



Friction behavior of tempo-oxidized nanofibrillated cellulose and its composites

Rowena Crockett, Sefora Riillo, Gilberto Siqueira, Empa

Endre Fülöp, Furka

Vesa Kunnari, VTT



TAPPI Nano 2021 Virtual Conference
15-16 June 2021



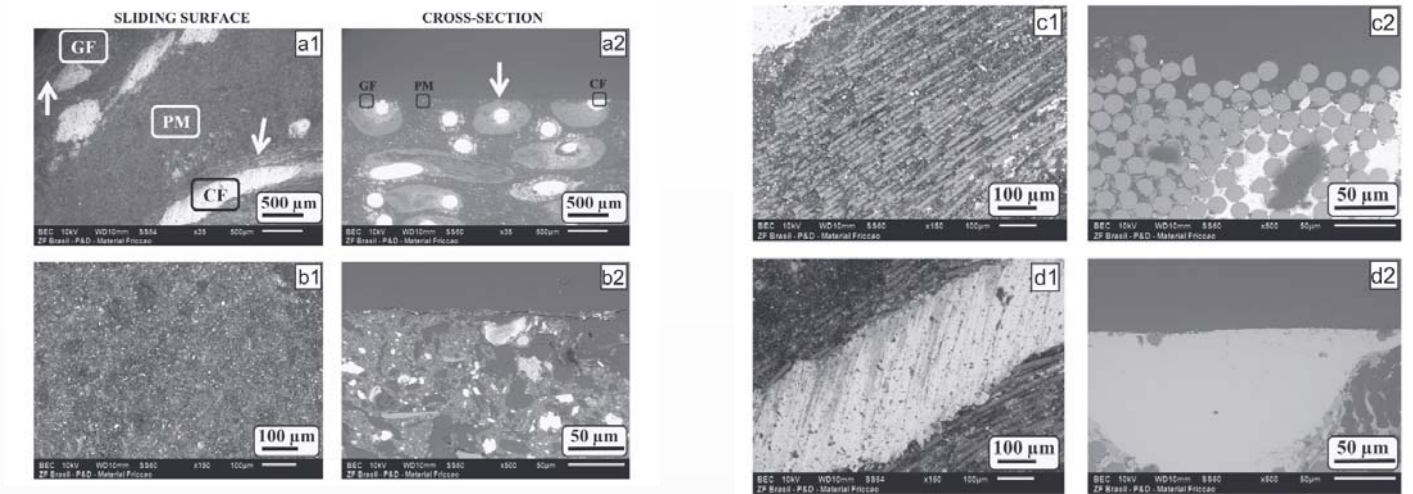
Introduction

Friction Materials



- Friction materials are used in brakes, clutches and transmission elements
- They can contain up to 30 different components
- Friction pads for clutches we developed using Tempo CNF and CNC coated onto cotton
- Important properties are load-bearing capacity, friction, wear, fading

