LEBENSDAUERVORHERSAGE FÜR KUNSTSTOFF-FLACH- UND SPEICHERKOLLEKTOREN

GLEISDORF SOLAR 2016
GLEISDORF, AUSTRIA

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solpol powered by klima+energie fonds
SHC TASK 54

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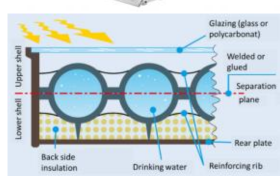
INTRODUCTION AND OBJECTIVES

Different Types of Polymer Collectors		
Unglazed Swimming Pool	Glazed Collector Systems	



Max. temperature ~70°C
→ PP, PE absorber

Helicol Pool Collector, US

Max. temperature ~110°C
→ PP absorber

SUNLUMO, AUT
(ONE WORLD SOLAR COLLECTOR)

Max. temperature ~90°C
→ PA-GF absorber

GREENoneTEC, AUT
(SOLCRAFTE)

COLLECTORS - REQUIREMENTS FOR ABSORBER MATERIALS

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OW-SC flat plate collector

System type & service requirements
- Pumped, pressurized hot water
- service life: > 10 years
- region: e.g., Phoenix (USA)

Key-property requirements for polymer *absorber materials*
- solar absorption: 93-95%
- thermal stability: >110°C
- low temperature capability: -30°C
- long-term stability in water/glycol:
  - 75-100°C: > 2,000 h (DHW)
  - 0-75°C: > 85,000 h
- pressure: max. 1,5 bar

Absorber: Polypropylene (PP)

GoT integrated storage collector (ISC)

System type & service requirements
- Non-pumped, pressurized hot water
- service life: > 5 years
- region: e.g., Athens (GRE)

Key-property requirements for polymer *absorber materials*
- solar absorption: 93-95%
- thermal stability: >110°C
- low temperature capability: 0°C
- long-term stability in (chlorinated) water:
  - 75-100°C: > 800 h (DHW)
  - 0-75°C: > 43,000 h
- pressure: max. 4/6 bar at 90°C/RT

Absorber: Polyamide glass fiber reinforced (PA-GF)

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EXPERIMENTAL *AGING CONDITIONS*

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Materials

OW-SC: 2 PP grades (100µm specimen)
- PP-Bα (used for pool absorbers)
- PP-Bβ (novel solpol-grade for absorbers)

ISC: 1 PA66-GF30 grade (4mm multi purpose specimen)

Exposure Conditions

- Hot Air (PP and PA-GF)
- Heat Carrier Fluid (OW-SC: water + glycol; ISC: water)

@ Temperatures of 95, 115, 135°C

Evaluated aging indicators

- Stabilizer analysis by HPLC-UV/MS (Agilent Technologies 1260 Infinity)
- Oxidation temperature (T_{ox}) by DTA (PerkinElmer DSC4000)
- Carbonyl Index (C.I.) by FT-IR (PerkinElmer Spectrum 100)
- Embrittlement/failure time by tensile testing (Zwick Roell Z2.5)


100µm thick micro-sized specimen (polypropylene)


1260 Infinity


DSC4000, PerkinElmer


Spectrum 100, PerkinElmer


Z2.5, Zwick Roell

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EXPERIMENTAL
LIFETIME ASSESSMENT

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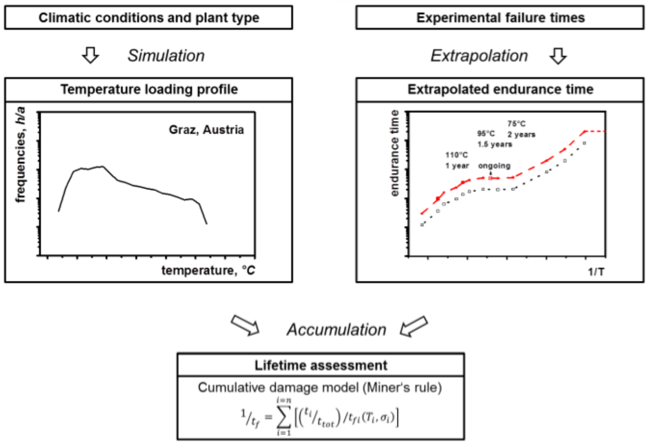
Methodology of the solpol-approach



- Temperature loading profiles for different climatic conditions were generated
- Experimental data were extrapolated to service temperatures (40-90°C)
- Deduction of lifetime by applying a cumulative damage model (Miner's rule)

