Workshop

New developments in joining technologies for hybrid metal constructions and hybrid metal fiber-composite constructions

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Automotive Circle International
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Content

Prof. Neugebauer

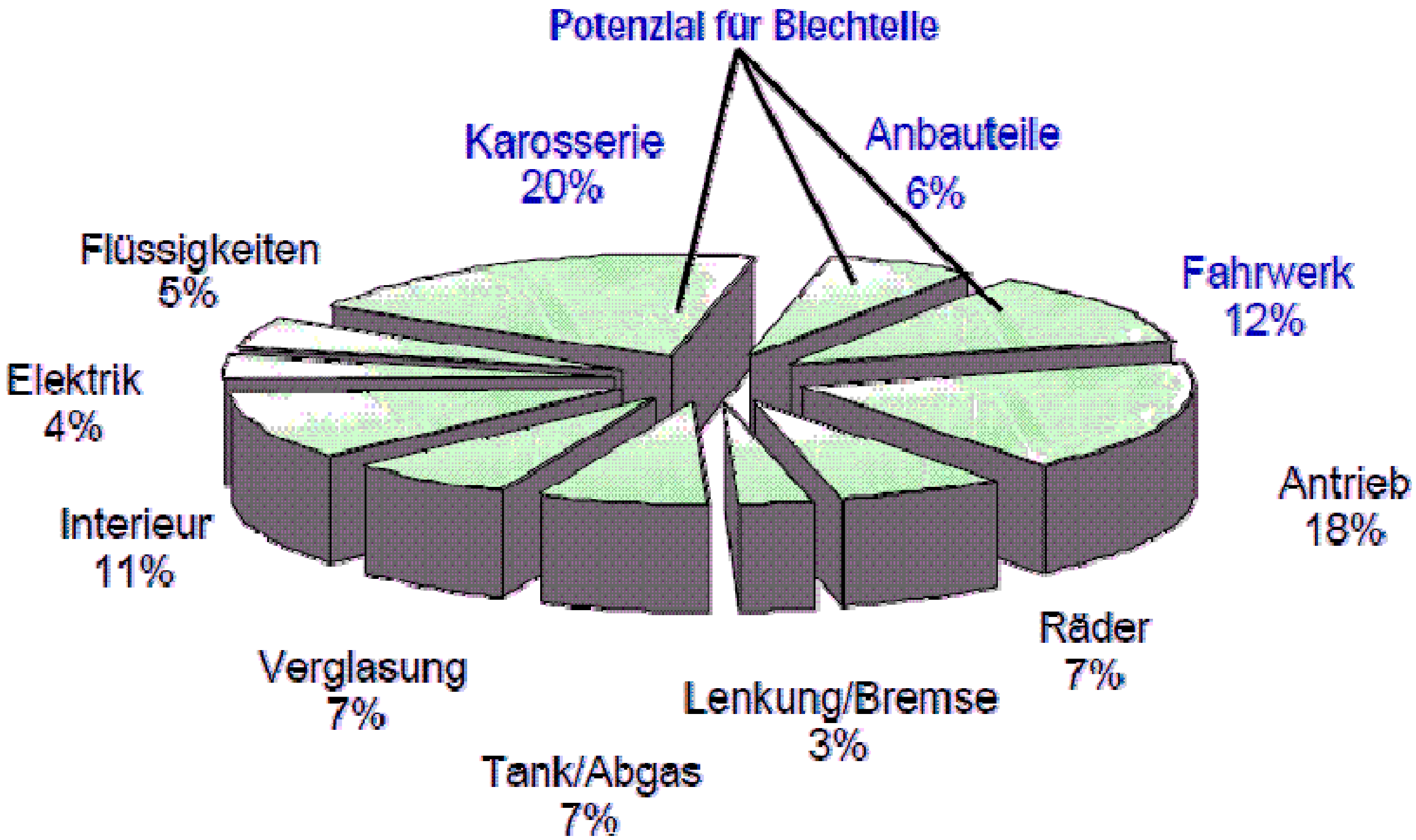
… 100 Kilogramm weniger Gewicht

➔ 0,3 bis 0,5 Liter weniger Verbrauch pro 100 Kilometer.

➔ Reduzierung von 8 bis 11 Gramm CO_2/km…

Quelle: Heinrich, T.: Leichtbau als Kernkompetenz. Audi AG

Potential of weight reduction in automotive engineering



Quelle: ThyssenKrupp Umformtechnik

Lightweight construction strategies for car bodies

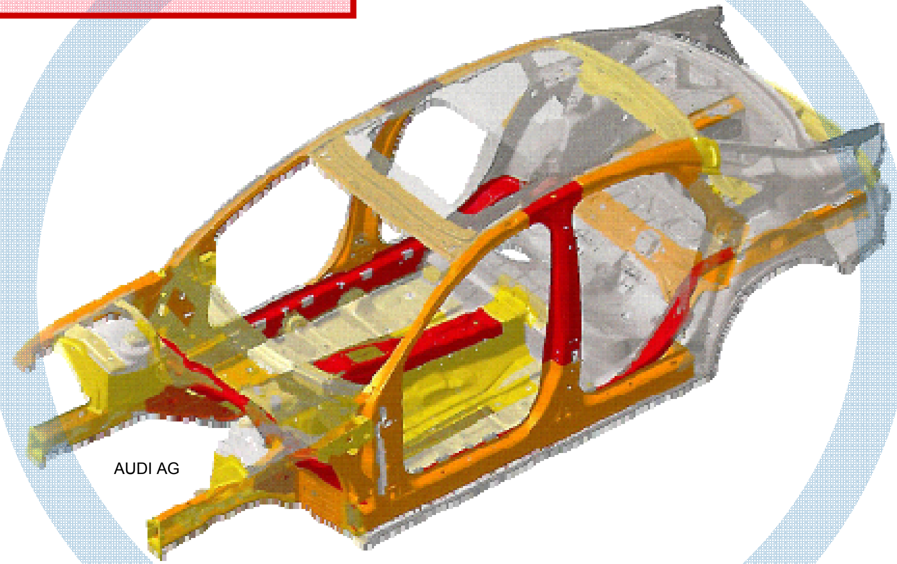
Stoffleichtbau

Mischbau

- höchstfeste Stähle
- Leichtmetalle
- faserverstärkte Kunststoffe

Strukturleichtbau

- tailored Blanks/Tubes
- strukturierte Bleche
- Patchwork-Bauteile

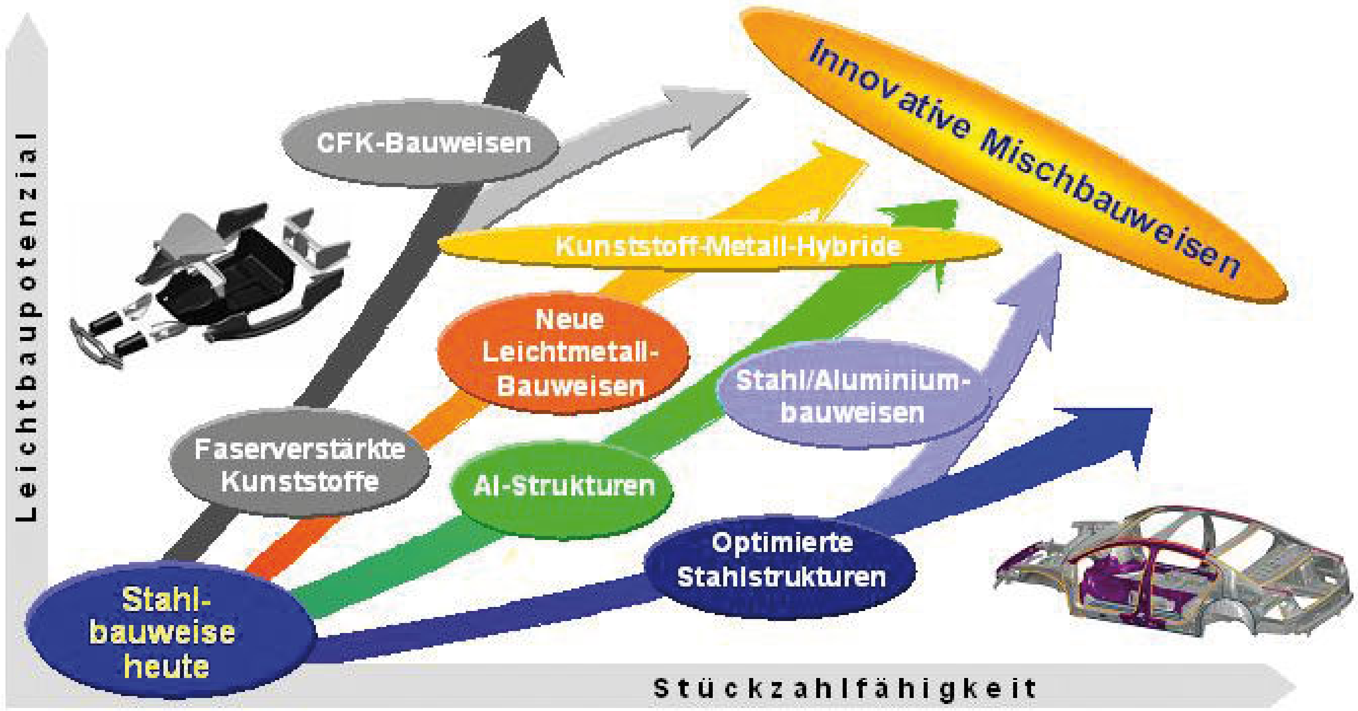


Konzeptleichtbau

- funktionsoptimierte Konzepte

Lightweight construction strategies for car bodies

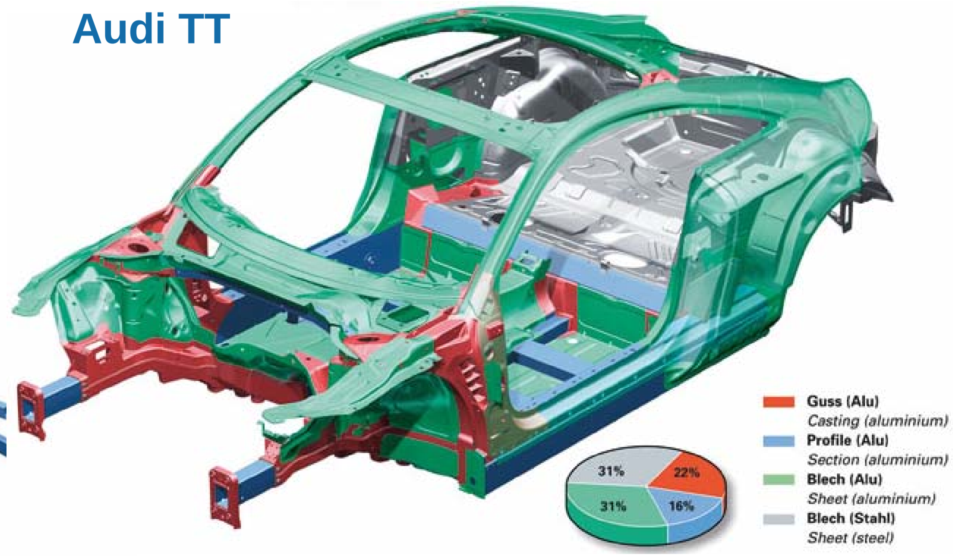
Mischbauweise - Trend für zukünftige Leichtbaukonzepte



