University of Applied Sciences and Arts Northwestern Switzerland
School of Engineering

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Welcome!
About Socrative student response system

Dear students

I look forward meeting you next Tuesday on the lecture on load introductions

We will be using the Socrative student response system for some small quizzes

To participate use the following link on your laptop or smartphone

https://b.socrative.com/login/student/

As Room Name use **brauner**

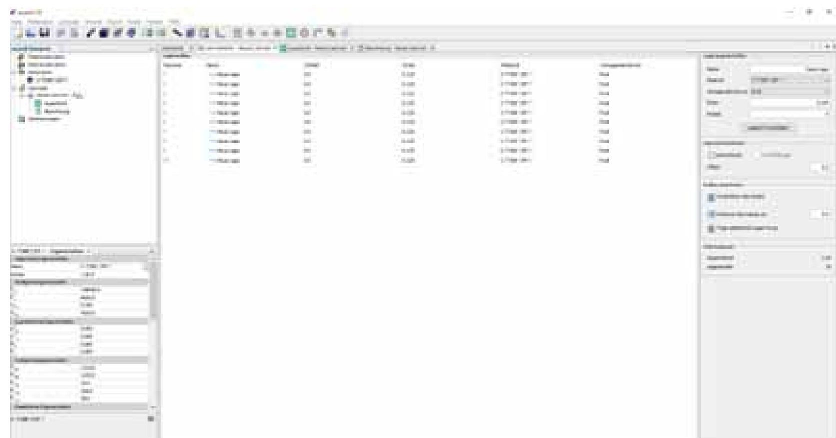
(alternatively you may us the socrative student app https://www.socrative.com/apps.html)

Welcome!

Second please install elamx from:

https://tu-dresden.de/ing/maschinenwesen/ilr/lft/elamx2/elamx

We will use it as a small tool to show the design workflow and to solve some small examples



University of Applied Sciences and Arts Northwestern Switzerland
School of Engineering

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Composites Technology

Load Introductions in Preliminary Design

Prof. Christian Brauner, Institute of Polymer Engineering

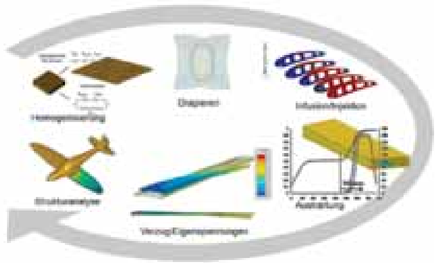
About myself

FH Bielefeld — Mechanical Engineering

Silence aircraft — Manufacturing and design

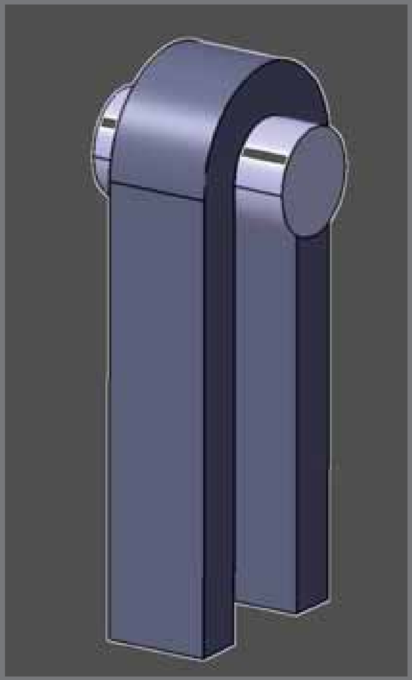
SAMTECH — Software Engineering

FASERINSTITUT FIBRE BREMEN — Universität Bremen

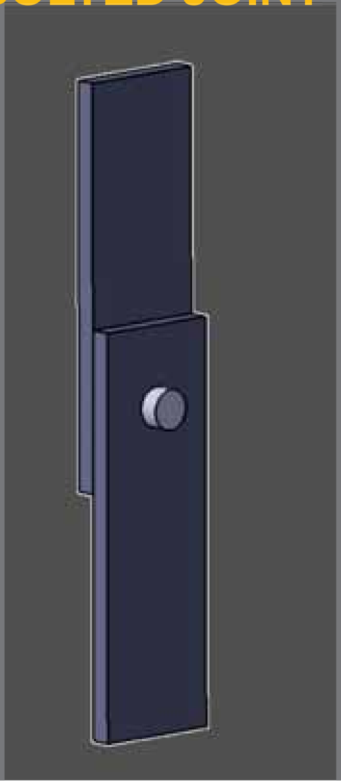


Since 2016
Institute of Polymer Engineering

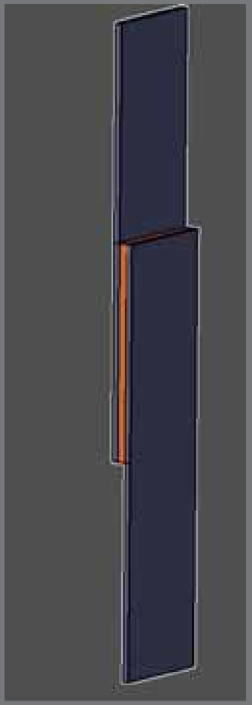
PIN LOADED STRAP



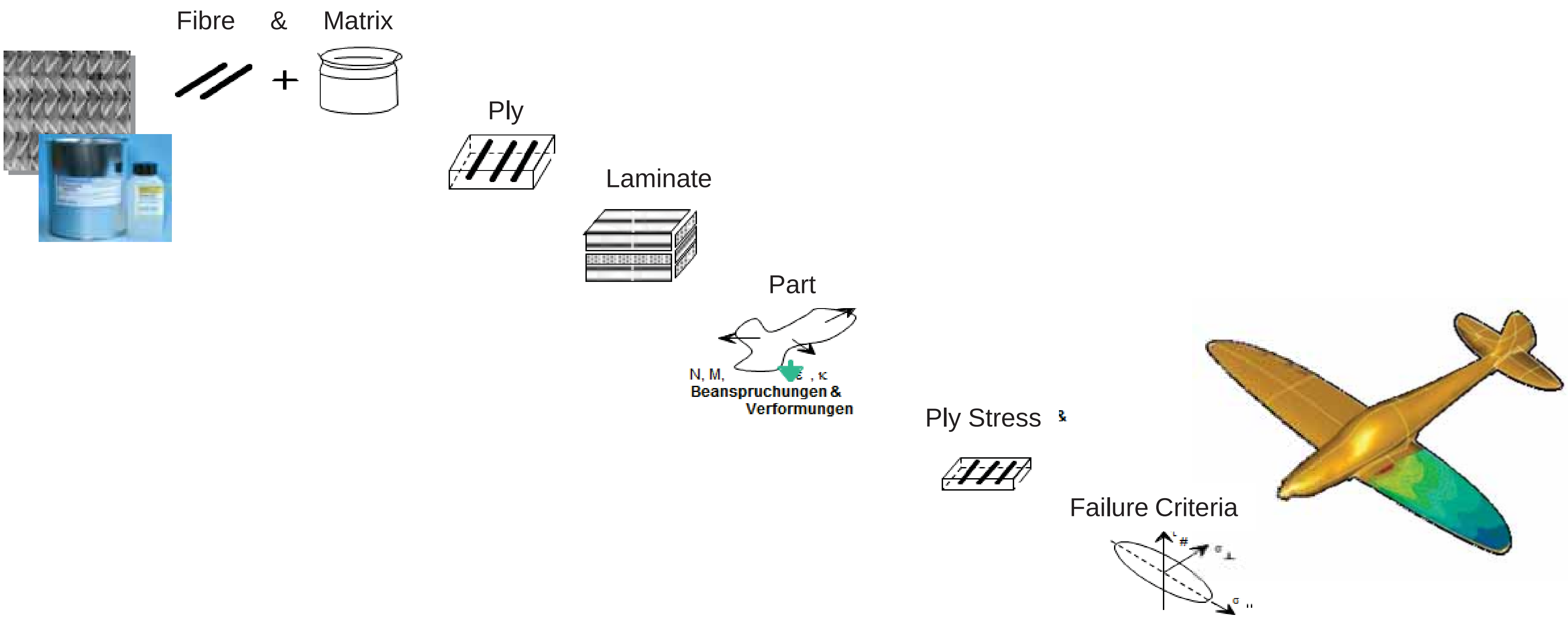
BOLTED JOINT



BONDED JOINT



General introduction into stress analysis of composite



Active unit : short introduction to elamx:

Please open elamx

Start with database material like T300

Add 10 layers, t=0.125

Add a “Berechnung” to check ABD matrix

Check “Polardiagram”

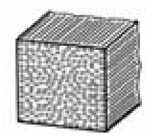
Check “Ingenieurskonstanten”

Check “Versagenskörper”

Process of stress analysis in a composite laminate: 12 steps

1. Basic material properties

Fibre, Matrix

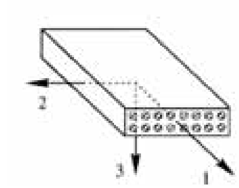


E_F, ν_F E_M, ν_M, V_F

2. Elastic constants of the UD ply

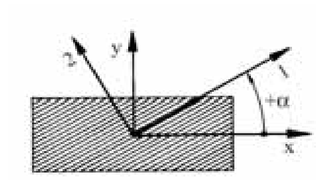
E_1, ν_{12}, $\nu_{21,}$ E_2, G_{12}

3. Stiffness of the UD plies related to the local ply coordinate system



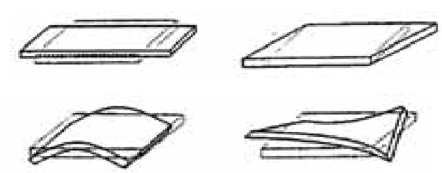
$$\begin{Bmatrix}\sigma_1\\ \sigma_2\\ \tau_{12}\end{Bmatrix}=\begin{bmatrix}Q_{11} & Q_{12} & 0\\ Q_{12} & Q_{22} & 0\\ 0 & 0 & Q_{66}\end{bmatrix}\begin{Bmatrix}\varepsilon_1\\ \varepsilon_2\\ \gamma_{12}\end{Bmatrix}$$

4. Transformed stiffness of the UD plies related to the global xy coordinate system



$$\begin{Bmatrix}\sigma_x\\ \sigma_y\\ \tau_{xy}\end{Bmatrix}=\begin{bmatrix}\overline{Q}_{11} & \overline{Q}_{12} & \overline{Q}_{16}\\ \overline{Q}_{12} & \overline{Q}_{22} & \overline{Q}_{26}\\ \overline{Q}_{16} & \overline{Q}_{26} & \overline{Q}_{66}\end{bmatrix}\begin{Bmatrix}\varepsilon_x\\ \varepsilon_y\\ \gamma_{xy}\end{Bmatrix}$$

5. Calculate A, B and D terms per ply and summation



$$A_{ij}=\sum_{k=1}^{n}\overline{Q}_{ij,k}\cdot t_k$$

$$B_{ij}=\sum_{k=1}^{n}\overline{Q}_{ij,k}\cdot t_k\cdot\left(z_k-\frac{t_k}{2}\right)$$

$$D_{ij}=\sum_{k=1}^{n}\overline{Q}_{ij,k}\cdot\left(\frac{t_k^3}{12}+t_k\left(z_k-\frac{t_k}{2}\right)^2\right)$$

Process of stress analysis in a composite laminate: 12 steps

6. Assembly of the ABD Matrix,

$$\begin{Bmatrix} N \\ -- \\ M \end{Bmatrix}_{xy} = \left[\begin{array}{c|c} A & B \\ \hline B & D \end{array}\right] \begin{Bmatrix} \varepsilon^{o} \\ -- \\ \kappa \end{Bmatrix}_{xy}$$

7. Analyse load case and calculate force and moment flux

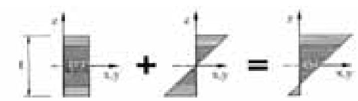
$$N_x = \int_{-h/2}^{h/2} \sigma_x dz \quad ; \quad N_y = \int_{-h/2}^{h/2} \sigma_y dz \quad ; \quad N_{xy} = \int_{-h/2}^{h/2} \tau_{xy} dz$$

$$M_x = \int_{-h/2}^{h/2} \sigma_x z dz \quad ; \quad M_y = \int_{-h/2}^{h/2} \sigma_y z dz \quad ; \quad M_{xy} = \int_{-h/2}^{h/2} \tau_{xy} z dz$$

8. If loads known compute the inverse ABD tensor = compliance tensor of the laminate

9. Calculate strain and curvature of the laminate and thereby of all UD plies related to the global xy coordinate system

$$\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix}_k = \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix}_0 + z_k \begin{bmatrix} \kappa_x \\ \kappa_y \\ \kappa_{xy} \end{bmatrix}_0$$



10. Transform lamina strain back into ply coordinate system

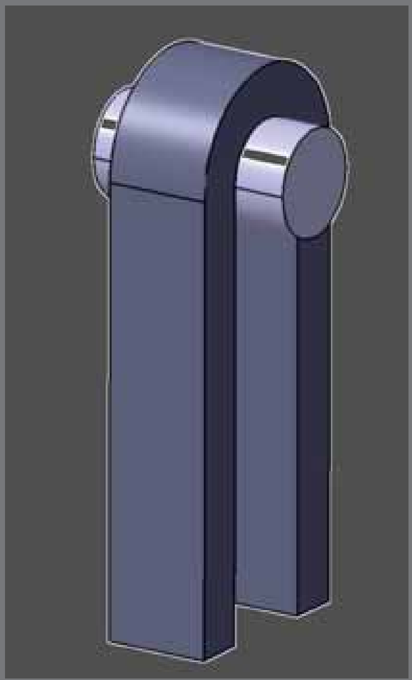
$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{bmatrix} = [T]^\wedge T \cdot [\varepsilon_x] = \begin{bmatrix} \cos^2\psi & \sin^2\psi & \sin\psi\cos\psi \\ \sin^2\psi & \cos^2\psi & -\sin\psi\cos\psi \\ -2\sin\psi\cos\psi & 2\sin\psi\cos\psi & \cos^2\psi - \sin^2\psi \end{bmatrix} \cdot \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix}$$

11. Stress in the single UD plies related to the local ply coordinate system

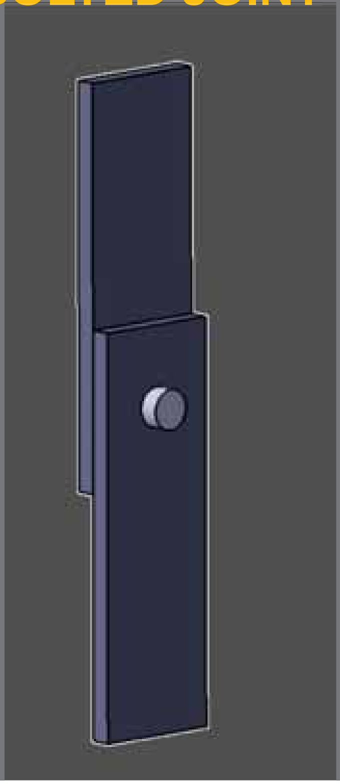
$$\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} = \begin{bmatrix} Q_{11} & Q_{12} & 0 \\ Q_{12} & Q_{22} & 0 \\ 0 & 0 & Q_{66} \end{bmatrix} \begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{Bmatrix}$$

12. Use failure criteria to evaluate failure (not shown here)

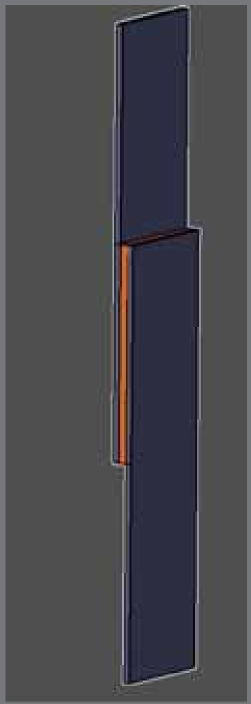
PIN LOADED STRAP



BOLTED JOINT



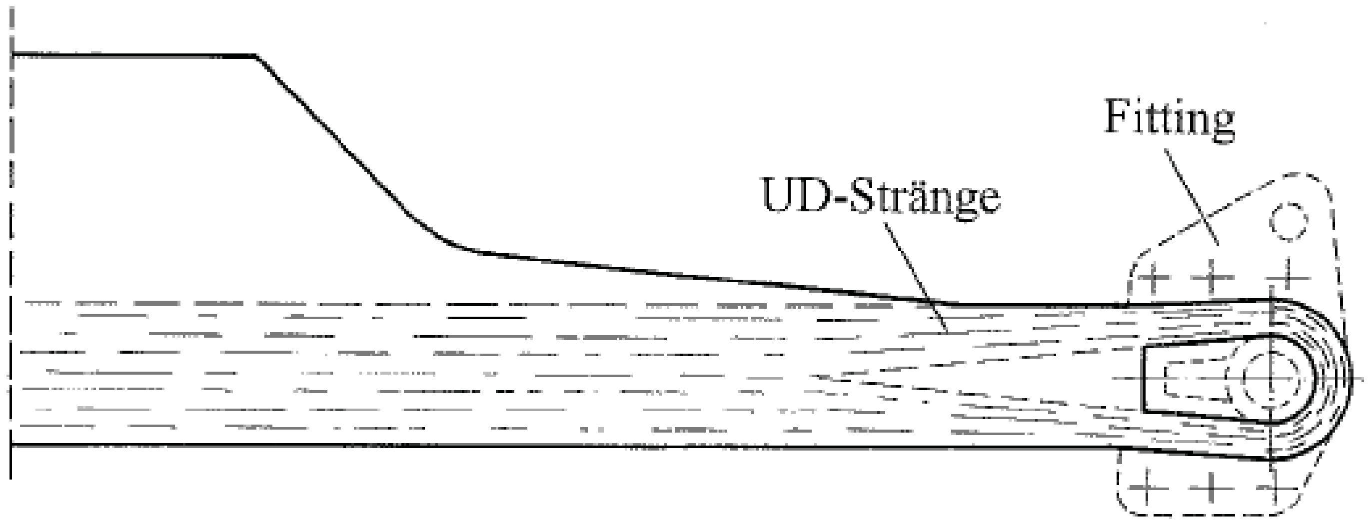
BONDED JOINT



Objective – to understand

- **Concept**
- **Manufacturing challenges**
- **Sizing**
- **Design integration**

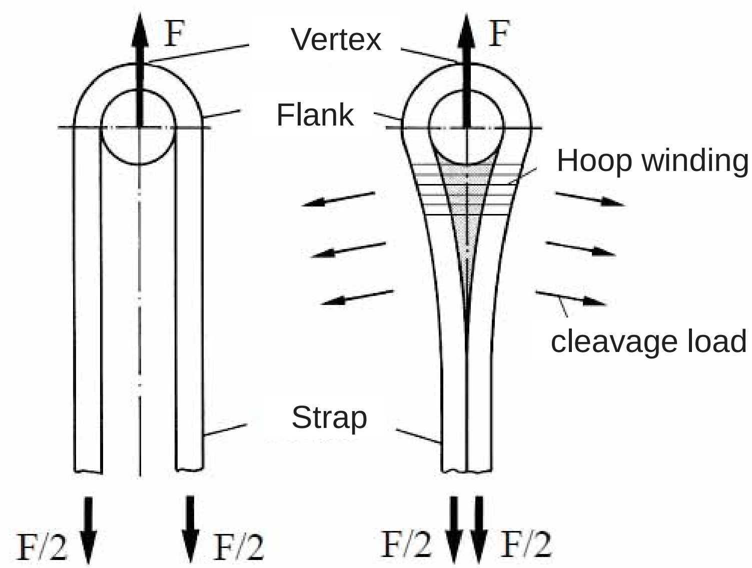
Pin loaded strap



A composite pin loaded strap in a nutshell

- **Uses unidirectional carbon fibres in a polymer matrix**
- **Fibres are aligned along the load path**

	Unidirectional CFRP	Steel
Strength [MPa]	2000	600
Density [kg/m3]	1560	7850
Spec. strength [kNm/kg]	1282	76



[Schürmann]

Applications

CFRP holdings bars

- **Lightweight: easy to assemble**
- **Lightweight: up to 50% higher lifting loads with longer reach**
- **non-corrosive**

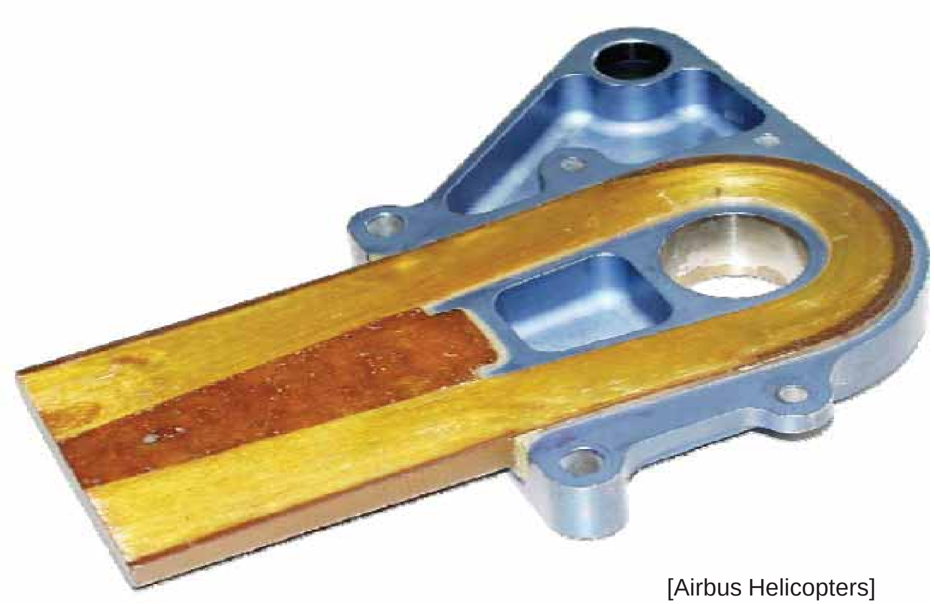
CFRP holding bars

- Connected by pin loaded straps and coupling plates

- Supression of vortex shedding vibration by helical strakes

Applications

BO105 Rotorcraft blade attachment



[Airbus Helicopters]

