





Adhesion and Damping in Skis Revisited

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Outline



Background

Inspiration

Case study: adhesion

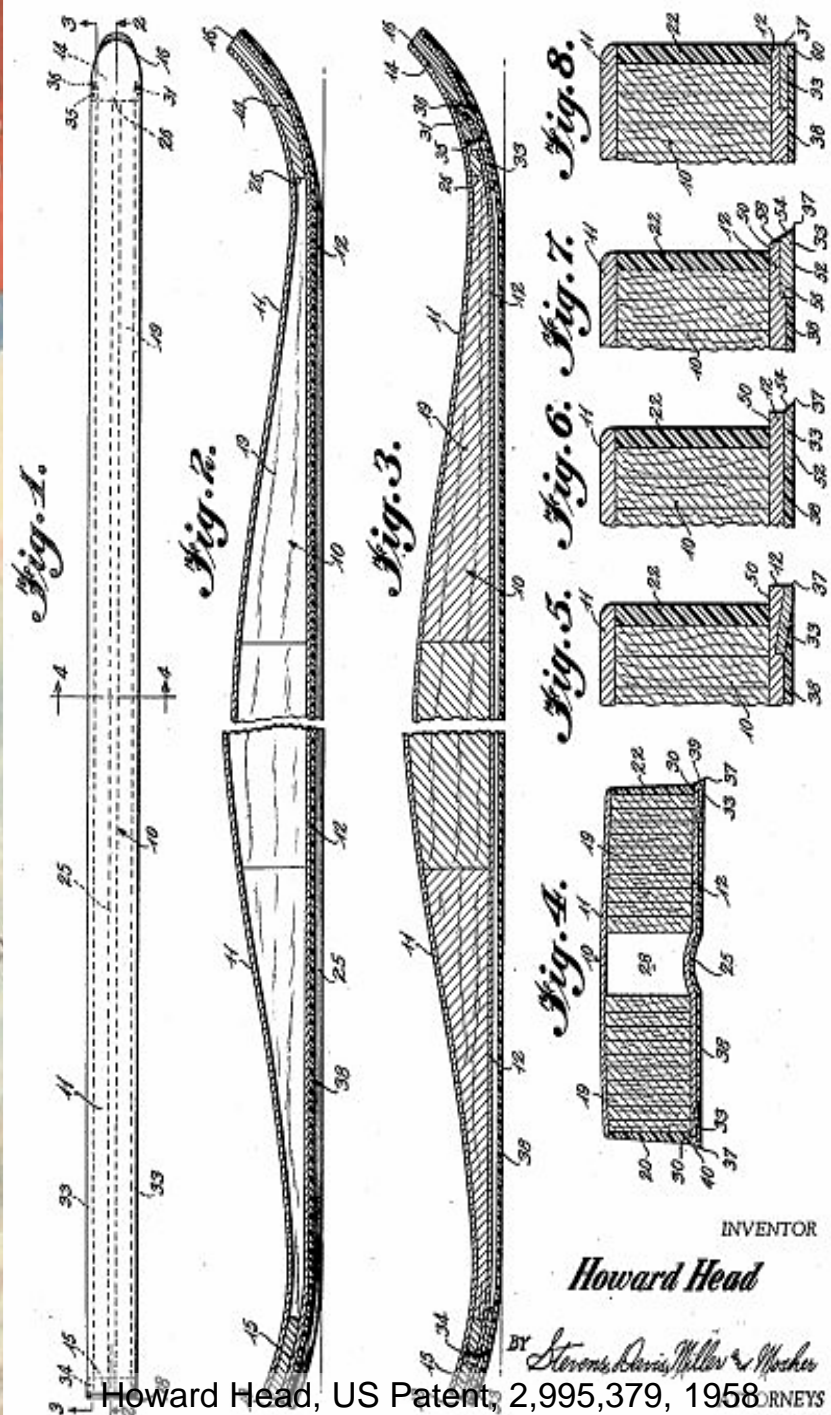
Case study: damping

Outlook





Olympic winter games ad, St. Moritz, 1948



Anavon, ski factory, 2022

Background

Ski manufacturing process



Manual assembly



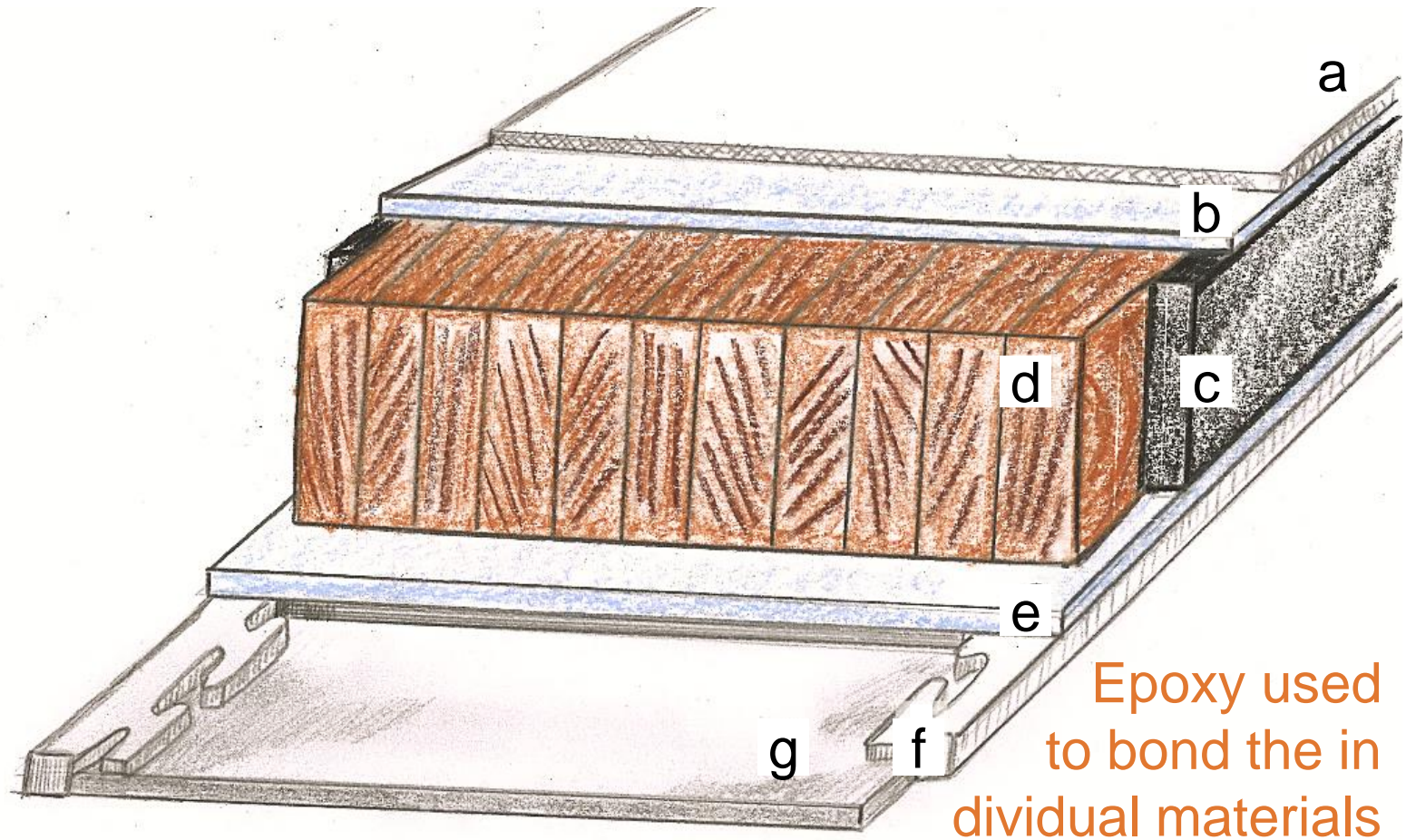