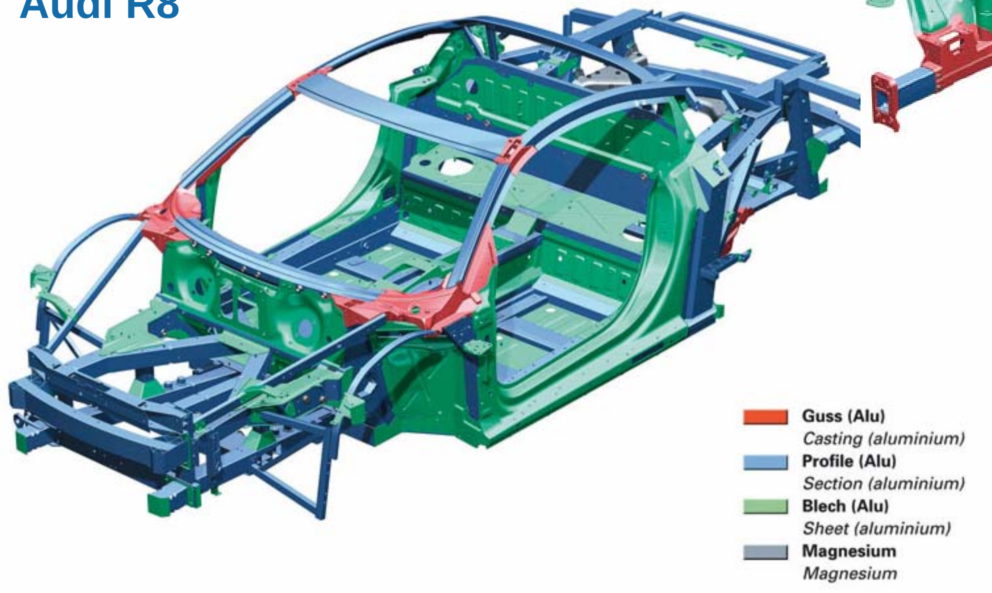
Quelle: Volkswagen AG

Lightweight construction strategies for car bodies

Audi TT

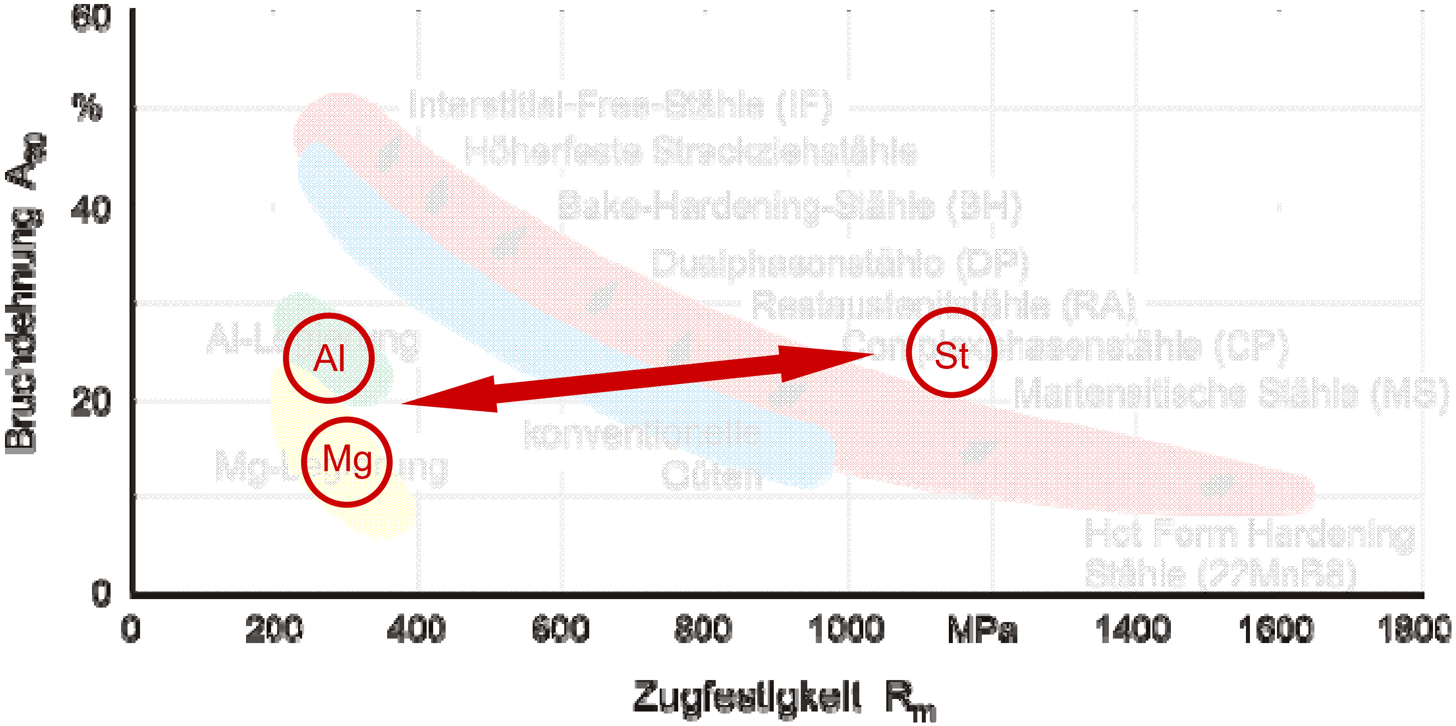


Audi R8



Quelle: Heinrich, T.: Leichtbau als Kernkompetenz. Audi AG

Steel-aluminium/magnesium metal combination



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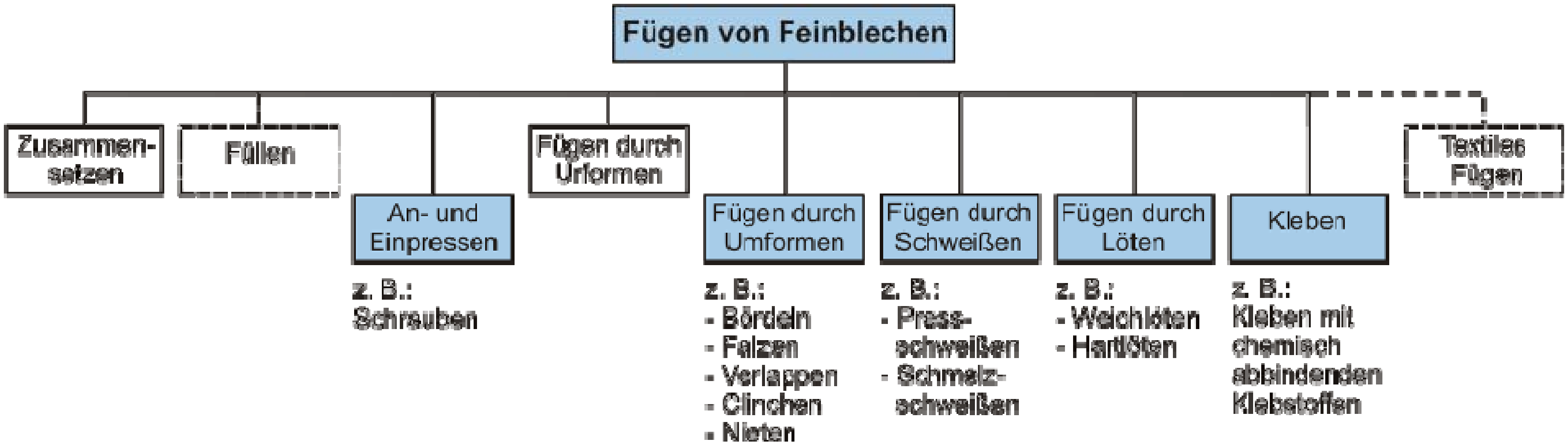
Overview of feasible joining technologies for sheet metals



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Physical problems during the brazing of material combinations

Aluminium, T_s= 660°C	Steel
Magnesium, T_s= 650°C	$T_s \leq 1538°C$

- widely differing melting points, thermal expansions and thermal conductivities
- widely differing properties of oxide layers ($T_{S,Al2O3}$ = 2050 °C!)
- formation of intermetallic compounds

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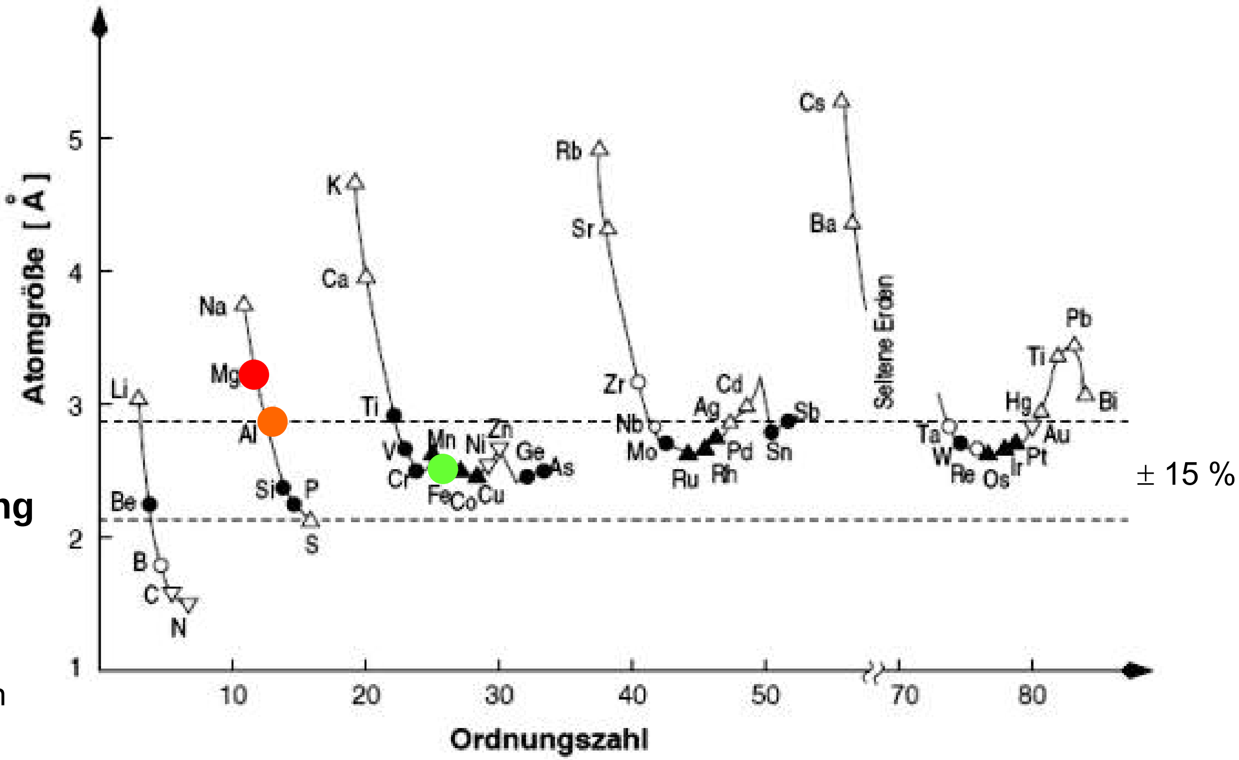
Metallurgical problems during the brazing of material combination

- **Great differences between crystalline lattice und atomic radius → weldability↓**
- **Solid solution alloying of metals (substitution of atoms in cristalline lattice) only for atom radii with max. 10-15% difference**
- **Intermetallic phase layers decrease joint strength (1 µm no influence, 2 -3 µm small influence)**

Atom size of the alloying elements in iron and their solubility

Quelle: Script „Physikalische Eigenschaften“ IFW Dresden



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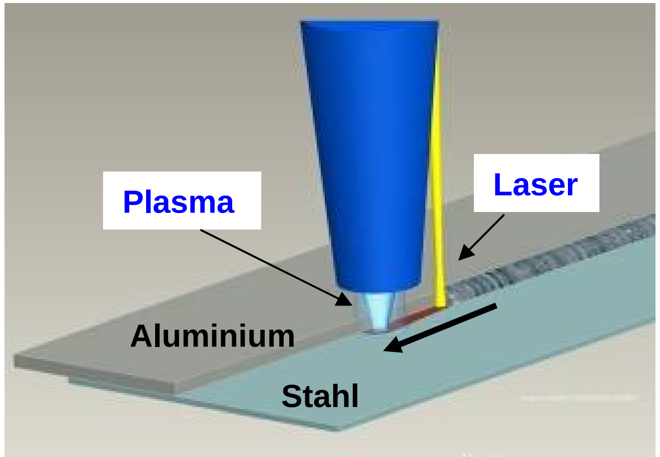
Potential of hybrid processes

Hybrid joining process	
Main processs	**Support process**
▪ Metallurgical joining process (alloying, wetting, diffusion)	▪ Pre-heat, -melt ▪ Surface activation, oxide removement ▪ Post-heat ▪ Influence on the melt pool ▪ Surface coating

