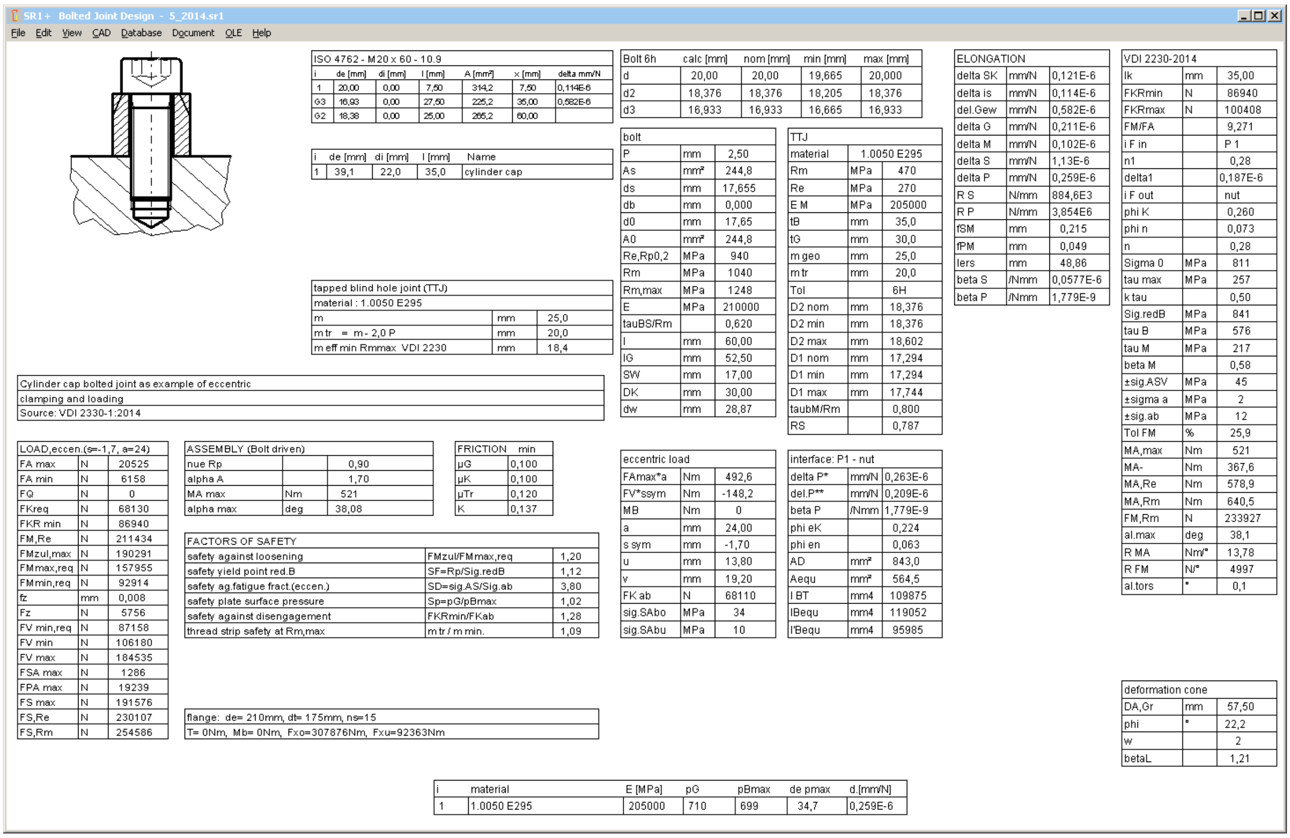
HEXAGON Info 149 Jan. / Feb. 2015

by Fritz Ruoss

SR1+ Quick3 View

New "Quick3 View" contains all input data and calculation results on one screen.



ISO 4762 - M20 x 60 - 10.9						
i	de [mm]	di [mm]	l [mm]	A [mm²]	x [mm]	delta mm/N
1	20,00	0,00	7,50	314,2	7,50	0,114E-6
G3	16,93	0,00	27,50	225,2	35,00	0,582E-6
G2	18,38	0,00	25,00	265,2	60,00	

i	de [mm]	di [mm]	l [mm]	Name
1	39,1	22,0	35,0	cylinder cap

tapped blind hole joint (TTJ)		
material : 1.0050 E295		
m	mm	25,0
m tr = m - 2,0 P	mm	20,0
m eff min Rmmax VDI 2230	mm	18,4

Bolt 6h	calc [mm]	nom [mm]	min [mm]	max [mm]
d	20,00	20,00	19,665	20,000
d2	18,376	18,376	18,205	18,376
d3	16,933	16,933	16,665	16,933

bolt		
P	mm	2,50
As	mm²	244,8
ds	mm	17,655
db	mm	0,000
d0	mm	17,65
A0	mm²	244,8
Re,Rp0,2	MPa	940
Rm	MPa	1040
Rm,max	MPa	1248
E	MPa	210000
tauBS/Rm		0,620
l	mm	60,00
lG	mm	52,50
SW	mm	17,00
DK	mm	30,00
dw	mm	28,87

TTJ		
material	1.0050 E295	
Rm	MPa	470
Re	MPa	270
E M	MPa	205000
tB	mm	35,0
tG	mm	30,0
m geo	mm	25,0
m tr	mm	20,0
Tol		6H
D2 nom	mm	18,376
D2 min	mm	18,376
D2 max	mm	18,602
D1 nom	mm	17,294
D1 min	mm	17,294
D1 max	mm	17,744
taubM/Rm		0,800
RS		0,787

ELONGATION		
delta SK	mm/N	0,121E-6
delta is	mm/N	0,114E-6
del.Gew	mm/N	0,582E-6
delta G	mm/N	0,211E-6
delta M	mm/N	0,102E-6
delta S	mm/N	1,13E-6
delta P	mm/N	0,259E-6
R S	N/mm	884,6E3
R P	N/mm	3,854E6
fSM	mm	0,215
fPM	mm	0,049
lers	mm	48,86
beta S	/Nmm	0,0577E-6
beta P	/Nmm	1,779E-9

VDI 2230-2014		
lk	mm	35,00
FKRmin	N	86940
FKRmax	N	100408
FM/FA		9,271
i F in		P 1
n1		0,28
delta1		0,187E-6
i F out		nut
phi K		0,260
phi n		0,073
n		0,28
Sigma 0	MPa	811
tau max	MPa	257
k tau		0,50
Sig.redB	MPa	841
tau B	MPa	576
tau M	MPa	217
beta M		0,58
±sig.ASV	MPa	45
±sigma a	MPa	2
±sig.ab	MPa	12
Tol FM	%	25,9
MA,max	Nm	521
MA-	Nm	367,6
MA,Re	Nm	578,9
MA,Rm	Nm	640,5
FM,Rm	N	233927
al.max	deg	38,1
R MA	Nm/°	13,78
R FM	N/°	4997
al.tors	°	0,1

Cylinder cap bolted joint as example of eccentric
clamping and loading
Source: VDI 2330-1:2014

LOAD,eccen.(s=-1,7, a=24)		
FA max	N	20525
FA min	N	6158
FQ	N	0
FKreq	N	68130
FKR min	N	86940
FM,Re	N	211434
FMzul,max	N	190291
FMmax,req	N	157955
FMmin,req	N	92914
fz	mm	0,008
Fz	N	5756
FV min,req	N	87158
FV min	N	106180
FV max	N	184535
FSA max	N	1286
FPA max	N	19239
FS max	N	191576
FS,Re	N	230107
FS,Rm	N	254586

ASSEMBLY (Bolt driven)		
nue Rp		0,90
alpha A		1,70
MA max	Nm	521
alpha max	deg	38,08

FRICTION	min
µG	0,100
µK	0,100
µTr	0,120
K	0,137

FACTORS OF SAFETY		
safety against loosening	FMzul/FMmax,req	1,20
safety yield point red.B	SF=Rp/Sig.redB	1,12
safety ag.fatigue fract.(eccen.)	SD=sig.AS/Sig.ab	3,80
safety plate surface pressure	Sp=pG/pBmax	1,02
safety against disengagement	FKRmin/FKab	1,28
thread strip safety at Rm,max	m tr / m min.	1,09

eccentric load		
FAmax*a	Nm	492,6
FV*ssym	Nm	-148,2
MB	Nm	0
a	mm	24,00
s sym	mm	-1,70
u	mm	13,80
v	mm	19,20
FK ab	N	68110
sig.SAbo	MPa	34
sig.SAbu	MPa	10

interface: P1 - nut		
delta P*	mm/N	0,263E-6
del.P**	mm/N	0,209E-6
beta P	/Nmm	1,779E-9
phi eK		0,224
phi en		0,063
AD	mm²	843,0
Aequ	mm²	564,5
I BT	mm4	109875
IBequ	mm4	119052
I'Bequ	mm4	95985

deformation cone		
DA,Gr	mm	57,50
phi	°	22,2
w		2
betaL		1,21

flange: de= 210mm, dt= 175mm, ns=15
T= 0Nm, Mb= 0Nm, Fxo=307876Nm, Fxu=92363Nm

i	material	E [MPa]	pG	pBmax	de pmax	d.[mm/N]
1	1.0050 E295	205000	710	699	34,7	0,259E-6

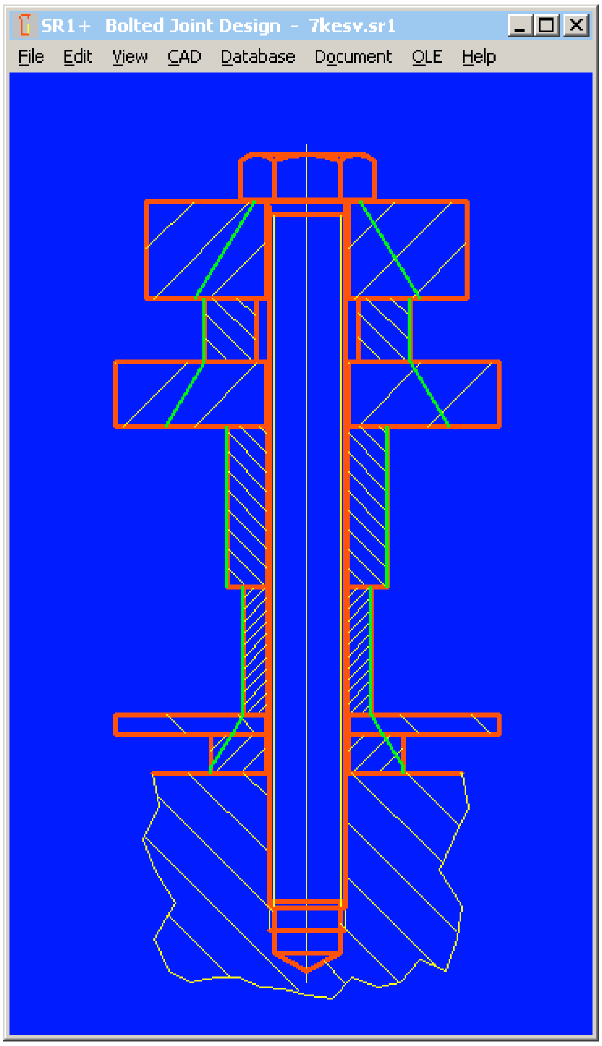
SR1 – Deformation cone to VDI 2230-1:2014

