Fibre metal laminates for improved structural behaviour under fire exposure

9 February 2017, Martin Liebisch, German Aerospace Center (DLR)

Overview

- ❑ Project background
- ❑ Fibre Metal Laminates (FML)
  - ❑ Manufacturing
  - ❑ Overview test plan
  - ❑ Experimental results for the FST behavior of FML
- ❑ Developments of a test facility for compression loading under fire exposure (test concept, specimen device, test conditions, test preparation)
- ❑ Summary & Outlook

FSS P7 Project background

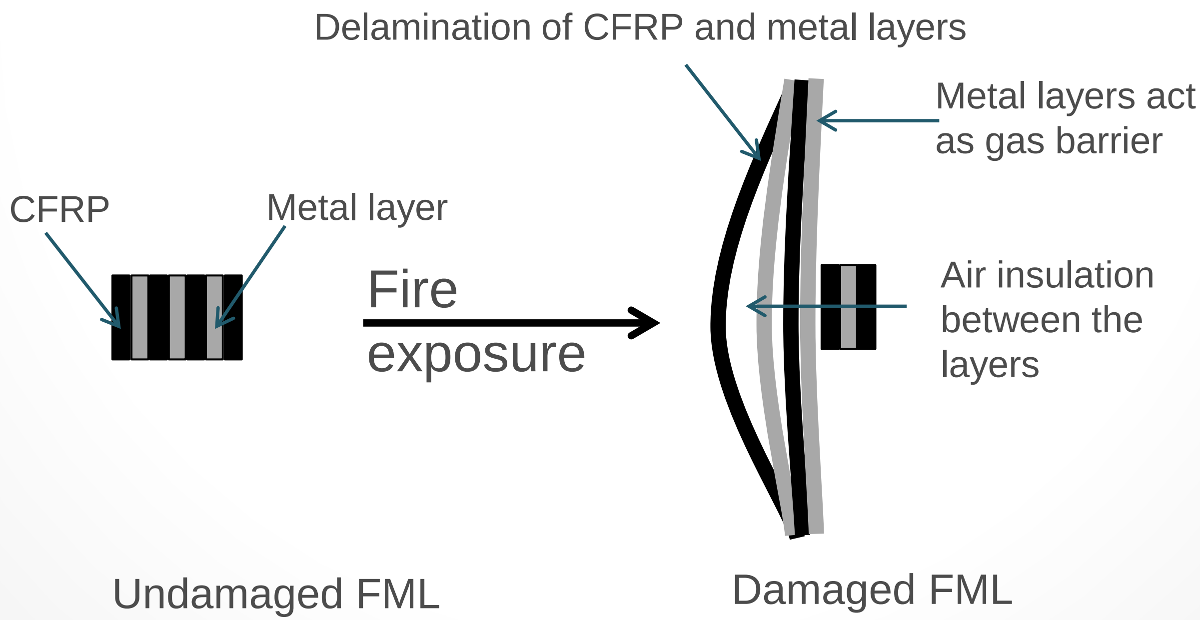
- „Mitigate risks of fire, smoke & fumes“
  - Improving knowledge concerning OMC materials and structures behaviours vs fire
  - Assessing mechanical properteis of heated/burned/degraded materials
  - Evaluating fire, smoke & toxicity (FST) behavior in order to propose mitigating solutions
  - Sharing database for future modelling purposes (expensive testing)
  - Establishing/giving design recommendations

WP7.2. Focus: Improved FST-behavior by material solutions (Geopolymers; Hybrid nonwovens; <u>Fibre-metal laminates</u>)

WP7.2. partners: DLR, VZLÚ ... partner průmyslu, LEONARDO INGENUITY AT YOUR SERVICE