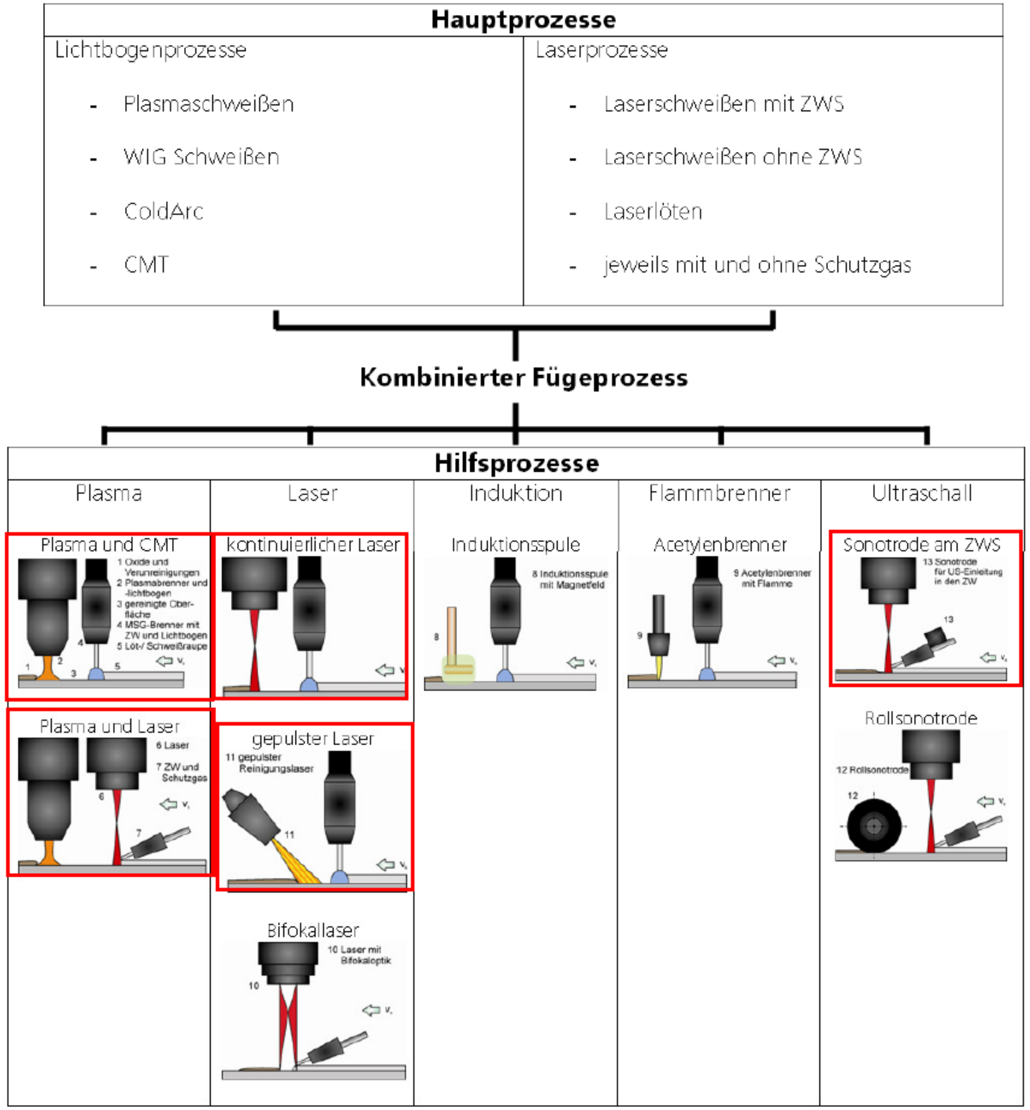
Example for a hybrid process



Main process: Laser, support process: plasma-arc for surface activation, pre-heating

Steel-aluminium/magnesium metal combination

Hybrid processes, selection



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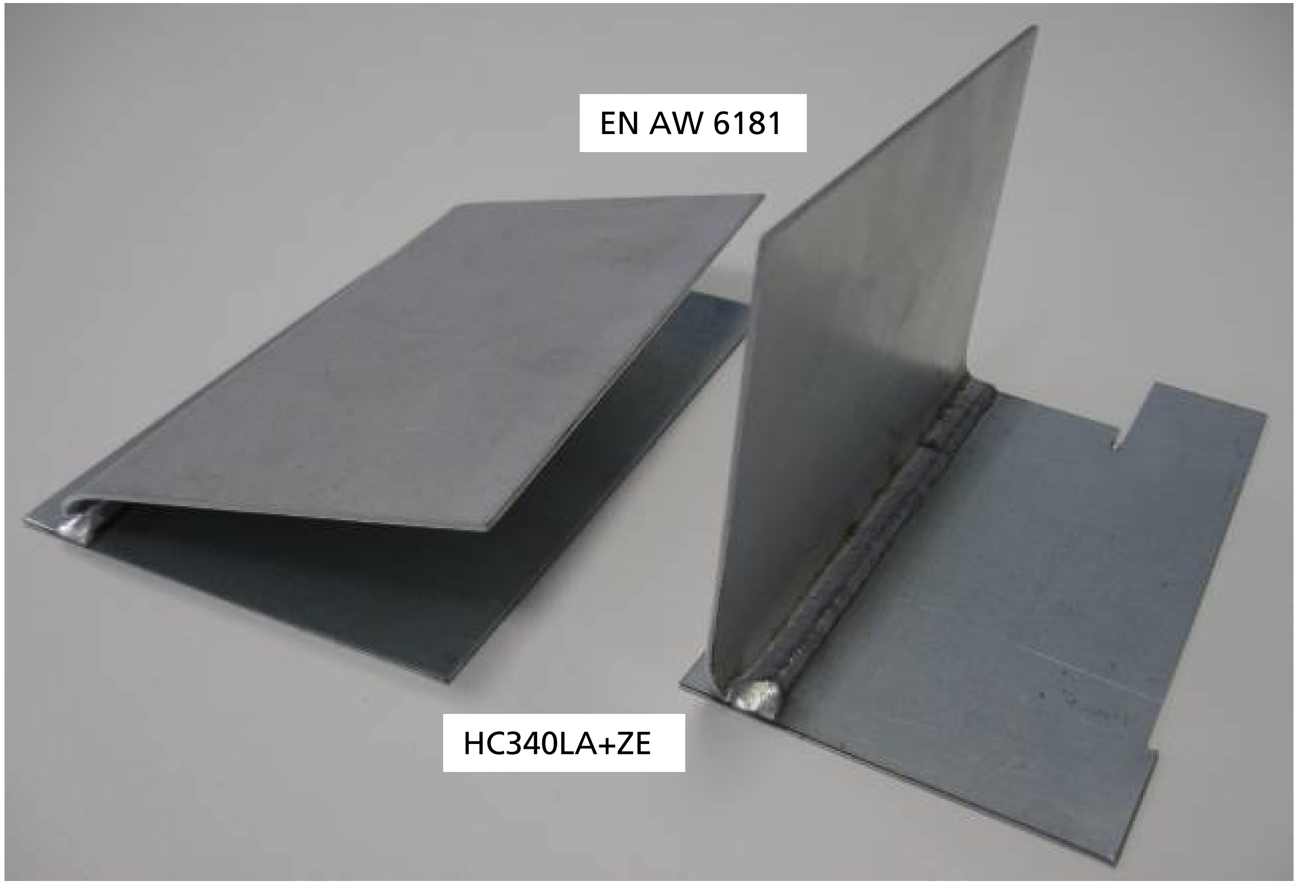
Weld-braze-joint with high joint strength



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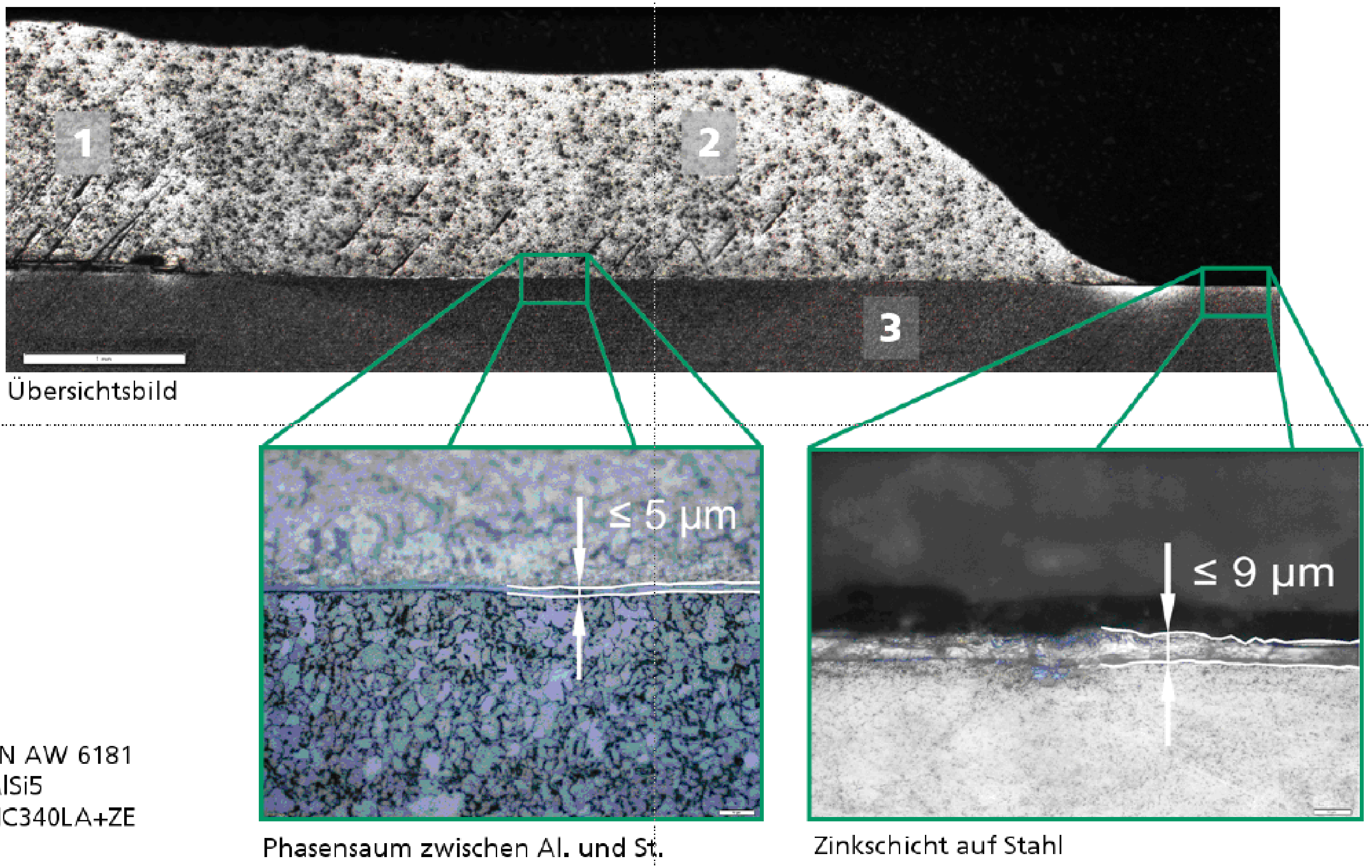
Weld-braze-joint, metallurgical formation



