# Towards Demisable Fiber Reinforced Plastics

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Thorn Schleutker, Ali Gülhan, Susanne Röddecke, Erhard Kaschnitz,
James Merrifield and James Beck

Presenting Author: Thorn Schleutker, Supersonic and Hypersonic

Technology Department, German Aerospace Center

Contact: Thorn.Schleutker@DLR.de


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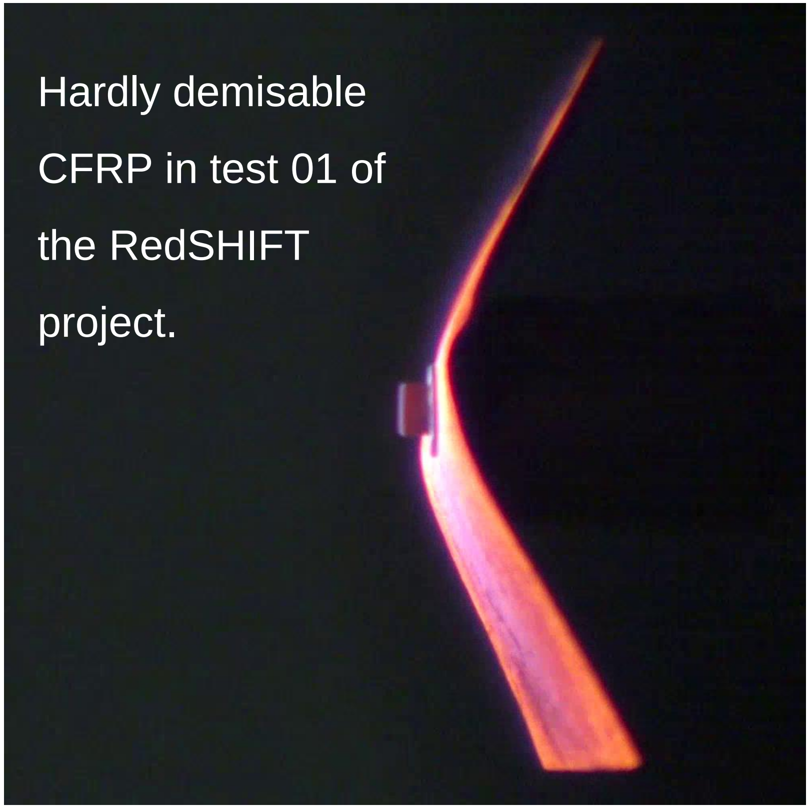
# The COMP2DEM Project

# The COMP2DEM Project - Background

Experimental entry flight simulations* show that fiber reinforced plastics typically

- Act like an ablative TPS material and
- Have very high demise resistance.

But, there has been one exception: a CFRP tested in the CHARDEM project in 2015.




* See for example ESA projects CoDM, SECRET and DHPT or EU project ReDSHIFT.

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# The COMP2DEM Project - Overview

The COMP2DEM project aims to

- Increase the understanding of composite demise and
- Allow development of demisable composites.

The first project phase, including characterization and testing of state-of-the-art composites, has been finished.

COMP2DEM is a small ESA EXPRO study (300k€).

# The COMP2DEM Project - Partners

Many thanks go to the partners:

- Austrian Foundry Institute ÖGI (material characterization),
- Invent GmbH (sample manufacturing),
- Fluid Gravity Engineering and Belstead Research Ltd. (both numerical simulations)

for their contribution!

# The COMP2DEM Project – Material Selection

There is a high number of composites being used in the space industry – too high for them all to be tested, so a structured, generic approach is used.

The selection of the set of 10 composites uses a common materials as baseline (unidirectional T300 fiber with a common epoxy matrix system). All other composites are derived by varying only one parameter, whenever possible.

Many parameters were identified to potentially have an influence on the demise behavior, so the most promising ones were selected.

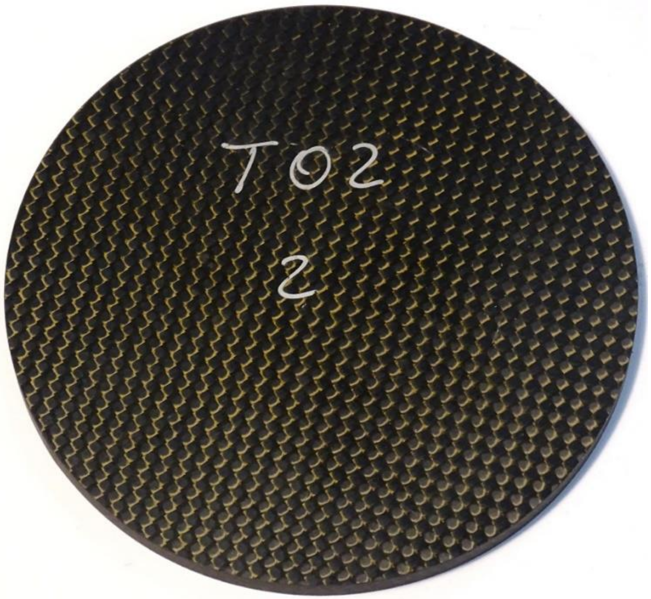
# The COMP2DEM Project – Material Selection