[flyingbulls.at]

[flyingbulls.at]

Applications

Composite Connecting Rod

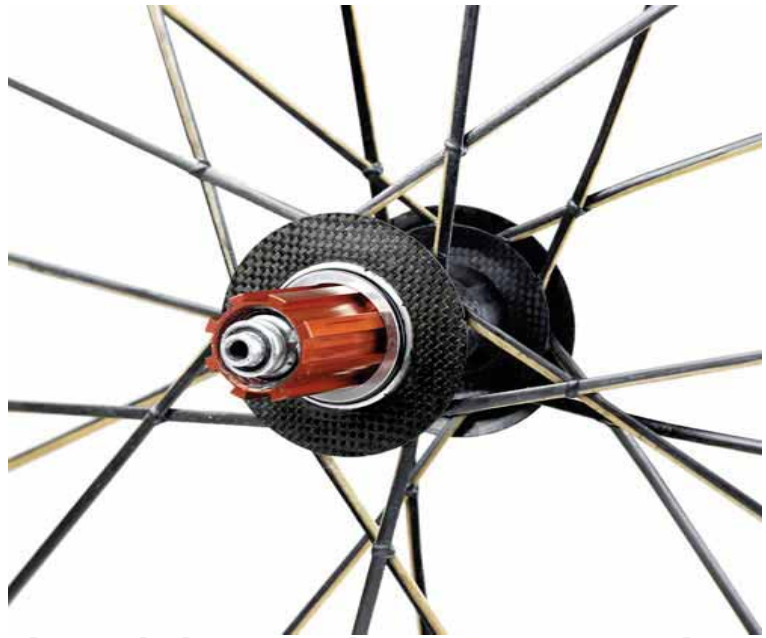
- **Axial load transfer by pre-stressed structure**
- **Reduced oscillating mass**

Jaguar 4.2L straight six cylinder engine

[Brauner 1990]

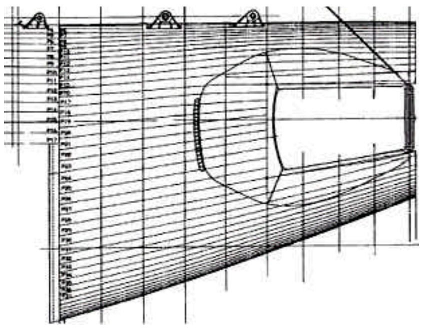
Applications

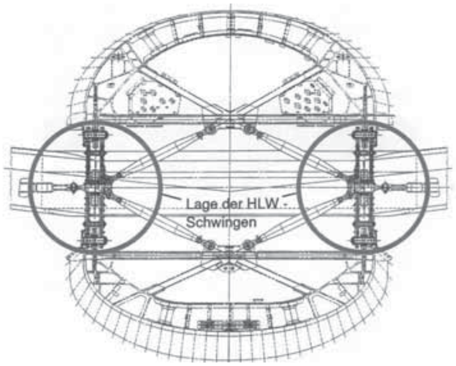
Bike wheel

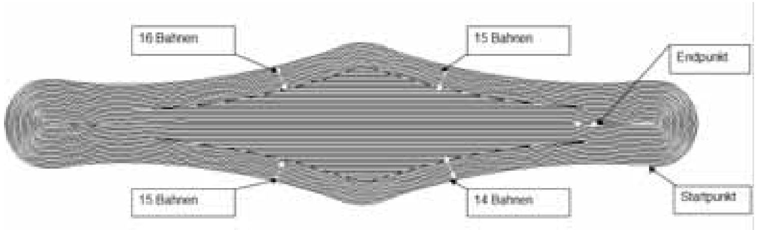


Radiate Engineering **Lightweight - CarbonSports GmbH**

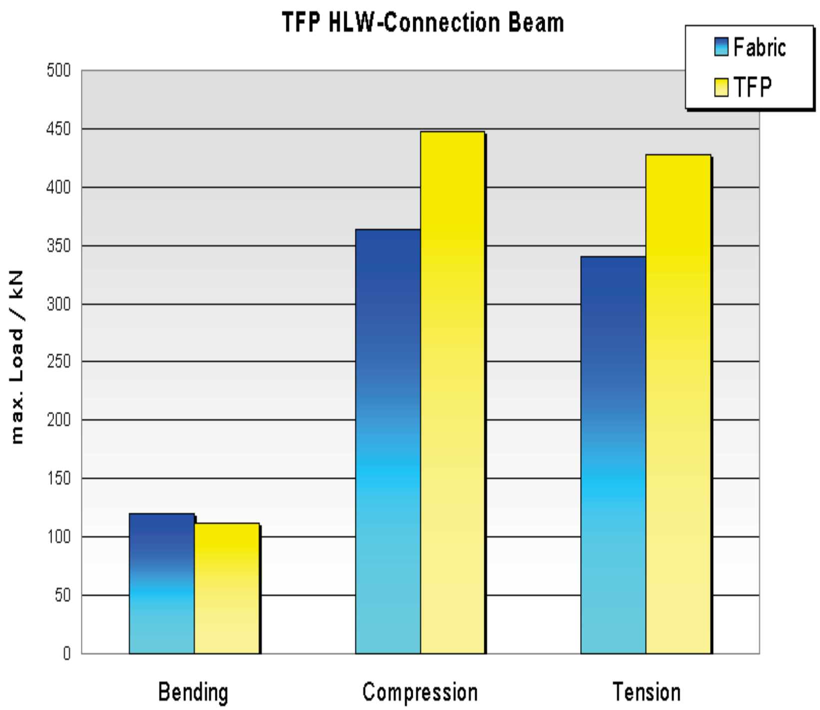
Applications



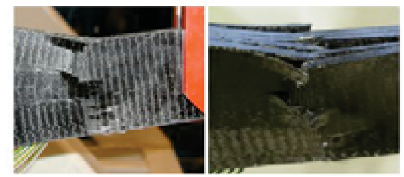




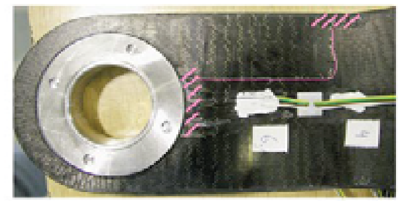
Applications



Statically load test



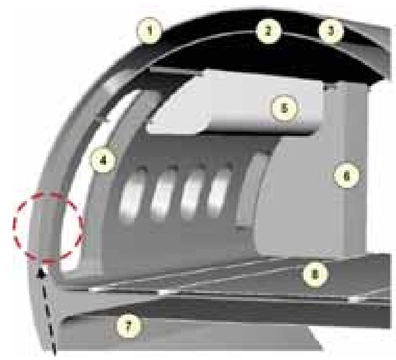
Bending

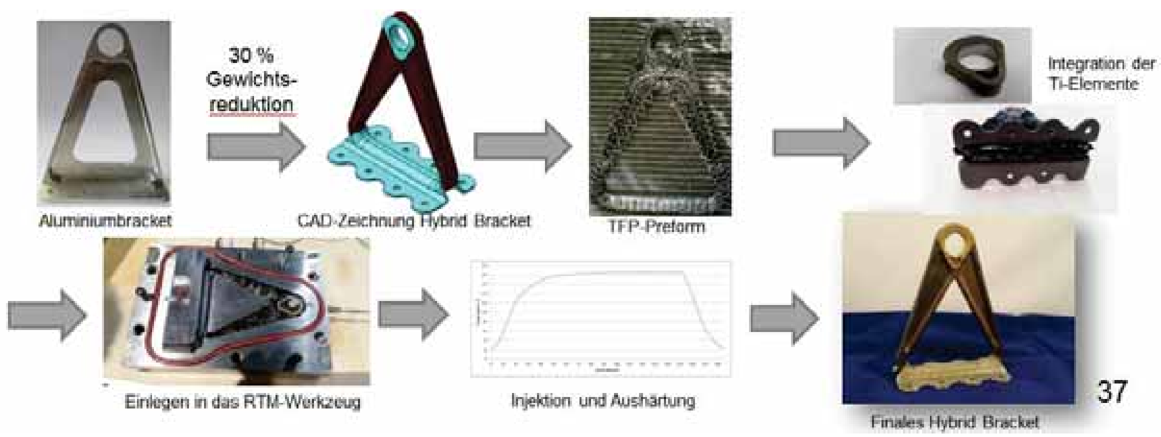


Compression

Tension

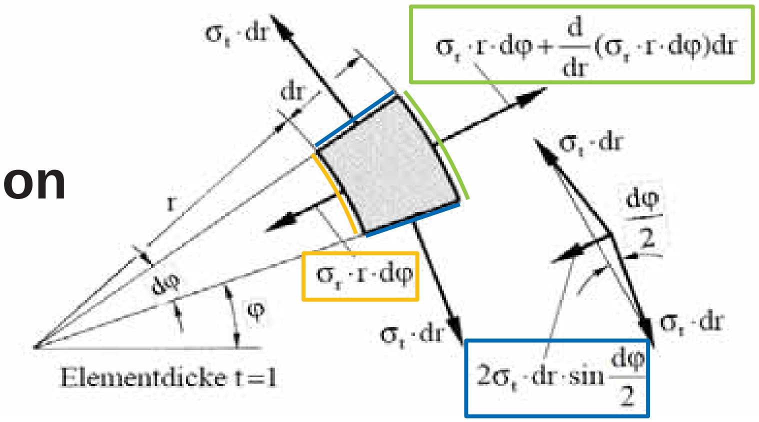
Applications





Equilibrium of forces in radial direction

Tangential stresses create radial compression on pin



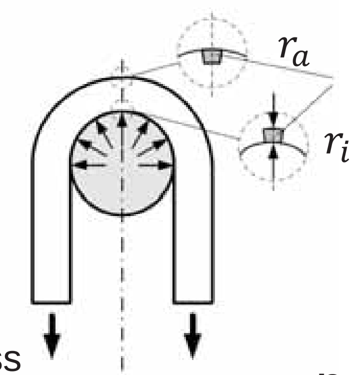
$$-\boxed{\sigma_r(r \cdot d\varphi)} + \boxed{\sigma_r(r \cdot d\varphi) + \frac{d}{dr}(\sigma_r \cdot r \cdot d\varphi) \cdot dr} - \boxed{\sigma_t \cdot dr \cdot d\varphi} = 0$$

Index r = radial; Index t = tangential

$$\sigma_r(r_i) = -p_i \qquad \sigma_r(r_a) = 0$$

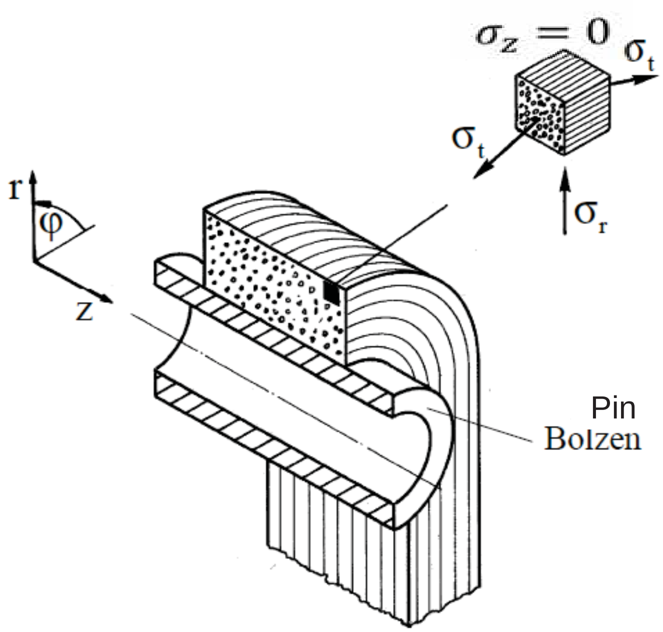
$$p_i = \frac{F}{2r_i \cdot b}$$

Radial pressure on pin corresponds to bearing stress



[Schürmann]

Strains in unsupported pin loaded strap



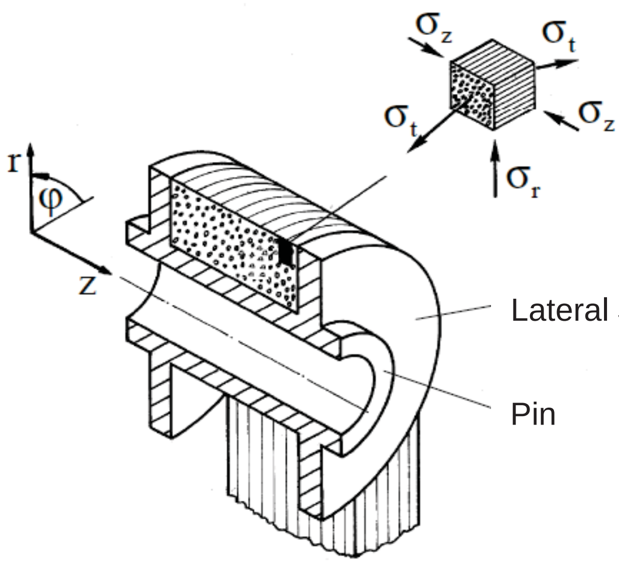
[Schürmann]

$$\varepsilon_r = \frac{\sigma_r}{E_\perp} - \nu_{\perp\parallel}\frac{\sigma_t}{E_\parallel}$$

$$\varepsilon_t = \frac{\sigma_t}{E_\parallel} - \nu_{\parallel\perp}\frac{\sigma_r}{E_\perp}$$

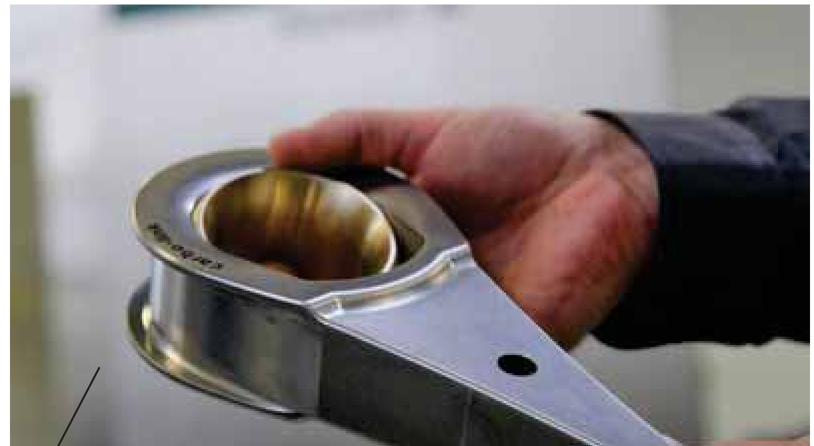
$$\varepsilon_z = -\nu_{\perp\perp}\frac{\sigma_r}{E_\perp} - \nu_{\perp\parallel}\frac{\sigma_t}{E_\parallel}$$

Strains in <u>supported</u> pin loaded strap



Lateral Support flange

Pin



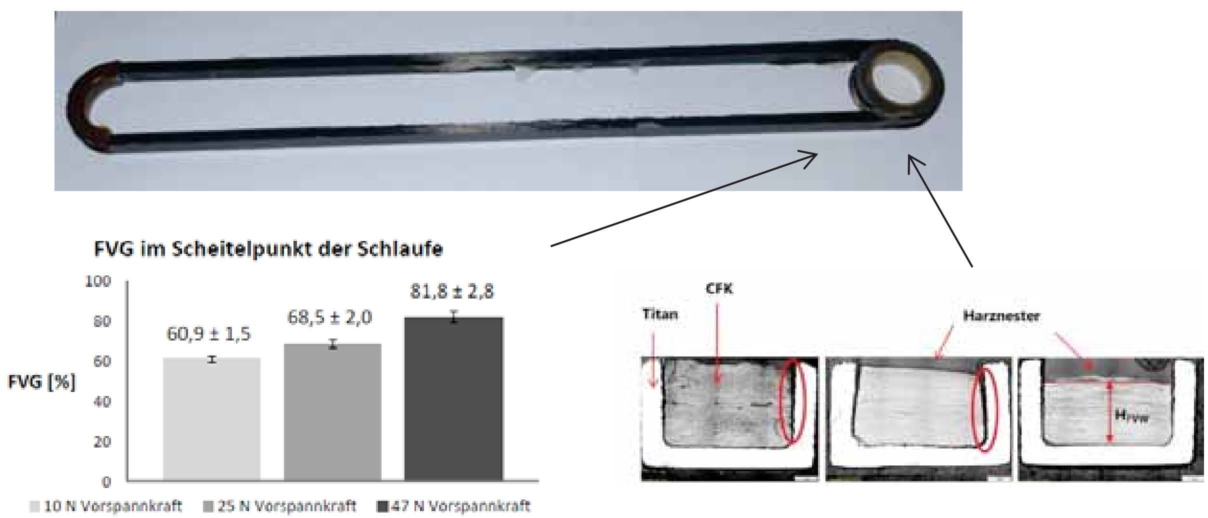
$$\varepsilon_r = \frac{\sigma_r}{E_\perp} - \nu_{\perp\parallel}\frac{\sigma_t}{E_\parallel} - \nu_{\perp\perp}\frac{\sigma_z}{E_\perp}$$

$$\varepsilon_t = \frac{\sigma_t}{E_\parallel} - \nu_{\parallel\perp}\frac{\sigma_z}{E_\perp} - \nu_{\parallel\perp}\frac{\sigma_r}{E_\perp}$$

$$0 = \frac{\sigma_z}{E_\perp} - \nu_{\perp\perp}\frac{\sigma_r}{E_\perp} - \nu_{\perp\parallel}\frac{\sigma_t}{E_\parallel}$$

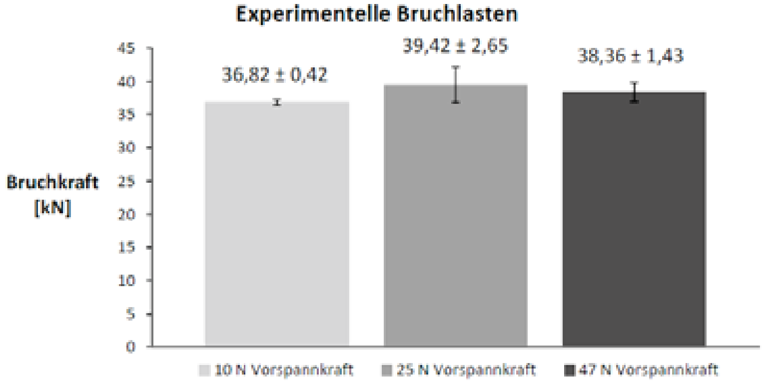
[Schürmann]

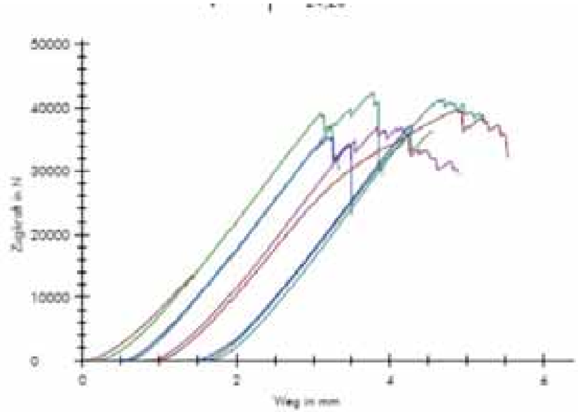
Strap example



Fibre volume content variation based on different pre load configurations

Strap example

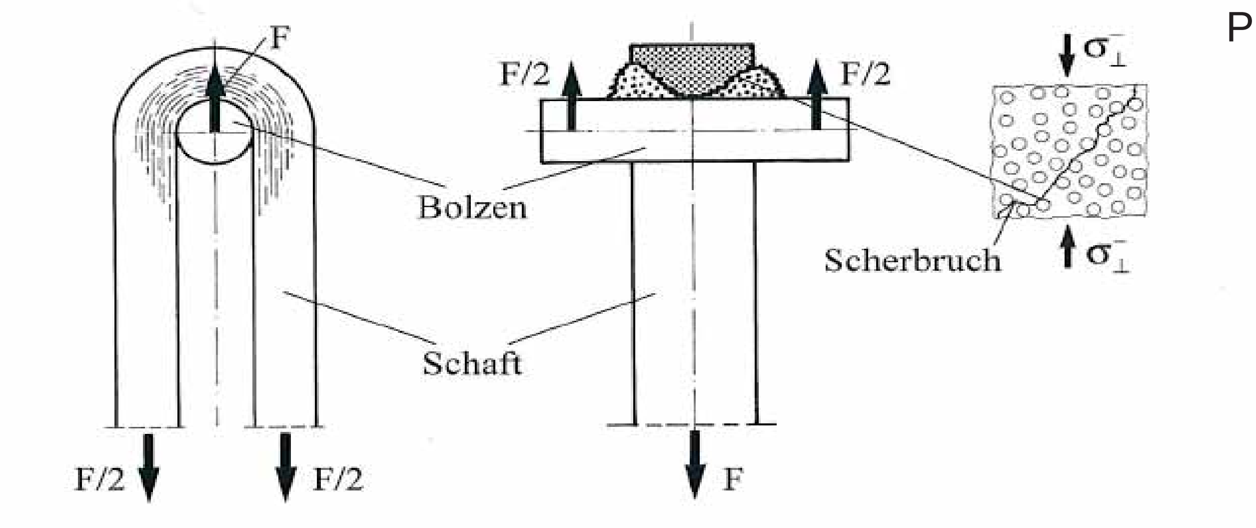




Failure load variation based on different pre load configurations

Failure of pin loaded straps

Failure dominated by radial stresses
(and shear stresses – not part of analytical solution)

