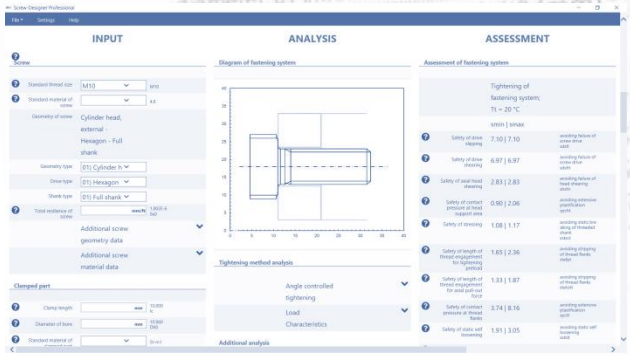


Dr.-Ing. Hendrik Hubbertz
M. Eng. Shiva Kumar Manoharan
Prof. Dr.-Ing. Christoph Friedrich

SCREW-DESIGNER Professional

AFS-E068

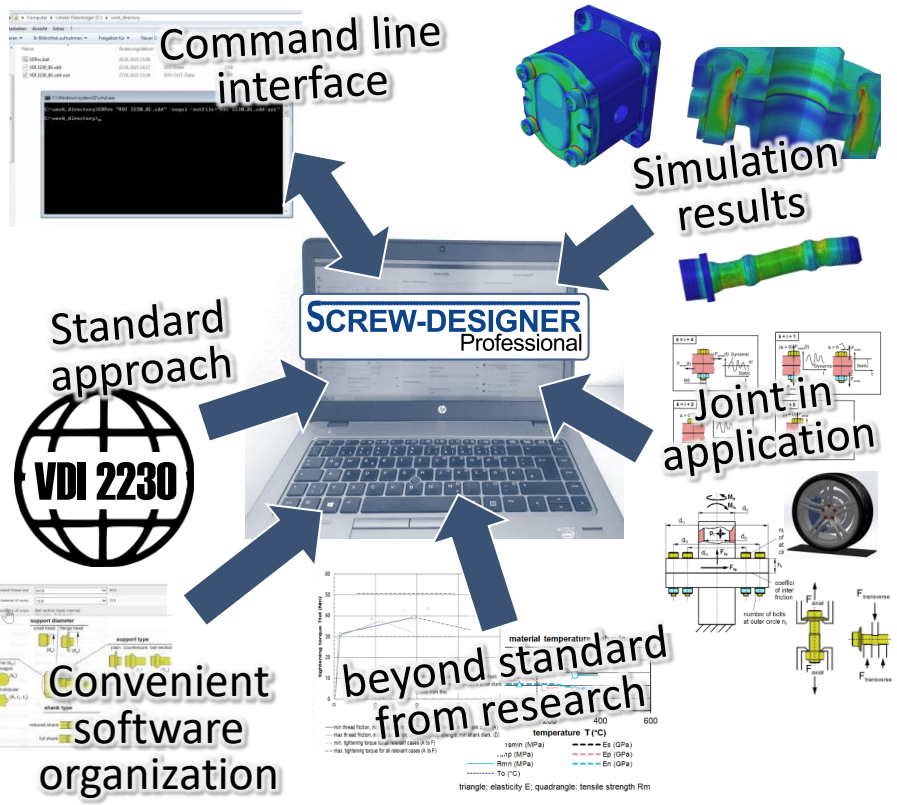
Case study of drones using Screw-Designer Professional

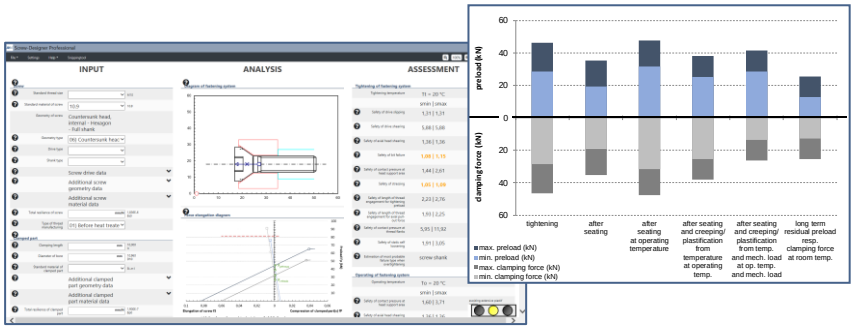
provides refinement approach, direct rating, easy variations, warnings for impact of deficits and much more…

Advanced Fastening Solutions

SHORT LIST OF BENEFITS FROM SCREW-DESIGNER

UNIQUE FEATURES AND RESULTING EFFECTS





- **Important features:**
  - clear structure (based on VDI 2230) with minimized Input (Refinement approach)
  - immediate calculation to have direct reply (allows to modify intuitively without equations)
  - automatic selection of material properties including degradation at elevated temp.
- **Resulting from this:**
  - saving of development time (shorter time to market – very important)
  - saving of testing (very cost-sensitive and key for time to market)
  - unloading design engineer (no risk to forget aspects of design)
- **Overall**
  - cost saving in processes and new work when using SCREW-DESIGNER Professional