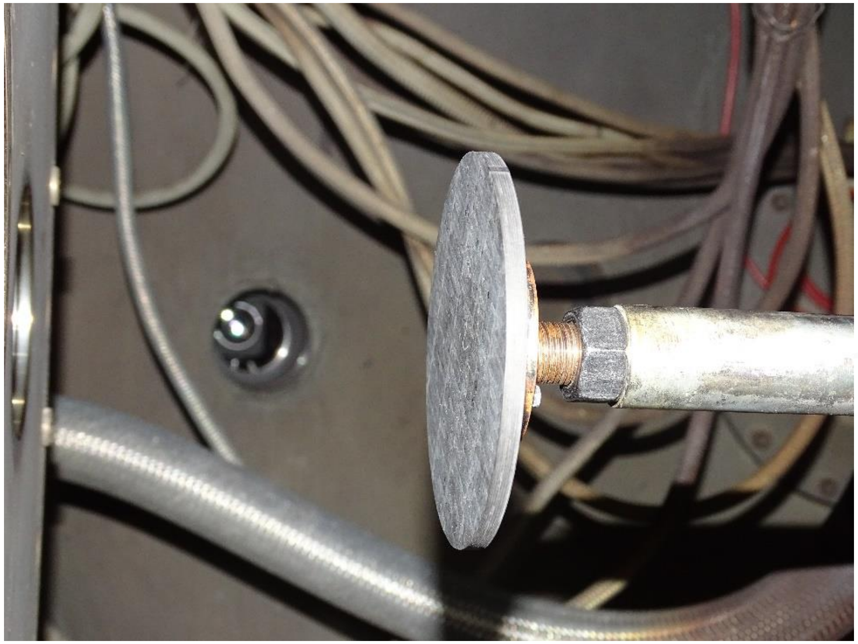
| ID | Short describtion | Type | Matrix | Fibre | Style | Comment |
|---|---|---|---|---|---|---|
| **C-01** | Baseline Composite | CFRP | LY556/HY906/DY070 | T300 | eUD200CHT | Baseline matrix, fibre and style/weave. Twill with hot melt warp thread. |
| **C-02** | Alternative Epoxy Matrix Composite | CFRP | L20/EPH 960 | T300 | eUD200CHT | Matrix system changed to alternative Epoxy Matrix. |
| **C-03** | Cyanate Ester Matrix Composite | CFRP | PT30 | T300 | eUD200CHT | Matrix system changed to Cyanate Ester Matrix. |
| **C-04** | Glass-Reinforced Composite | CFRP | LY556/HY906/DY070 | T300 | Style 756 | Warp thread made from glass instead of Copolyamid. |
| **C-05** | Glass Fibre Composite, UD | GFRP | LY556/HY906/DY070 | G1 | G U300-0/SO | Fibre replaced by E-glass fibre, unidirectional material. |
| **C-06** | Glass Fibre Composite, woven | GFRP | LY556/HY906/DY070 | G2 | Style 92105 | Fibre replaced by E-glass fibre, plane weave. |
| **C-07** | High Modulus Composite | CFRP | LY556/HY906/DY070 | HR40 | Style 863-2 | Fibre replaced by high-modulus carbon fibre. |
| **C-08** | Ultra-High Modulus Composite | CFRP | LY556/HY906/DY070 | K63712 | C-08 | Fibre replaced by thick ultra high modulus fibre made from pitch precursor. |
| **C-09** | Woven Fabric Composite | CFRP | LY556/HY906/DY070 | T300 | Style 450 | Baseline material with woven carbon fibre fabric. |
| **C-10** | Full-unidirectional Composite | CFRP | LY556/HY906/DY070 | T300 | eUD200CHT | Layup changed to near 100% UD. |

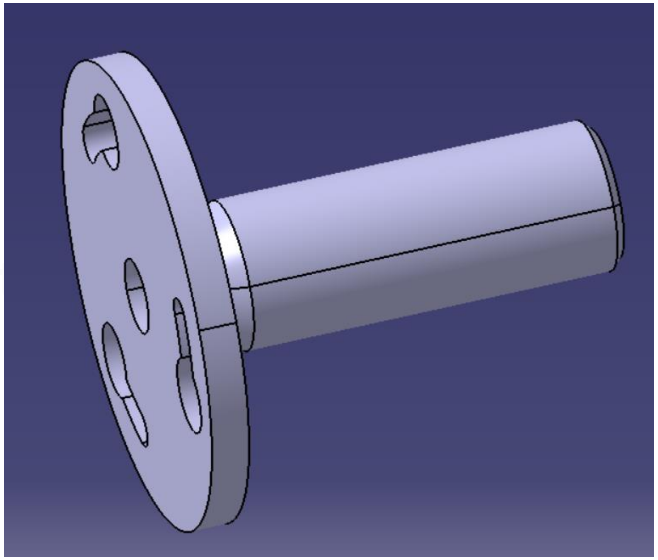
# Samples, Setups and Expectations

# Stagnation Setup

- Cylindrical samples with 5mm thickness and 100mm diameter.
- Standard demise-test-holder for fixation.