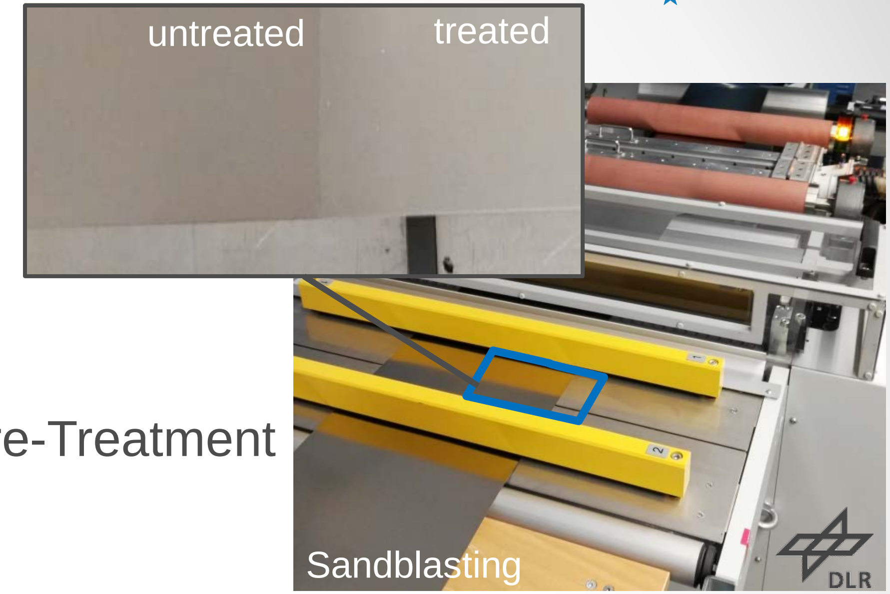
Fibre Metal Laminates (FML)

- Carbon fibre laminates reinforced by steel plies for improved FST properties
  - Metal layers act as gas barrier
  - Better burn-through resistance compared to cfrp
  - Less smoke and toxic gases

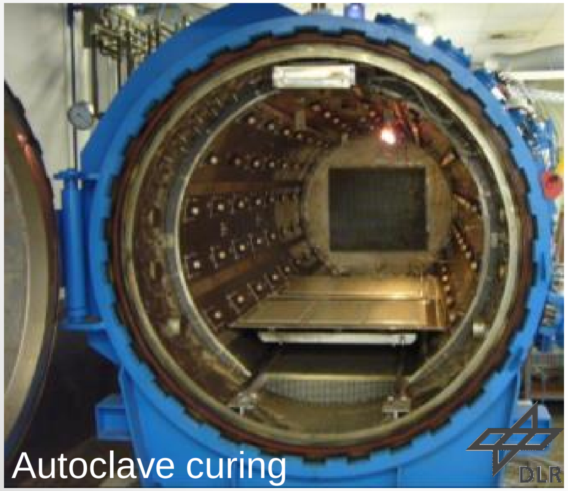


FML - manufacturing

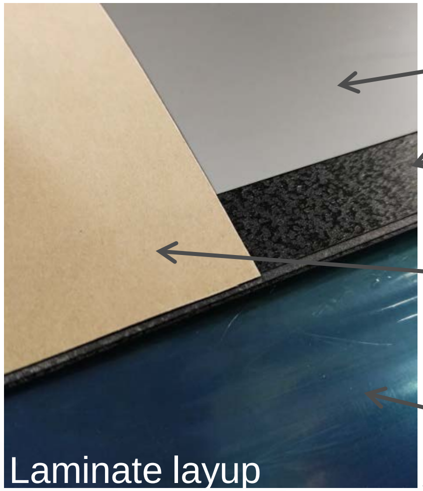
- Prepreg - Stainless Steel (Type 1.4310)
- Pre-Treatment of steel layers
  - Sandblasting
  - using coupling agent 3M™ Surface Pre-Treatment AC-130 from 3M Deutschland GmbH
- Autoclave curing @ 180°C