1 EN AW 6181
2 AlSi5
3 HC340LA+ZE

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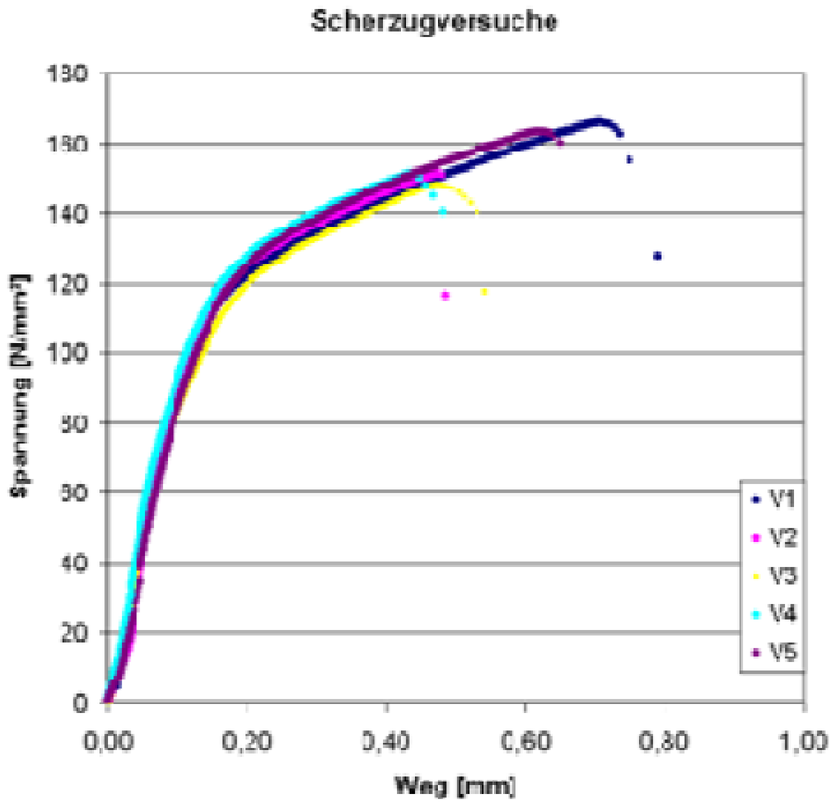
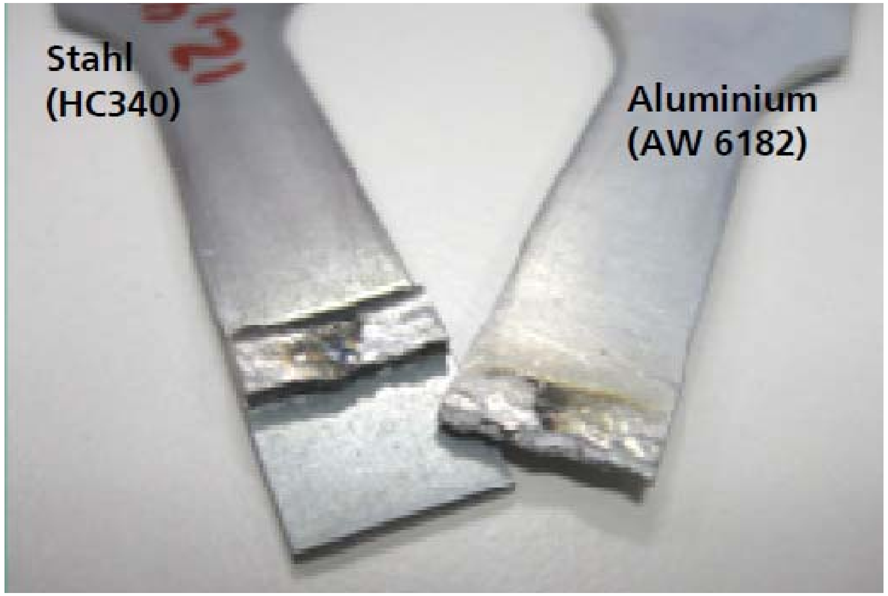
Weld-braze-joint, mechanical properties





parent und filler material:

- Aluminium: EN AW 6181, t = 1,5 mm
  (R_m = 235 N/mm²)
- Mild steel: HC340LA+ZE, t = 1,2 mm
  (R_m = 410 N/mm²)
- Filler wire: AlSi5, d = 1,0 mm
  (R_m = 165 N/mm²)

Joint strength:

- Mean: 156,05 N/mm²
- Standard deviation: 7,97 N/mm²

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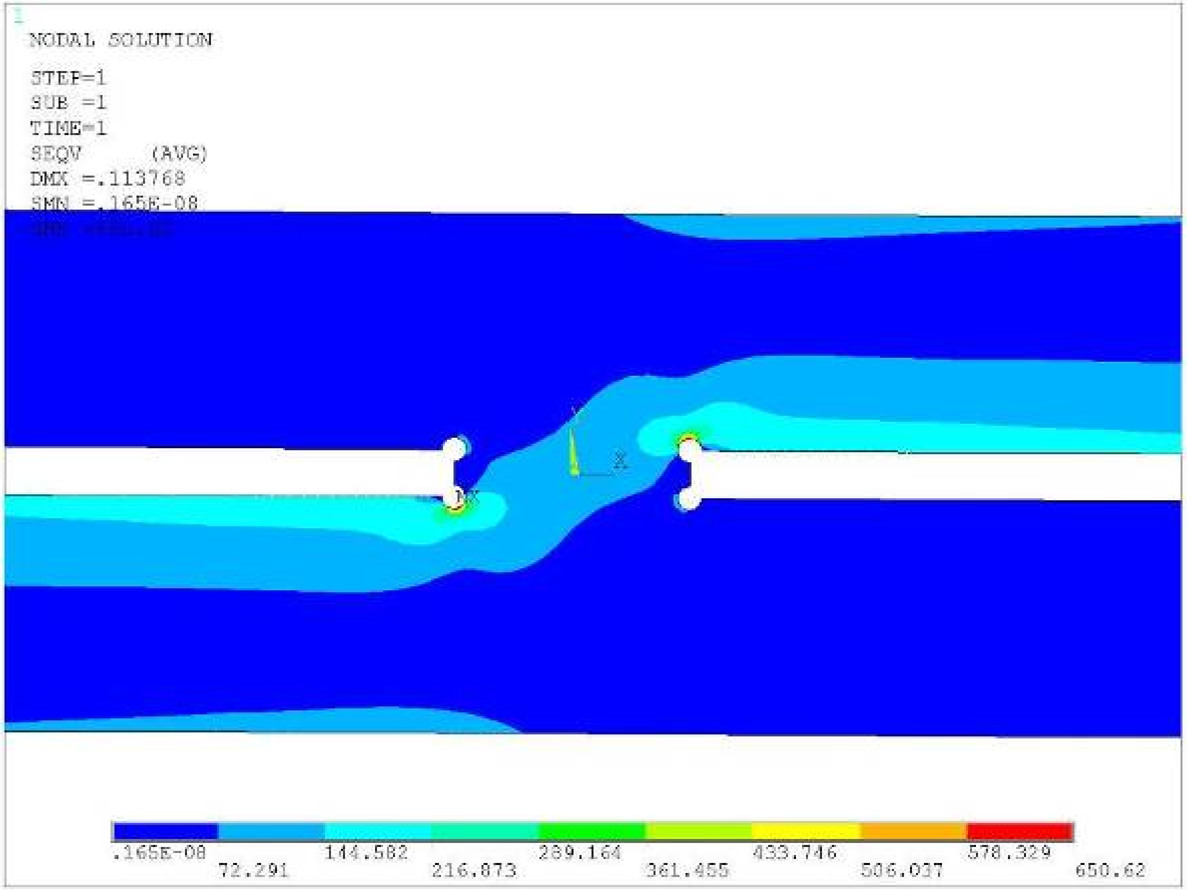
Stress distribution (FEM simulation) in the joining region



Kerbspannungsmodell

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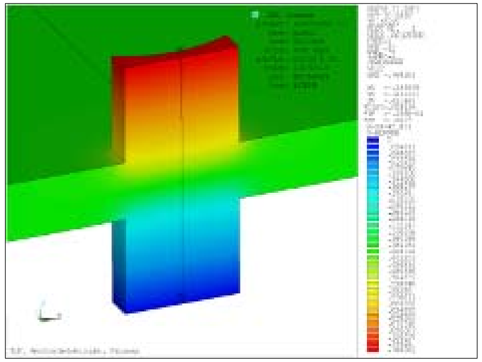
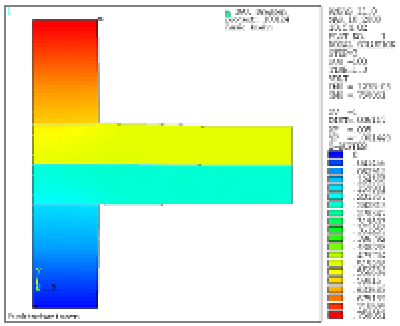
FE-process-simulation resistance spot welding

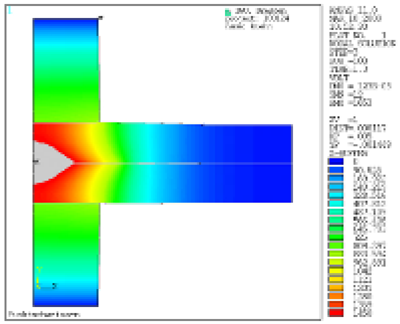


3D calculation

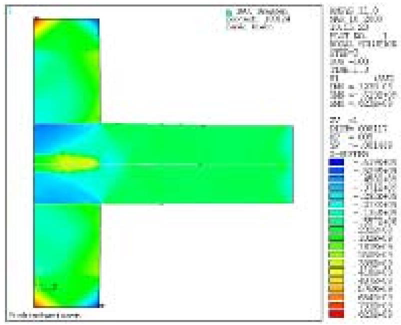
- Simulation of the weld process via coupled calculation mechanical/thermal/elektrical
- Development of a parametric simulation model
- 2 1/2D- and 3D-calculations possible
- Simulation and measurement results correspond approximatly



elektric potential



temperature distribution

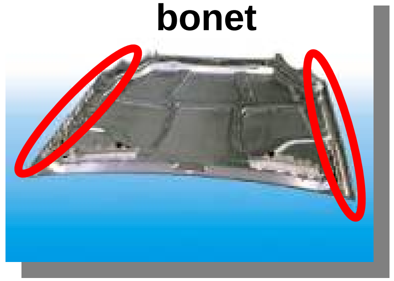


equivalent tensile stress

Clinching in automotive engineering

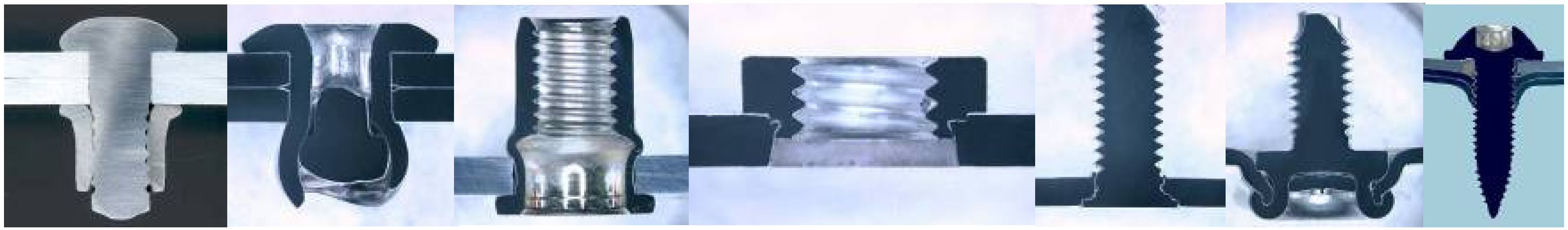
2 spots

2 spots



52 spots

Clinching in automotive engineering



Lockbolt fastener | Blind-riveting | Blindrivet-nut | Rivetnut | Rivet-stud | Pierce-stud | FDS

Dieless Clinching | Clinching | Rivetclinching | SPR | Solid riveting

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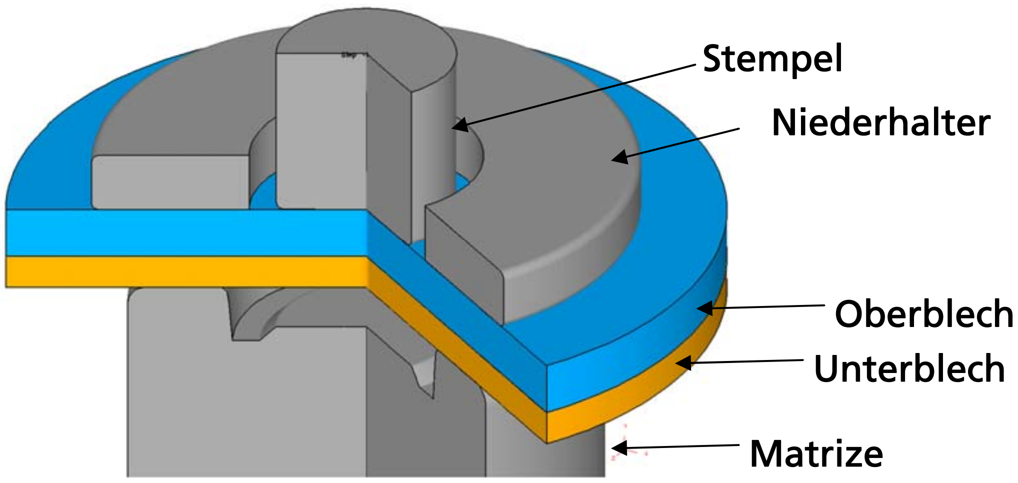
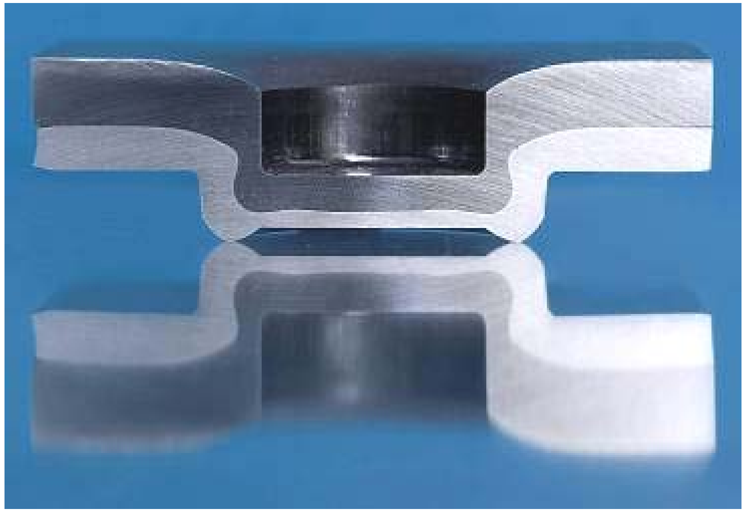
Clinching steel / aluminium



