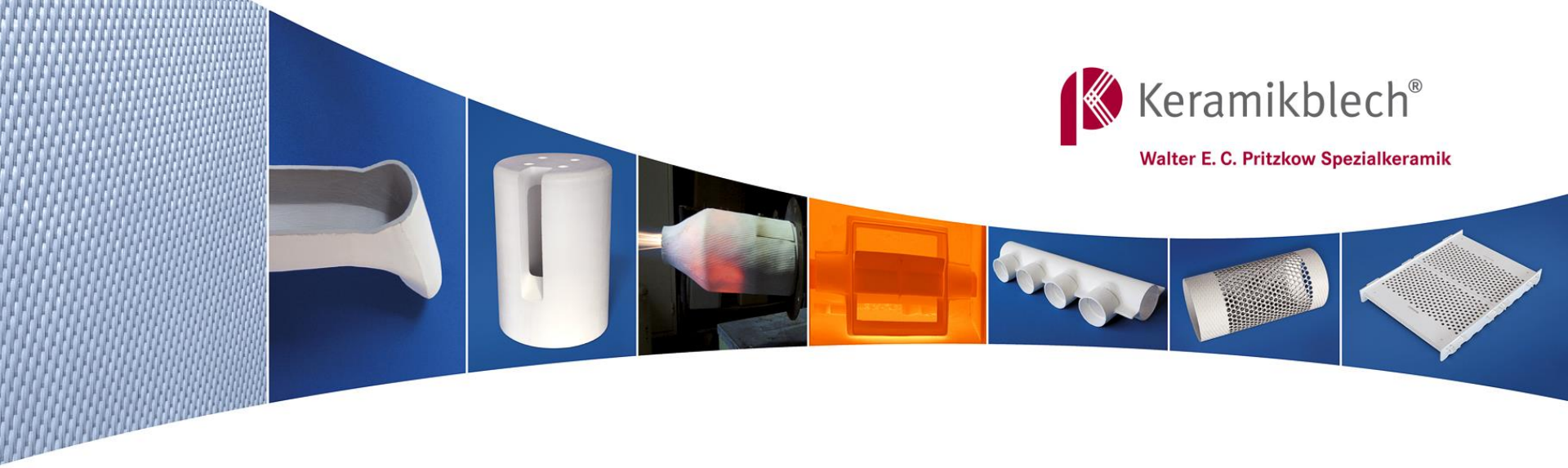

Keramikblech®

Walter E. C. Pritzkow Spezialkeramik

All-oxide ceramic matrix composites (OCMC) based on low cost 3M™ Nextel™ 610 fabrics

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Kurosch Rezwan **
Kamen Tushtev **

*** Walter E.C. Pritzkow Spezialkeramik**
**** Advanced Ceramics, University of Bremen**

HT-CMC 10, 22.-26.09.2019, Bordeaux, France

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Introduction

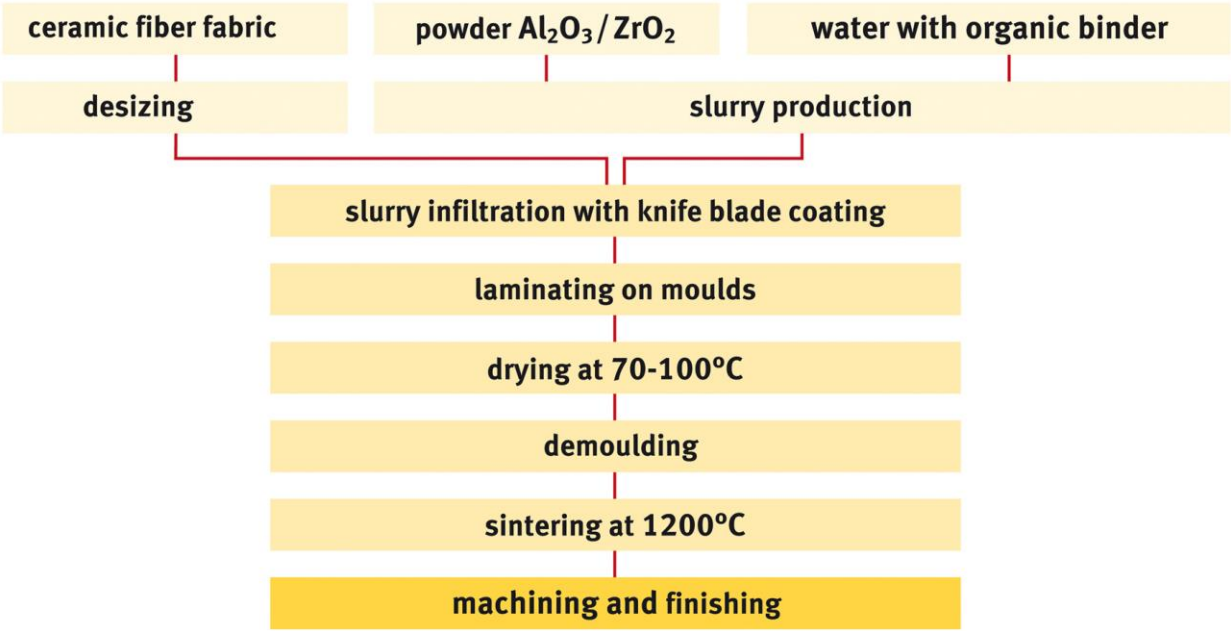
- Overview on production and characteristics of OCMC‘s based on 3M™ Nextel™ fabric Type DF11
- What happens with fiber and fabric during the production process
- Experimental 3M™ Nextel™ 610 fabrics
- OCMC‘s based on experimental 3M™ Nextel™ 610 fabrics and a matrix Al_2O_3/ZrO_2 (FW12), production and characterisation
- Complex parts made of OCMC
- Cost reduction using the new fabrics
- Summary

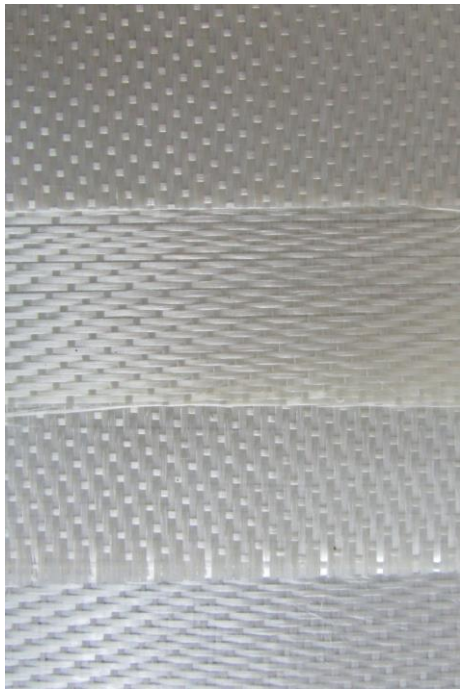
Overview of companies working since more than 10 years on OCMC's based on 3M™ Nextel™ 610 fabric Type DF11

Company	COI Ceramics (COIC)	Composites Horizons Inc. (CHI)	Walter E.C. Pritzkow Spezialkeramik (WPS)
Process technology	Autocalve	Autoclave	Open laminated press technology
Matrix	Al_2O_3/SiO_2	Al_2O_3/SiO_2	Al_2O_3/ZrO_2 (FW12)
Sintering temperature	Unknown	Unknown	1200 ºC

Literature:
- 3M™ Nextel™ Spread tow: enabling automated processing methods and unique composite construction
Aaron Beaber et al., USACA Jan 23, 2018
- Oxide-Oxide Ceramic Matrix Composites – Enabling Widespread Industry Adoption
Barrett Jackson et al, HTCMC 9, 2016
- Designing with oxide-oxide CMCs: Understanding the price-performance relationship in new fabric designs
Aaron Beaber et al., USACA Jan 24, 2017

