DIE ingenieure.

3DEXPERIENCE Conference 2019

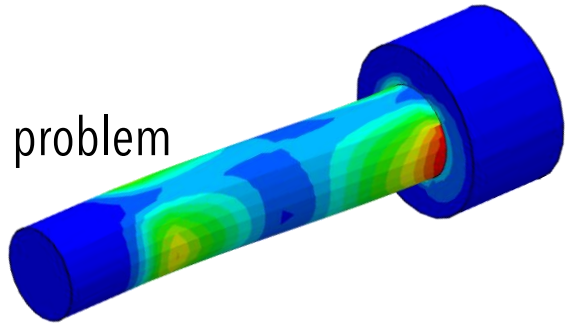
Efficient modeling and evaluation method of bolt connections based on VDI 2230 guideline.

Motivation and Typical Problems of a bolt assessment

- Bolts are one of the most used conneciton types between components.
- Bolts have to resist loads in service (proof of strength needed, VDI 2230 widely used standard)
- Reduce modeling effort as much as possible
- Assemblies may include many (different) bolts and load cases, proof of strenght can be very time consuming
- Proof of strength for the bolts must be furnished identically for all engineers in the company and for every project (reliability)
- If proof of strength cannot be furnished, the engineer needs to understand fast why are the bolts failing / which load causes failure

  AND

  answer the question very fast, which modifications are required to fix the problem



Motivation and Typical Problems of a bolt assessment

A standard-compliant assessment of bolted connections is often in contradiction with the tools that the CAE programs supply.

VDI 2230

- R0 – R13

Many steps are not needed for FEM

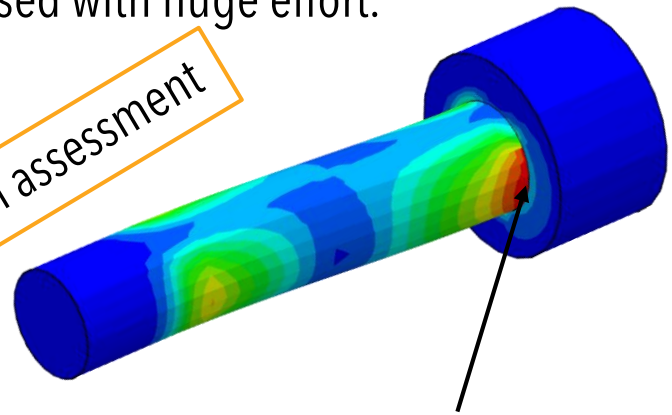
By using the FEM, 4 steps are needed

- R8: working stress
- R9: alternating stress
- R10: surface pressure
- R12: slipping, shearing

FEM

- Only the pretension node forces can be queried easily.
- The maximum stress occurs at a singularity.
- For a proof of bolts, the resulting stress can only be used with huge effort.

Not enough for an assessment



Singular with simplified bolts

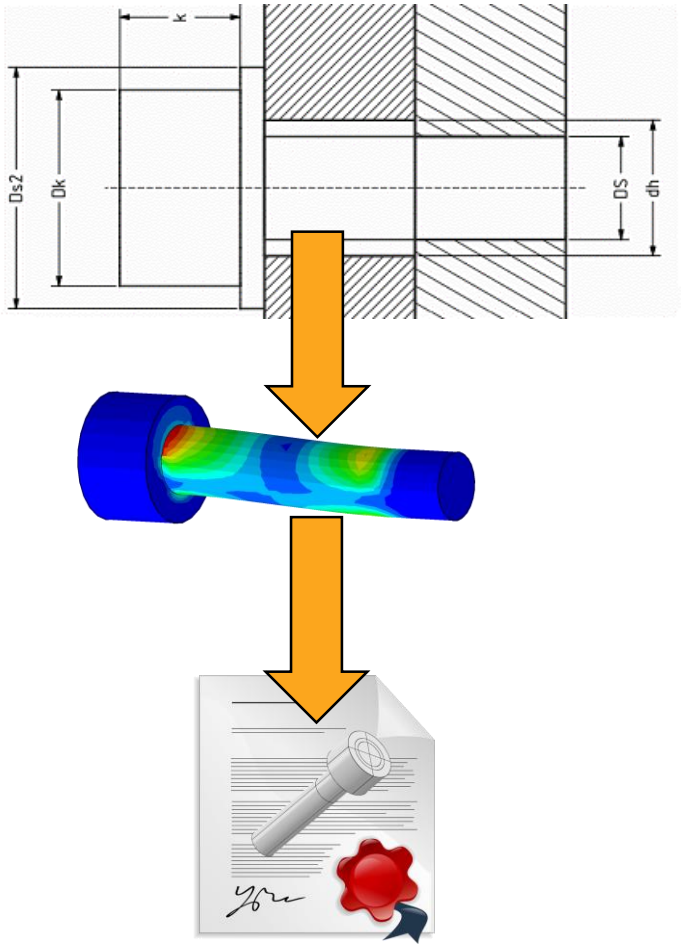
Our strategy

The goal must be to furnish the bolt assessment in less than 10 active minutes effort.