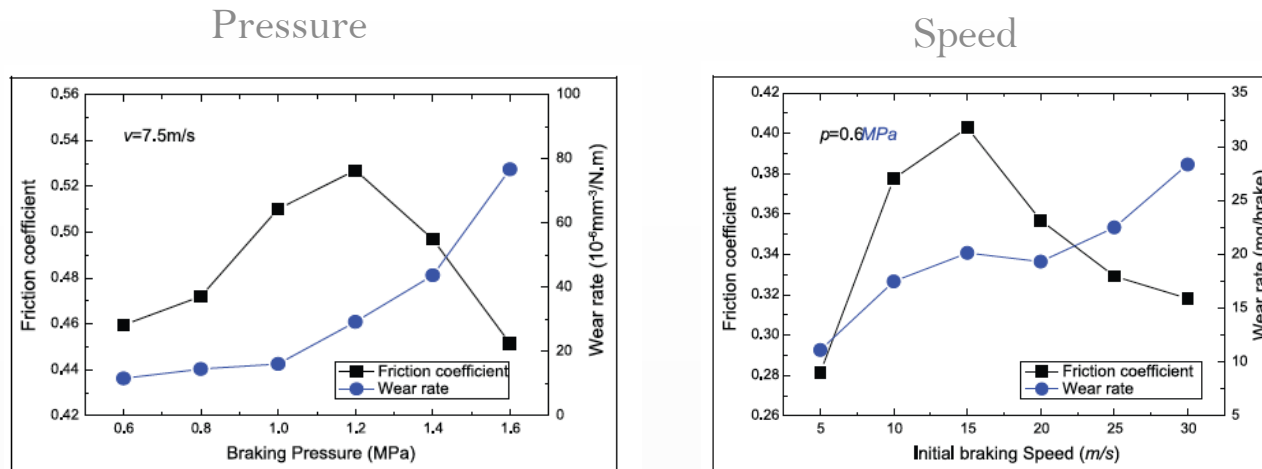
Braking Materials



- materials presently used: cellulose, carbon fiber, Kevlar, steel fibers, graphite, molybdenum sulfate, zinc sulfide, iron oxide, copper powder, aluminum silicates, metal carbides, silicon carbide, rubber powder, sea coal, cashew dust and phenolic resin.

G.P. Fernandes, P.S. Zanotto, A. Sinatora Wear 342–343, (2015), 364–376

Non-metallic friction materials-friction behaviour

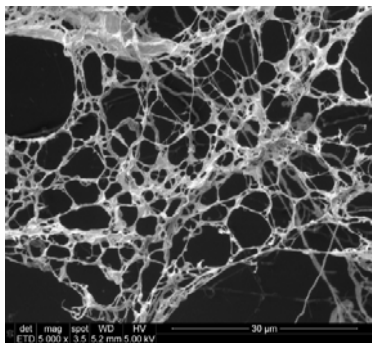


Xingming Xiao et al. Advances in Mechanical Engineering 8 (2016) 1–10

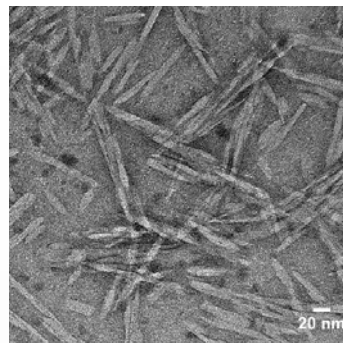
- Measurements of a breaking material with several components
 1. Unstable behaviour
 2. Confused friction with different speed and pressure

Materials and Methods

Materials: Cellulose Composites

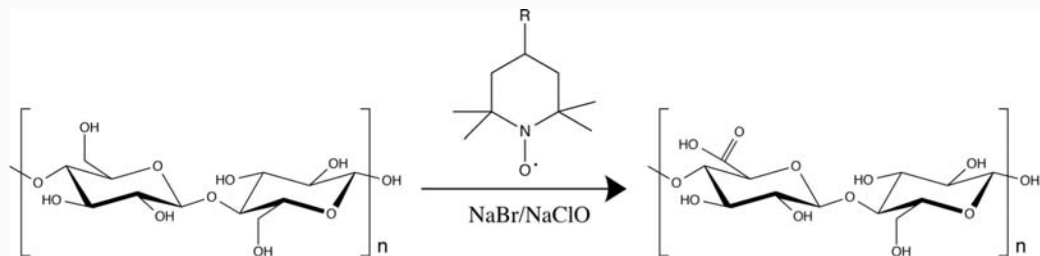


Nanofibrillated Cellulose

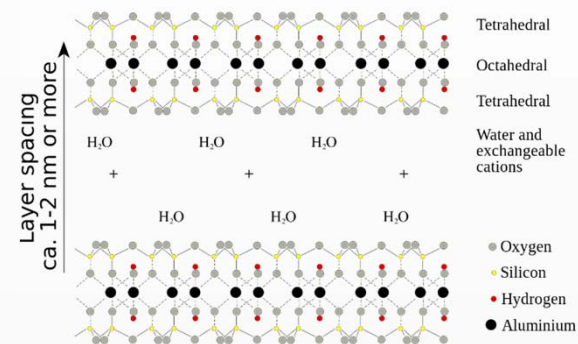


Cellulose Nanocrystals

- New development of NFC-tempo and NFC as main component
- Natural biodegradable mixture
- Montmorillonite and chitosan