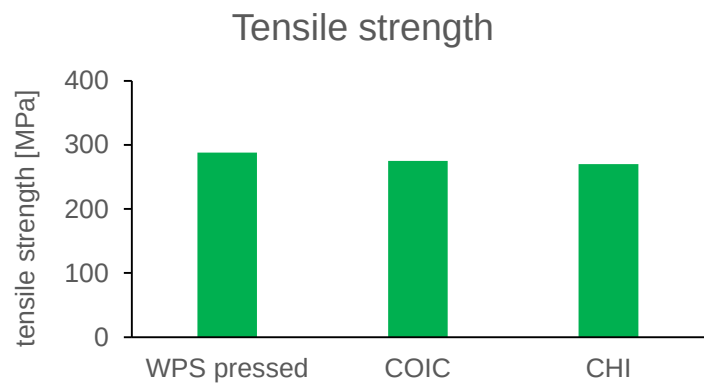
Processing of OCMC‘s at WPS

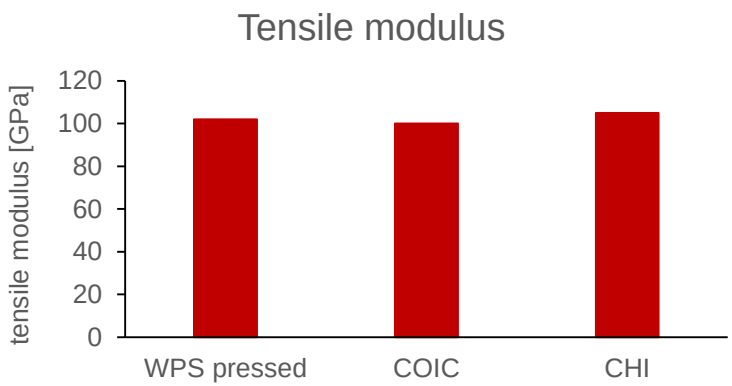


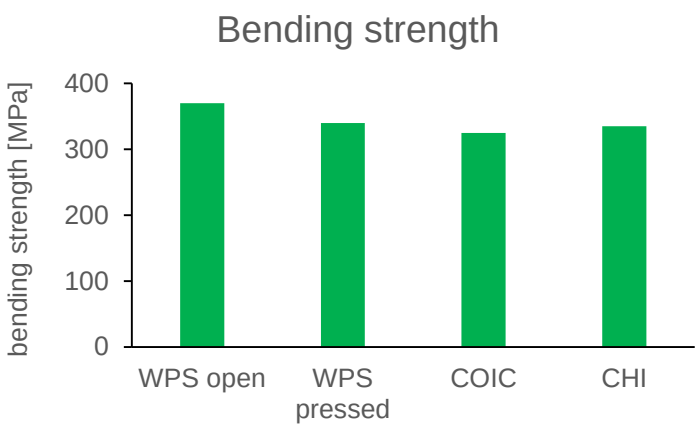


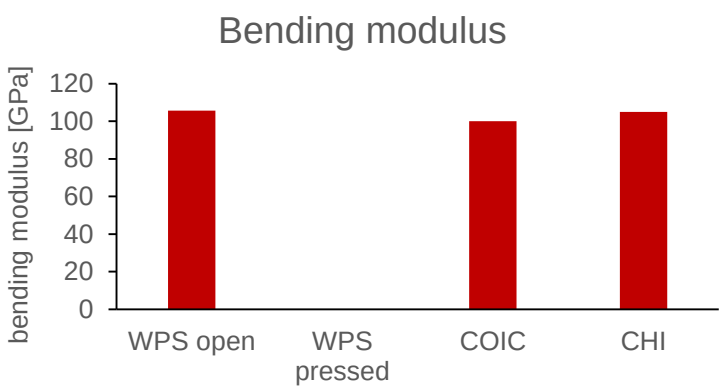
Standard layup with
3M™ Nextel™ 610 fabric DF11

Characteristics of OCMC (1)