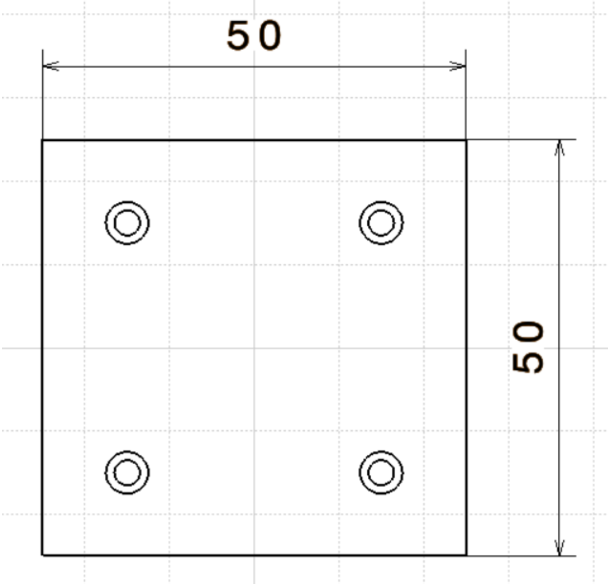



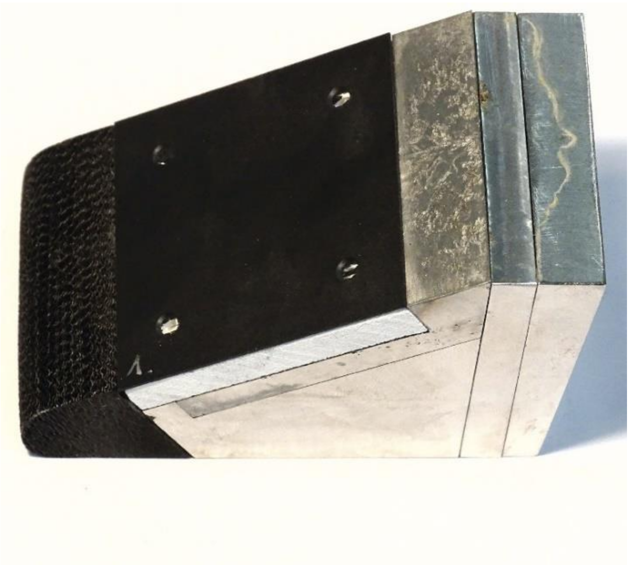


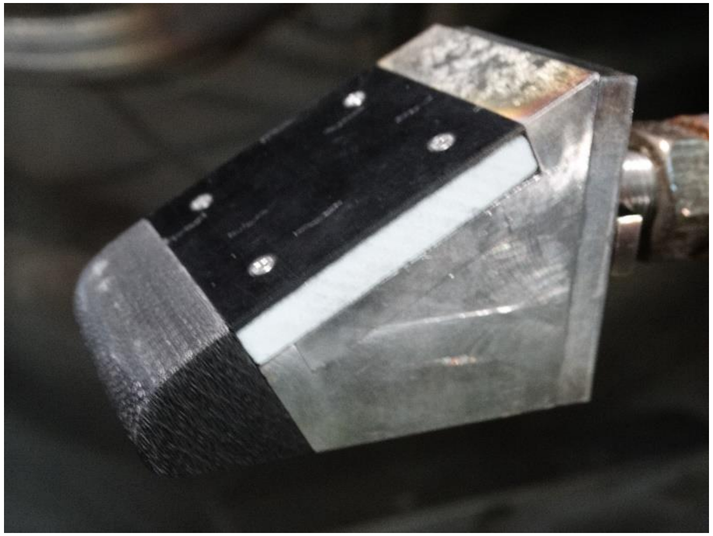
# Shear Setup

The shear samples are characterized by:

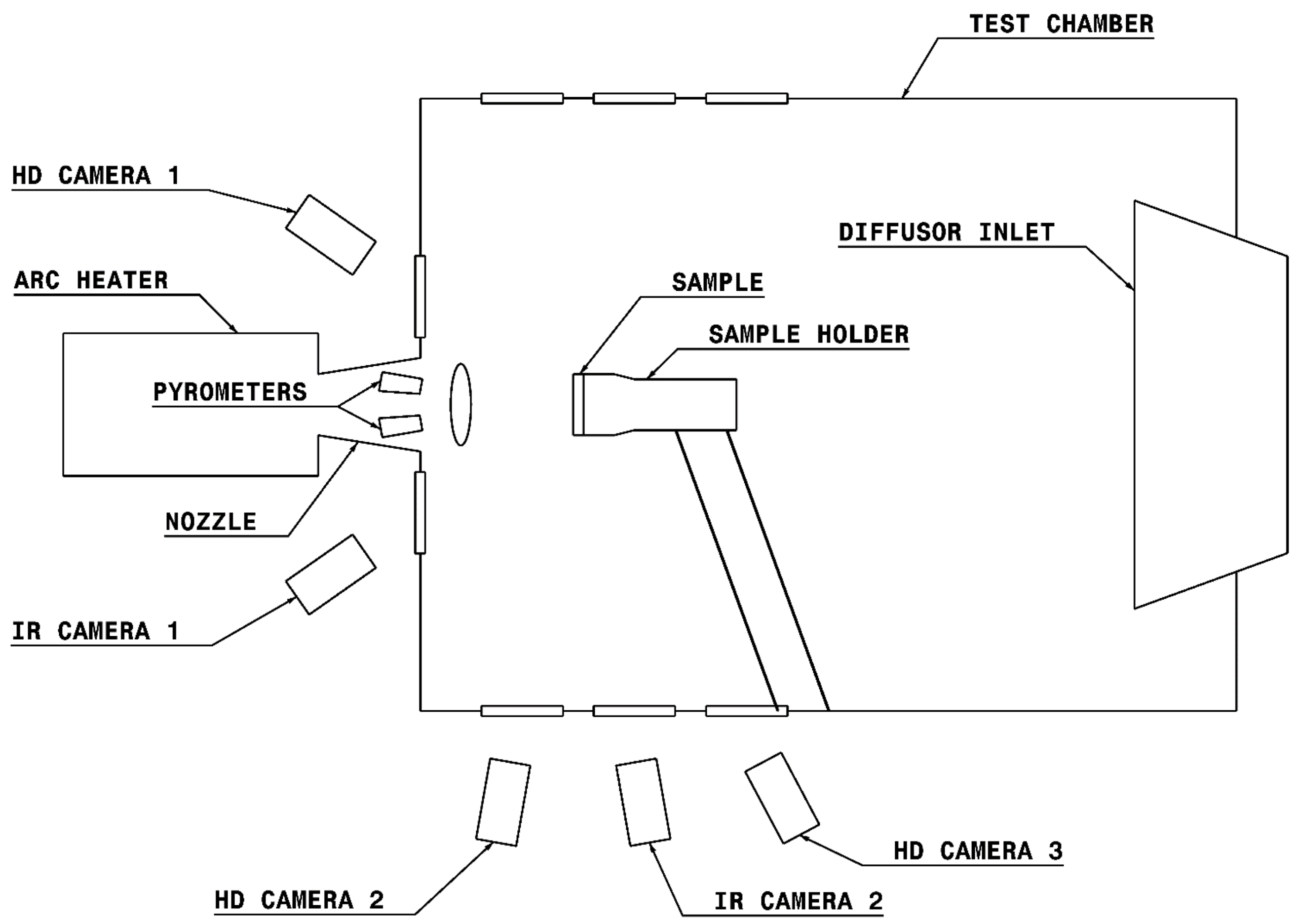
- Square sheets with 0.6-1.5mm thickness (8 plies) and 50mm side length
- Smaller wedge holder for use in front the 100mm nozzle to allows high fluxes and shear loads.





# Optical instrumentation setup

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# Expectation for material behavior

**Extreme 1**

Full thermal decomposition of the matrix with no or negligible char yield.

Subsequent mechanical ablation of dry fibers.

**Real composites**

Some behavior in between the extremes?

**Extreme 2**

High char yield of the matrix, yielding solid C/C ceramic.

Demise through oxidization / melting of the fiber and oxidization of the char.

Can we demonstrate the two extremes?

Are we missing something?

What influence does the shear load have?

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# Observed Material Behavior