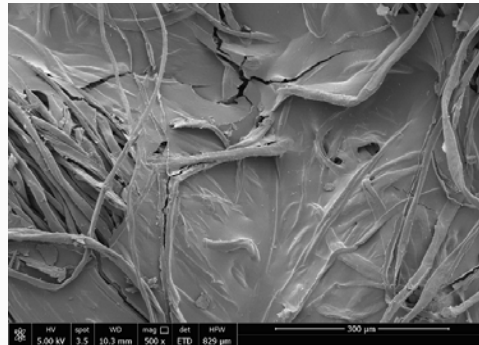
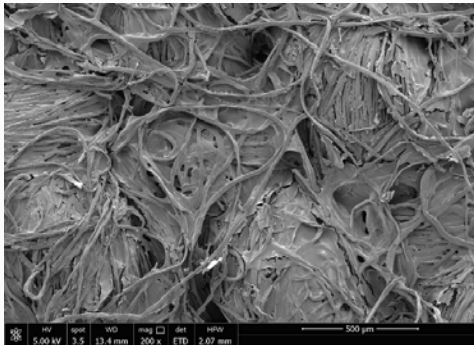


TEMPO-Nanofibrillated cellulose



Montmorillonite

Methods: Coating of cotton



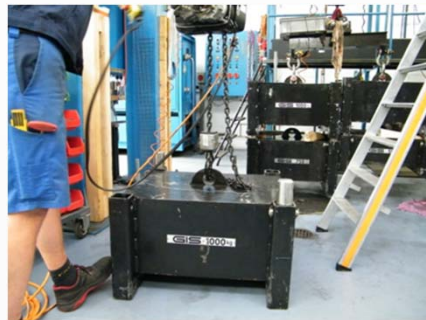
- The mixture of Tempo oxidised CNF, CNC was coated onto cotton using varying processes to increase coverage and impregnation
- SEM images showing the good coverage of one of the two samples

Coating in Cooperation with VTT

Method: Clutch disk



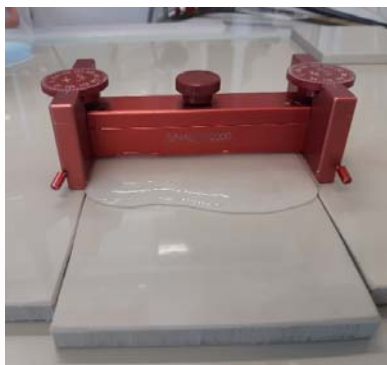
A binder formulation made up of Neuburg clay, phenolresin, nitrile rubber (NBR), and iron sulfide was impregnated into the coated cotton to **improve integrity**.