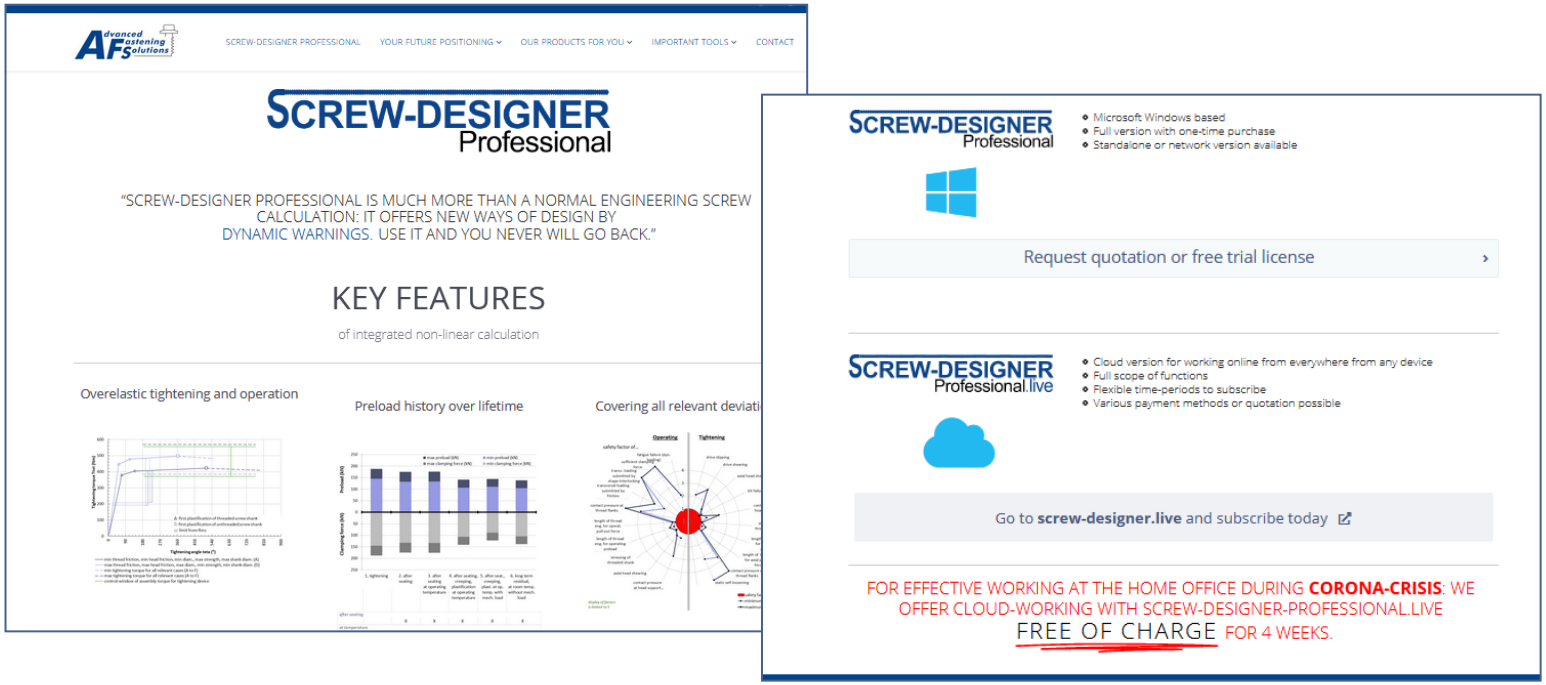
NOTICE

SCREW-DESIGNER Professional

THIS CASE STUDY IS NO SOFTWARE MANUAL

– This case study does not explain the structure and features of the software Screw-Designer Professional.

– For this please refer to
www.afs-engineering.de/screw-designer-professional



or contact us via screw-designer@afs-engineering.de or use E-Mail-Addresses at the end of this presentation.

INTRODUCTION TO CASE STUDY

SCREW-DESIGNER Professional

WHERE SUCH FASTENING SYSTEMS ARE USED AND WHY, RISKS FOR SCREW JOINTS

drone with camera

drone for transportation

spraying drone in agriculture

- **Background:**
  For fastening at drones it is of extreme importance to realize light weight design, because it affects directly carriage weight (2-200 kg) of drone and time of flight (app. 30 mins). Besides this, unlimited fatigue behavior is required to be safe. Both together mean careful design of any screw joint. Very important is rotor fastening (accidents took place); but also any other component has to be positioned very well with sufficient stiffness, to achieve precise flight behavior.
- **Risks of screw joints:**
  too low preload over time (preload-relaxation; breaking of screw or self loosening); special risk of corrosion or fretting fatigue in Light Weight Design LWD (requires Load Deformation Behavior LDB with FEA).
- **Future applications of drones:**
  Inspection drone, picture movie drone, cleaning drone, spraying drone, transportation drone (goods or persons), fire fighting drone.

