

Influence of Water on the Adhesion on Polyamide 6 for Reliable Joining Processes

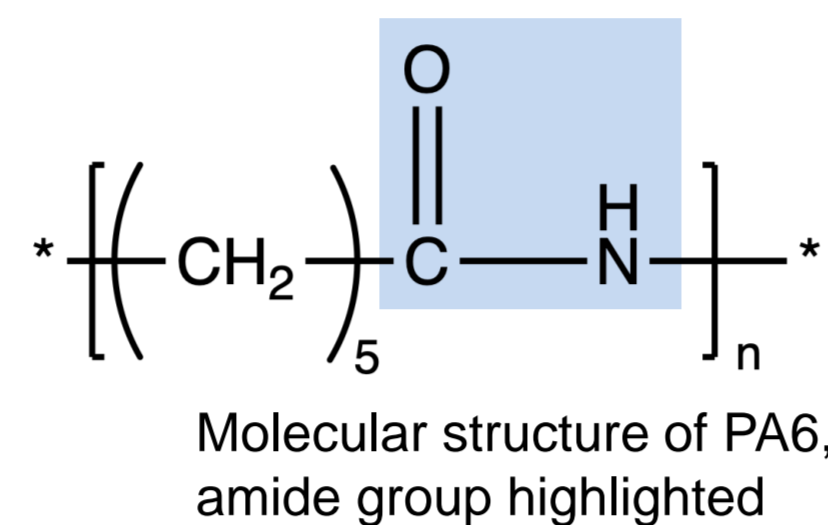
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Introduction

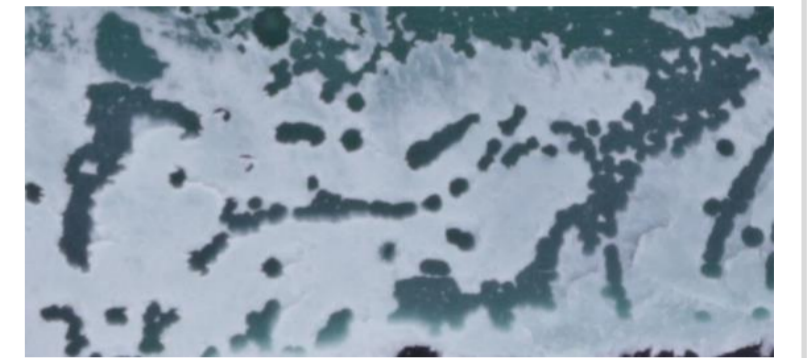
Polyamide 6 (PA6)

- Versatile polymer with various applications because of high impact resistance (automotive, electrical components, etc.)
- Hydrophilic amide group → high water absorption (~3 wt.-% at atmosphere, > 10 wt.-% in water)
- Water functions as plasticizer → affects mechanical properties: → reduced strength, increased flexibility



Challenges

- Pre-treatment for high and long-term stable bonding strength → Atmospheric pressure plasma jet (APPJ)
- Water might react with adhesive (Isocyanates) and cause defects in the boundary layer
- Influence of water on pre-treatment process**
 - Does water influence the pre-treatment process and resulting adhesion?
 - How does water effects adhesion, can the effect be measured?



Adhesive surface of tested lap shear specimen with macroscopic defects

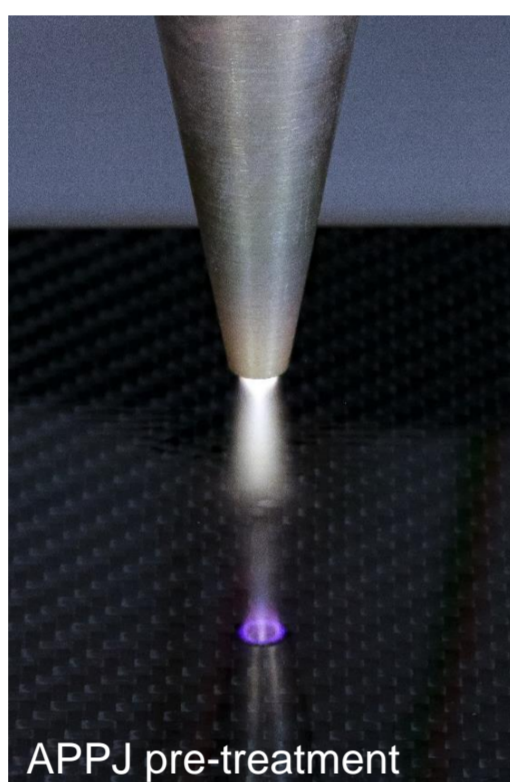
Materials & Methods

PA6: Durethan B30S by Envalior

- Saturated: 3 wt.-% H₂O
- Dried: 0 wt.-% H₂O

APPJ pre-treatment

Tigres T-Spot S1	
Power	1000 W
Jet Diameter	8 mm
Process gas	Air
Jet velocity	100 mm/s
Jet distance	15, 20, 25 mm