Ski press

Background

Ski layout and materials



- a) CoPA top sheet
- b) Aluminum top chord
- c) ABS sidewall
- d) Wood core
- e) Aluminum bottom chord
- f) Steel edge
- g) UHMWPE running surface



Epoxy used
to bond the in
dividual materials

CoPA: copolyamid

ABS: acrylonitrile-butadiene-styrene

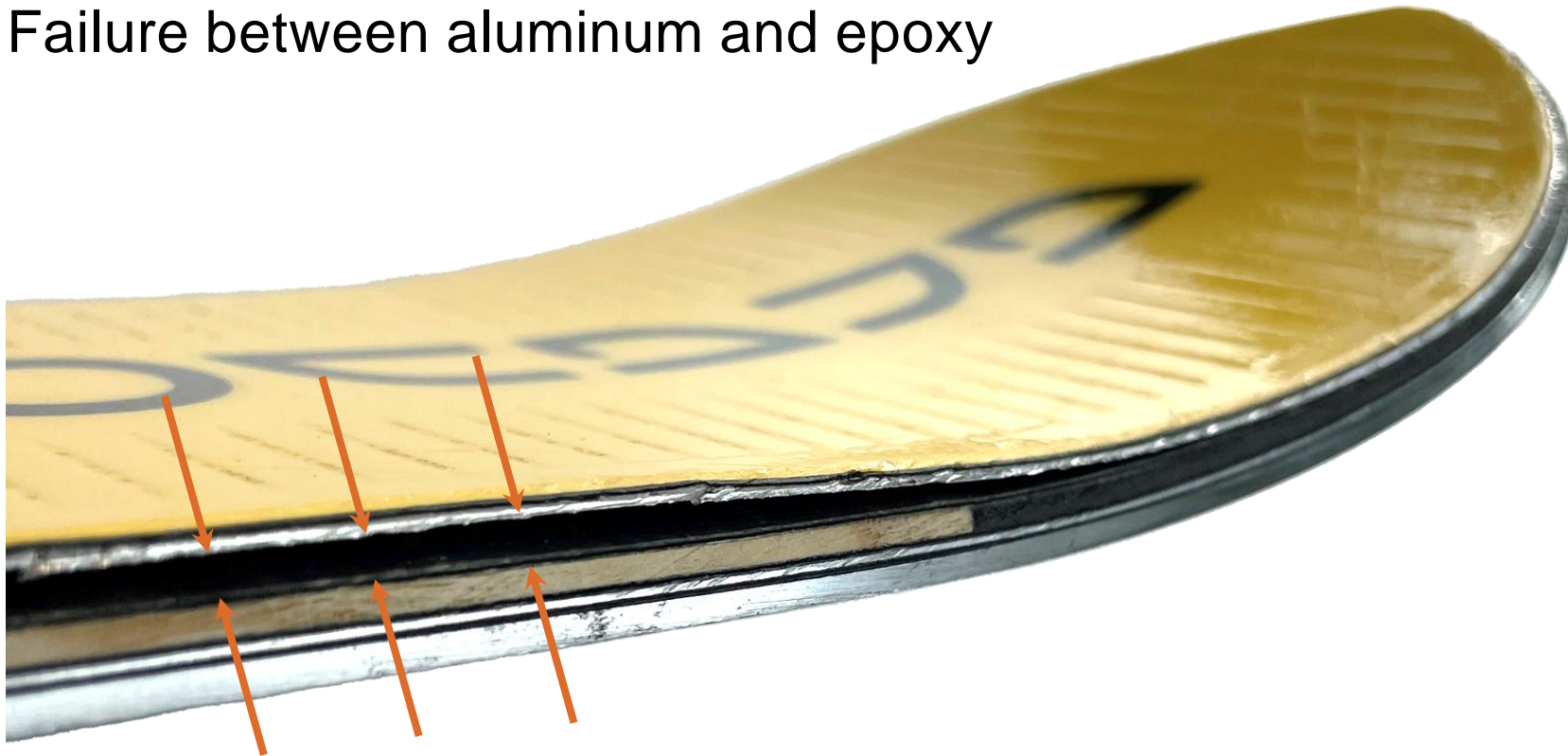
UHMWPE: ultra-high molecular weight polyethylene