Sandblasting



Autoclave curing



Steel

Prepreg

Prepreg with protective leaf

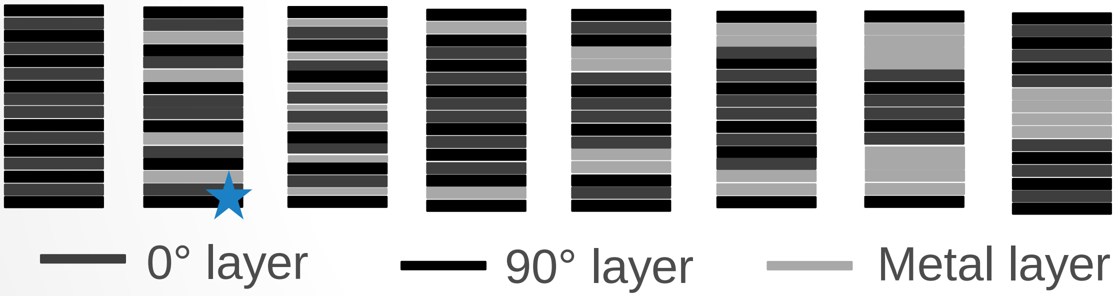
Tool-Part separation layer

Laminate layup

Pre-Treatment with coupling agent

FML - manufacturing

- 2mm thick laminates with symmetric and balanced layups with
- 8 Laminates dividing 3 test groups to different layup, weight and number of metal layers

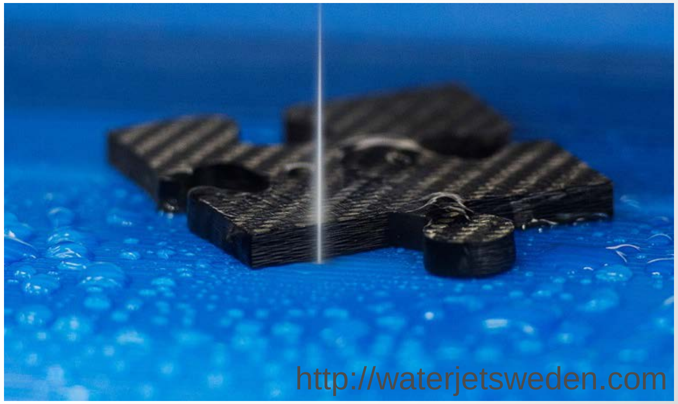


- Water jet cutting to produce specimens

Thickness (mm)	Grammage (g/m²)
0,030	237
0,080	632
0,125	987,5
0,250	1975
0,500	3950

Steel Type 1.4310 sheets used

Manufactured FML cross section



Overview Test-plan

- ❑ Test Batch 1
  - ❑ FST-Test of FML setups
  - ❑ Prepreg: Determination of mechanical properties wrt temperature
- ❑ Test Batch 2
  - ❑ Compression under fire exposure test
  - ❑ FML: Determination of mechanical properties wrt temperature

Test	Prepreg	FML
Burn through	✓	✓
Smoke density	✓	✓
Smoke toxicity	✓	✓
DMA	✓	●
Tension	✓	
Shear	✓	●
Compression	●	●
Compression under fire exposure		●