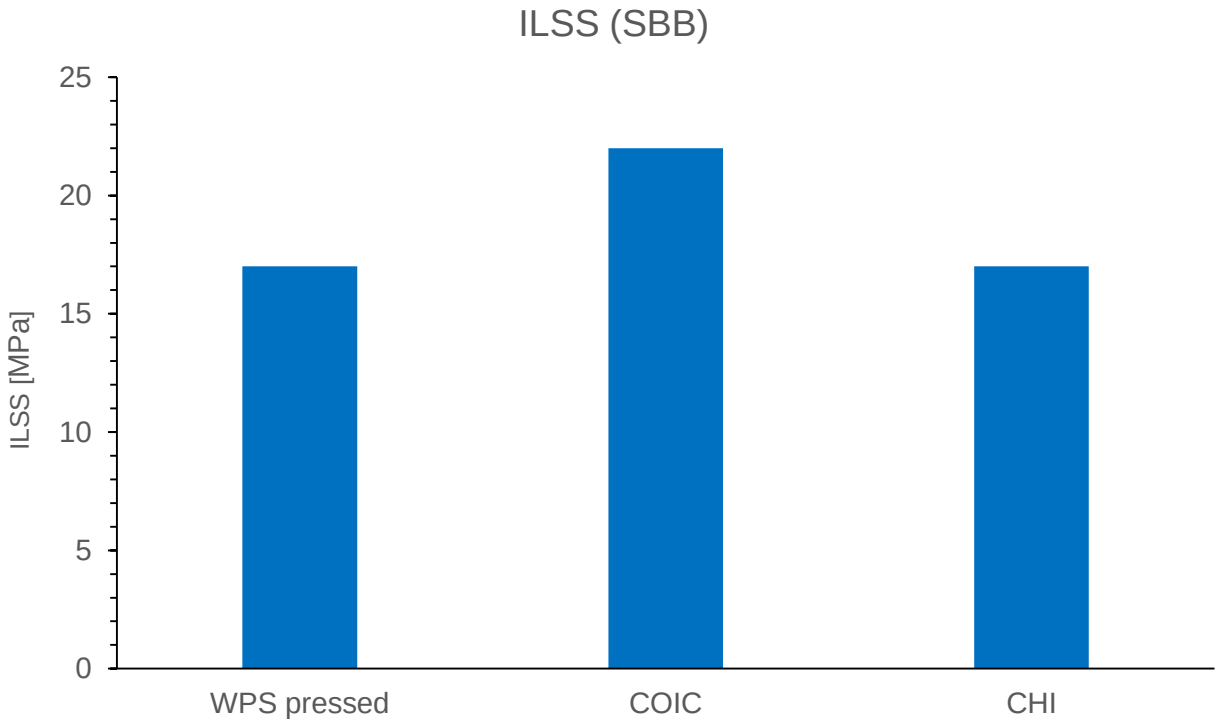




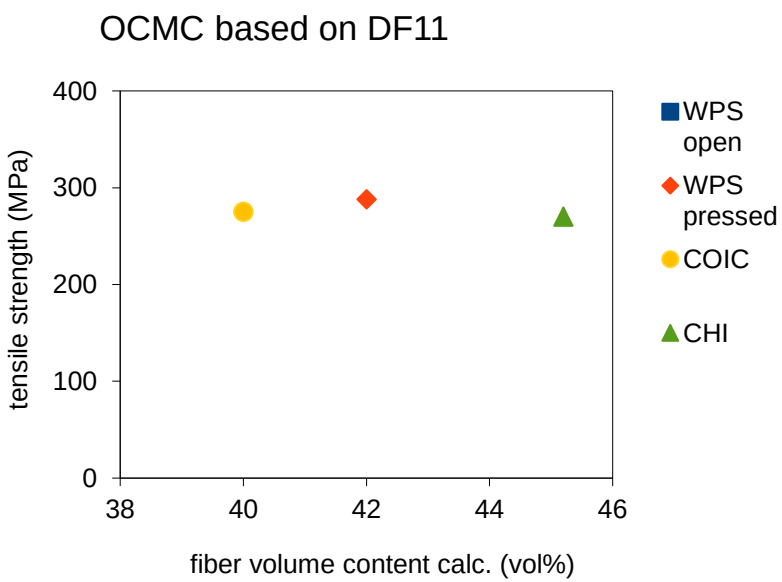


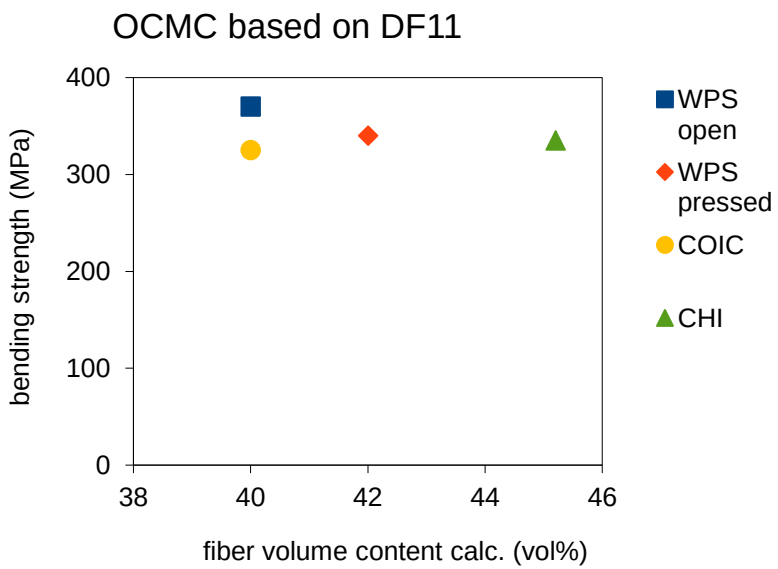


Characteristics of OCMC (2)

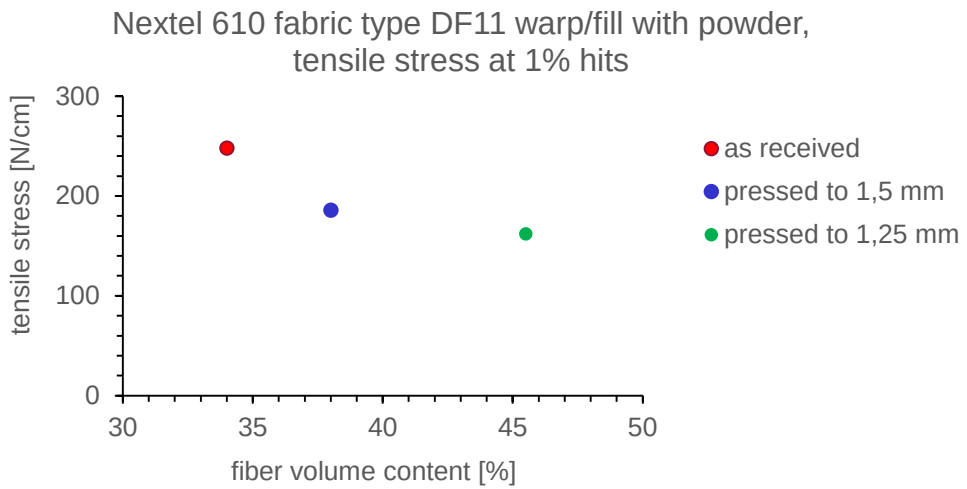


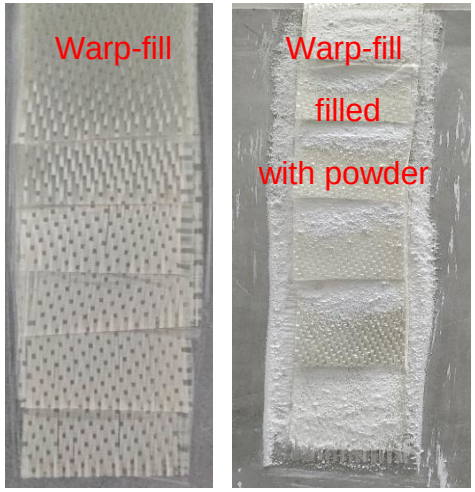
Tensile strength and bending strength dependent upon the fiber volume content

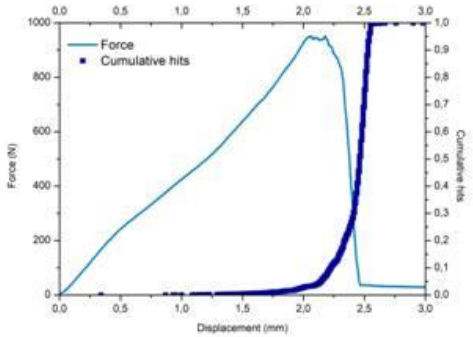




What happens when a fabric layup filled with powder is pressed to high fiber volume content?







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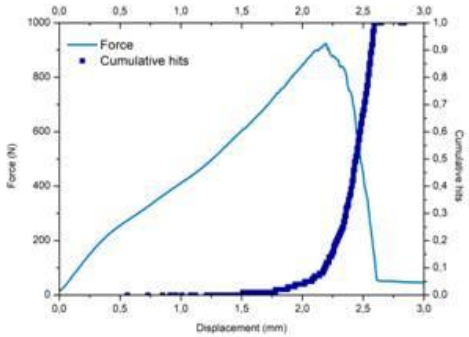
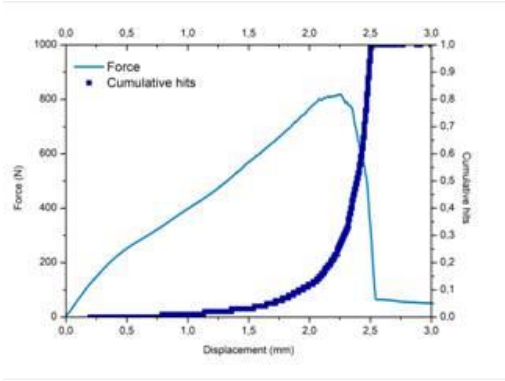
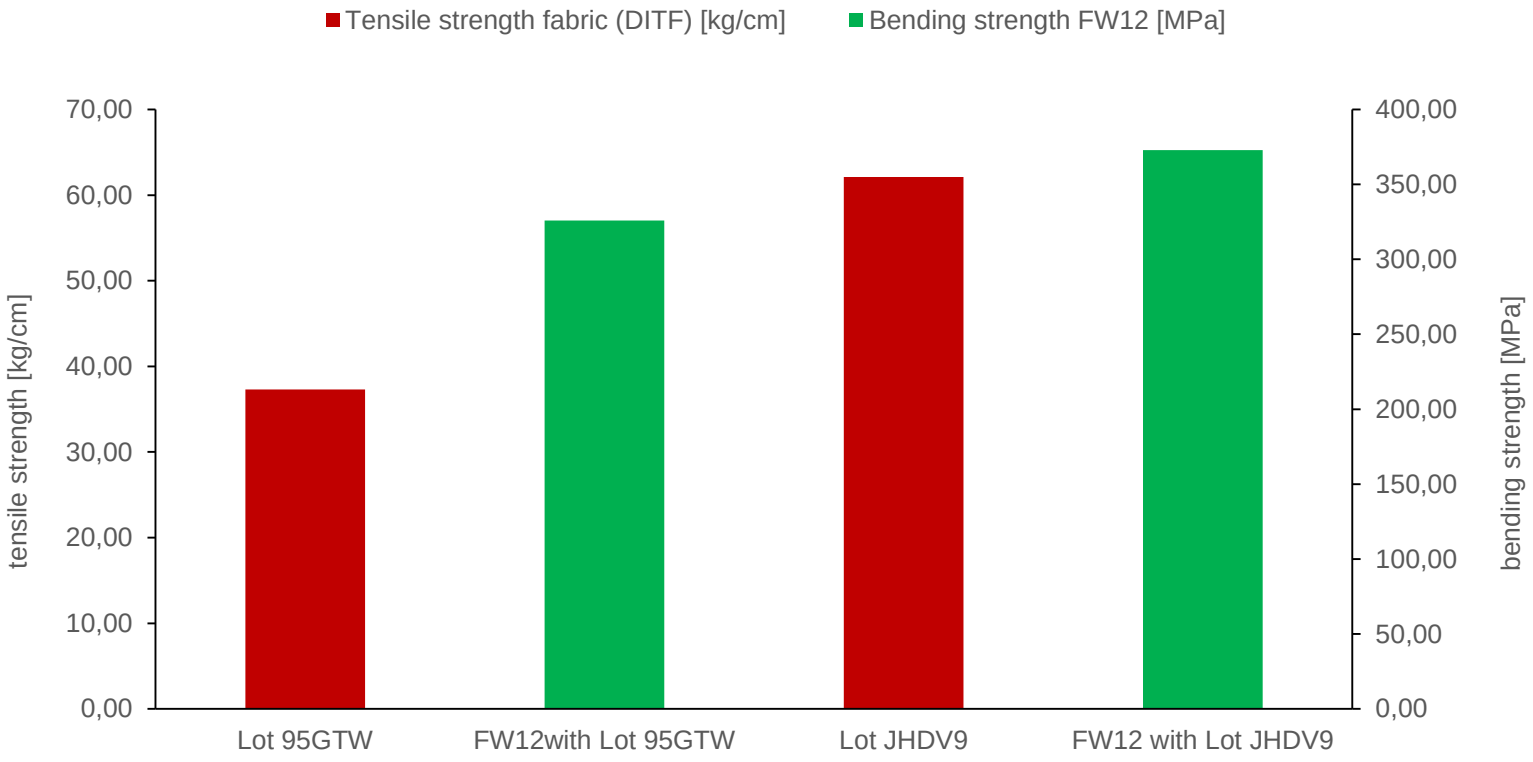