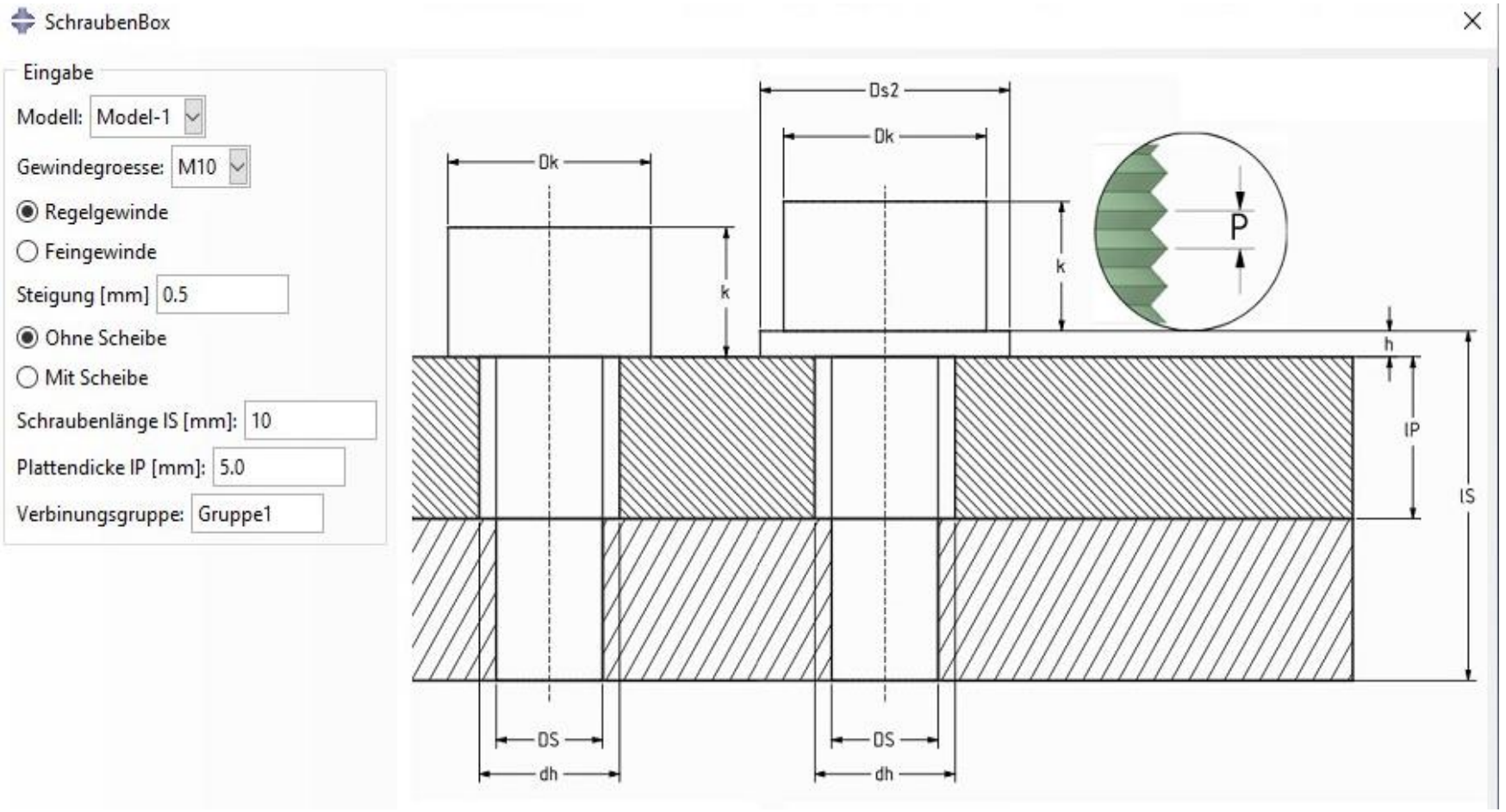
1. parametric bolt models

2. automatic definition of the pretension forces
3. automatic definition of the necessary output variables
4. automatic extraction of the cutting forces and moments
5. automatic extraction of the inner surface shear forces

6. easy VDI2230 assessment setup
7. easy forecast studies
8. **real-time documentation!**

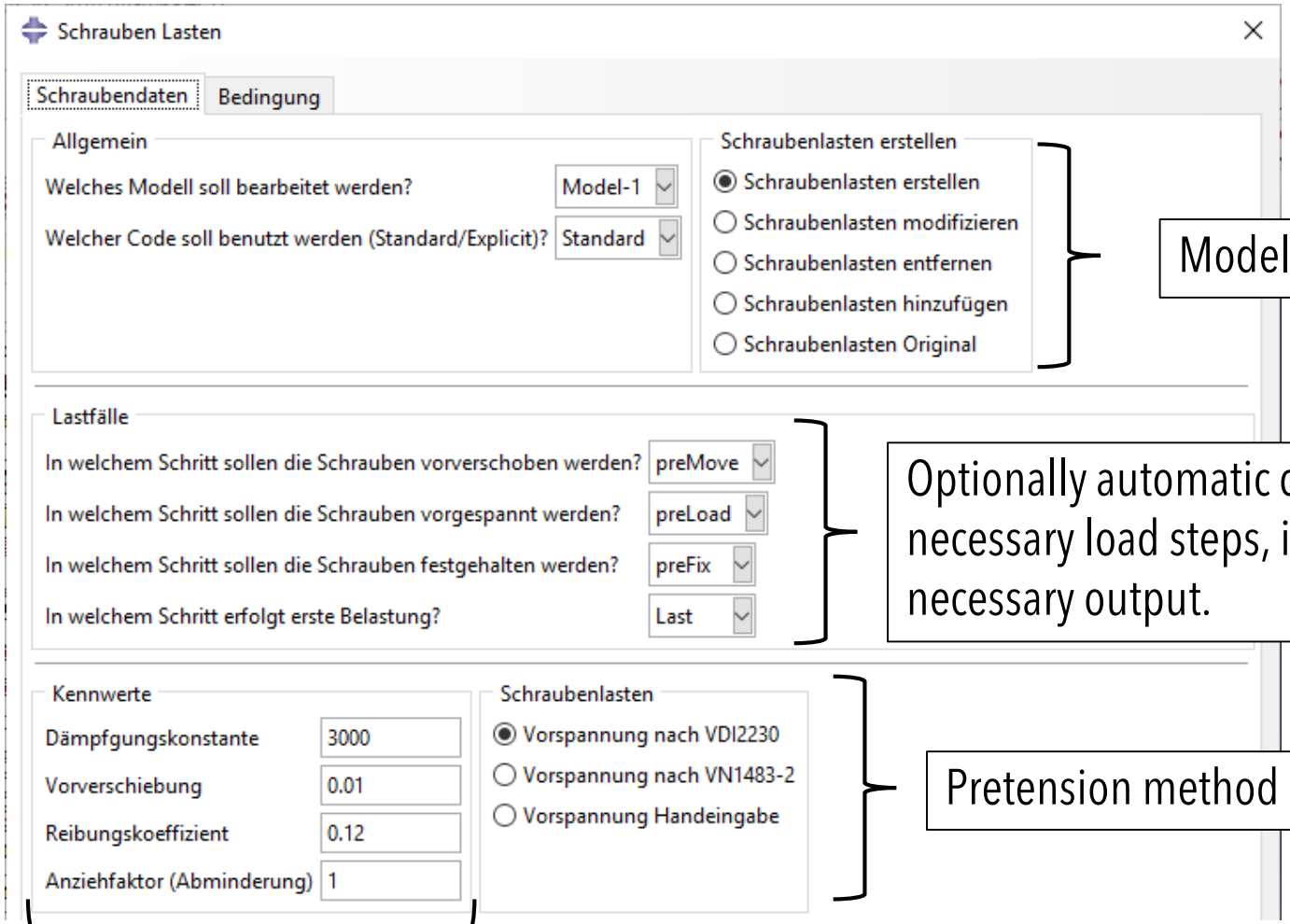


Bolt modeling (screen record in real time)