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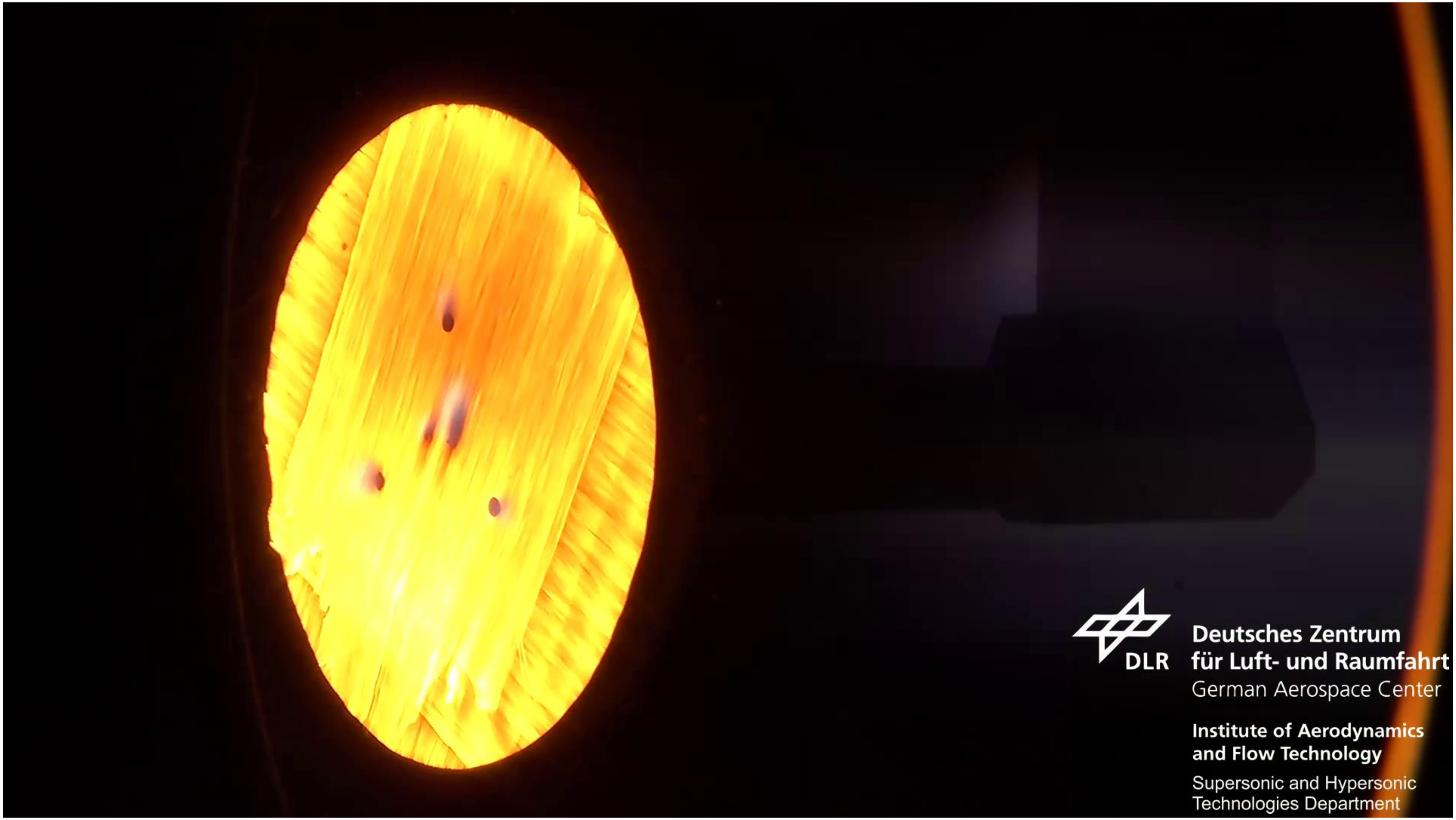
# C01: Baseline (T300 + Epoxy 1)



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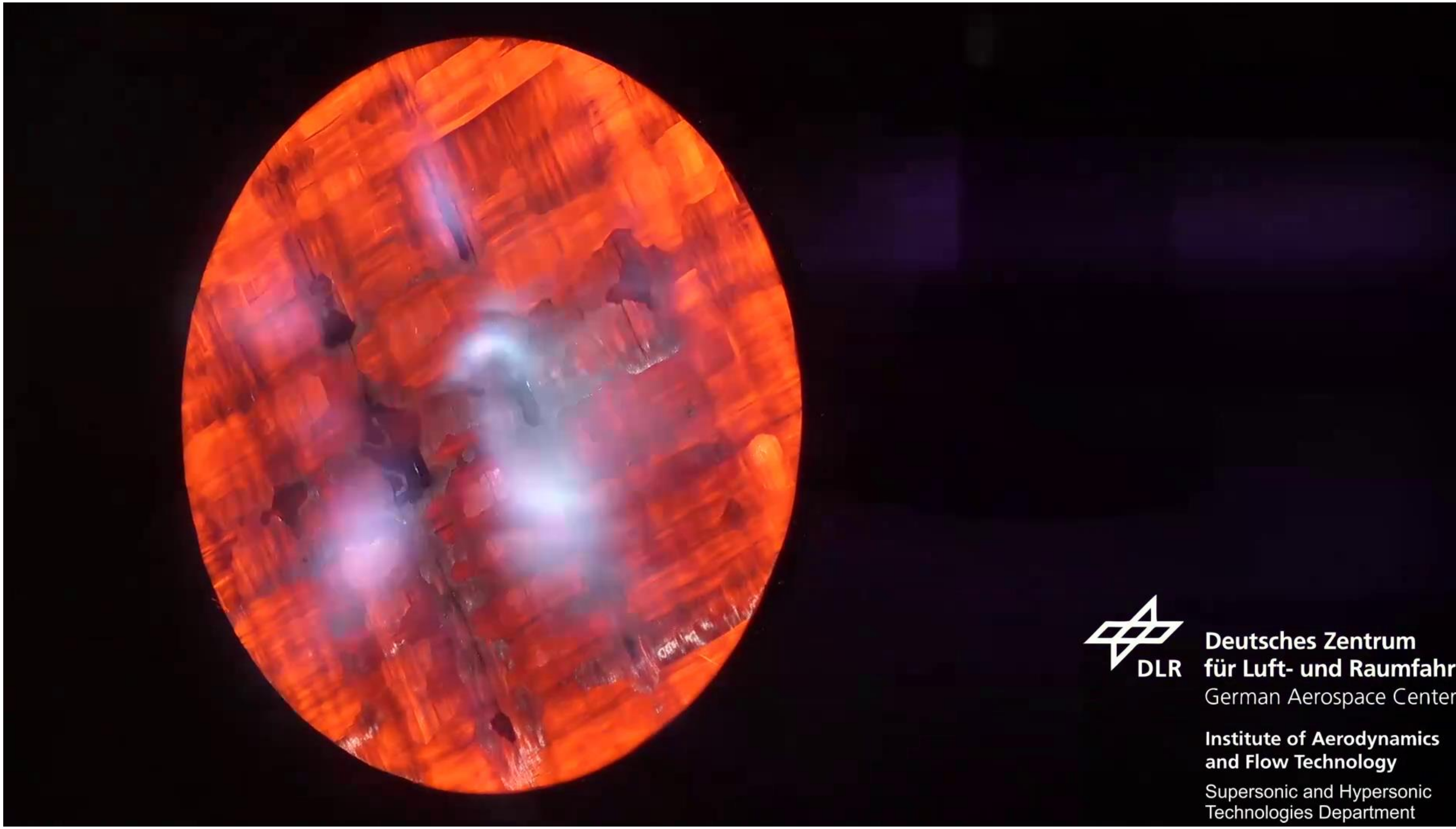