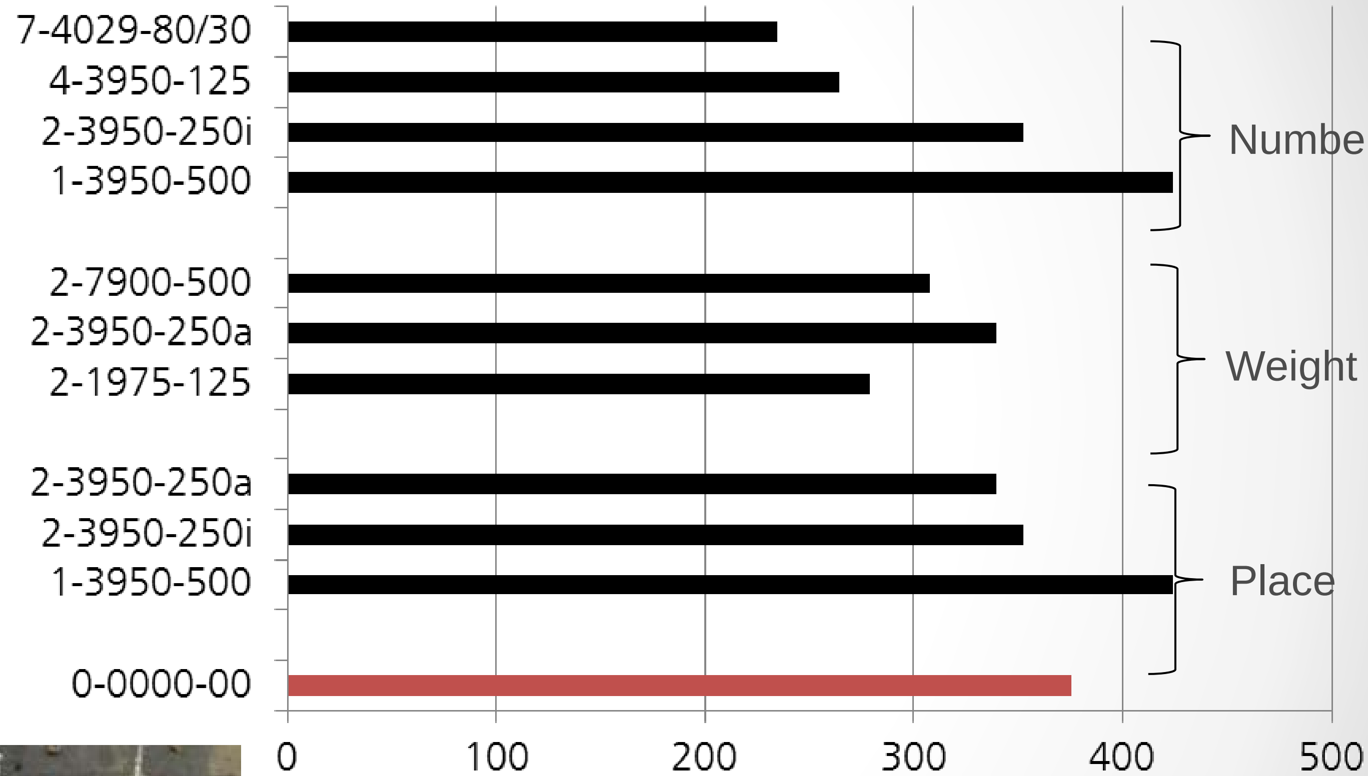
Current status of the test program

✓ Done

● Ongoing

Results of Burn-through test

- Temperature decrease of 100°C and more possible
- Number of metal layers reduces temperature most
- Small influence through layer weight or place



Temperature after 4min of fire exposure [°C]

