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Oxidation and wear protection of pultruded C/C composites using atmospheric plasma-sprayed environmental barrier coatings

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INTRODUCTION & AIM

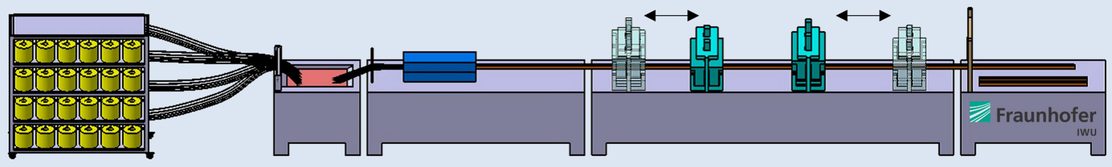
- C/C materials offer numerous advantageous properties (e.g. high specific strength, low thermal mass, very low coefficient of thermal expansion) making them suitable for use in high-temperature applications, but:
  - Quite expensive
  - Not stable in oxidative environment at high temperatures (>500°C)

$$C + O_2 \rightarrow CO_2$$

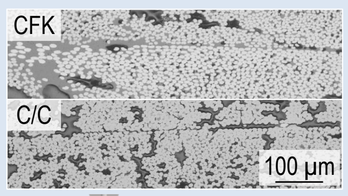
  - Low wear resistance

➢ Solution approach:

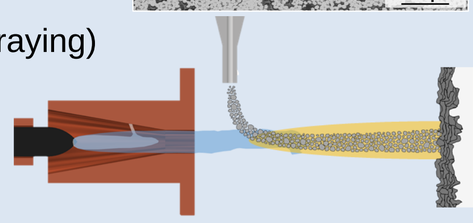
1. Development of a new continuous production route (pultrusion) for CFRP materials for the production of C/C profiles
   - Adapting the fibre volume ratio (Higher share (>60%) favourable for pultrusion, but lower proportion (approx. 50%) better for C/C production (higher matrix content)
   - Selection of the phenolic resin (C yield, viscosity, curing)



2. Pyrolysis
   - Specific structure of the C/C material depending on the pultruded CFRP material (proportion of pores, open / closed porosity, ...)



3. Coating deposition (atmospheric plasma spraying)
   - Environmental barrier coating (protection of the C/C material against oxygen)
   - Increasing wear resistance

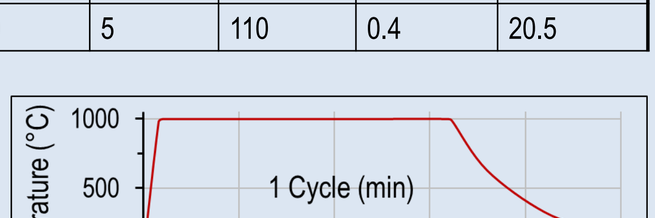


METHOD

- Coating of pultruded C/C- and standard C/C-SiC composites using APS with Si interlayer and $Yb_2Si_2O_7$ top coat:
  - No substrate pre-treatment except cleaning in ethanol ultrasonic bath (blasting/grinding damages fibre-matrix interface and promotes delamination)
  - Torch system: F6 (non cascaded, single anode – single cathode torch)
  - Materials: Si (Amperit ® 170.084, -75+20µm)
    $Yb_2Si_2O_7$ (Metco 6157, -90+11)
  - Spray parameters:

