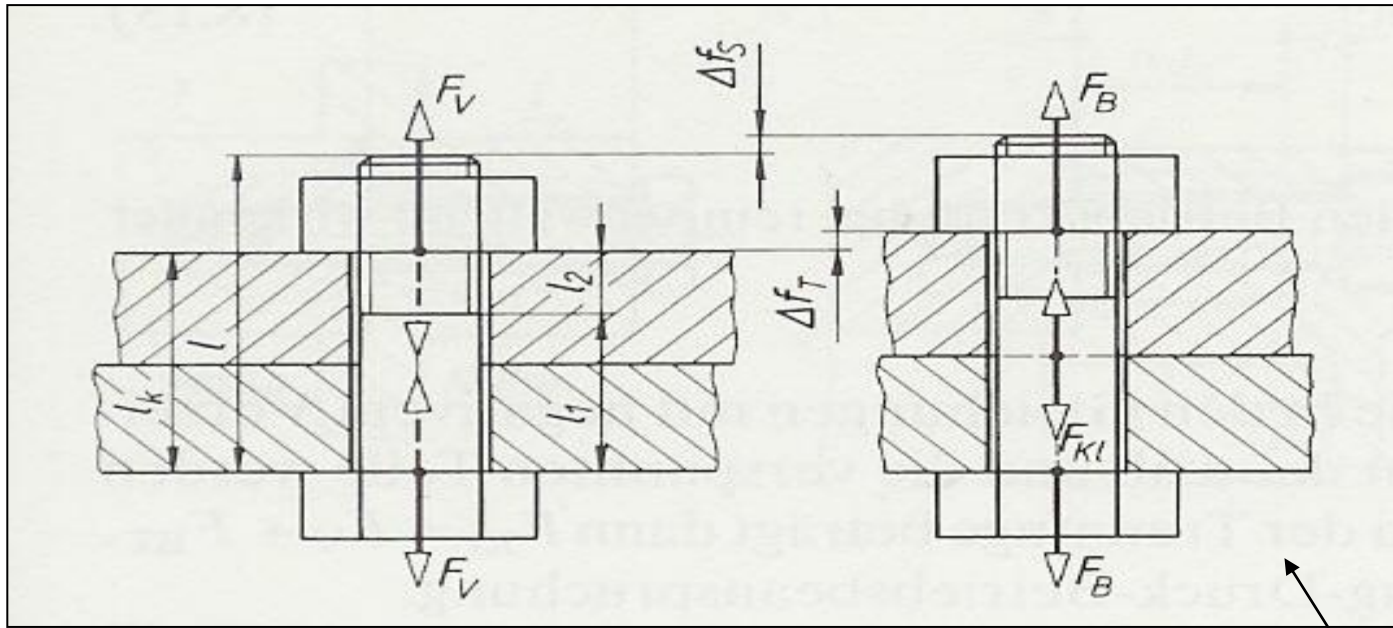
Elasticidad

$$f_S = \delta_S \cdot F_V$$

$$f_T = \delta_T \cdot F_V$$

Fuerza Pretensado

APLICANDO SOBRE LA UNIÓN PRETENSADA LA CARGA DE SERVICIO “ F_B ” TORNILLO Y JUNTA COMO DOS RESORTES EN PARALELO ELONGAN, EN LA MISMA MAGNITUD.

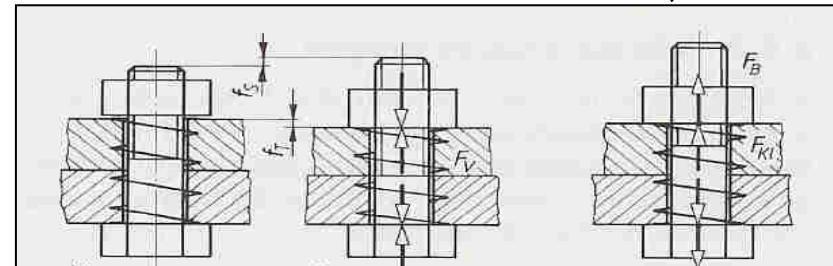


$$\Delta f_S = \Delta f_T = \Delta f$$

DEFORMACIONES DE LA JUNTA

POR EFECTO DE F_V : $-f_T$

POR EFECTO DE $F_V + F_B$: $-f_T + \Delta f_T$



SOLICITACIÓN EXTERNA VARIABLE

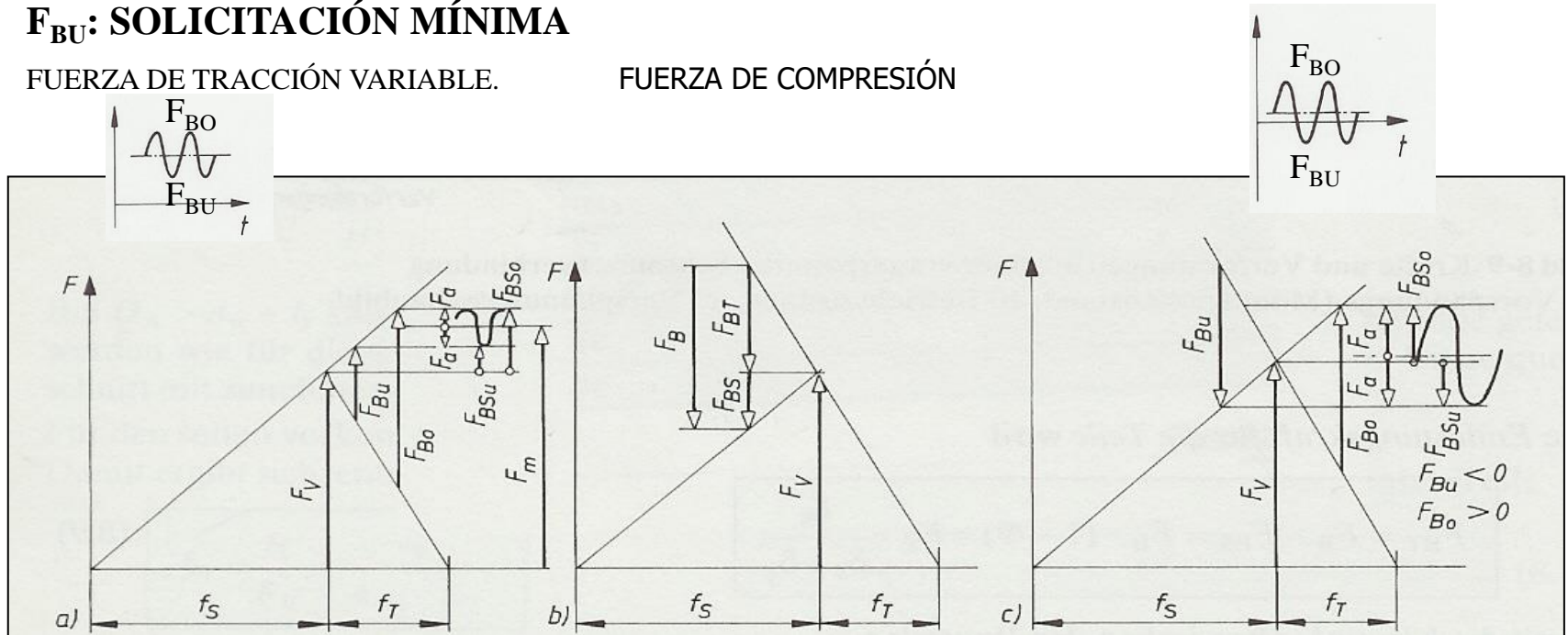
F_{BO} : SOLICITACIÓN MÁXIMA

F_{BU} : SOLICITACIÓN MÍNIMA

FUERZA DE TRACCIÓN VARIABLE.

FUERZA DE COMPRESIÓN

FUERZA ALTERNATIVA



FUERZA MEDIA SOBRE EL TORNILLO

$$F_m = F_v + \frac{F_{BO} + F_{BU}}{2} \Phi$$

AMPLITUD DE LA FUERZA VARIABLE

$$\pm F_a = \pm \frac{F_{BSO} - F_{BSU}}{2} = \frac{F_{Bo} - F_{Bu}}{2} \cdot \Phi$$

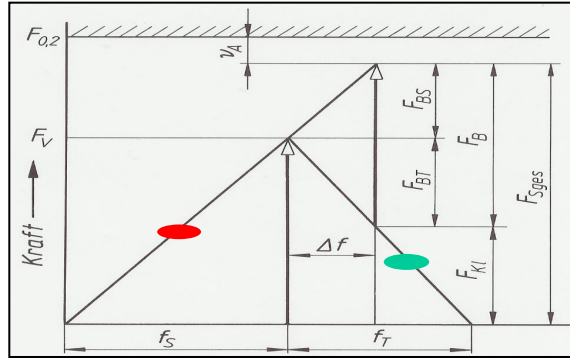
Bases para el dimensionamiento
 Goodman - Soderberg -
 Smith - Haig 9

Complejidades – Incertidumbres

$$F_S = F_V + \Phi \cdot F_B$$

$$F_{Kl} = F_V - (1 - \Phi) \cdot F_B$$

1) Factor de Junta



$$\Phi = \frac{\delta_T}{\delta_S + \delta_T}$$

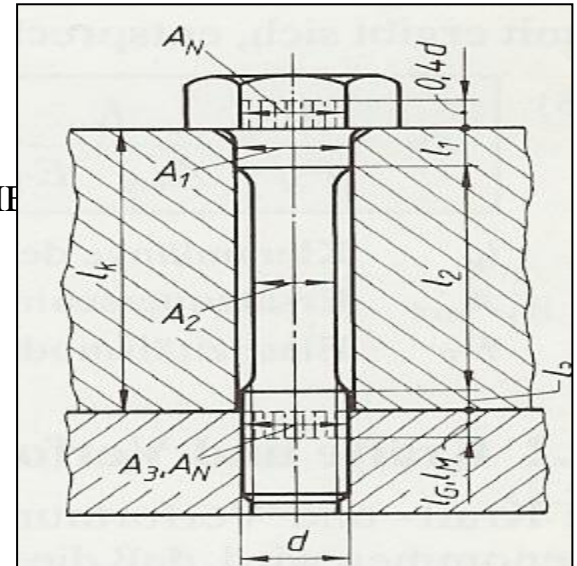
- ELASTICIDAD DEL TORNILLO

PARTES DEL TORNILLO CONSIDERADOS COMO RESORTES EN SERIE

$$\delta_S = \delta_K + \delta_1 + \delta_2 + \delta_3 + \dots + \delta_G + \delta_M$$

TENIENDO PRESENTE QUE

$$\delta = \frac{1}{k} = \frac{l}{EA}$$



$$\delta_S = \frac{1}{E_S} \left[\frac{0.4d}{A_N} + \frac{l_1}{A_1} + \frac{l_2}{A_2} + \dots + \frac{0.5d}{A_3} + \frac{0.4d}{A_N} \right]$$