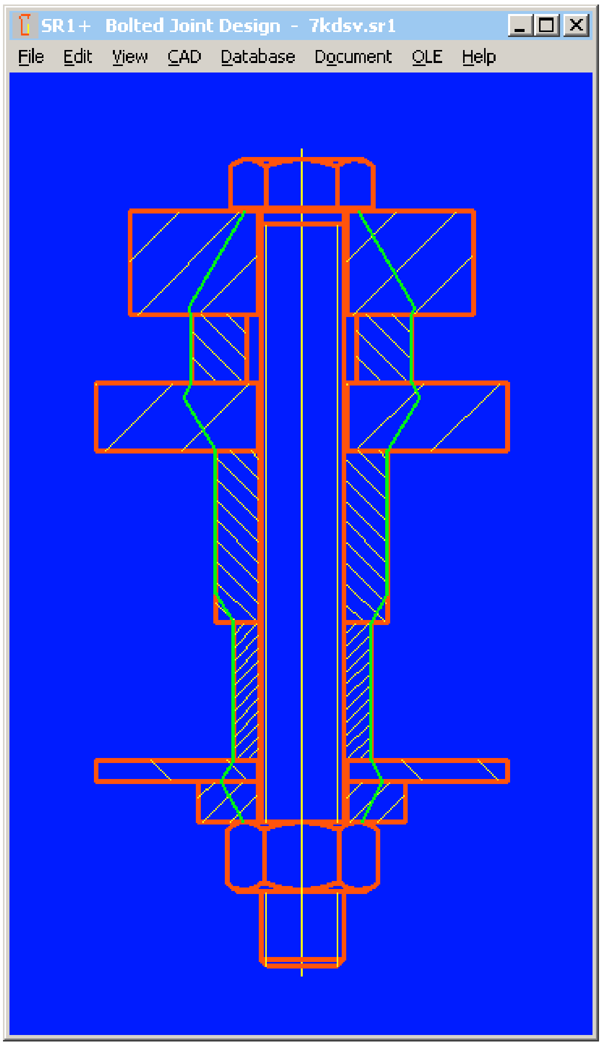
In the latest version of SR1 you can configure to calculate the elastic resilience by means of deformation cylinders to VDI2230:1986, or by means of deformation cones according to VDI 2230-1:2014. Unfortunately, calculation to VDI 2230-1:2014 assumes that clamping plates of every bolted joint can be treated as one deformation cone. But therefore, outside diameters should be similar, or should increase to a maximum in the middle between bolt head and nut. If this not applies, or E modules of clamping plate materials are not equal, elastic resilience of each clamping plate must be calculated separately. Bearing diameter dw for the upper surface of the next clamping plate is then bearing diameter for the lower side of the previous clamping plate. Formula (52) in VDI 2230-1:2014 is valid only if outside diameter of every clamping plate lies inside of the calculated deformation cone.

For the case that the calculated deformation cone is interrupted by a clamping plate with a small external diameter, SR1 uses a lightly modified formula (46) for clamping plate i:

dwmin = dw or dw of previous or next clamping plate
dwmax = dw + 2 lv(i) * tan (phi), or dw of previous or next clamping plate
tan(phi) = (dwmax-dwmin) / (2*li)
deltapvi = ln ((dwmin+dhi)*(dwmax-dhi)/(dwmin-dhi)*dwmax+dhi)) / (EP*dhi*pi*tan(phi)

VDI 2230-1:2014 makes a difference between TTJ (ESV) and TBJ (DSV) to ease the TTJ calculation with deformation cone and deformation cylinder, this leads to sequential errors. This can be shown in the following example, first as TTJ, and then as TBJ with nut.



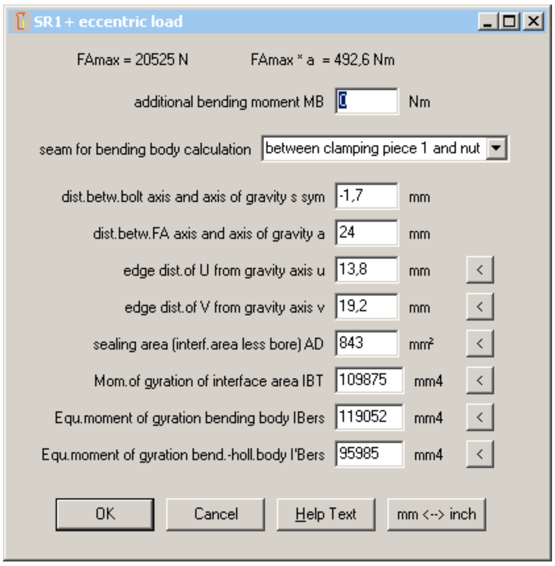


To avoid this error, VDI should define how to calculate a cone for tapped thread, or define a virtual bearing diameter dw for the internal threaded plate.

In SR1, you can configure at "Edit->Calculation Method", if elastic resilience should be calculated with cylindrical deformation bodies according to VDI 2230:1986, or with deformation cones according to VDI 2230-1:2014. For the present, old calculation with deformation cylinders is set as default method. You can change default settings by saving your individual default values in a file with file name "NULL". If a NULL.SR1 file exists, it will be loaded automatically when running SR1.

SR1 – Bending Moment MB

At "Eccentric Application", an additional bending moment can be entered. As defined in VDI2230-1:2014, additional to bending moment FA * a. MB is always static, and can be with positive or negative value.



FAmax = 20525 N   FAmax * a = 492,6 Nm

additional bending moment MB: 0 Nm

seam for bending body calculation: between clamping piece 1 and nut

dist.betw.bolt axis and axis of gravity s sym: -1,7 mm

dist.betw.FA axis and axis of gravity a: 24 mm

edge dist.of U from gravity axis u: 13,8 mm

edge dist.of V from gravity axis v: 19,2 mm

sealing area (interf.area less bore) AD: 843 mm²

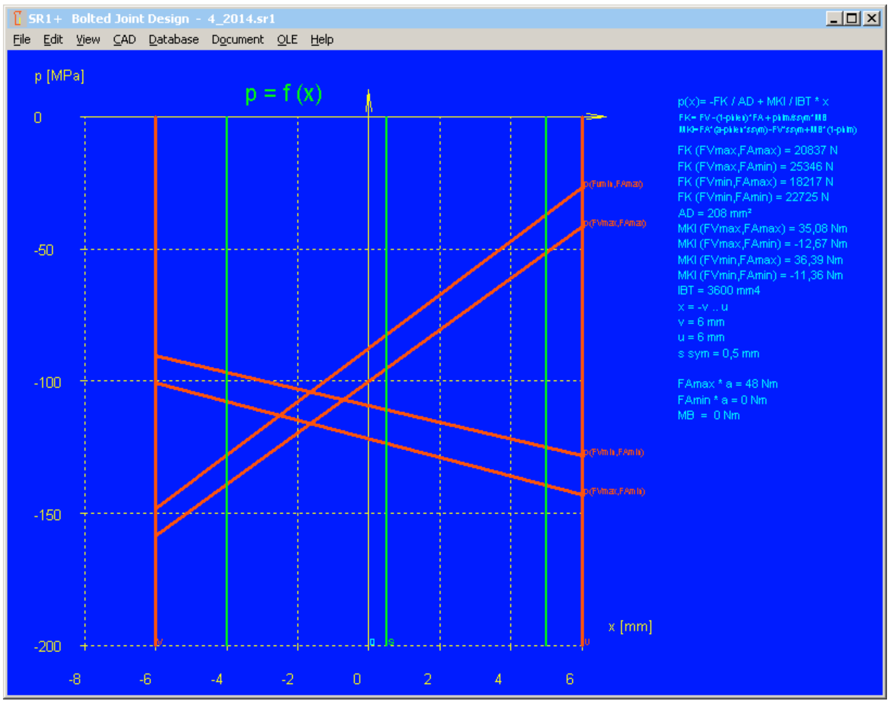
Mom.of gyration of interface area IBT: 109875 mm4

Equ.moment of gyration bending body IBers: 119052 mm4

Equ.moment of gyration bend.-holl.body I'Bers: 95985 mm4

SR1+ New Diagram p = f (x) for eccentric Load

Distribution of pressure along the interface (according to figure 25 in VDI 2230-1:2014) can be displayed as diagram in SR1+.



p(x)= -FK / AD + MKI / IBT * x

FK= FV-(1-phien)*FA+phim/ssym*MB

MKI=FA*(a-phien*ssym)-FV*ssym+MB*(1-phim)

FK (FVmax,FAmax) = 20837 N

FK (FVmax,FAmin) = 25346 N

FK (FVmin,FAmax) = 18217 N

FK (FVmin,FAmin) = 22725 N

AD = 208 mm²

MKI (FVmax,FAmax) = 35,08 Nm

MKI (FVmax,FAmin) = -12,67 Nm

MKI (FVmin,FAmax) = 36,39 Nm

MKI (FVmin,FAmin) = -11,36 Nm

IBT = 3600 mm4

x = -v .. u

v = 6 mm

u = 6 mm

s sym = 0,5 mm

FAmax * a = 48 Nm

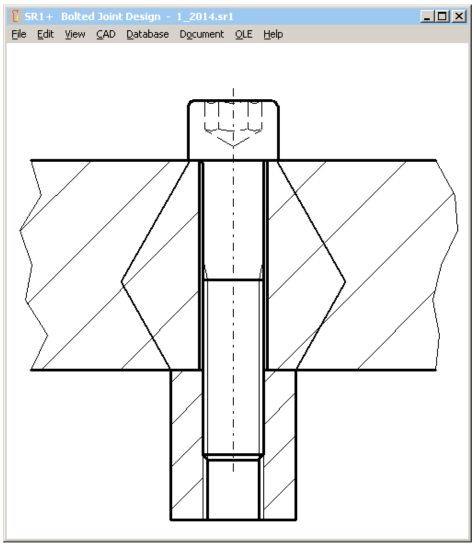
FAmin * a = 0 Nm

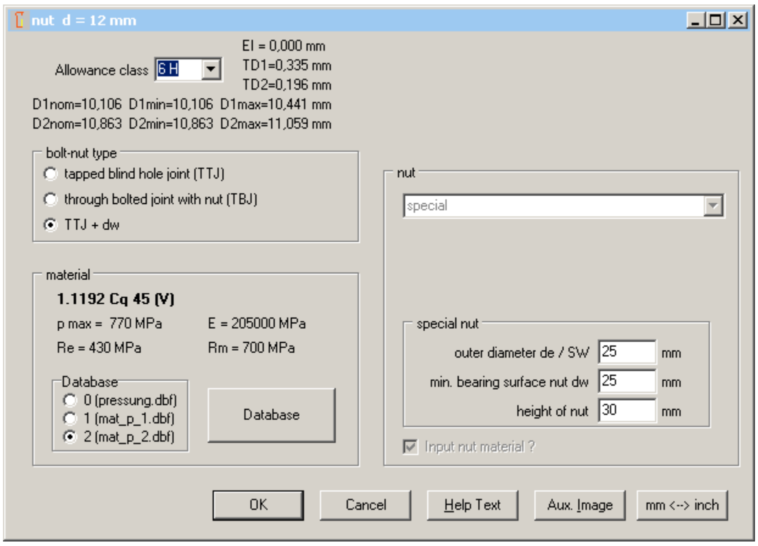
MB = 0 Nm

Interface between the eccentric loaded clamping plates begins at U and ends at V. "0" is center line (if symmetric) or center of gravity of the interface section. "S" is the center line of the bolt. If FAmax = FAmin, bending load is static, and the diagram shows two curves p (FVmax) and p(FVmin). For alphaA=1 (without tolerances) there is only one curve. Else, the diagram shows four curves: pressure for FAmax and FAmin with FVmin and FVmax.

