Dynamic Experimental Simulation of the Demise during Re-Entry Flight

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Thorn Schleutker, Sebastian Willems and Ali Gülhan

Supersonic and Hypersonic Technologies Department

German Aerospace Center DLR

Dynamic Entry Flight Simulation – Why?

Dynamic Entry Flight Simulation – Why?

Space debris may tumble during entry flight. This results in two major problems for static experimental simulation.

Transient evolution of the flow environment:

- Transient heat flux distribution - which heat flux will be representative? Stagnation point heat flux or surface averaged heat flux?
- Transient pressure distribution - influence on demise behavior?

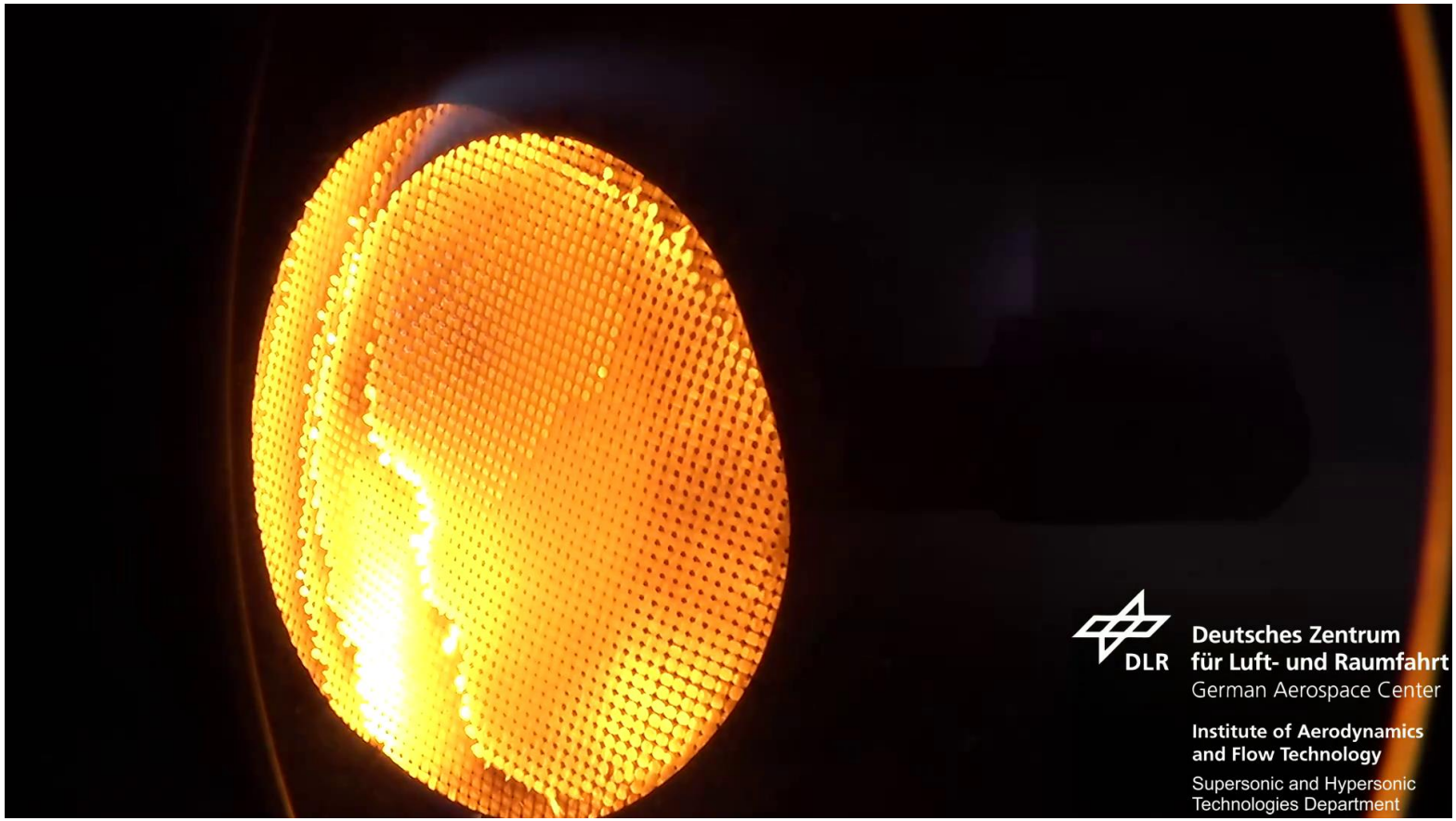
Mechanical environment:

- How to rebuild inertial forces?
- Mechanical ablation and separation?