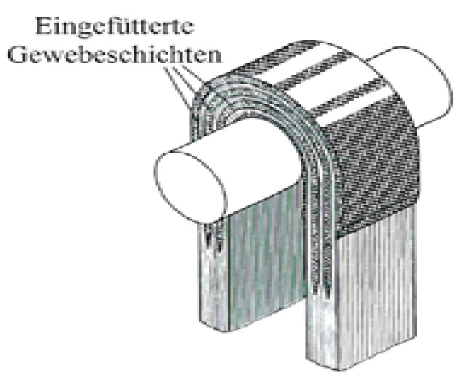


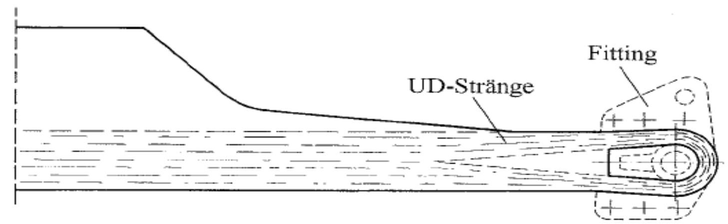
Puck mode C

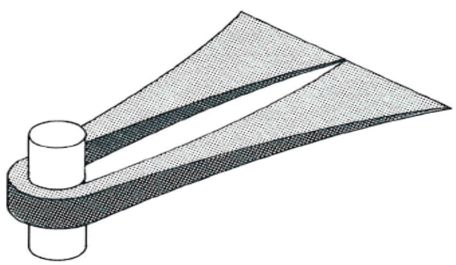
[Schürmann]

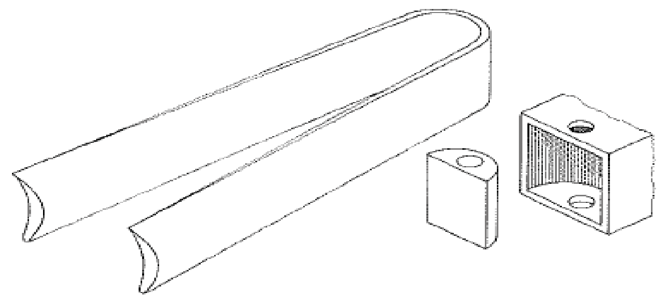
[Schürmann]

Design integration





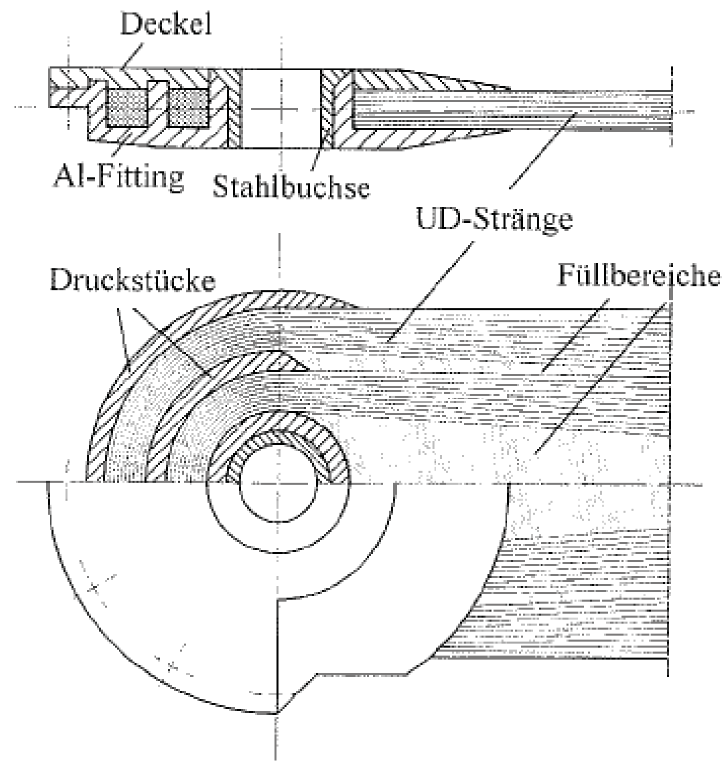




[Schürmann]

Design variations

- Reduces $^{r_a}/_{r_i}$ by subdivision
- Also transmits compression
- Suitable for wing root attachments



[Schürmann]

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School of Engineering

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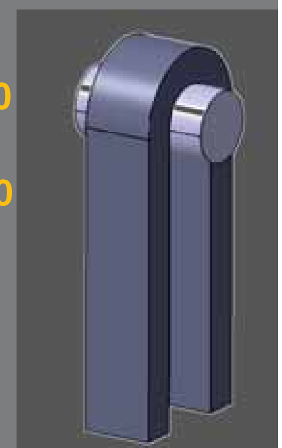
Questions on pin loaded strap

What is the primary failure mode of a pin loaded strap?

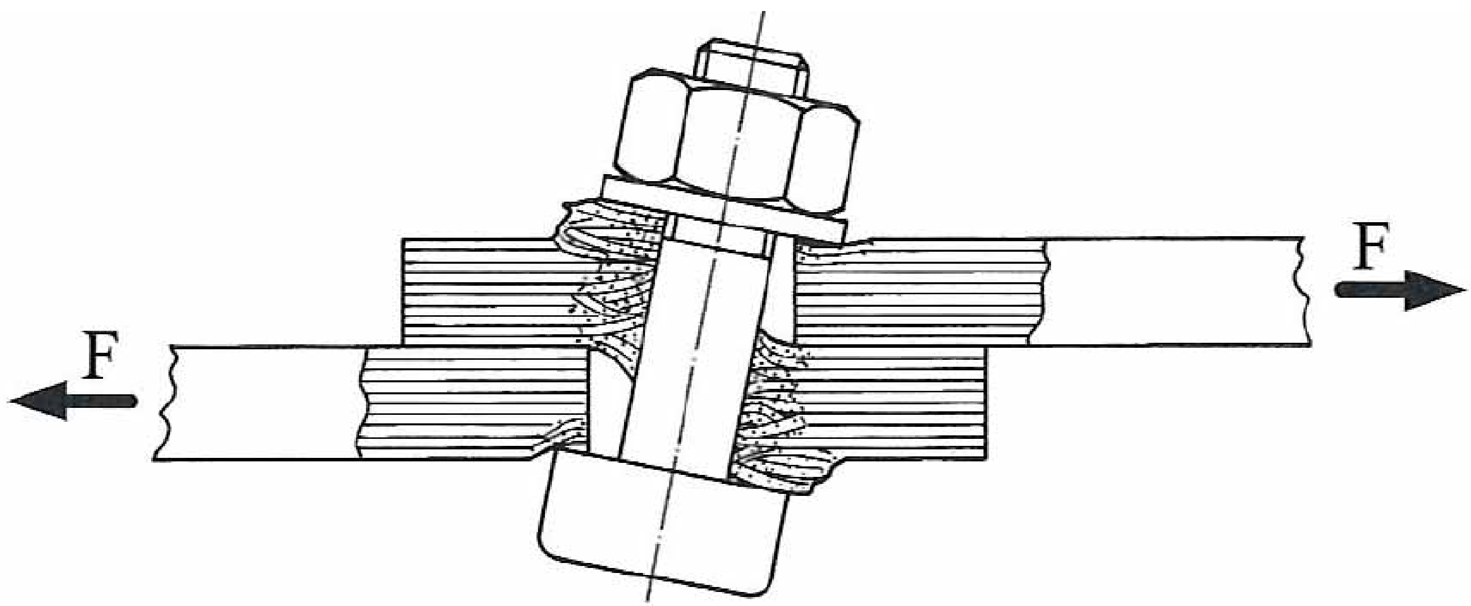
a. Coaxial bifurcation
b. Bearing failure due to radial compressive stresses
c. Fiber tensile failure

In a unsupported pin loaded strap

a. Stresses in bolt axis ≠ 0
b. Stresses in bolt axis = 0
c. Failure load is higher than in a supported configuration



Bolted joints

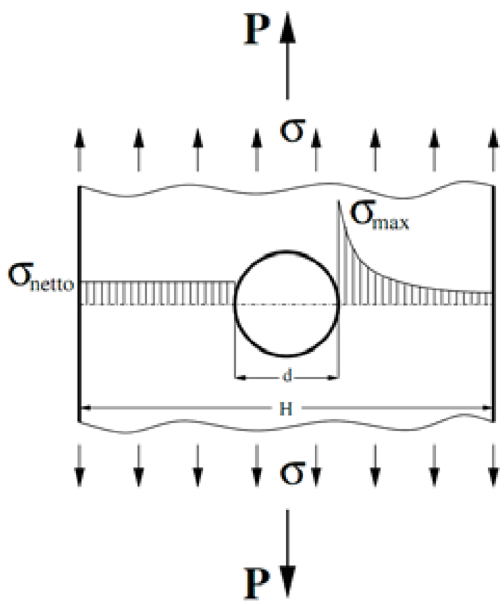


Bolted joints in aviation

Why bolted joint

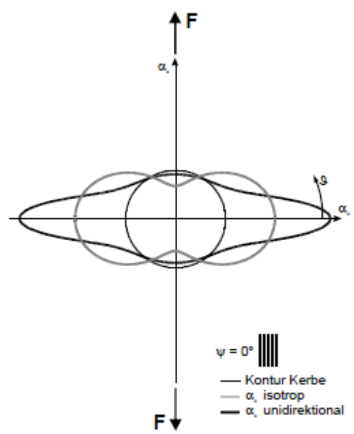
- Strap: localised oriented loads.
- **Bolts: high distributed loads.**
- Bonded joints: low distrisbuted loads.

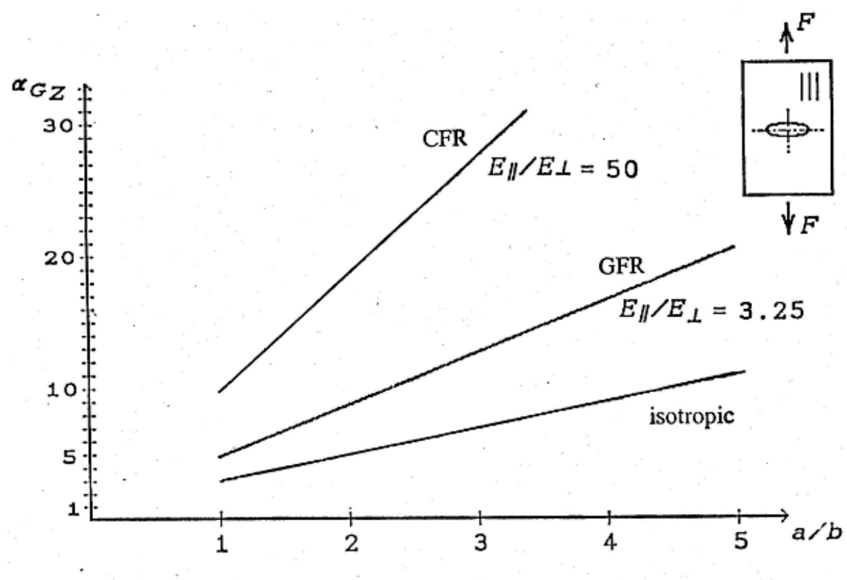
Principles of stress distribution around holes in composites



Difference from isotropic materials to composites?

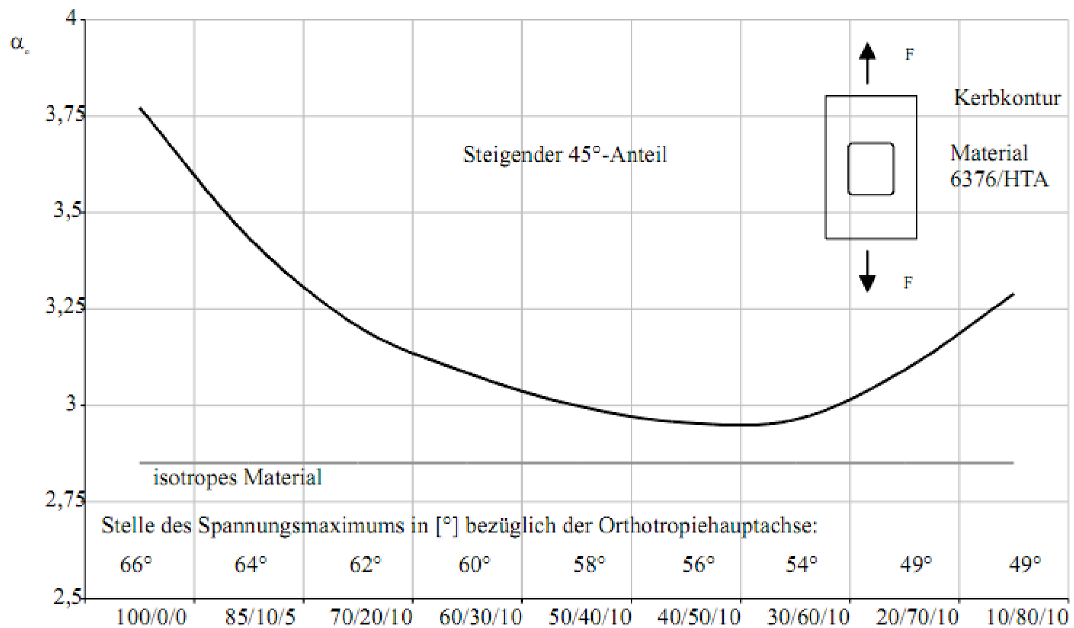
Principles of stress distribution around holes in composites



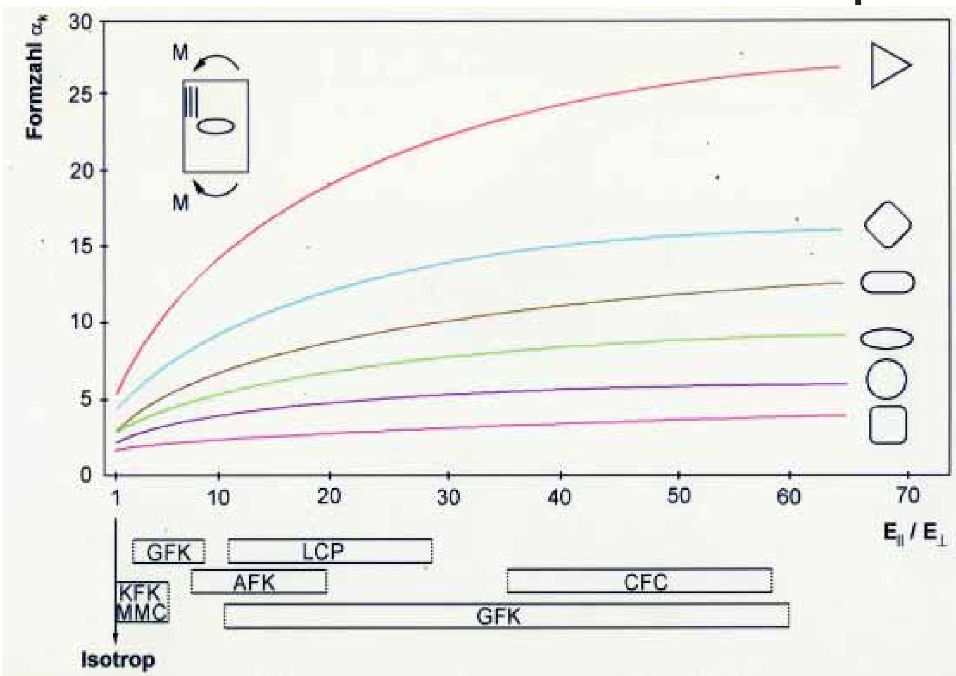


Maximum Stress Concentration Factor

Principles of stress distribution around holes in composites

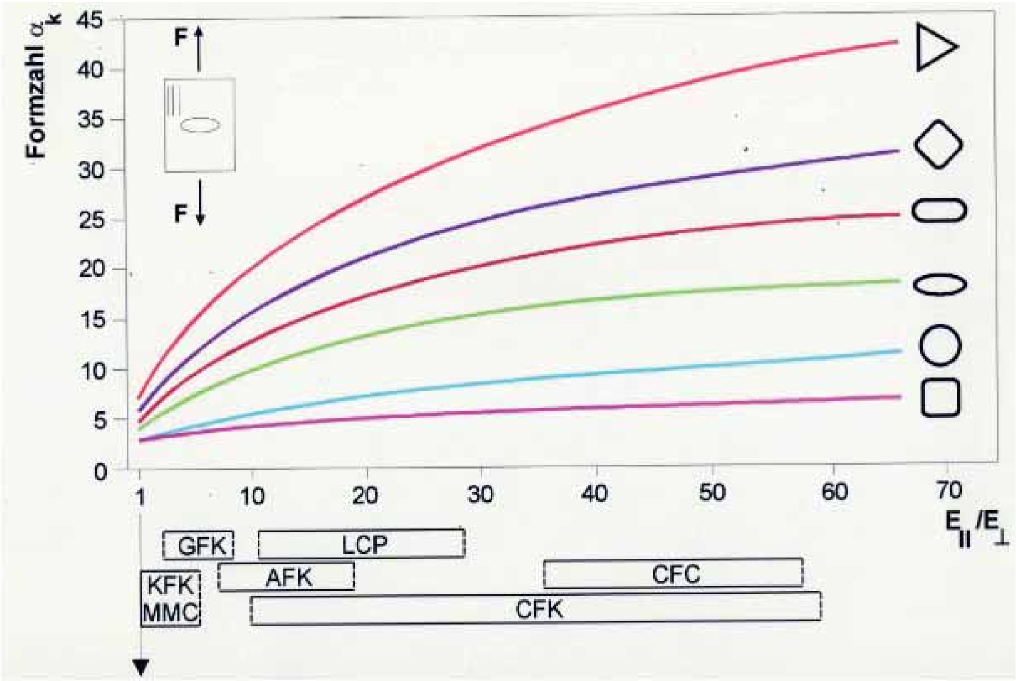


Principles of stress distribution around holes in composites



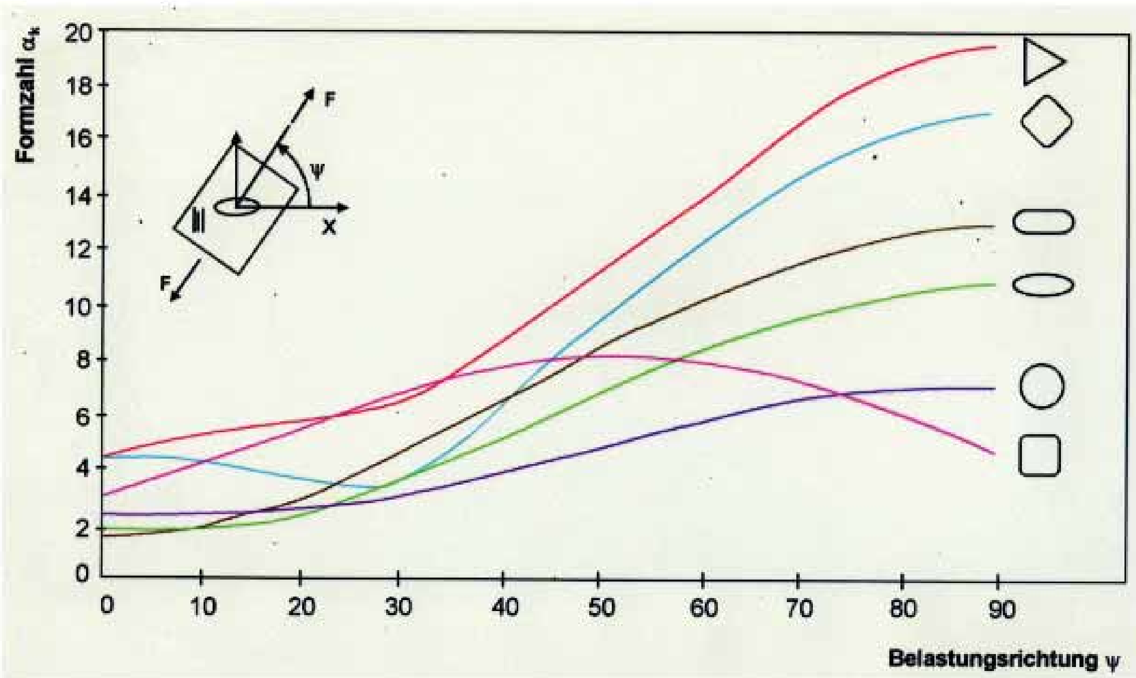
Bending moment – Fibre direction (0°)