- ELASTICIDAD DE LA JUNTA

Roloff – Matek determinan del área de un cilindro hueco equivalente en rigidez, al de los troncos de cono / paraboloides.

$$\text{PARA } d_w \leq D_A \leq d_w + l_k$$

EL ÁNGULO “ α ” SEGÚN
DIVERSOS AUTORES:

- Birguer: $26^\circ 40'$
- Osgood: $25^\circ < \alpha < 33^\circ$
- Shigley: 30°

$$A_{ers} = \frac{\pi}{4} \left(d_w^2 - d_h^2 \right) + \frac{\pi}{8} d_w \left(D_A - d_w \right) \left[(x+1)^2 - 1 \right]$$

$$\text{DONDE } x = 3 \sqrt{\frac{l_k \cdot d_w}{D_A^2}}$$

$$\text{PARA } D_A \leq d_w$$

$$A_{ers} = \pi \left(D_A^2 - d_h^2 \right) / 4$$

LA RIGIDEZ DE LOS ELEMENTOS A UNIR

$$k_T = \frac{A_{ers} \cdot E_T}{l_k}$$

ELASTICIDAD DE LA JUNTA

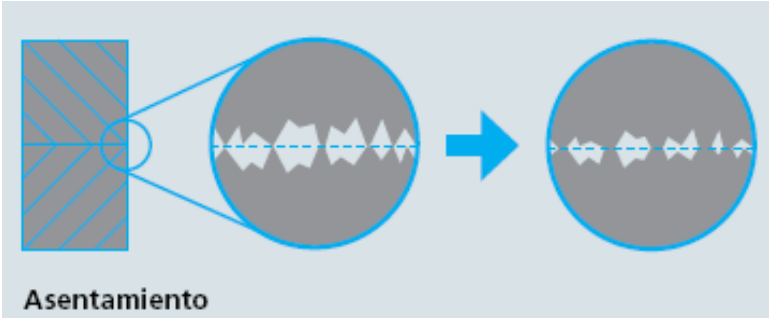
$$\delta_T = \frac{1}{k_T}$$

2) Asentamiento – Relajación de componentes

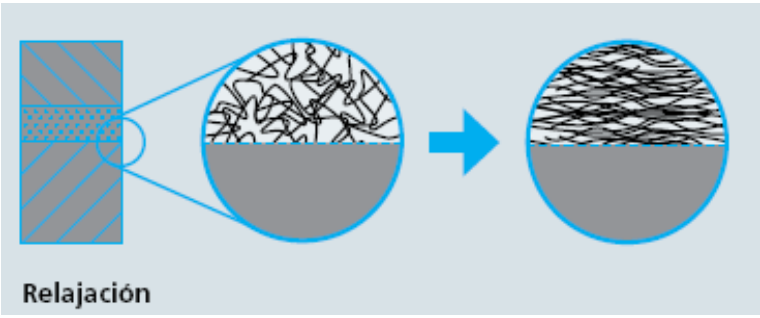
Se produce un asentamiento f_z . Disminuye la fuerza la fuerza de pretensado inicial F_{VM} en un valor F_Z

$$f_Z = 3,29 \left(\frac{l_k}{d} \right)^{0,34} \cdot 10^{-3}$$

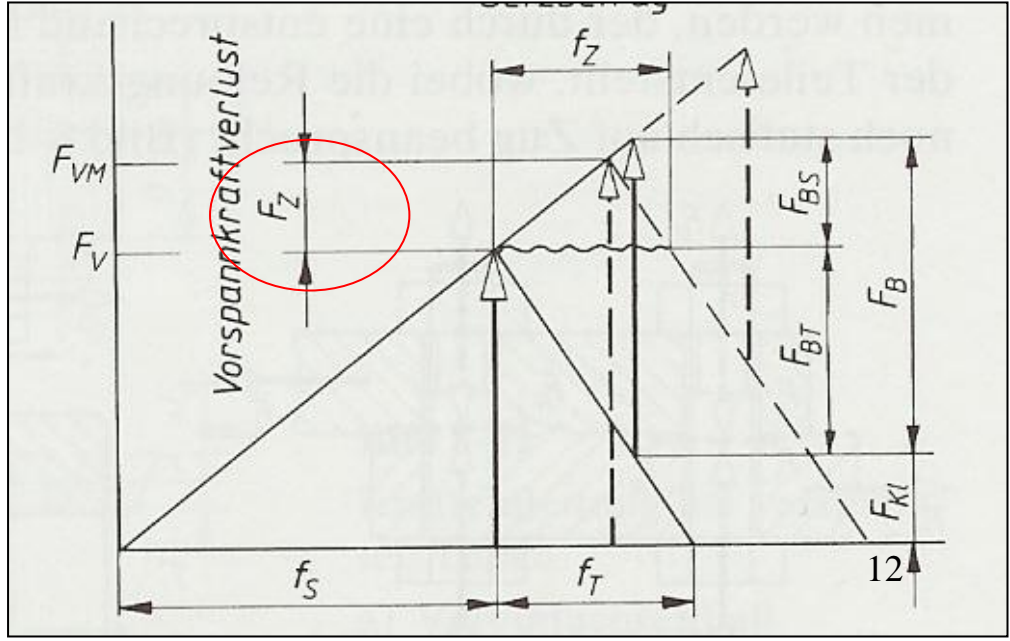
$$F_Z = \frac{f_Z}{\delta_S + \delta_T} = \frac{f_Z}{\delta_T} \Phi_k = \frac{f_Z}{\delta_S} (1 - \Phi_k)$$



