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Additive Manufacturing – 3D Printing of Friction Materials (2)
Water-based Liquid Friction Compounds

Dr. Milczarek, R. (Presenter); Dr. Wittig, U.; Wittig, N.; Wittig, L.; LF GmbH & Co. KG, Innovationspark Leverkusen, Marie-Curie-Straße 8, D-51377 Leverkusen; INFO@LIQFRIC.COM, WWW.LIQFRIC.COM
DI (FH) Schmied, C.; Tribotecc GmbH Industriestraße 23, A-9691 Arnoldstein; office@tribotecc.at, www.tribotecc.at

Objective

In prior years it has been shown that friction materials can, besides being based on phenolic resins, be created by using other polymer networks. It has also been shown that inorganic polymers may be utilized for this. The objective of this work was to show that dry friction materials can be produced using inorganic polymers in the fluid state. These friction materials can be used for brake-friction and clutch-friction prototypes. The preferred production method is 3D Printing and or die-casting.

Hypothesis

- Quite many friction materials are based on particles dispersed in a phenolic resin matrix to date.

1. Is it possible to use an inorganic polymer to generate a liquid friction compound with stable shelf live?
2. Is it possible to pressure-free die-cast these compounds to become dimensionally stable friction parts?
3. Can these compounds, after drying, exhibit friction properties enabling to survive AK-Master testing?
4. Can formulations be found, allowing liquid friction materials to be applied by casting, printing or, mostly preferred, in 3D Printing processes?

Project overview

To allow for the development of the formulation, a simple DOE was used to understand the effects of various raw materials regarding friction per-formance:

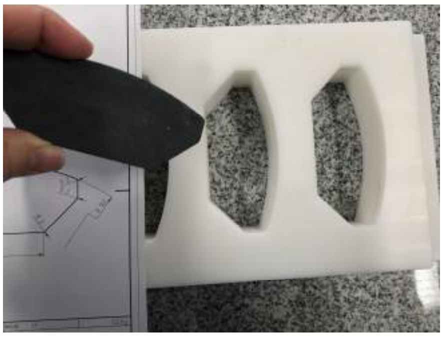
1. A DOE was created using the key raw materials for the compound.
2. A ratio of polymer/filler was tested and defined.
3. A tool was tested for the die-casting process.
4. A curing process was defined to give stable friction pads.
5. The preparation of the test specimen (Golf VI) PCP was defined.
6. Static temperature tests of the friction pad without baking plate was carried out at 600°C/3h.
7. Finished goods to undergo AKM-testing (LINK 2800; AK Master SAE J 2522, Disc GG25).

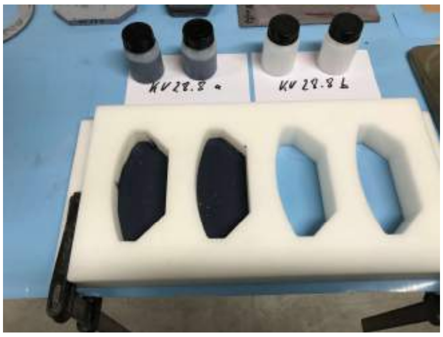
Which implications are to be expected?

- Based on the inorganic and water-based nature of the compounding technology used, a number of potential implications may be foreseen:
  1. Curing can be achieved at temperature below 100°C.
  2. A pressure–free molding process (die-casting, 3D Printing, …) can be used for producing the part.
  3. In pad sensoring will be possible.
  4. A very free design capability of pad shapes will be possible.
  5. A lot size of 1 will be possible and prototyping will be made easily.
  6. No organic decomposition products will be released during manufacturing.
  7. A tempering process will be necessary to drive off water.
  8. NVH due to brittleness may be a critical issues.

Casting and Printing of Prototypes

1. A mold (Golf VI contour), was prepared based on an industrial polymer.
2. The compounded highly viscous liquid friction material was poured into a form.
3. Curing at room temperature, slightly exothermic.
4. Brake pad finish for friction testing by adhering the cured sample to the backing plate.
5. Grinding the surface for appropriate planarity for testing.





The above pictures show the production process starting with the drawing, the mold and the casted friction pads being glued to the backing plates. (The video showing the die-casting process can be seen at booth #30 at Eurobrake).

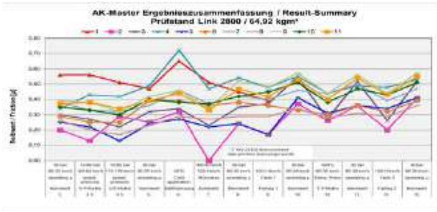
For further testing the liquid friction material was transferred into 1K cartridges for enabling 3D Printing. Besides the above described procedure for automotive brake applications, samples can be produced for a range of friction applications, including bicycle pads and clutch facings. Bicycle pads have already been produced and tested.

Friction Test Results

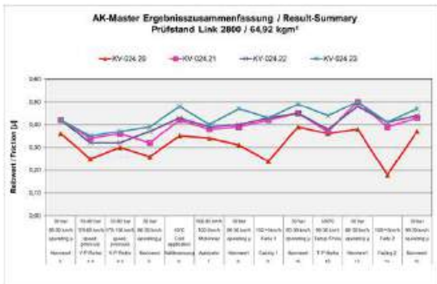
1. sDOE with key ingredients for friction compound
2. Friction testing LINK 2800, AK-Master SAE J2522, Disk GG25

sDOE for inorganic polymer friction compounds LIQFRIC®HP

Versuchsnummer	An.Pol.+Fiber	Petrolcoke	Filler + Abrasive	MS 1	MS2	MS3	MS4	MS5	St	Vers
1	x	-	-	-	-	-				KV
2	x	x	-	-	-	-				KV
3	x	x	x	-	-	-				KV
4	x	-	-	x	-	-				KV
5	x	x	-	x	-	-				KV
6	x	x	x	x	-	-				KV
7	x	x	x	-	x	-				KV
8	x	x	x	-	-	x				KV
9	x	x	x	-	-	-	x		(x)	KV
10	x	x	x	-	-	-	-	x	(x)	KV
11	x	x	x	-		x			x	KV



Optimizing performance charakteristic of pads



Conclusions

1. It could be shown that liquid inorganic friction compounds with excellent friction properties can be found.
2. Depending on the polymer matrix, stable µ-levels up to 600°C can be achieved.
3. Some materials generated noise during AKM testing, room for improvement.
4. Liquid friction materials can be used in die-casting, enabling for a wide geometrical portfolio even in a lot size 1.
5. In view of changing market requirements (autonomous driving, electric vehicle braking,…), we see a potential for utilization in the friction brake market.
6. First tests on bicycle brakes show good results.
7. Some of the above results may be patent protected.

Based on these promising results, industrial partners are kindly invited to discuss and test our liquid friction materials in their area of interest.

Acknowledgment

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