For animation, please visit https://di-gmbh.com/single_bolt.mp4

load and output modeling



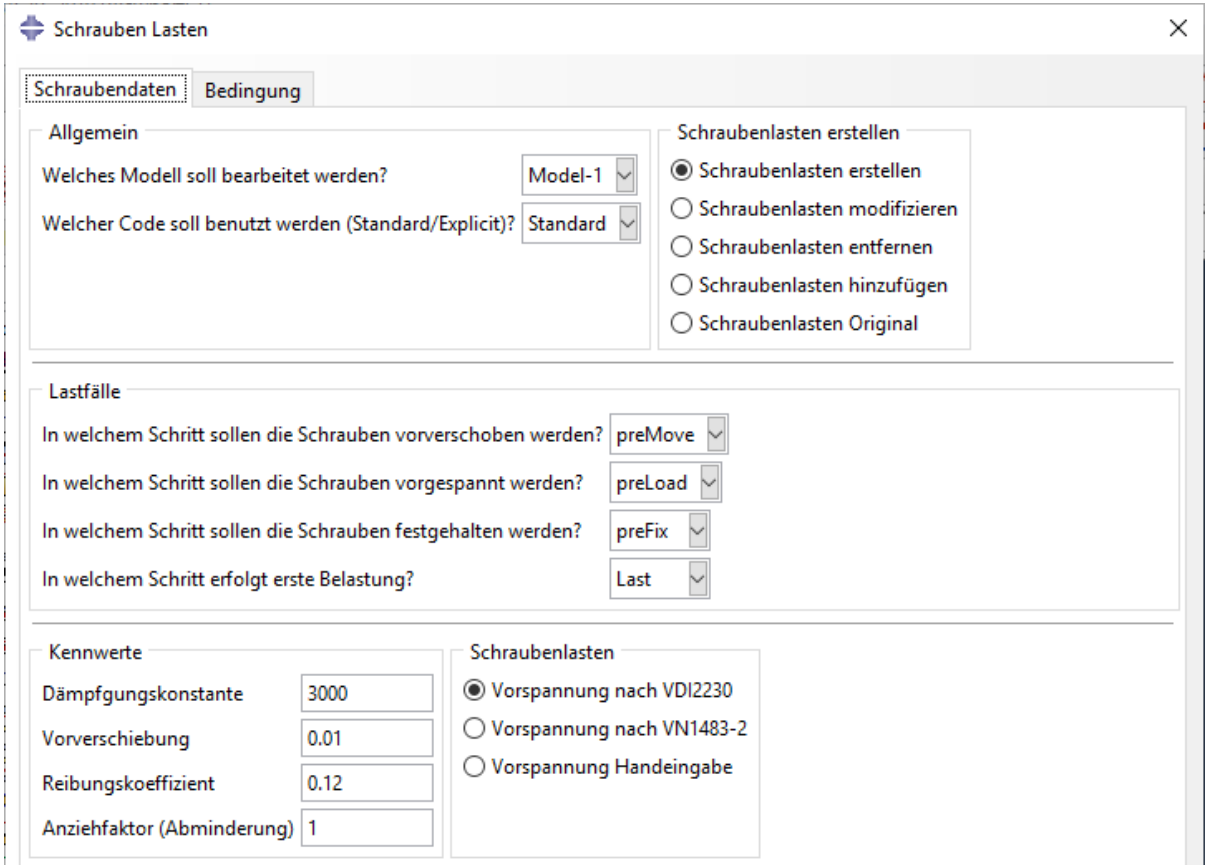
Model modification method

Optionally automatic creation of the necessary load steps, including necessary output.

Pretension method

Numerical stabilization parameters

load and output modeling

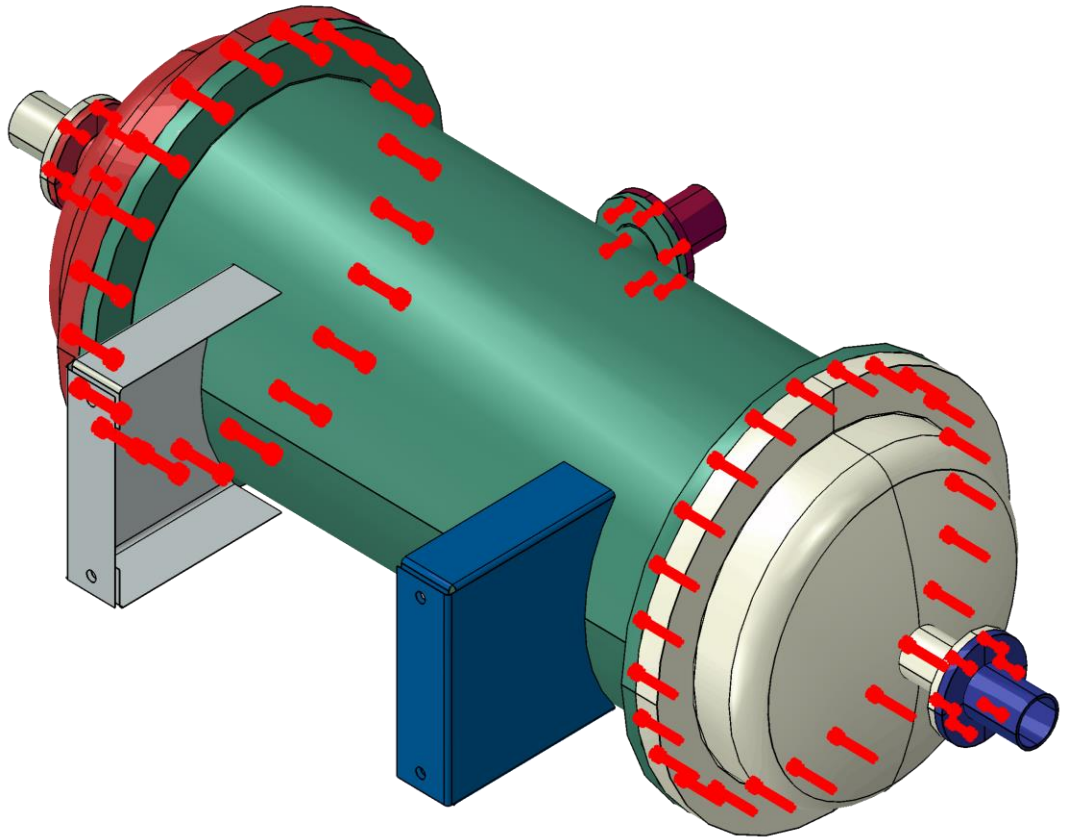


Required Parameter for each Bolt group:

- Strength grade
- friction coefficient
- tightening factor
- utilization factor of the yield point stress

The application of a preload losses due to relaxation is easily possible.

Example:
load definition for 62 bolts in less than 1,2 min
(screen record in real time)



For animation, please visit https://di-gmbh.com/assembly.mp4

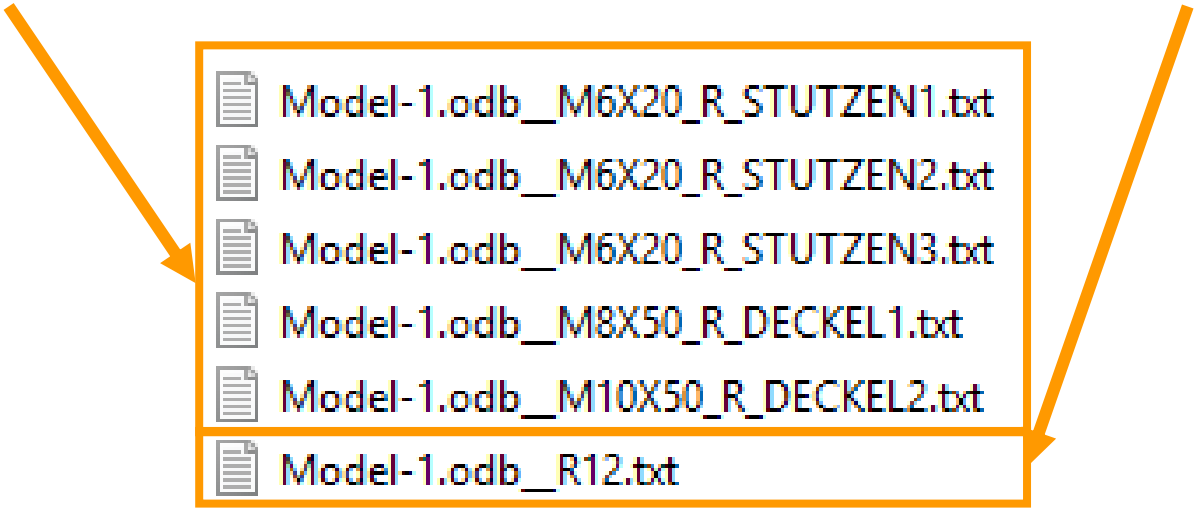
Postprocessing in abaqus

Extract the bolt forces:

1. Open Result file
2. Click on "bolt assessment"
3. Get a text- file for each bolt group
4. Fast: less than 5 minutes for > 60 bolts and 16 load cases

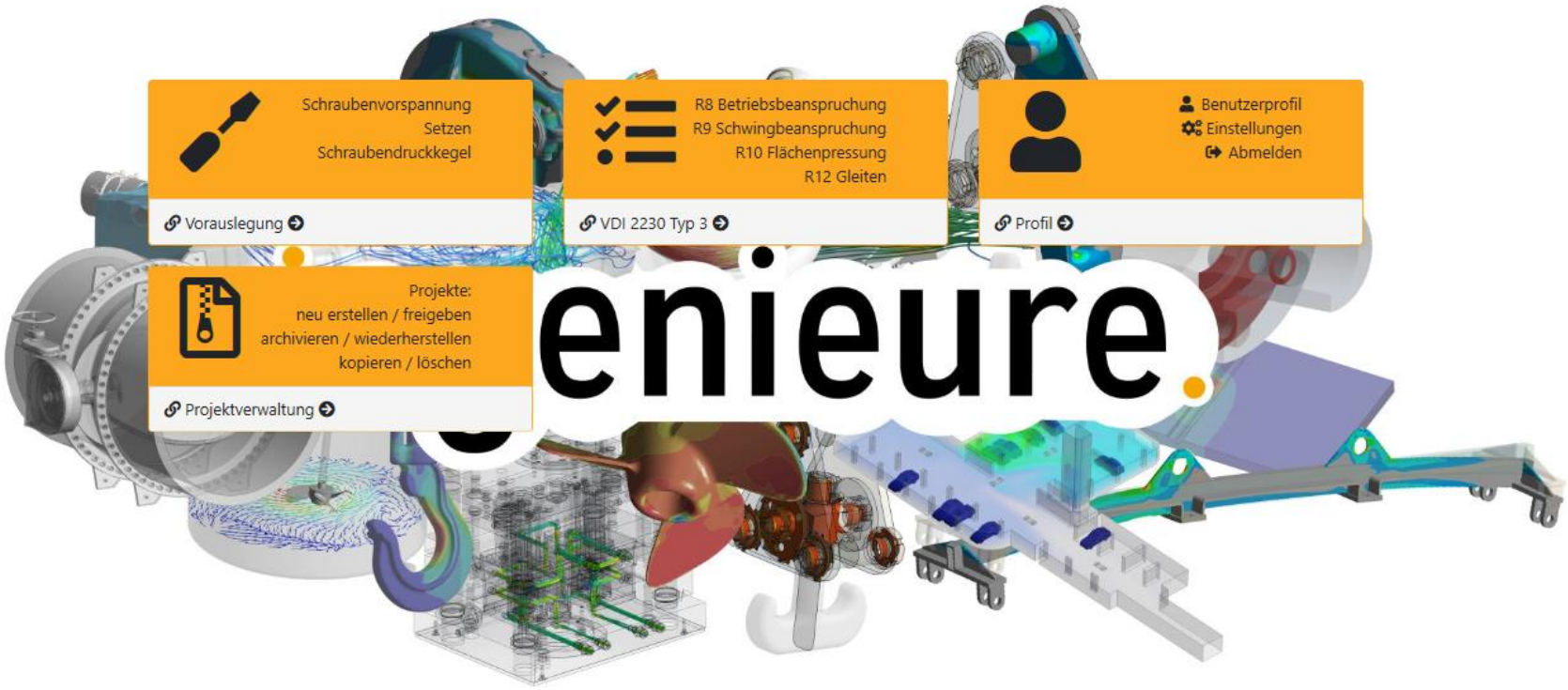
Extract the inner surface shear forces:

1. Open Result file
2. Click on "R12 Contact assessment"
3. Get one text- file
4. This maybe takes some time (depending on amount of contact pairs and load cases)