Pressed to 1,5 mm

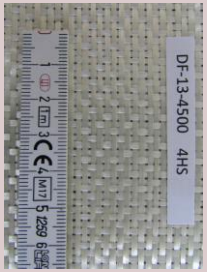


Pressed to 1,25 mm

Tensile strength of fabric 3M™ Nextel™ 610 type DF11 compared with bending strength of the composite FW12



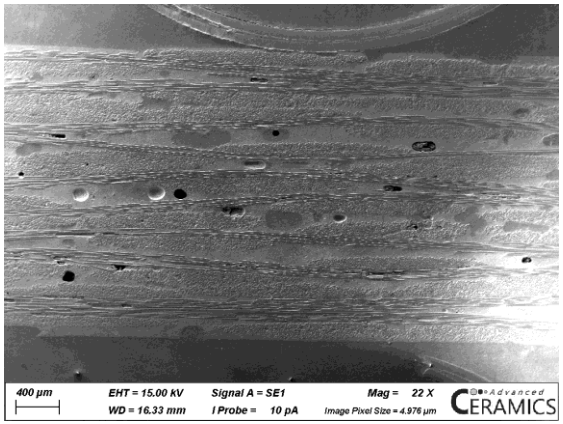
Experimental 3M™ Nextel™ 610 fabrics

Fabric type	DF11-3000 5HS	DF13-4500 5HS	DF13-4500 4HS	DF13-4500 Twill	DF19-4500 8HS	10.000 Semi Uni	20.000 Semi Uni
Yarn type Nextel 610	3000 Denier	4500 Denier	4500 Denier	4500 Denier	4500 Denier	10000/1500 Denier	20000/1500 Denier
Weaving	5HS	5HS	4HS	Twill	8HS	UD	UD
Areal weight [g/m²]	390	500	496	501	682	393	590
Thickness heat cleaned [mm]	0,28	0,33	0,33	0,33	0,43	0,26	0,48
							

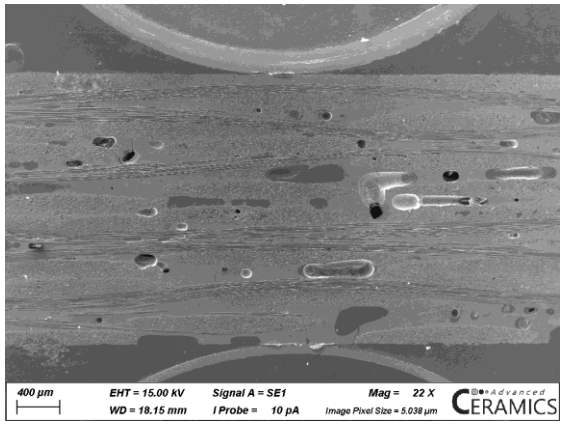
Composites with matrix Al_2O_3/ZrO_2 and experimental 3M™ Nextel™ 610 fabrics

Fabric type	DF11-3000 5HS	DF13-4500 5HS	DF13-4500 4HS	DF13-4500 Twill	DF19-4500 8HS	10.000 Semi Uni	20.000 Semi Uni
Number of plies	10	10	8	8	6	12	8
Fiber volume content [%]	38,5	41,4	39,6	40,0	39,9	39,0	37,5
Matrix volume [%]	33,1	30,6	29,8	27,8	32,1	30,8	30,7
Porosity volume [%]	28,2	28,0	30,6	32,2	28,0	30,2	31,8
Density [g/cm³]	2,74	2,75	2,69	2,75	2,83	2,79	2,78
Laminate thickness [mm]	2,63	3,1	2,57	2,6	2,57	3,3	3,17
Thickness per ply [mm]	0,263	0,31	0,32	0,325	0,428	0,275	0,396

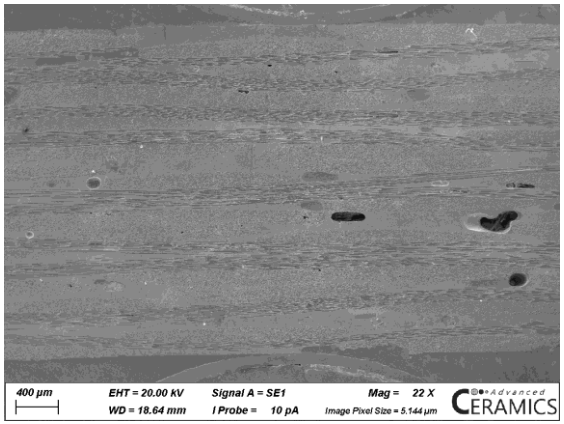
SEM-micrographs of composites with experimental 3M™ Nextel™ 610 fabrics (1)