SR1 – TTJ, TBJ, and „TTJ + dw“

In application example B1 of VDI 2230:2014, deformation cone is calculated as TTJ (through bolted joint with bearing diameter of a nut), but the elastic resilience of the inner thread is calculated as TTJ (tapped thread joint). So, a new bolt-nut type "TTJ + dw" has been defined in SR1 for to calculate this case, a tapped blind hole joint with bearing diameter.





Allowance class 6 H
EI = 0,000 mm
TD1=0,335 mm
TD2=0,196 mm
D1nom=10,106 D1min=10,106 D1max=10,441 mm
D2nom=10,863 D2min=10,863 D2max=11,059 mm

bolt-nut type
○ tapped blind hole joint (TTJ)
○ through bolted joint with nut (TBJ)
● TTJ + dw

material
1.1192 Cq 45 (V)
p max = 770 MPa E = 205000 MPa
Re = 430 MPa Rm = 700 MPa

Database
○ 0 (pressung.dbf)
○ 1 (mat_p_1.dbf)
● 2 (mat_p_2.dbf)

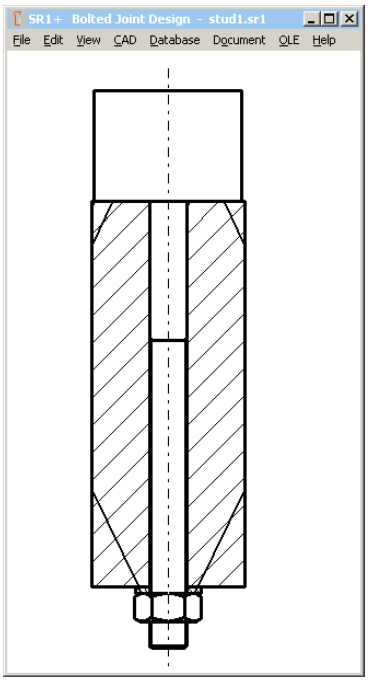
nut
special

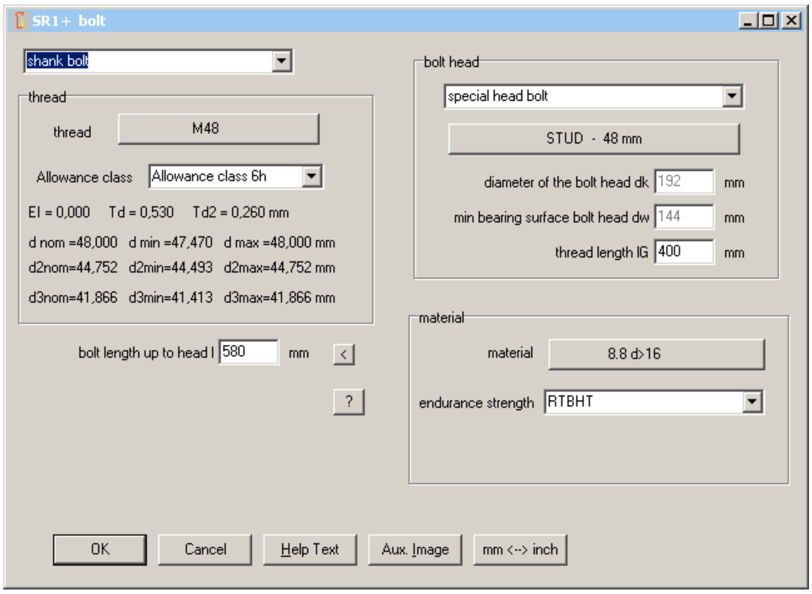
special nut
outer diameter de / SW 25 mm
min. bearing surface nut dw 25 mm
height of nut 30 mm
☑ Input nut material ?

Application example 3 VDI 2230 should be calculated in the same manner, but merely a simple TTJ was used there.

SR1 – Special head database for studs

If you selected "special bolt head" in the past, maybe you got a message „D=xx not found – Append dbf“, and you first had to define the bolt head data in the "sondkopf" database. Now, for all thread sizes a "special bolt head" was defined with head height h =3d, external diameter de=4d, and bearing diameter dw=3d. Such a bolt head can be used if a stud instead of a bolt should be calculated. In this case, bolt head is assumed as body with screwed-in stud.





shank bolt

thread
thread M48
Allowance class Allowance class 6h
EI = 0,000 Td = 0,530 Td2 = 0,260 mm
d nom =48,000 d min =47,470 d max =48,000 mm
d2nom=44,752 d2min=44,493 d2max=44,752 mm
d3nom=41,866 d3min=41,413 d3max=41,866 mm

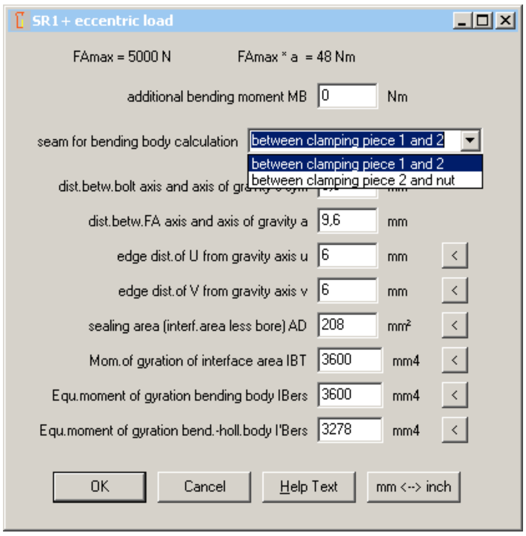
bolt length up to head l 580 mm

bolt head
special head bolt
STUD - 48 mm
diameter of the bolt head dk 192 mm
min bearing surface bolt head dw 144 mm
thread length lG 400 mm

material
material 8.8 d>16
endurance strength RTBHT

SR1 – Interface for eccentric load between clamping plate and nut

In the past, interface had to be selected between two clamping plates. Now, you can also select the bending interface between the last clamping plate and the plate with the internal thread.



FAmax = 5000 N   FAmax * a = 48 Nm

additional bending moment MB: 0 Nm

seam for bending body calculation: between clamping piece 1 and 2
- between clamping piece 1 and 2
- between clamping piece 2 and nut

dist.betw.FA axis and axis of gravity a: 9,6 mm

edge dist.of U from gravity axis u: 6 mm

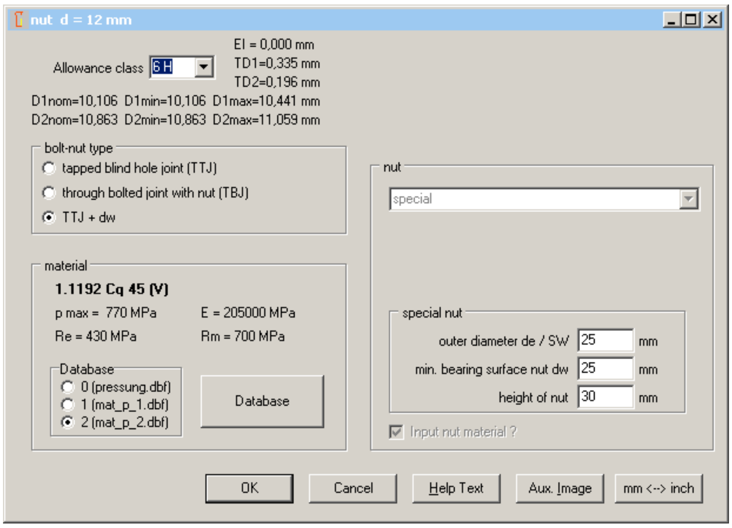
edge dist.of V from gravity axis v: 6 mm

sealing area (interf.area less bore) AD: 208 mm²

Mom.of gyration of interface area IBT: 3600 mm4

Equ.moment of gyration bending body IBers: 3600 mm4

Equ.moment of gyration bend.-holl.body I'Bers: 3278 mm4



Allowance class: 6 H

EI = 0,000 mm
TD1=0,335 mm
TD2=0,196 mm
D1nom=10,106 D1min=10,106 D1max=10,441 mm
D2nom=10,863 D2min=10,863 D2max=11,059 mm

bolt-nut type
- ○ tapped blind hole joint (TTJ)
- ○ through bolted joint with nut (TBJ)
- ● TTJ + dw

material
1.1192 Cq 45 (V)
p max = 770 MPa   E = 205000 MPa
Re = 430 MPa   Rm = 700 MPa

Database
- ○ 0 (pressung.dbf)
- ○ 1 (mat_p_1.dbf)
- ● 2 (mat_p_2.dbf)

nut: special

special nut
outer diameter de / SW: 25 mm
min. bearing surface nut dw: 25 mm
height of nut: 30 mm

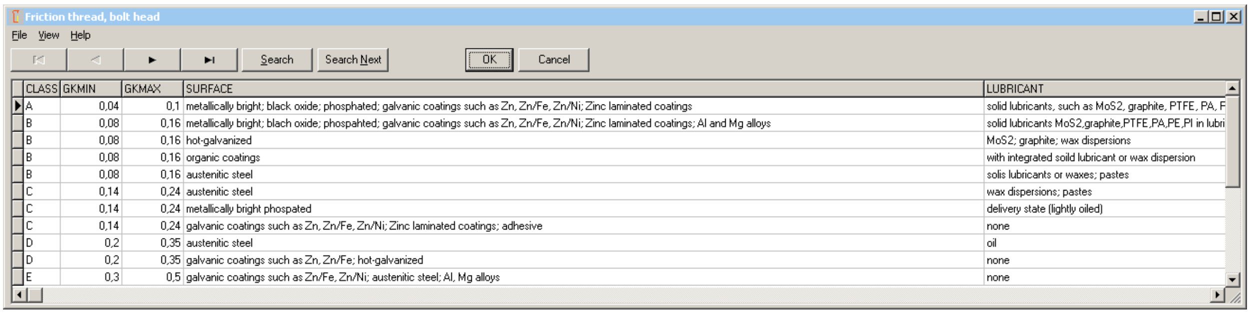
☑ Input nut material ?