Principles of stress distribution around holes in composites



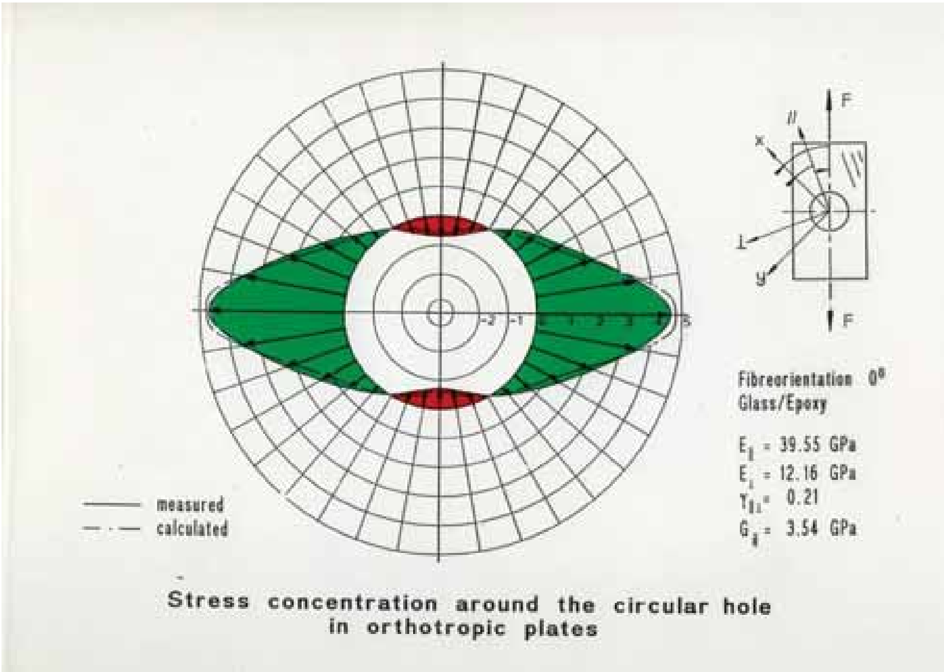
Tensile Force – Fibre direction (0°)

Principles of stress distribution around holes in composites



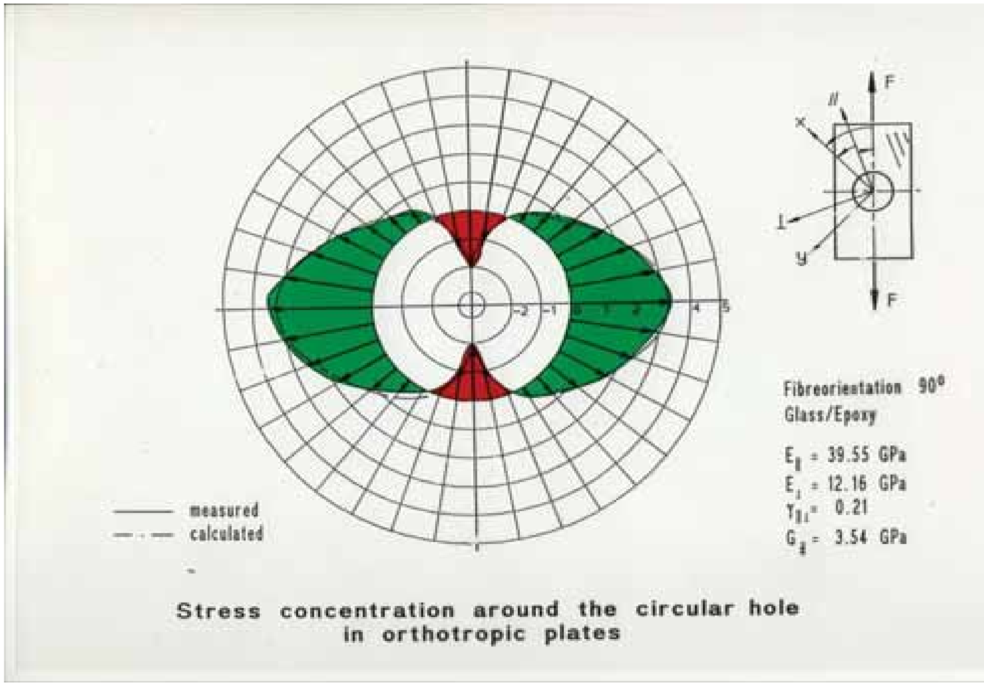
Tensile Force with different directions

Principles of stress distribution around holes in composites



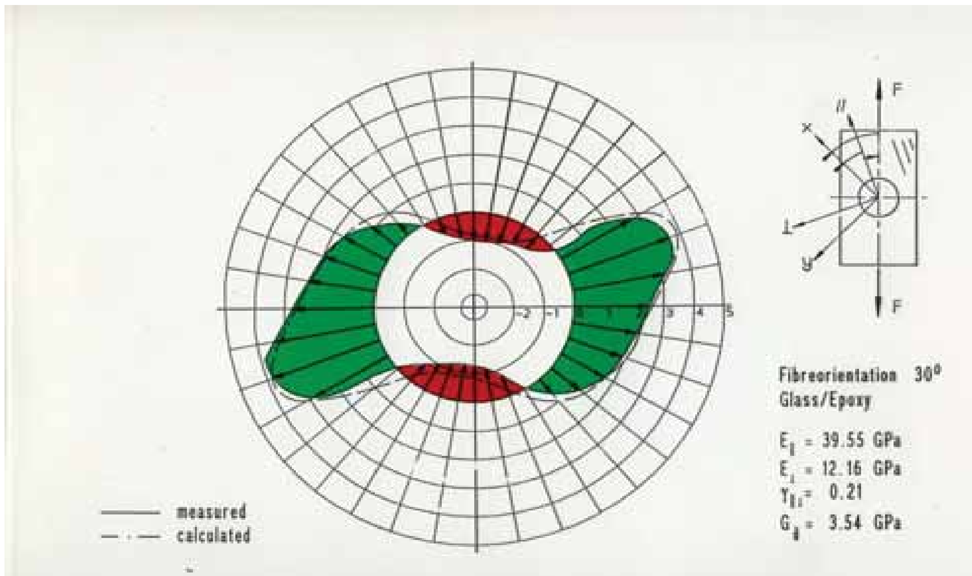
Glas/Epoxy – Load direction(0°)

Principles of stress distribution around holes in composites



Glas/Epoxy – Load direction(30°)

Principles of stress distribution around holes in composites



Stress concentration around the circular hole in orthotropic plates

Glas/Epoxy – Load direction(30°)

Active unit stress around a holes:

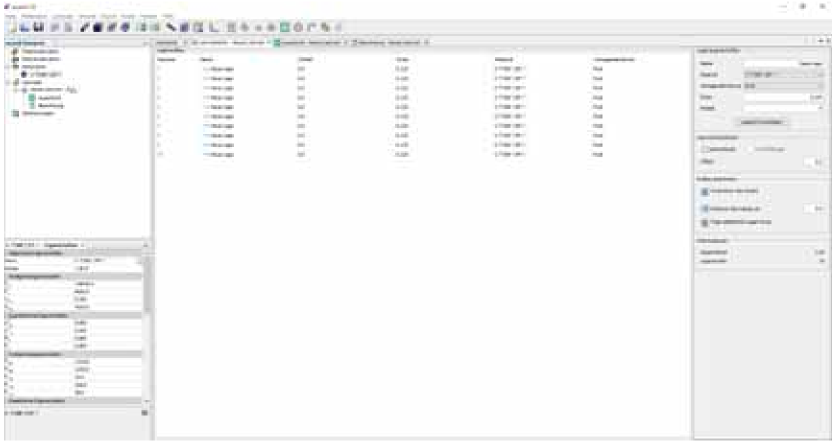
Please open elamx

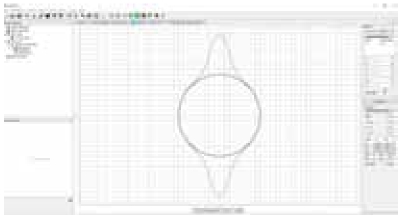
Start with database material like T300

Add 10 layers, t=0.125

Analyse stress around a hole, d=8

Define a load case and post your solution in the chat

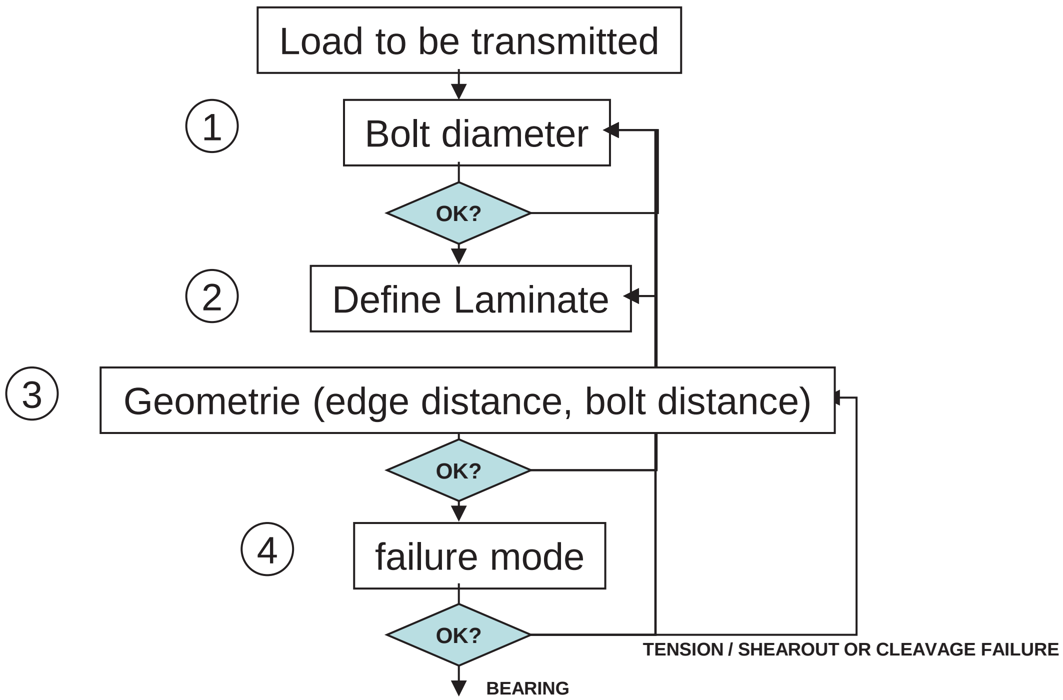




Advantages of bolted joints

- Joining of dissimilar materials.
- Reversible joints.
- Simple quality survey (vs. bond)
- High energy absorption possible (if designed accordingly)

Methodology for preliminary design of bolted joint

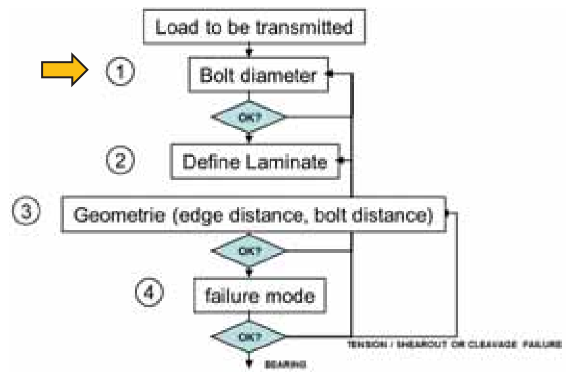


1 Definition of bolt diameter

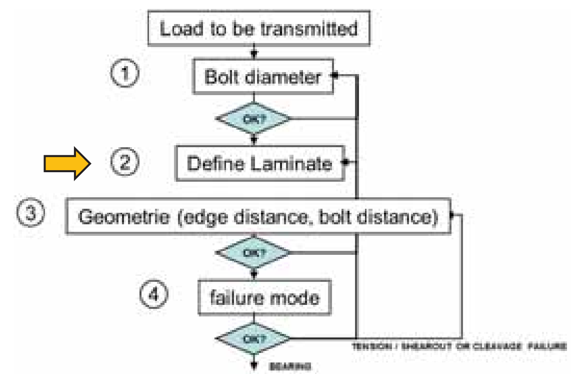
- Shearing of bolt

$$F_{ult} = R_s \cdot \frac{d^2 \cdot \pi}{4} \cdot i$$

- Usually not critical as metals have higher strength than composites

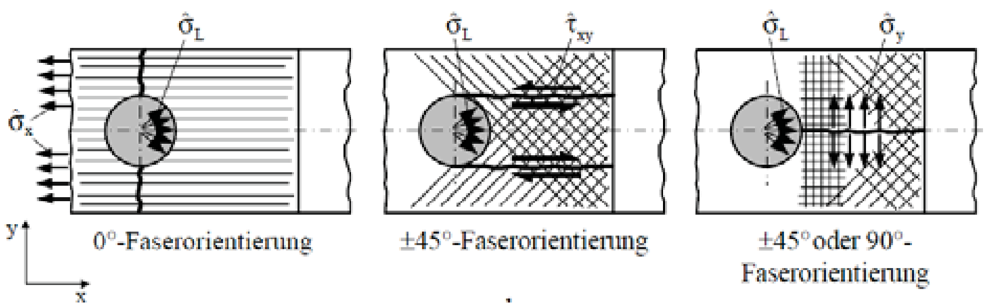


2 Definition of laminate



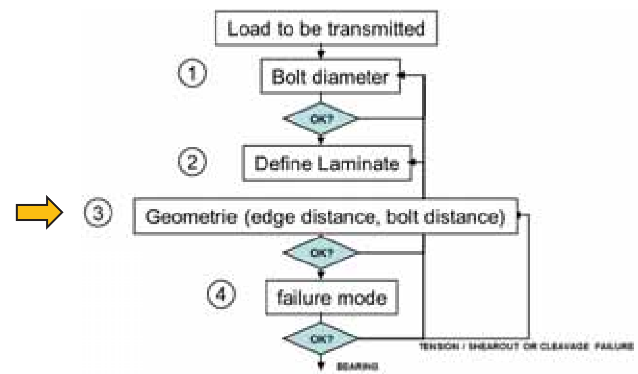
Ideal laminate in respect o load direction 0°

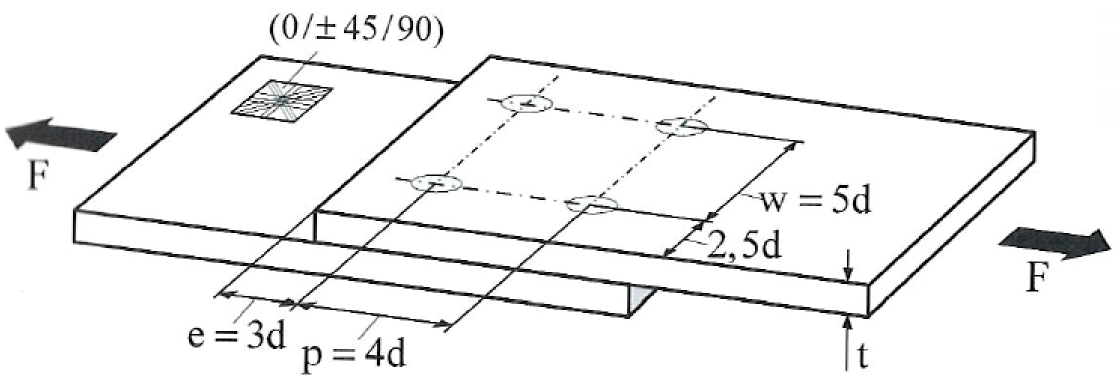
- 50% in 0°
- 40% in ±45°
- 10% in 90°



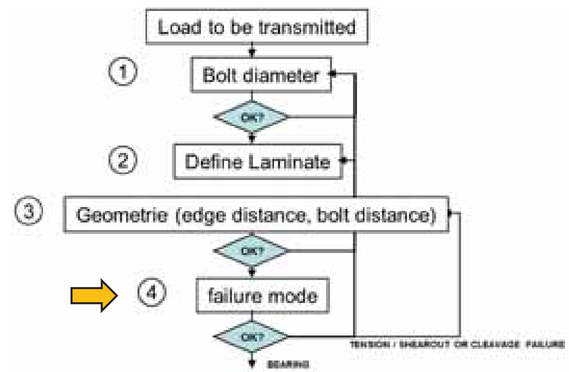
If base laminate does not fullfill this additional layer have to be interstacked

3 Design rules





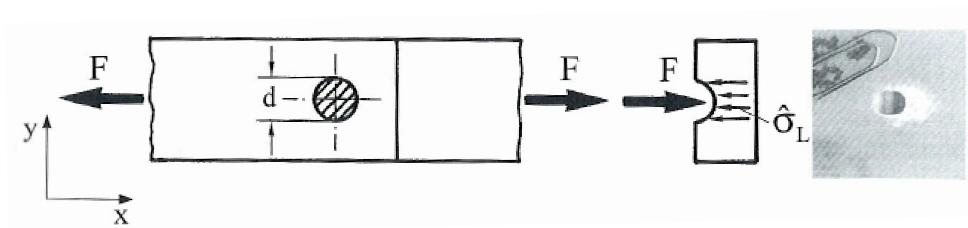
4 Failure modes (Schü 22.2.3 bis 22.2.7)

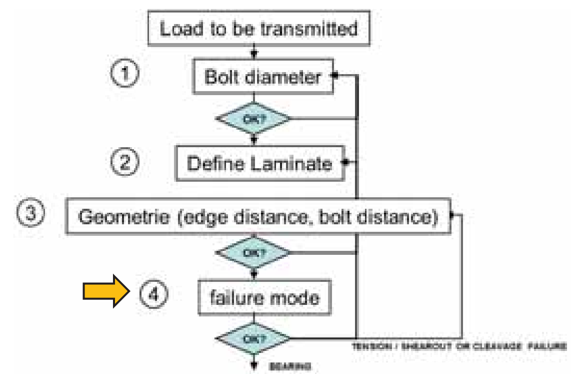


- Bearing failure: tolerant failure by opening of hole
- Tension failure: catastrophic failure mode
- shearout failure: catastrophic failure mode
- Cleavage failure: catastrophic failure mode
- Cleavage tension failure: catastrophic failure mode

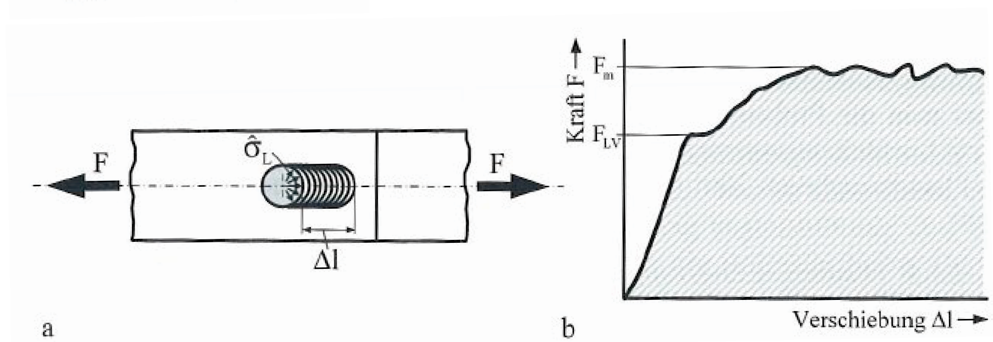
The objective is to have bearing as the dominant failure mode. All other failure modes have to be excluded.