Issue

Delamination



Failure between aluminum and epoxy



Typical delamination failure in skis



Outline



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Case study: damping

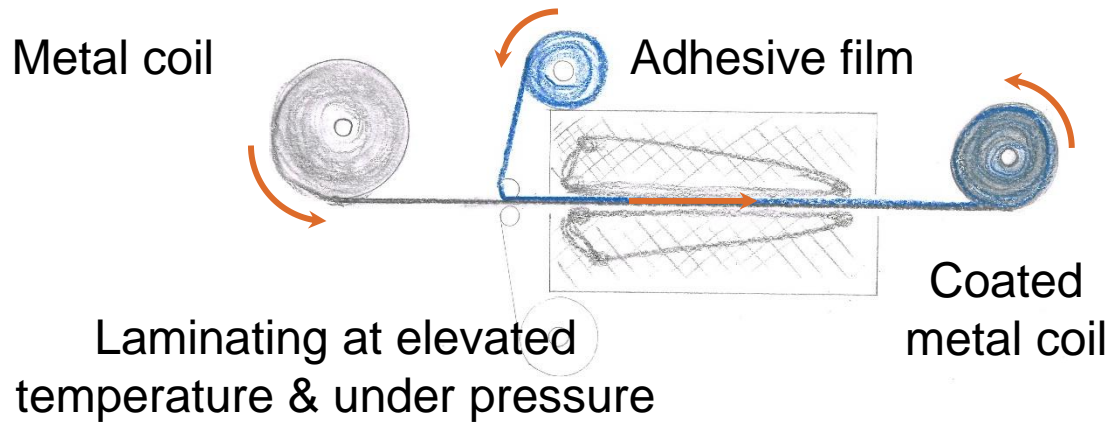
Outlook

Inspiration

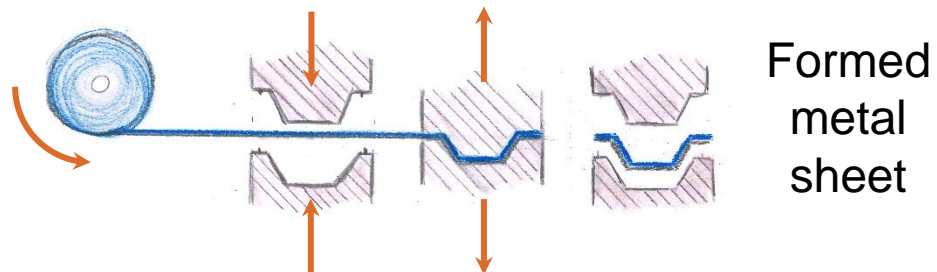
Metal rear injection molding



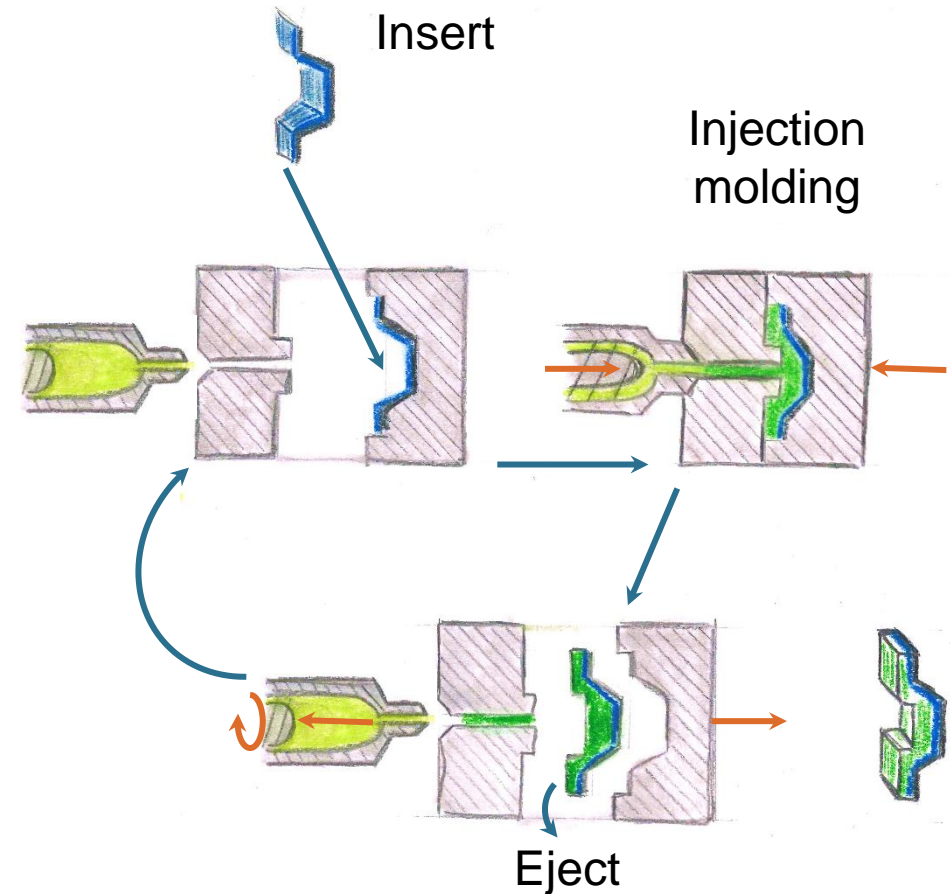
Step 1: coating



Step 2: forming & stamping



Step 3: rear injection



Inspiration

Metal rear injection molding



BMW X4 door line



Outline



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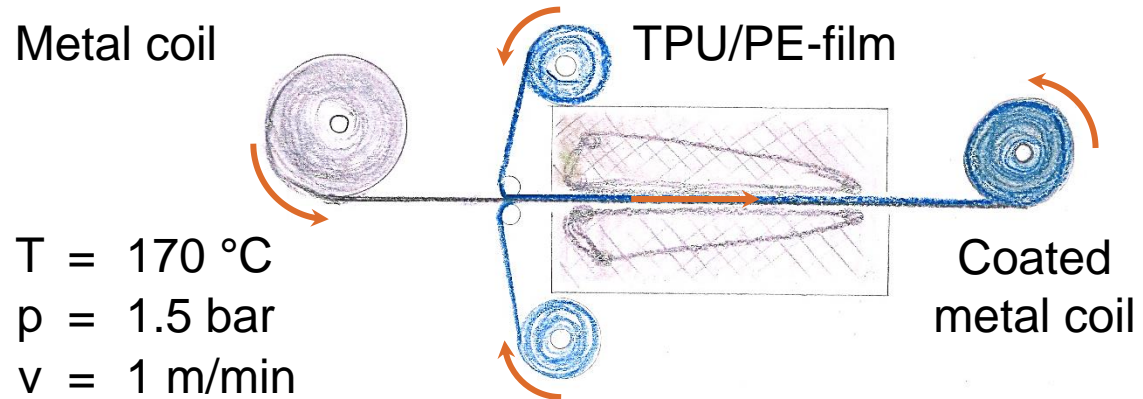
Outlook