SR1 – Special Nut

Until now, self-defined nuts were defined by nut height and bearing diameter dw (which was also used as external diameter). For a more realistic drawing, you can now also define an external diameter de (which can be width across flats, too).

SR1 – Friction Input with Database according to VDI2230:2014

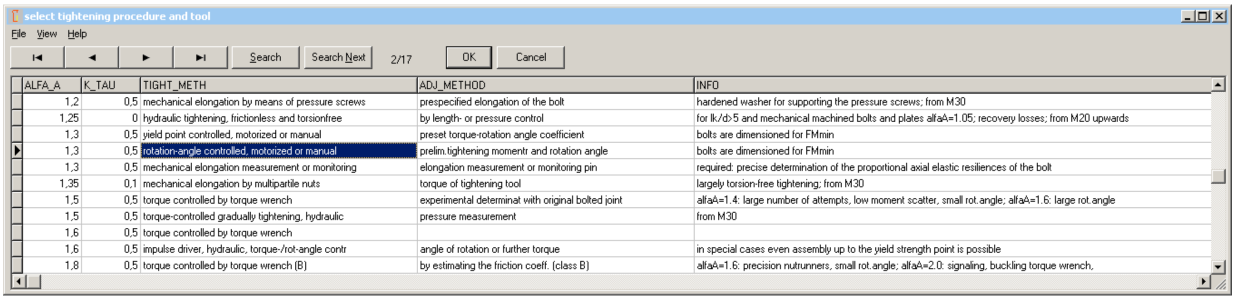
Min and max values of the friction coefficients can be selected from a new database with friction classes according to VDI 2230-1:2014.



CLASS	GKMIN	GKMAX	SURFACE	LUBRICANT
A	0,04	0,1	metallically bright; black oxide; phosphated; galvanic coatings such as Zn, Zn/Fe, Zn/Ni; Zinc laminated coatings	solid lubricants, such as MoS2, graphite, PTFE, PA, F
B	0,08	0,16	metallically bright; blach oxide; phospahted; galvanic coatings such as Zn, Zn/Fe, Zn/Ni; Zinc laminated coatings; Al and Mg alloys	solid lubricants MoS2,graphite,PTFE,PA,PE,PI in lubri
B	0,08	0,16	hot-galvanized	MoS2; graphite; wax dispersions
B	0,08	0,16	organic coatings	with integrated soild lubricant or wax dispersion
B	0,08	0,16	austenitic steel	solis lubricants or waxes; pastes
C	0,14	0,24	austenitic steel	wax dispersions; pastes
C	0,14	0,24	metallically bright phospated	delivery state (lightly oiled)
C	0,14	0,24	galvanic coatings such as Zn, Zn/Fe, Zn/Ni; Zinc laminated coatings; adhesive	none
D	0,2	0,35	austenitic steel	oil
D	0,2	0,35	galvanic coatings such as Zn, Zn/Fe; hot-galvanized	none
E	0,3	0,5	galvanic coatings such as Zn/Fe, Zn/Ni; austenitic steel; Al, Mg alloys	none

SR1 - Tightening Procedure with database according to VDI2230:2014

Tightening coefficient alphaA and reduction coefficient k tau together with tightening procedure and adjustment procedure can be loaded from the actualized database according to VDI 2230-1:2014.



ALFA_A	K_TAU	TIGHT_METH	ADJ_METHOD	INFO
1,2	0,5	mechanical elongation by means of pressure screws	prespecified elongation of the bolt	hardened washer for supporting the pressure screws; from M30
1,25	0	hydraulic tightening, frictionless and torsionfree	by length- or pressure control	for lk/d>5 and mechanical machined bolts and plates alfaA=1.05; recovery losses; from M20 upwards
1,3	0,5	yield point controlled, motorized or manual	preset torque-rotation angle coefficient	bolts are dimensioned for FMmin
1,3	0,5	rotation-angle controlled, motorized or manual	prelim.tightening momentr and rotation angle	bolts are dimensioned for FMmin
1,3	0,5	mechanical elongation measurement or monitoring	elongation measurement or monitoring pin	required: precise determination of the proportional axial elastic resiliences of the bolt
1,35	0,1	mechanical elongation by multipartile nuts	torque of tightening tool	largely torsion-free tightening; from M30
1,5	0,5	torque controlled by torque wrench	experimental determinat with original bolted joint	alfaA=1.4: large number of attempts, low moment scatter, small rot.angle; alfaA=1.6: large rot.angle
1,5	0,5	torque-controlled gradually tightening, hydraulic	pressure measurement	from M30
1,6	0,5	torque controlled by torque wrench		
1,6	0,5	impulse driver, hydraulic, torque-/rot-angle contr	angle of rotation or further torque	in special cases even assembly up to the yield strength point is possible
1,8	0,5	torque controlled by torque wrench (B)	by estimating the friction coeff. (class B)	alfaA=1.6: precision nutrunners, small rot.angle; alfaA=2.0: signaling, buckling torque wrench,

SR1 – Safety against shearing and bolt bearing pressure if radial load FQ

Because safety against shearing and bolt bearing pressure is listed in VDI 2230-1:2014, safety factors SA and SL have been added to SR1, too. Even though shearing by radial load cannot occur, if safety factor SG is higher than 1.
Similar for safety factor SL: because radial load is transferred by friction, a safety factor SL smaller than 1 maybe is no severe problem, if safety factor SG against slipping is higher than 1.

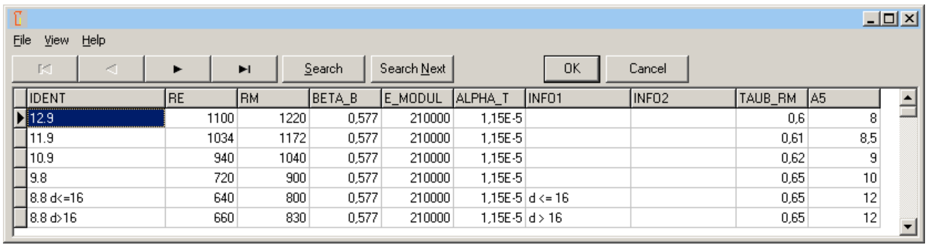
SR1 - Thread database

Row-2 and row-3 sizes added (M9, M11, M45, M52, M60, M68, M52x3, M39x3, M45x3 etc.)

SR1 – Database Hexagon Head Bolt

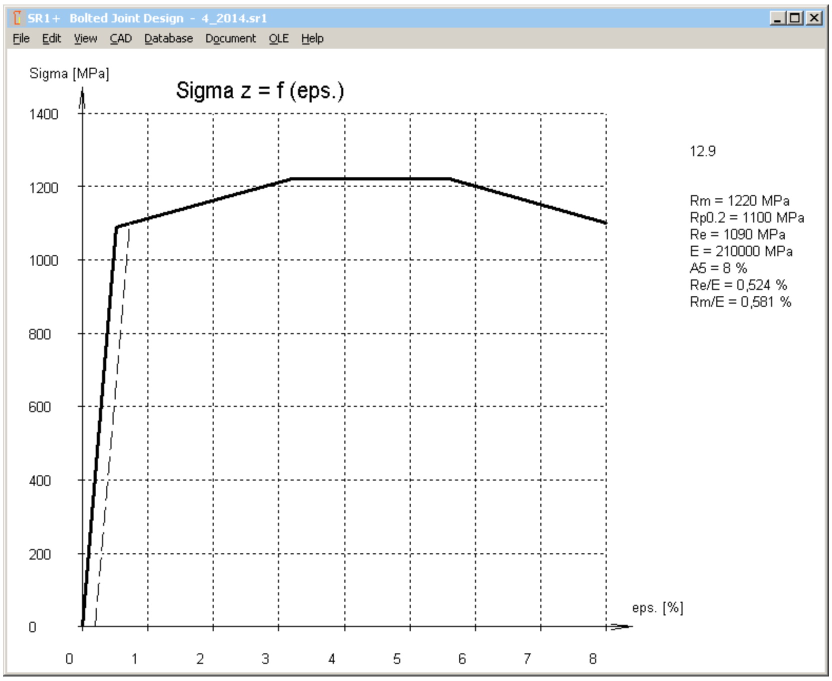
Fine thread bolts ISO 8676 and ISO 8765 added.

SR1 – Tension-Elongation Diagram



IDENT	RE	RM	BETA_B	E_MODUL	ALPHA_T	INFO1	INFO2	TAUB_RM	A5
12.9	1100	1220	0,577	210000	1,15E-5			0,6	8
11.9	1034	1172	0,577	210000	1,15E-5			0,61	8,5
10.9	940	1040	0,577	210000	1,15E-5			0,62	9
9.8	720	900	0,577	210000	1,15E-5			0,65	10
8.8 d<=16	640	800	0,577	210000	1,15E-5	d <= 16		0,65	12
8.8 d>16	660	830	0,577	210000	1,15E-5	d > 16		0,65	12

Elongation at fracture (A5) had been added in the mat_bolt database with bolt materials.
Elongation at fracture together with modulus of elasticity, tensile strength and yield point can be used to design a stress-elongation diagram for the bolt material.
Hypotheses:
Heat-treated steel, elastic elongation until yield point, then linear increase of stress until tensile strength and plastic elongation until 40 per cent of A5, then further elongation at tensile strength until 70% of A5, then further elongation until A5 with decrease of stress until yield point.

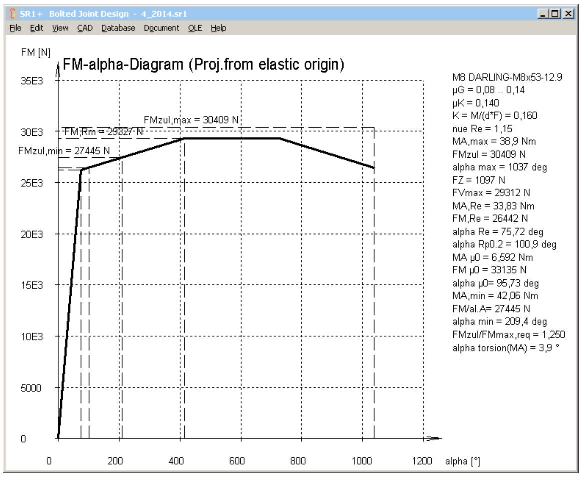


12.9

Rm = 1220 MPa
Rp0.2 = 1100 MPa
Re = 1090 MPa
E = 210000 MPa
A5 = 8 %
Re/E = 0,524 %
Rm/E = 0,581 %

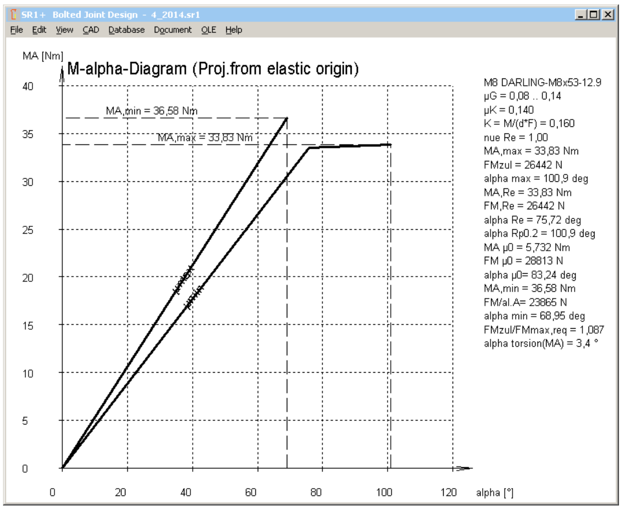
F-alpha, M-alpha Diagram for over-elastic tightening

Tightening angle for clamp load and tightening torque beyond yield point can be calculated from the stress-elongation diagram of the bolt material. If a yield point factor nueRe of 1.0 or higher was defined, F-alpha diagram and M-alpha diagram now consider torque angle beyond yield point. Here you can see that plastic deformation grows much higher than elastic deformation. Module of plasticity can be calculated as
P module = (Rm-Re)/(0.4 * A5 % / 100% - Re / E-Module)
In the example shown, P module is only 0.02 of E module.