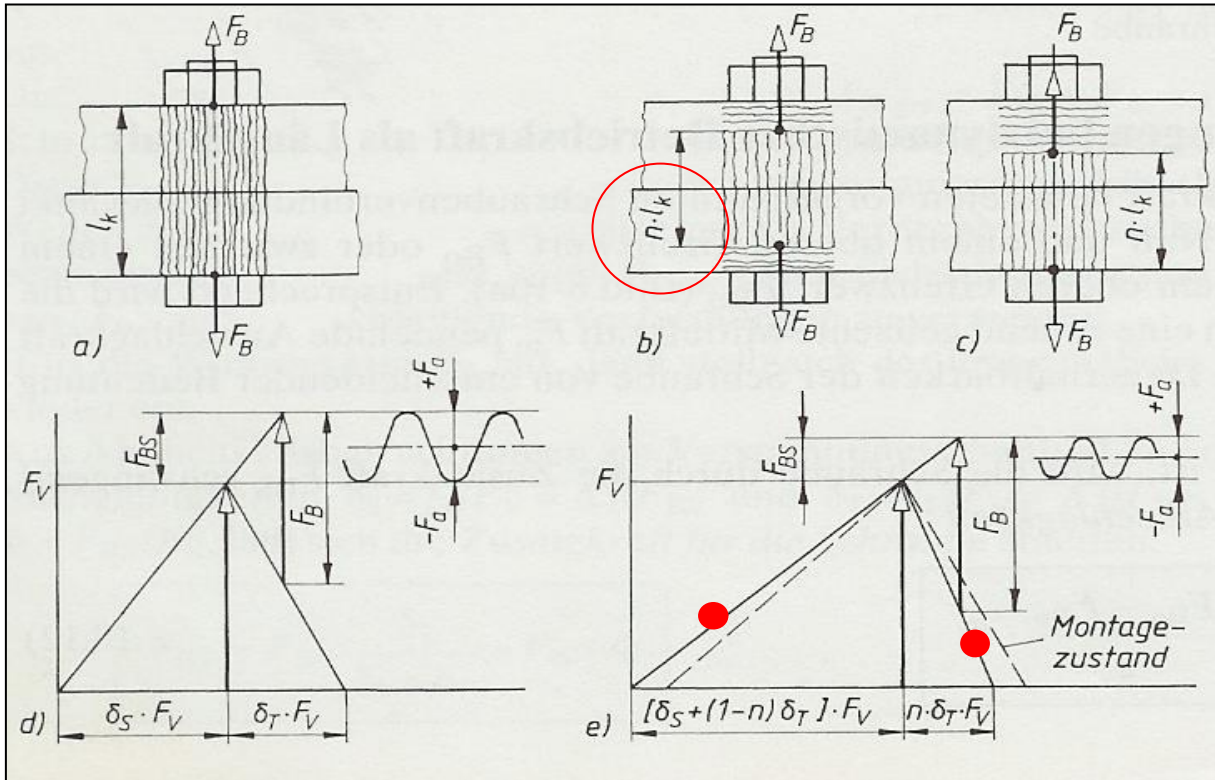
Asentamiento



Relajación



3) Influencia del punto de aplicación de la fuerza exterior en la unión

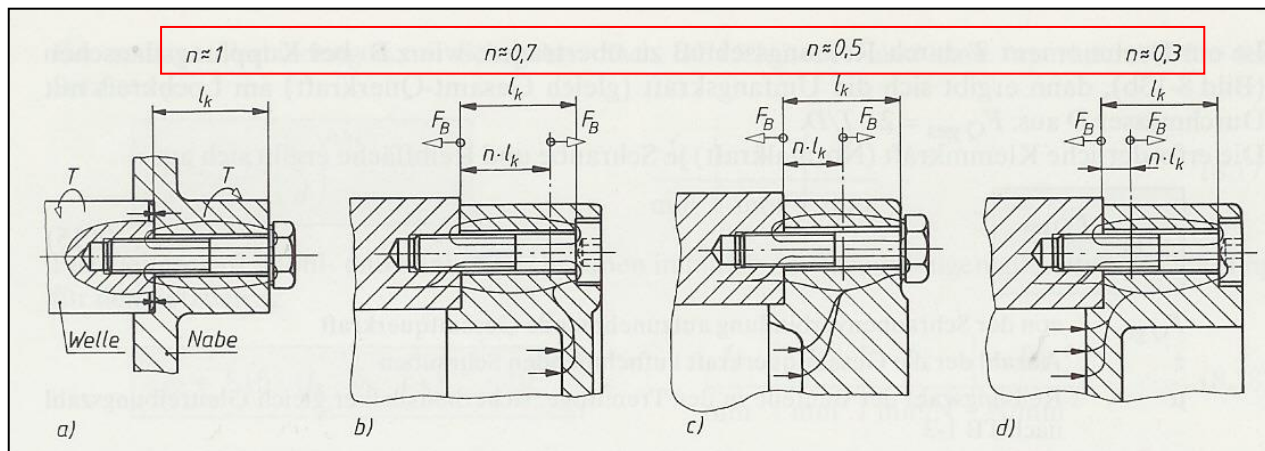


FUERZA APRIETE JUNTA

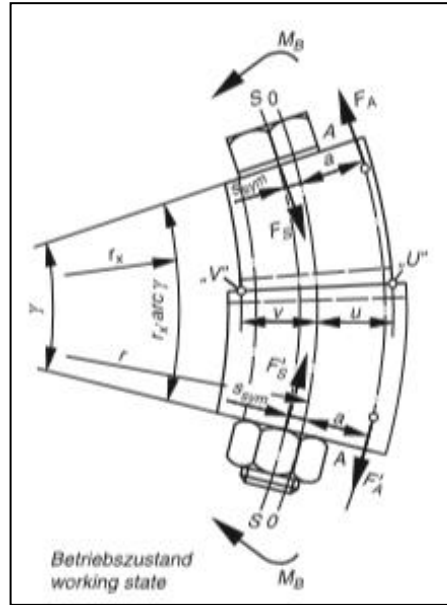
$$F_{Kl} = F_V - (1 - n\Phi)F_B$$

FUERZA MÁXIMA TORNILLO

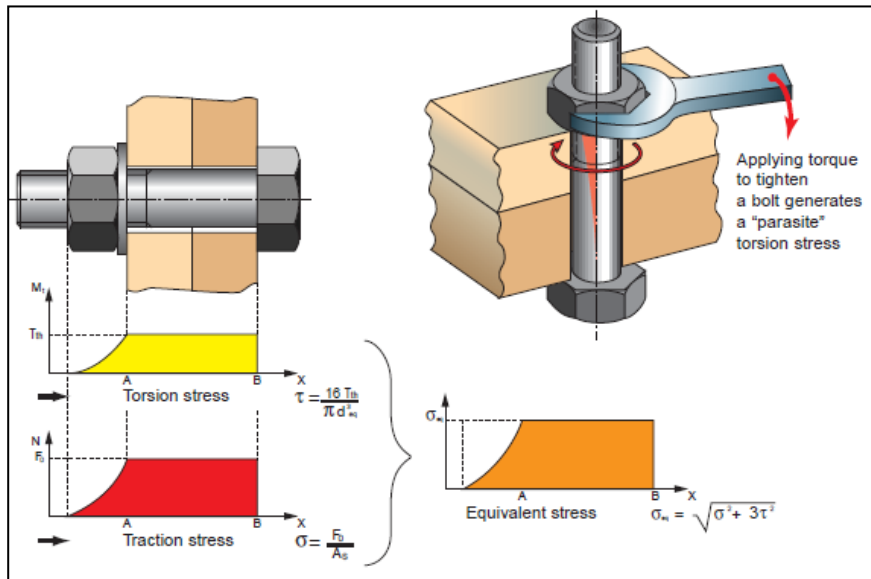
$$F_S = F_V + n \cdot \Phi \cdot F_B$$



5) Condición de asiento / Montaje impropia



6) Tensiones por condición de montaje



$$\sigma_{red} = \sqrt{\sigma_M^2 + 3\tau_t^2} \leq 0,9\sigma_{0.2}$$

7) Fuerza de pretensado “F_V”

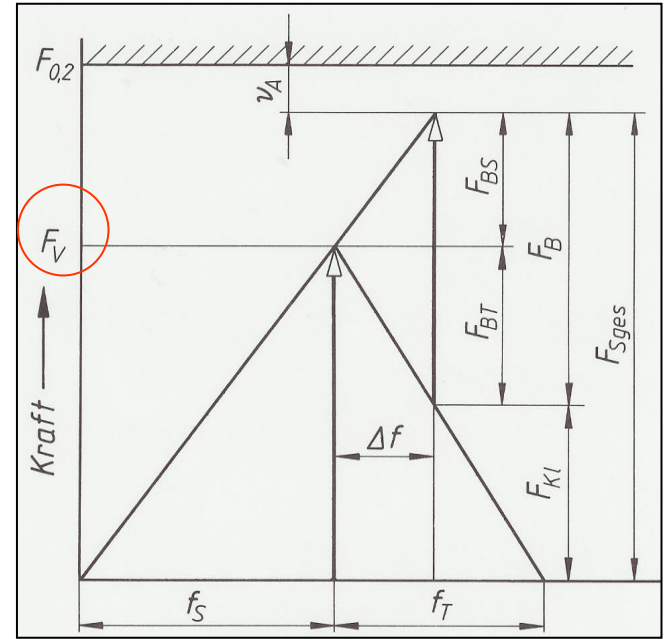
- Determinación

Bridas $F_V = 1.3 \text{ a } 1.6 F_B (P)$

$$\sigma_V = F_V / A_t = 0.5 \text{ a } 0.75 \sigma_{fl}$$

Aplicaciones Especiales

Bielas – Tapas de Cilindro $F_V = 2 \text{ a } 3 F_B (P)$



Teniendo presente la fuerza de cierre necesaria en la unión

$$F_V = F_{KL} + (1 - n\Phi) F_B$$

Se incrementa en un 10 a 15% por efecto de relajación -asentamiento de los elementos de la unión.

- Ajustes con llaves comunes $V (Kgr) = 2800 d (cm)$

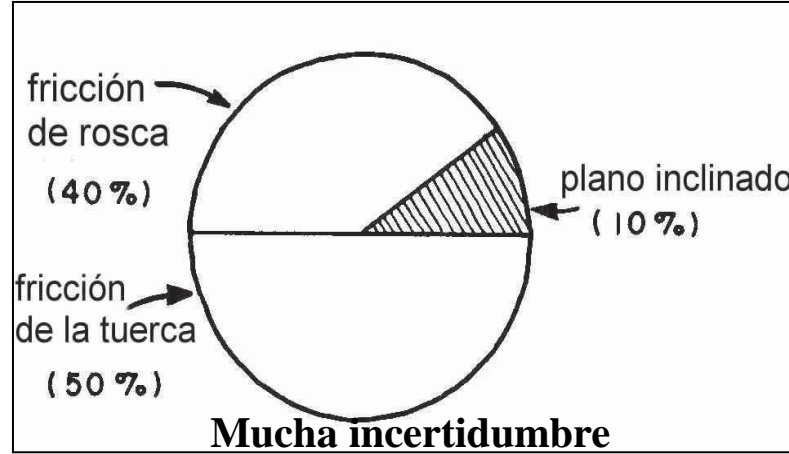
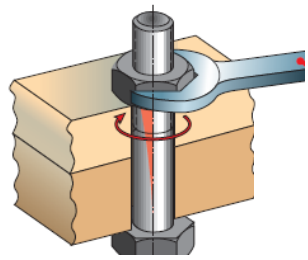
DIAMETRO NOMINAL	Sección resistente mm ²	CARGA EN EL LIMITE ELASTICO 0.2% (kg)				FUERZA DE PRETENSADO (kg) (70-75% de carga en límite elástico)				TORQUE DE APRIETE (kgm) (*)			
		5.6	8.8	10.9	12.9	5.6	8.8	10.9	12.9	5.6	8.8	10.9	12.9
M12 x 1,75	84,3	2530	5400	7600	9100	1900	3830	5400	6450	4	9	12	15

- Implementación Pretensado

a) Torque

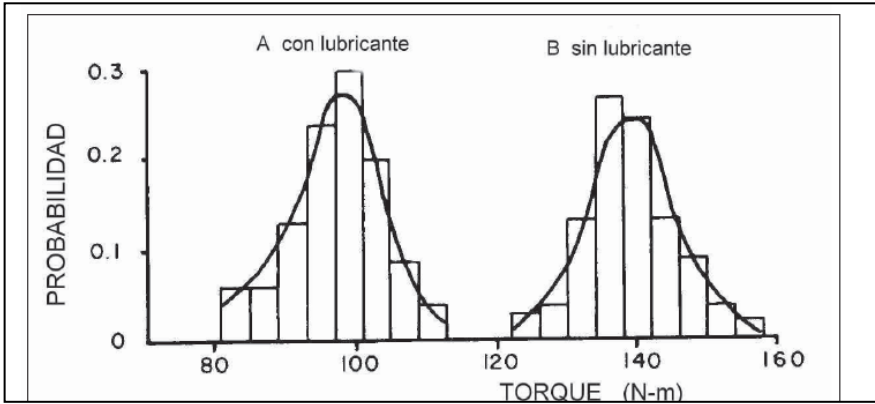
$$T = K \cdot F_V \cdot d$$

Expresión típica con $\mu = 0.15$ y $D_{\text{tuerca}} : 4/3 d$

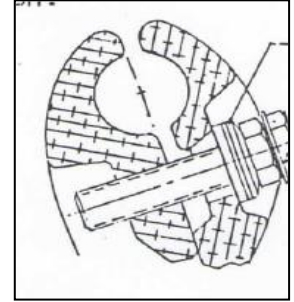
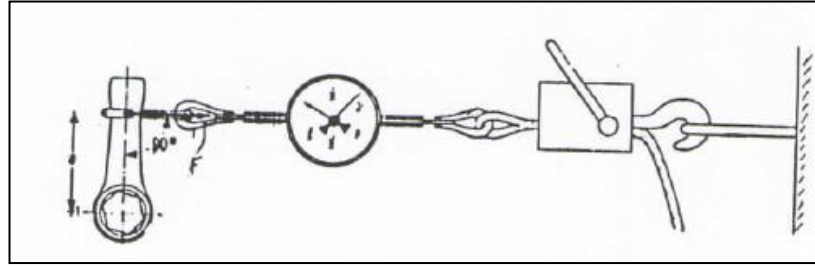
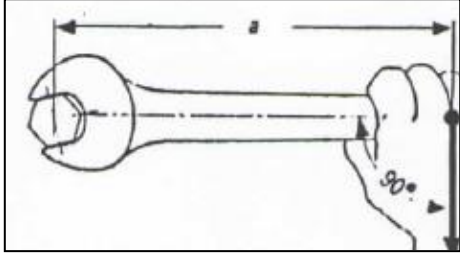


$$T(Kgr.m) = 0.2 \cdot F_V(Kgr) \cdot d(cm)$$

Materiales de sujetadores y recubrimientos ^{af}	Factores de tuerca reportados		
	Min	Medio	Max
Recubrimiento de aluminio puro sobre acero aleado AISI 8740	0,42	0,52	0,62
Aluminio electrolaminado sobre acero aleado AISI 8740	---	0,52	---
Como recibido, acero blando o aleado sobre aceroaleado sobre	0,158	0,2	0,267



$$T(Kgr.m) = 0.2 \cdot F_V(Kgr) \cdot d(cm)$$



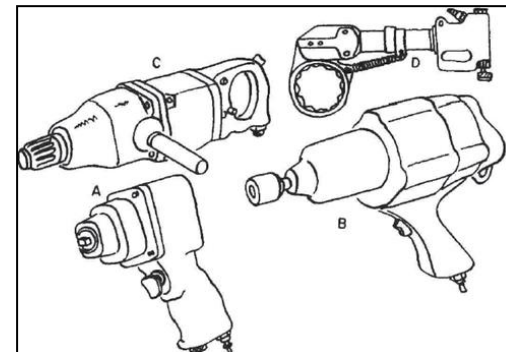
$$V(Kgr) = 2.800 \cdot d(cm)$$



Robust Bi-Directional Ratchet Head
 Large, Colour Organic LED Screen High Visibility + Colour Warning Signals
 Tactile Switch Green/Red LED Signals
 USB Bi-directional Comms
 Ergonomic Soft Grip
 4 x AA Batteries