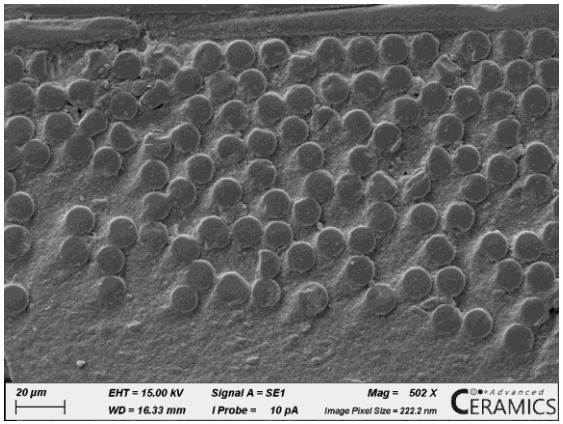
FW12-DF11-3000 5HS

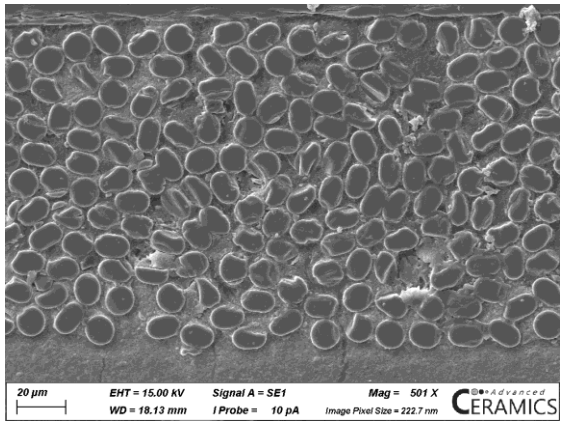


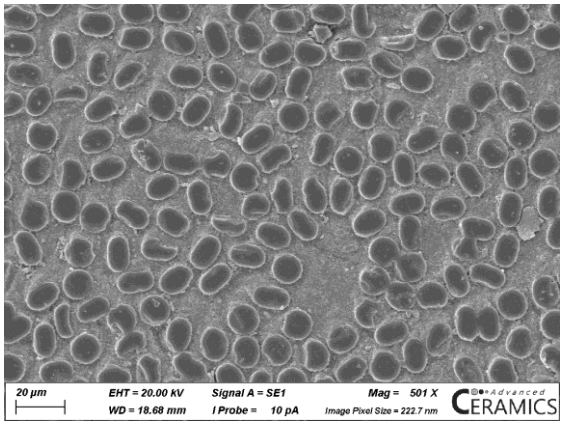
FW12-DF13-4500 4HS



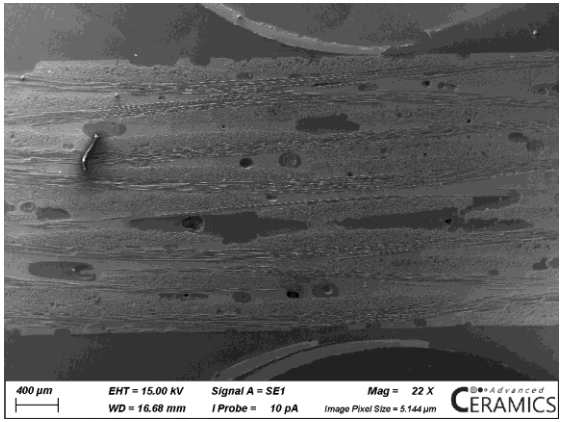
FW12-DF13-4500 5HS



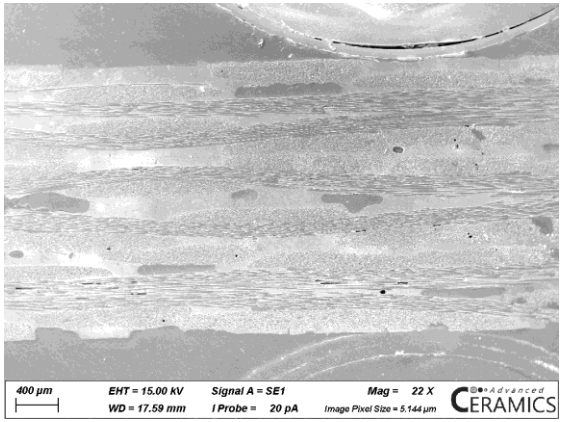




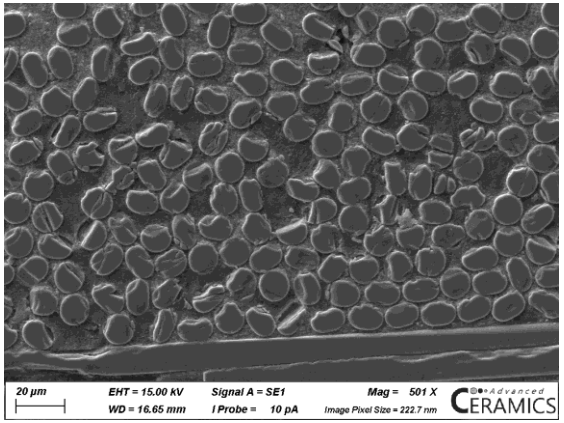
SEM-micrographs of composites with experimental 3M™ Nextel™ 610 fabrics (2)

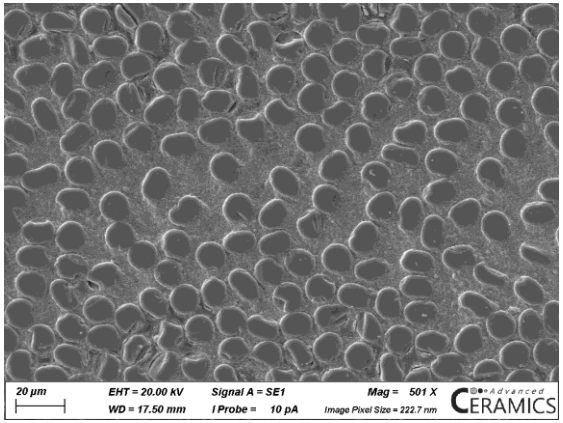


FW12-DF13-3000 Twill

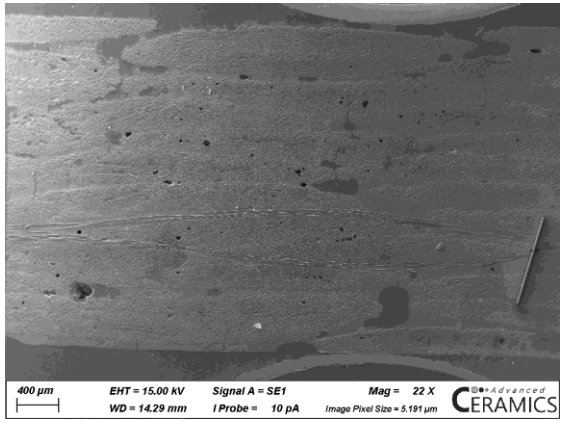


FW12-DF19-4500 8HS

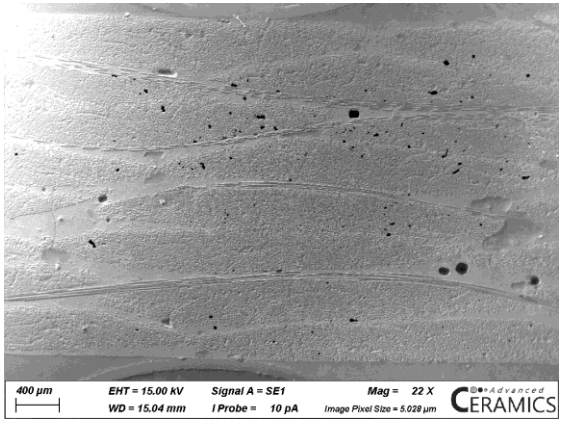




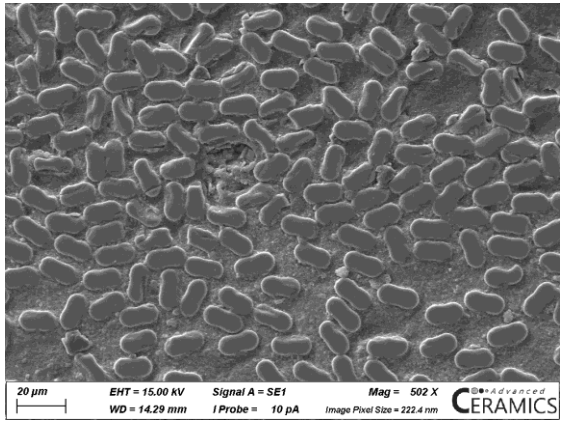
SEM-micrographs of composites with experimental 3M™ Nextel™ 610 fabrics (3)