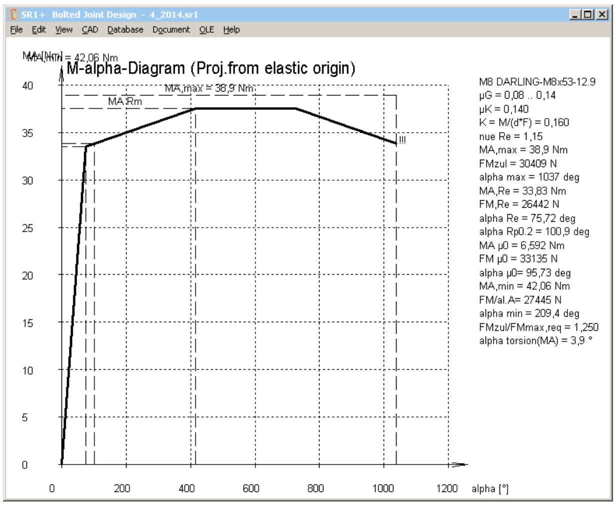


```
M8 DARLING-M8x53-12.9
μG = 0,08 .. 0,14
μK = 0,140
K = M/(d*F) = 0,160
nue Re = 1,15
MA,max = 38,9 Nm
FMzul = 30409 N
alpha max = 1037 deg
FZ = 1097 N
FVmax = 29312 N
MA,Re = 33,83 Nm
FM,Re = 26442 N
alpha Re = 75,72 deg
alpha Rp0.2 = 100,9 deg
MA μ0 = 6,592 Nm
FM μ0 = 33135 N
alpha μ0= 95,73 deg
MA,min = 42,06 Nm
FM/al.A= 27445 N
alpha min = 209,4 deg
FMzul/FMmax,req = 1,250
alpha torsion(MA) = 3,9 °
```

In the example with nueRe=1.15 (only 15% beyond yield point), yield point is reached at a torque angle of 75 degrees. Further tightening until 400 deg increases the clamp load by only 10 per cent. Then you can tighten without increasing torque, and finally the bolt breaks at a tightening angle of 1000 degrees.



```
M8 DARLING-M8x53-12.9
μG = 0,08 .. 0,14
μK = 0,140
K = M/(d*F) = 0,160
nue Re = 1,00
MA,max = 33,83 Nm
FMzul = 26442 N
alpha max = 100,9 deg
MA,Re = 33,83 Nm
FM,Re = 26442 N
alpha Re = 75,72 deg
alpha Rp0.2 = 100,9 deg
MA μ0 = 5,732 Nm
FM μ0 = 28813 N
alpha μ0= 83,24 deg
MA,min = 36,58 Nm
FM/al.A= 23865 N
alpha min = 68,95 deg
FMzul/FMmax,req = 1,087
alpha torsion(MA) = 3,4 °
```



```
M8 DARLING-M8x53-12.9
μG = 0,08 .. 0,14
μK = 0,140
K = M/(d*F) = 0,160
nue Re = 1,15
MA,max = 38,9 Nm
FMzul = 30409 N
alpha max = 1037 deg
MA,Re = 33,83 Nm
FM,Re = 26442 N
alpha Re = 75,72 deg
alpha Rp0.2 = 100,9 deg
MA μ0 = 6,592 Nm
FM μ0 = 33135 N
alpha μ0= 95,73 deg
MA,min = 42,06 Nm
FM/al.A= 27445 N
alpha min = 209,4 deg
FMzul/FMmax,req = 1,250
alpha torsion(MA) = 3,9 °
```

At over-elastic tightening, yield point should be overridden as little as possible. Already the 0.2 per cent plastic deformation at Rp0.2 corresponds in the example to 20 degrees tightening angle. For torque-and-angle-controlled tightening, this may be sufficient to recognize the yield point and stop tightening process. If dynamic load, sum of FVmax+FSA must not override the yield point, else bolt would be elongated with every load cycle until fracture.
VDI 2230-1:2014 increases pressure between clamping plates because of yield point tolerance (+25%) to pmax = FMTab/Apmin*1.4 (R10/3)   (with FMTab = RM,Re*0.9)

In SR1, we use another method with the same result: If a yield point factor nueRe >= 1 was defined, you get a warning if safety Sp = pG/pBmax is less than 1.25.

Mistakes in VDI 2230-1:2014 (Continuation of Info 148)
New VDI 2230 contains so many mistakes that it would require too much space to describe all in this info letter. So all of the mistakes, together with my comments, are described on separate pages:
www.hexagon.de/rs/vdi2230e.htm
The VDI did not publish correction pages until now. My inquiry remained unanswered.

Modulus of elasticity of bolt material
All application examples in VDI 2230-1:2014 are calulated with an E module of 205 000 MPa. But the E module of 8.8, 10.9 and 12.9 is 210000 MPa at 20°C. If you recalculate the application examples with SR1 and compare the results, this difference has to be considered.

Pg. 11: I, IB, Ibers, IBT ..
Translation error: Flächenträgheitsmoment = area moment of inertia (not moment of gyration)

Pg. 36 (R9/1):
Stress area of Sigma a is A0 instead of AS (at least for necked-down bolts and hollow bolts).

Pg. 50, 51, 52
Bending body must be calculated from the real geometry (prismatic), not from a virtual deformation body (cylinder and cone) of the bolted joint.
Pg. 67 Equation (98): phim* = n * ...
Load introduction coefficient of axial load FA must not be used with MB.

Pg. 88 (149)
Cit.: SigmaZ = 1/A0*(FMzul + FSAmax – delta FVth) + MSbmax/Wb
For eccentric load, bending stress by MB has to be added. And for operating state, FMzul can be replaced by FVmax.
Centric: SigmaZ = max(FMzul/A0, 1/A0*(FVmax + FSAmax – delta FVth)
Eccentric: SigmaZ = max(FMzul/A0, 1/A0*(FVmax – delta FVth) + SigmaSAb
Remark: FSAmax/A0 and Msbmax/Wb is included in SigmaSab. And equation (186) has to be modified, so that external bending moments MB are considered., see Pg.95.

Pg. 88: (150):
Equation (150) is redundant, equation (149) is sufficient.

Pg. 90,91: FV1
Clamp Load FV1 calculated with equation (161) is higher than permissible assembly preload FMzul.

Pg. 95 (186)
Bending moment MB is not considered in Sigma Sab calculation.
And stress in the weakest area (with A0 and Wb0 instead of AS and WS) should be calculated (concerns hollow bolts and waisted bolts)
Equation (186) with bending moment FA*a and bending moment MB should be:
`Sigma Sab = phien*FA/A0 + ßP/ßS*(FA*a – FA*ssym*phien + MB(1-sign(ssym)phim)/Wb0`

Pg. 96 (187, 188, 189)
Equations (187), (188), (189) are redundant.

VDI 2230-1:2014: Pg.144: Example B3:

delta i = (l1+l2+l3)/ES/(A0-ABore)
A0 wrong, because of different diameters d1,d2,d3

Pg.147: Example B3: R11 Length of engagement

Equation used for calculation of RS is valid for equal shear stress coefficients of bolt material and nut material only. But tauBS/Rm of 8.8 is 0.65 and tauBM/Rm of 16MnCr5 is 0.85 according to VDI2230-1:2014 tables. Calculated RS is then 2.0, and not 1.52.

Pg.148: Example B3: R11 Length of engagement

Cit.: „__while this applies to the hollow bolt: Rmmax*AS = FMzul“__
What? Rm,max*AS = FMzul ? Why?
For hollow bolts, use A0 instead of AS, but not FMzul.
Rm,max * A0 = 830 N/mm^2 * 1.2 * 251 mm^2 = 250 kN
That is approx. twice as FM zul.
Calculated length of engagement is then 4.85 mm only, plus mzu=2.4mm
Here the correct results:
meffmin = 8,0mm (instead of 4,8mm) with Rmmax*A0=250Nm and C2=1.16 from RS=2.0
mgesmin = meffmin + mzu = 8 + 1.2*2 = 10.4 mm
Why is mzu 1.2 P only? Normally, it is 2.0 P.

Pg.149: Example B4: Initial conditions

Cit: “Cq 45 heat treated to a tensile strength of 900 N/mm^2“
Cq45 cannot be heat-treated to 900 N/mm^2. +QT: 700-850 N/mm^2 for t<8mm

Pg.150: Example B4: R1: Determining the tightening factor alphaA

Cit.: The bolt is tightened using the angle-controlled tightening technique. According to table A8, the tightening factor is alphaA=1.
Right: According to table A8, the tightening factor alphaA is between 1.2 and 1.4.
alphaA=1 is a theoretical ideal case without scatter nor friction tolerance.

Pg.155: Example B4: R8:

FV1 = 31 467 N
Then the clamp load following initial loading is higher than permissible assembly clamp load FMzul = 26 444 N!