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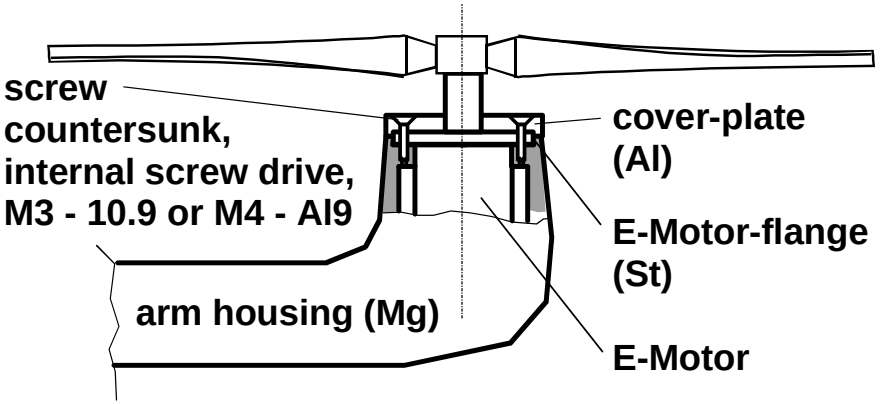
EXAMPLE PLATE FASTENING FOR ROTOR

SCREW-DESIGNER Professional

DESCRIPTION OF FASTENING SYSTEM

Basic explanation

The E-Motor is fastened by a plate which combines holding of E-Motor-flange, arm housing and cover plate. This case study does not refer to fastening of rotor itself to rotating E-Motor shaft.



Key data geometry

- Outside diameter of arm at plate D_A = 50 mm
- Diameter of screw positions D_t = 37.5 mm (circle diameter)
- Height of cover-plate h_p = 3 mm
- Height of E-Motor flange h_m = 2 mm

Key data materials

- Screw: steel property class 10.9 DIN EN ISO 898
- Clamped part: AlMg3 (plate for high corrosion resistance at low weight), Motor flange steel for deep drawing St 14
- Nut thread component: Magnesium casting AZ91 (Light weight)

Key data system

- Number of screws per motor flange i = 4
- Friction coefficient thread μ_G = 0.08…0.16
- Friction coefficient head μ_K = 0.08…0.16
- Interface friction coefficient μ_T = 0.10 (0.20)
- Roughness Rz <10 µm in component interface
- Torque controlled tightening to M_A = 4.0 Nm

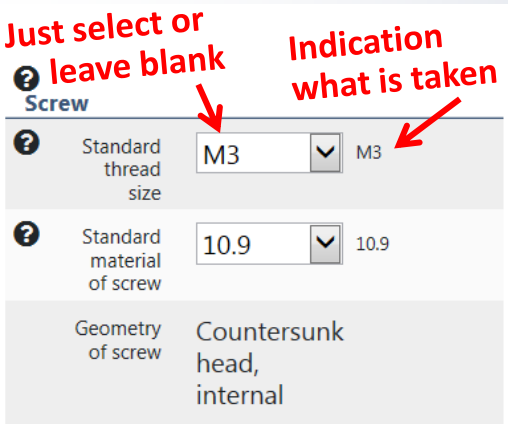
Key data loading

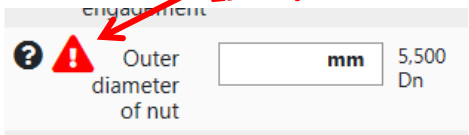
- Axial force from flying (6 rotors per drone, weight of drone 15 kg), this means F_a = 6.25 N per screw
- Transverse force from motor torque $M_{t\text{-E-Motor}}$ = 3 Nm, this means F_{tr} = 40 N per screw (F_{tr} = 2 * Mt/i/Dt)

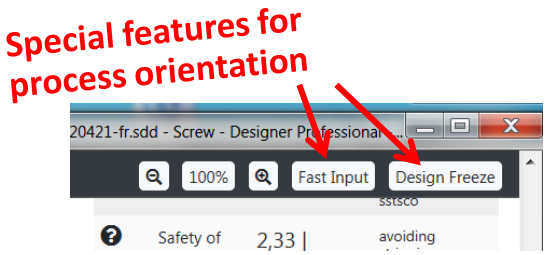
EXAMPLE PLATE FASTENING FOR ROTOR

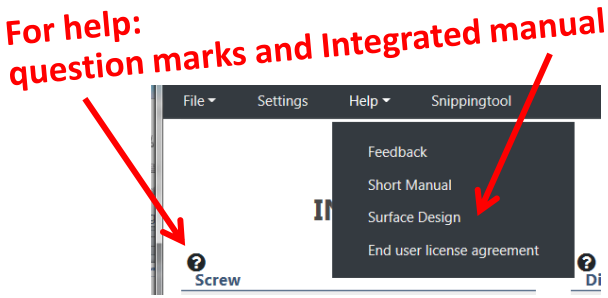
SCREW-DESIGNER Professional

WORKING WITH SCREW-DESIGNER PROFESSIONAL









- Working with Screw-Designer Professional is very easy.
- For maximizing efficiency we developed Screw-Designer Professional with latest approach in finding the optimum solution, as simple and fast as possible and considering latest technology. For this you only need 3 steps:

1. **Starting:** use refinement approach
2. **Optimizing:** vary parameters with help of warnings and recommendations
3. **Finishing:** release final version

- This accelerates design work and reduces efforts for testing (verification), because you immediately have the optimum version – therefore, you can save significant cost by using Screw-Designer Professional, if you look to the complete process of product development.
- And the best is: your screw joints are at leading edge of innovation, if you follow the suggestions.