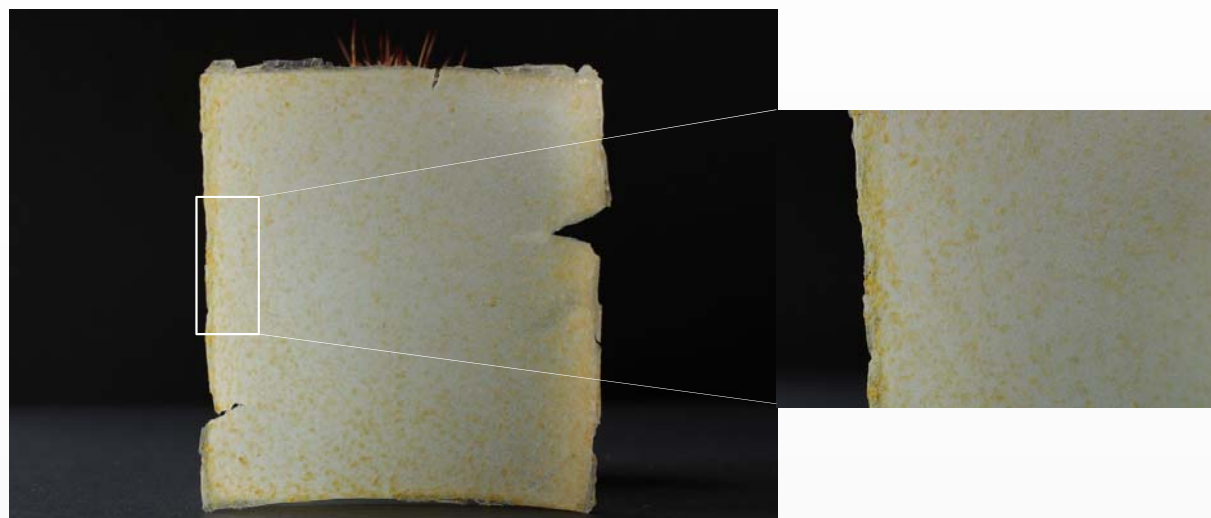
The friction pad was inserted into the **gears of a crane** and a 1'000 Kg of load was applied.

The CNF/CNC coated material was able to hold **24% overload**.

Method: coating Paper



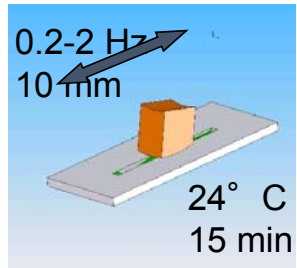
Mixture coated onto metal or PTFE sheets, final product dried at 100 mBar, 30°C at for 24hrs directly before measurement, 200-300 μm thick sheet



