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Additive Manufacturing – 3D-Printing of Friction Materials

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Objective

The objective of the work conducted was to show that friction materials can be dispersed in liquid phase and converted into solid state to yield friction materials to be utilized for the manufacturing of brake-friction and clutch-friction prototypes. The targeted means of application is 3D-Printing.

Hypothesis

- Todays friction materials are based on particles dispersed in a phenolic resin matrix.

1. Can a liquid system disperse friction materials in a way that the resulting compound is stable over a defined shelf life?
2. Can those compounds when dried show friction properties which enables it to be used in friction related applications?
3. Can formulations be found which allow the liquid friction materials to be applied by casting, printing or most prominently in 3D-Printing processes?

Project overview

To achieve comparable data with various mixtures a routine program was established:

1. Premixed friction constituents were added under shear conditions to the polymer solution. The resulting compound was allowed to mature for 24 h before further processing.
2. A number of polymers were tested to see whether friction materials can be dispersed in high solid content.
3. Attention to chemical side reactions is needed to achieve stable compounds.
4. Energy intake (shearing) in manufacturing needs to be tightly controlled to avoid early crosslinking.
5. Dried/crosslinked compound needs to undergo friction testing (Krauss-Test; Test for pad assemblies 2012 ECE-R90 Annex 9)

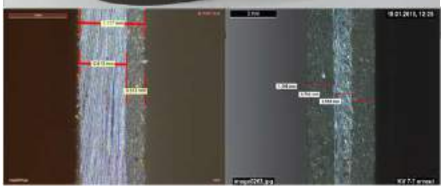
What kind of polymers can be used?

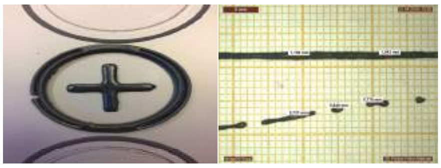
- Based on the initial trials and tests along side other polymers the following polymers have shown promising results:
- Acrylic-Resins
- Epoxy-Resins
- Phenolic-Resins
- Poly-Urethans
- Inorganic-Polymers
- The polymers were dissolved or dispersed in appropriate solvents to allow for coating of the pigments.
- Shelf life tests have been conducted to select most stable compound versions.

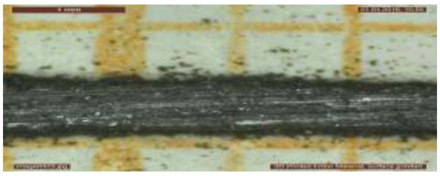
Conditions of Application

1. The compounded viscous liquid friction material composition was poured into a form to:
   1. Learn about the drying characteristics
   2. Have test samples for friction testing.
   3. Have samples for other purposes.
2. The liquid friction compound was poured into die to yield samples of friction prototypes for brake, clutch and others.
3. The liquid friction compound transferred into 1K and 2K cartridges for enabling 3D-Printing

Parts Produced





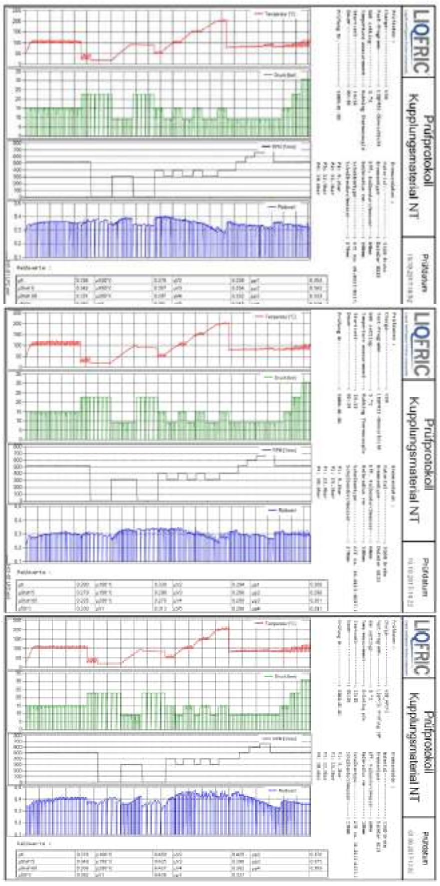


Casting & Printing of Prototypes

- Initially steel plates (190 X 104 mm) were coated with layers of various thickness (400 – 6500 µm) in a casting process.
- For proving processability coated parts were surface ground to receive an active friction surface with layer thicknesses of 300 – 6000 µm for friction testing.
- 3D-Printed parts were tested on Krauss-Tester

Friction Test Results

1. Krauss-Test (µ=f(v), f(T), f(p))
   v=4,7-11,7m/s, T=20-200°C, p=60-200N/cm²
   Test Specimen Size 84 X 52 X 10 mm



Conclusions

1. It can be conclusively shown that liquid friction materials with friction properties in dry state can be formulated.
2. Depending on the polymer matrix, µ-levels of 0,25-0,35 can be stabilized at temperatures below 300°C.
3. Liquid friction materials can be used in 3D-Printing for generating a wide portfolio of geometries on short notice.
4. Based on these promising results industrial partners may be invited to discuss and test liquid friction materials in their field of interest.
5. Some of the above results are Patent protected.

Acknowledgment

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