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EXAMPLE PLATE FASTENING FOR ROTOR

SCREW-DESIGNER Professional

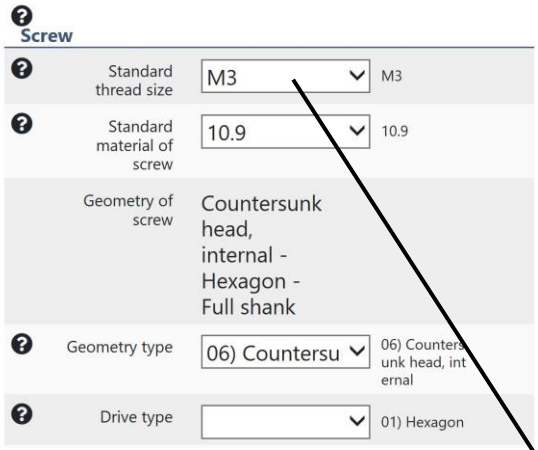
MODELLING IN SCREW-DESIGNER PROFESSIONAL: PRINCIPLE

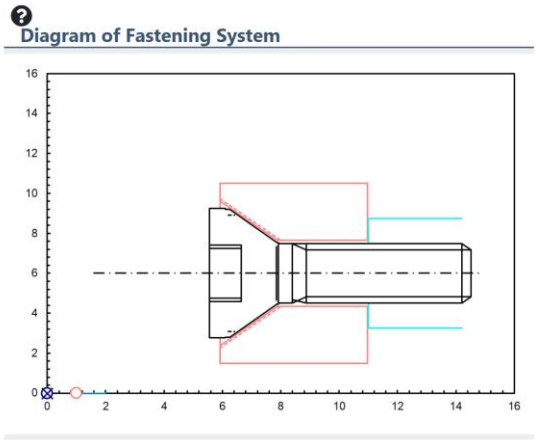
The user-interface of Screw-Designer Professional consists of **three** columns

Modeling **INPUT**

Calculation results **ANALYSIS**

Ratings for decisions **ASSESSMENT**





Only in this column input is made

Predefined selection field for easy input

The section assessment consists of safety-factors, distinguishing tightening and operating. With this, not only results are available, but also decision-making is possible (important).

For more information refer to website or to user's manual

Example from app. 25 safety factors

Hint: Screw-Designer Professional also provides full over-elastic tightening and operating with plastification. For tightening, not only torque, but also tightening control window is available.

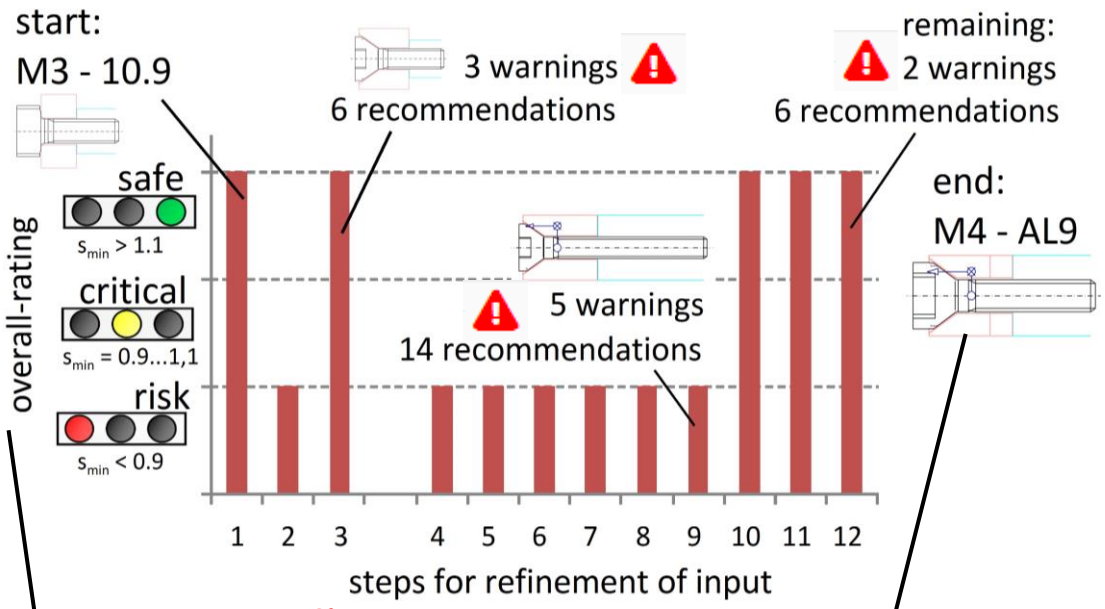
Example for overall-rating and assessment traffic light for overview

EXAMPLE PLATE FASTENING FOR ROTOR

SCREW-DESIGNER Professional

MODELLING IN SCREW-DESIGNER PROFESSIONAL; REFINEMENT APPROACH

Screw-Designer Professional opens a new way of screw design procedure: do not care about equations and values, but concentrate on overall-rating and follow warnings and recommendations – this is the was to excellent behavior throughout lifetime.