OLED Screenshots

Track Mode	Preset Mode	Torque & Angle	Recall
Displays Actual Torque as applied	Screen Changes Colour as Preset Torque is reached	View Torque & Angle simultaneously	Store & View 2000+ results or upload to PC or SPC



b) Precarga y Giro

$$L = P \cdot \frac{R}{360}$$

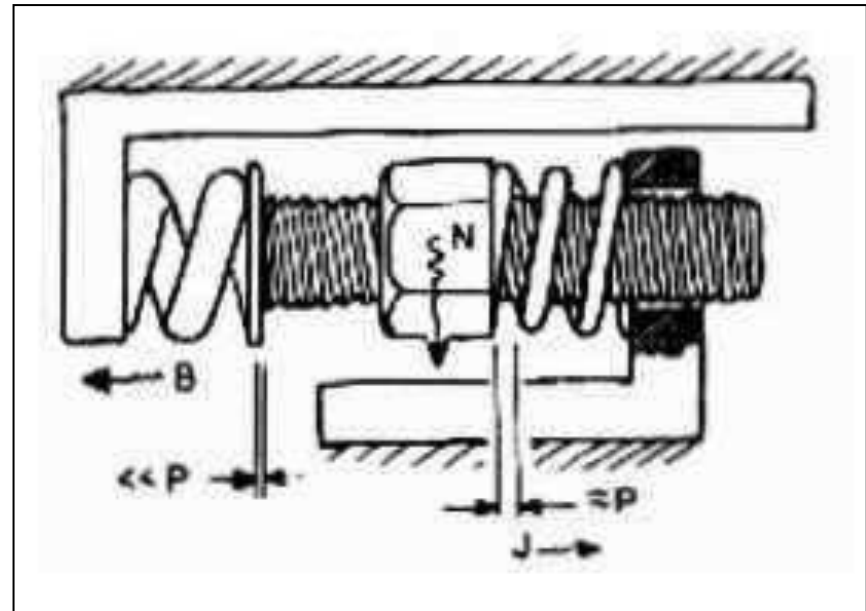
L: alargamiento del bulón

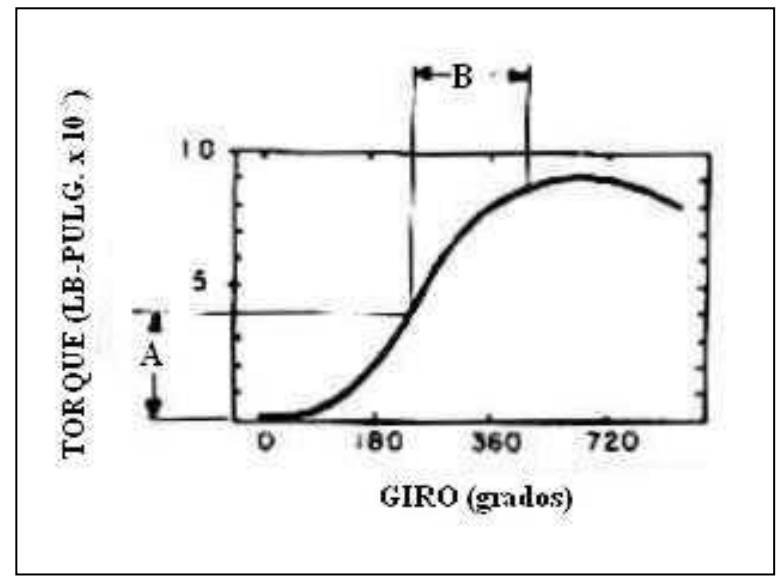
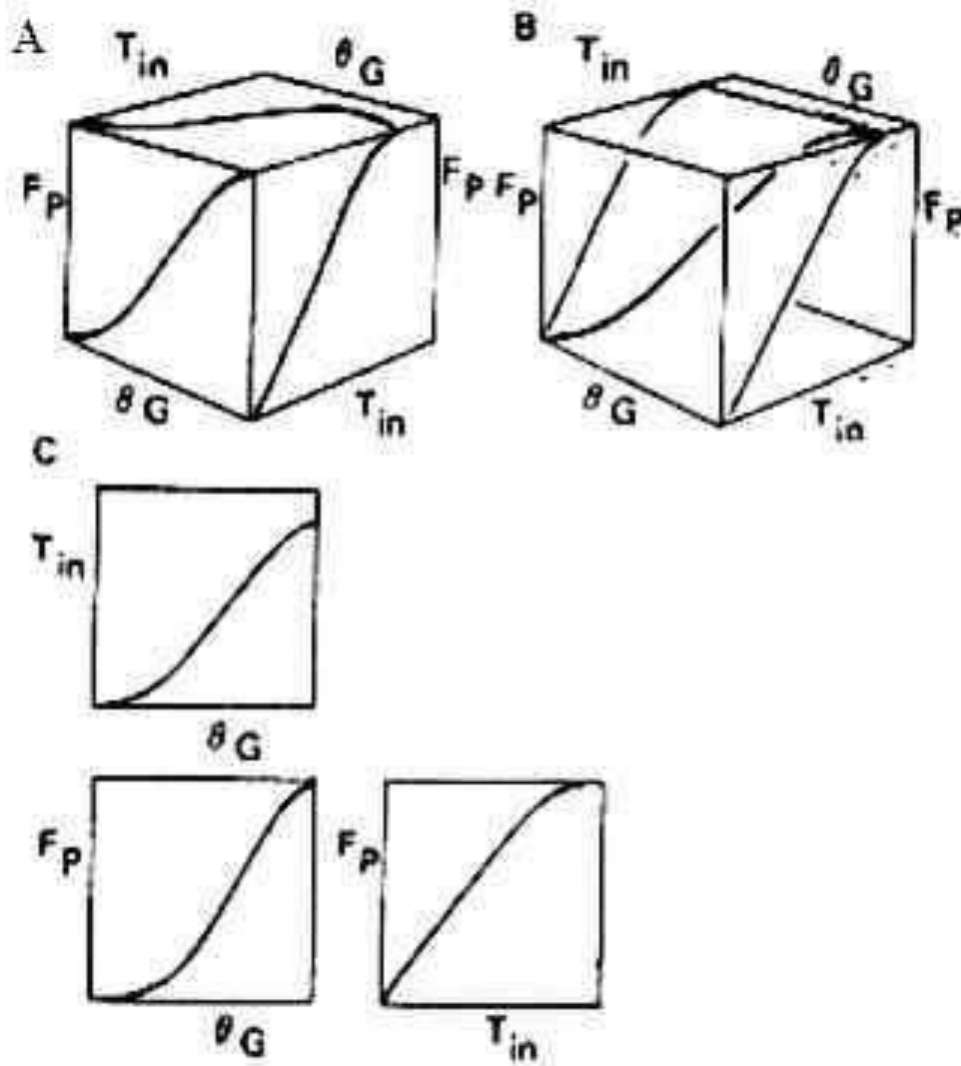
P: paso de la rosca

R: es la rotación de la tuerca (grados) respecto del tornillo.