→ Dynamic setup required for realistic entry simulation.

Dynamic Entry Flight Simulation – Why?

Example for one of the two problems: frontmost fabric layer of demising CFRP held in position by the constant flow. Different behavior in dynamic environment?



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Dynamic Entry Flight Simulation – Why?

Dynamic testing is able to address both problems.

Transient evolution of the flow environment:

- Transient heat flux and pressure distribution can be rebuilt correctly by testing with flight rotation rate.
- However, the setup is limited to rotation around one axis (true random tumbling not possible).

Mechanical environment:

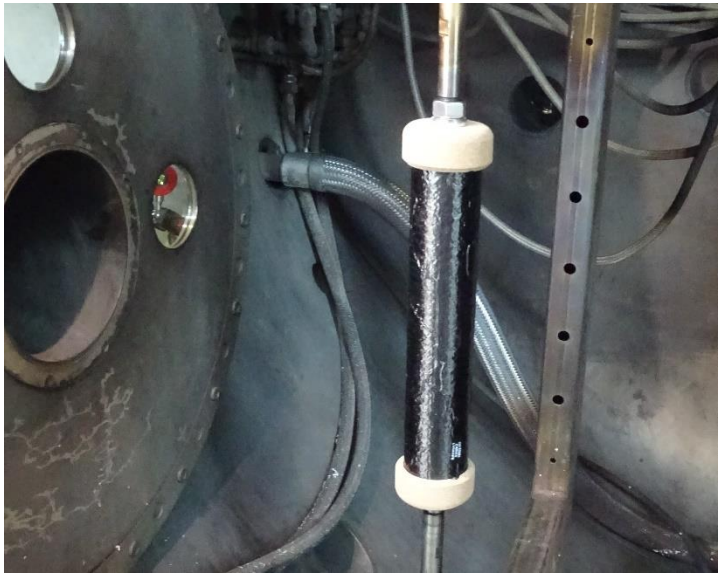
- The rotation allows the flow to attack from varying directions, thus allowing the mechanical ablation.
- Inertial forces can be simulated, but scaled models require adjusted rotation rate. This means testing of the influence of transient flow and inertial forces in separate tests.