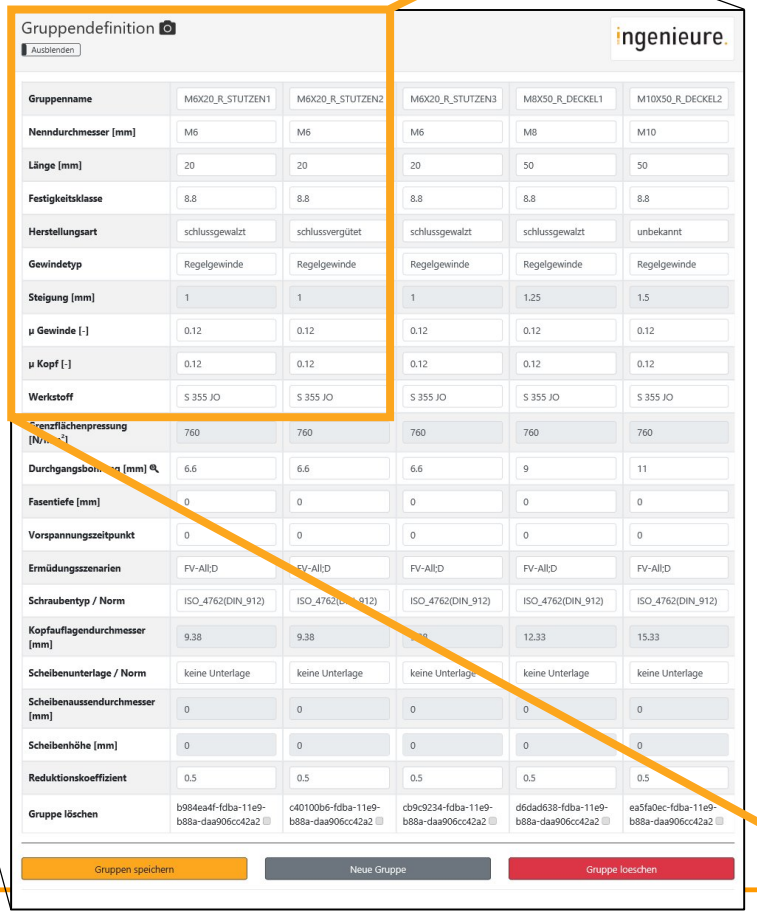


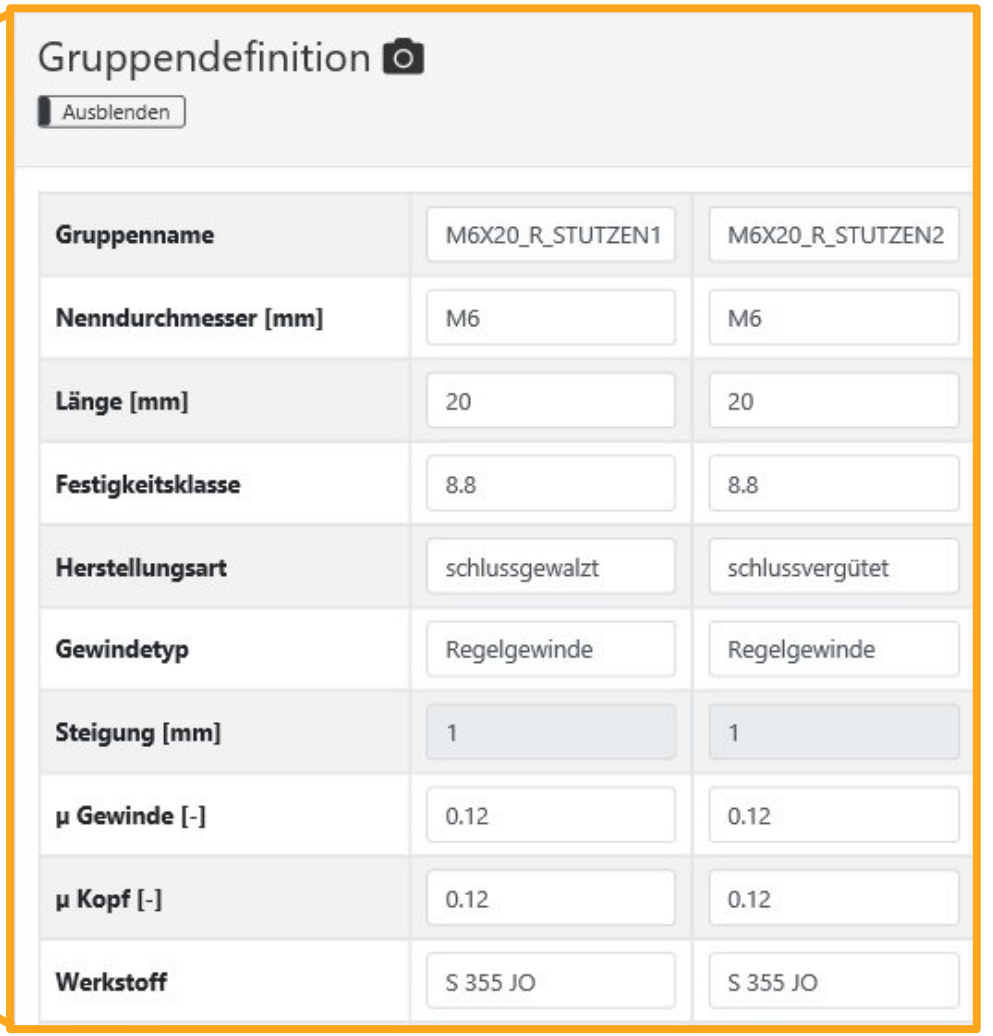
Both tasks are automatically done with our macros

Start with our Bolt Tool



Group definition





Little helpers: Mouse hover and popups

Steigung [mm]
µ Gewinde [-]
µ Kopf [-]
Werkstoff
Grenzflächenpressung [N/mm²]
Durchgangsbohrung [mm]
Fasentiefe [mm]
Vorspannungszeitpunkt
Ermüdungsszenarien

DITools - Durchgangsbohrung - DIN 7...

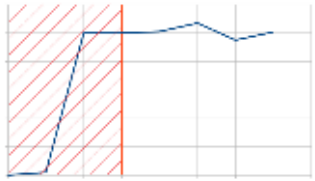
https://ditools.di-gmbh.com/pages/Schrauben_Type_3/D

Durchgangsbohrung nach DIN 75

Gewinde	fein [mm]	mittel [mm]	grob [mm]
M1	1.1	1.2	1.3
M1.2	1.3	1.4	1.5
M1.4	1.5	1.6	1.8
M1.6	1.7	1.8	2
M1.8	2	2.1	2.2

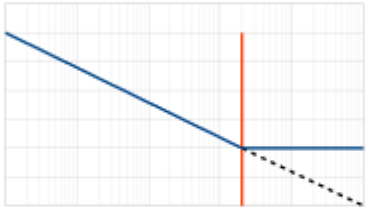
Mouse hover

Jeder Lastpunkt vor dem Vorspannzeitpunkt wird nicht ausgewertet.



Mouse hover

Die einzelnen Ermüdungsszenarien mit | (Pipe) trennen.
Die einzelnen Lastzeitpunkte mit - trennen.
Die Lastwechselzahl mit ; von den Lastzeitpunkten trennen.

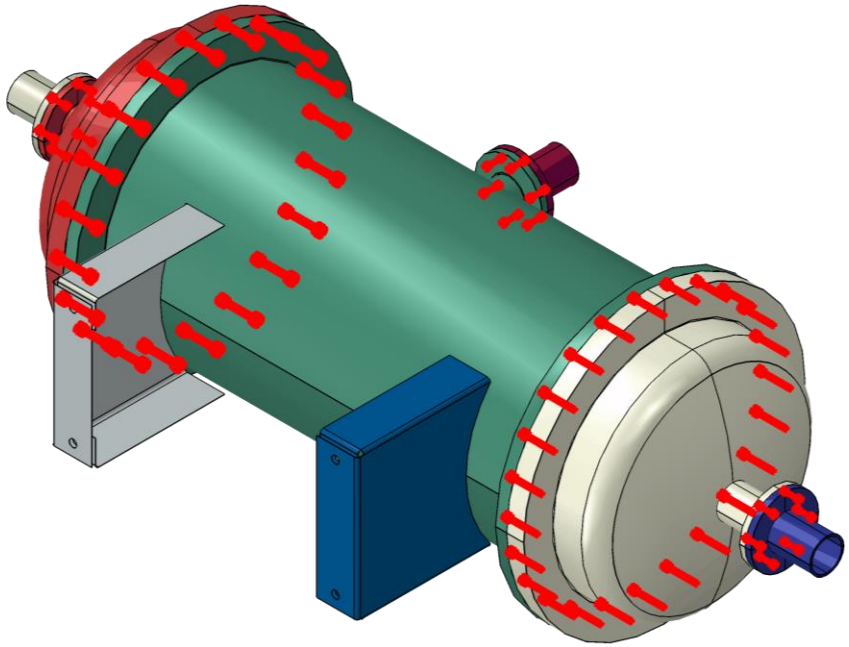


VDI 2230 Dauerfest:
N_D = D = 2.000.000
Achtung: Die Software rechnet mit Miner Elementar.
FV = Vorspannzeitpunkt
All = Alle Lastfälle
D = Dauerfest
Bsp.
FV - All ; D | 3 - 4 ; 4e5
All - 4 ; 20000 | FV - 3 ; 2.5e5
All - All ; D