Pg.156: Example B4: R8:

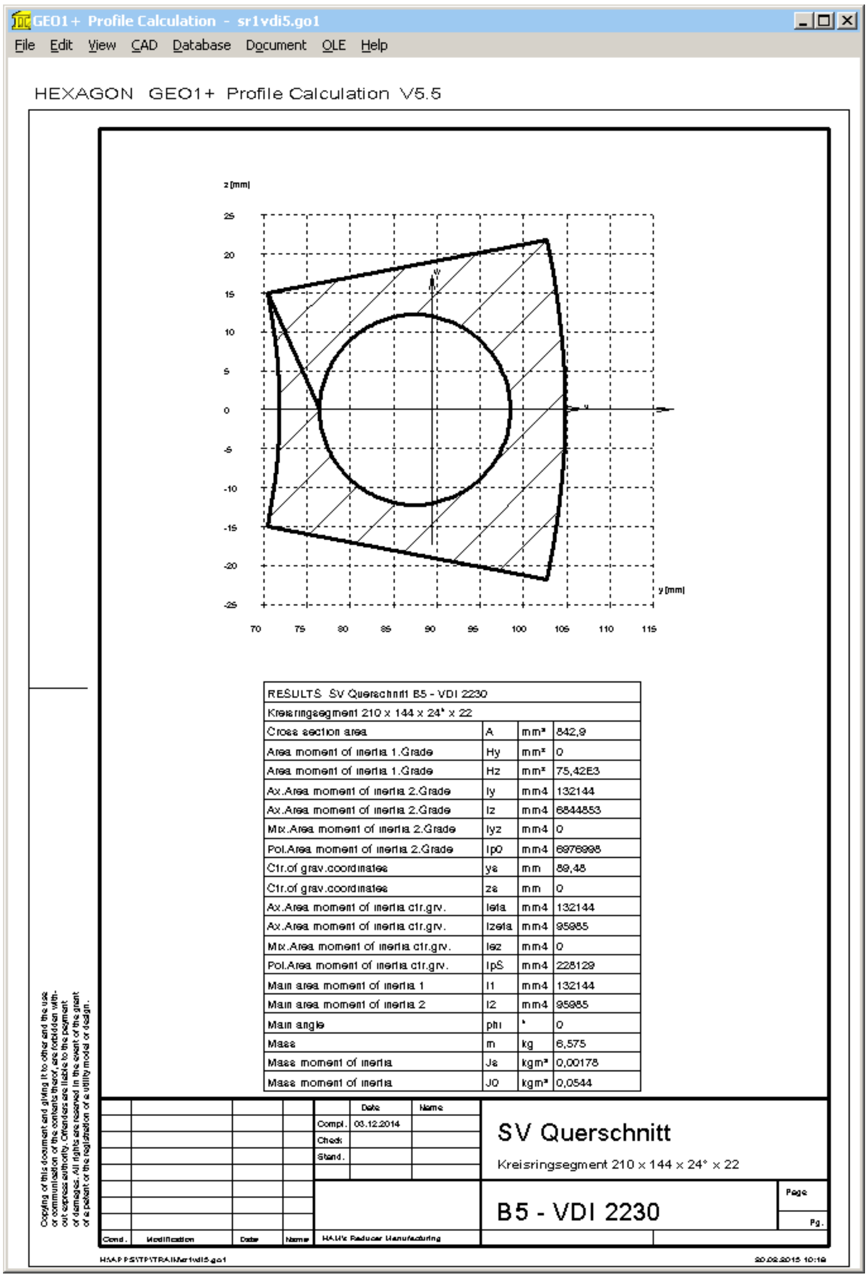
Cit.: The BJ satisfies the requirements.
But working stress sigma red,B should be calculated in R8, and not the remaining clamp load!
Sigma0 = FMzul/A0 + SigmaSabmax = 26442 / 26.6 + 61 = 1055 N/mm^2
taumax = MG/Wp = 363 N/mm^2
Sigma red,B = 1102 N/mm^2 (with ktau=0.5)
SF = Rp0.2 / Sigma red,B = 1100 / 1102 = 0.998

Pg. 157: Example B4: R9:

SigmaSAbo: For maximum bending stress in the weakest cross-section, dS = 6.827 mm must be replaced by dT= 5.82 mm, and AS must be replaced with A0=pi/4*dT^2.
Sigma SAbo is then 62 N/mm^2

VDI 2230-1:2014: Pg. 162: Example B5:

Recalculation: ssym is +1.98 mm, and not –1.7 mm. Even in figure B7, ssym is positive.
"Check for the sign rule according to table 4" corresponds to case I, and not to case III.
ssym is the distance between center of gravity axis and bolt axis. GEO1+ software may be used to calculate center of gravity and ssym.



RESULTS SV Querschnitt B5 - VDI 2230			
Kreisringsegment 210 x 144 x 24° x 22			
Cross section area	A	mm^2	842,9
Area moment of inertia 1.Grade	Hy	mm^3	0
Area moment of inertia 1.Grade	Hz	mm^3	75,42E3
Ax.Area moment of inertia 2.Grade	Iy	mm4	132144
Ax.Area moment of inertia 2.Grade	Iz	mm4	6844853
Mix.Area moment of inertia 2.Grade	Iyz	mm4	0
Pol.Area moment of inertia 2.Grade	Ip0	mm4	6976998
Ctr.of grav.coordinates	ys	mm	89,48
Ctr.of grav.coordinates	zs	mm	0
Ax.Area moment of inertia ctr.grv.	Ieta	mm4	132144
Ax.Area moment of inertia ctr.grv.	Izeta	mm4	95985
Mix.Area moment of inertia ctr.grv.	Iez	mm4	0
Pol.Area moment of inertia ctr.grv.	IpS	mm4	228129
Main area moment of inertia 1	I1	mm4	132144
Main area moment of inertia 2	I2	mm4	95985
Main angle	phi	°	0
Mass	m	kg	6,575
Mass moment of inertia	Js	kgm^2	0,00178
Mass moment of inertia	J0	kgm^2	0,0544

	Date	Name
Compl.	03.12.2014	
Check		
Stand.		

Cond.	Modification	Date	Name

HAU's Reducer Manufacturing

SV Querschnitt

Kreisringsegment 210 x 144 x 24° x 22

B5 - VDI 2230

Page

Pg.

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H:\APPS\TP\TRAIN\sr1vdi5.go1

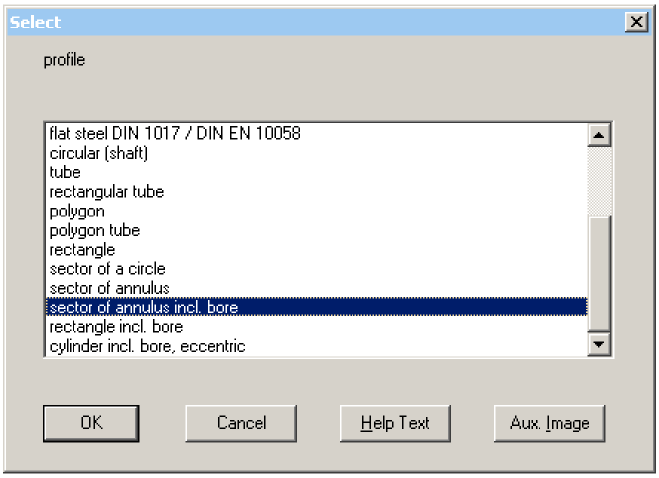
20.02.2015 10:19

With coordinates of interface area are ri=72mm, re=105mm, alpha = 24°, rS=87.5mm and dh=22mm, GEO1+ calculates ys=89.48 mm. Thus ssym = ys – rS = 89.48-87.5 = 1.98 mm, u = ys – ri = 89.48-72=17.48 mm, and v = re - ys = 15.48 mm.
Area moment of inertia at w axis is Izeta= IBT = 95985 mm^4.

Pg. 168: R8

Cit.: sigma zmax = FSmax/AS = 780.3 N/mm²
Comment: Bending stress by eccentric load not considered
Correct: Sigma zmax = FMzul / As + Sigma Sab = 190000/245 + 35,6 = 811 N/mm²
Sigma red,B = 841 N/mm²
SF = 1,12

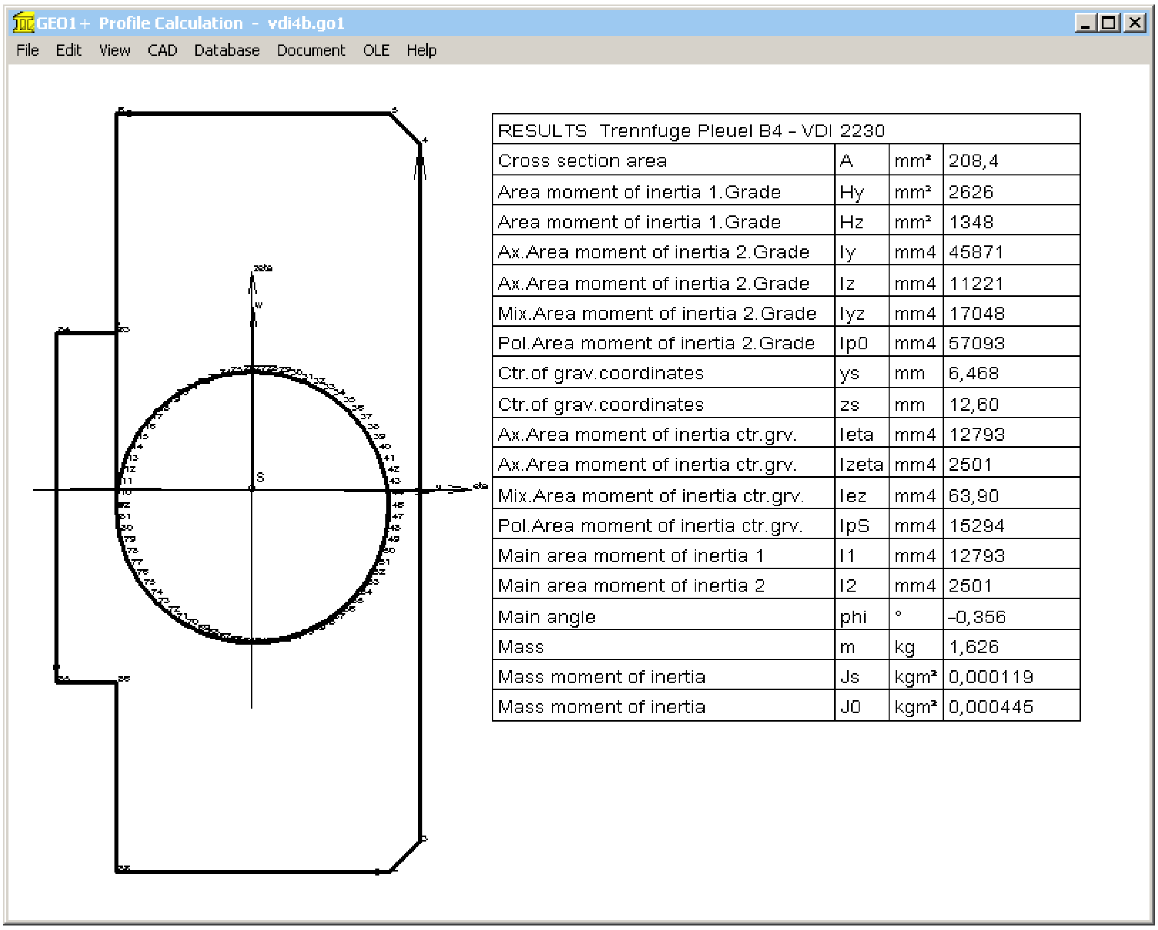
GEO1+, TR1 – Sector of circle and sector of annulus with or without bore



profile

flat steel DIN 1017 / DIN EN 10058
circular (shaft)
tube
rectangular tube
polygon
polygon tube
rectangle
sector of a circle
sector of annulus
sector of annulus incl. bore
rectangle incl. bore
cylinder incl. bore, eccentric

GEO1 software is a good tool to calculate interface section and section of bending body of eccentric loaded bolted joints. But the input of coordinates was inconvenient for the annulus sector of VDI 2230 example B5. Therefore, sector of circle and sector of annulus has been added to the predefined profiles, so that you can define the geometry of the cross section now by input of external and inner diameter, arc angle, bore diameter and pitch-circle diameter. Other new predefined profiles are "rectangle with hole" and "circle with eccentric hole" to calculate interface sections of prismatic and cylindrical clamping plates of bolted joints. Pre-defined profiles are available in GEO1+ only, not in GEO1. We will no longer provide GEO1, only GEO1+ with profile databases and pre-defined profiles is available in future.