Contains all safety-factors; distinguishing tightening and operating

Release with APPROVAL & NOTES

Name And Date	AFS sample case drones
Changes And Date 1.	optimization April 2021
Changes And Date 2.	
Changes And Date 3.	
Legend/notes	remaining warnings have been checked and rated as ok.

Sequence of refinement approach

1. thread size
2. property class of screw

Fast Input — Estimating first preload values with just size and material of thread

3. geometry of screw (head support)
4. materials of components
5. loadings and eccentricity
6. preload relaxation
7. friction (reality or allowed band)
8. clamp length
9. tightening
10. length of thread engagement
11. outer diameter of nut
12. other details…

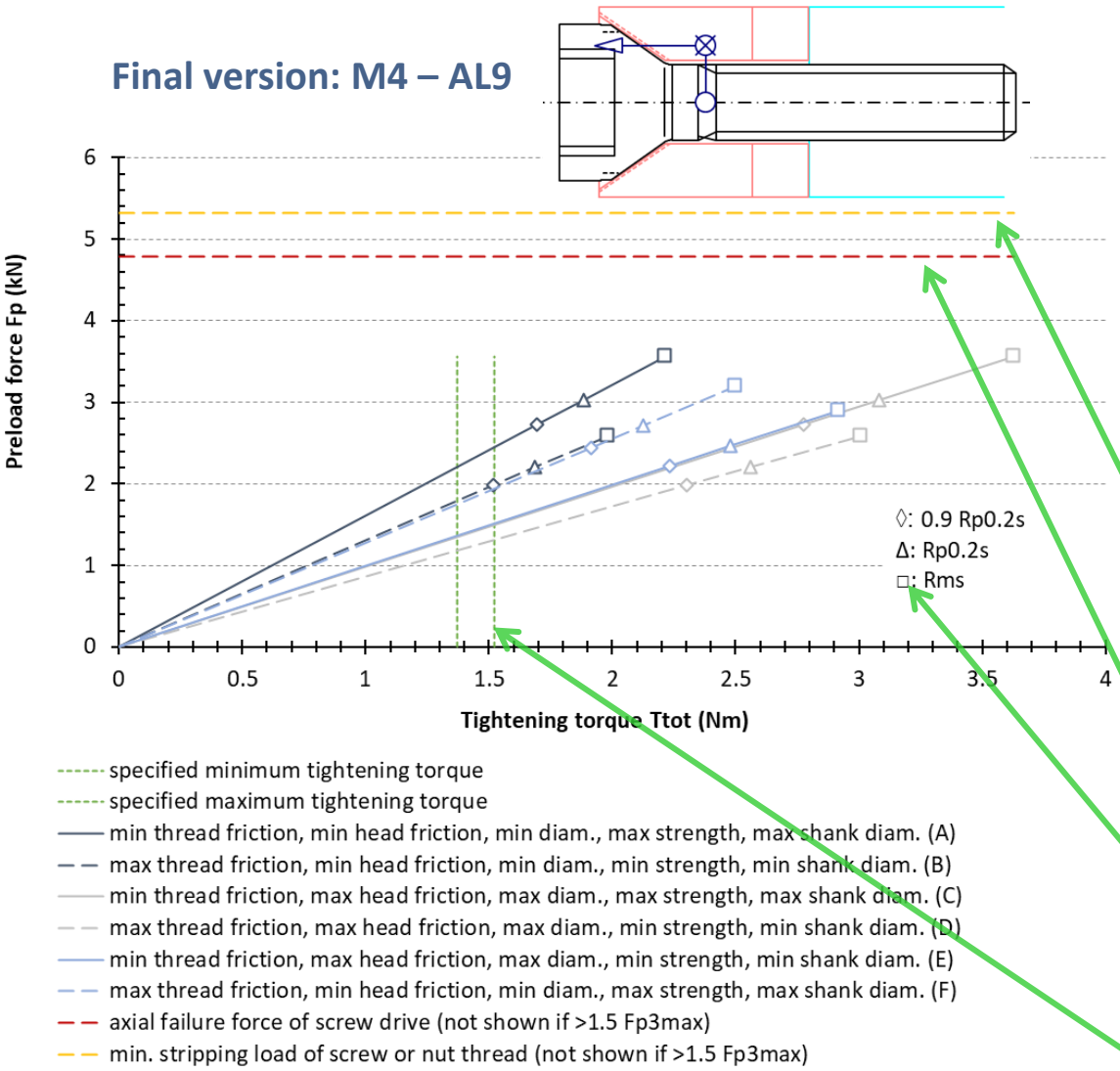
…and recheck parameters before

Design Freeze — Locking design for release purposes

EXAMPLE PLATE FASTENING FOR ROTOR

SCREW-DESIGNER Professional

RESULTS FROM SCREW-DESIGNER PROFESSIONAL: TIGHTENING



- Only some main results are shown here (M4 – AL9). Calculation file saved with extension -.sdd can be opened with any text editor to see all inputs that were made.
- The diagram left is a standard output for Screw-Designer Professional. It shows tightening preload Fp versus tightening torque Ttot.
- The horizontal line in yellow refers to axial failure load of thread (in many cases stripping; dependent on length of thread engagement).
- The horizontal red line refers to the axial failure force of screw drive (important for internal drives).
- Markings indicate levels of stressing of screw shank; cases A..F refer to combinations with lowest and highest preload.
- Vertical lines indicate the torque from tightening specification.