k_S : Rigidez del tornillo

$$F_V = k_S \cdot L = k_S \cdot P \cdot \frac{R}{360}$$



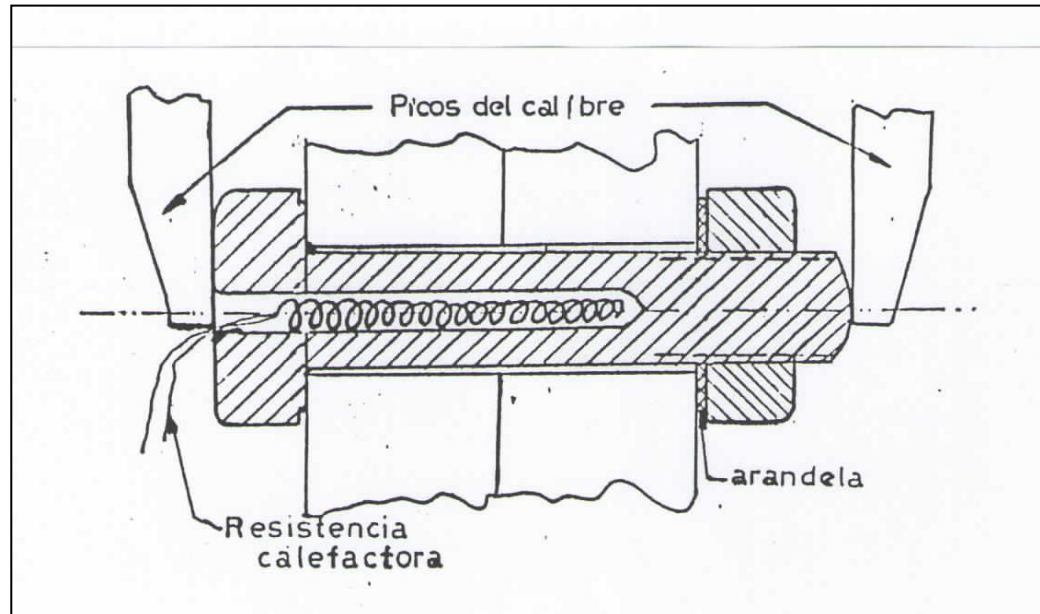


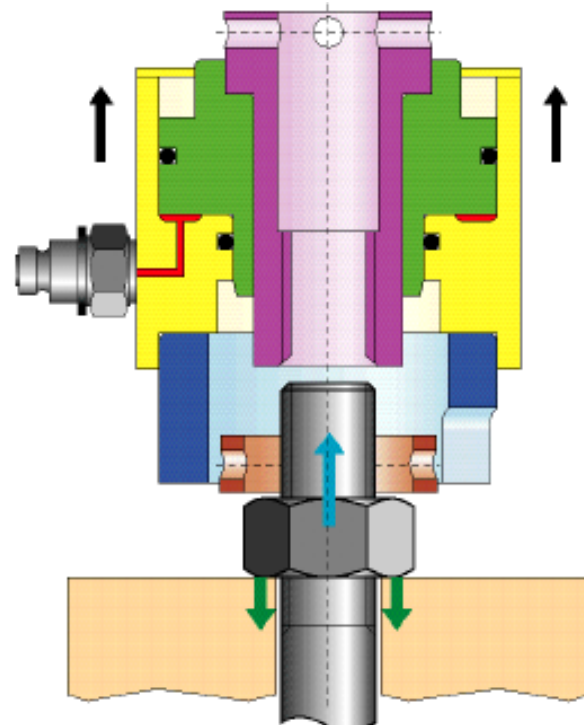
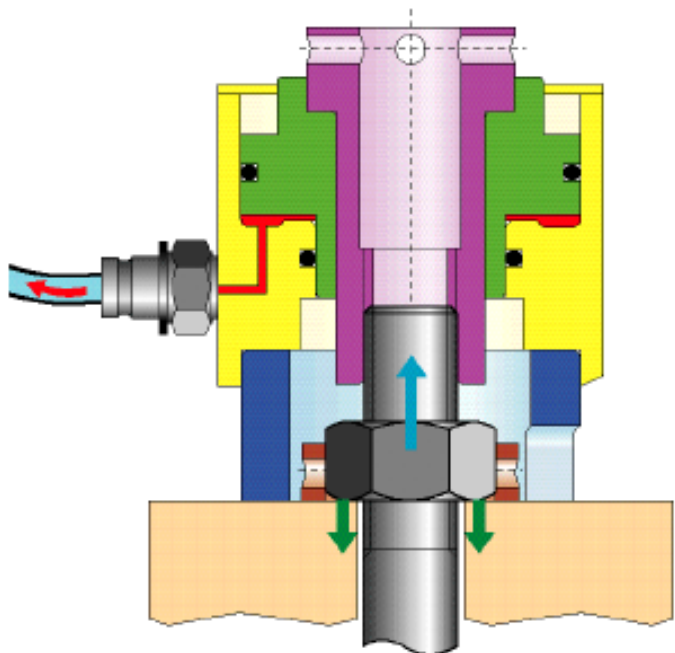
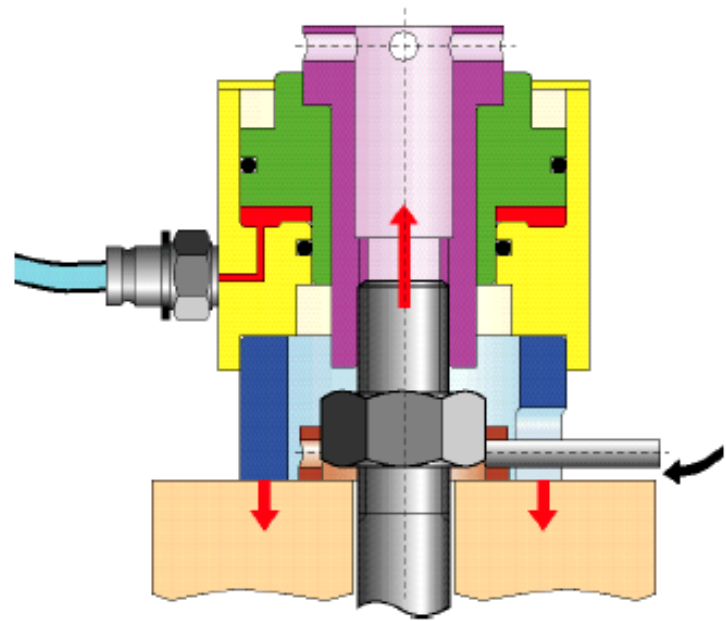
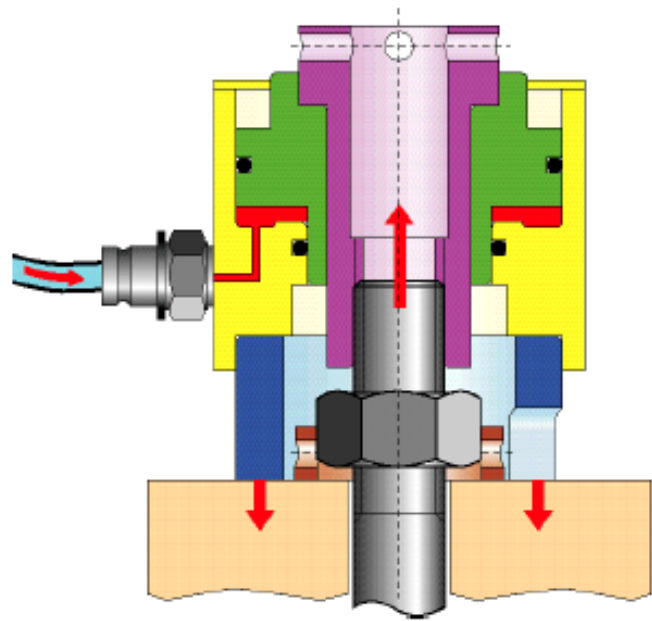
En técnicas de giro, la tuerca es ajustada inicialmente con un torque aproximado (A) y luego se sigue ajustando con un giro medido (B). Bulón de 7/8 x 5 1/2 ASTM A 325.

c) Elongación del tornillo - Medición

$$F_V = E \cdot A \cdot \frac{\Delta L}{L}$$

Ventajas de la elongación directa del tornillo..... Métodos





Dispersión de Precarga Reportada para una variedad de Herramientas o Procedimientos de abulonado.

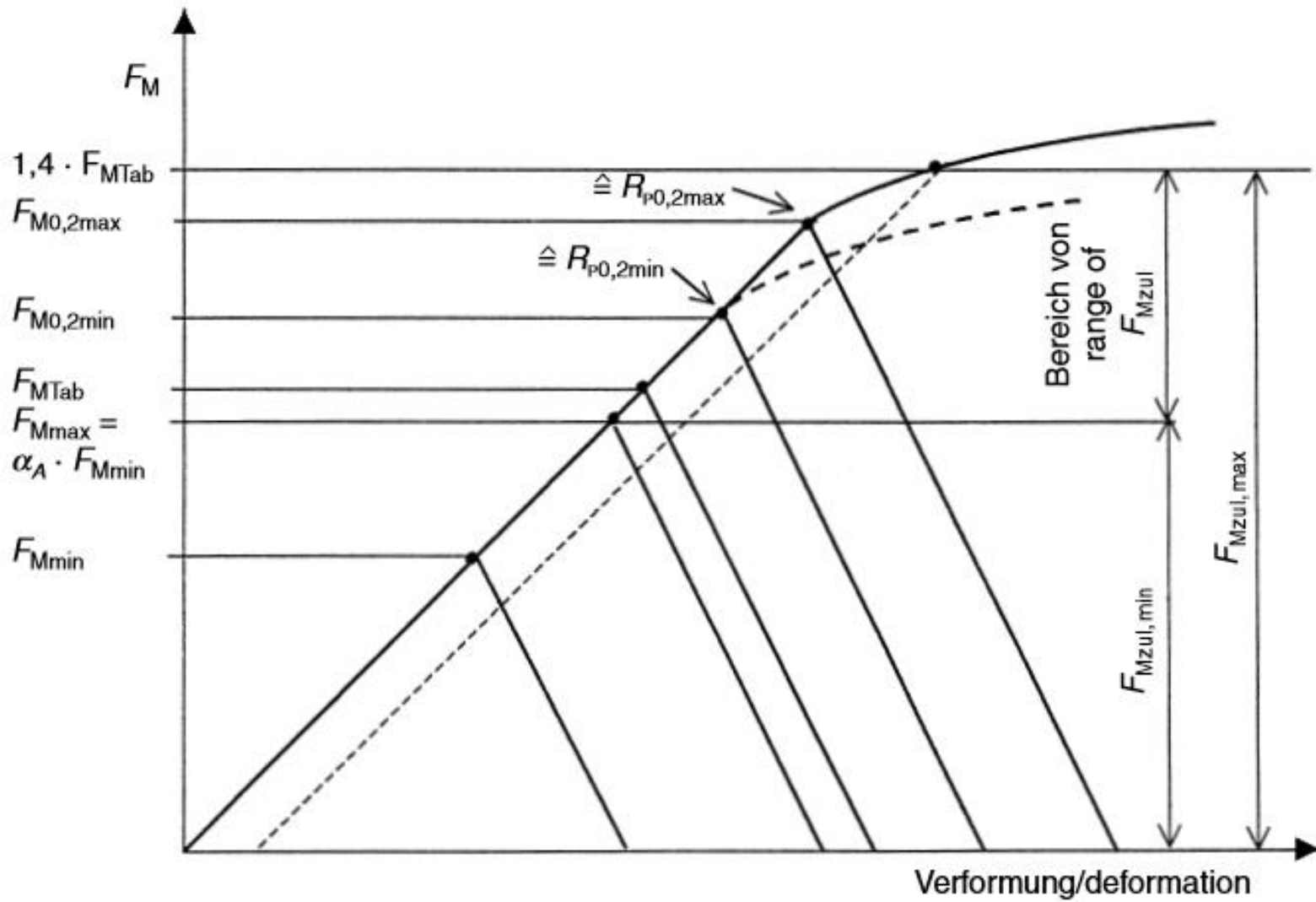
Control de torque con una llave de mano	+/-30
Herramienta neumática de torque con tope	+/-35
Llave de torque del tipo Click	+/-60 a 80
Llave de torque más multiplicador	-70 a +150
Giro de la tuerca (acero estructural)	+/-15
Herramienta neumática controlada por computadora hasta el límite elástico	+/-3 a 10
Sistema LRM de Rockwell Internacional (torque-ángulo)	+/-3 a 10
Arandelas de carga de tensión autoajustable	+/-15
Bulones de tensión autoajustable	+/-1
Bulones de Traba Forjados	+/-5
Llave de impacto neumática	-100 a +150
Tensionadores hidráulicos con calibre de lectura	+/-20
A tacto del operador	+/-35
Alargamiento del bulón (micrómetros)	+/-3 a 15
Control ultrasónico	+/-1 a 10