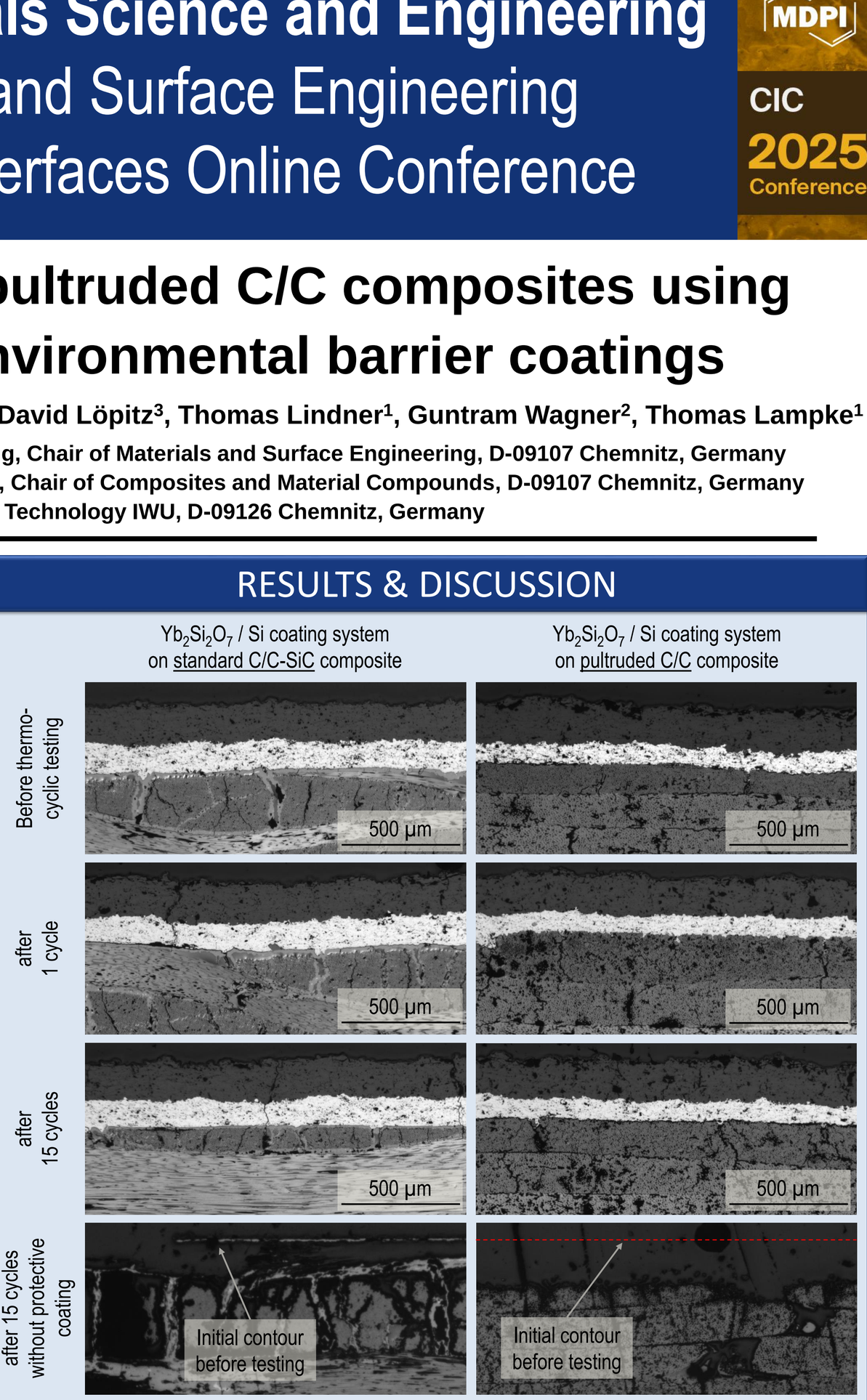
Material	Current (A) / Power (kW)	Flowrate plasma gases (l/min)		Spray distance (mm)	Traverse speed (m/s)	Powder feed rate (g/min)
		Ar	H_2			
Si	520 / 35	50	8	130	0.4	14.0
$Yb_2Si_2O_7$	550 / 34	50	5	110	0.4	20.5

- Thermo-cyclic testing of coated samples:
  - Temperature: 1000°C
  - Atmosphere: Ar
  - Cooling: Air

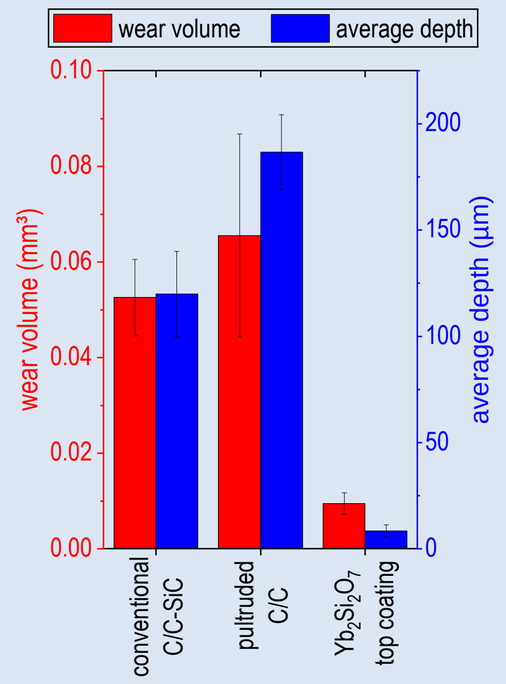


- Microstructure analysis before and after thermo-cyclic testing using optical microscope
- Scratch test (50N constant load, 5mm, 2.5mm/s)

RESULTS & DISCUSSION



- $Yb_2Si_2O_7$ / Si – coating system can be deposited on both standard C/C-SiC and pultruded C/C-composite
- $Yb_2Si_2O_7$ / Si – coating system demonstrates great resistance to thermo-cyclic stress and protects the C/C composites from degradation due to oxidation
  - Only minor microcrack formation after the first cycle (especially on standard C/C-SiC composites), no further increase in defects
- $Yb_2Si_2O_7$ top coating provides high wear resistance in scratch test



CONCLUSION

Pultrusion can be used to continuously manufacture CFRP profiles that can serve as the base material for C/C composites. Plasma-sprayed $Yb_2Si_2O_7$ coatings increase the wear and oxidation resistance of conventional and pultruded C/C profiles and withstand thermo-cyclic stresses. In further progress, the composite materials produced by pultrusion are further optimized, e.g. by adding Si additives (SiC formation) or multiaxial fiber orientation.

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IGF INDUSTRIELLE GEMEINSCHAFTSFORSCHUNG