RESULTS – OW-SC
LIFETIME-TEMPERATURE LOADING PROFILES

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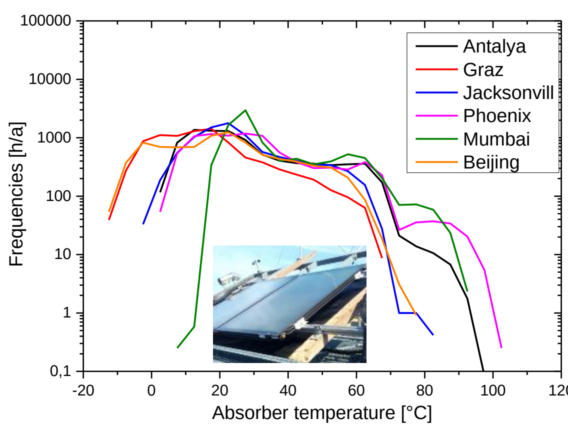
Loading profiles for OW-SC at different sites



- OW-SC collector system for DHW (domestic hot water) in single family houses
- Maximum operating temperatures are below 110°C
- Similar loads in the temperature range from 35 to 65°C for investigated climate zones
- Highest loads for Phoenix, Mumbai and Antalya; temperatures higher 90°C
- In Graz and Beijing temperatures below 0°C

RESULTS – OW-SC
HOT AIR AGING BEHAVIOR

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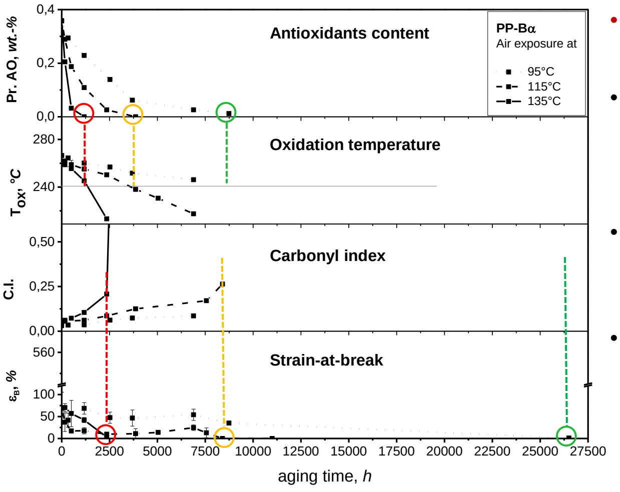
Hot air aging behavior of PP-Bα



- So far no failure in hot heat-carrier fluid!
- Temperature difference of 20°C – acceleration factor for stabilizer loss of about 3
- Antioxidants detection limits agree with critical T_{ox} of 240°C
- Significant increase of C.I. and associated embrittlement after 2,500 h at 135°C, 8,000 h at 115°C and 26,500 h at 95°C.

RESULTS – OW-SC
HOT AIR AGING BEHAVIOR

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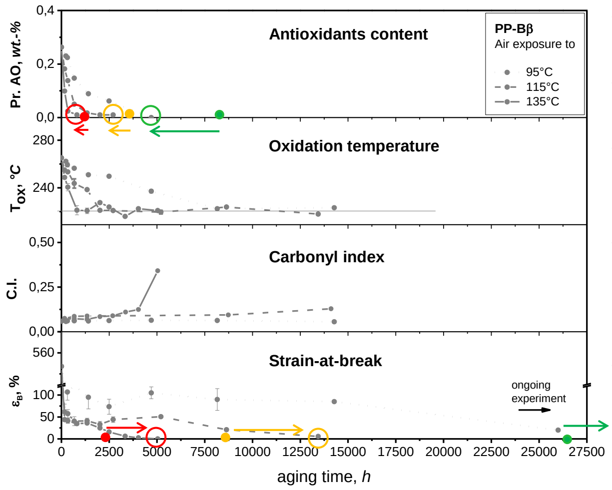
Hot air aging behavior of PP-Bβ (solpol)



- So far no failure in hot heat-carrier fluid!
- Faster loss of stabilizer package than PP-Bα
- Faster drop in oxidation temperature levelling of at 220°C
- Better long-time performance of mechanical properties compared to PP-Bα
- Attributable to coarse spherulitic structure of PP-Bα

RESULTS – OW-SC
SERVICE TEMPEATURE EXTRAPOLATION

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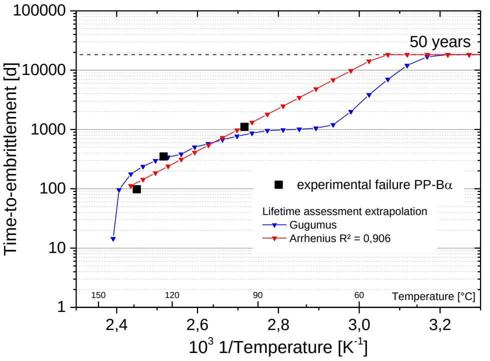
Extrapolated endurance times for PP-Bα



- Experimental data were extrapolated using the Arrhenius and the Gugumus approach
- Embrittlement cut-off was defined at 50 years
- More critical – Gugumus: Experimental data for PP-H with comparable stabilizer formulation published by Gugumus (1999); vertical shift of Gugumus data to ultimate failure points of PP-grades → synthetic endurance time/temperature curve achieved
- Less critical - Arrhenius: Arrhenius-extrapolation shows better material performance at temperatures from 50 to 90°C