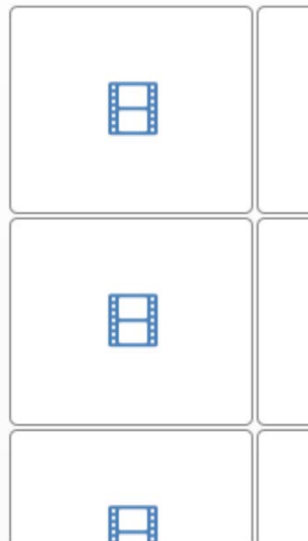
Results: Friction Paper



Result: Measurements on composites

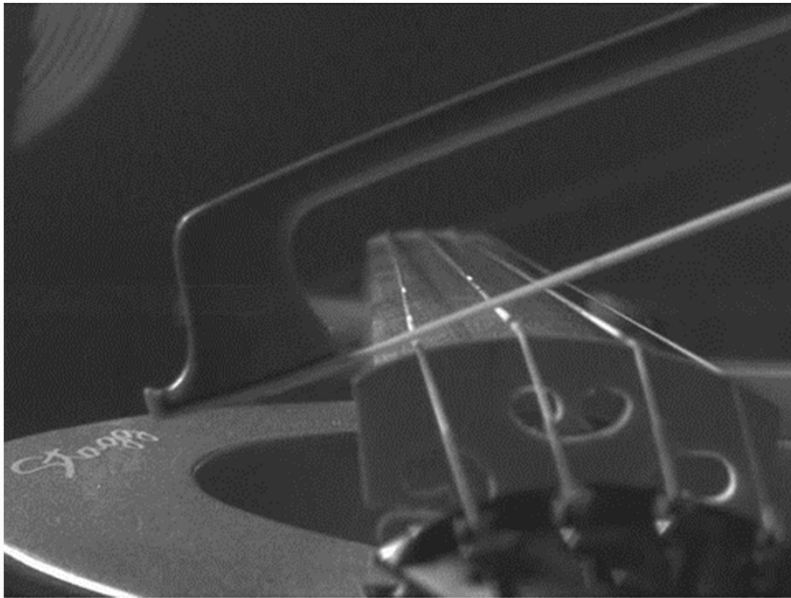


Reciprocating sliding using 4N load on a segment with a radius of 25.4 mm



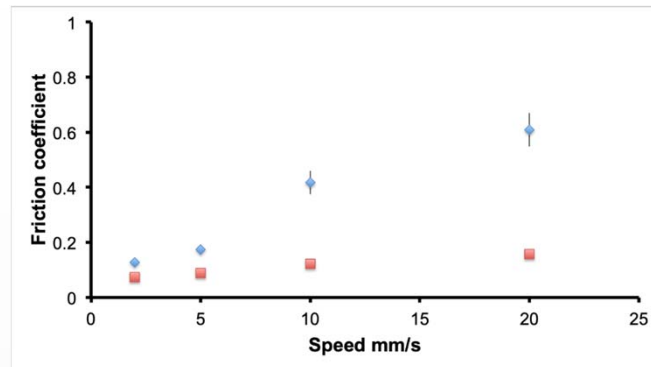
Dynamic mechanical analysis at constant temperature of 27 °C, and 0 or 50% relative humidity

Result: Stick Slip

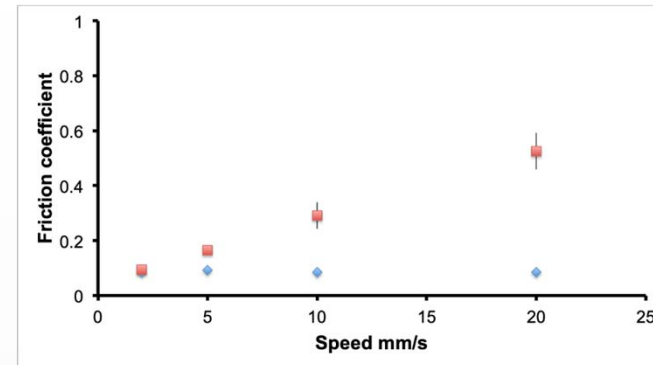


- Stick slip in general is to avoid in every breaking material
- Stick slip comes from the vibration

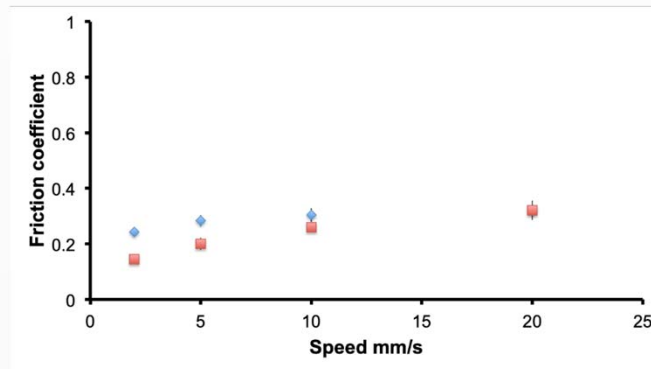
Results: Effect of moisture on friction behaviour