Note: countersunk screws need special attention to positioning tolerances.

EXAMPLE PLATE FASTENING FOR ROTOR

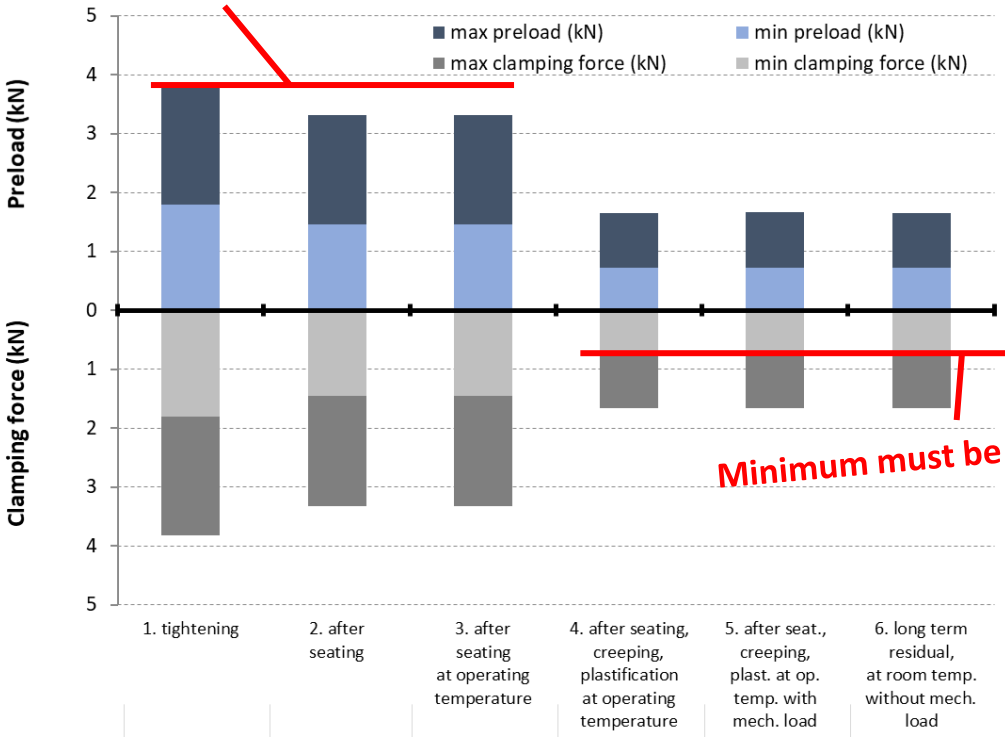
SCREW-DESIGNER Professional

RESULTS FROM SCREW-DESIGNER PROFESSIONAL: OPERATNG

Safety of stressing 1.25 | 2.82 avoiding static breaking of threaded shank sstsct

Here only some main results are shown (M3 – 10.9).

Maximum must not overload screw

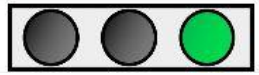


Safety of transversal loading submitted by friction 1.81 | 4.14 avoiding micro slipping between components strfro

Minimum must be sufficient for transverse force transmission

Total Safety of Threaded Fastening System

The rating is **safe with 25/25 criteria** Check warnings below!



Overall-rating is available for easy assessment

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EXAMPLE PLATE FASTENING FOR ROTOR

SCREW-DESIGNER Professional

VARIATION FOR IMPROVEMENT OF FASTENING SYSTEM

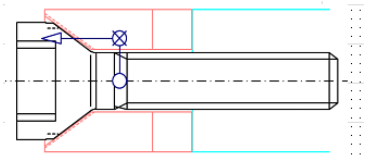
Very important for innovation of products;
always the existing design can be improved;
for screw joints this means:

- take a smaller screw
- take a better screw geometry
- reduce eccentricity
- enhance preload stability
- take screw with higher material strength
- specify better tightening method
- take lower deviation of friction
- take into account deficits for robustness
  (can be at screw, clamped part,
  nut thread component, tightening process)