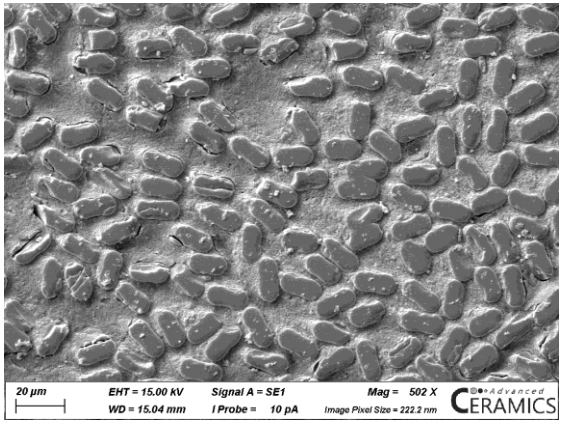


FW12-10.000 Semi Uni

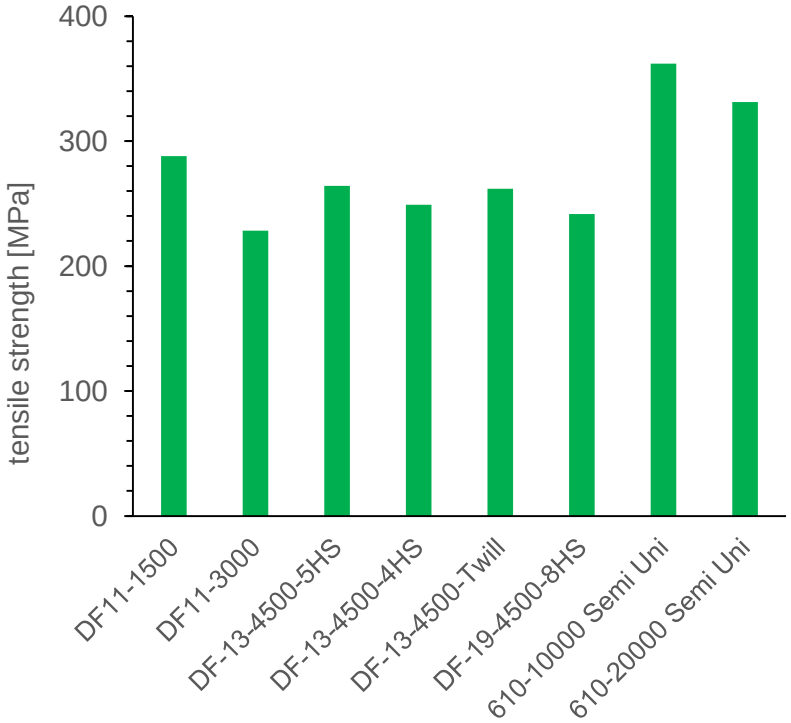


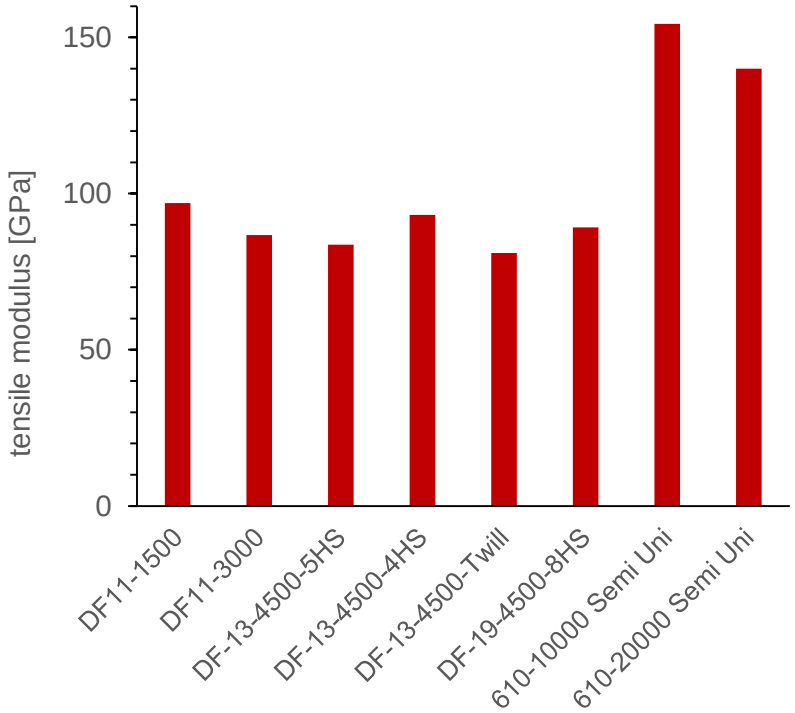
FW12-20.000 Semi Uni



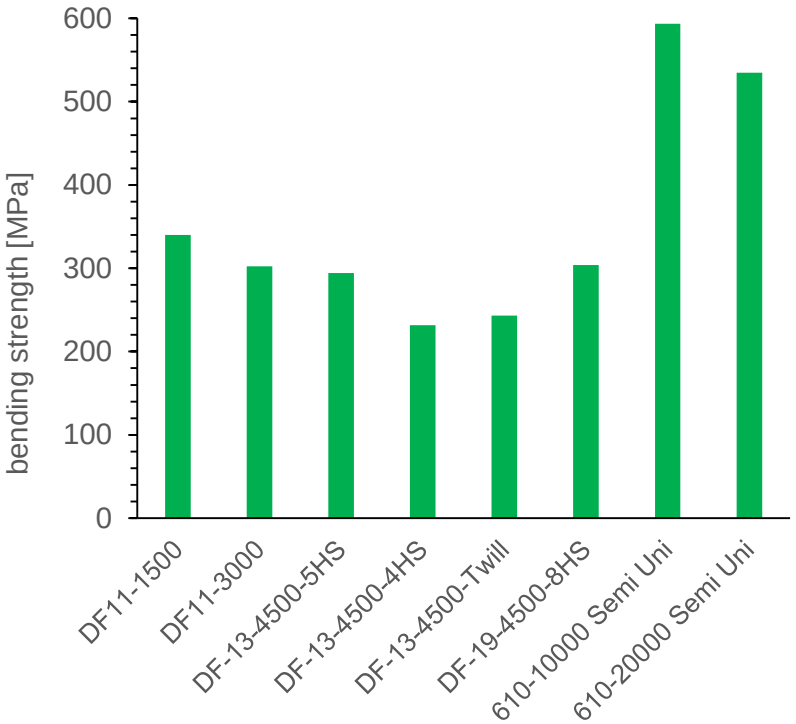


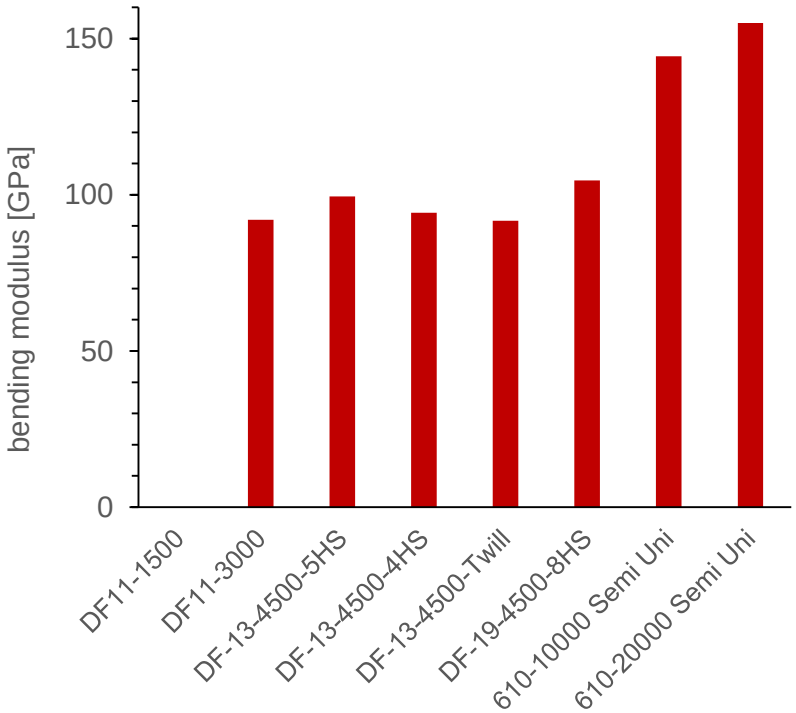
Tensile tests on composites with matrix Al_2O_3/ZrO_2 and experimental 3M™ Nextel™ 610 fabrics