Case study: adhesion

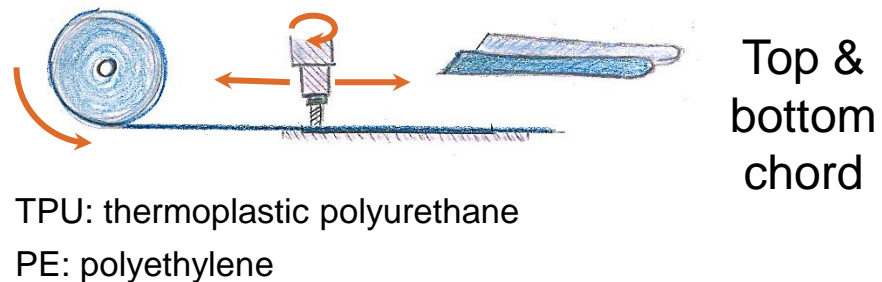
From automotive to skis

Step 1: coating

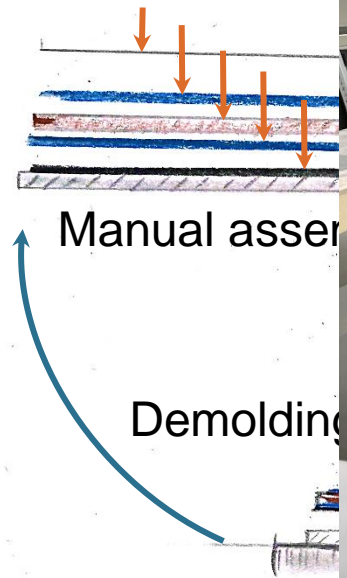
Metal coil



Step 2: shaping



Step 3: ski manufacturing

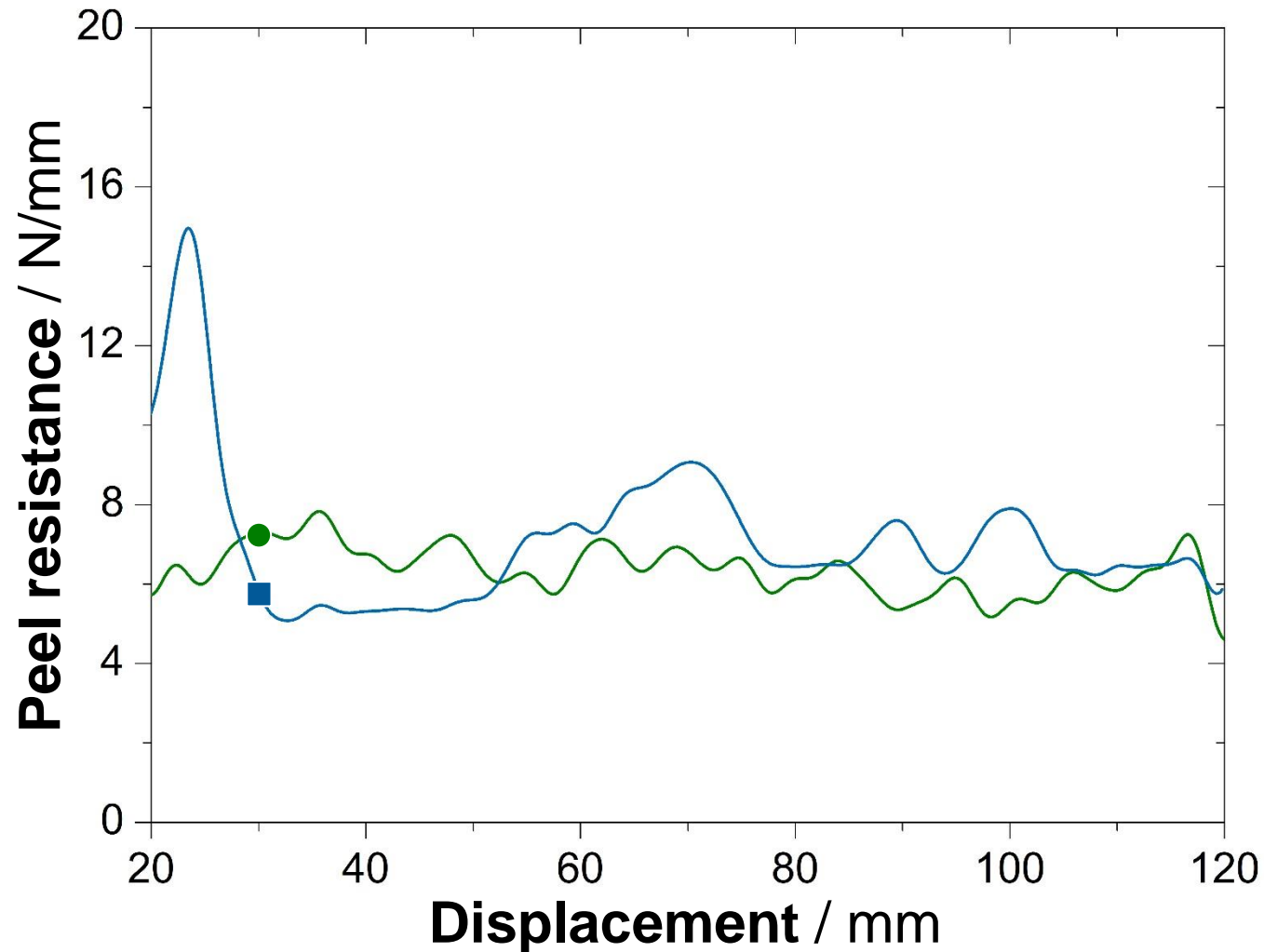


Case study: adhesion