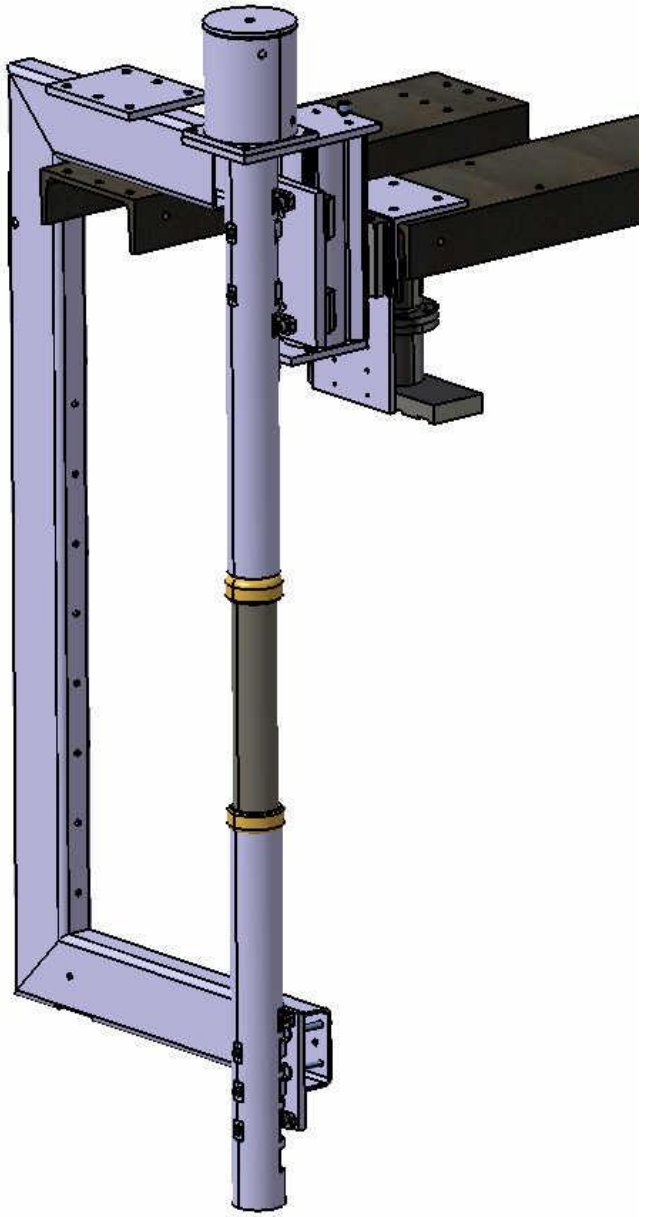
Dynamic Setup Overview

Dynamic Setup Overview - Fixture

C-shaped holder allows sample support from both sides, which reduces centrifugal forces through bending/displacement of sample.

Both supports are axles that rotate with the sample.





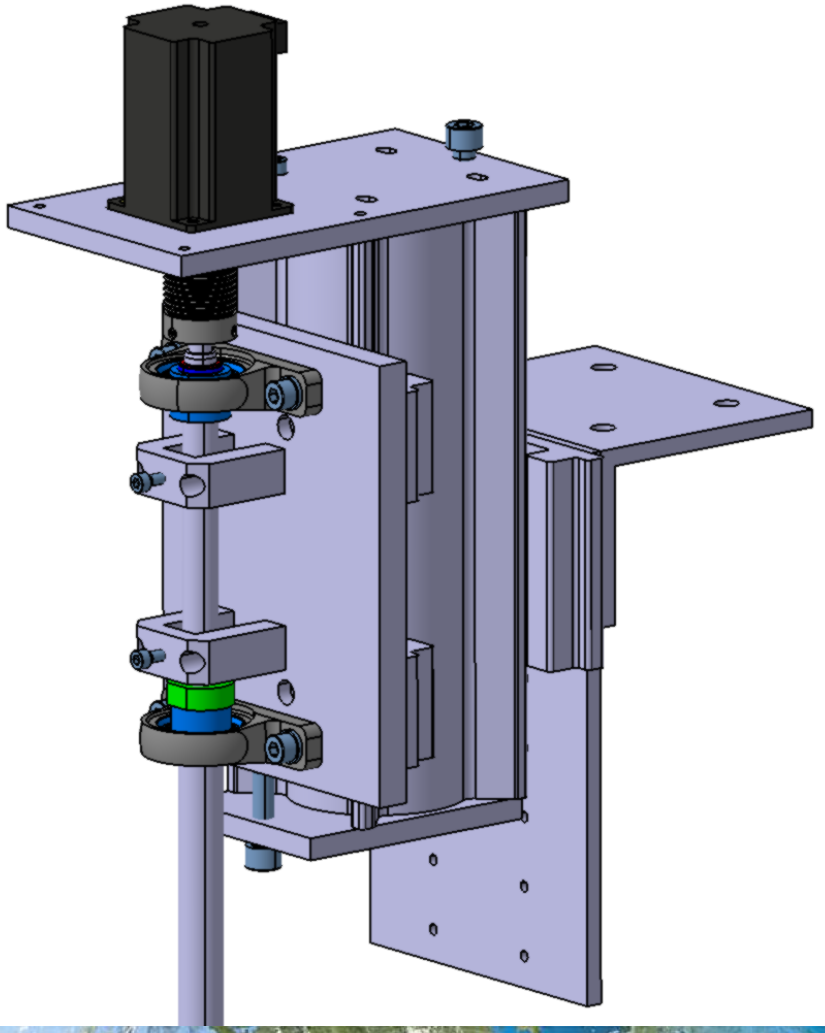
Dynamic Setup Overview – Drive Line

Rotational motion introduced by stepper motor acting on the upper axle.

The drive line allows:

- Rotation rates in the range of 0.1 -10 Hz,
- Remote control and
- Complex rotation patterns (e.g. sine or saw-tooth functions for rotation rate).

All mechanical and electrical parts are protected by stainless steel shields.