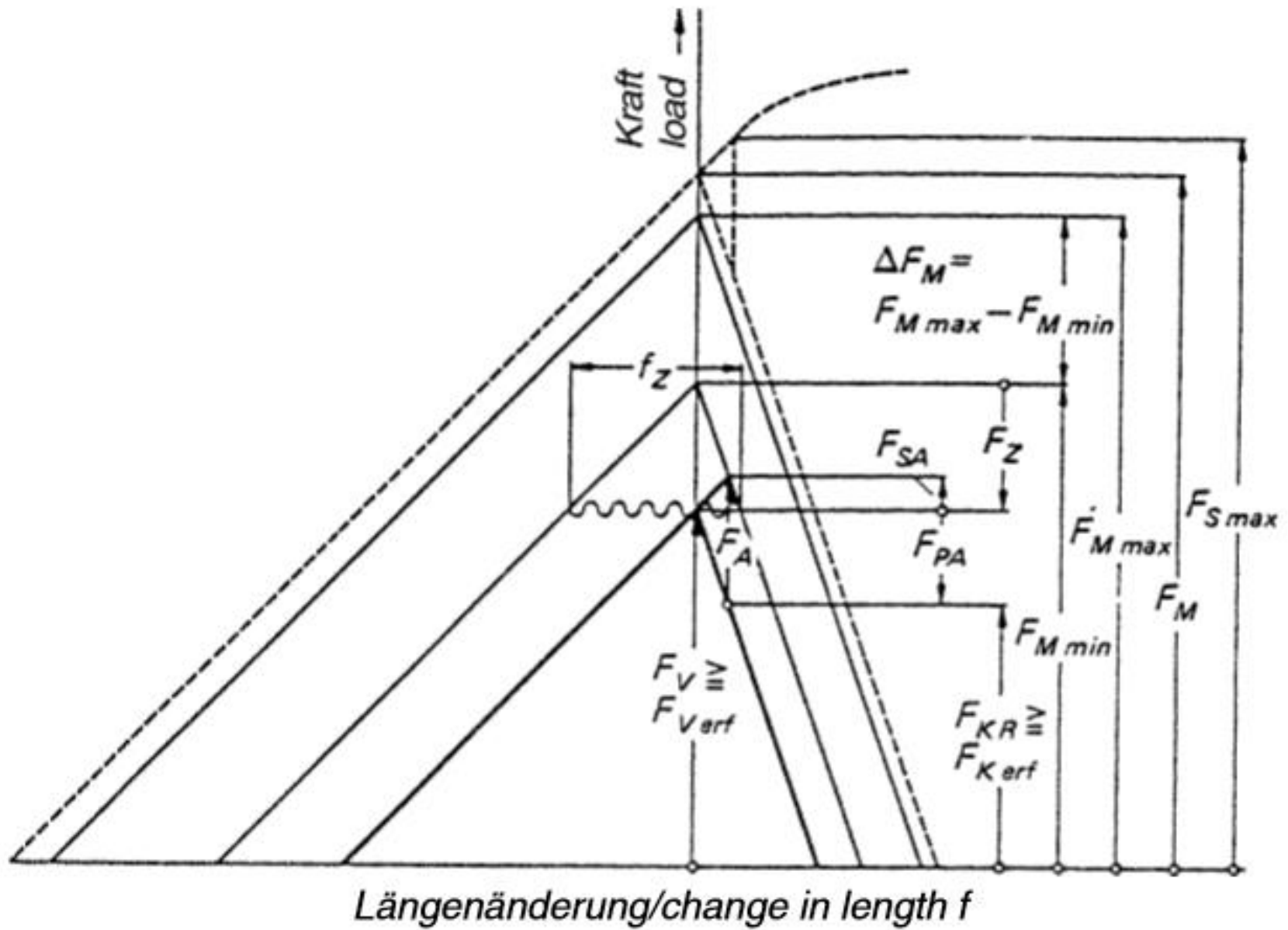
Todos los valores están en “%” y vienen de la propia experiencia del autor o del Manual de Mano Estándar de Diseño de Máquinas, editado por Joseph R. Shigley y Charles R. Mishcke, McGrawHill, New York, 1986, p. 23.23.

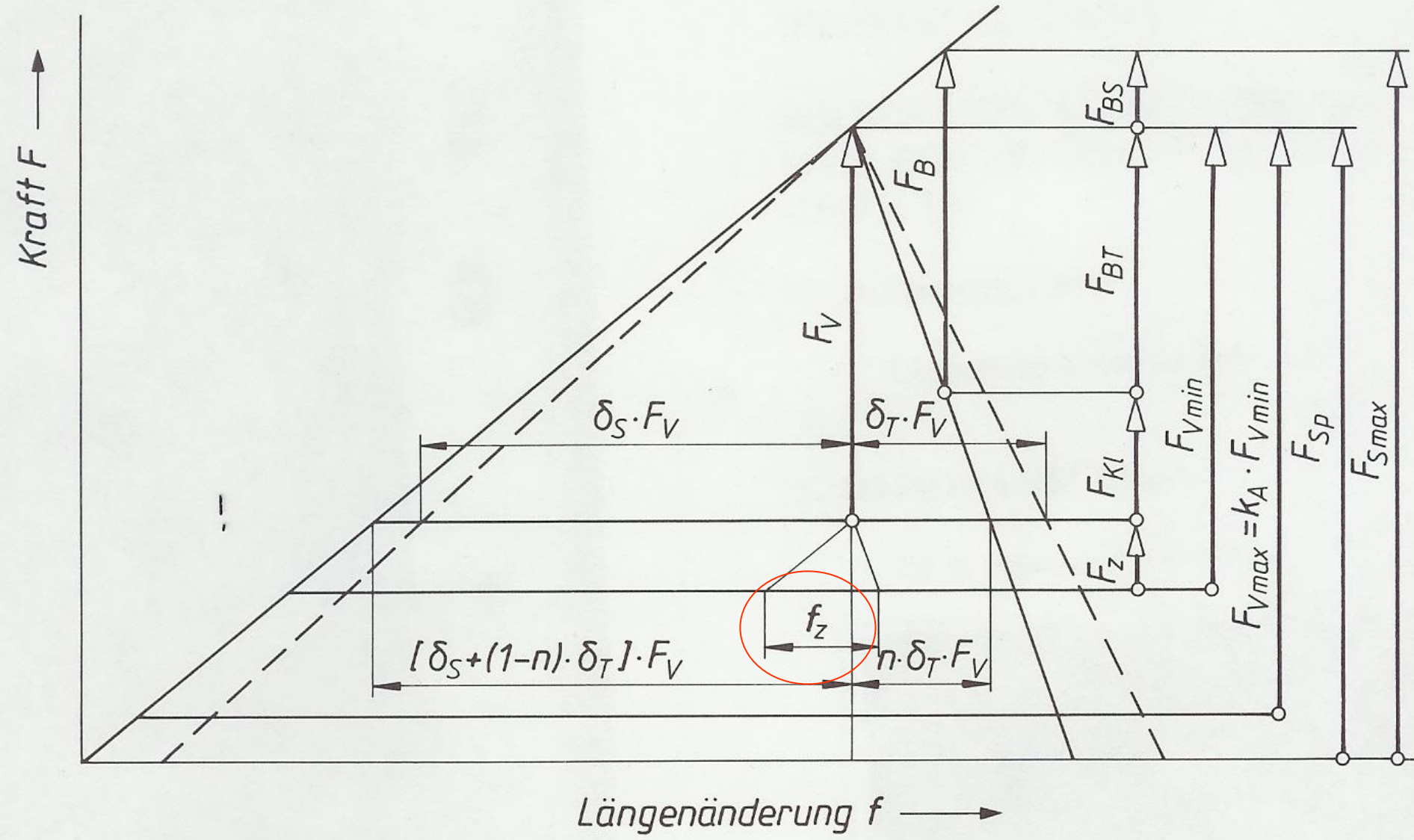
DISPERSIÓN DEL VALOR DE PRETENSADO

Tightening method	Accuracy on pre-load	γ
<ul style="list-style-type: none"> • Calibrated torque wrenches • Power tightening tools with regular calibration on application (measurement of elongation of the bolt or measurement of torque value using a calibrated torque wrench) 	± 20 %	1.5
<ul style="list-style-type: none"> • Impact wrenches with stiffness adjustment and periodic calibration on application (measurement of torque value using a calibrated torque wrench per batch) 	± 40 %	2.5
<ul style="list-style-type: none"> • Hand wrenches • Shock wrench (uncalibrated) 	± 60 %	4

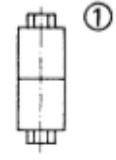
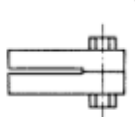
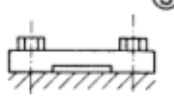
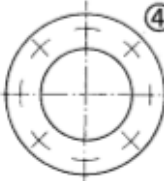
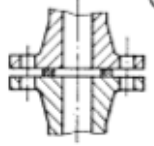
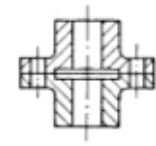
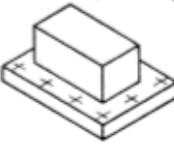
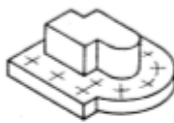
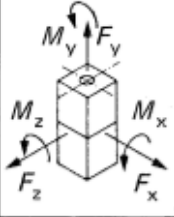
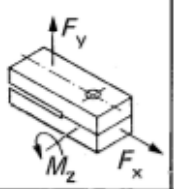
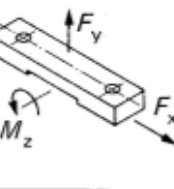
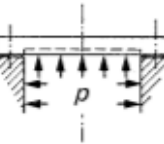
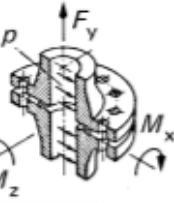
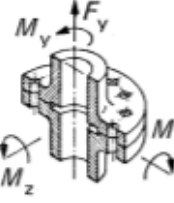
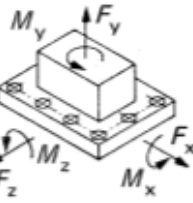
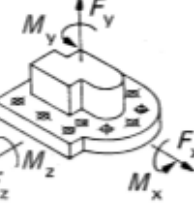
$$\gamma = \frac{F_o \text{ max.}}{F_o \text{ min.}} : \text{Uncertainty factor on tightening load}$$







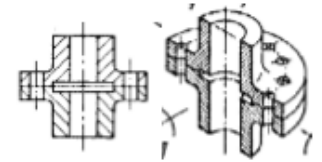
--- Montagezustand

Single-bolted joints		Multi-bolted joints						Bolted joints
concentric or eccentric		in a plane	axial symmetry			symmetrical	asymmetrical	bolt axes
Cylinder or prismatic body	Beam	Beam	Circular plate	Flange with sealing gasket	Flange with plane bearing face	Rectangular multi-bolted joint	Multi-bolted joint	
 ①	 ②	 ③	 ④	 ⑤	 ⑥	 ⑦	 ⑧	Joint geometry
								Relevant loads
Axial force F_A Transverse force F_Q Working moment M_B	Axial force F_A Transverse force F_Q Moment in the plane of the beam M_Z	Axial force F_A Transverse force F_Q Moment in the plane of the beam M_Z	Internal pressure p	Axial force F_A (Pipe force) Working moment M_B Internal pressure p	Axial force F_A Torsional moment M_T Working moment M_B	Axial force F_A Transverse force F_Q Torsional moment M_T Working moment M_B	Axial force F_A Transverse force F_Q Torsional moment M_T Working moment M_B	Forces and moments
VDI 2230		limited treatment by VDI 2230		DIN 2505 AD Note B7 VDI 2230 (limited treatment)	limited treatment by VDI 2230			Calculation procedure
Bending beam theory with additional conditions			Plate theory	limited treatment using simplified models				
Finite Element Method (FEM)								

2.1 Task description

Sizing and rating of the bolting for a flanged coupling with data as shown:

Torque to be transmitted	13kNm	Coefficient of friction	0.15
Pitch diameter	258mm	Minimal axial force	0kN
Number of bolts on pitch circle	12	Maximum axial force	10kN
Material flange (left/right)	GG25/34CrNiMo6	Strength class of bolt	10.9
Thickness flange(left/right)	22mm/18mm	Hexagon head screw with shank (AB)	
Surface flange (left/right)	N7/N8	ISO4014	
		Tightening: with dynamometric key	



The connection realised with through bolts (notation according VDI 2230:2003 bolted joint) with nuts and washer under nuts and under bolt head.