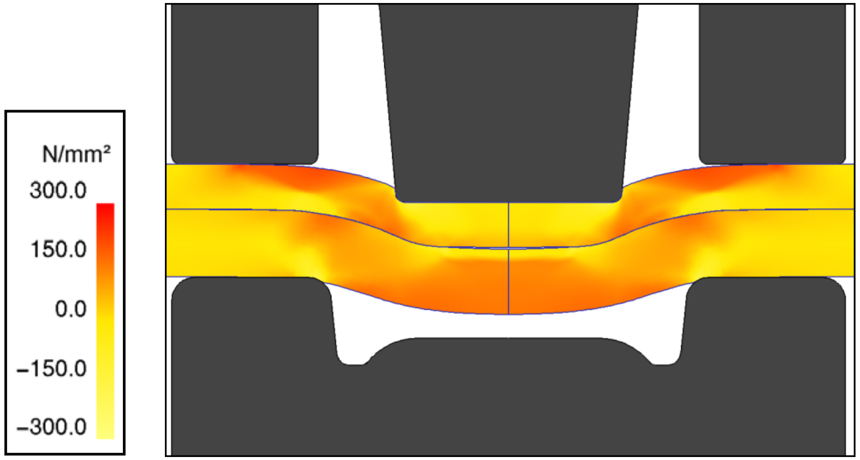
Setzprozess Clinchen



S380 (6 mm) in
AlMg4.5Mn (4 mm)
Matrizen-Ø30 mm
Fügekraft ca. 600 kN
Scherzugkraft ca. 53 kN

Main problems of conventional clinching of magnesium materials

- **Tensile stress** in the material at the contoured counter tool **induces cracking** in magnesium



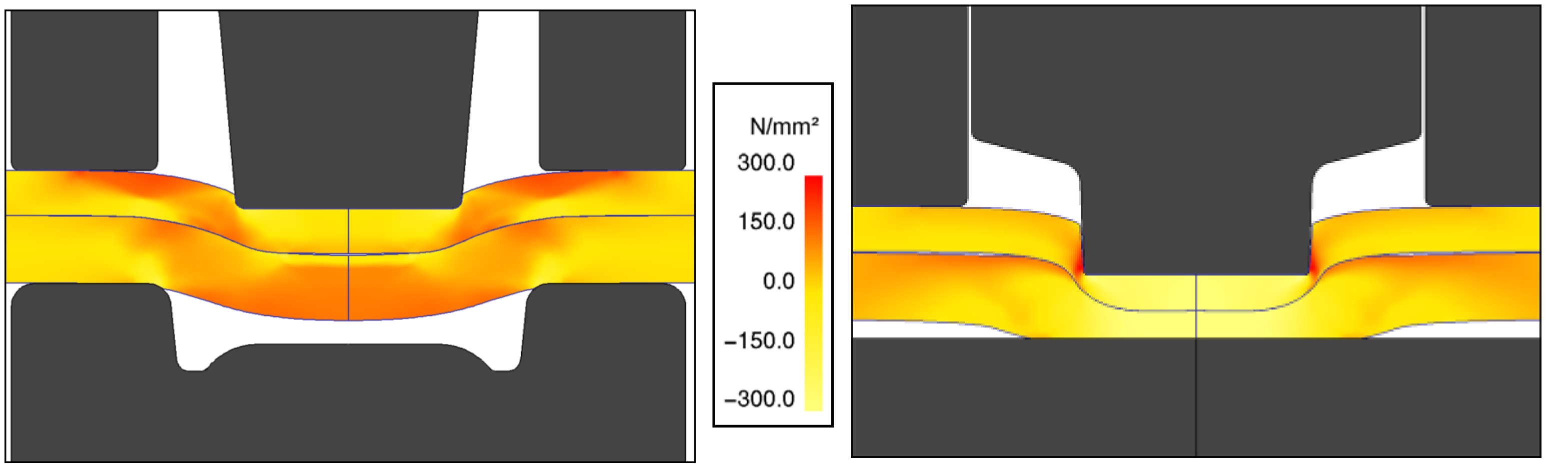
Maximum principal stress when standard Clinching is used

- **Formability** of magnesium is **low at room temperature**
  (Formability can be significantly improved at over 220 °C)

Comparison of the stress distribution in the joint with different clinching methods

Stress distribution in the anvil side part is better...

→ ... because the fraction of compressive stress influence in the joining process



TOX Clinching   Clinching without die

Stress distribution (FEM simulation) in the joining region

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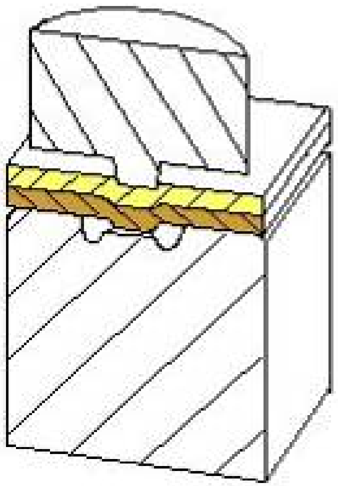
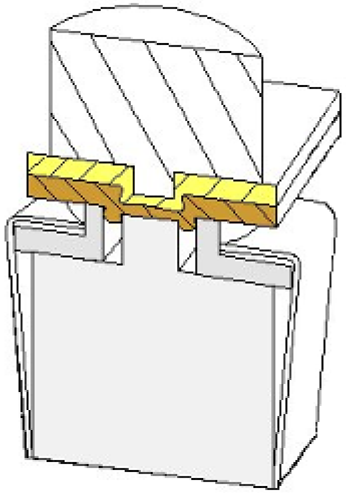
Replacement of conventional clinching with a flat anvil





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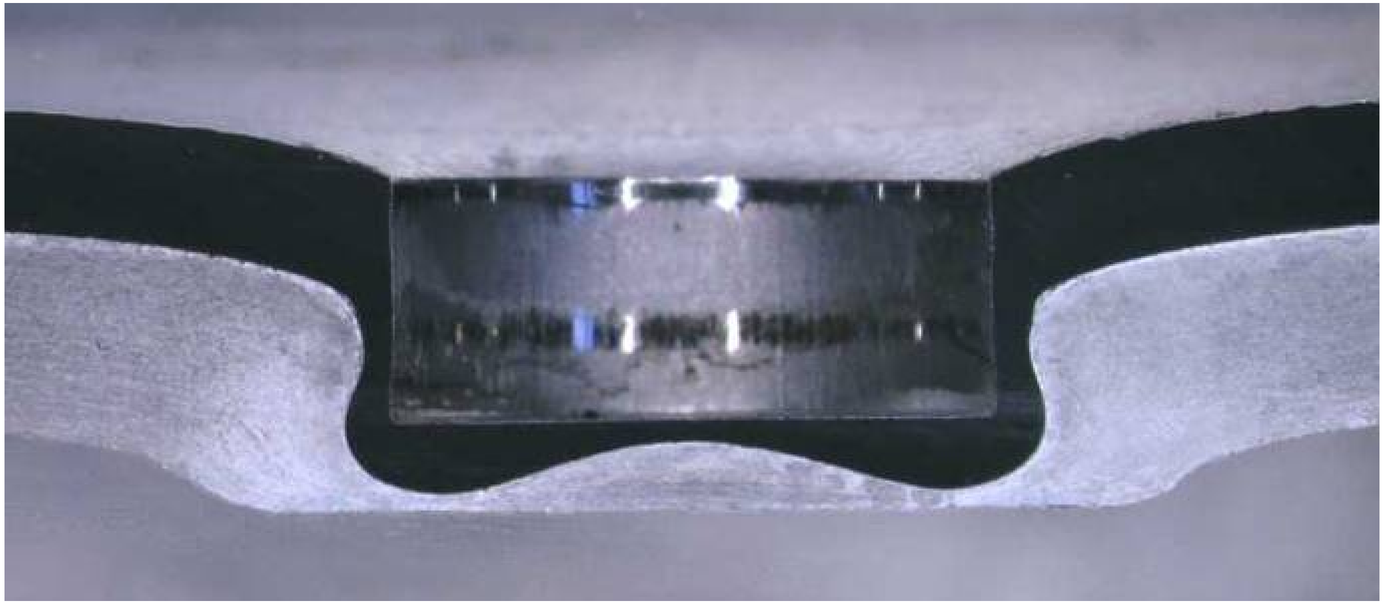
Clinching without die of steel-magnesium joints



H340 sheet
t = 1,2 mm

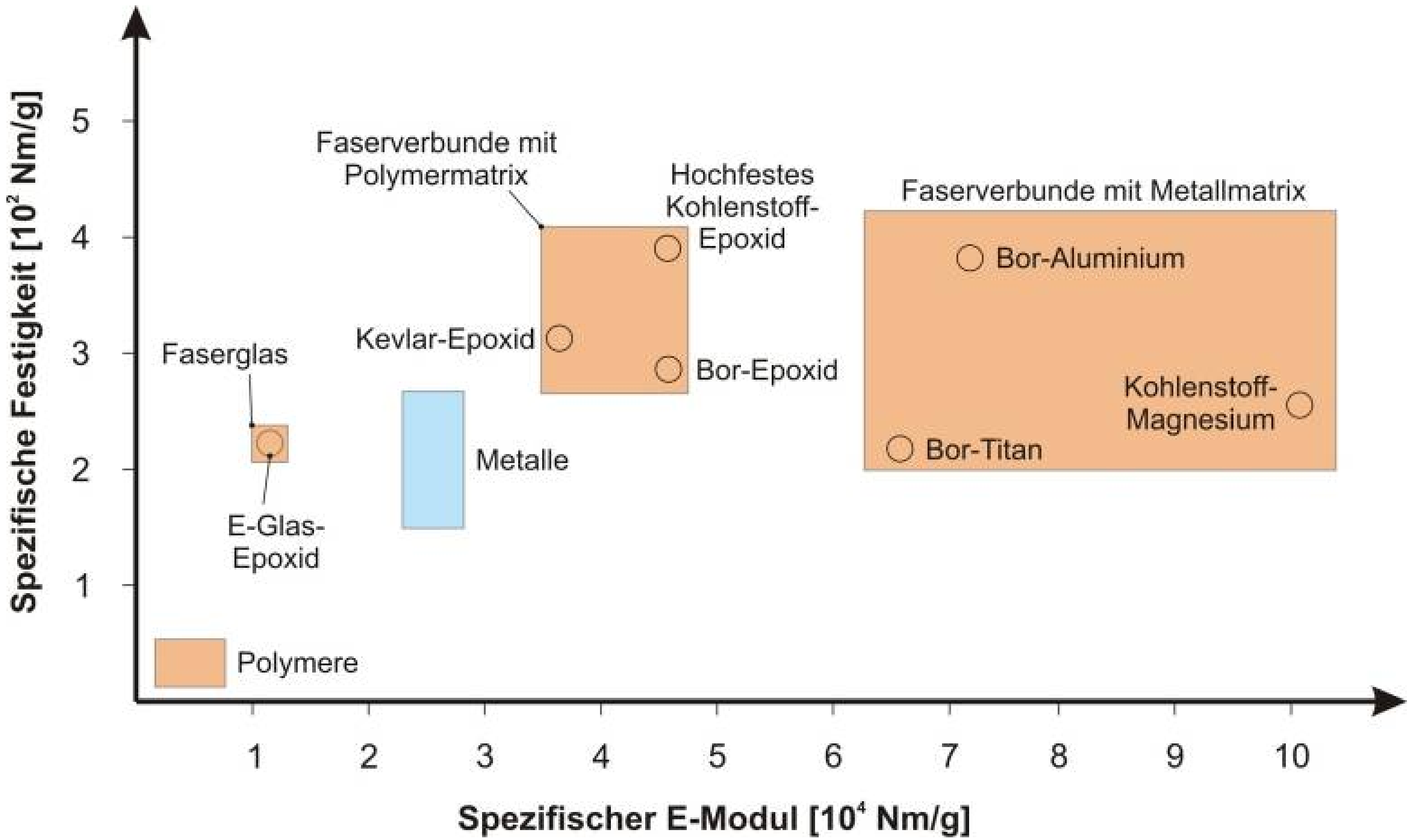
AZ91 die casting
t = 1,9 mm

Clinch joint without die (d_S = 6 mm)