4 Bearing failure

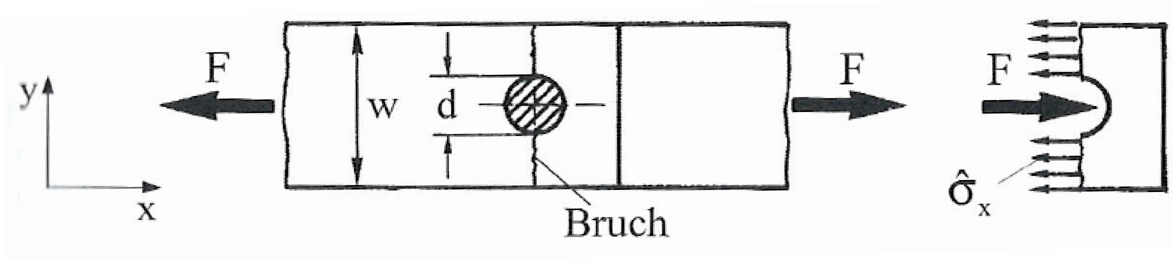


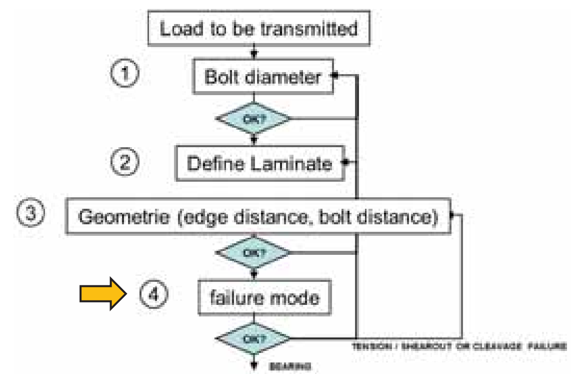


$$F_{ult} = \hat{R}_L \cdot d \cdot t$$



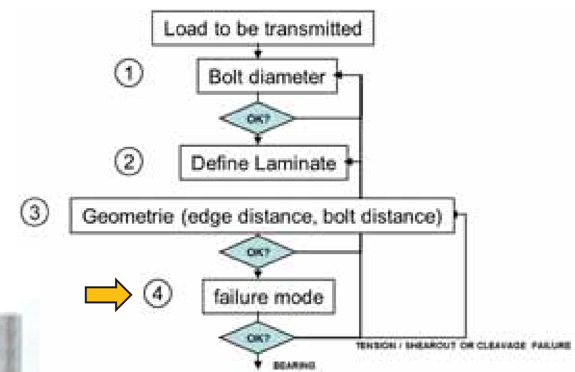
4 Tension failure

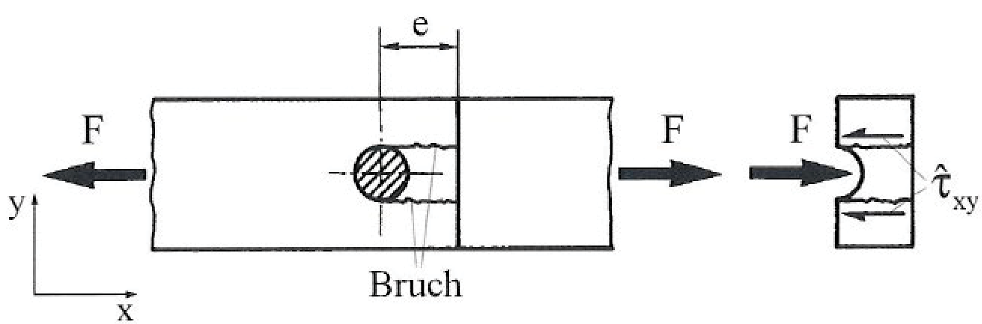


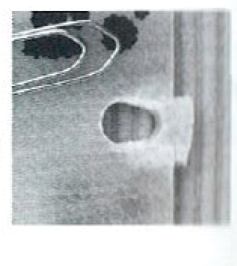


$$F_{ult} = \hat{R}_x^+ \cdot (w - d) \cdot t$$

4 Shearout failure

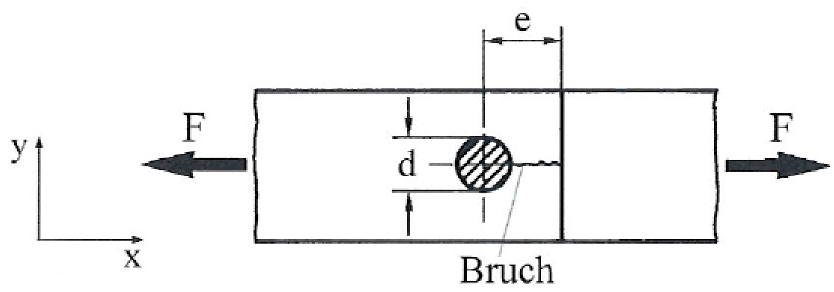


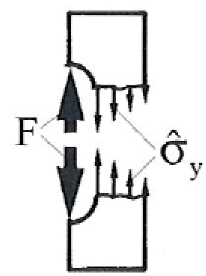


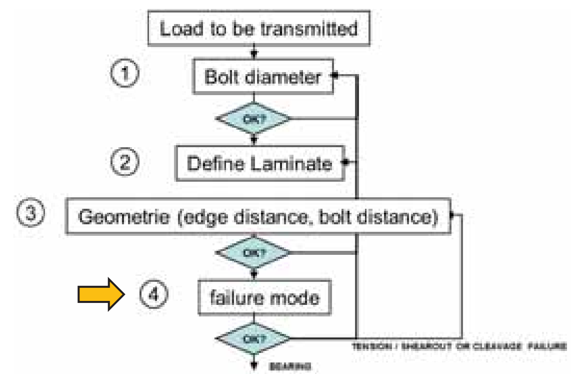


$$F_{ult} = \hat{R}_{xy} \cdot 2e \cdot t$$

4 Cleavage Failure

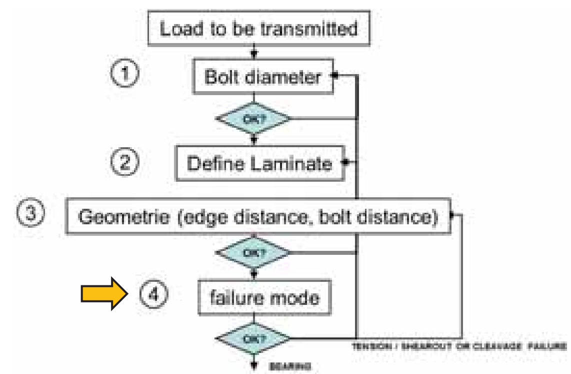


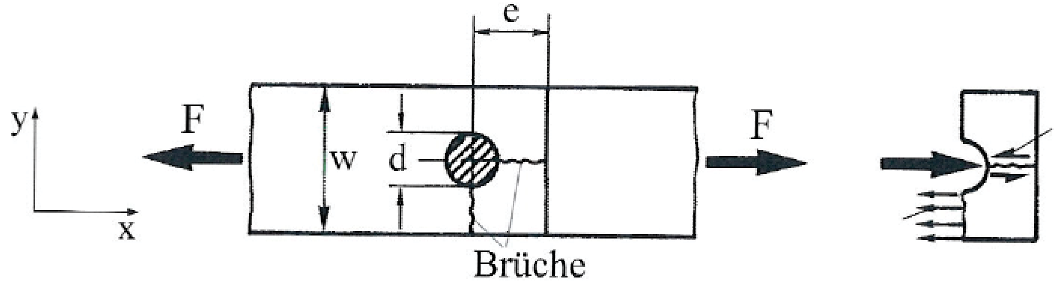




$$F_{ult} = \hat{R}_y^+ \cdot (e - \frac{d}{2}) \cdot t$$

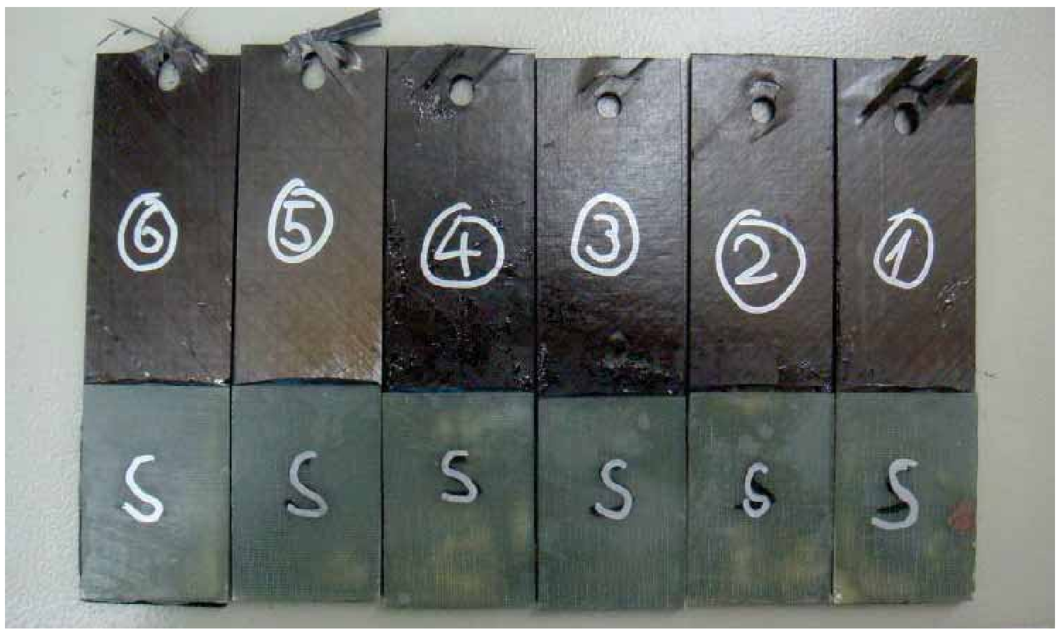
4 Cleavage tension failure





$$F_{ult} = \hat{R}_x^+ \cdot \frac{1}{2}(w-d)\cdot t + \hat{R}_{xy}\cdot\left(e-\frac{d}{2}\right)\cdot t$$

Test series cleavage vs. bearing



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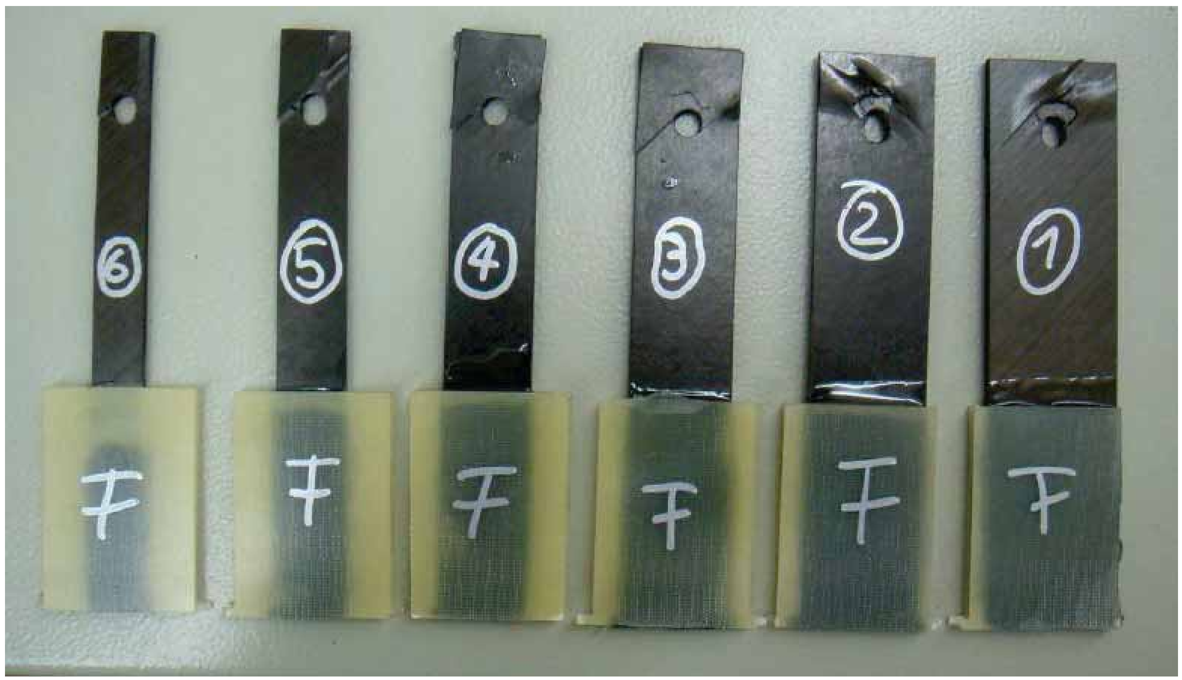
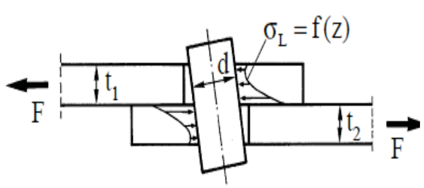
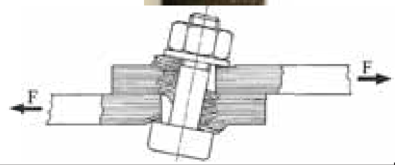
Test series tensile vs. bearing



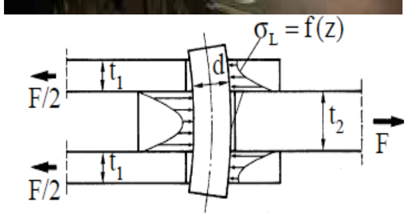
Determination of load bearing strength: ASTM Standard D 5961M – 08

Single lap



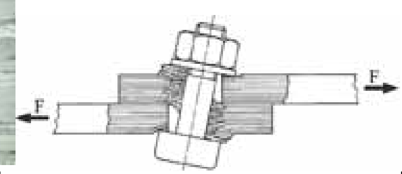


Double lap

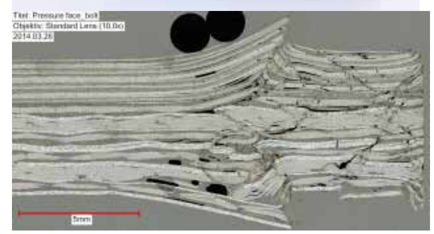


Determination of load bearing strength: ASTM Standard D 5961M – 08

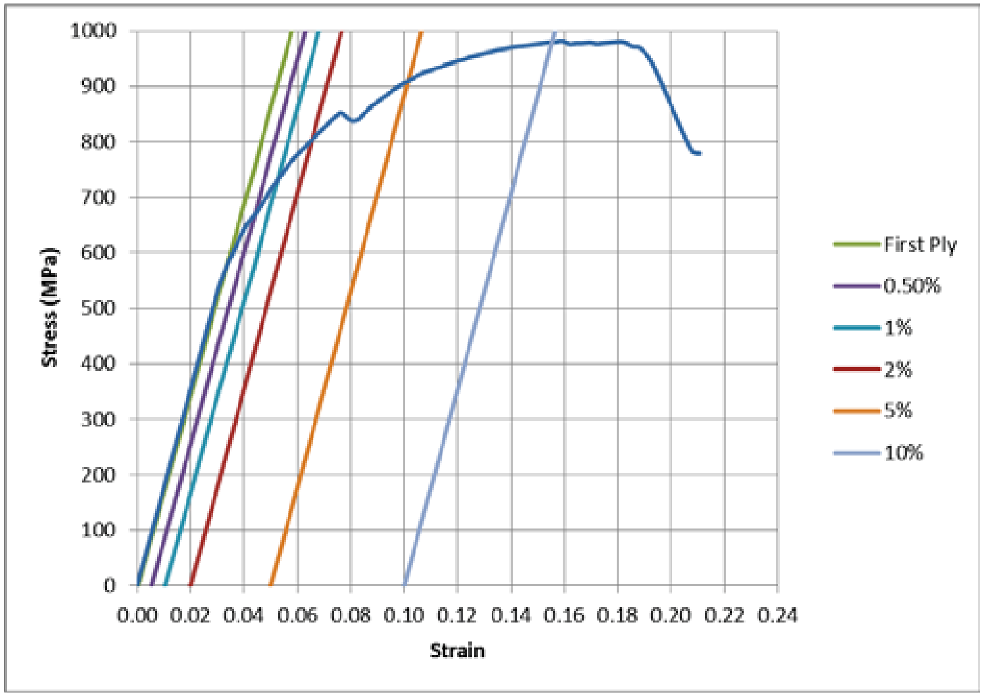
single lap



double lap



Load displacement curves – relevant design limits



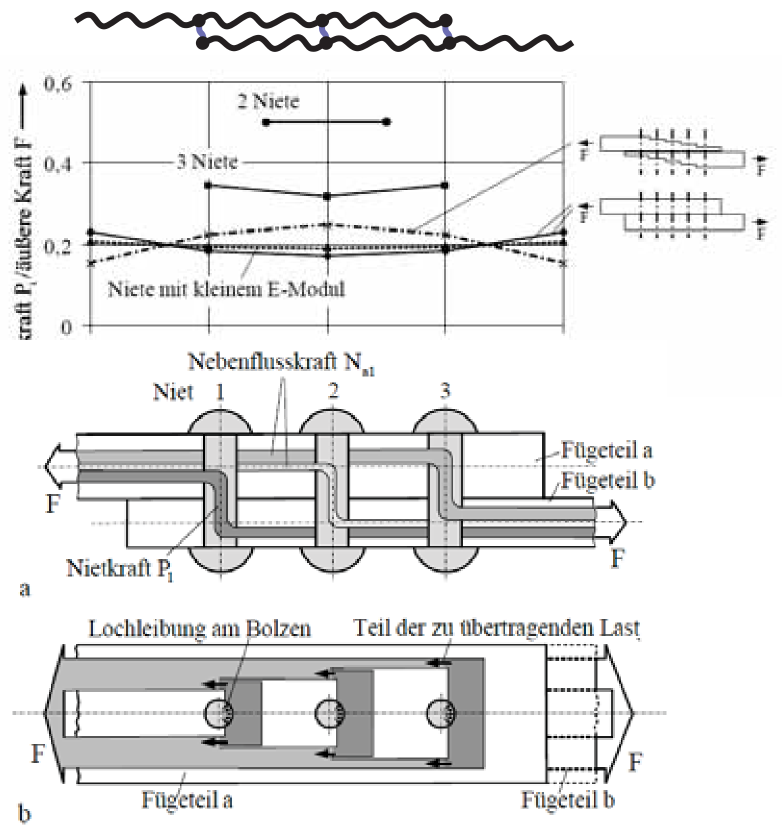
$$\hat{R}_l = \frac{\boldsymbol{F}}{\boldsymbol{i} * \boldsymbol{d} * \boldsymbol{t}}$$

Analysis of bolts

- Two bolts: both bolts equally share load
- N bolts > 2: outer bolt carry more load
- Stepping speciment thickness may inverse this trend
- Bolt loads allow the determination of tensile load $\mathbf{N_{aj}}$ on bolt whole

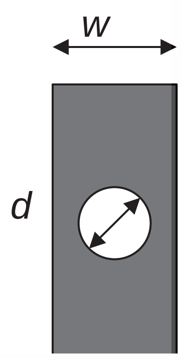
$$F = N_{aj} + \sum_{i=1}^{j} P_i$$

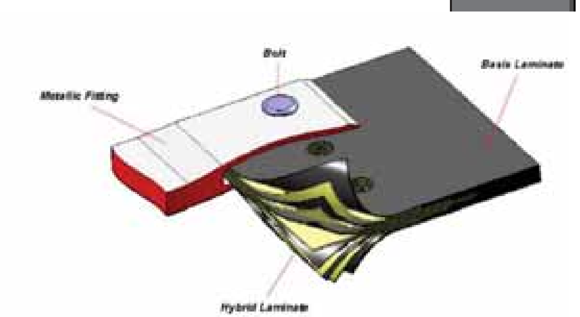
- Bolt hole is loaded in tensile load + bearing load



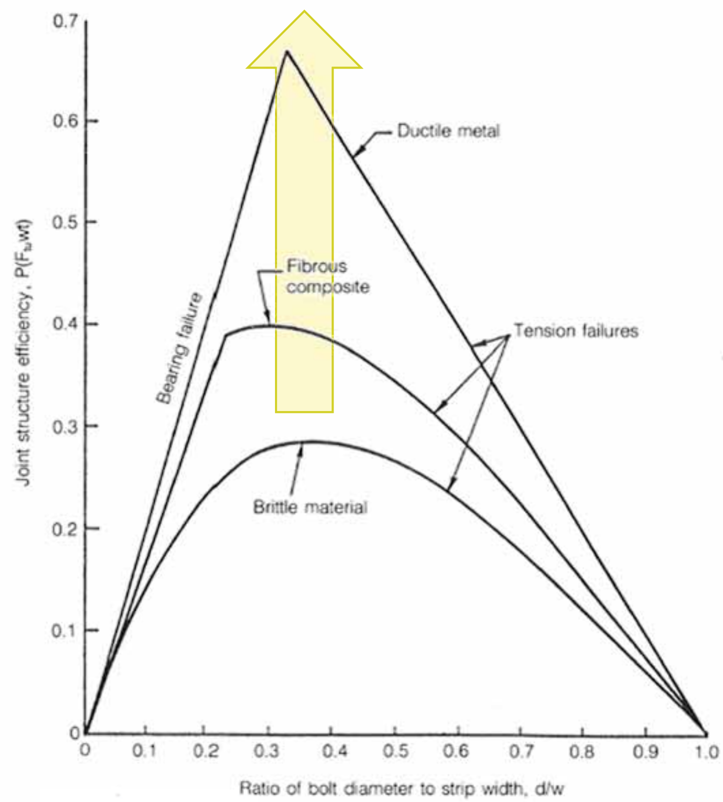
The joint efficiency challenge

Metal foil hybridization



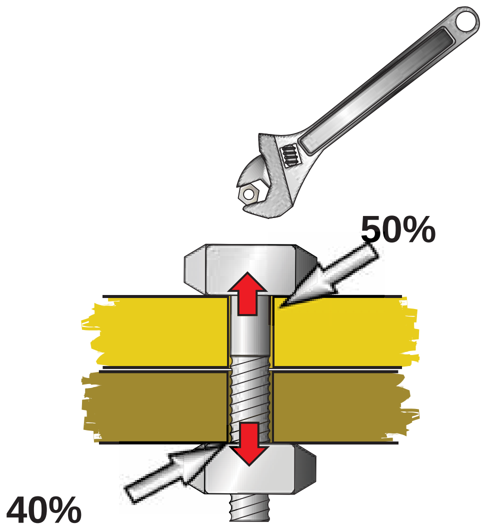


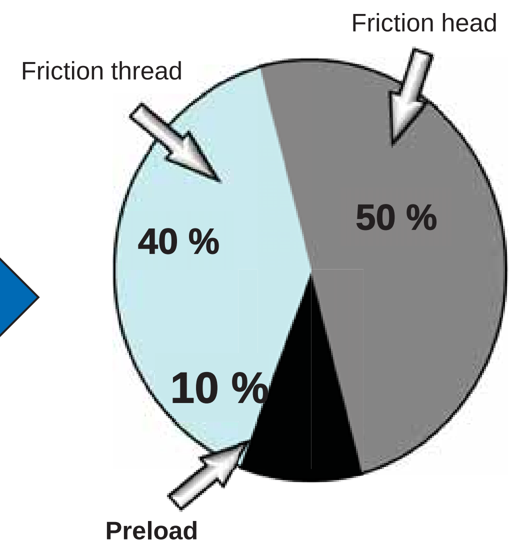
Source: DLR



Source: Niu

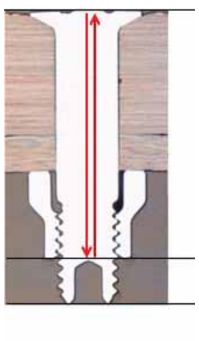
Preload in bolted joints

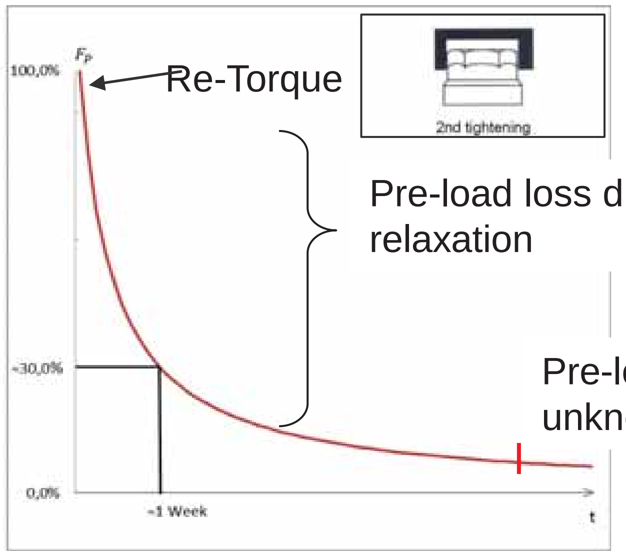




Source: DLR

Preload in bolted joints





Re-Torque

Pre-load loss due to relaxation

Pre-load during life time is unknown

Source: Unckenbold, Prof. Dr.-Ing. Wilm. Hybrid Structures (HYS) Part 1 Adhesive Joints and Boltings. 2014.