RESULTS Trennfuge Pleuel B4 - VDI 2230			
Cross section area	A	mm²	208,4
Area moment of inertia 1.Grade	Hy	mm³	2626
Area moment of inertia 1.Grade	Hz	mm³	1348
Ax.Area moment of inertia 2.Grade	Iy	mm4	45871
Ax.Area moment of inertia 2.Grade	Iz	mm4	11221
Mix.Area moment of inertia 2.Grade	Iyz	mm4	17048
Pol.Area moment of inertia 2.Grade	Ip0	mm4	57093
Ctr.of grav.coordinates	ys	mm	6,468
Ctr.of grav.coordinates	zs	mm	12,60
Ax.Area moment of inertia ctr.grv.	Ieta	mm4	12793
Ax.Area moment of inertia ctr.grv.	Izeta	mm4	2501
Mix.Area moment of inertia ctr.grv.	Iez	mm4	63,90
Pol.Area moment of inertia ctr.grv.	IpS	mm4	15294
Main area moment of inertia 1	I1	mm4	12793
Main area moment of inertia 2	I2	mm4	2501
Main angle	phi	°	-0,356
Mass	m	kg	1,626
Mass moment of inertia	Js	kgm²	0,000119
Mass moment of inertia	J0	kgm²	0,000445

FED1+ Increased coil diameter De1 and De2

A new column with external coil diameters De1, De2, Dec has been added to the table with spring loads and dimensions at position 0,1,2,n,c. Because the formula for deltaDe in EN 13906 calculates increase of coil diameter on block length Lc only, a formula with variable spring length Lx had to be developed:

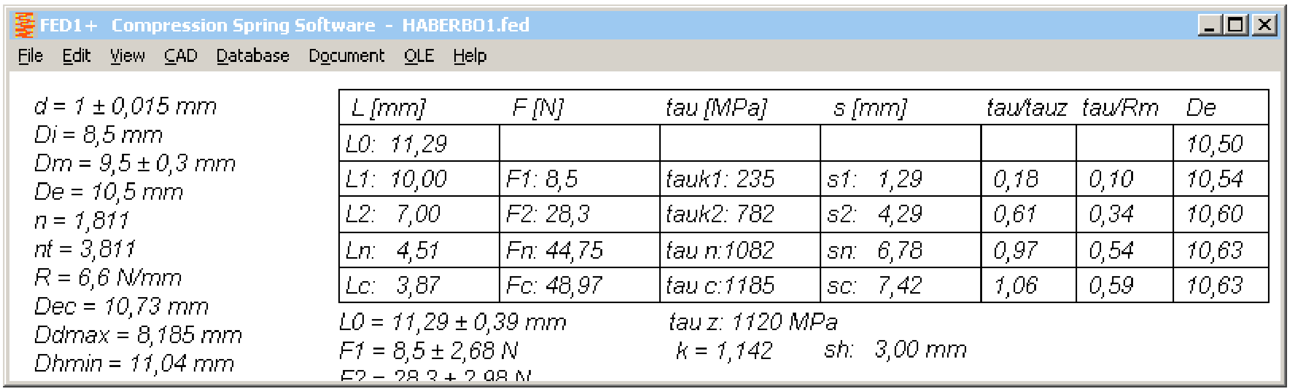
```
DeltaDe = sqrt(D²+(P0²-Px²)/pi²) – D
With pitch Px = (Lx-Lc)/n + d and  P0 = (L0-Lc)/n + d
x = 0,1,2,n,c
Pc (pitch at block length) = d
```

To verify the results, one could calculate coil diameter from wire length:

```
D = Lwire / (nt * pi)
```

The value is a bit smaller than to the previous formula, because the end coils are calculated with increased coil diameter, too.

Compared with the results of the EN 13906 formula, new value for Dec in FED1+ is always lower than De+deltaDe to EN 13906, maybe due to a safety margin. Therefore, both values are listed now in FED1+ (until further advice): Dec according to EN 13906, and De1, De2, Den and Dec in the table according to new formula.



d = 1 ± 0,015 mm
Di = 8,5 mm
Dm = 9,5 ± 0,3 mm
De = 10,5 mm
n = 1,811
nt = 3,811
R = 6,6 N/mm
Dec = 10,73 mm
Ddmax = 8,185 mm
Dhmin = 11,04 mm

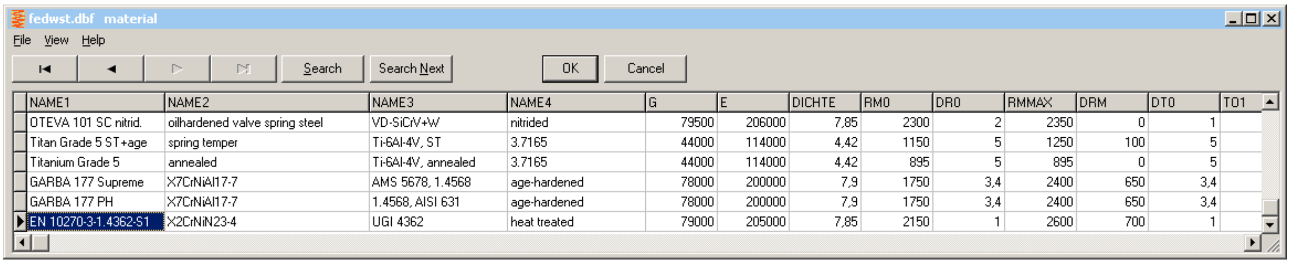
L [mm]	F [N]	tau [MPa]	s [mm]	tau/tauz	tau/Rm	De
L0: 11,29						10,50
L1: 10,00	F1: 8,5	tauk1: 235	s1: 1,29	0,18	0,10	10,54
L2: 7,00	F2: 28,3	tauk2: 782	s2: 4,29	0,61	0,34	10,60
Ln: 4,51	Fn: 44,75	tau n:1082	sn: 6,78	0,97	0,54	10,63
Lc: 3,87	Fc: 48,97	tau c:1185	sc: 7,42	1,06	0,59	10,63

L0 = 11,29 ± 0,39 mm
F1 = 8,5 ± 2,68 N
F2 = 28,3 ± 2,98 N

tau z: 1120 MPa
k = 1,142
sh: 3,00 mm

FED1+, 2+, 3+, 5, 6. 7, 8, 9, 11: Spring Material UGI 4362 (1.4362 / X2CrNiN23-4)

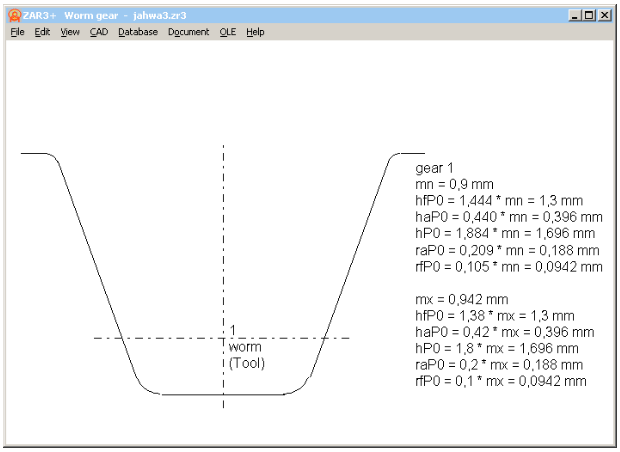
New material has been added to fedwst.dbf database (No.88). Data according to data sheet UGI 4362. Properties: tensile strength as 1.4310-HS, corrosion-resistant as 1.4401.



NAME1	NAME2	NAME3	NAME4	G	E	DICHTE	RM0	DR0	RMMAX	DRM	DT0	T01
OTEVA 101 SC nitrid.	oilhardened valve spring steel	VD-SiCrV+W	nitrided	79500	206000	7,85	2300	2	2350	0	1	
Titan Grade 5 ST+age	spring temper	Ti-6Al-4V, ST	3.7165	44000	114000	4,42	1150	5	1250	100	5	
Titanium Grade 5	annealed	Ti-6Al-4V, annealed	3.7165	44000	114000	4,42	895	5	895	0	5	
GARBA 177 Supreme	X7CrNiAl17-7	AMS 5678, 1.4568	age-hardened	78000	200000	7,9	1750	3,4	2400	650	3,4	
GARBA 177 PH	X7CrNiAl17-7	1.4568, AISI 631	age-hardened	78000	200000	7,9	1750	3,4	2400	650	3,4	
EN 10270-3-1.4362-S1	X2CrNiN23-4	UGI 4362	heat treated	79000	205000	7,85	2150	1	2600	700	1	

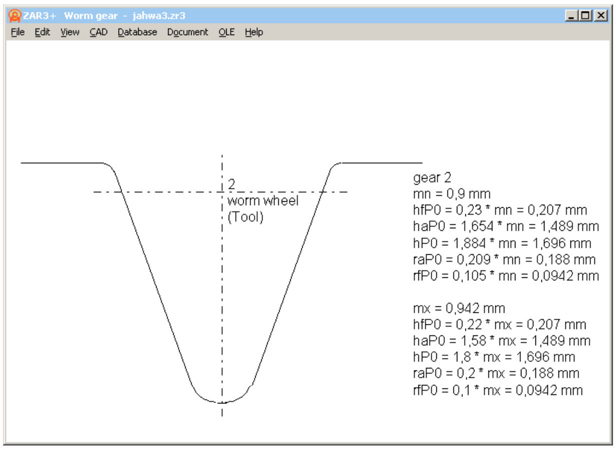
ZAR3+ Tool Profile

Reference profile of the tool can now be drawn on screen, or exported at "CAD".



```
gear 1
mn = 0,9 mm
hfP0 = 1,444 * mn = 1,3 mm
haP0 = 0,440 * mn = 0,396 mm
hP0 = 1,884 * mn = 1,696 mm
raP0 = 0,209 * mn = 0,188 mm
rfP0 = 0,105 * mn = 0,0942 mm

mx = 0,942 mm
hfP0 = 1,38 * mx = 1,3 mm
haP0 = 0,42 * mx = 0,396 mm
hP0 = 1,8 * mx = 1,696 mm
raP0 = 0,2 * mx = 0,188 mm
rfP0 = 0,1 * mx = 0,0942 mm
```