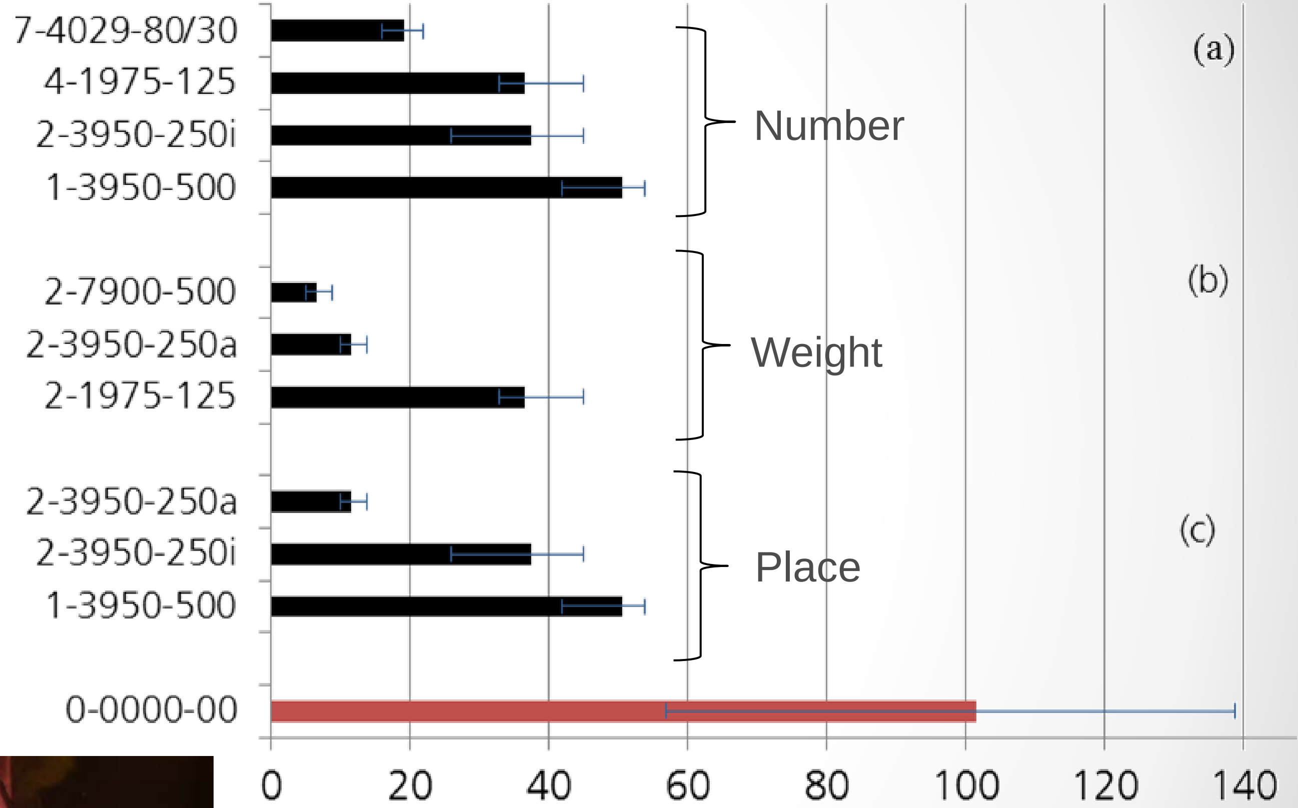
Burn-through test using a propane torch (Type K6 85kW):
5min fire exposure; temperature measurement at the specimen back


Flame exposure (5min)


TC at specimen back

Results of Smoke density test

- Significant decrease of more than 50%
- All test groups allow less smoke density, especially:
  - Thicker metal layers
  - Metal layer position close to outside