Source: DLR

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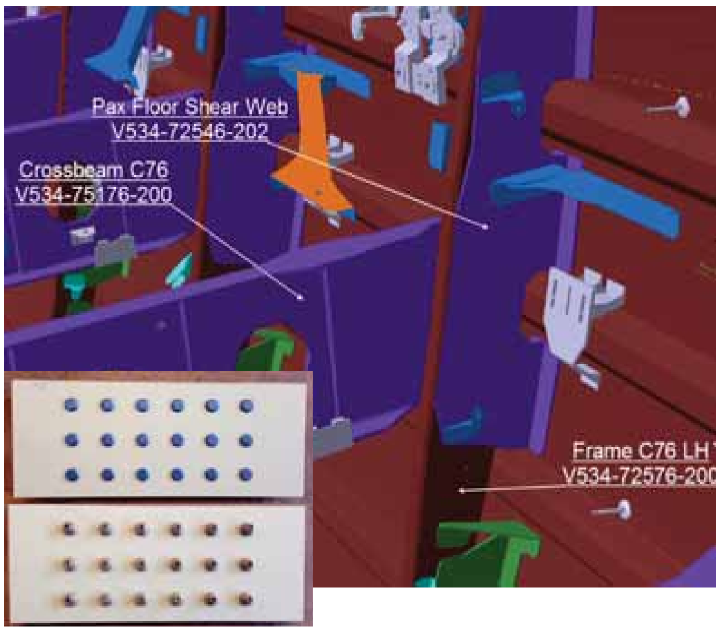
Preload in bolted joints

A350XWB Querträger/ Spant Verbindung



Materialien

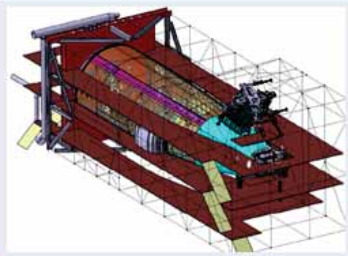
Metall Frame:
Aluminium Legierung 2099/2196
Zustand: T83 and T8511

Composite Frame:
IMA-M21e
Matrix: M21e (Duroplast)
Faser: IMA carbon fiber
Faserflächengewicht: 134g/m²
Faserhalbzeug: UD-Tape (Prepreg)
Harzgehalt (% Gewicht): 34 %

PAX Shear Web
Aluminium Legierung 7010/7050
Zustand: T7451

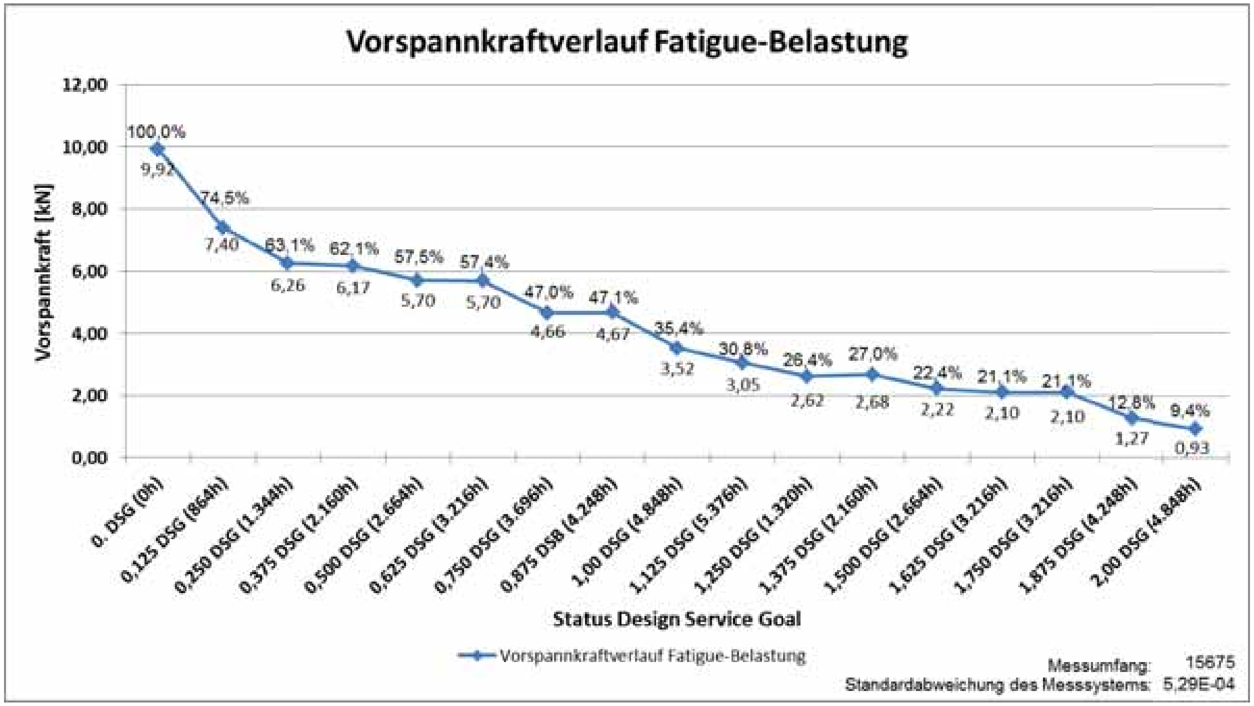
Bolted Joint:
Niet: EN6115B4E08 Collar: ABS1738K
Ti6Al4V

Preload in bolted joints

	1	2
Umgebung	A350XWB Full Scale Fatigue Test – EF3	A350XWB Strukturmontage Hamburg
Darstellung		
Ziel:	Messungen in 0,125 DSG* Schritten → Einfluss der Fatigue Belastung auf die Vorspannkraft	Messungen nach der Installation → erzielte Vorspannkraft (Retorque-Einfluss)

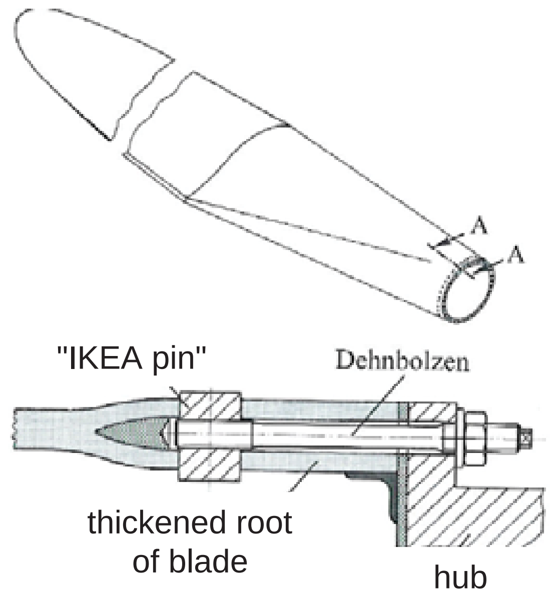
*DSG = Design Service Goal = Flugzeugleben (28800 Flüge)

Preload in bolted joints

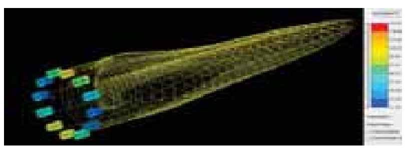


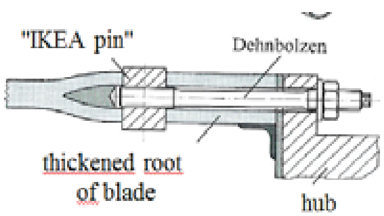
Bolted joints in highly loaded structures

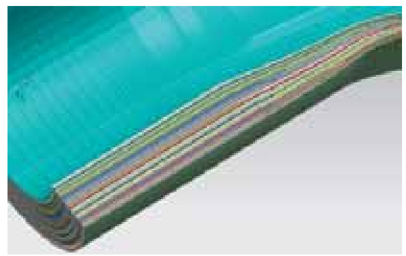
IKEA Billy

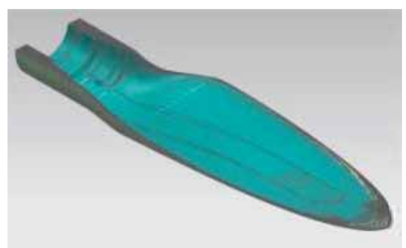


Bolted joints in highly loaded structures









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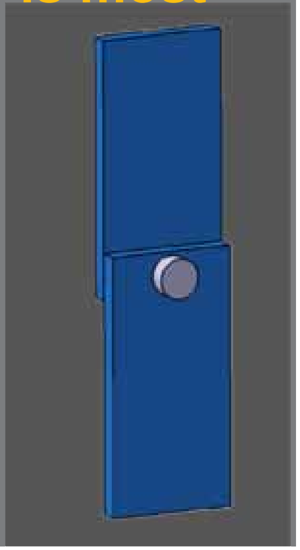
Questions on bolted joints

Why is bearing the preferred failure mode?

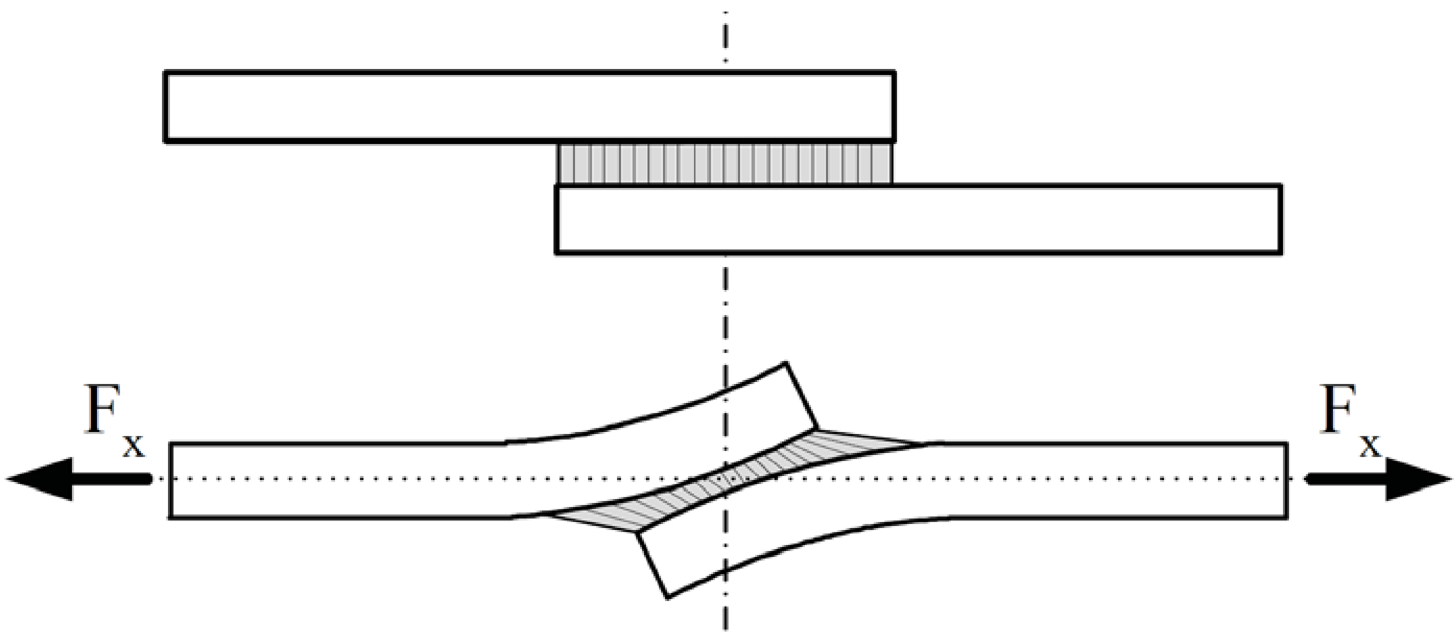
a. It is the strongest
b. It is damage tolerant
c. It is easier to design

Which failure mode is most likely here?

a. Bearing failure
b. Cleavage failure
c. Tensile failure



Bonded joints

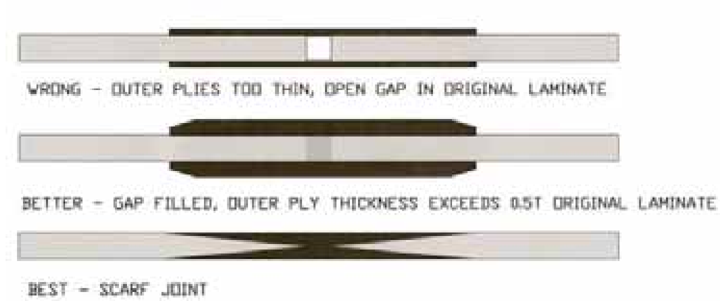


Why bonded joints

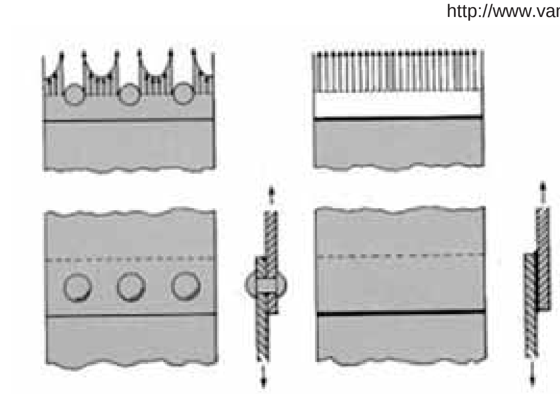
- Strap: localised oriented loads.
- Bolts: high distributed loads.
- **Bonded joints: low distributed loads.**

Advantage versus bolted joints

- No reduction of load bearing section
- Adapting to tolerances
- No gap corrosion
- Moderate stresses over large area



http://www.vansairforce.com

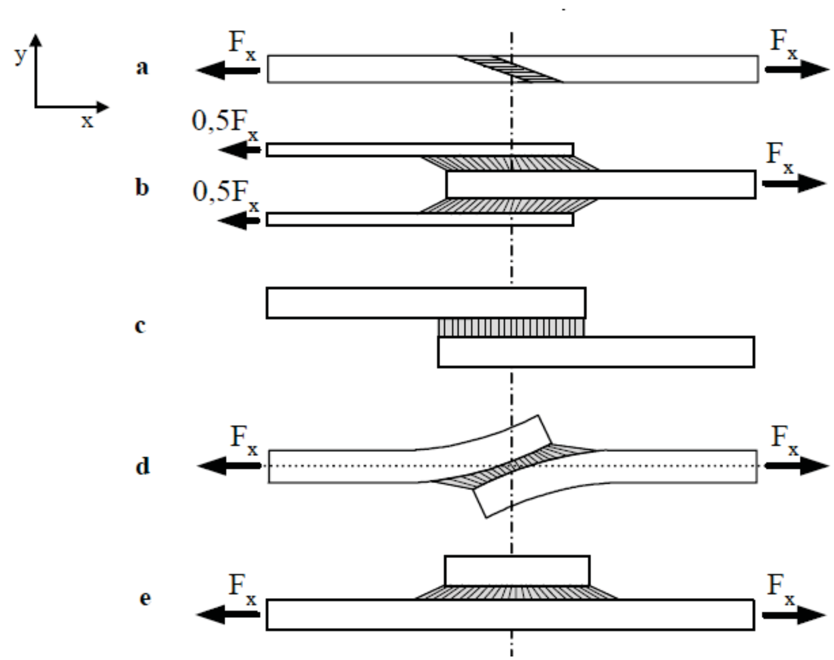


Drawbacks vs bolted joints

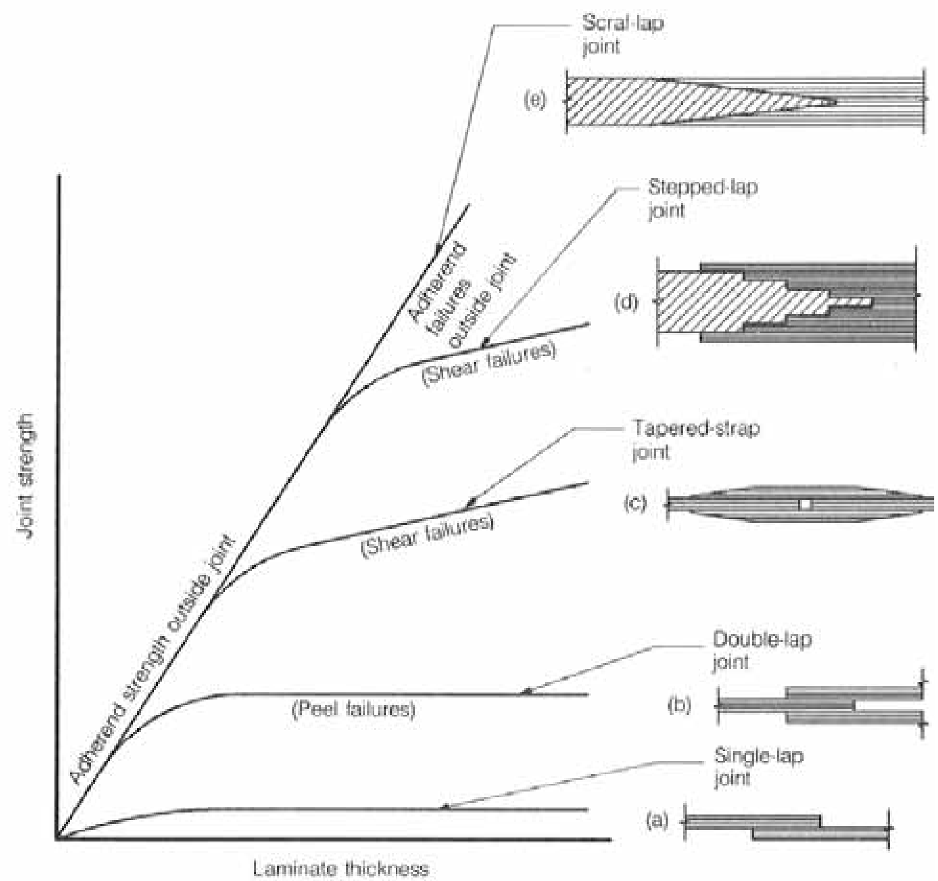
- Connection not detachable
- Sensitive to peel stresses
- Stress peaks
- Catastrophic failure
- Sensitive to moisture and humidity
- Preparation of bonding partners, surafce and geometry
- Chemical reaction: temperature, pressure and time have influence on quality
- Quality control

Bond types

- **Scarf joint**
- **Double lap**
- **Single lap**
- **Local patch**



Bond types



Source: Niu

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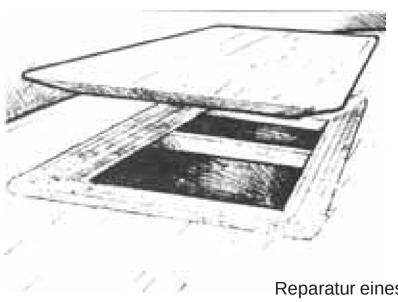
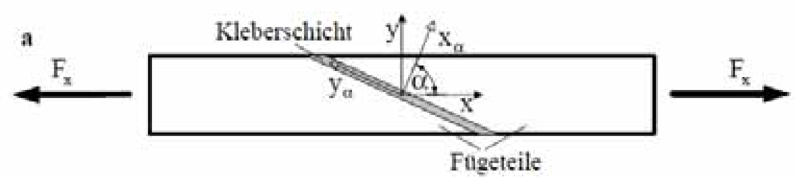
Scarf joint

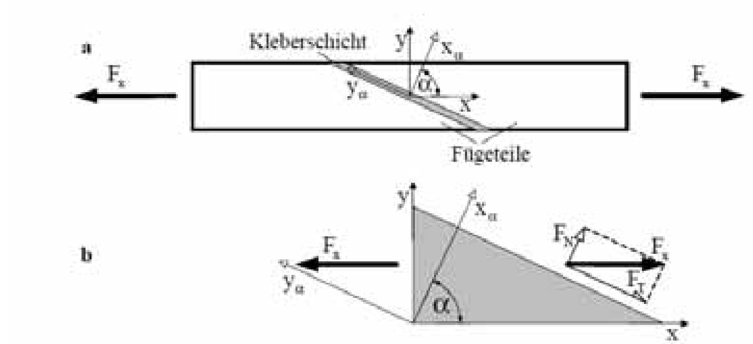
- **No stress peak**
- **No added weight**
- **May be expensive to realize**
- **Efficient repair technique**