→ Materials can be joined without dwell time to heat the parts

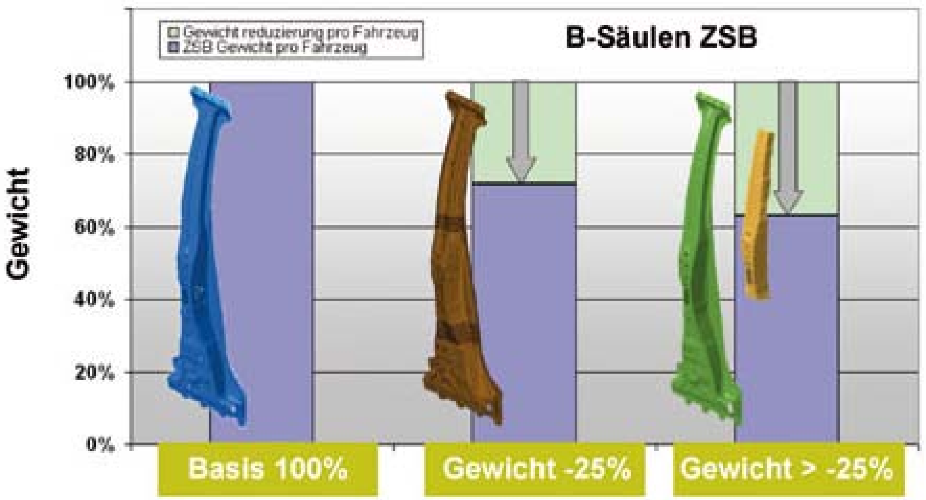
Content

Properties of fiber-reinforced plastics



Quelle: Askeland, D.: Materialwissenschaften.

Potential of light weight constructions



cold formed assembly | **warm formed & tailor rolled blank** | **warm formed & fiber-reinforced plastic**

Quelle: Frehn, A. u. a.: Hybridkonzepte. Benteler Automobiltechnik

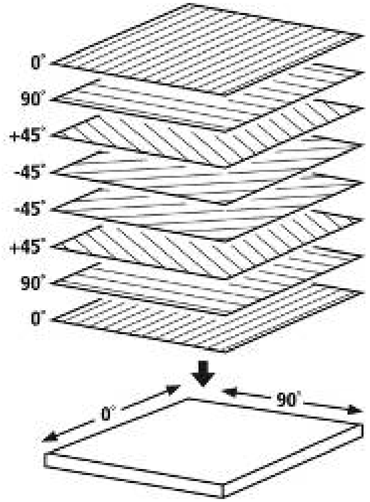
Examples of usage

Bauteile aus CFK am Beispiel Audi R8 GT:

- Frontspoiler
- Winglets vorn
- Außenspiegel
- Sideblade
- Heckklappe
- Heckspoiler
- Heckabschlussteil
- Stoßfänger hinten
- Diffusor
- Motorraum
- Sitze
- Mittelkonsole
- Einstiegsleisten
- Schalthebel
- Monoposto
- Instrumentenhutze
- Einsatzteil Schalttafel

Quelle: Heinrich, T.: Wo liegt der Bedarf für CfK im Automobilbau? Audi AG

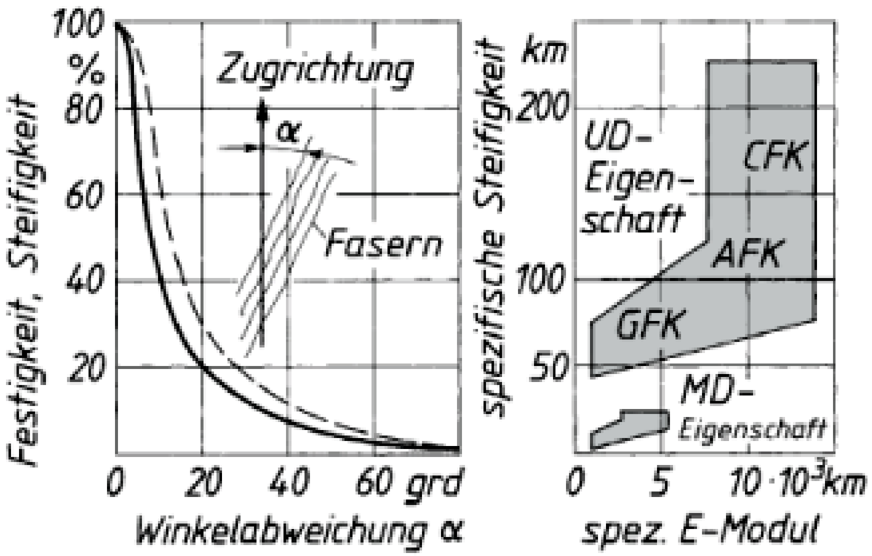
Directional dependence of FRP properties



Properties of CFRP-laminates

Eigenschaft	Einheit	Epoxidharz 913 C	HTS-Faser-Laminate 0°	90°	0/90°	+/- 45°
Faservolum.anteil	%	0	60	60	60	60
Dichte	kg/dm³	1,25	1,55	1,55	1,55	1,55
Zugfestigkeit	N/mm²	40-140	1950	75	850	200
E-Modul (Zug)	kN/mm²	3 – 4,5	130	9,1	70	23
Biegefestigkeit	N/mm²	60-160	2000	100	700	-
Druckfestigkeit	N/mm²	10-200	1300	260	700	190
E-Modul (Druck)	kN/mm²	3,5	130	9	70	23
Bruchdehnung	%	2-10	1,1	0,6	1,0	5 – 6
Wärmedehnung	10^{-6}/K	60	- 0,5	40	1 – 2	3 – 5

Quelle: Ahlborn, H.: Herstellung, Eigenschaften und Varianten kohlestofffaserverstärkter Kunststoffe. konstruktionspraxis.de



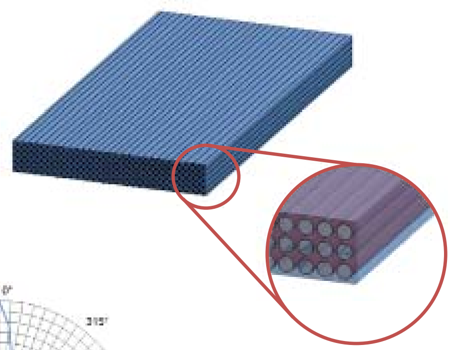
UD…unidirectional fiber alignment (one direction)
MD…multidirectional fiber alignment (at least 3; 0° / 90° und +/- 45°)

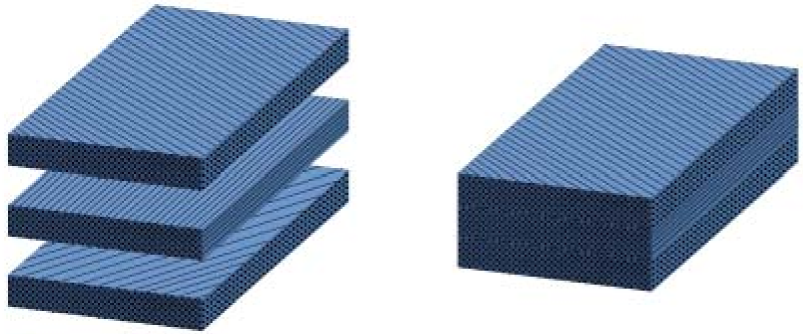
Quelle: Weißbach, W.: Werkstoffkunde. Vieweg Verlag

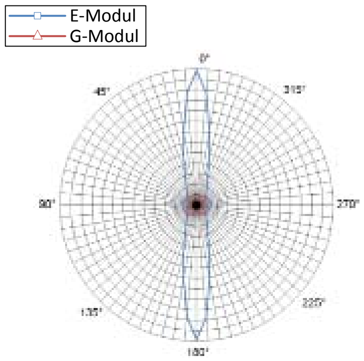
Directional dependence of FRP properties

UD-Schicht

MSV mit unterschiedlich aufgebauten Einzelschichten







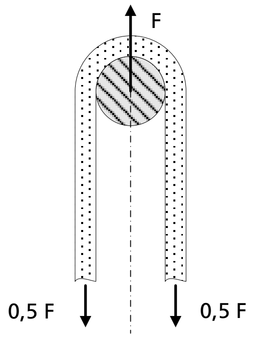
- max. E-Modul und Festigkeit in Faserrichtung
- Senkrecht zur Fasserrichtung nur geringe Werte

➜ Anordnung der Fasern in Lastrichtung

Quelle: Schürmann, H.: Konstruieren mit Faser-Kunststoff-Verbunden

Metal-FRP material combination

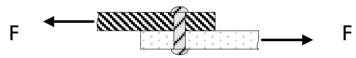
Schlaufenanschluss



Vorteile:
- sehr fasergerechte Verbindung
- sehr hohe, punktförmige Lasten können eingeleitet werden

Nachteile:
- aufwendige Herstellung

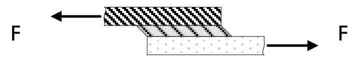
Bolzen- / Nietverbindung



Vorteile:
- Fügen von ungleichen Materialien
- exakte Berechnung möglich
- preiswerte Verbindung

Nachteile:
- nicht fasergerecht (durchtrennen der tragenden Fasern)
- Korrosionsprobleme an der Bohrstelle
- nur geringe Lochleibungs-spannung zulässig
- erhöhtes Gewicht

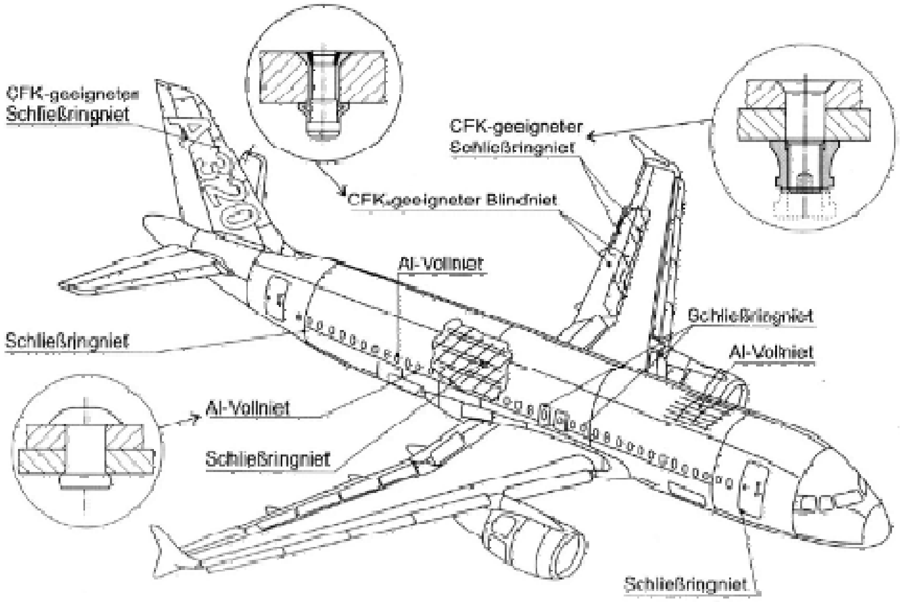
Klebverbindung



Vorteile:
- ganzflächige Verbindung
- gleichmäßige Spannungs-verteilung
- hohe stat. und dyn. Festigkeiten
- …