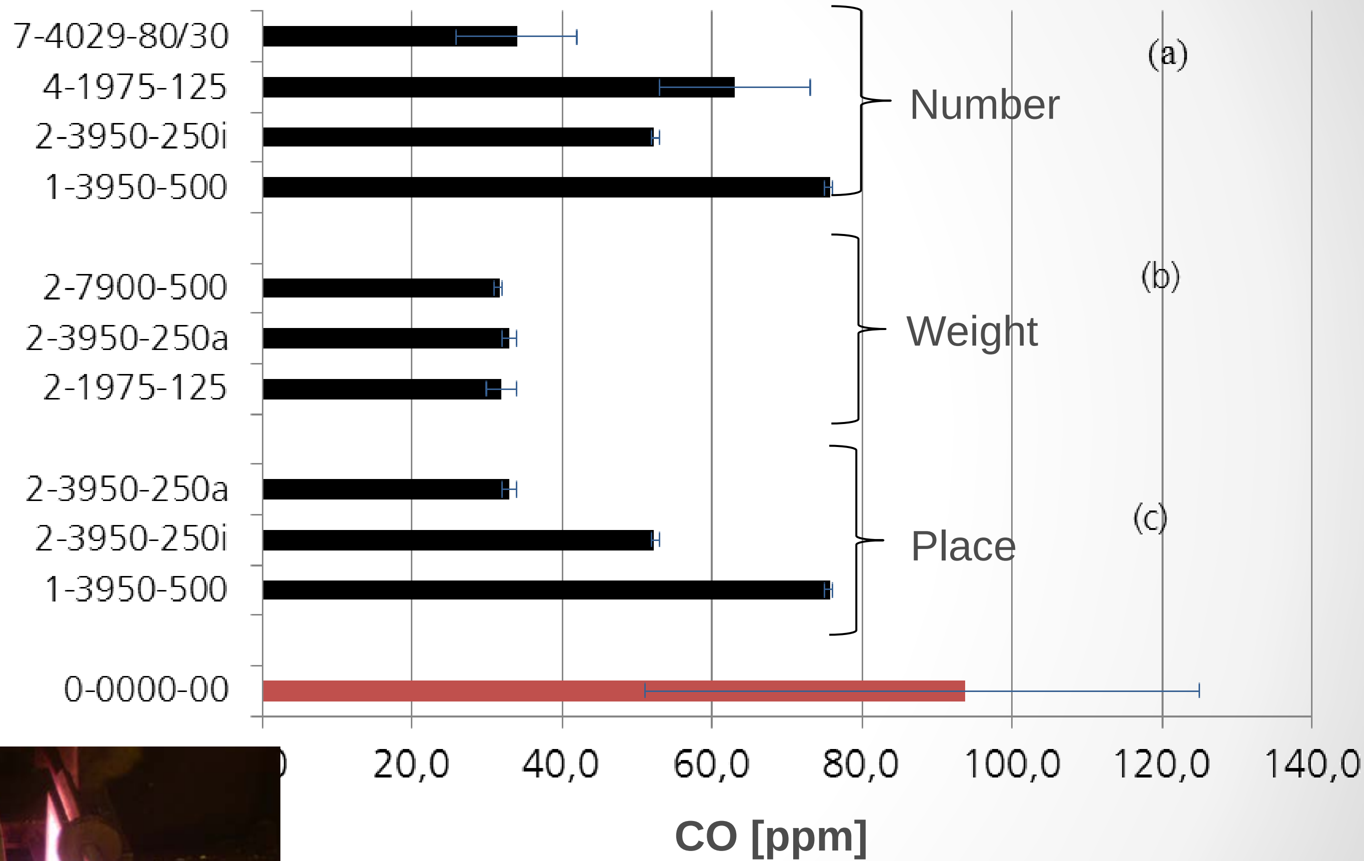
Smoke density test according to CS/FAR Part 25
(Flaming mode 4min; Heat flux of 35 kW/m²)


Smoke chamber


Heater and sample

Results of smoke toxicity test

- CO reduction to less than the half of cfrp possible
- Highest impact by the layer number and place
- No influcence through metal layer grammage




Smoke chamber


Heater and sample

Results of Smoke toxicity test according to ABD 0031
(Measurement of HCl, HF, SO2, NOx, CO, HCN content)

Compression test under Fire exposure

Present results:

- ❑ Temperature reduction through substition of CFRP by FML of approx. 380°C to 240°C possible

Open questions & aims:

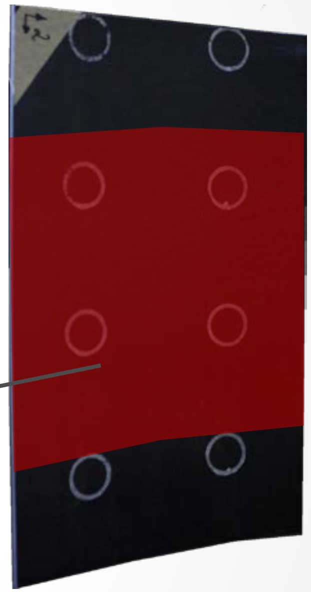
- ➢ Investigation of the interaction between mech. loading and fire
- ➢ Does the thermal behavior of FML also improve the load carrying capability under fire exposure? How much?
- ➢ Is the accuracy of numerical predictions sufficient?
- ➢ Outlook: Comparison of CFRP and FML to different material solutions