RESULTS – OW-SC
LIFETIME ESTIMATION

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Lifetime estimation for PP absorber of OW-SC collector

- Lifetime estimation strongly depends on extrapolation method
- Estimated lifetimes are more than 20 years for both grades
- Lowest lifetime values for hot and humid climate zone (Mumbai, IND)
- solpol-grade PP-Bβ: deduced lifetime years are higher (~ 10-20%) → improved performance

Lifetime, years	Antalya, TR		Graz, AT		Jacksonville, US		Phoenix, US		Mumbai, IND		Beijing, CHN	
	Gug.	Arrh.	Gug.	Arrh.	Gug.	Arrh.	Gug.	Arrh.	Gug.	Arrh.	Gug.	Arrh.
PP-Bα	26	45	43	49	36	49	22	41	20	41	39	49
PP-Bβ	30	47	46	50	40	49	26	43	24	43	42	49

RESULTS – ISC
LIFETIME-TEMPERATURE LOADING PROFILES

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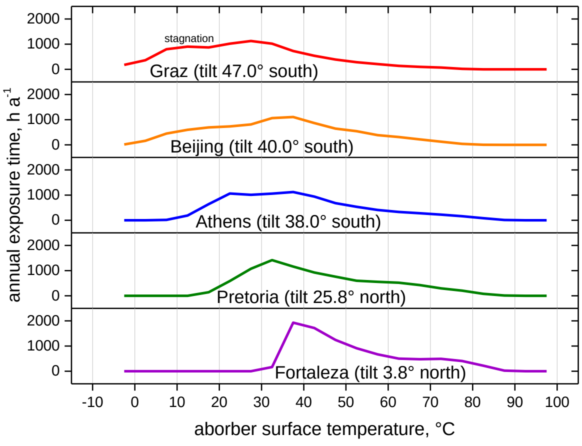
Loading profiles for ISC at different sites



- ISC for DHW in single family houses
- Maximum operating temperatures are < 90°C
- Peaks loads are varying between 30 and 40°C
- Highest loads for Fortaleza, Pretoria or Athens
- ISC not recommended for Graz or Beijing

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RESULTS – ISC
LIFETIME ESTIMATION

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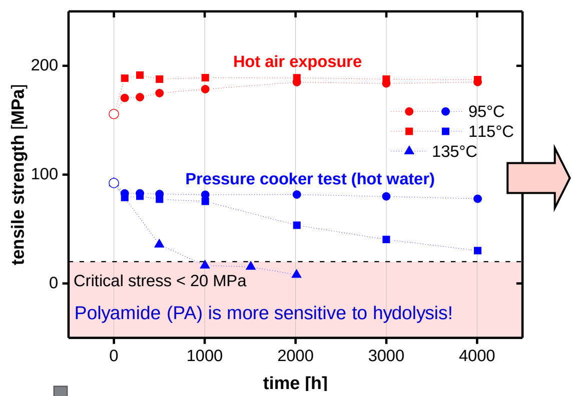
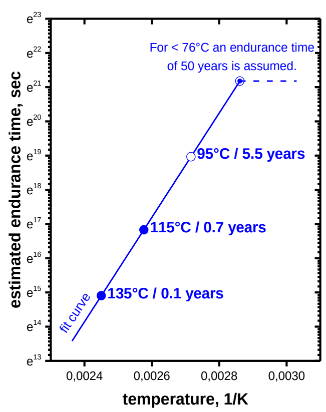
Aging behavior and Lifetime for PA-GF absorber of ISC collector

Aging at elevated temperatures
(specimen level)



Extrapolation of aging data



Lifetime, years	Graz, AT	Beijing, CHN	Athens, GR	Pretoria, SA	Fortaleza, BRA
PP-GF	48	46	39	37	31

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SUMMARY AND CONCLUSION

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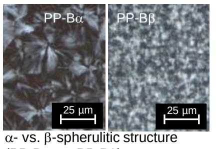
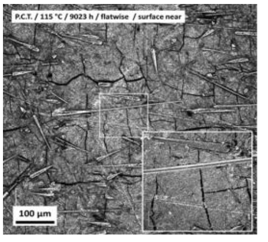
PP absorber for pumped OW SC system

- Hot air exposure is more critical than hot heat carrier fluid (with corrosion inhibitors)
- solpol-grade PP-Bβ exhibited better long-term performance under service relevant conditions



α- vs. β-spherulitic structure (PP-Bα vs. PP-Bβ)

- More critical: hot and humid climate zone (e.g., Mumbai, Phoenix)
- Lifetimes of 20 years and more were deduced



PA-GF absorber for non-pumped ISC system

- Hot water exposure is more critical (hydrolysis)
- Lifetimes of 30 years and more; lower values for hot climates (e.g., Fortaleza, Pretoria)
- Validation by tests on component level, considering also pressure and chlorinated water to be done