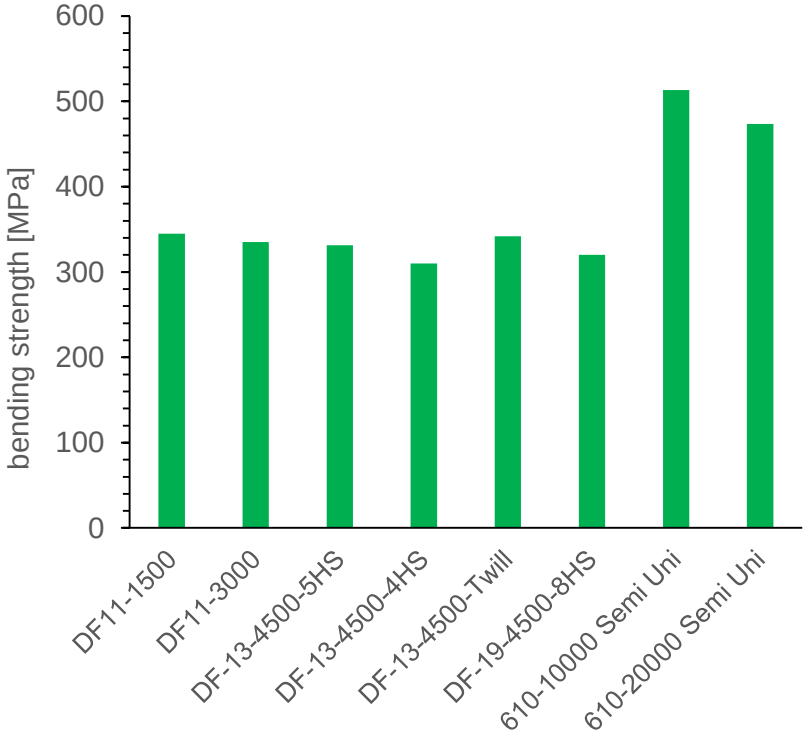


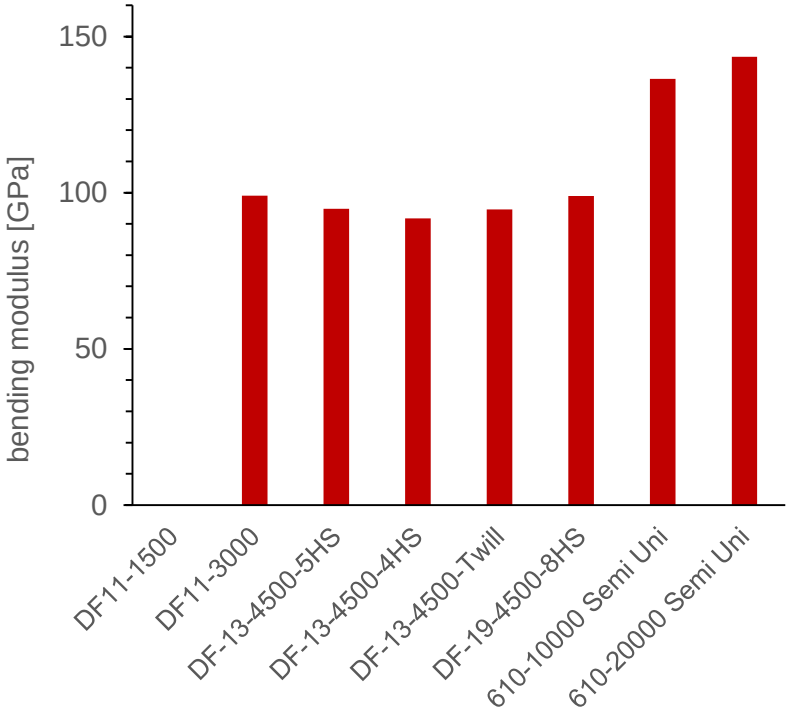
4-Point-bending tests on composites with matrix Al_2O_3/ZrO_2 and experimental 3M™ Nextel™ 610 fabrics



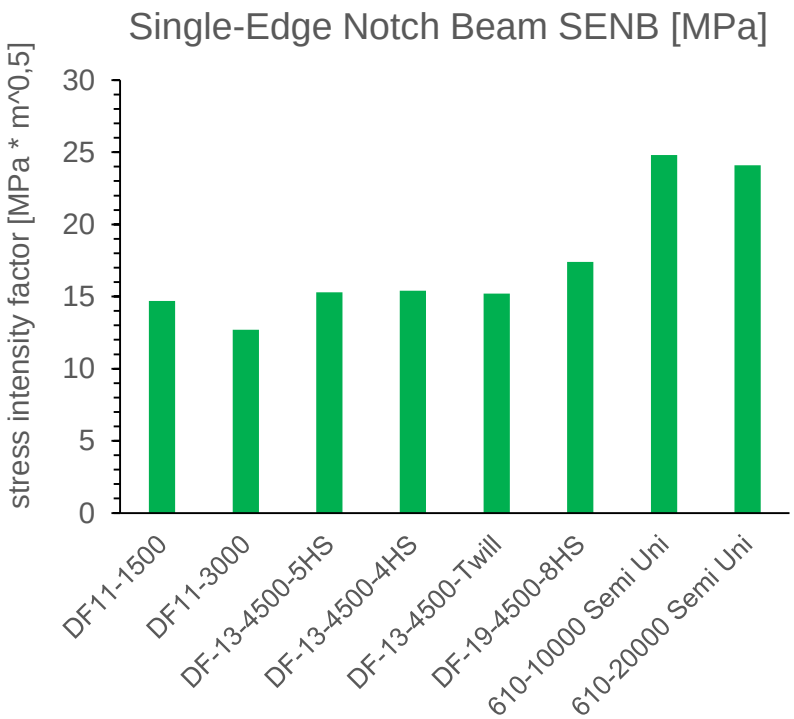


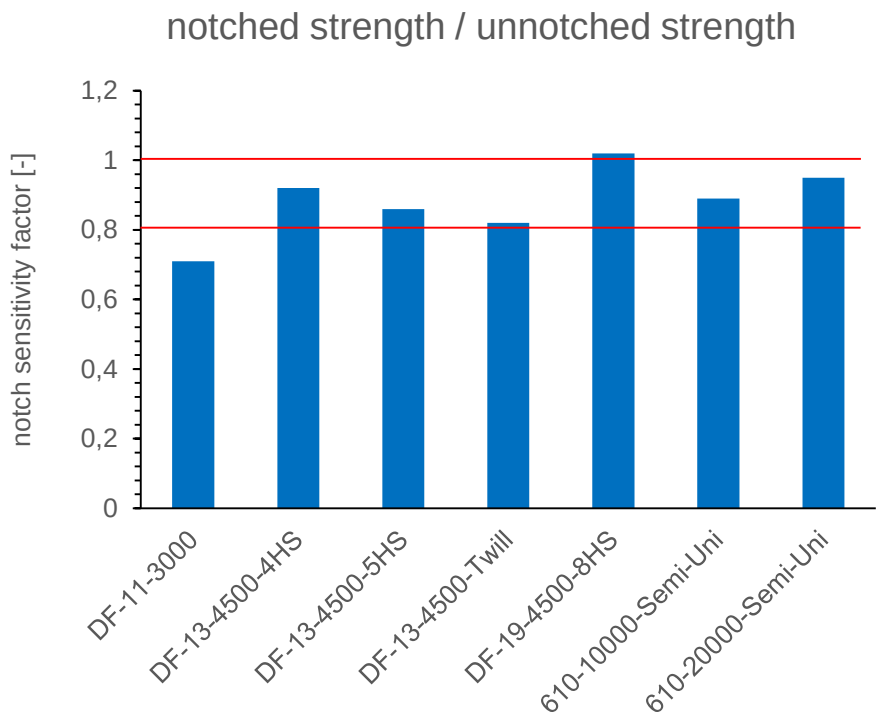
4-Point-bending on edge tests on composites with matrix Al_2O_3/ZrO_2 and experimental 3M™ Nextel™ 610 fabrics