M3 – 10.9

- long screw
- difficult handling
- large preload loss
  by material misfit

M4 – AL9

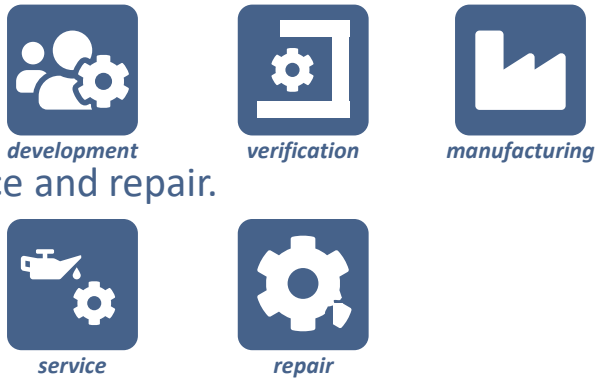


- shorter screw
- robust handling
  by special geometry
- relatively stable preload
  by fit of thermal elongation

– **Way of improvement**

Any improvement needs changing some parameters of the design. This can be done best with variations to see the impact to the safety-factors.

Screw-Designer allows this very easily by the refinement approach; this can be used in development, verification, production as well as service and repair.



– **Results of variation here**

Varied was type of screw geometry (head support from plain to countersunk), length of screw (length of thread engagement) and screw material from 10.9 to AL9 (significant advantages).

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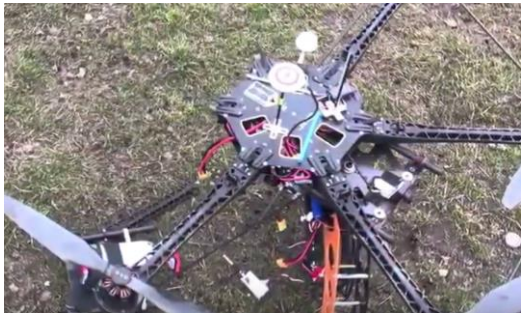
EXAMPLE PLATE FASTENING FOR ROTOR

SCREW-DESIGNER Professional

INTENTION FOR VARIATIONS IN GENERAL

- **Optimization with variation of parameters is important**; it has a large impact on the behavior of your products at your users - therefore, it is base for product innovation you make. If you do not have best behavior, then competitors will have more success.
- This is the reason, why following listing shows targets of variations:
  - load cases (cover all user situations, regular loads)
  - peak loading (extra loads, misuse)
  - materials (especially consider thermal limit and thermal stability)
  - geometry (especially head support area)
  - tightening level (including retightening and worst case tightening)
  - bending effects (eccentricity and partial/complete opening)
  - aging of joint (friction, material properties, preload relaxation)
  - self loosening

Drone crash
source: www.dronegenuity.com



Drone crash, Mexico 2015
source: YouTube

Drone crash during ski racing
Italy, Marcel Hirscher, Dec. 2015
source: www.kleinezeitung.at

- **In the event of accidents with drones the question of responsibility of pilot and integrity of the drone always has to be clarified.**

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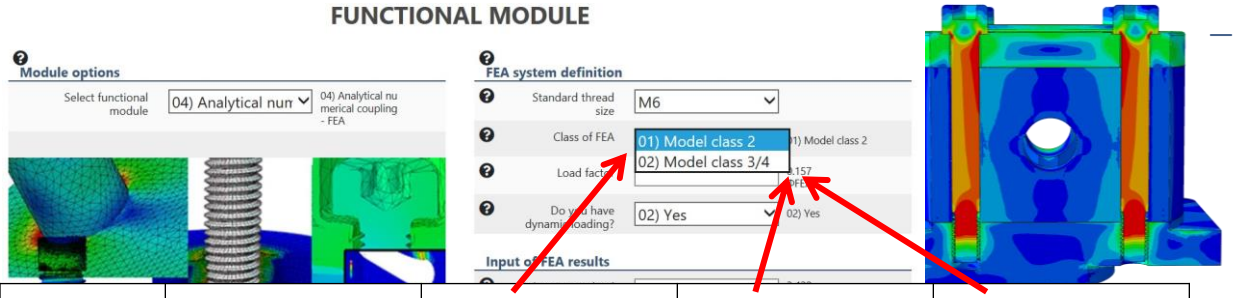
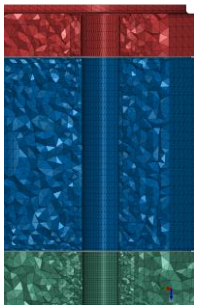
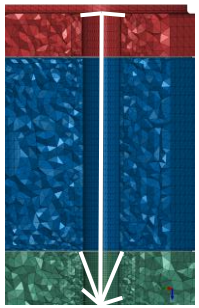
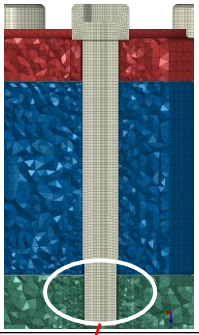
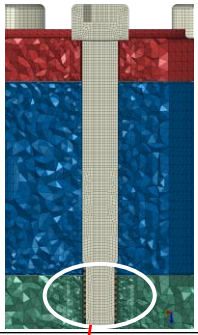
NEW FEATURE: NUMERIC EVALUATION

