Investigation of friction surfaces during a preconditioning process concerning the behavior of surface parameters and friction coefficient stability

Rüdiger Fehrenbacher[1)*], Arn Joerger[1)], Katharina Bause[1)], Sascha Ott[1)], Albert Albers[1)]

1) IPEK – Institute of Product Engineering at Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

*Corresponding author: ruediger.fehrenbacher@kit.edu

1. Introduction

The demand for compact clutch and brake systems is increasing. These systems fulfill safety- and reliability-relevant functions, for example, in machine tools, production lines, mining, and especially in passenger transportation division. Furthermore, clutch and brake systems must fulfill high requirements in energy conversion by wind power, wastewater, or medical technology. For a safe and reliable operation, stable behavior over a working life is an essential aspect of reliability. Factory-new friction combinations, in particular, are exposed to tolerances due to manufacturing tolerances, storage and transport, and the surrounding construction, which makes preconditioning processes essential from a functional point of view. However, the evaluation of such processes is generally indicated only unclearly by evaluations based on friction coefficient curves over various types of energy input into the friction pairing. Standardization exists neither for the type and amount of energy input nor for the evaluation of successfully completed preconditioning.
In the latter case, the evaluation of the progression of friction coefficient and its approximation to a constant value over numbers of circuits has become established. That, however, without the knowledge of the mechanisms behind it. This research aims to take a first step towards investigating the processes happening on friction surfaces during preconditioning. We drew the correlations of friction coefficient, topology changes, and the calculated values of surface parameters by analyzing the friction surfaces of several system variants under different load collectives during a typical preconditioning process.

2. Infrastructure of Measurement and testing, methodology

We used a test environment at a test bench of the IPEK – Institute of Product Engineering for preconditioning during this research work. In addition to a rigid structural design, all sensors are positioned near the friction contact to minimize measurement errors. An electric machine converts electrical energy into rotational energy. Coincident a mass inertia simulation controls the rotational speed. We analyzed the friction surfaces using a white light interferometer during the preconditioning process in specific time steps. The collected Data on this instrument builds a base for different evaluation methods and the calculation of typical surface profile parameters. In addition, we can set up a FEM simulation based on the recorded details to enable an in-situ analysis of the frictional contact.
Due to the large volume of data, we decided to create a method for visualizing the measurement data by operationalizing relevant functions in a practical software tool among a background database for storing the surface data. In addition to a chronological sequence of the surface structures, the engineer assisted by the software can evaluate all measured surface characteristics and their relations to their minimum and maximum values. The tool further has an input mask, which displays desired scans to the operator, considering the position and progress of the preconditioning process. In addition, it can calculate relevant surface characteristics via measurement clouds and show abott-curves (material ratio curves) of the measured areas.

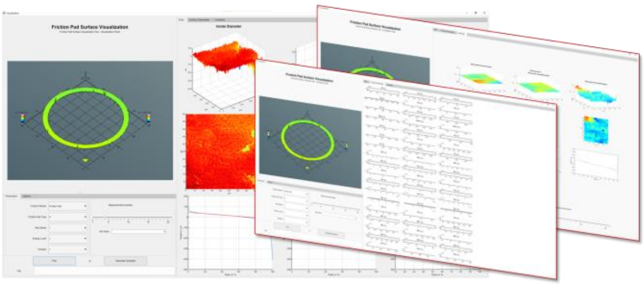

Fig. 1: The Software tool for Visualizing and calculating

To support a systematic analysis, we split the methodology into several sub-areas. First, we start the preconditioning process on the test bench by performing brake circuits. The number of circuits and thus the ranges of the investigation intervals are different during the preconditioning process. Second, the engineers inspected neuralgic phases at the beginning of the process in short measuring intervals. In contrast, there were no significant changes after further energy input expectable, so we increased the number of successive brakings between surface scans. The tests were carried out on several systems with identical properties with

the same input parameter combination to achieve a higher validity of the results. Then, high-resolution measurements follow each test interval by a white-light interferometer. We localized the measurement points of the surfaces concerning expected inhomogeneous load distributions over the complete friction lining width [1]. Finally, different friction materials with identical dimensions, varying mainly in their stiffnesses, were investigated.
The initial load parameters (energy input, speed, surface pressure) by tests in similar projects with corresponding friction materials and evaluations of the results of preliminary tests have to be defined at the beginning of the research work by us.