TPU/PE-film coated aluminum



5 cm



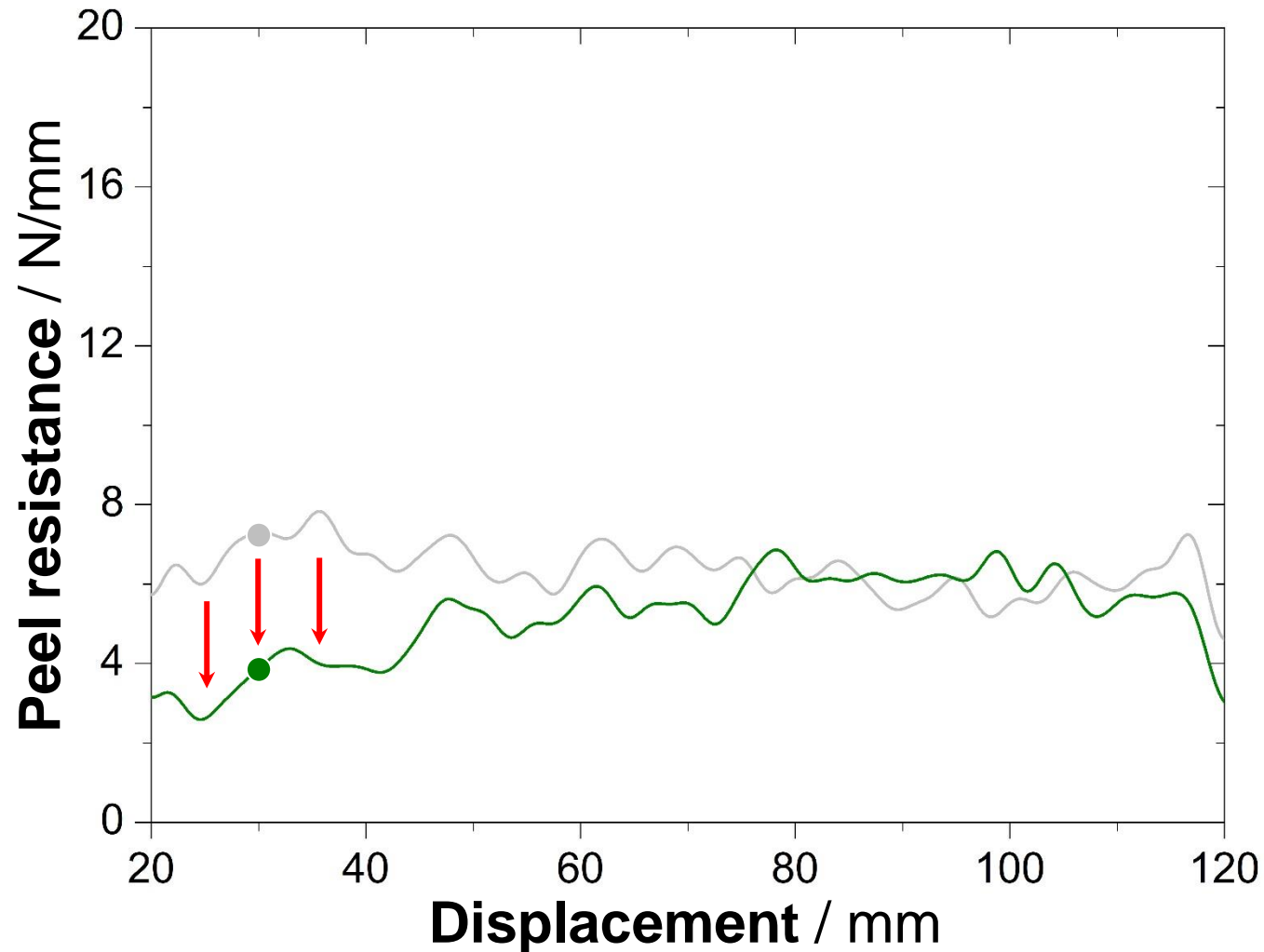
Initial:

- aluminum used as delivered
- aluminum coated with TPU/PE-film

➤ Highest peel resistance with TPU/PE-film

Case study: adhesion

Peel resistance after alternating climate test (ATC)



Initial:

—●— aluminum used
as delivered

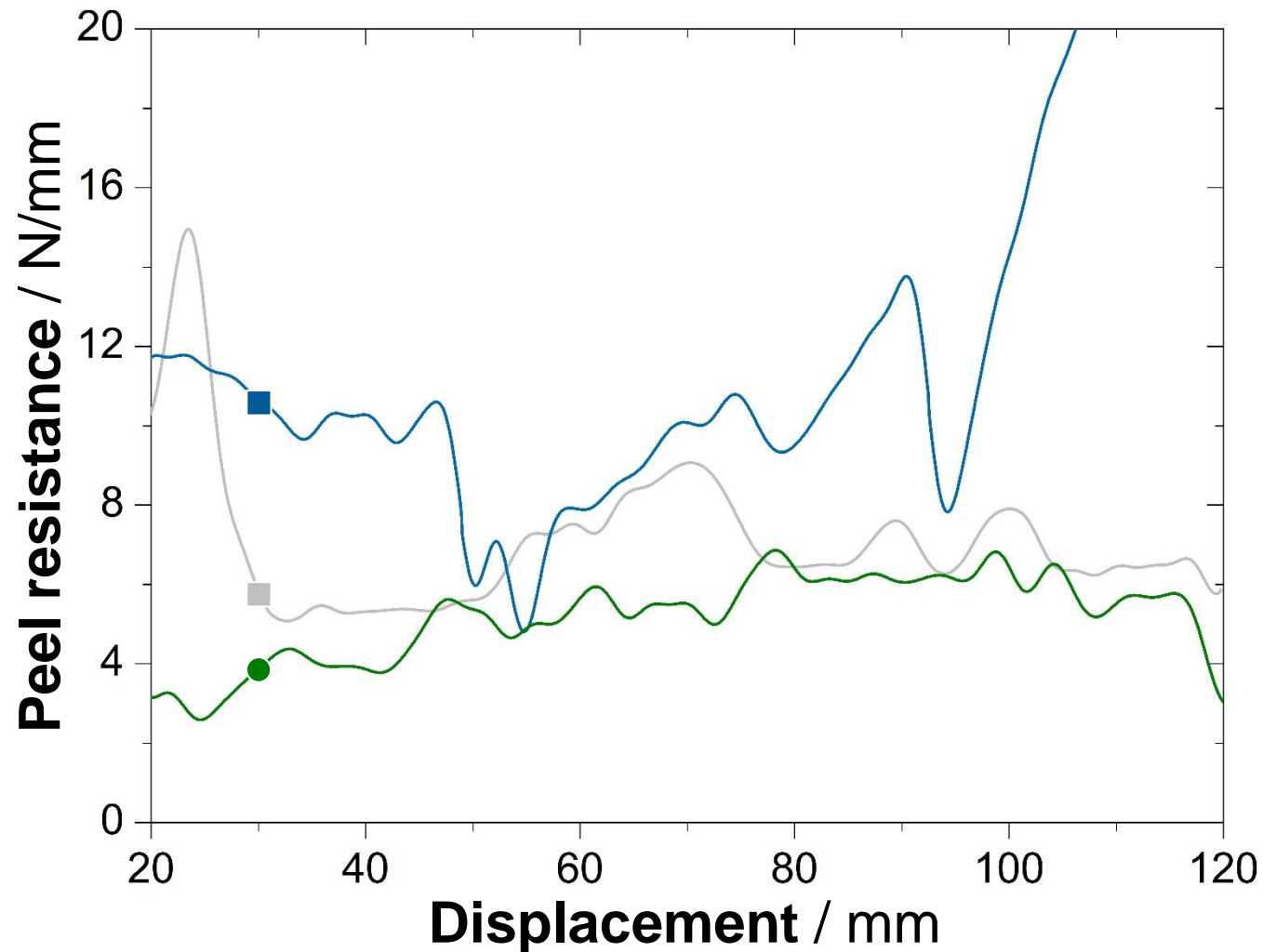
After ACT:

—●— aluminum used
as delivered

➤ Lower peel
resistance values
at start after ACT

Case study: adhesion

Peel resistance after alternating climate test (ATC)



Initial:

—■— aluminum coated with TPU/PE-film

After ACT:

—●— aluminum used as delivered

—■— aluminum coated with TPU/PE-film

➤ Highest peel resistance with TPU/PE-film

Case study: adhesion

Conclusions



- Reliable bond to aluminum in skis
- No change in design or manufacturing process
- Cost benefits:
 - No time-consuming pretreatments
 - Failure rate due to delamination reduced from up to 30 to 0%



Outline



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Case study: damping

Outlook

Case study: damping

Why is vibration damping important?

Slope irregularities can cause vibration and significantly impact ski performance and control.

How do ski manufacturers reduce vibration?

- Weight
- Stiffness
- Damping materials/devices



Figure 1. Preparing the recorder.



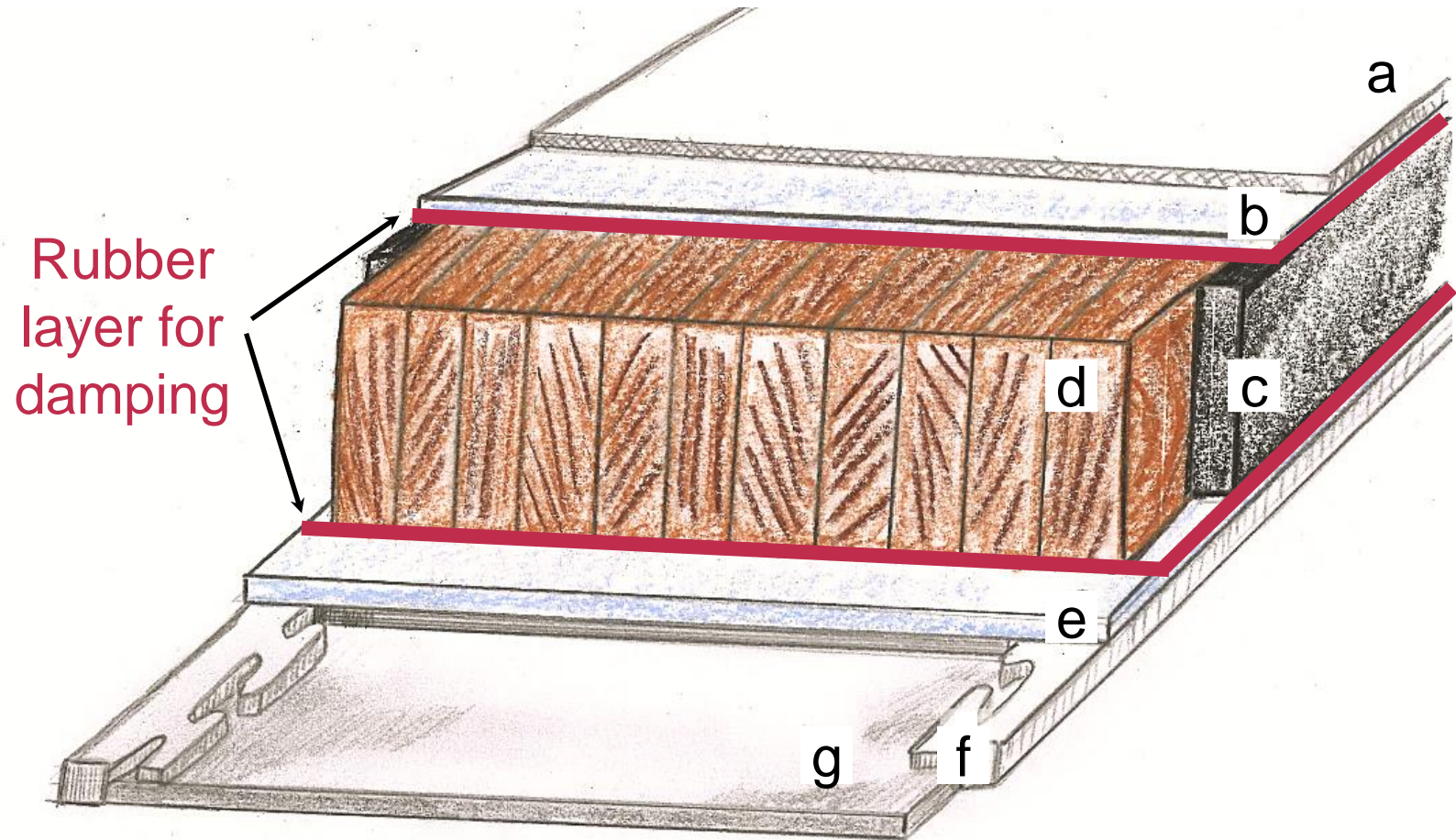
Figure 2. Ski testing.

