CarboBreak – Conditions and Mechanisms for Releasing Alveolar Fibrous Carbon Fibre Fragments

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Introduction/Motivation:

Innovative fibre materials and composites have been continuously developed in recent years and are enjoying a rising demand in various applications and products. Especially for carbon fibres (CF), the global demand has more than doubled within the last decade. In the case of fibres and composite materials made from them, preliminary investigations showed in some cases a strong tendency to splinter under mechanical stress and mechanical processing. To date, it is still unclear how high the potential for the release of alveolar fragments is in the life cycle of the fibres (WHO criteria: length > 5 µm, diameter < 3 µm, aspect ratio > 3:1). Against the background of the asbestos problem, it is necessary to develop material-related expertise on the fracture behaviour of carbon fibres of different types and precursors.

Objectives:

The main goal is a deeper understanding of the fracture behaviour of carbon fibres as well as the investigation of the release processes of alveolar fragments from CF and carbon fibre reinforced plastics (CFRP) under mechanical stress. A method of testing the tendency of the fibres for spall fractures under reproducible conditions is developed. Possible relationships between the physical properties of the carbon fibres, the splinter potential and the formation of alveolar fibre fragments are evaluated. Another focus of the project is the implementation of workplace measurements according to VDI 3492 and DGUV-Information 213-546 to determine the concentrations of respirable inorganic fibres in work environments.

Fibre Selection:

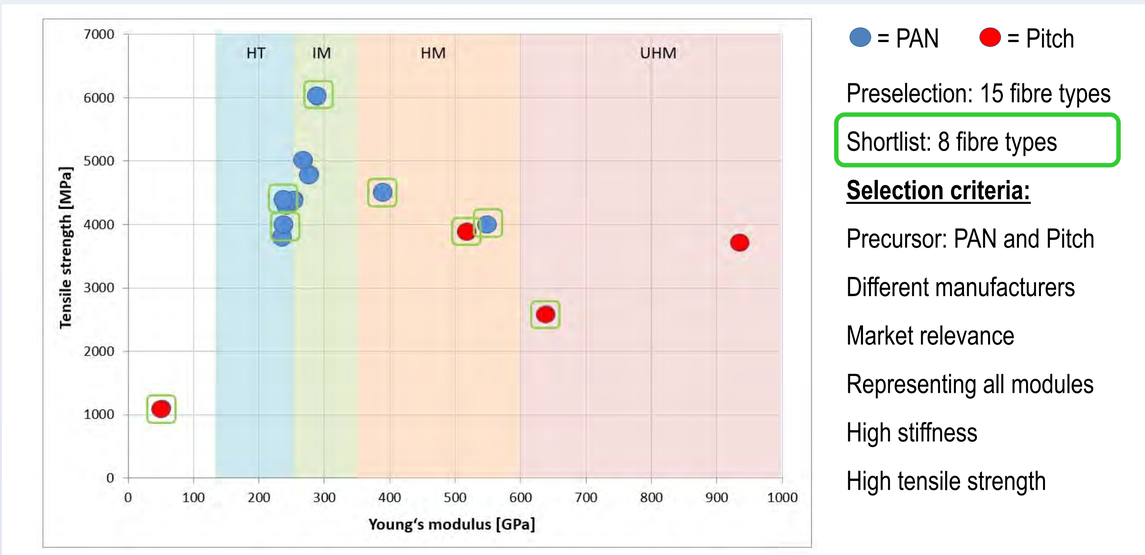


Figure 1: Graph of tensile strength & Young's modulus values of the selected fibres

Spall Fracture Tendency Screening:

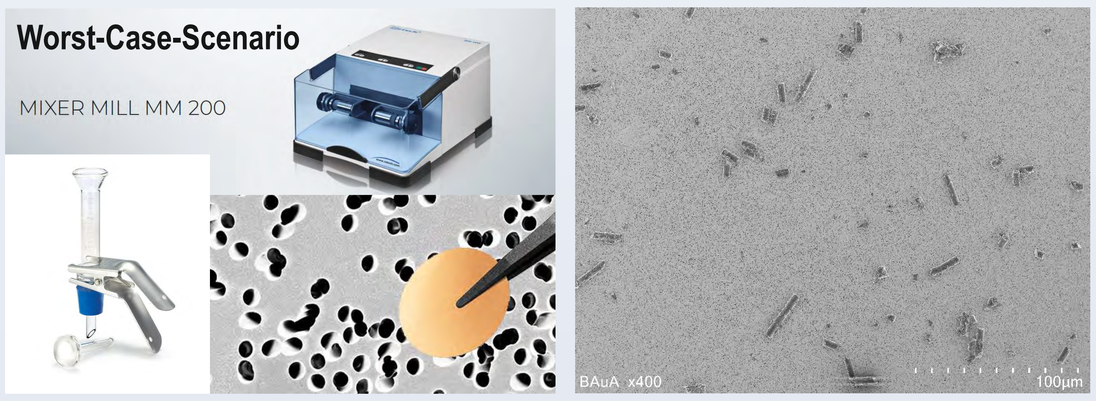


Figure 5: Milled CF are suspended in isopropanol, diluted and drawn onto a nuclear pore filter. SEM images are taken automatically at random locations on the filter. All objects on these images are analysed regarding their length, diameter and other morphological parameters.