DIRECT USE OF FEA-RESULTS FOR DESIGN WITH SCREW-DESIGNER PROFESSIONAL



	Model class 1	Model class 2	Model class 3	Model class 4
				
FEA model attributes	No bolt and clamped part interface	Bolt represented using beam elements	Bolt represented using solid elements without threads	Bolt represented using solid elements with threads
Consideration of bolt preload	Not possible	Possible	Possible	Possible
Friction between clamped parts	Not possible	Possible	Possible	Possible
Friction between mating threads	Not possible	Limited treatment possible	Limited treatment possible	Possible
Bending moment analysis of bolt	Not possible	Possible	Possible	Possible
Intention of FEA simulation	Determining the reaction forces in the clamped part interface and/or load-deformation study of the clamped parts	Inclusion of bolt resillience, reaction forces and moments on the bolt, stress distribution in clamped part interface, relative movement and opening of clamped part interface	All intentions of model class 2 along with stress distribution in different cross-sections of bolt and possibilty to simulate preload relaxation	All intentions of model class 3 along with possibility to simulate rotational self-loosening, behaviour of self-thread-forming screws and loading capacity of threads and inserts

- **Situation today:**
  Almost any Design is done with FEA, but Screw-Design is still done analytically – with SD-Pro this is changed. Without consideration of eccentricities your design is unsafe or over-dimensioned; and eccentricities depend on Load Deformation Behavior LDB (requires FEA).
- **Way of solution:**
  Use Functional Module FEA of Screw-Designer Professional (see left); with this your assessment does not depend on rough estimation of eccentricity a (responsible for bending moment in screw, which leads to early failure).
- **Conclusion:**
  Rigid Body approach is not yet sufficient for innovative products, but it is used in most guidelines. Do use Functional Module FEA of Screw-Designer – this saves time for you and results in better fastening systems.

SCREW-DESIGNER Professional

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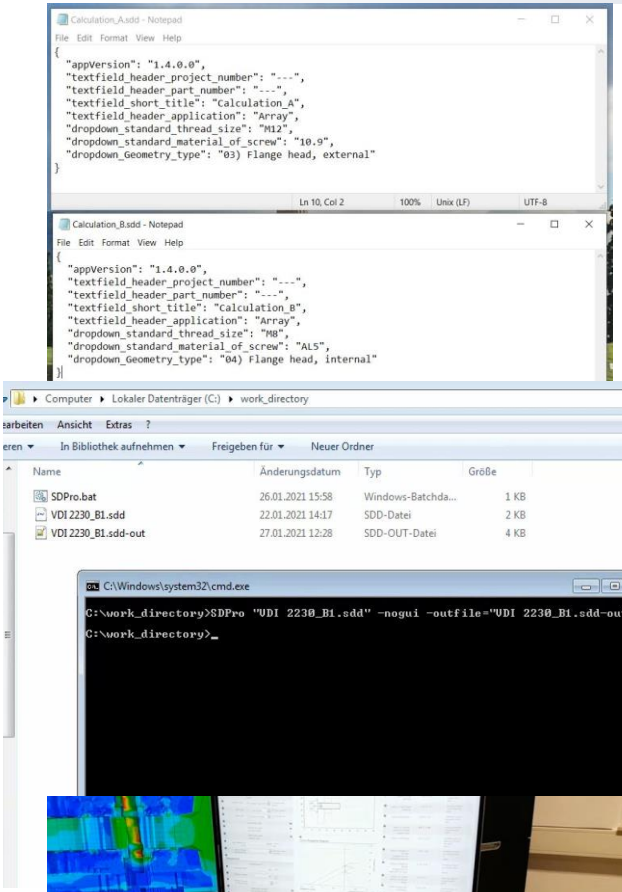
NEW FEATURE: AUTOMIZED DESIGN

COMMAND LINE IN- AND OUTPUT WITH SCREW-DESIGNER PROFESSIONAL



- **Situation today:**
  Today new product designs are developed by a large number of engineers. They are using CAE and calculate Machine Elements manually, such as screw joints. The outcome then has to be verified, so it is of very strong impact that the first design outcome has no problems in verification (also it is very critical for short development times). The next step is to transfer this work to machines.
- **Way of solution:**
  Therefore, it is possible with Screw-Designer Professional to exchange data, so you can do full integration of this tool in your automized design process. It is really impressive to see when new designs appear from machines. It only works with our full approach. In future, the engineers will more control the design machines than calculating manually.
- **Conclusion:**
  This has a really huge impact on your design process. Therefore, **our strong recommendation** to all decision-takers is: The implementation of automized design is extremely important to stay state-of-the-art in your business field.

SCREW-DESIGNER Professional

AFS Advanced Fastening Solutions

FURHTER INFORMATION

AFTER THIS CASE STUDY: YOU CAN ALSO USE THESE CLEAR BENFITS FOR YOUR PRODUCTS

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BETTER PRODUCTS

especially for Digitalization and Mechatronics with Light Weight Design of your mechanical structure

SCREW-DESIGNER Professional

BETTER PROCESSES

especially for short time to market, reduced testing without success, more lean and up-to-date-processes in manufacturing and quality management

BETTER SERVICE

especially for fast finding of reasons of failures or complaints - this is important to show agility

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