Basic data | Clamped parts | Entries

Working data

Configuration: Flange connection with torque and forces (multiple bolts)

Number of bolts: 12

Reference diameter d_e : 258.0000 mm

Shearing force F_{\perp} : 0.0000 N

Clamping force for sealing F_{sp} : 0.0000 N

Axial force (min/max) F_A : 0.0000 0.0000 N

Torque M_T : 13000.0000 Nm

Bending moment M_b : 0.0000 Nm

Coefficient of friction between: 0.1500

Bolt data

Bolt type: Hexagon head screw with shank (A B) EN ISO 4014

Reference diameter d : 16.0000 mm

Bolt length l : 80.0000 mm

Surface roughness of thread: N7 Rz=8.0 (Turned with diamond)

Surface roughness of bearing surface: N7 Rz=8.0 (Turned with diamond)

Strength class: 10.9

Type of bolting

Blind hole

Nut

Washer

under bolt head

under nut

Tightening technique

Dynamometric key (with guess of coefficient of friction)

Tightening factor: 1.6000

Bolt data

Bolt type: Hexagon head screw with shank (A B) EN ISO 4014

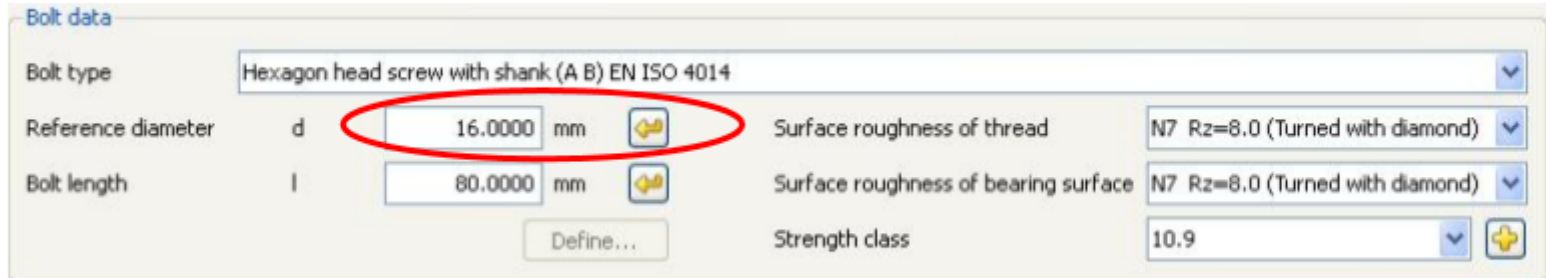
Reference diameter	d	22.0000 mm	+
Bolt length	l	80.0000 mm	+

Define...

Surface roughness of thread	N7 Rz=8.0 (Turned with diamond)
Surface roughness of bearing surface	N7 Rz=8.0 (Turned with diamond)
Strength class	10.9

Figure 2.2-1: Using the sizing button will result in a proposal for the bolt diameter (based on VDI2230), here, M18.

The nominal bolt diameter can be changed manually, here to 16mm.

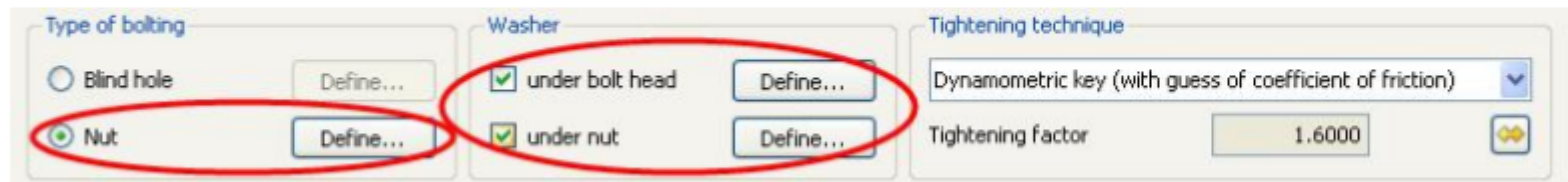


Bolt data	
Bolt type	Hexagon head screw with shank (A B) EN ISO 4014
Reference diameter d	16.0000 mm
Bolt length l	80.0000 mm
Surface roughness of thread	N7 Rz=8.0 (Turned with diamond)
Surface roughness of bearing surface	N7 Rz=8.0 (Turned with diamond)
Strength class	10.9

Figure 2.2-3: Nominal bolt diameter set to 16mm.

2.3 Definition of washer and nut

Under the tab 'Basic data' the settings for the washer and the nut can be set as follows:

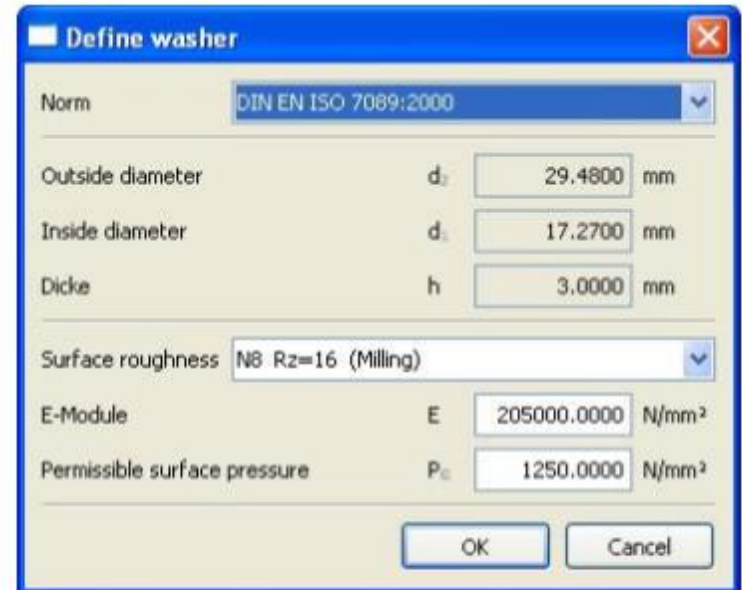


Type of bolting	Washer	Tightening technique
<input type="radio"/> Blind hole	<input checked="" type="checkbox"/> under bolt head	Dynamometric key (with guess of coefficient of friction)
<input checked="" type="radio"/> Nut	<input checked="" type="checkbox"/> under nut	Tightening factor: 1.6000

Figure 2.3-1: Call of program module definition.



Choose nut from standard or define own geometry



Defining the washer (once for the washer underneath the nut, once for underneath the bolt head). Choose from standard or define own geometry.

Figure 2.3-2: Detailed input on nut, washer and flange geometry.

Basic data **Clamped parts** Entries

Segment of annulus Geometry... Bore...

	Material Surface roughness	Depth of Layer [l]	Permissible pressure [P]	E-F
1	EN-GJL-250 (GG 25), Cast iron flake graphite, untreated, VDI 2230 (2003)	22.0000	850.0000	
	N7 Rz=8.0 (Turned with diamond)			
2	34 CrNiMo 6 (1), Through hardened steel, alloyed, through hardened, VDI 2230 (2003)	18.0000	1080.0000	
	N7 Rz=8.0 (Turned with diamond)			

Clamping length (without washer) l: 40.0000 mm

Distance for eccentric load/clamping

Load application a: 0.0000 mm

Bolt axis s: 0.0000 mm

Edge distance of the point of splitting u: 0.0000 mm

Distances measured from the axis through center of gravity

Load application

Load introduction factor: 0.5000

Bolting type: **SV 3**

Length of connected solid l_k: 0.0000 mm

Distance of connected solid a_k: 0.0000 mm

Definition of Bore

geometrical definition of the segment of annulus

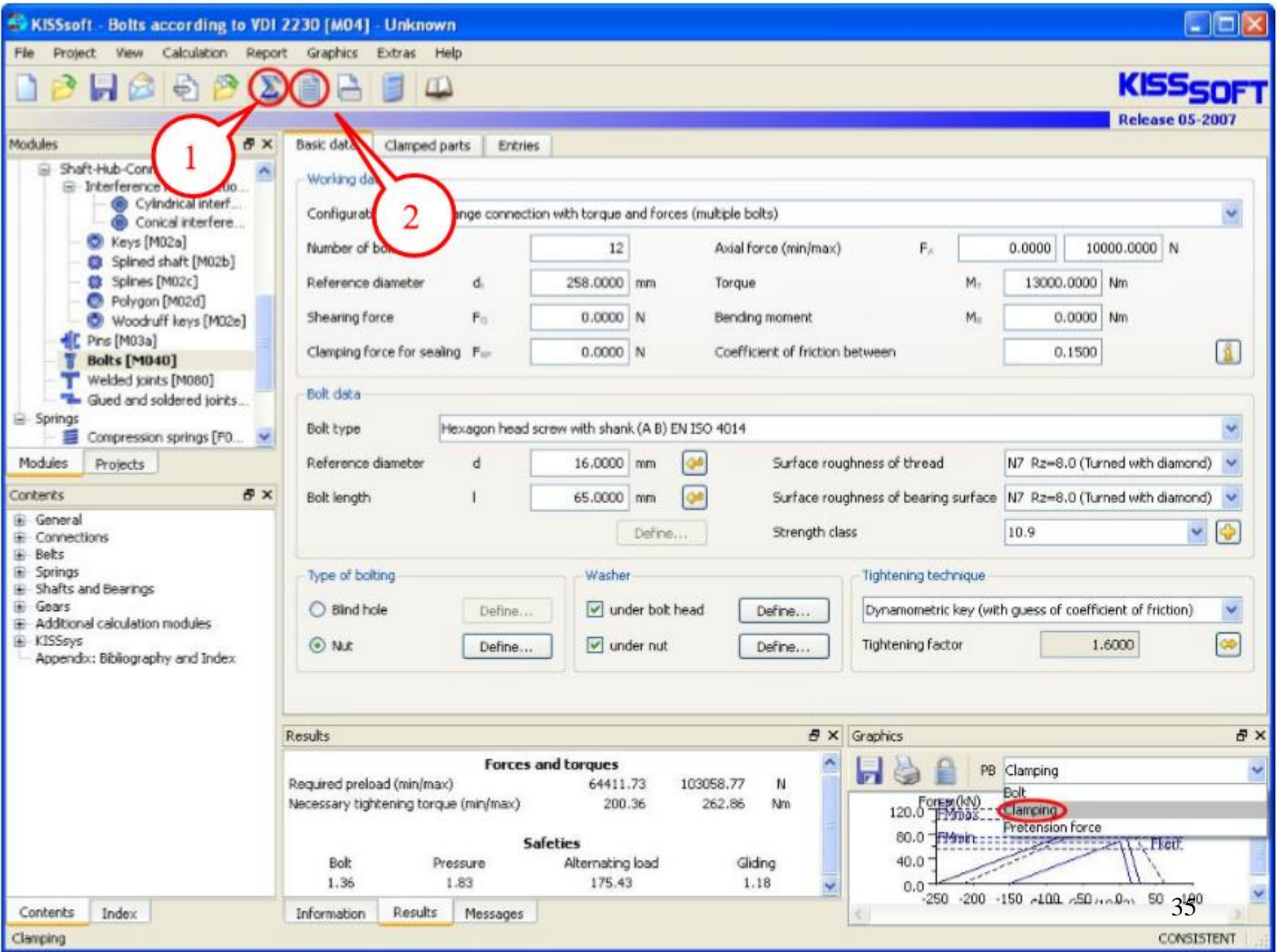
Choice of the type here "segment of annulus"

Input of material and depth of layer

add a new depth of layer: "+"
 deleted depth of layer: "_"

clear all: "x"

Application of force is according to figure SV3 (Use „i“ button for figures)



Modules

- Shaft-Hub-Conn...
- Interference fit...
- Keys [M02a]
- Splined shaft [M02b]
- Splines [M02c]
- Polygon [M02d]
- Woodruff keys [M02e]
- Pins [M03a]
- Bolts [M040]**
- Welded joints [M080]
- Glued and soldered joints...
- Springs
- Compression springs [F0...]