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- Composite 02 shows extreme behavior on one side of the spectrum – (almost) complete **matrix decomposition and mechanical ablation of the dry fibers**.

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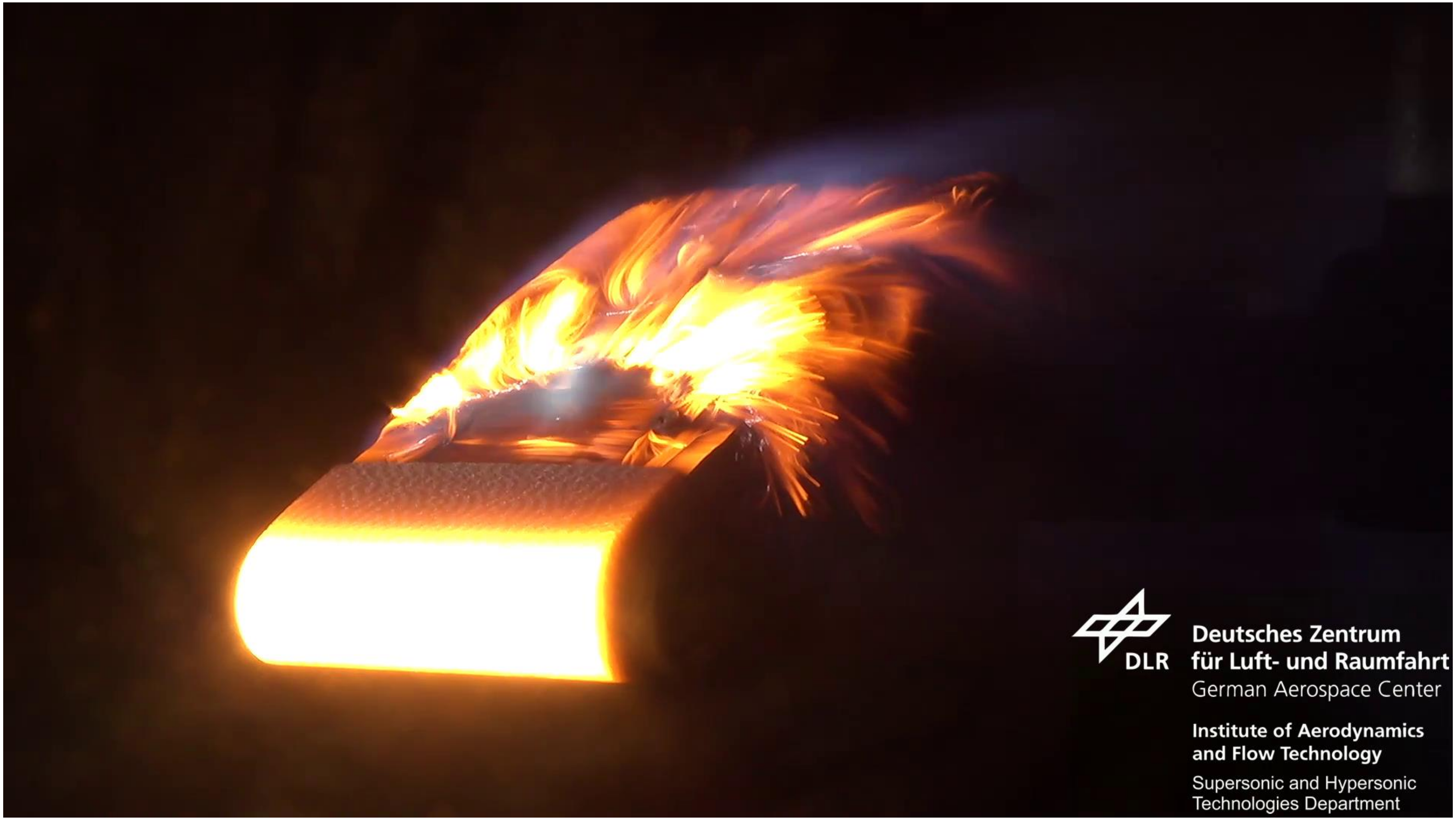