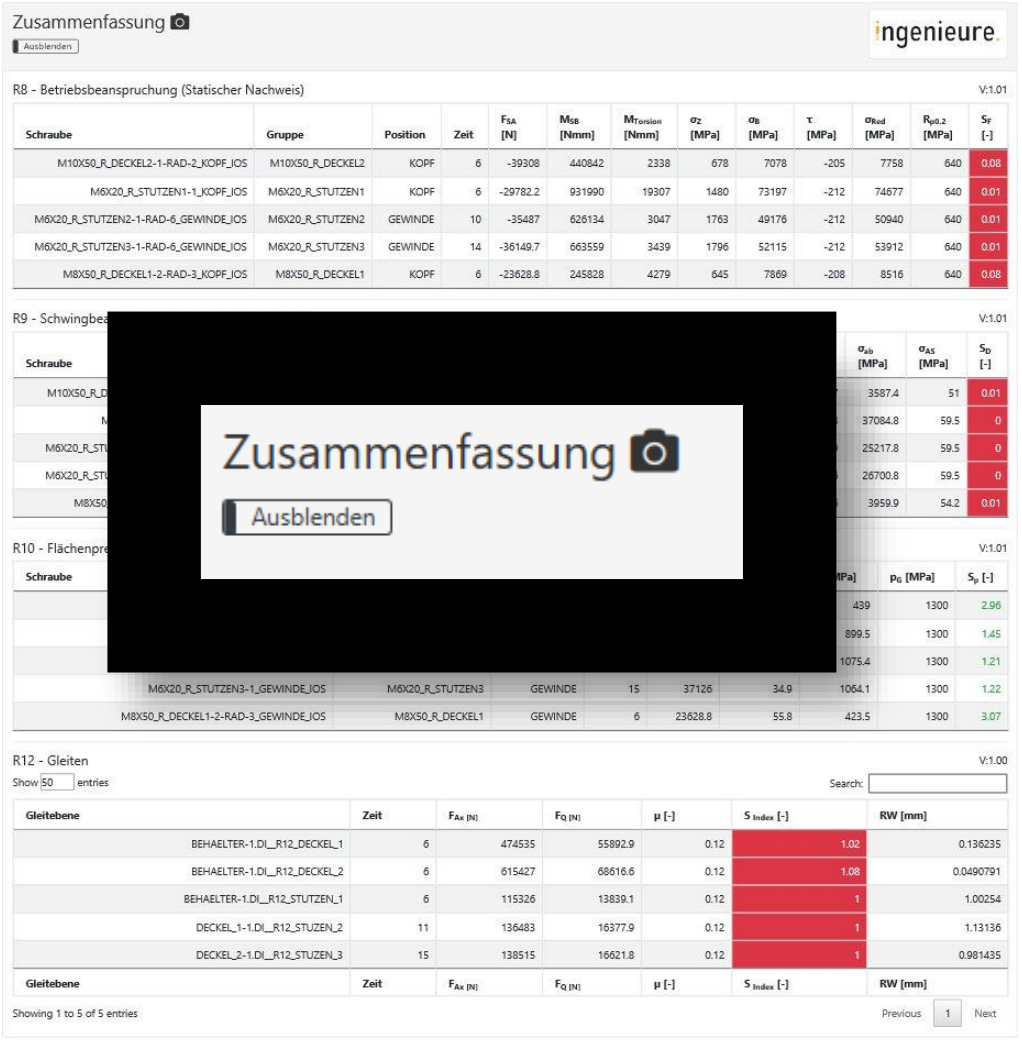
Bolt evaluation

- 62 bolts
- 16 load cases
- 2 section cuts per bolt
- 3 forces and 3 moments per section cut
- → 62 x 16 x 2 x 6 = 11904 values
- Evaluation of all load case scenarios

→ Cumbersome and risky for possible errors



Realtime documentation with screenshot function



R8 | R9 - Assessment

Zusammenfassung

Ausblenden

R8 - Betriebsbeanspruchung (Statischer Nachweis)

V:1.01

Schraube	Gruppe	Position	Zeit	F_{SA} [N]	M_{SB} [Nmm]	$M_{Torsion}$ [Nmm]	σ_Z [MPa]	σ_B [MPa]	τ [MPa]	σ_{Red} [MPa]	$R_{p0.2}$ [MPa]	S_F [-]
M10X50_R_DECKEL2-1-RAD-2_KOPF_IOS	M10X50_R_DECKEL2	KOPF	6	-39308	440842	2338	678	7078	-205	7758	640	0.08
M6X20_R_STUTZEN1-1_KOPF_IOS	M6X20_R_STUTZEN1	KOPF	6	-29782.2	931990	19307	1480	73197	-212	74677	640	0.01
M6X20_R_STUTZEN2-1-RAD-6_GEWINDE_IOS	M6X20_R_STUTZEN2	GEWINDE	10	-35487	626134	3047	1763	49176	-212	50940	640	0.01
M6X20_R_STUTZEN3-1-RAD-6_GEWINDE_IOS	M6X20_R_STUTZEN3	GEWINDE	14	-36149.7	663559	3439	1796	52115	-212	53912	640	0.01
M8X50_R_DECKEL1-2-RAD-3_KOPF_IOS	M8X50_R_DECKEL1	KOPF	6	-23628.8	245828	4279	645	7869	-208	8516	640	0.08

R9 - Schwingbeanspruchung (Ermüdungsnachweis)

V:1.01

Schraube	Gruppe	Position	Szenario	Zyklen	ΔF_{SA} [N]	ΔM_{SB} [Nmm]	$\Delta\sigma_Z$ [MPa]	$\Delta\sigma_B$ [MPa]	σ_{ab} [MPa]	σ_{AS} [MPa]	S_D [-]
M10X50_R_DECKEL2-1-RAD-2_GEWINDE_IOS	M10X50_R_DECKEL2	GEWINDE	3 - 6	2000000	9704.8	436464.6	83.7	3503.7	3587.4	51	0.01
M6X20_R_STUTZEN1-1_KOPF_IOS	M6X20_R_STUTZEN1	KOPF	3 - 6	2000000	19600.3	931968.4	487	36597.8	37084.8	59.5	0
M6X20_R_STUTZEN2-1-RAD-6_GEWINDE_IOS	M6X20_R_STUTZEN2	GEWINDE	3 - 10	2000000	25305.1	626163.1	628.7	24589	25217.8	59.5	0
M6X20_R_STUTZEN3-1-RAD-6_GEWINDE_IOS	M6X20_R_STUTZEN3	GEWINDE	3 - 14	2000000	25967.8	663510.4	645.2	26055.6	26700.8	59.5	0
M8X50_R_DECKEL1-2-RAD-3_KOPF_IOS	M8X50_R_DECKEL1	KOPF	3 - 6	2000000	5001.2	243163.9	68.3	3891.6	3959.9	54.2	0.01