3. Results

The software tool can also display the results. In addition, it can organize surface parameters based on matrices to offer a direct comparison between different coatings and load collectives based on diagrams.

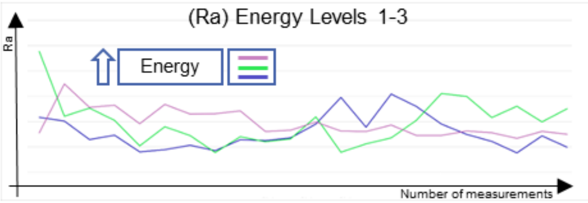

Fig. 2: Arithmetic average roughness value (Ra) (different energy loads)

The evaluations of the surface parameters show that the surface smooths out during the preconditioning process. The arithmetic (exemplified in Fig. 1) or the quadratic average roughness value (Ra, Rq) indicate that. Furthermore, the progression of the friction coefficient tends to increase with an increase in energy input overall power stages (Fig. 2).

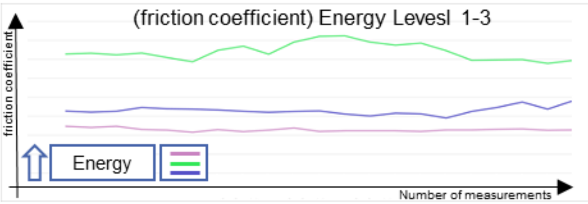

Fig. 3: friction coefficient (different energy loads)

A significant value for evaluating these processes is the reduced peak height Rpk; it offers an excellent informative value regarding the tip combing of a profile, which can also be relevant for evaluating the material ratio curve [2].

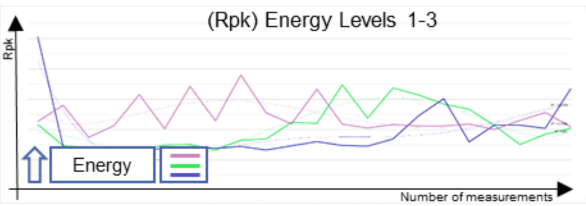

Fig. 4: reduced peak high (Rpk) (different energy loads)

We figured out that the curves of the reduced peak height correlate with those of the friction coefficient. However, the reader can see differences between the series with various energy inputs. Also noticeable are substantial changes in the characteristic values with an increase in the number of continuous braking cycles. In this case, there are indications of a change in the surface area associated with increasing temperature at friction surfaces [3]. In this regard, correlations between some surface characteristics and friction coefficients are observable. A change in the type of pavement also affects the gradients here. For example, the expression of the gradient for stiffer linings is more significant than for soft ones.

4. Conclusion

In this research, we developed a new investigation methodology for determining the progress of a preconditioning process. The extension by new evaluation criteria for the success of preconditioning by surface characteristics shows correlations with the friction coefficient progression. In this context, first experiences for evaluating mechanisms on the friction surface, which influence the progression of the friction coefficients, are shown. In addition, the parallel recording of surfaces in 3-D offers the possibility of validating the calculated surface characteristics and a deep insight into the structure of surface topographies and their changes.

5. References

[1] Albers, A., Ott, S., Merkel, P.: Kupplungsmodell zur Beschreibung der Übertragbarkeit tribologischer Prüfergebnisse von Teilbelag- auf Bauteiluntersuchungen. Abschlussbericht FVA Forschungsvorhaben 607. Karlsruhe 2013

[2] Mahr GmbH. 2015. MarSurf. Oberflächenkenngrößen.

[3] Severin, D., Musiol, F.: Der Reibprozess in trockenlaufenden mechanischen Bremsen und Kupplungen, Artikel. Konstruktion 47. Berlin 1995