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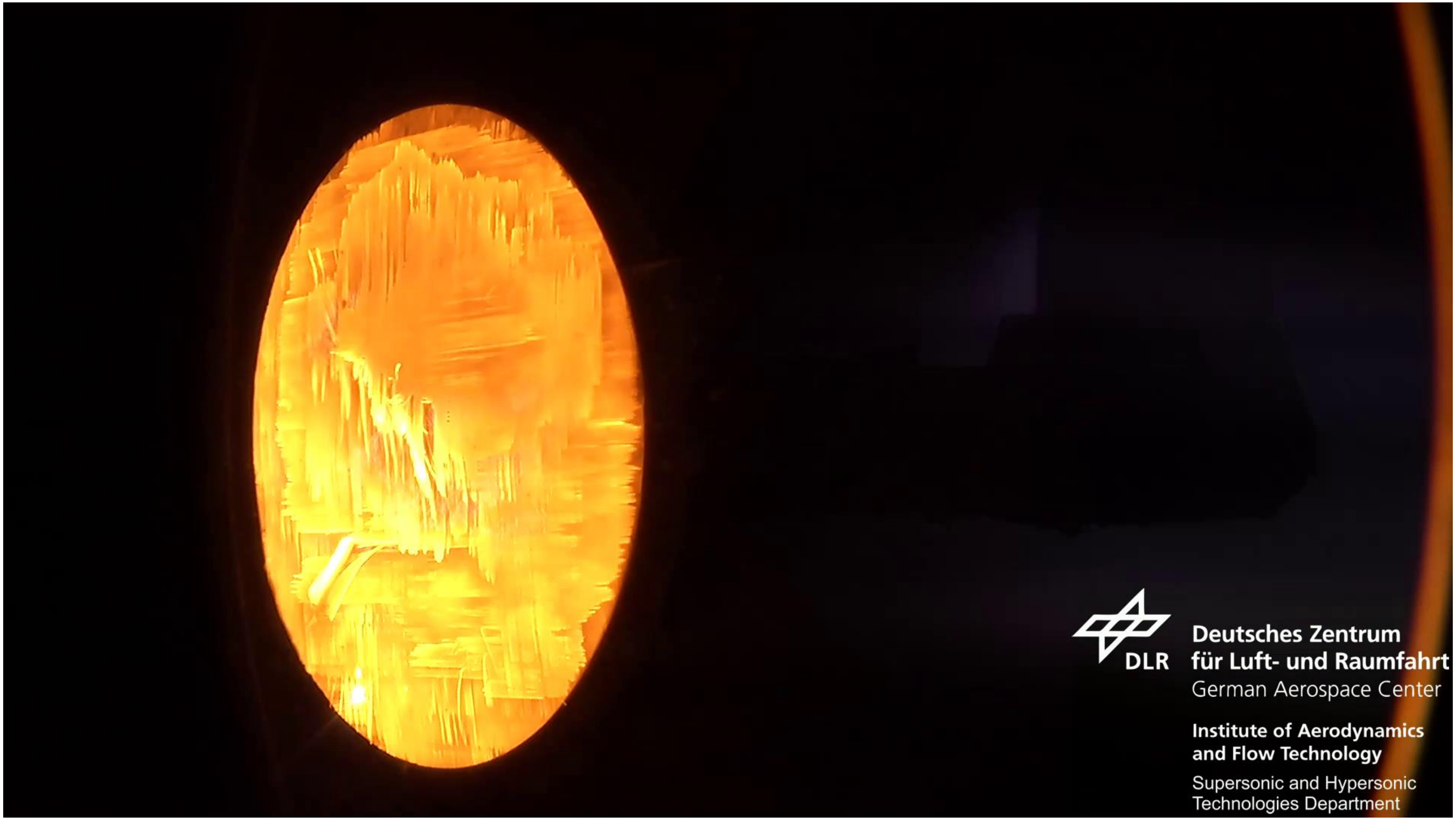
- Composite 02 shows extreme behavior on one side of the spectrum – (almost) complete **matrix decomposition and mechanical ablation of the dry fibers**.
- <u>Shear load can reduce demisability</u> through shielding by still-attached fibers. It is unknown whether this is only the case in an arbitrarily constrained wind tunnel environment with fixed orientation. Dynamic testing could answer this.