Nachteile:
- keine exakte Festigkeits-berechnung möglich
- komplizierter Produktionsablauf
- aufwendige Halbzeug-vorbereitung
- …

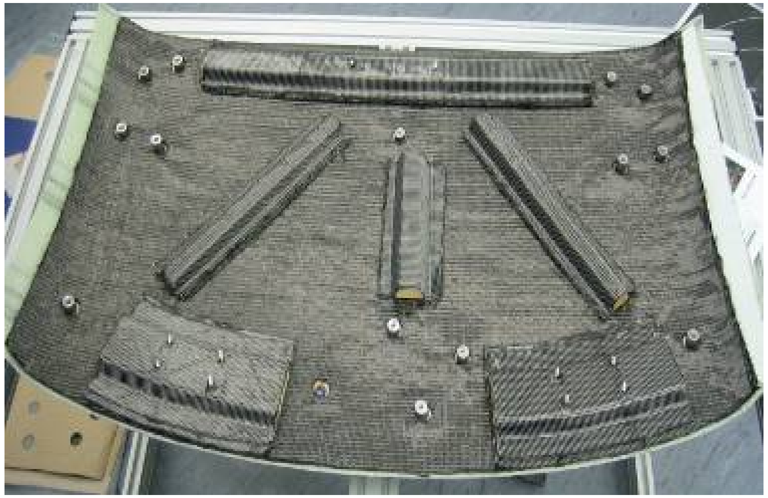
Quelle: Schürmann, H.: Konstruieren mit Faser-Kunststoff-Verbunden
Michaeli, W.; Huybrechts, D.; Wegener, M.: Dimensionieren mit Faserverbundkunststoffen
Michaeli, W.; Wegener, M.: Einführung in die Technologie der Faserverbundwerkstoffe



Mechanisch gefügte Stahl-CFK-Verbindung am Flugzeugbauteil

Quelle: [1] K.-J. Matthes; F. Riedel: Fügetechnik: Überblick, Löten, Kleben, Fügen durch Umformen
[2] Fraunhofer IPA

CFK Dachsegment BMW M6
Geklebt [1]



Automobil Dachelement mit Metall-Inserts [2]

Quelle: [1] BMW
[2] Fraunhofer IPA

Vorbereitung der Metalloberfläche durch:

Mikrostrukturierung mit Hilfe der Heißprägung

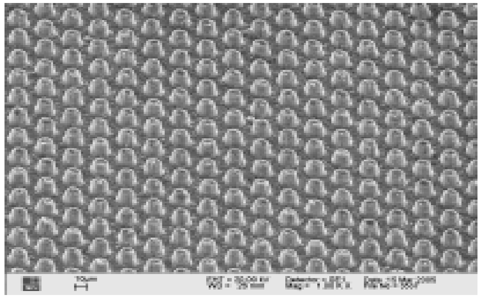


Bild: Schubert, A.: Workshop Fertigung von kleinen Präzisionsteilen für die Medizintechnik und Analytik

- definierte, gleichmäßige Oberfläche

Mikrostrukturierung durch Sandstrahlen bzw. Ätzen

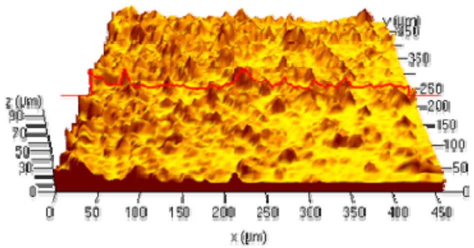


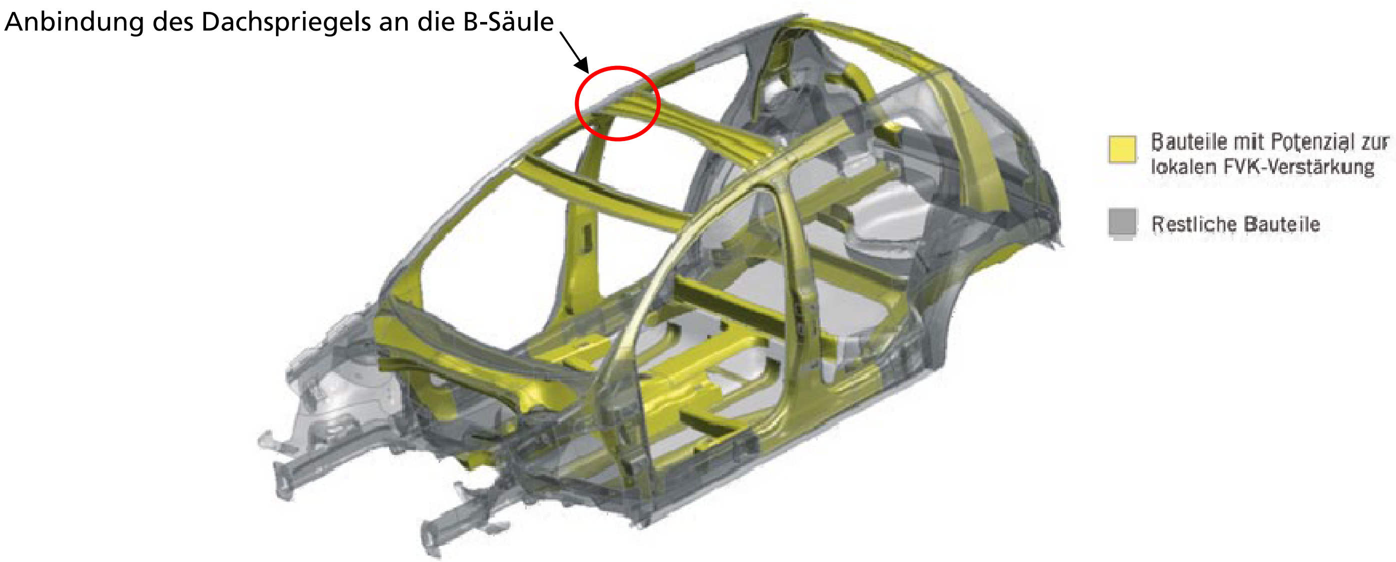
Bild: Fachhochschule Osnabrück

- undefinierte Oberfläche
- preisgünstige Herstellung

Aufbringung von CMT PINs

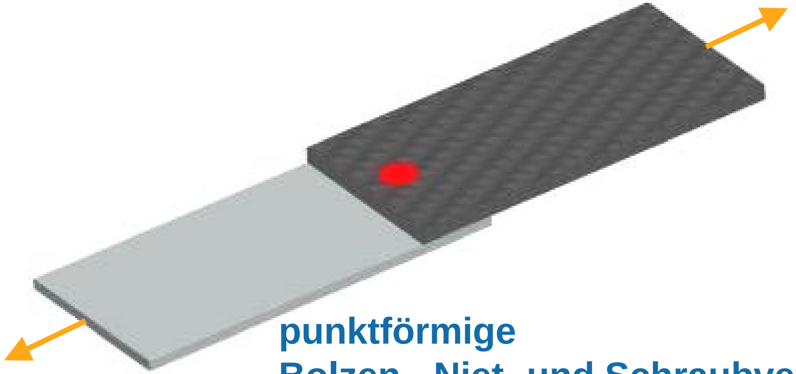
Bild: Fronius International GmbH

- definierte, gleichmäßige Oberfläche
- hohe übertragbare Kräfte

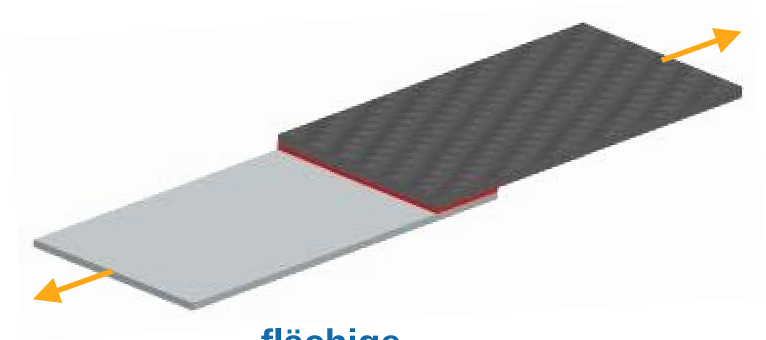


Quelle: * ATZ: Leichtbau-Bodengruppe mit Verstärkungen aus CFK und GFK

Principles of force transmission of metal-FRP constructions

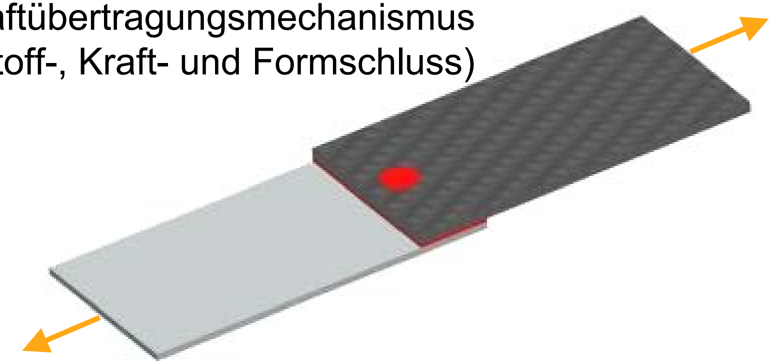


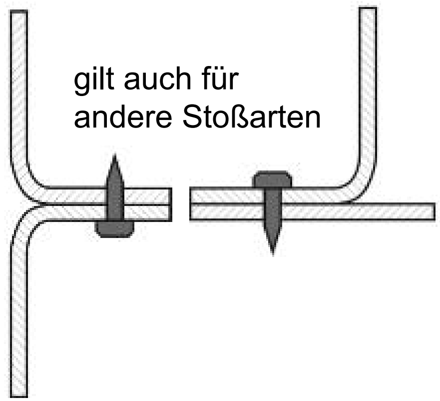
punktförmige
Bolzen-, Niet- und Schraubverbindungen
Kraftübertragung durch Kontakt-Druckspannungen
(Kraft- und Formschluss)



flächige
Klebverbindungen
Kraftübertragung durch Adhäsion
(Stoffschluss)

Hybridverbindungen
komplexer Kraftübertragungsmechanismus
(Stoff-, Kraft- und Formschluss)