Microstructure of Carbon Fibres:

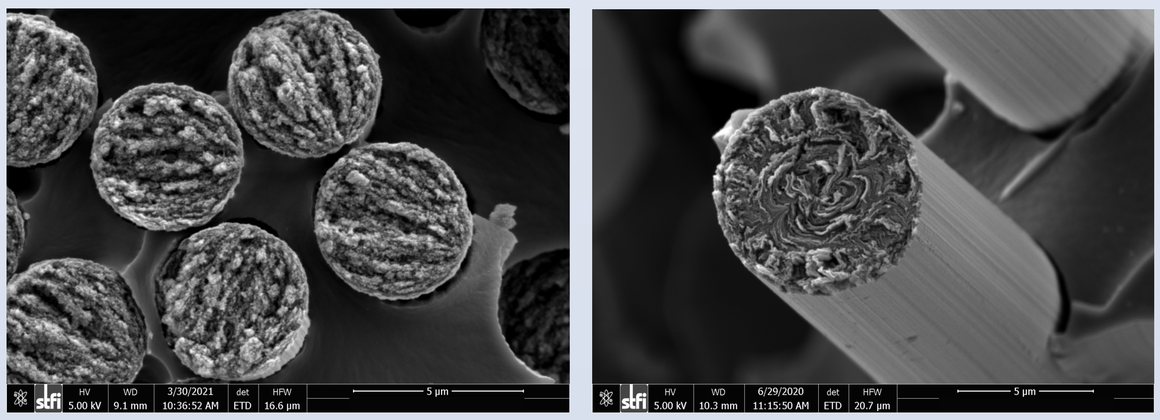


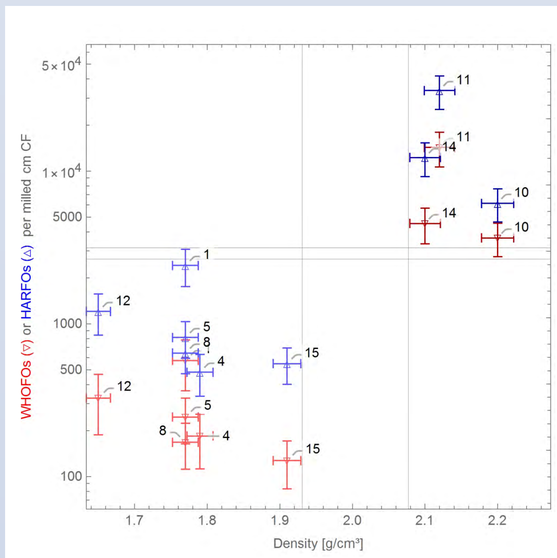
Figure 2: SEM images of the fracture lines of PAN-based (left) and pitch-based (right) CF rovings with similar mechanical properties

Table 2: Results of the spall fracture tendency screening [HARFO: High Aspect Ratio Fibre Object | WHOFO: WHO-Fibre Object]

Fibre No.	Precursor	Percentage of HARFO found
11	mPitch	74
10	mPitch	47,6
14	mPitch	39,5
8	PAN	14
15	PAN	13
5	PAN	12
1	PAN	10,5
12	iPitch	5
4	PAN	5

Fibre No.	Precursor	reduction of mean fibre diameter [%]
11	mPitch	87
10	mPitch	83
14	mPitch	79
1	PAN	76
12	iPitch	57
4	PAN	52
5	PAN	48
8	PAN	46
15	PAN	36

Fibre No.	Precursor	WHOFO per milled cm
11	mPitch	14263
14	mPitch	4499
10	mPitch	3649
1	PAN	575
12	iPitch	285
5	PAN	245
4	PAN	175
8	PAN	167
15	PAN	127

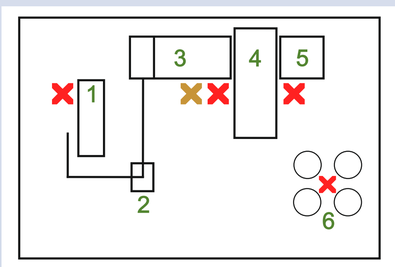


Both fibre types, PAN and pitch CF, break along their fibre axis and can form WHO-fibres when under mechanical stress.

Precautionary measures when working with either materials are highly recommended.

Figure 6: Amount of HARFOs/WHOFOs per milled cm CF shown over the density of the fibre types. A distinctive bandgap between fibres with higher and lower propensity to produce fibrous splinters is revealed.

Workplace Measurements at STFI:



1 Tearing machine
2 Filling cage unit
3 Airlay unit
4 Crosslapper
5 Needleloom
6 Filter unit
✖ Filtering measurement
✖ Online measuring devices

Figure 3: Measurement points

Figure 4: Carbon fibre nonwoven plant at STFI

Table 1: WHO fibre concentrations (8 hour shift values)

*) Acceptance concentration for mineral wool according to technical rule TRGS521 50,000 F/m³ and for asbestos according to TRGS910 10,000 F/m³

Sample	WHO fibre objects	WHO fibre concentration [F_{WHO}/m³]	95% confidence interval [F_{WHO}/m³] Lower limit	Upper limit*)
Background	0	———	———	<10,000
Outside measuring	0	———	———	<10,000
Tearing machine	24.5	76,068	48,986	63,400
Airlay unit	22.5	65,711	41,422	55,700
Crosslapper	14.5	40,957	22,663	38,300
Filter unit	13	39,309	20,930	37,800
Personalised	14	44,047	24,081	41,600

Project Outputs:

- Recommendations concerning work procedures and personal safety
- Development of a protective guideline "Safety by Design and Application Safety"
- Implementation of a practice-oriented workshop

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