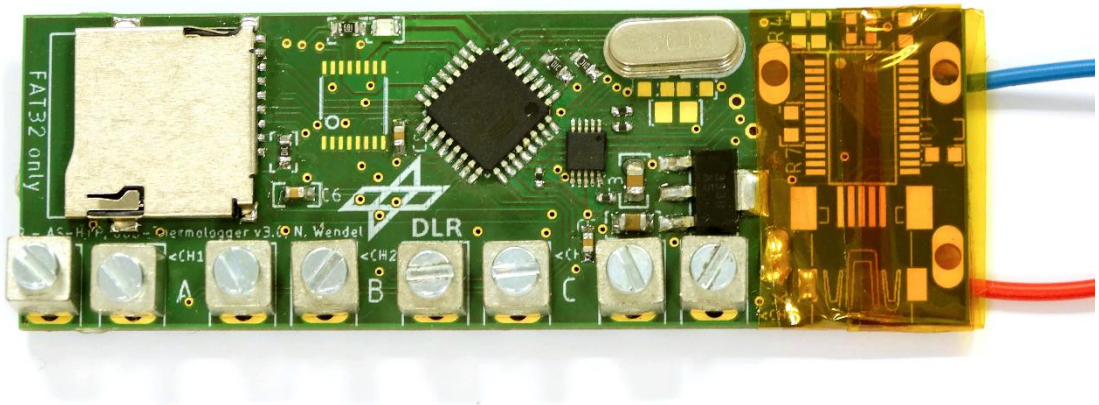
Dynamic Setup Overview – Data Acquisition

Dynamic testing has one major drawback; thermocouples integrated into the sample cannot be connected to the wind tunnel data acquisition system!

→ Thermocouple data logger had to be developed by the department.

Thermocouple Data Logger:

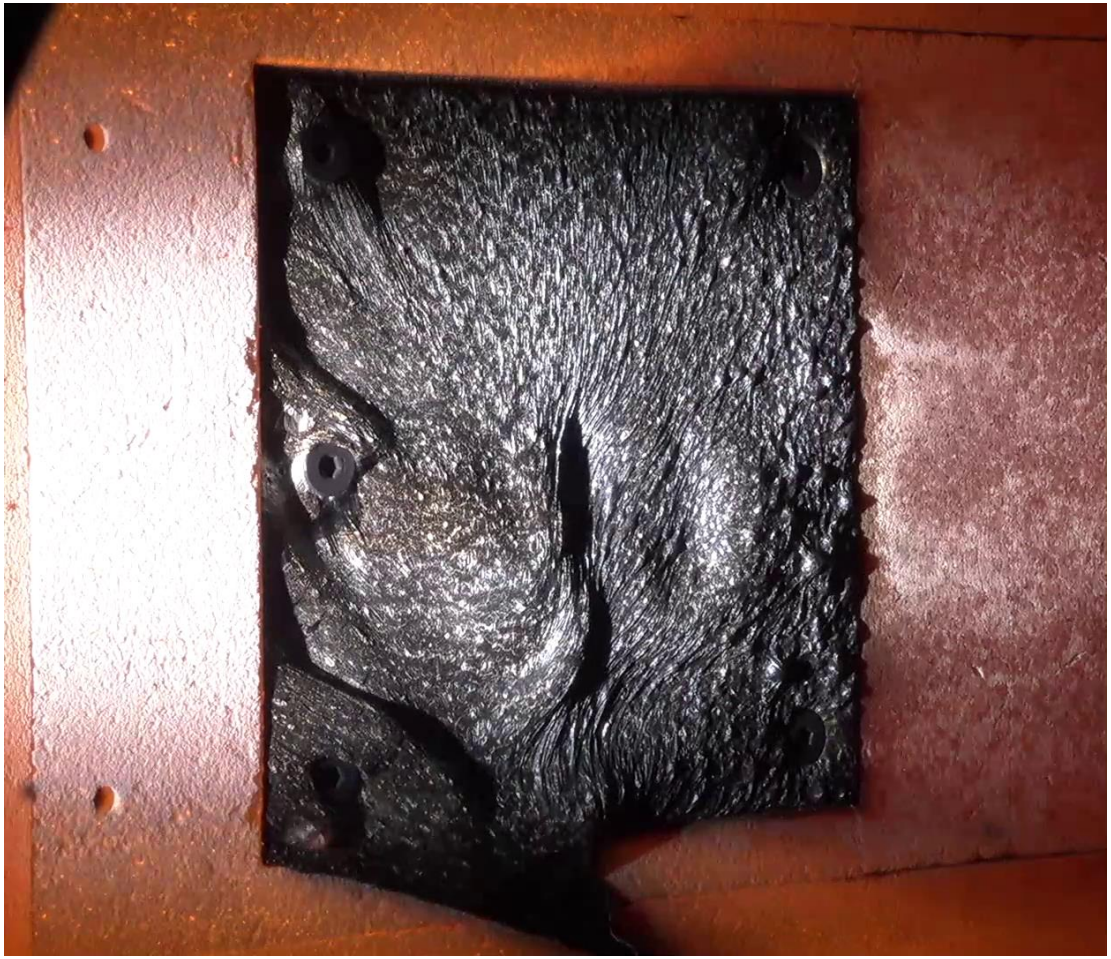
- 4 Channels,
- 10 Hz sampling rate and
- ~30 min recoding time.