Tempo-NFC, CNC



Tempo-NFC, CNC, MMT

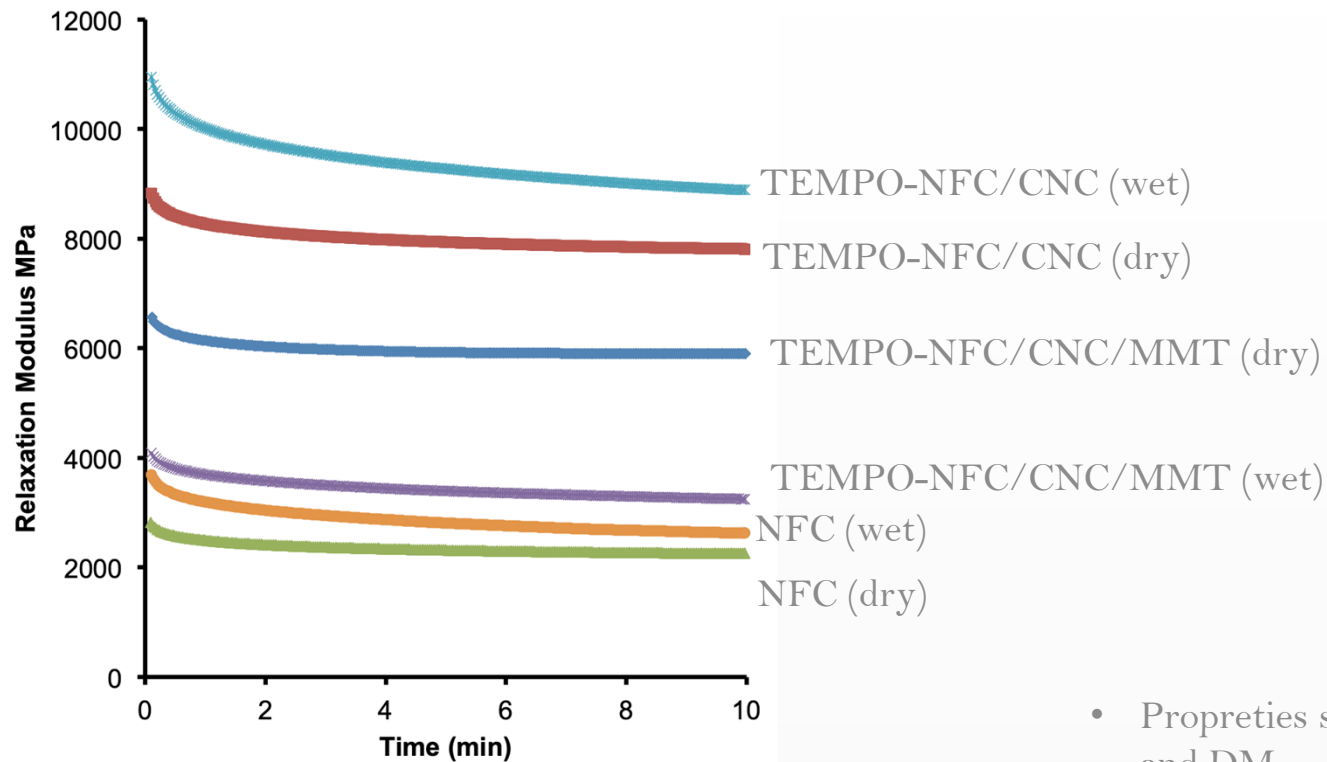


NFC

Dry:  Oven at 100 mBar, 30°C at for 24hrs directly before measurement
Wet:  Equilibrated at 23°C in 50% Relative Humidity