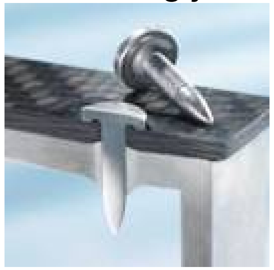




Joining technologies for metal-FRP material combination

Self piercing solid-rivet joint

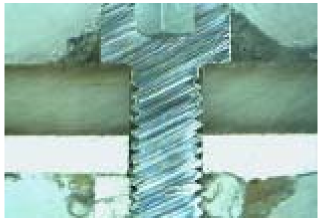
Bolt setting joint



Quelle: Wilhelm Böllhoff GmbH & Co. KG

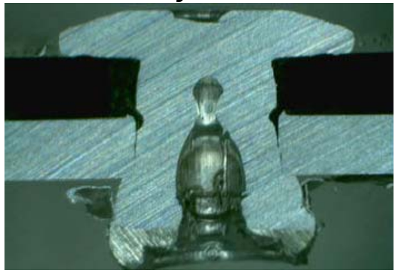
Semi-tubular self piercing rivet joint

Screw joints

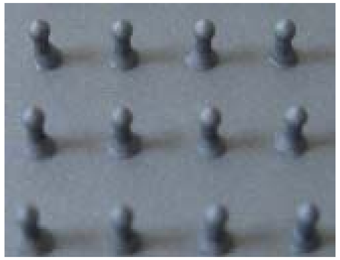


Quelle: DLR

Blind rivet joint



Quelle: DLR

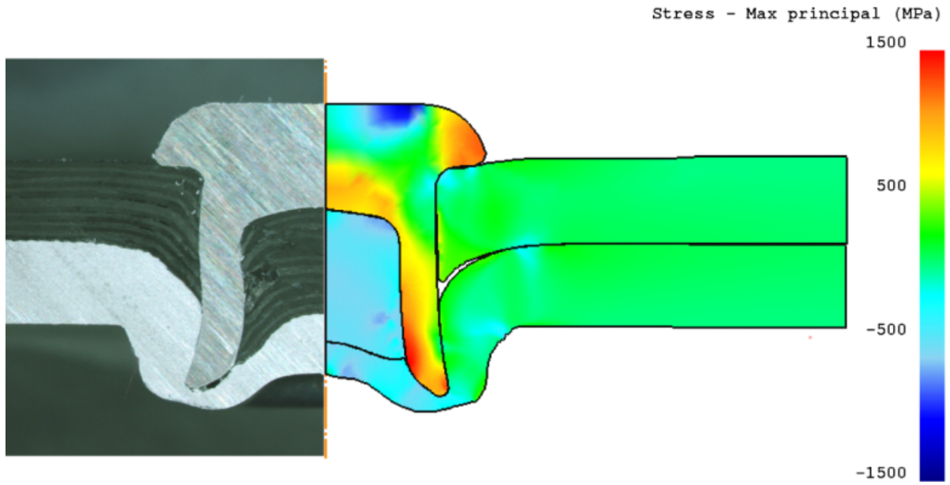


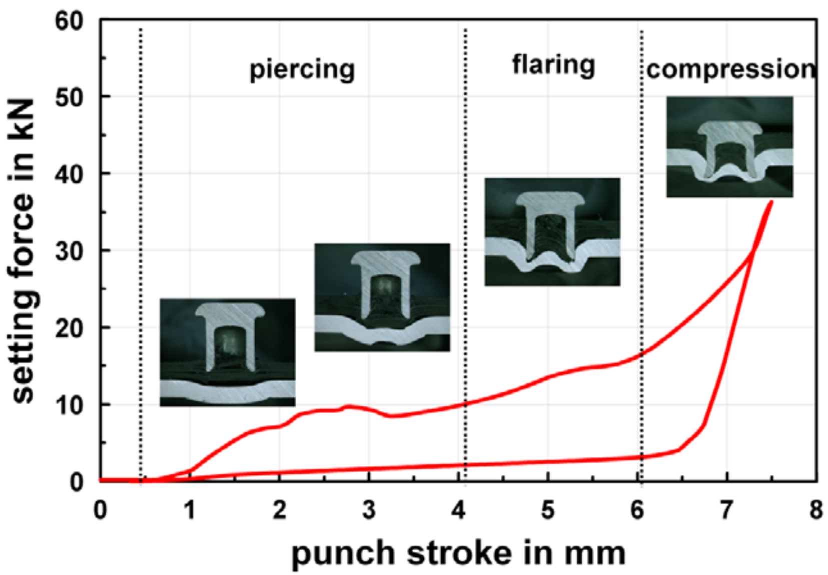
Quelle: Fronius CMT-Technik

Prof. Neugebauer

half-tube-rivet Ø5,3 x 5,6 H4

**CFK T700SC/RIM935-[0/90]4S (2,1mm)
in AlMgSi0,5 T6 (2,0mm)**





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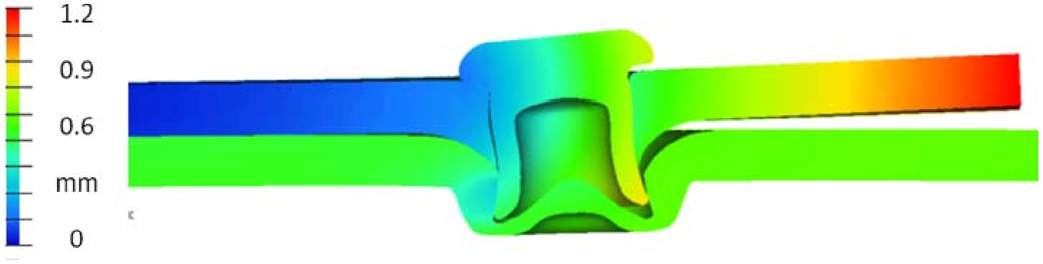
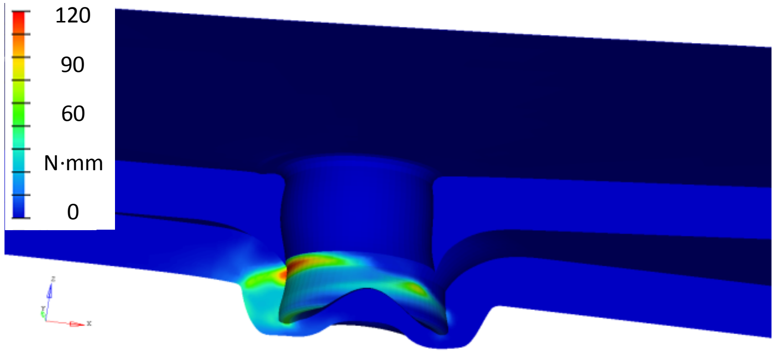
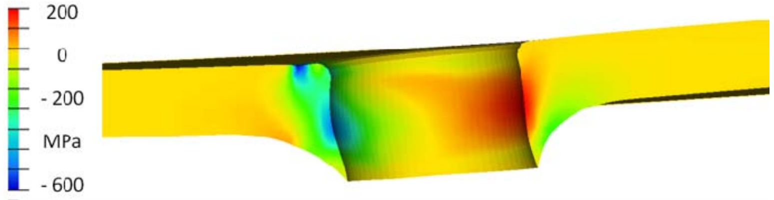


Friction coefficient are very sensitive

Total deformation



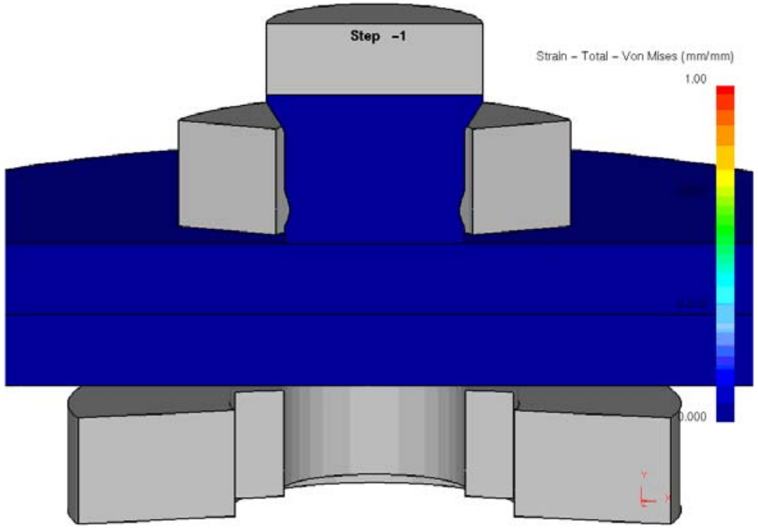
Plastic work
-> the closure opens and allows the tilting of the rivet



Stress in z-direction
-> rivet head tilts and cuts into the top CFRP laminate

Quelle: L. Kroll, S. Mueller, R. Mauermann, R. Gruetzner
18th International Conference on Composite Materials; Jeju Island, Korea; August 22, 2011

Self piercing turn solid-rivet for metal-FRP material combination



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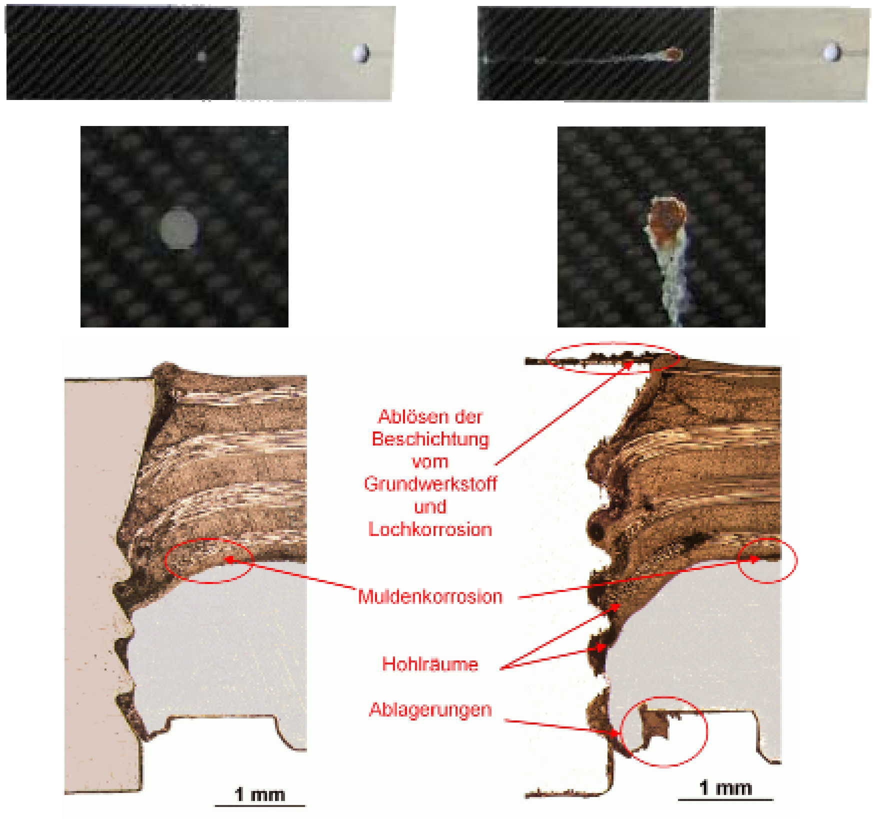
Current points of development

Quelle: KOMMA cluster-DFG-AIF-project

Ceramic-rivet **Steel-rivet**



Corrosion after 6 Cycles „VDA-Wechseltest“

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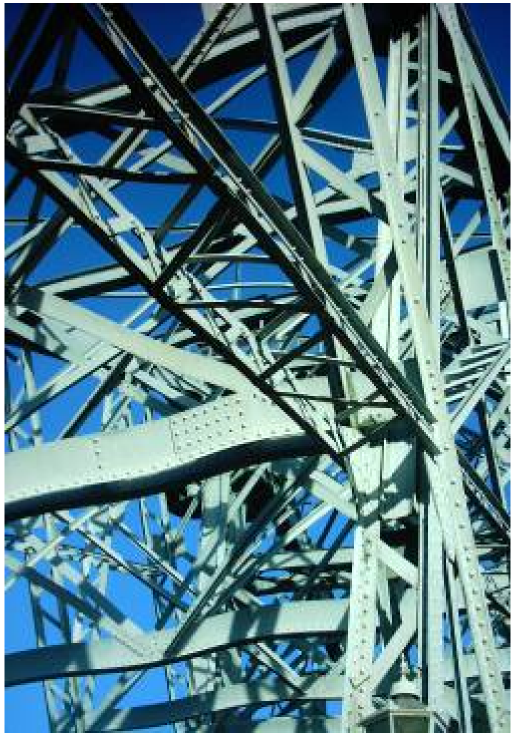


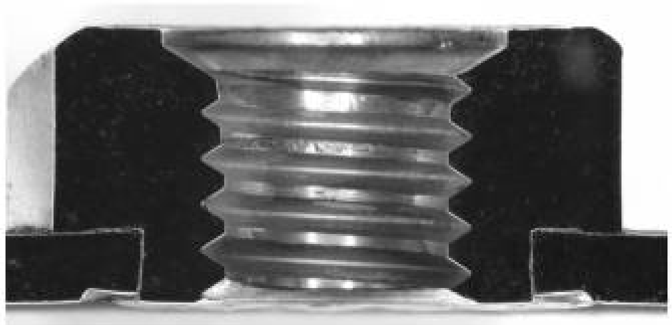
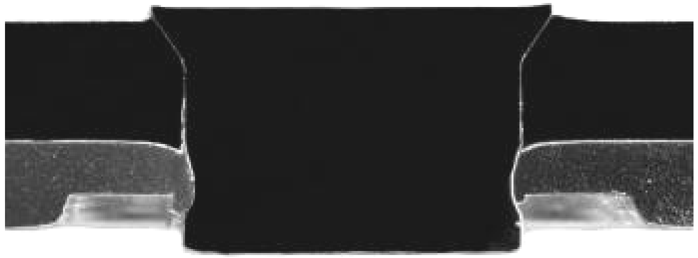

Joining hybrid constructions