Dynamic Simulation Examples

Dynamic Simulation Example 1

In static testing, aluminum fails by spilling after melting (and rupture of the oxide skin).



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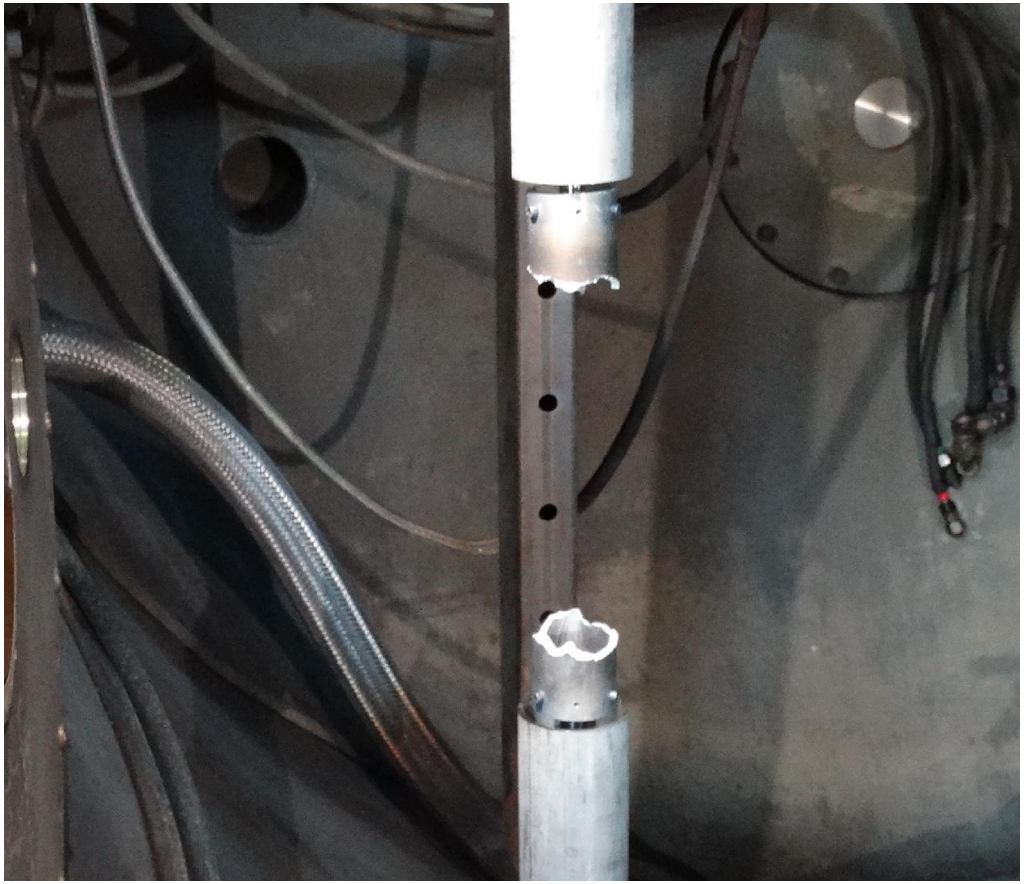
Dynamic Simulation Example 1

Initial testing of the rotation device with an aluminum cylinder and high rotation rates (8 Hz).