- Adding MMT opposite properties
- Crosslinking

Results: Relaxation Modulus



- Properties showing same results in RM and DM

Results: Hornification

TEMPO-NFC, CNC

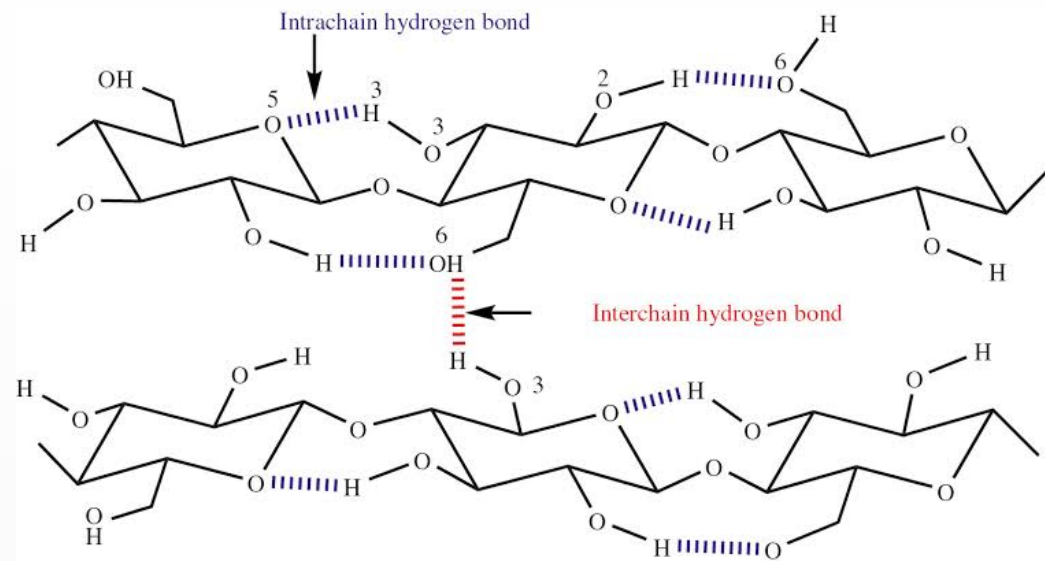
Friction increases when dry,
lower DM (Dynamic Modulus) when dry,
highest RM (Relaxation Modulus), dry 1.0 % wet 3.0 %

TEMPO-NFC/CNC/MMT

Friction increases when wet,
lower DM when wet, 2nd highest RM,
dry 3.4 %-wet 5.9 %

NFC

similar friction coefficients,
lower DM when dry, dry 1.1 % wet 1.90 %

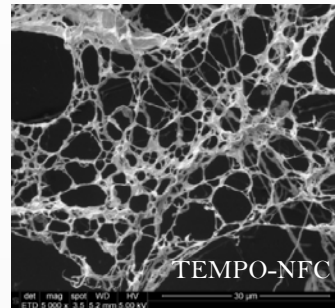


Conclusion

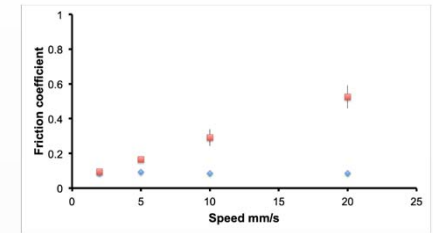
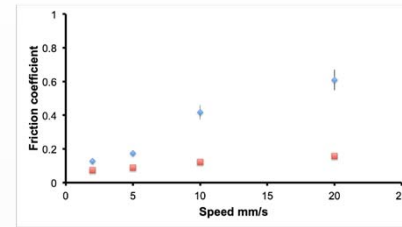
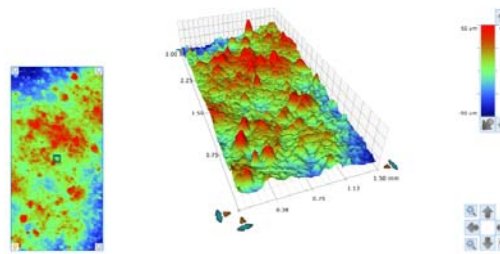
Conclusion: Friction Paper

The fully formulated materials contains four components in addition to the Tempo-CNF/CNC mixture. This is a large improvement on the 20-30 components required to make traditional friction materials.

In all tests required for braking materials, including compression, load carry capacity, friction behavior, and wear, the Tempo-CNF/CNC coated samples showed a significant improvement compared to a reference sample used presently as a friction material.



Profilometer, Surface before Measuring



Acknowledgements



Founding: NO. 760601

Especially:
Tina Künniger
Sigfried Roos
Marcel Rees