Case study: damping

Rubber layer for damping



- a) CoPA top sheet
- b) Aluminum top chord
- c) ABS sidewall
- d) Wood core
- e) Aluminum bottom chord
- f) Steel edge
- g) UHMWPE running surface



CoPA: copolyamid

ABS: acrylonitrile-butadiene-styrene

UHMWPE: ultra-high molecular weight polyethylene

Case study: damping

Bending vibrations according ISO 6267



Bending vibrations at 0 °C:

- Laboratory multi-material laminates
- Prototype skis

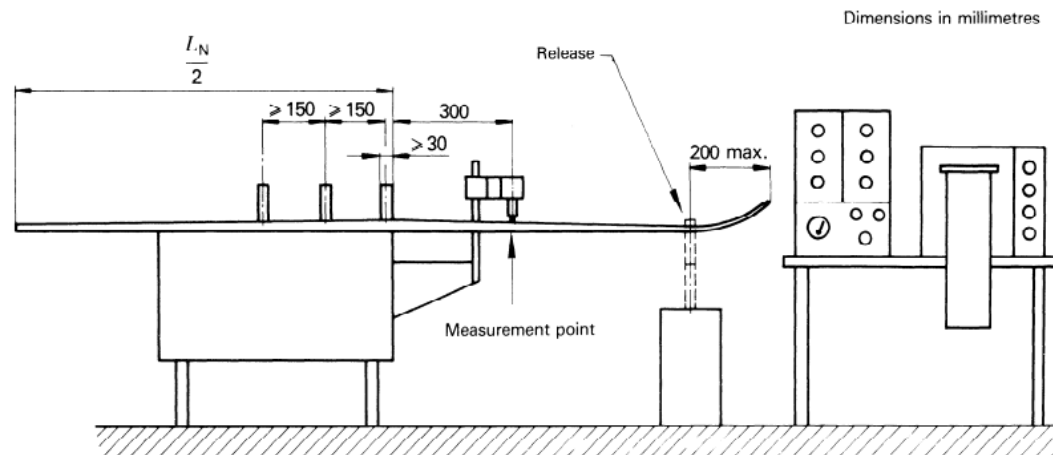
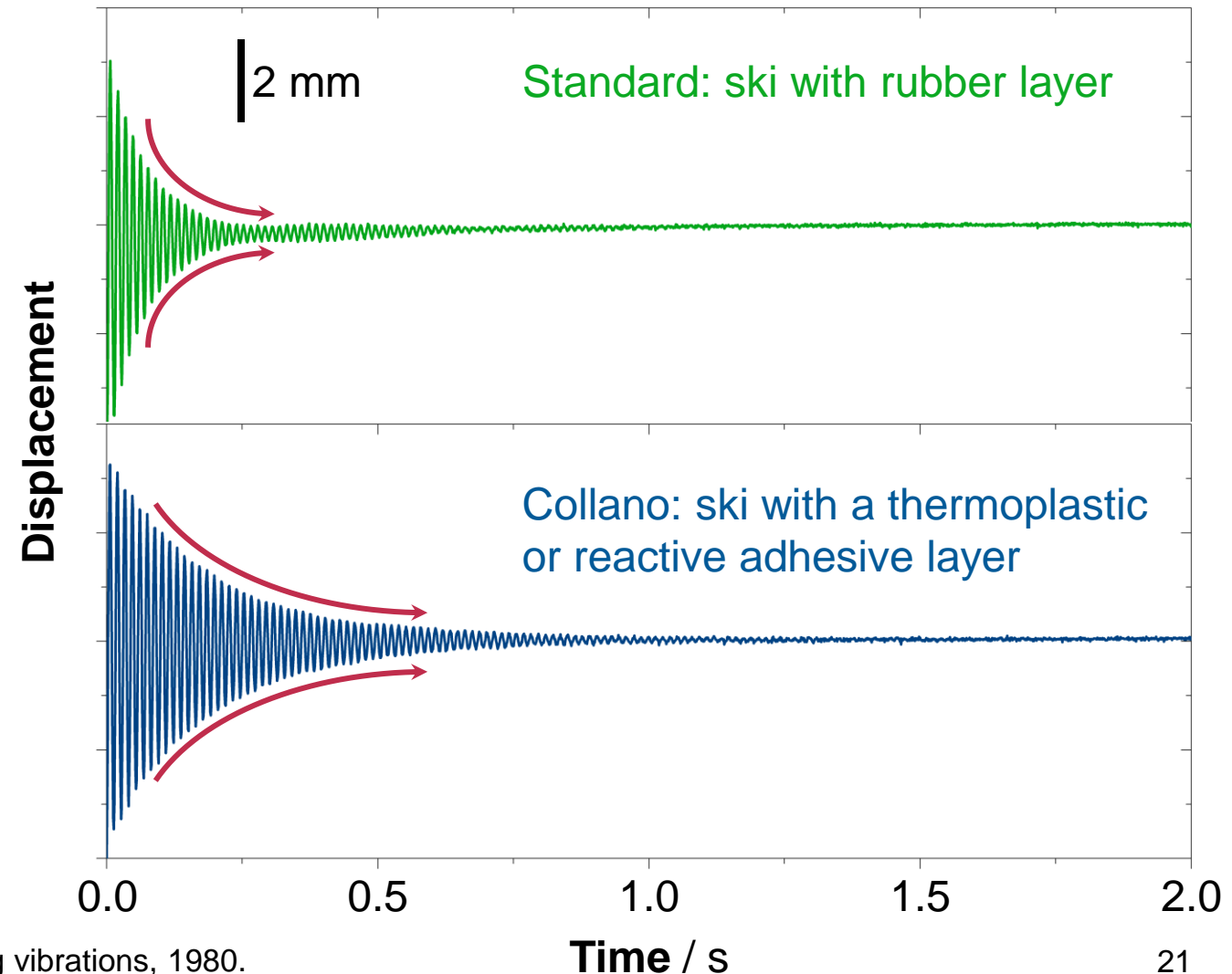