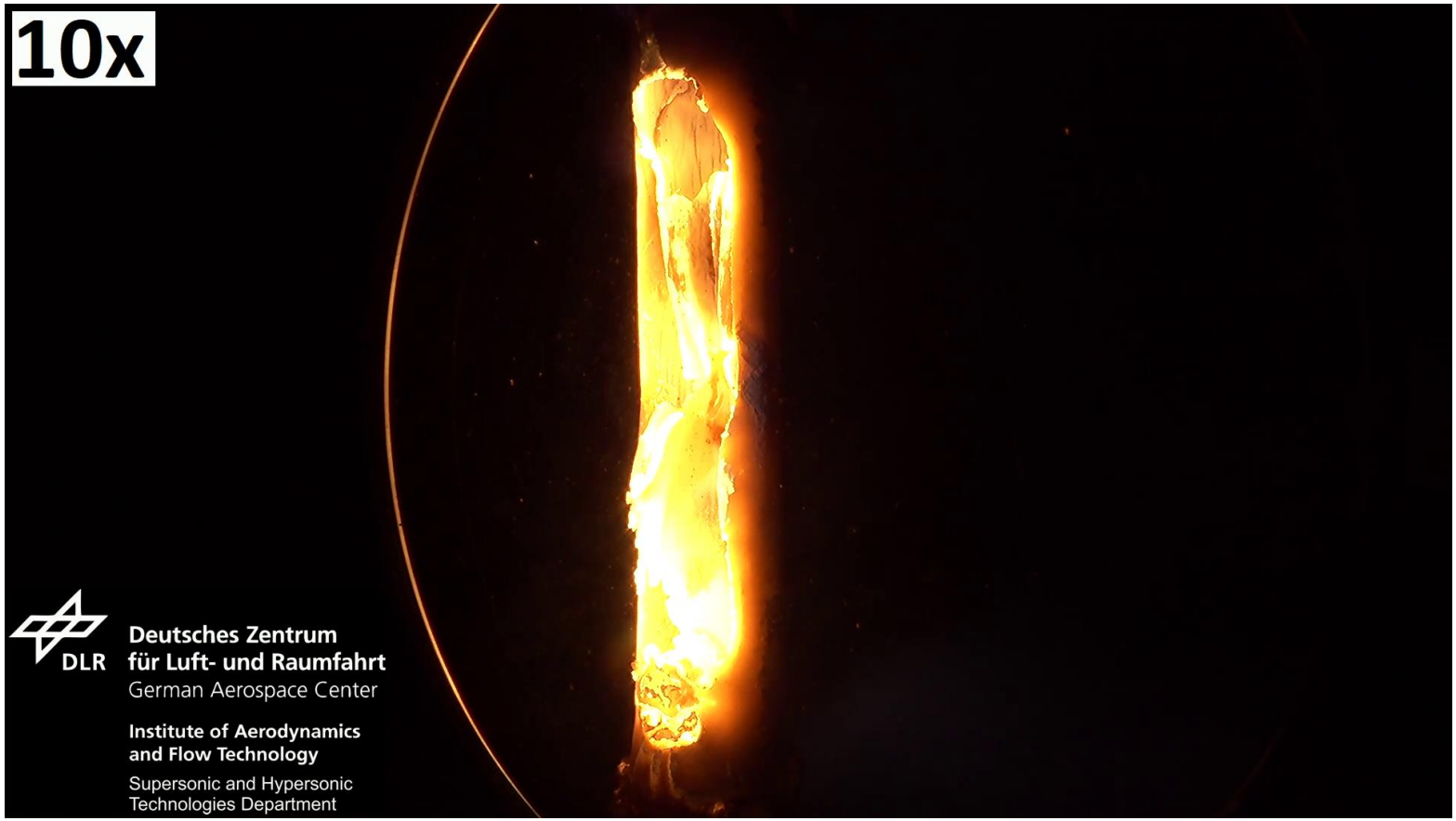


This fast rotation gives high centrifugal forces and averages the heat load.

The aluminum demises by mechanical destruction at temperature below the melting range.

Dynamic Simulation Example 2

Static testing of CFRP cylinders shows very low demisability.