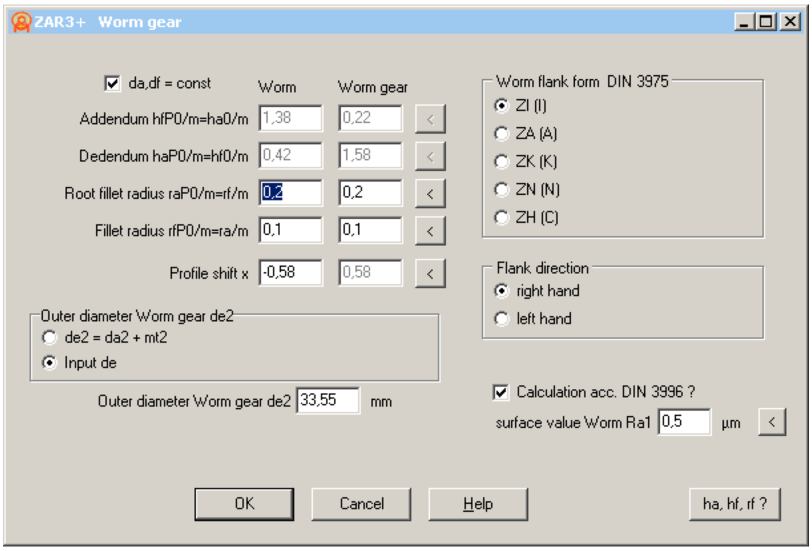


```
gear 2
mn = 0,9 mm
hfP0 = 0,23 * mn = 0,207 mm
haP0 = 1,654 * mn = 1,489 mm
hP0 = 1,884 * mn = 1,696 mm
raP0 = 0,209 * mn = 0,188 mm
rfP0 = 0,105 * mn = 0,0942 mm

mx = 0,942 mm
hfP0 = 0,22 * mx = 0,207 mm
haP0 = 1,58 * mx = 1,489 mm
hP0 = 1,8 * mx = 1,696 mm
raP0 = 0,2 * mx = 0,188 mm
rfP0 = 0,1 * mx = 0,0942 mm
```

ZAR3+ Tooth height coefficients and complementary gear pairs

At "Edit->Production", a fillet radius at tip diameter (=root fillet at tool) had been added.
And if you set „da,df = const“, you can only input x1. Profile shift x2 is set -x1, so that tip diameter and root diameter remain unchanged, and tooth height factors are calculated accordingly.
For a complementary gear pair with thin worm teeth and thick teeth of the worm wheel, profile shift of the worm is negative, and positive for worm wheel.



☑ da,df = const

	Worm	Worm gear
Addendum hfP0/m=haO/m	1,38	0,22
Dedendum haP0/m=hf0/m	0,42	1,58
Root fillet radius raP0/m=rf/m	0,2	0,2
Fillet radius rfP0/m=ra/m	0,1	0,1
Profile shift x	-0,58	0,58

Outer diameter Worm gear de2
○ de2 = da2 + mt2
● Input de

Outer diameter Worm gear de2 33,55 mm

Worm flank form DIN 3975
● ZI (I)
○ ZA (A)
○ ZK (K)
○ ZN (N)
○ ZH (C)

Flank direction
● right hand
○ left hand

☑ Calculation acc. DIN 3996 ?
surface value Worm Ra1 0,5 µm

HEXAGON Software in Command line mode – Application example SR1

Vossloh Locomotives GmbH uses SR1+ for verification of bolted joints according to VDI 2230. By use of SR1+ in command line mode, calculations of bolted joints with many different load cases can realized more efficiently. First clamping plates, bolt and nut are defined in SR1+. Then, variable data (loads, load positions, friction coefficients..) are provided by an Excel table, SR1+ executed in command line mode by Excel, and results loaded from text file.

PRICELIST OF 01.03.2015

PRODUCT	EUR
DI1 Version 1.1 O-Ring Seal Software	190,-
DXF-Manager Version 8.6	383,-
DXFPLOT V 3.0	123,-
FED1 Version 26.7 Calc.of Helical Compression Springs	491,-
FED1+ V26.7 Helical. Compression Springs incl. Spring Database, Animation, Relax., 3D,..	695,-
FED2 V 18.6 Calc.of Helical. Tension Springs	501,-
FED2+ V 18.6 Helical Tension Springs incl, Spring Database, Animation, Relaxation, ...	675,-
FED3 Version 17.3 Helical Torsion Springs	388,-
FED3+ V17.3 Helical Torsion Springs incl. Prod.drawing, Animation, 3D, Rectang.wire, ...	480,-
FED4 Version 6.4 Calc.of Disk Springs	430,-
FED5 Version 13.5 Conical Compression Springs	741,-
FED6 Version 14.1 Nonlinear Cyl. Compression Springs	634,-
FED7 Version 11.5 Nonlinear Compression Springs	660,-
FED8 Version 6.3 Torsion Bar Calculation	317,-
FED9 Version 5.4 Spiral Spring	394,-
FED10 Version 2.5 Leaf Spring	500,-
FED11 Version 2.9 Spring Lock and Bushing	210,-
FED12 Version 2.2 Elastomere Compression Spring	220,-
FED13 Version 3.4 Wave Spring Washers	185,-
GEO1+ V5.4 Cross Section Calculation incl. Profile Database	294.-
GEO2 V2.3 Moment of Inertia	194,-
GEO3 V3.1 Hertzian Pressure	205,-
GEO4 V3.8 Cam Software	265,-
HPGL-Manager Version 8.5	383,-
LG1 V6.2 Roll-Contact Bearing Calculation	296,-
LG2 V1.9 Hydrodynamic Plain Journal Bearings	460,-
SR1 V19.8 Bolted Joint Design	640,-
SR1+ V19.8 Bolted Joint Design incl. Flange calculation	750,-
TOL1 V11.5 Tolerance Analysis	506,-
TOL1CON V1.5 Conversion Program for TOL1	281,-
TOL2 Version 3.1 Tolerance Analysis	495,-
TOLPASS V4.1 Library for ISO tolerances	107,-
TR1 V3.5 Girder Calculation	757,-
WL1+ V19.5 Shaft Calculation incl. Roll-contact Bearings	945,-
WN1 Version 11.2 Cylindrical and Conical Press Fits	485,-
WN2 V 9.2 Involute Splines to DIN 5480	250,-
WN2+ V 9.2 Involute Splines to DIN 5480 and non-standard splines	380,-
WN3 V 5.2 Parallel Key Joints to DIN 6885, ANSI B17.1, DIN 6892	245,-
WN4 V 4.2 Involute Splines to ANSI B 92.1	276,-
WN5 V 4.2 Involute Splines to ISO 4156 and ANSI B 92.2 M	255,-
WN6 V 2.7 Polygon Profiles P3G to DIN 32711	180,-
WN7 V 1.6 Polygon Profiles P4C to DIN 32712	175,-
WN8 V 1.7 Serration to DIN 5481	195,-
WN9 V 1.8 Spline Shafts to DIN ISO 14	170,-
WN10 V 3.5 Involute Splines to DIN 5482	260,-
WN11 V 1.2 Woodruff Key Joints	240,-
WST1 V 9.2 Material Database	235,-
ZAR1+ V 23.6 Spur and Helical Gears incl. Database, Load Spectrum	1115,-
ZAR2 V7.2 Spiral Bevel Gears to Klingelnberg	792,-
ZAR3 V8.4 Worm Gears	404,-
ZAR3+ V8.4 Worm Gears incl. Profile drawings, variable tooth height, OPD measure	620,-
ZAR4 V3.6 Non-circular Spur Gears	1610,-
ZAR5 V8.3 Planetary Gearings	1355,-
ZAR6 V3.2 Straight/Helical/Spiral Bevel Gears	585,-
ZARXP V1.8 Involute Profiles - Calculation, Graphic, Measuring	275,-
ZAR1W V1.2 Gear Wheel Dimensions, Tolerances, Measuring	450,-
ZM1.V2.1 Chain Gear Calculation	326,-

Packages

PACKAGES	EUR
HEXAGON Mechanical Engineering Package (TOL1, ZAR1+, ZAR2, ZAR3+, ZAR5, ZAR6, WL1+, WN1, WN2+, WN3, WST1, SR1+, FED1,+, FED2+, FED3+, FED4, ZARXP, HAERTE, TOLPASS, LG1, DXFPLOT, GEO1+, TOL2, TOL1CON, GEO2, GEO3, ZM1, WN6, WN7, LG2, FED12, FED13, WN8, WN9, WN11, DI1)	8,500.-
HEXAGON Mechanical Engineering Base Package (ZAR1+, ZAR3+, ZAR5, ZAR6, WL1+, WN1, WST1, SR1+, FED1,+, FED2+, FED3+)	4.900,-
HEXAGON Spur Gear Bundle (ZAR1+ and ZAR5)	1,585.-
HEXAGON Graphic Package (DXF-Manager, HPGL-Manager, DXFPLOT)	741.-
HEXAGON Helical Spring Package (FED1+, FED2+, FED3+, FED5, FED6, FED7)	2,550.-
HEXAGON Tolerance Package (TOL1, TOL1CON, TOL2, TOLPASS)	945.-
HEXAGON Complete Package (All Programs of Engineering Package, Graphics Package, Tolerance Package, Helical Spring Package, TR1, FED8, FED9, FED10, ZAR4, GEO4, WN4, WN5, FED11,WN10, ZAR1W)	11,500.-

Quantity Discount for Individual Licenses

Licenses	2	3	4	5	6	7	8	9	>9
Discount %	25%	27.5%	30%	32.5%	35%	37.5%	40%	42.5%	45%

Network Floating License

Licenses	1	2	3	4	5	6	7..8	9..11	>11
Discount/Add.cost	-50%	-20%	0%	10%	15%	20%	25%	30%	35%

(Negative Discount means additional cost)

Language Version:

- **German and English :** all Programs
- **French**: FED1, FED1+, FED2, FED2+, FED3, FED3+, FED5, FED6, FED7, FED9, WL1+.
- **Italiano**: FED1, FED1+, FED2, FED2+, FED3, FED3+, FED5, FED6, FED7, FED9, DXFPLOT.
- **Swedish**: FED1, FED1+, FED2, FED2+, FED3, FED3+, FED5, FED6, FED7, DXFPLOT.
- **Portugues**: FED1, FED1+
- **Spanish**: FED1, FED1+

Updates:

Update prices	EUR
Software Update (software + pdf manual)	40,-
Software Update (software 64-bit Win + pdf manual)	50,-

Update Mechanical Engineering Package: 800 EUR, Update Complete Package: 1000 EUR

Maintenance contract for free updates: annual fee: 150 EUR + 40 EUR per program

Upgrades

For upgrades to network licenses or plus versions or software bundles, upgraded licenses are credited 75%.

Hexagon Software Network Licenses

Floating License in the time-sharing manner by integrated license manager
Individual licenses may not be installed in a network!

Conditions for delivery and payment

General packaging and postage costs are EUR 60, (EUR 25 inside Europe)
Delivery by Email (program packed, manual as pdf files): EUR 0.
Conditions of payment: bank transfer in advance with 2% discount, or by credit card (Master, Visa) net.

Key Code

After installation, software has to be released by key code. Key codes will be sent after receipt of payment.

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