Figure 1 — Test apparatus



Case study: damping

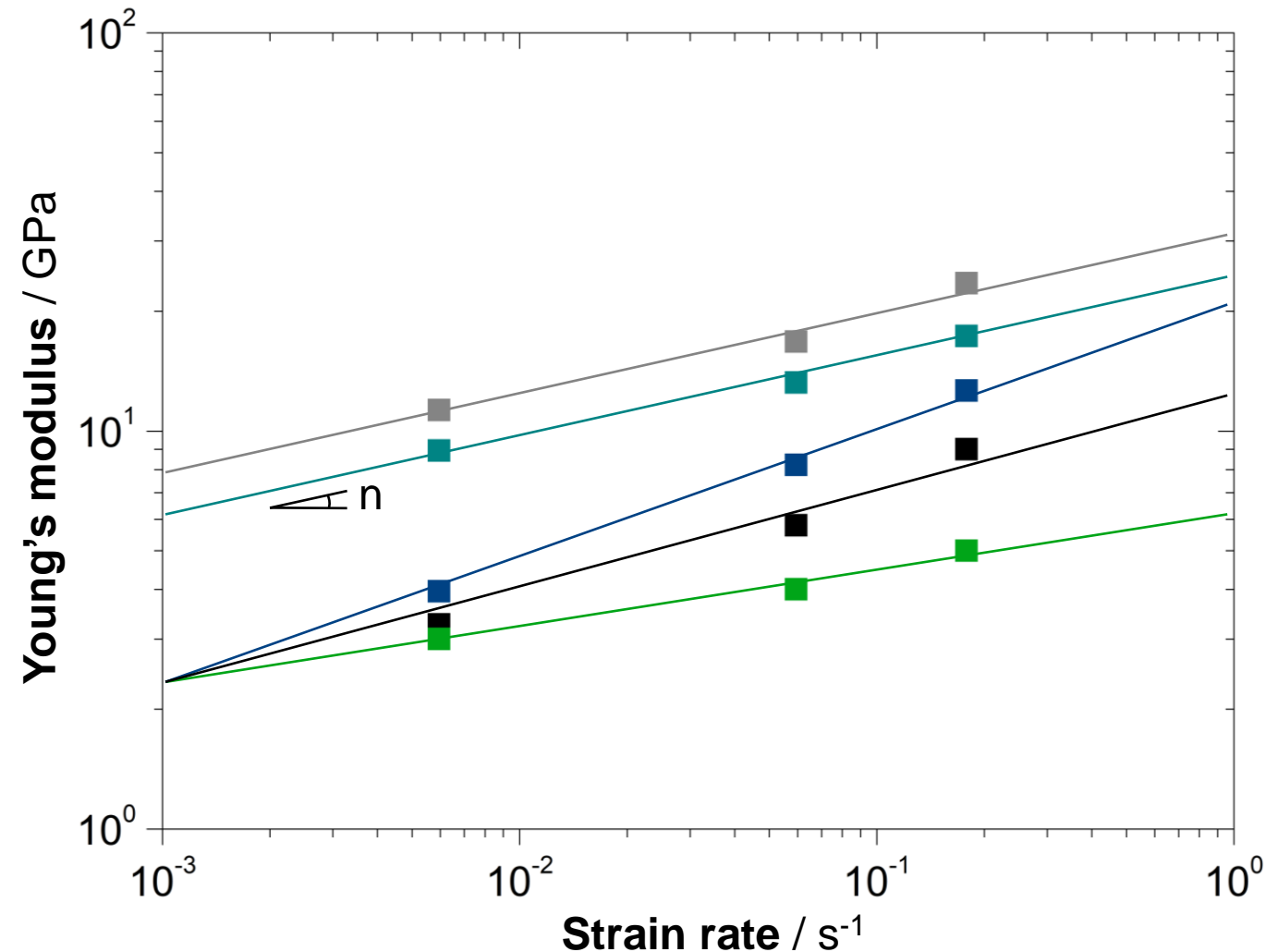
Strain-rate sensitivity



Strain-rate studies reflect feedback from skier' interaction on ski slope.

4-point-bending test at 0 °C:

Ski sample	Strain-rate coefficient n / -
■ Standard with rubber	0.1432
■ Collano "Boost I"	0.2909
■ Collano "Boost II"	0.3382
■ Collano "React I"	0.1913
■ Collano "React II"	0.2089



Case study: damping

Conclusions



- The adhesive dramatically influences the vibration behavior of the ski
- Skiers rate skis with Collano “Boost” & “React” better compared to those with rubber
- Two questions remain open:
 - What makes a good ski?
 - Which laboratory measurements can predict ski performance?