R10 | R12- Assessment

R10 - Flächenpressung

V:1.01

Schraube	Gruppe	Position	Zeit	F_{SA} [N]	A_p [mm²]	p_B [MPa]	p_G [MPa]	S_p [-]
M10X50_R_DECKEL2-1-RAD-2_GEWINDE_IOS	M10X50_R_DECKEL2	GEWINDE	6	39308	89.5	439	1300	2.96
M6X20_R_STUTZEN1-1-RAD-2_KOPF_IOS	M6X20_R_STUTZEN1	KOPF	5	31383.9	34.9	899.5	1300	1.45
M6X20_R_STUTZEN2-1_GEWINDE_IOS	M6X20_R_STUTZEN2	GEWINDE	11	37519.8	34.9	1075.4	1300	1.21
M6X20_R_STUTZEN3-1_GEWINDE_IOS	M6X20_R_STUTZEN3	GEWINDE	15	37126	34.9	1064.1	1300	1.22
M8X50_R_DECKEL1-2-RAD-3_GEWINDE_IOS	M8X50_R_DECKEL1	GEWINDE	6	23628.8	55.8	423.5	1300	3.07

R12 - Gleiten

V:1.00

Show 50 entries

Search:

Gleitebene	Zeit	$F_{Ax\ [N]}$	$F_{Q\ [N]}$	μ [-]	S_{Index} [-]	RW [mm]
BEHAELTER-1.DI__R12_DECKEL_1	6	474535	55892.9	0.12	1.02	0.136235
BEHAELTER-1.DI__R12_DECKEL_2	6	615427	68616.6	0.12	1.08	0.0490791
BEHAELTER-1.DI__R12_STUTZEN_1	6	115326	13839.1	0.12	1	1.00254
DECKEL_1-1.DI__R12_STUZEN_2	11	136483	16377.9	0.12	1	1.13136
DECKEL_2-1.DI__R12_STUZEN_3	15	138515	16621.8	0.12	1	0.981435
Gleitebene	**Zeit**	**$F_{Ax\ [N]}$**	**$F_{Q\ [N]}$**	**μ [-]**	**S_{Index} [-]**	**RW [mm]**

Showing 1 to 5 of 5 entries

Previous 1 Next

Detailed assessment: R8 - working stress

Detailed assessment **for each bolt result**. A simple click is enough.

→ Easy identifying of the possible failure mode

M10X50_R_DECKEL2-1-RAD-2_KOPF_IOS

M10X50_R_DECKEL2

KOPF

Zeit: 6

Festigkeitsklasse: 8.8

Betriebsbeanspruchung (VDI2230 R8/4) mit Biegung (VDI2230 149)

$$\sigma_{red,B} = \sqrt{(\sigma_Z + \sigma_B)^2 + 3 \cdot (k_\tau \cdot \tau_{max})^2} =$$

$$\sigma_{red,B} = \sqrt{\left(678\frac{N}{mm^2} + 7078\frac{N}{mm^2}\right)^2 + 3 \cdot \left(0.5 \cdot -205\frac{N}{mm^2}\right)^2} =$$

$$\sigma_{red,B} = 7758\frac{N}{mm^2}$$

Sicherheit gegen Überschreitung der Streckgrenze: (VDI2230: R8/5-2)

$$S_F = \frac{R_{p0.2}}{\sigma_{red,B}} = \frac{640\frac{N}{mm^2}}{7758\frac{N}{mm^2}} = 0.08$$

Zugspannung: $\sigma_Z \left[\frac{N}{mm^2}\right]$

Biegespannung: $\sigma_B \left[\frac{N}{mm^2}\right]$

Torsionsspannung: $\tau \left[\frac{N}{mm^2}\right]$

Reduktionskoeffizient: $k_\tau\,[-]$

Streckgrenze (T = 23°C): $R_{p0.2} \left[\frac{N}{mm^2}\right]$

Detailed assessment

R9 - alternating stress

M10X50_R_DECKEL2-1-RAD-2_GEWINDE_IOS

M10X50_R_DECKEL2

GEWINDE

Szenario: 3 - 6

Lastwechsel: 2000000

Herstellungsart: unbekannt

Schwingfestigkeit für schlussvergütete (SV) Schrauben (R9/5-1 | R9/6-1)

$$\sigma_{ASV} = 0.85 \cdot \left(\frac{150}{d} + 45\right) \cdot \left(\frac{N_D}{N_Z}\right)^{\frac{1}{3}} =$$

$$\sigma_{ASV} = 0.85 \cdot \left(\frac{150}{10} + 45\right) \cdot \left(\frac{2000000}{2000000}\right)^{\frac{1}{3}} =$$

$$\sigma_{ASV} = 51 \frac{N}{mm^2}$$

Schwingfestigkeit für schlussgewalzte (SG) Schrauben (R9/5-1 | R9/5-2 | R9/6-2)

$$\sigma_{ASG} = \left(2 - \frac{\frac{\Delta F_{SA}}{2} + F_M}{R_{p0.2} \cdot A_S}\right) \cdot 0.85 \cdot \left(\frac{150}{d} + 45\right) \cdot \left(\frac{N_D}{N_Z}\right)^{\frac{1}{6}} =$$

$$\sigma_{ASG} = \left(2 - \frac{\frac{9705}{2} + -29603}{640 \cdot 58}\right) \cdot$$

$$\cdot \left(\frac{150}{10} + 45\right) \cdot \left(\frac{2000000}{2000000}\right)^{\frac{1}{6}} =$$

$$\sigma_{ASG} = 136 \frac{N}{mm^2}$$

Schwingfestigkeit für unbekannte Schrauben (keine VDI2230 Formel)

$$\sigma_{AU} = \min(\sigma_{ASV} | \sigma_{ASG}) =$$

$$\sigma_{AU} = \min\left(51 \frac{N}{mm^2} \middle| 136 \frac{N}{mm^2}\right) =$$

$$\sigma_{AU} = 51 \frac{N}{mm^2}$$

Dauerschwingbeanspruchung: (VDI2230: R9/2 modifiziert)

$$\sigma_{ab} = \Delta\sigma_Z + \Delta\sigma_B = 83.7 \frac{N}{mm^2} + 3503.7 \frac{N}{mm^2} = 3587.4$$

Sicherheit der Schwingbeanspruchung: (VDI2230: R9/4)

$$S_D = \frac{\sigma_{AS}}{\sigma_{ab}} = \frac{51 \frac{N}{mm^2}}{3587.4 \frac{N}{mm^2}} = 0.01$$