→ Compression test under fire exposure (test batch 2)

Test concept

- Constant compression load at virgin structure state
  - Properties degrade or decompose with increasing fire exposure duration → less load carrying capability
  - Deformation due to thermal gradients and different thermal expansion coefficients
  - Failure over time
- Coupon-level specimens
  - Higher possible number of tests due to decrease manufacturing effort
  - Area exposed to fire approx. 120mm x 120mm
  - Curved specimens

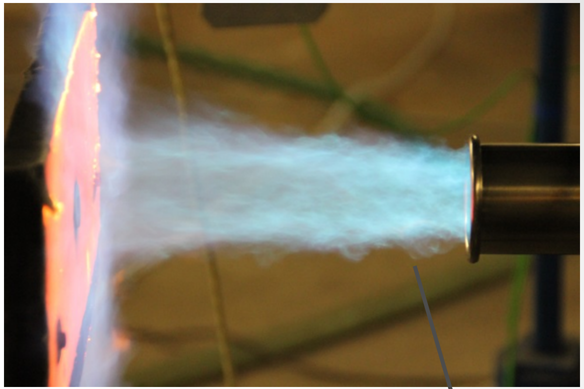
Area exposed to fire



Curved test specimen

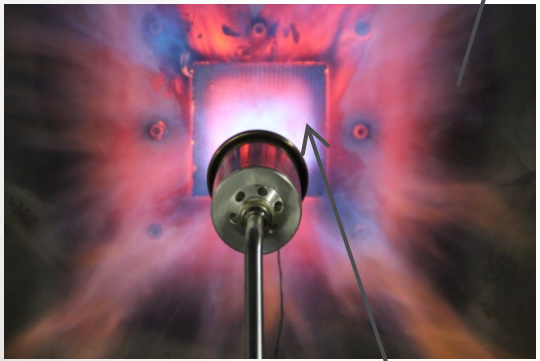
Test Conditions

- ❑ Insulation at the front → only a small window for fire introduction to specimen
- ❑ Load cell for loads up to 40kN
- ❑ Measurement of temperatures at the back side via thermocouple(s)
- ❑ Measurement of the axial distance between the adapter plates



Fire exposure

Possible insulation plate



Window for fire introduction to specimen

Frontal view

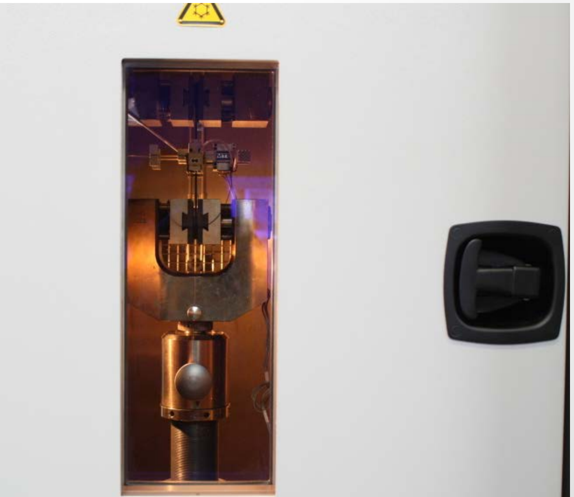
Hydraulic press with mounted adaper plates

Side view

Possible insulation plate

Summary and Outlook

- ❑ FST behavior of cfrp can be improved through integration of metal layers
- ❑ Compression under Fire exposure test to investigate the mechanical behavior
- ❑ Round-Robin tests
  - ❑ Geopolymers @ DLR facility
  - ❑ Burn-through tests of FML @ VZLU
- ❑ Temperature dependent material models to be verified by static material tests @ different temperatures
- ❑ Test simulation by numerical methods



Temperature chamber for static tests

Questions?

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Consortium

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