Surface analysis

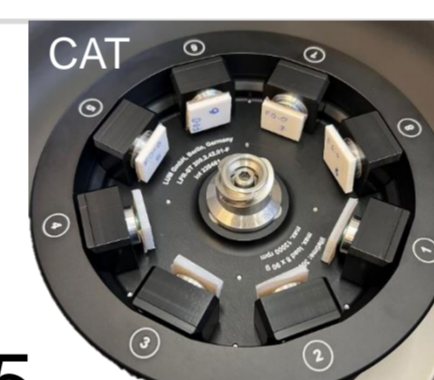
- Wetting behavior: contact angle measurement according to EN 828
- Morphological surface changes
 - Extraction of the top layer (30 μm) via microtome cut
 - Analysis of crystallinity in DSC

Adhesives:

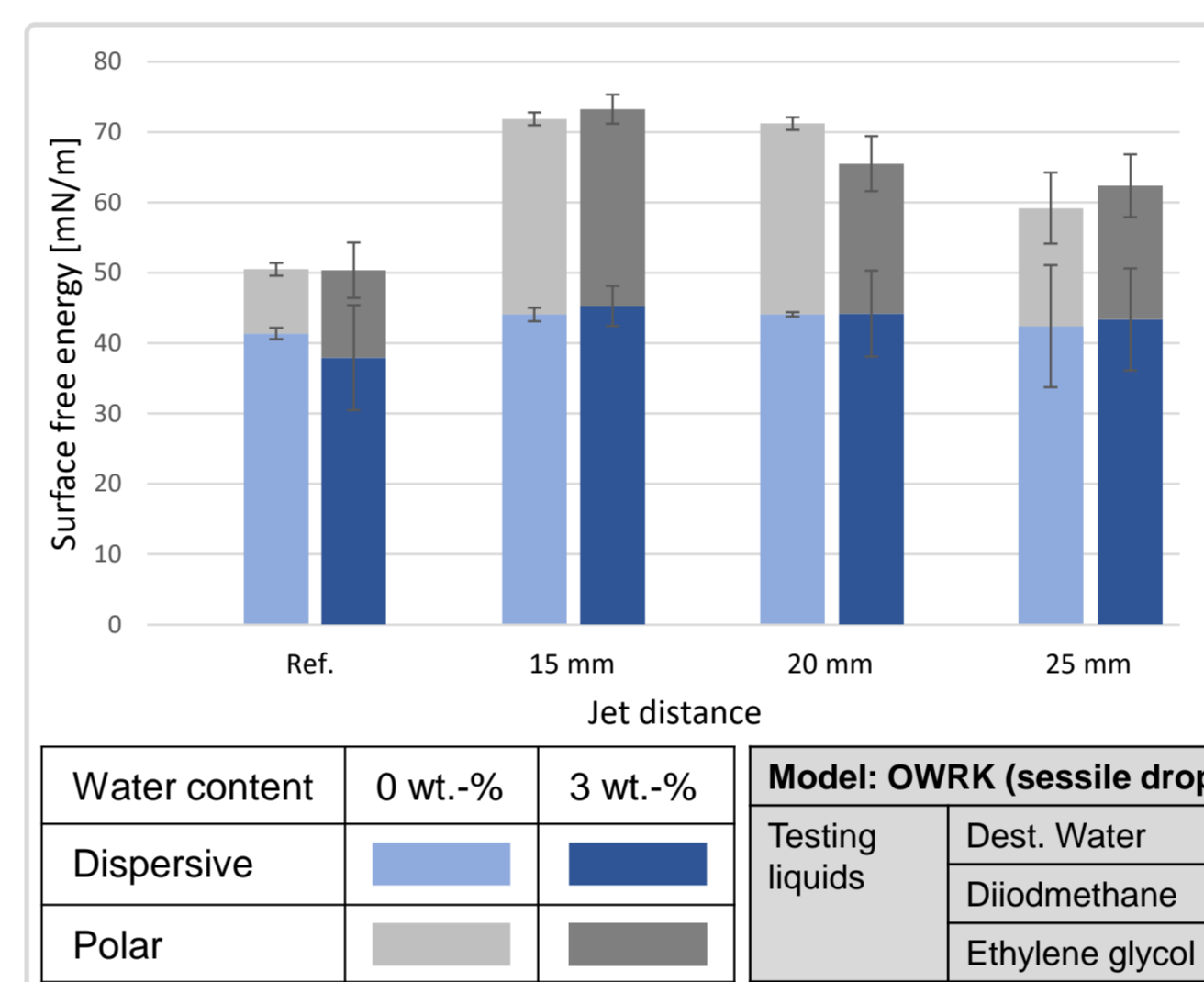
- 2C-PUR (polyurethane) SW DP6330 NS by 3M contains isocyanates
- 2C-MMA (methyl methacrylate) SW DP8910 NS by 3M Low surface energy adhesive developed for polyamides