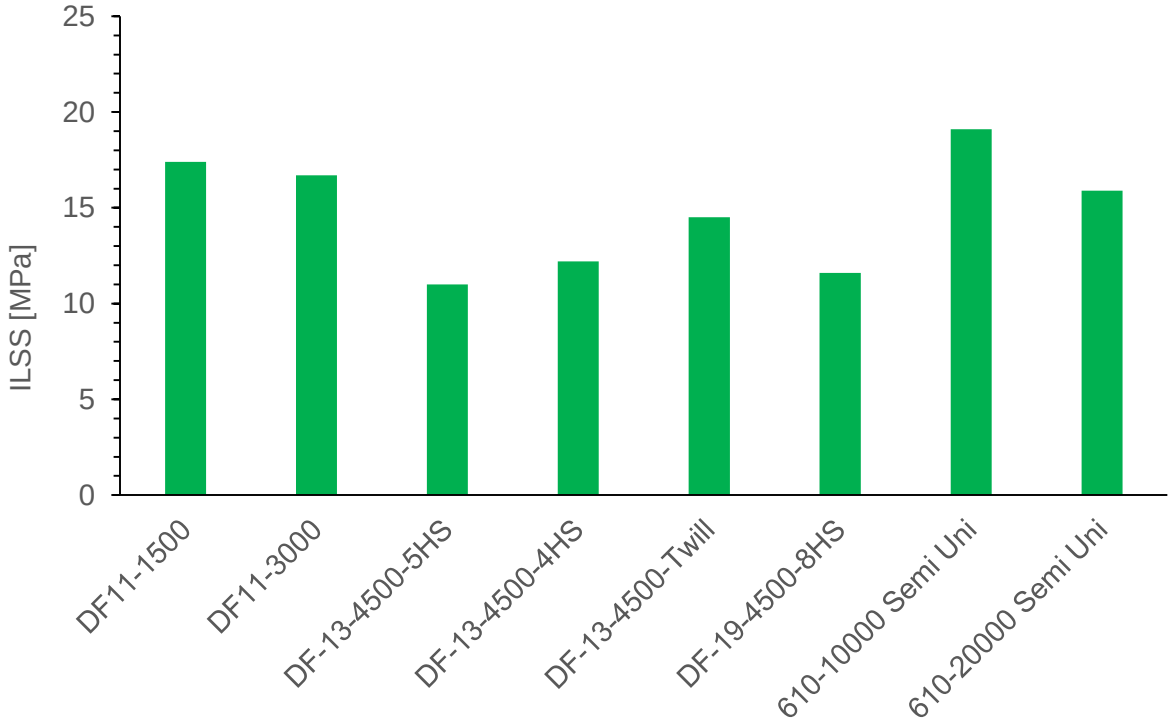


Stress intensity factor and notch sensitivity on composites with matrix Al_2O_3/ZrO_2 and experimental 3M™ Nextel™ 610 fabrics





Short beam bending / interlaminar shear tests on composites with matrix Al_2O_3/ZrO_2 and experimental 3M™ Nextel™ 610 fabrics



Complex structures made of oxide-oxide CMC

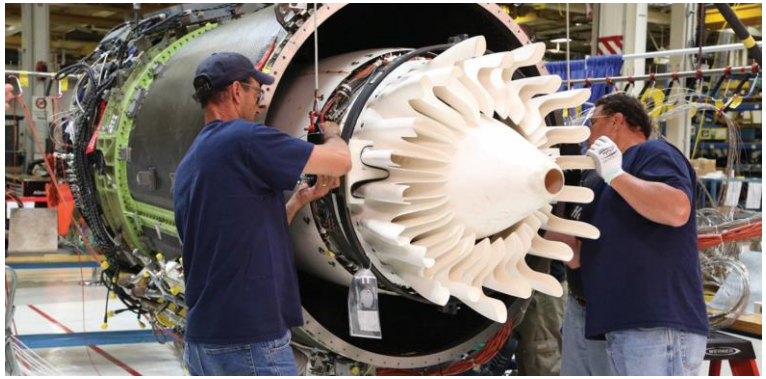
Thrusters for a
Fluidic Propulsion System™
for unmanned aerial
vehicles from the company
Jetoptera Inc.

Picture source:
Jetoptera Inc. (left), WPS (right)

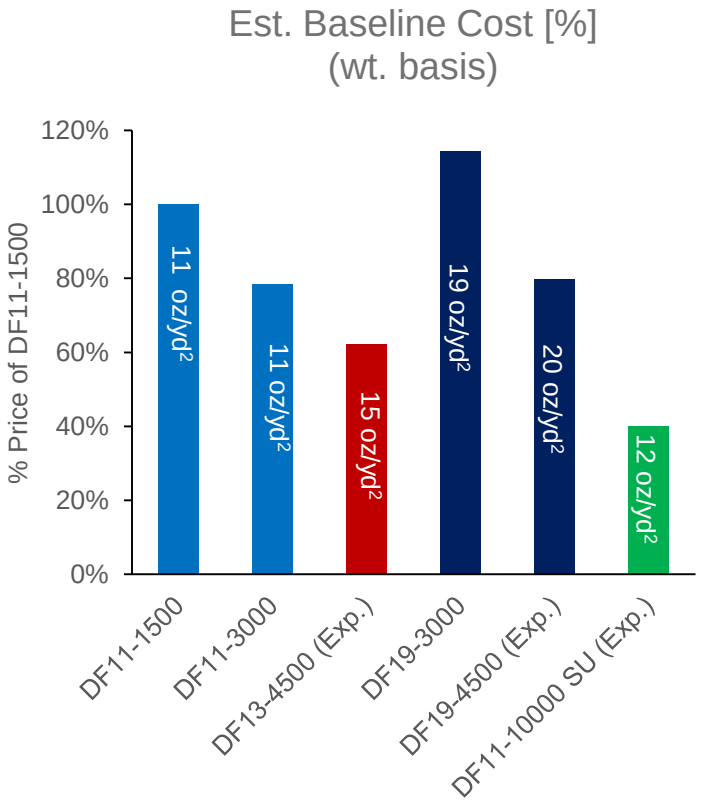
Static mixer

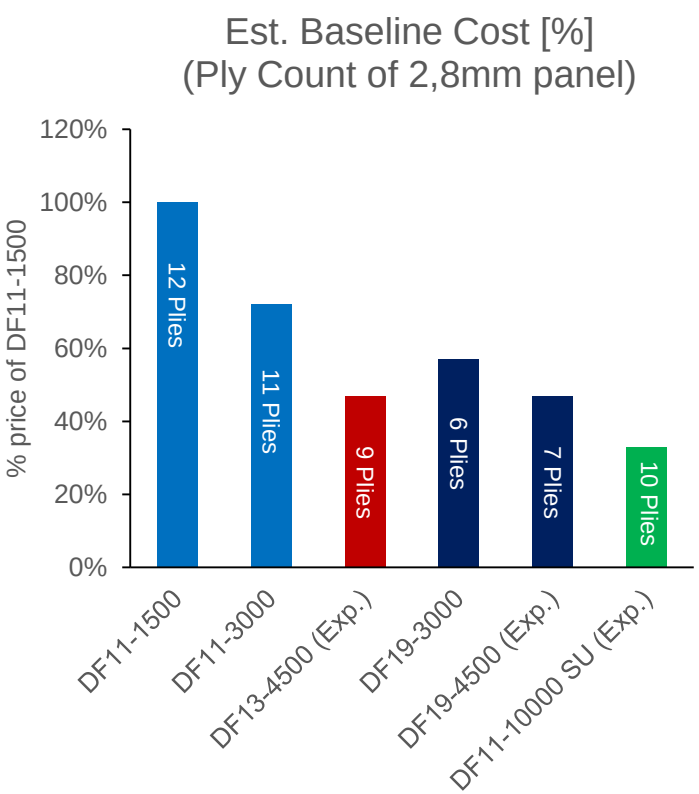
Development and production done
by COIC and CHI

Picture source:
aviation international news



Cost reduction possibilities using experimental 3M™ Nextel ™ 610 fabrics





Data bases: 3M

Summary

- Tensile strength and bending strength are independent of the fiber volume content when producing OCMC within the range of 38-46%
- Pressing to higher fiber volume content with powder based slurries will damage the fibers
- Fabrics based on higher denier rovings can be well infiltrated with the Al_2O_3/ZrO_2 (FW12) slurry
- With some of the experimental 3M™ Nextel™ 610 fabrics better characteristics in comparison to DF11 based OCMC‘s can be realized
- Estimated cost reduction using the experimental fabrics is more than 20%

Acknowledgement

3M:

- Peter Dietrich, Germany
- Larry Visser, USA (retired)
- Andrew d‘Souza, USA
- Stan Fast, USA

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- Kürsat Cihan
- Vincent Conrads
- Liesa Kelling
- Igor Myskin

Walter E.C. Pritzkow Spezialkeramik

- Robert da Silva
- Adriana Conrad
- Frank Wehner

Thanks for your attention

OCMC-Thrusters for
the „Fluidic Propulsion System™
from Jetoptera Inc.