# C10: Carbon fiber prepreq (M55J + cyanate ester matrix)



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- Composite 10 shows the other extreme – high char yield means creation of solid C/C ceramic and demise only through oxidation; **behavior close to high-density ablators**.

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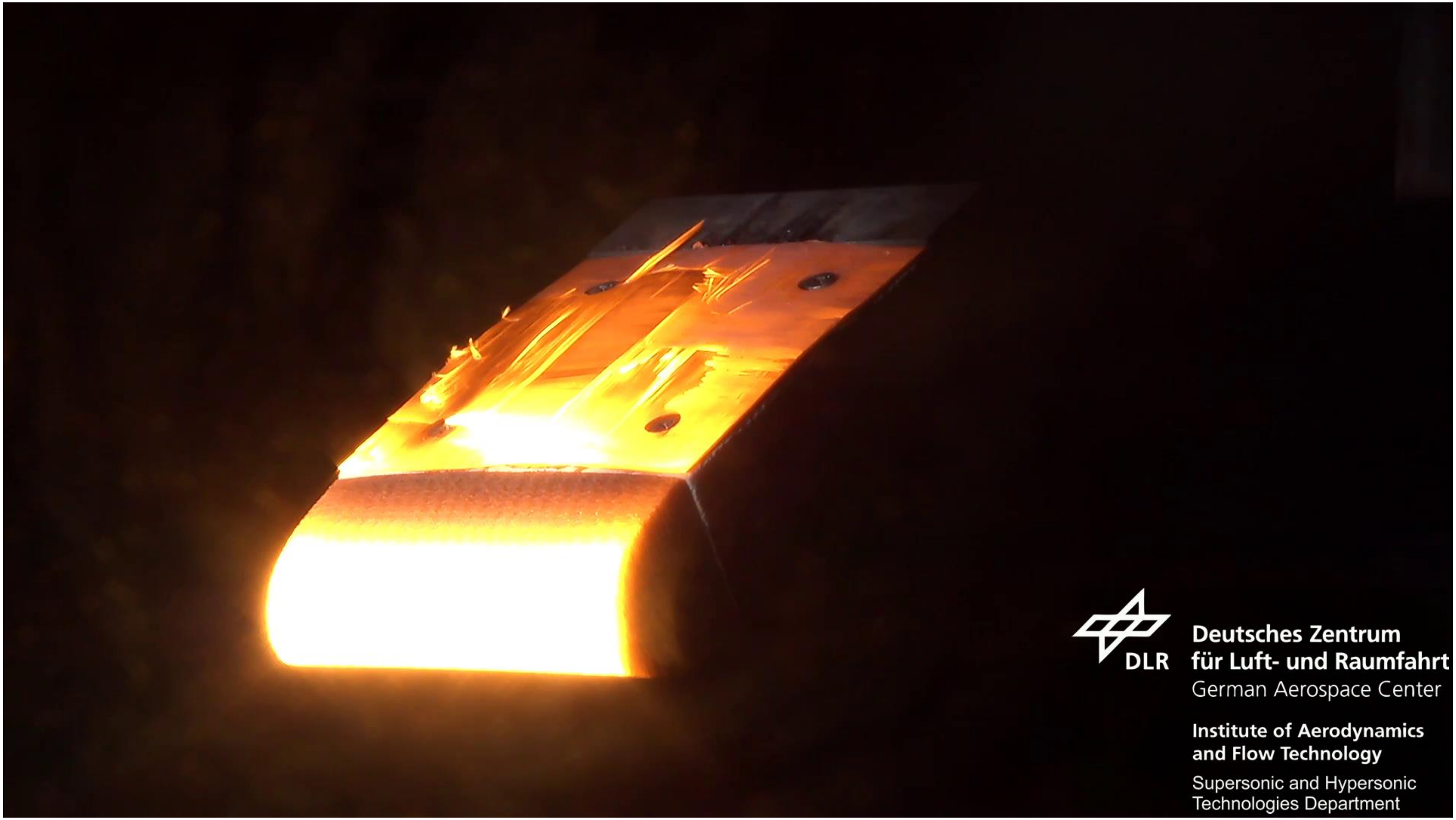

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- Composite 10 shows the other extreme – high char yield means creation of solid C/C ceramic and demise only through oxidation; **behavior close to high-density ablators**. Shear seems to have small impact on the general demise behavior.

# Summary

Different material behaviors observed:

- Extreme 1: Matrix decomposition and mechanical ablation of the dry fibers.
- Intermediate behavior: matrix decomposition and mechanical ablation of fiber stands or fabric layers when decomposition reaches the layer boundary or when char residue is oxidized.
- Extreme 2: Behavior as for ablative TPS materials.
- Shear loading has a minor effect only.

Material behavior changes with heating rate (and heat flux / pressure / shear stress?).

-> Material specific critical heat flux depending on all FRP properties.

-> Demisability investigation necessary for every FRP formulation.

-> Early exposure probably makes FRPs less demisable.