Reparatur eines Holzschiffes durch Schäftung
http://www.sailingbreezes.com/sailing_breezes_current/articles/sept99/repair.htm

Design of a scarf joint



- **Load vector:** $F_N = F_x \cdot \cos\alpha; \quad F_T = F_x \cdot \sin\alpha$
- **Bond area:** $A_\alpha = b \cdot \frac{t}{\cos\alpha} = \frac{A}{\cos\alpha}$
- **Normal stress:** $\sigma_\alpha = \frac{F_N}{A_\alpha} = \frac{F_x \cdot \cos\alpha}{A/\cos\alpha} = \sigma_x \cdot \cos^2\alpha$
- **Shear stress:** $\tau_\alpha = \frac{F_T}{A_\alpha} = \frac{F_x \cdot \sin\alpha}{A/\cos\alpha} = \sigma_x \cdot \sin\alpha \cdot \cos\alpha = \frac{1}{2}\sigma_x \cdot \sin 2\alpha$

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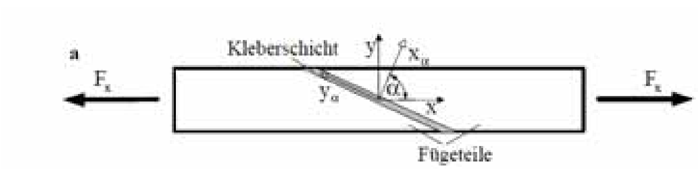
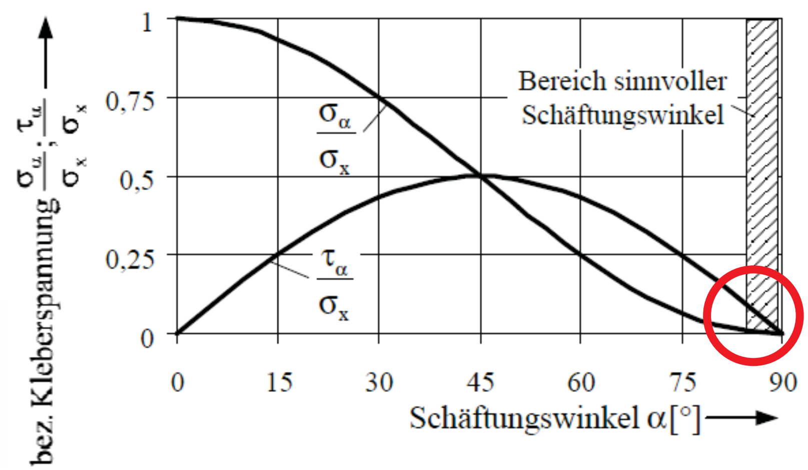
Scarf joint

Large scarf angle

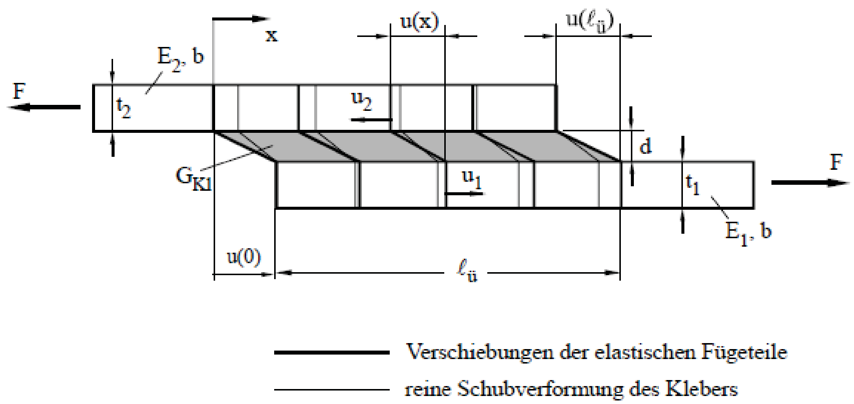
- Larger bond area > reduction in stresses
- Normal stress vanishes
- Pure shear loading
- No shear stress peak





Single lap joint

- High shear stress peaks
- Limited influence of overlap length on shear stress peak
- High stiffness ratio between partners and adhesive reduces shear stress peaks



[Klein]

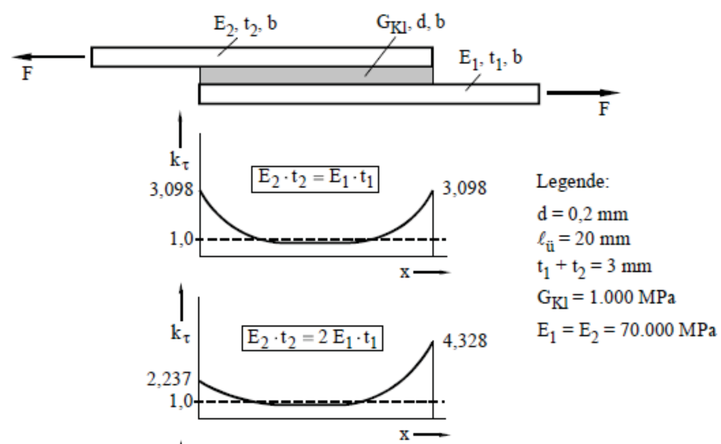
Single lap joint

Analytical approach for shear stress distribution (constant sections, no bending)

$$\tau(x) = \frac{\omega \cdot \tau_m}{(\beta + 2) \cdot (\cosh \omega - 1)} \left[\sinh\left(\omega\left(1 - \frac{x}{\ell_{ü}}\right)\right) + (\beta + 1) \sinh\left(\omega \frac{x}{\ell_{ü}}\right)\right].$$

$$\omega = \lambda \cdot \ell_{ü} = \sqrt{\frac{G_{Kl} \left(E_1 \cdot t_1 + E_2 \cdot t_2\right) \ell_{ü}^2}{E_1 \cdot t_1 \cdot E_2 \cdot t_2 \cdot d}}$$

$$\beta = \frac{\left(E_2 \cdot t_2 - E_1 \cdot t_1\right) G_{Kl} \cdot \ell_{ü}^2}{E_1 \cdot t_1 \left(G_{Kl} \cdot \ell_{ü}^2 + E_2 \cdot t_2 \cdot d\right)} \; .$$



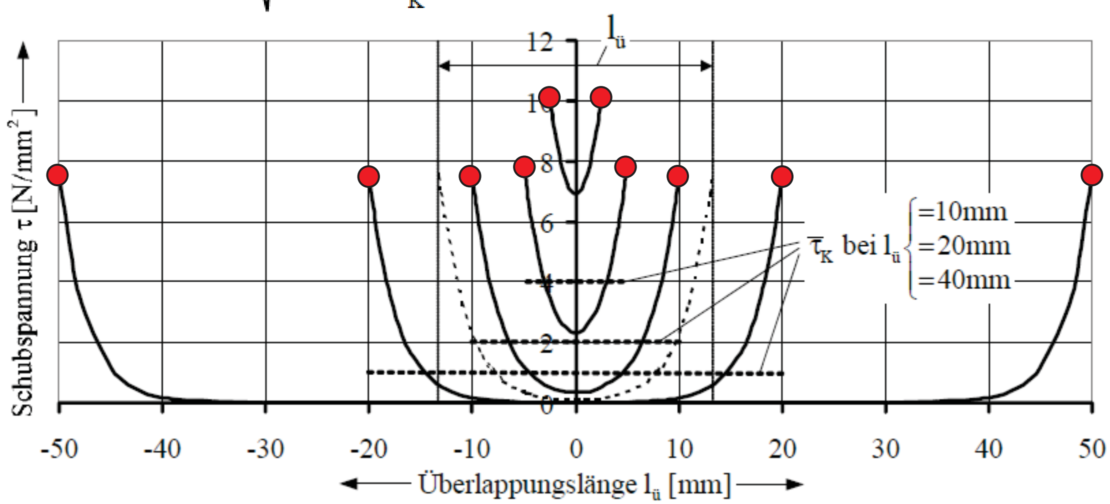
[Klein]

Single lap joint

Aproximation by Volkersen for τ_{max}

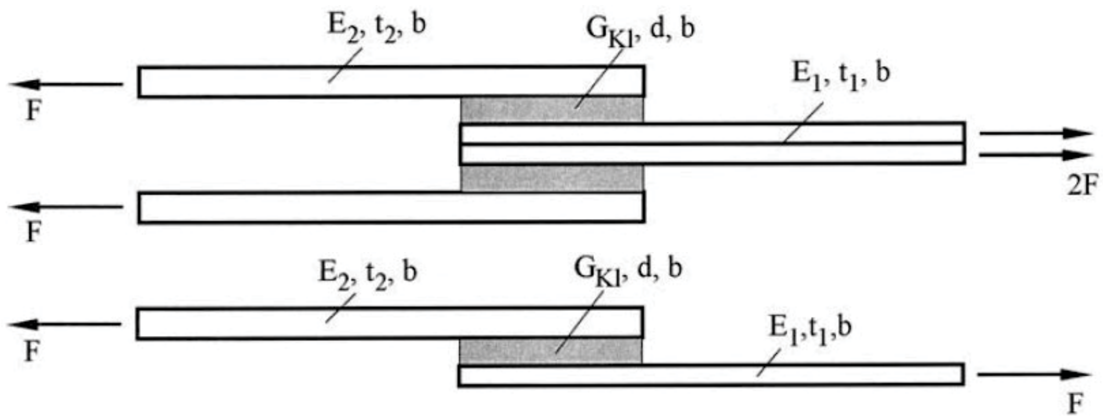
$$\tau_{K\,max} = \frac{F_{10}}{b} \sqrt{\frac{1}{2} \cdot \frac{1}{Et} \cdot \frac{G_K}{t_K}}$$

τ_{Kmax} = Schubspannungsspitze
F_{10} = äussere Kraft an den Fügeteilen
b = Fügeteilbreite
E = E-Modul Fügeteile
t = Fügeteildicke
G_K = Schubmodul des Klebers
t_K = Klebefugendicke

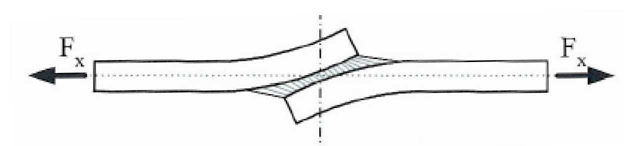


Double lap joint

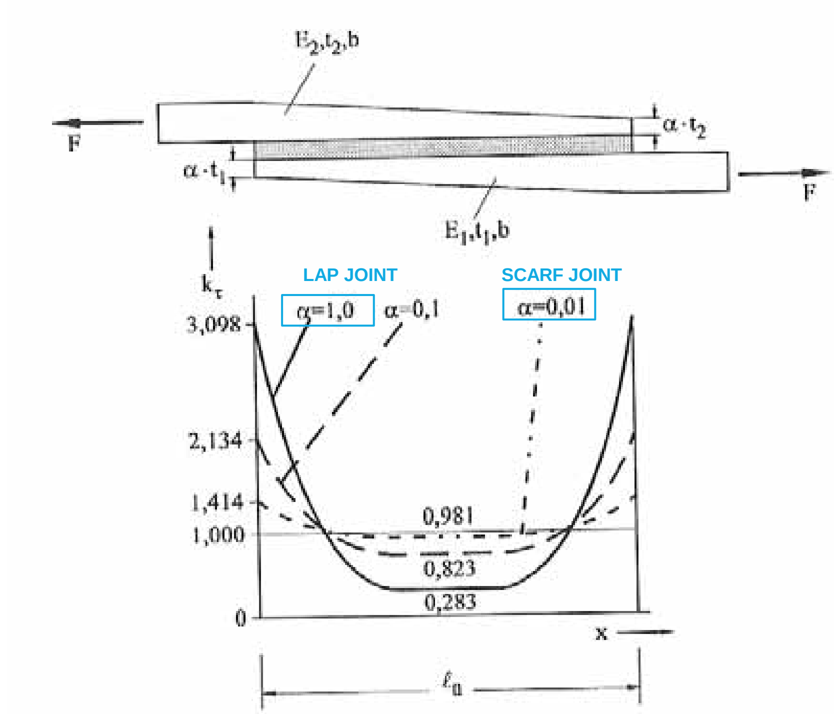
Symmetry of single lap joint



No secondary bending



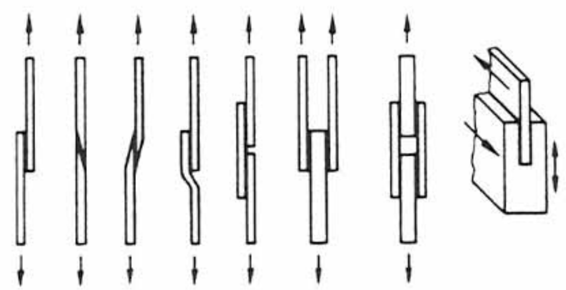
Lap vs scarf joint

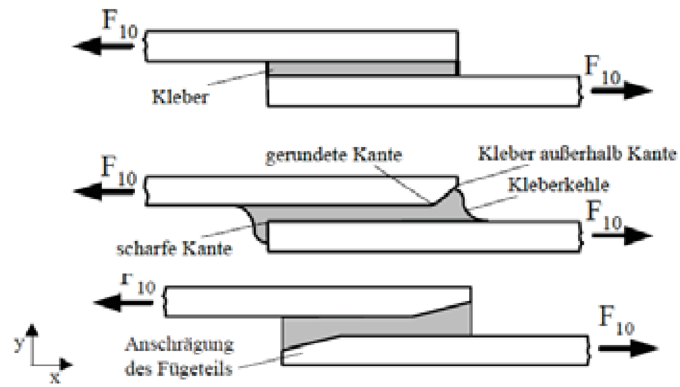


Quelle: Klein

Design recommendations for joints

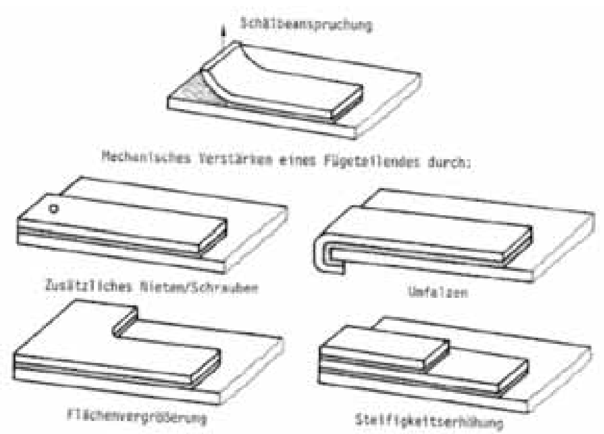
- Optmize for shear loading
- Wedged bond gap
- Fillet joint

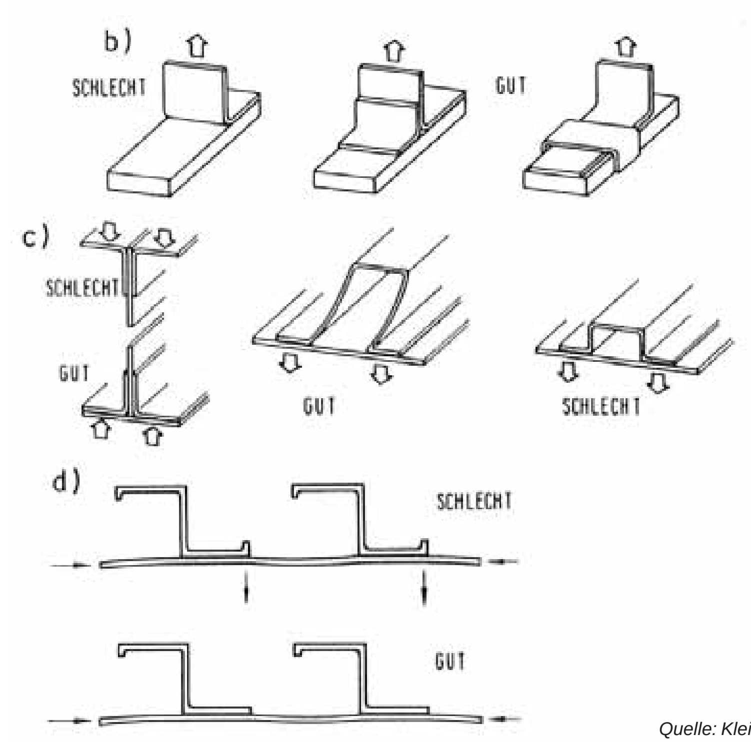




Quelle: Klein/Schürmann

Design recommendations for joints – avoiding peel stresses





Quelle: Klein

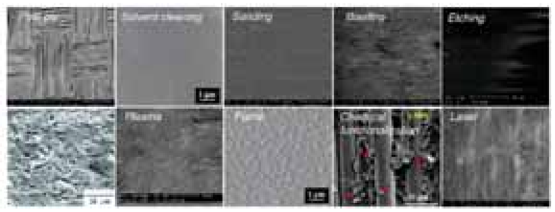
Surface treatment of adhesives

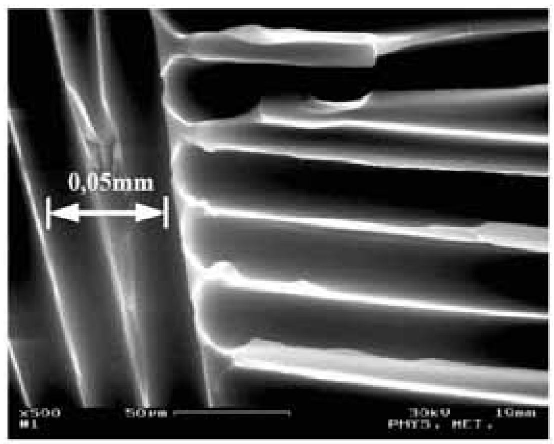
God wetting = good adhesion

Increase surface
- peel ply (CFK)
- sanding (120er grit)
- sand blasting

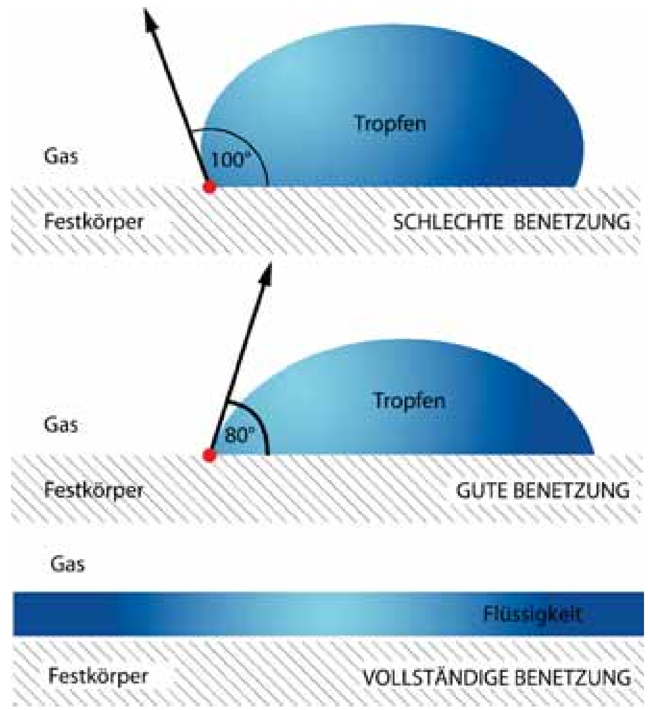
Degrease
- organic solvent
- bases
- acids

Option
- plasma / flame treatment
- etching
- primers
- laser





Structure from peel ply



How to determine lap shear strength

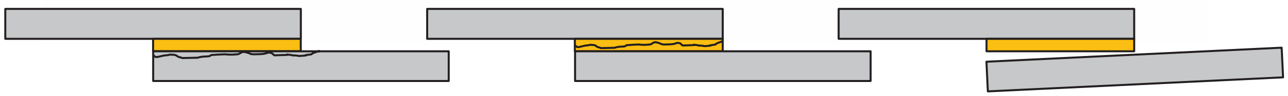
Preparatation:

Test:

Fachhochschule Nordwestschweiz
Hochschule für Technik

How to determine lap shear strength

Preparation of specimen, remove fillet joint

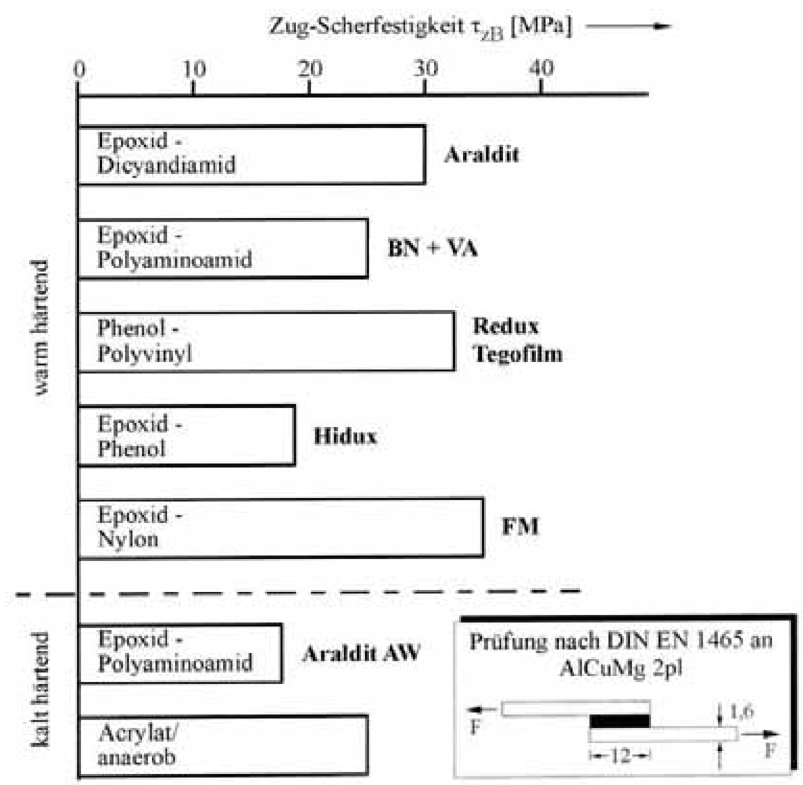


Cohesive failure of composite **Cohesive failure of adhesive** **Adhesion failure**