Nenndurchmesser: $d[mm]$

Schwingspiele: $N_Z[-]$

Zugspannungsamplitude: $\Delta\sigma_Z\left[\frac{N}{mm^2}\right]$

Biegespannungsamplitude: $\Delta\sigma_B\left[\frac{N}{mm^2}\right]$

Spannungsquerschnitt: $A_S[mm^2]$

Montagevorspannkraft: $F_M[N]$

Betriebskraftschwingbreite: $\Delta F_{SA}[N]$

Streckgrenze (T = 23°C): $R_{p0.2}\left[\frac{N}{mm^2}\right]$

R10 - surface pressure

M10X50_R_DECKEL2-1-RAD-2_GEWINDE_IOS

M10X50_R_DECKEL2

Sicherheit gegen Flächenpressung: (VDI2230: R10/4)

$$S_p = \frac{p_G}{p_{b,max}} = \frac{p_G}{\frac{F_{SA,max}}{A_{p,min}}} = \frac{1300 \frac{N}{mm^2}}{\frac{39308\,N}{89.54\,mm^2}} = 2.96$$

maximale Axialkraft: $F_{SA,max}[N]$

Auflagefläche: (VDI2230: 129,193,194) $A_{p,min}[mm^2]$

Flächenpressung: $p_{b,max}\left[\frac{N}{mm^2}\right]$

Grenzflächenpressung: $p_G\left[\frac{N}{mm^2}\right]$

R12 - slipping, shearing

BEHAELTER-1.DI__R12_DECKEL_1

Sicherheit gegen Gleiten: (VDI2230: R12/4 modifiziert)

$$S_G = \frac{F_{Ax} \cdot \mu}{F_Q} = \frac{474535\,N \cdot 0.12}{55892.9\,N} = 1.02$$

Axialkraft: $F_{Ax}[N]$

Querkraft: $F_Q[N]$

Reibungskoeffizient: $\mu[-]$

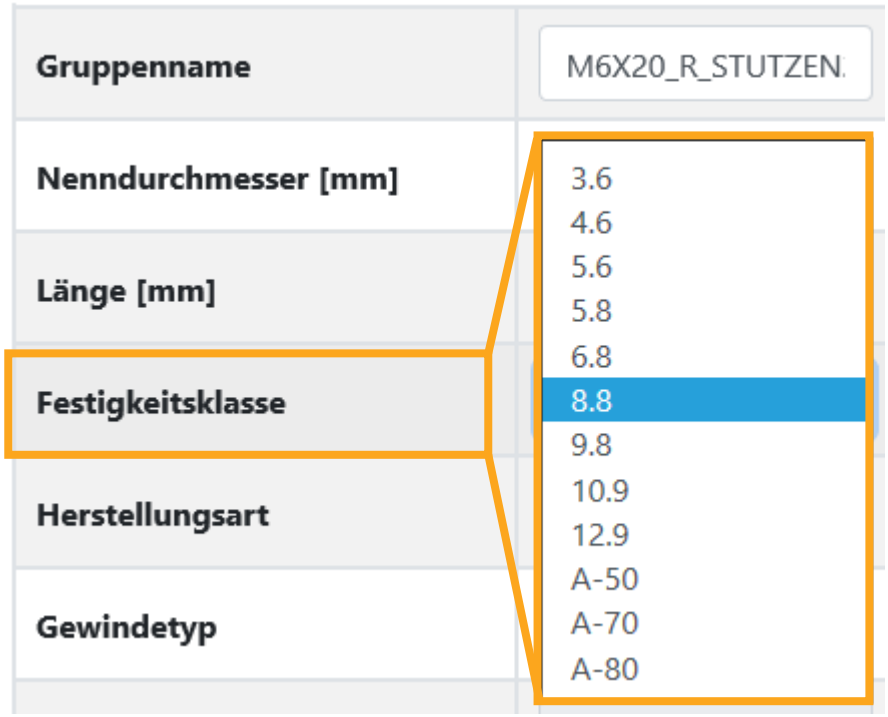
Forecast studies

Just change the bolt properties of a group

- Bolt diameter
- Strength grade
- Manufacturing
- Thread type

and click on the save button.

Caution: This is an engineering guess, a final verification is needed.



Additional features

Web tool

- Determination of:
  - Pretension force, including documentation
  - Compression cone
  - Preload losses due to relaxation
- Copy project setups for nearly similar FEM- Models
  - Cold and hot conditions
  - Part modifications
- Export whole data table results to:
  - Clipboard
  - CSV
  - Excel
  - PDF
  - Direct printing
- Multi CAE software support:

Web based

- No local installation required
- No local updates needed
- No CAE license needed
- Operating system independent

Abaqus

- Boolean of bolt surfaces and sets for all instances per Part
- Automatic general Contact definition
- Automatic generation of Solid property cards for each material
- Several toggle features
- High resolution picture capture to clipboard

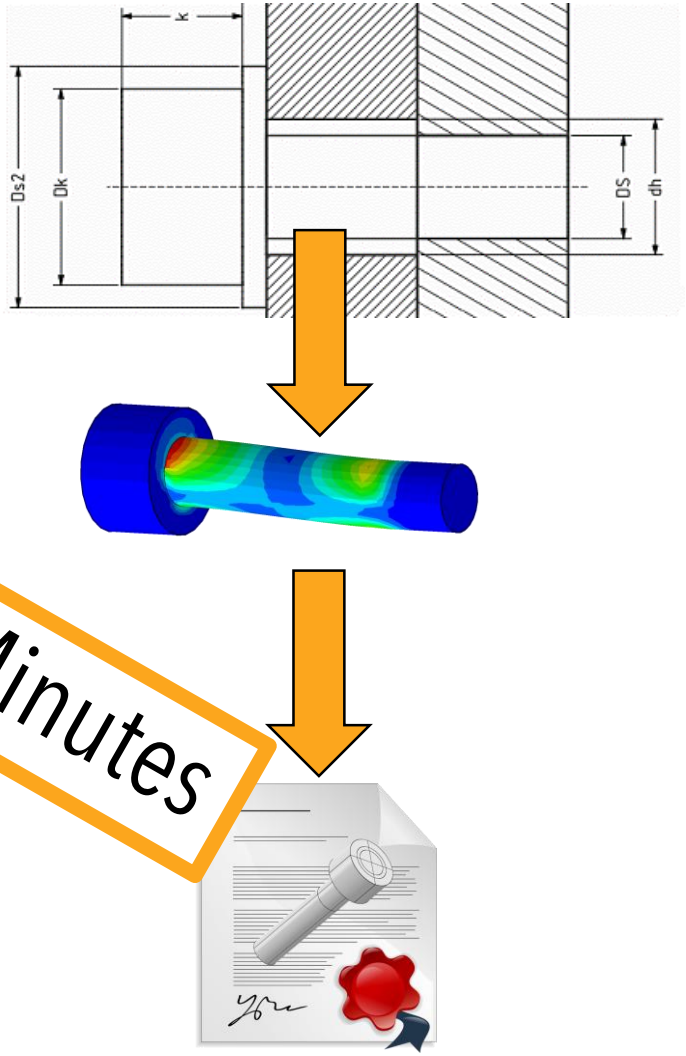
Conclusion

Parametric geometry setup

Automatic / parametric
pre- and postprocessing

Fast and comprehensible
VDI 2230 assessment

Engineering time < 10 Minutes



Thank you for your attention

For additional information or a websession/live demo, please contact:

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