Contents

- General
- Connections
- Belts
- Springs
- Shafts and Bearings
- Gears
- Additional calculation modules
- KISSsys
- Appendix: Bibliography and Index

Basic data

Working data

Configuration: Change connection with torque and forces (multiple bolts)

Number of bolts	12	Axial force (min/max)	F_A	0.0000	10000.0000	N	
Reference diameter	d	258.0000	mm	Torque	M_T	13000.0000	Nm
Shearing force	F_C	0.0000	N	Bending moment	M_B	0.0000	Nm
Clamping force for sealing	F_{Cl}	0.0000	N	Coefficient of friction between		0.1500	

Bolt data

Bolt type: Hexagon head screw with shank (A B) EN ISO 4014

Reference diameter	d	16.0000	mm	Surface roughness of thread	N7 Rz=8.0 (Turned with diamond)
Bolt length	l	65.0000	mm	Surface roughness of bearing surface	N7 Rz=8.0 (Turned with diamond)
				Strength class	10.9

Type of bolting

- Blind hole
- Nut

Washer

- under bolt head
- under nut

Tightening technique

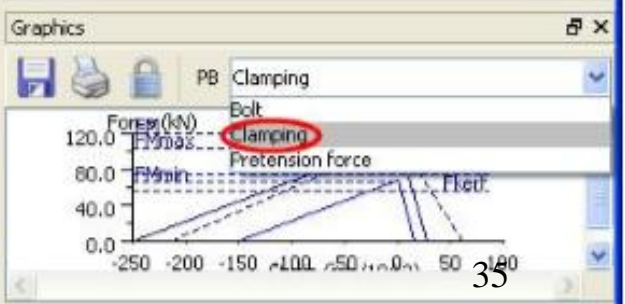
Dynamometric key (with guess of coefficient of friction)

Tightening factor: 1.6000

Results

Forces and torques			
Required preload (min/max)	64411.73	103058.77	N
Necessary tightening torque (min/max)	200.36	262.86	Nm

Safeties			
Bolt	Pressure	Alternating load	Gliding
1.36	1.83	175.43	1.18



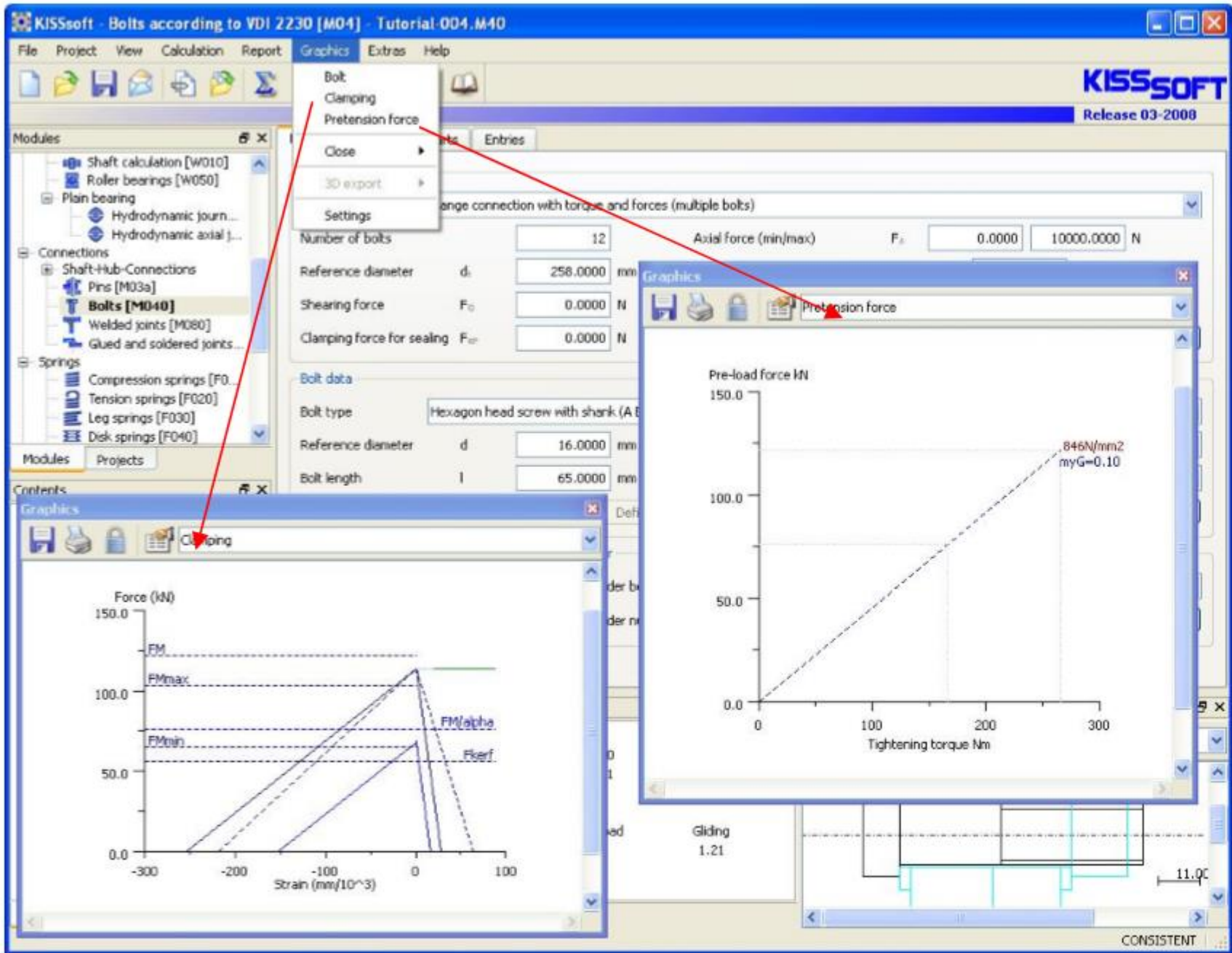


Figure 3.1-2: display further graphic

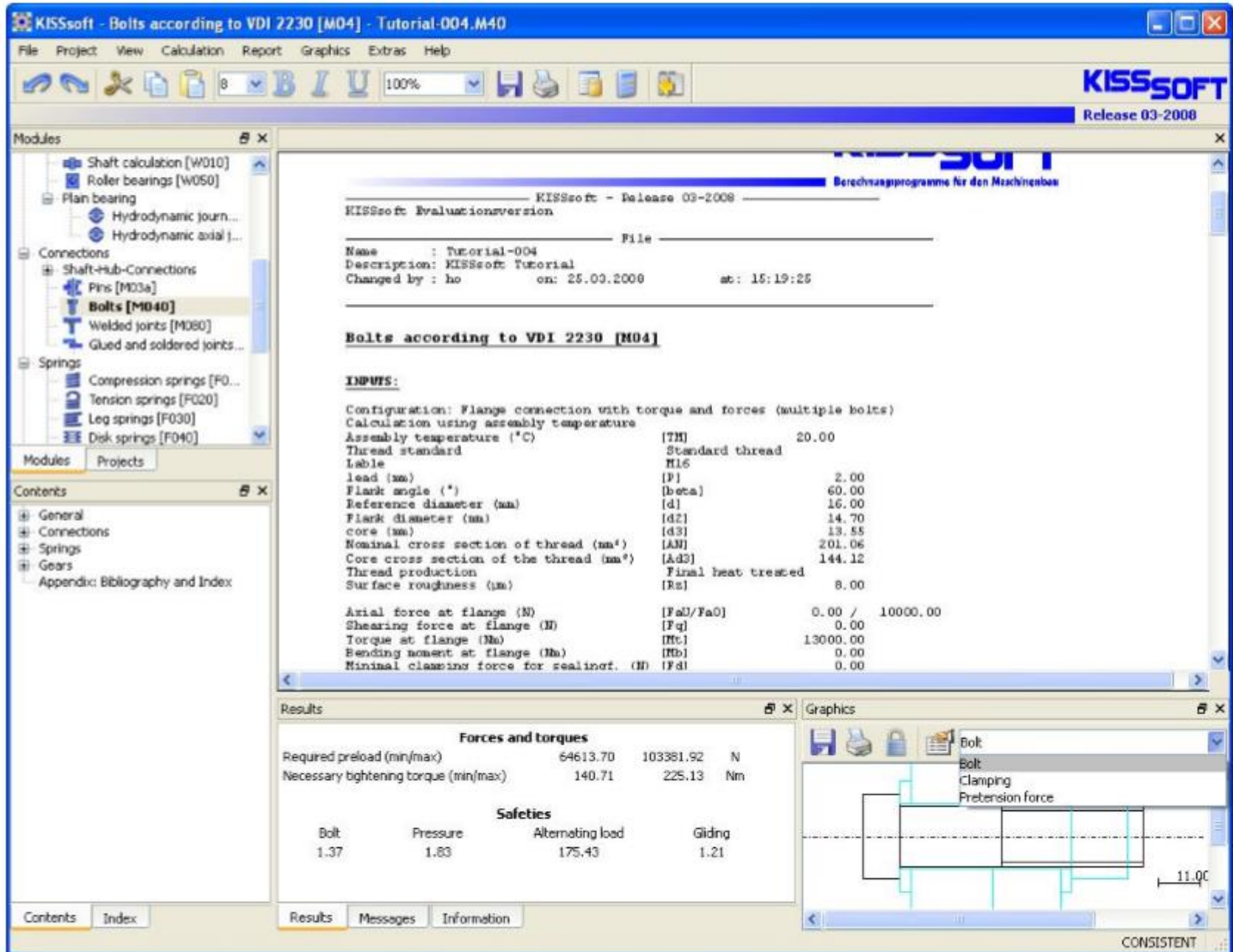


Figure 3.1-3: show the report display and selection other graphics

A todos los **PRESENTES**,
MUCHAS GRACIAS por su atención.

Al



el **RECONOCIMIENTO** por brindar este espacio de
encuentro y comunicación.