Mechanical testing

- Lap shear tests according to EN 1465
 - 0.5 mm adhesive layer thickness
- Centrifugal Adhesion Test (CAT) following EN 15870
 - 10 mm stamp diameter
 - 0.5 mm adhesive layer thickness

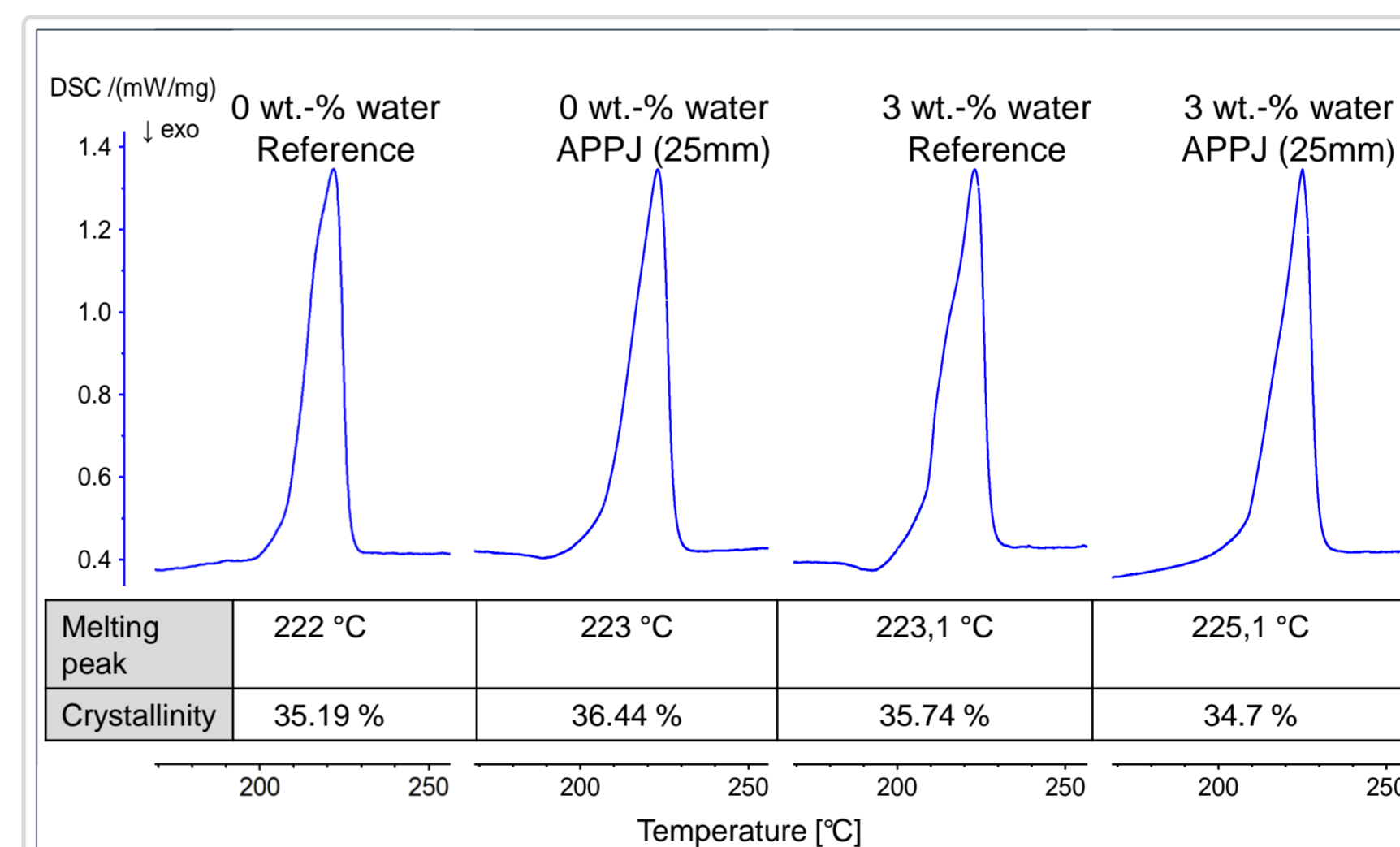


Result: Chemical Analysis