Fachhochschule Nordwestschweiz
Hochschule für Technik

Choice of adhesive

- cold / hot curing
- Strength depending on adhesive partners
- Reduced strength
  - Wrong curing cycle
  - Aging and creep up to 40%



Klebstoffe	ν_{Kl}	E_{Kl} [MPa]	G_{Kl} [MPa]	τ_{zB} [MPa]
warm abbindende Klebstoffe	0,38-0,40	3.000-4.200	900-1.520	20-35
kalt abbindende Klebstoffe	0,38-0,44	1.500-2.500	1.500-2.500	18-25

Quelle: Klein

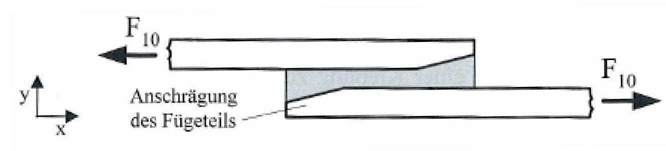
Design aspects of bonded joints

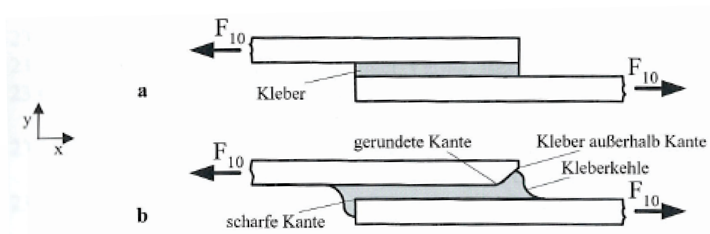
Avoid peel stresses

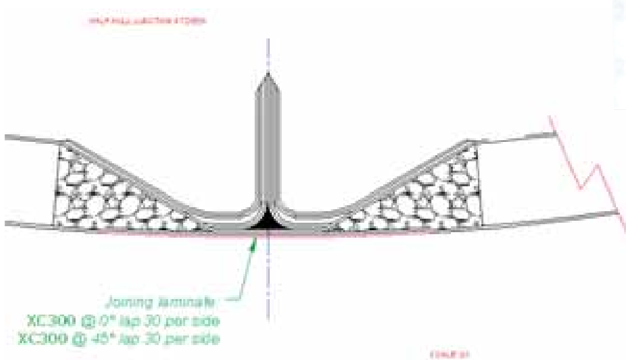
Favor shear stresses

conical bond gap

bond fillets at ends

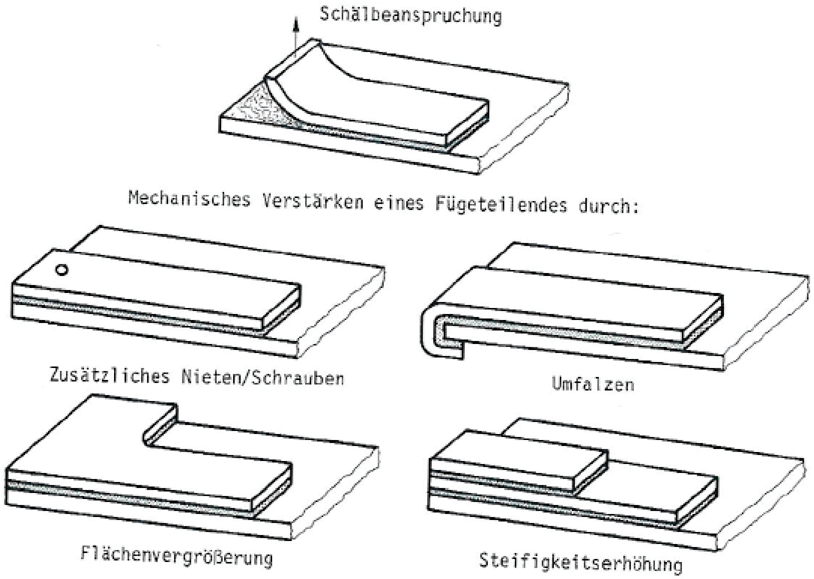






Design aspects of bonded joints

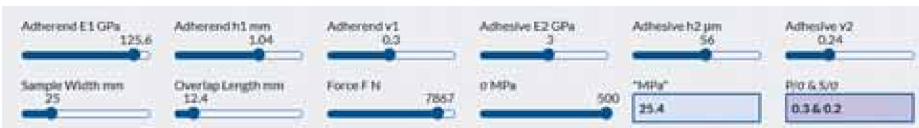
Avoiding peel stresses



Active unit on lap joints:

Please go to https://www.stevenabbott.co.uk/practical-adhesion/g-rlap.php

Use the sliders to optimise the following lap joint, start with this values:



How can the stress reduced, please post your result in the chat as a screen shot

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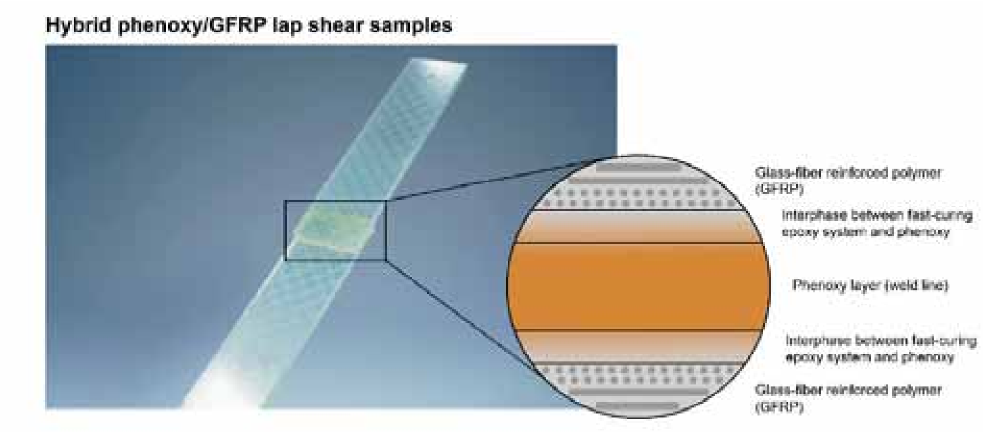
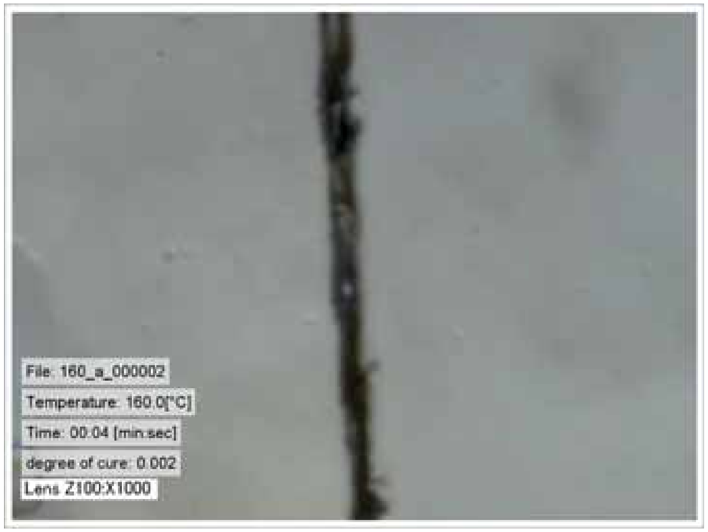
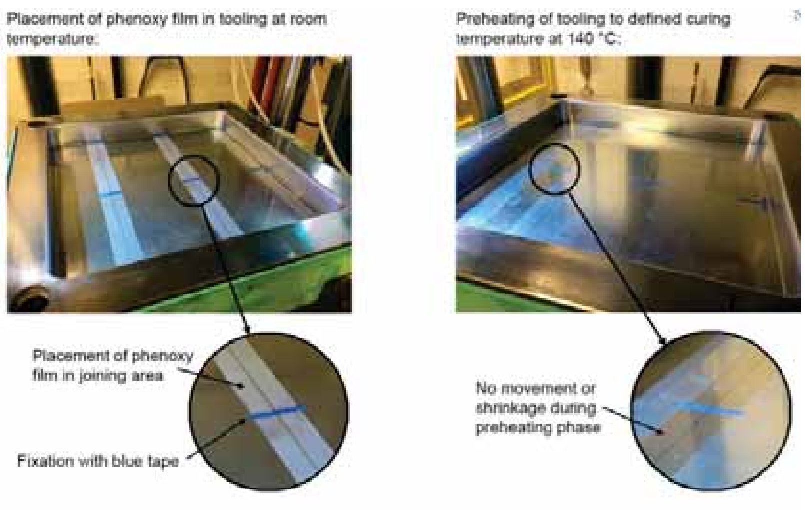
Hochschule für Technik

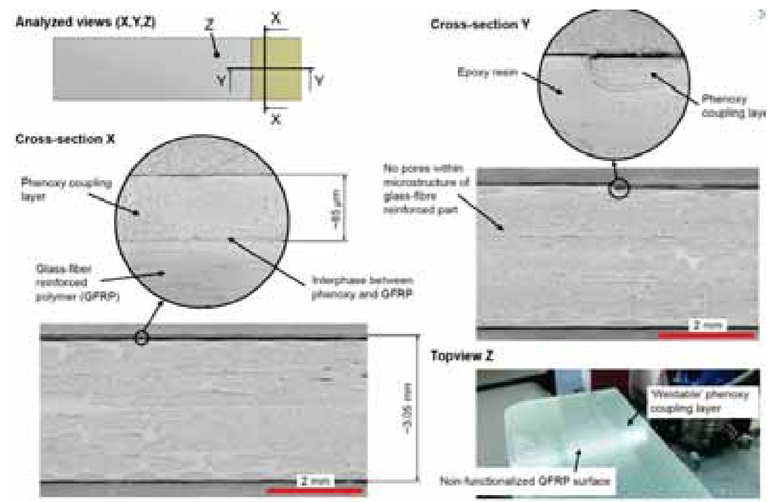
Advanced concepts applying welding to thermosets



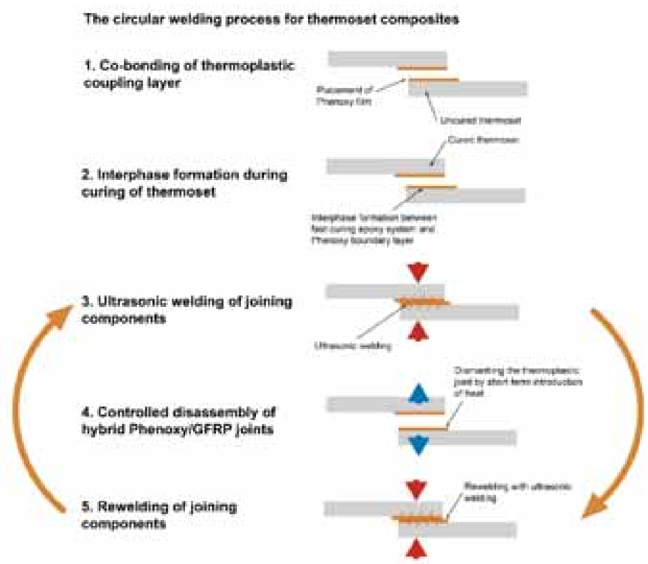


Advanced concepts applying welding to thermosets





Advanced concepts applying welding to thermosets



Zweifel, Lucian & Ritter, Klaus & Brauner, Christian. (2022). The Mechanical Characterization of Welded Hybrid Joints Based on a Fast-Curing Epoxy Composite with an Integrated Phenoxy Coupling Layer. Materials. 15. 1264. 10.3390/ma15031264.

Questions on bonded joints

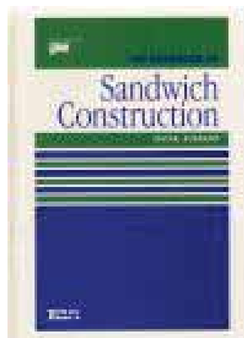
Which bond type bears more load (with same basic geometry and bond area)?

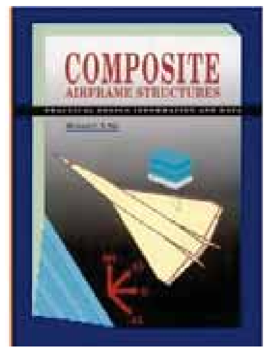
a. Single lap stronger than scarf
b. Scarf stronger than single lap
c. Same bond area, same strength

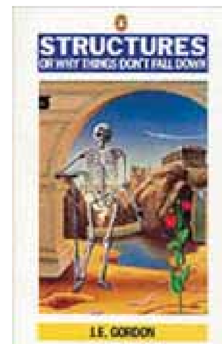
In a single lap joint, lower adhesive modulus leads to …?

a. Higher peak shear stress
b. Lower peak shear stress
c. Higher average shear stress

Recommended design related textbooks







Helmut Schürmann: Konstruieren mit Faser-Kunststoff-Verbunden ISBN 978-3-540-72190-1
All non referenced pictures from here

Bernd Klein: Leichtbau-Konstruktion ISBN 978-3-658-02272-3

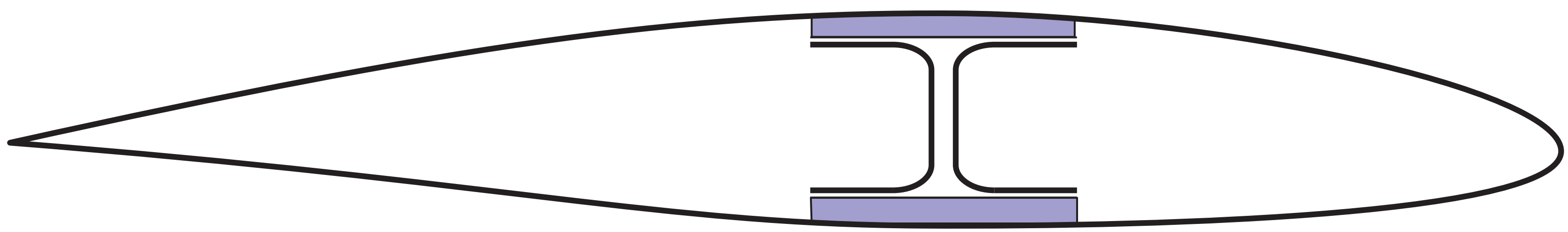
Dan Zenkert: Handbook of Sandwich Construction Department of Lightweight Structures, Royal Institute of Technology, 1993

Michael Chun-Yu Niu: Composite Airframe Structures ISBN 978-9627128069

J. E. Gordon: Structures or or why things don’t fall down, 2003 by Da Capo Press (first published 1978), ISBN 0306812835

Exam Questions

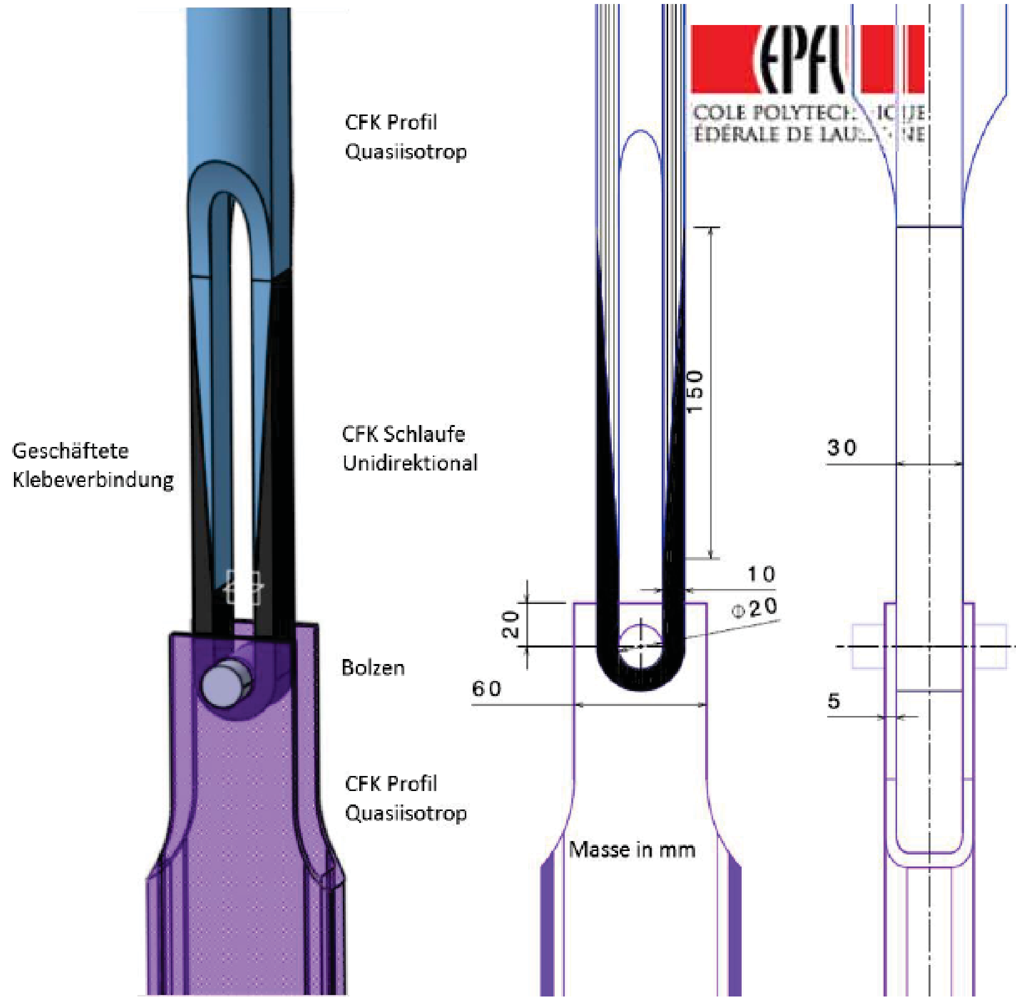
- How would you use pin loaded straps to attach a composite wing spar to the fuselage of an glider airplane?
- Illustrate by sketches



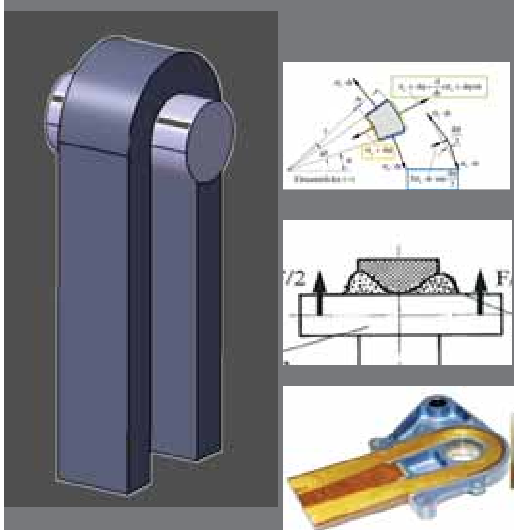
Exam Questions

Preliminary sizing of given design

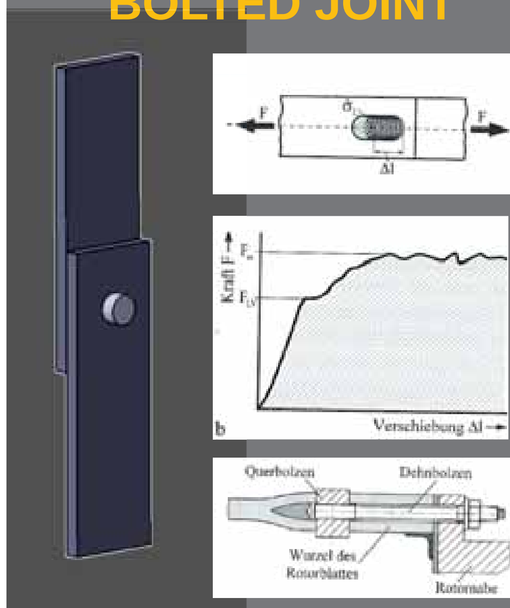
- Which load introductions do we have?
- How to you calculate the failure load?



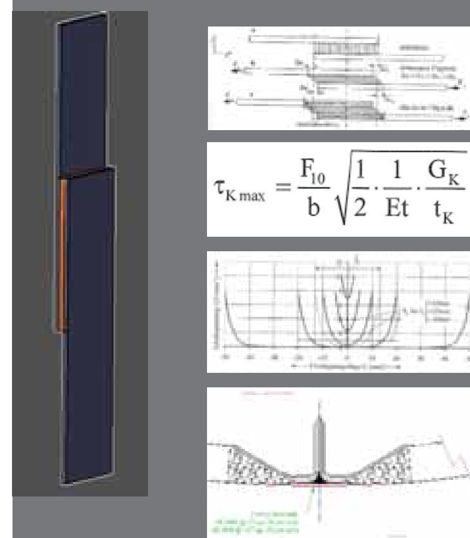
PIN LOADED STRAP



BOLTED JOINT



BONDED JOINT



Concept, manufacturing, sizing, design integration

Contact

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