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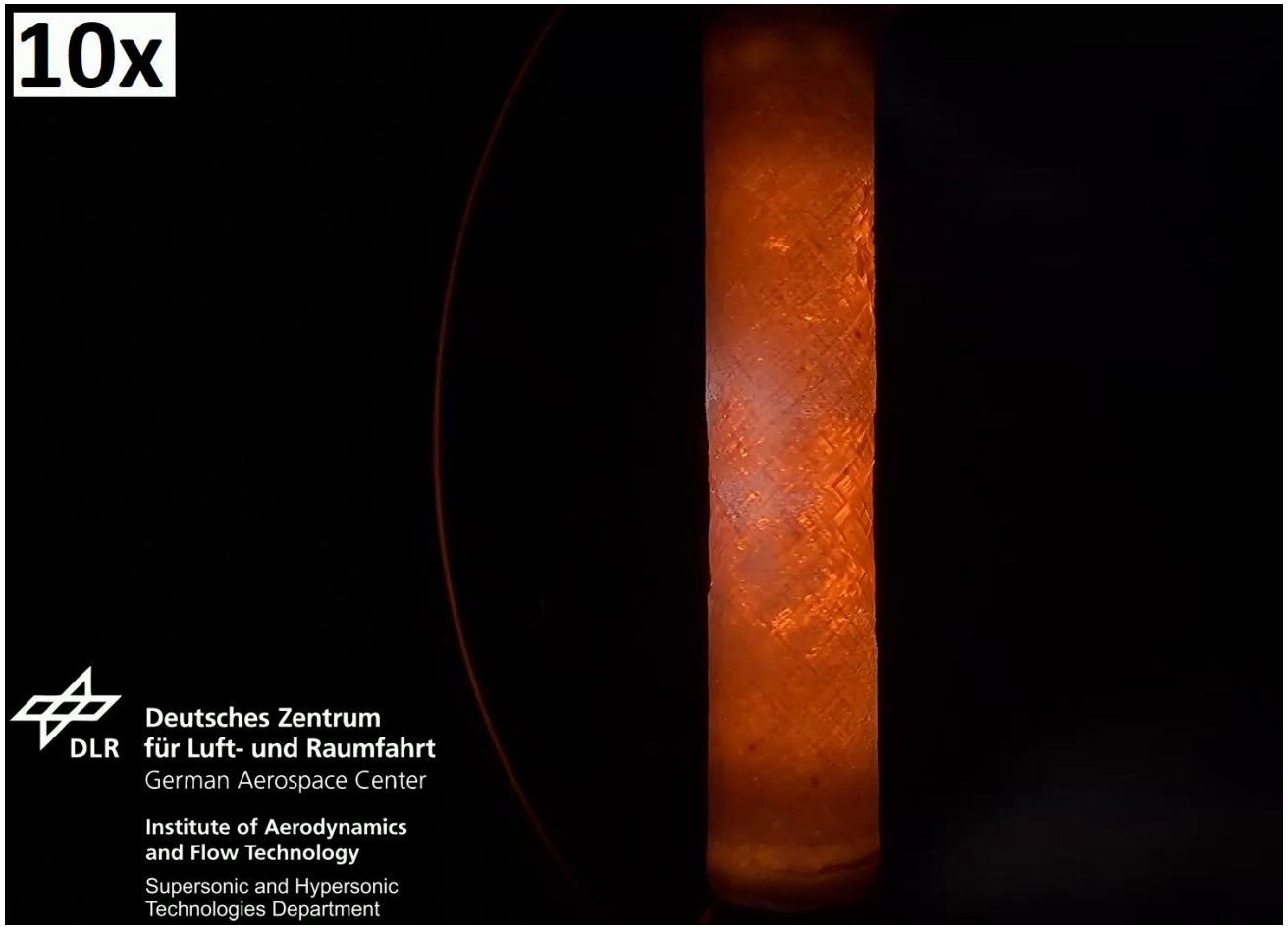
Dynamic Simulation Example 2

Dynamic testing distributes the heat load and thus increases the area available for re-radiation of heat.

→ Impact on demise behavior and (in this case) reduced demisability.



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Dynamic Simulation Example 2

Static test

Dynamic test

Summary

Device for rotation of wind tunnel test samples has been designed, build and integrated into the L2K wind tunnel.

Static testing fails to simulate inertial forces and the transient flow environment. Dynamic testing has been demonstrated to shift the limits on realistic ground simulation.

Material and component demise behavior may be very different in a dynamic environment.