Contact angle measurement

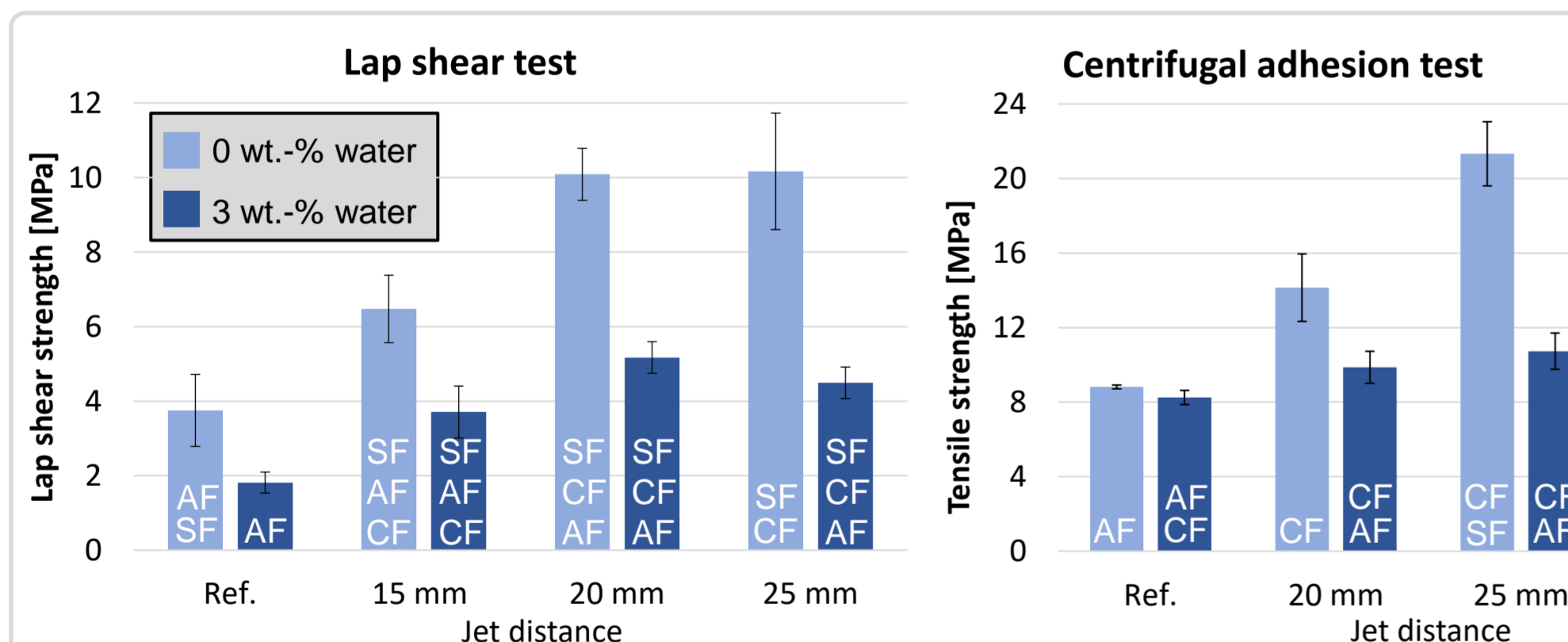
- Polar component increased by APPJ pre-treatment
- Lower jet distance leads to higher polar component
- No significant difference between the different water contents → **no impact of water detectable**



DSC

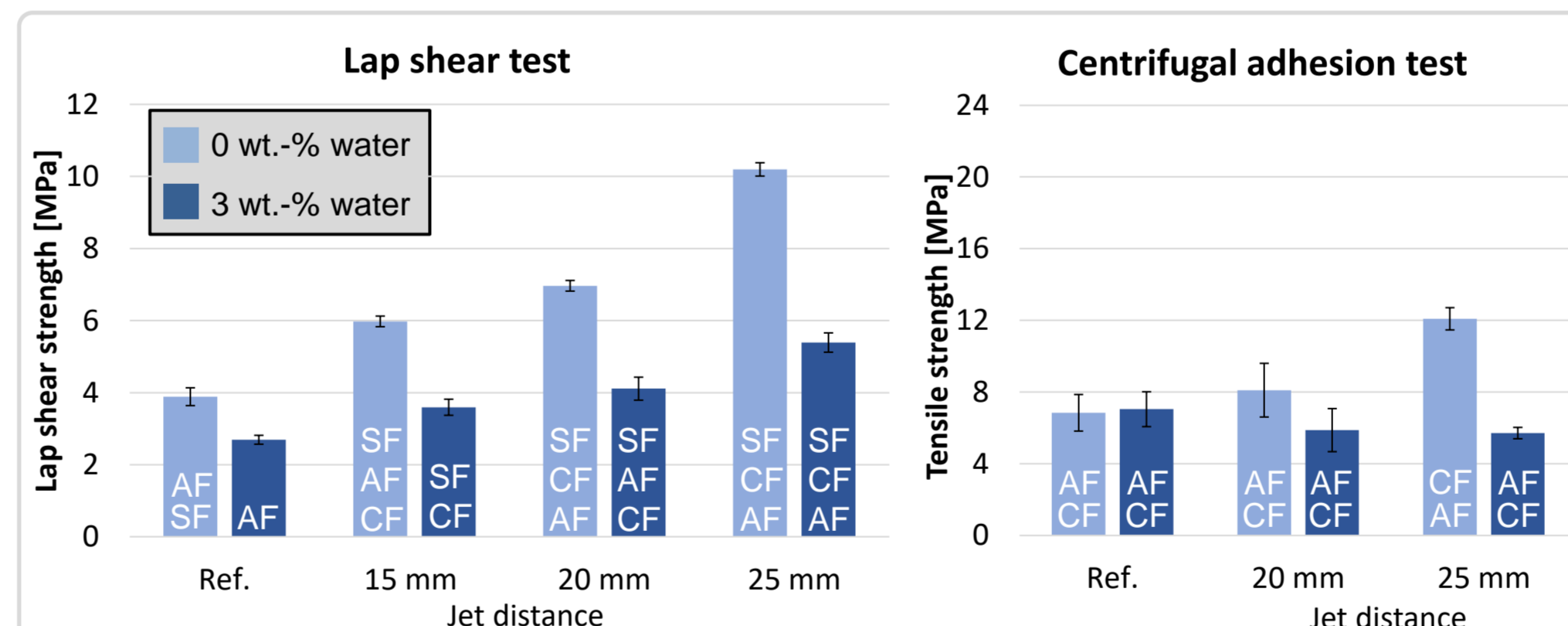
- No significant difference in surface crystallinity
- Slight change in curve shape and increase in melting peak indicate change of crystal phases after treatment

Results: Mechanical Analysis



- Water content significantly impacts bonding strength in both tests
- Inconclusive fracture patterns in lap shear tests due to (partial) SF even at lower forces
- CF at lower forces in saturated material → Isocyanate reacts with water at the surface → Forming of weak boundary layer (see challenges)
- Tensile strength is only minorly improved by APPJ pre-treatment in saturated samples
- Water majorly affects the bonding strength**

PUR adhesive 3M SW DP6330NS



- Material properties affect measured lap shear strength due to major bending of the samples → Material limit around 10 MPa
- Water content does not impact initial tensile strength, but impacts the APPJ pre-treatment
- MMA adhesive bonding strength is limited due to cohesive strength of the adhesive
- No reaction of adhesive components → **Water majorly affects the effectivity of APPJ pre-treatment**

MMA adhesive 3M SW DP8910NS

Summary

- Water content affects bonding strength** by reacting with adhesive components (isocyanates) and **interfering with adhesion**
- Influence of water is **not detectable by contact angle** measurement or in crystallinity
- Surface energy did not correlate with bonding strength
- Drying necessary for structural bond

Outlook

- Definition of tolerable level of water content in material → economically feasible processes
- Process adjustments, monitoring & control regarding water content



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