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IMPROVEMENT OF TRIBOLOGICAL PROPERTIES OF PLASTIC COMPOUNDS

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ABSTRACT

Nearly every physical movement is associated with friction, which implies a loss of kinetic energy. Tribology helps to reduce friction losses and improves the energy balance of movement. The main influencing parameters on friction are the material properties and the contact surface.

Increased surface properties are needed for insufficient tribological partners to keep friction and wear down. Sand, typically known as wear intensive material, is a poor friction partner. Thus sand is used as the reference tribology partner to examine plastic materials and their surface properties to friction and wear.

To find the best material for tribological use on sand, measurement devices need to achieve the environmental and dynamic requirements. Then, the measurement results are correlated to selected properties to formulate connections between both, to turn the tribological measurement to a needless procedure. Thus, the calculated formula should simplify the choice of fillers for a tribological compound on sand.

1. INTRODUCTION

Friction is a loss of energy caused by movement upon the interaction of two or more objects. The method of interaction (here sliding) reduces the number of feasible measuring devices. This research uses selected tribological partners and will be able to simulate the temperature conditions during measurement. Additionally the sliding direction should be straightforward and not curved.

2. RESEARCH OF EXISTING TRIBOLOGICAL MEASUREMENT DEVICES

The measurement of friction is possible by uncountable devices like inclined plane or pin-on-disk. All of the possibilities available to purchase are optimized for tests against hard, solid friction partners [1] [3] [5].

Figure 2.1: Tribological measurement for bearings, ball on three plates [1]

Most of these standardized instrumentations simulate the conditions in a bearing, as shown in Figure 2.1. Thus, for the friction measurement of a plastic component on sand, a device could not be found that would allow to simulate temperature development and other characteristic pattern of that particular pair of frictional partners.
In order to assess abrasion the taber abrazer is a possible device to measure abrasion by a defined normal force and revolution. Because of the hard surface lubrication is taking place. To avoid lubrication, an integrated vacuum cleaner removes the spill from the tested material.

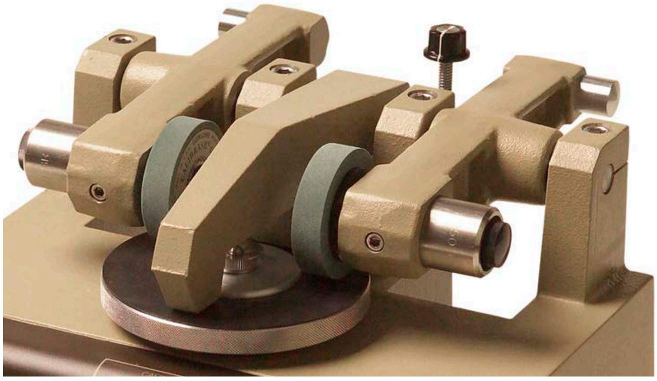

Figure 2.2: Measuring cell of the taber abraser [3]

This device does not allow a temperature control before and during measurement. Additionally, the abrasive wheels effect a width dependent abrasion on the tested material. The sliding direction differs here from the straightforward direction.

3. A POSSIBILITY TO CORRELATE TRIBOLOGICAL MEASUREMENTS

3.1 Friction Measurement Device

For measurement of friction of plastic components on sand, a new method for analysis of the different impacting factors is required. In order to represent similar environmental conditions as i.e. in a desert, a regulated temperature setting up to 60 °C has to be achievable.
The base of the developed device is a conventional rotary rheometer with a heat chamber, a modified grid and a new container. The container is the reservoir for the sand and the grid should be able to connect to a plastic disk. The analyzer is able to measure the temperature, axial force and the torque.

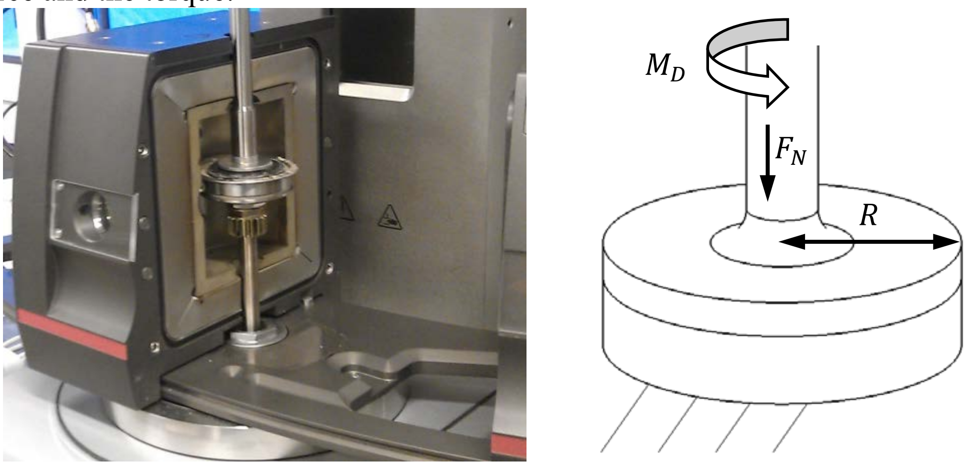

Figure 3.1: Heatable measuring system (rotatory rheometer) [2]

The friction coefficient can be calculated with these parameters and the knowledge of the radius of the plastic disk on the grid.

$$\mu = \frac{3 \cdot M_D}{2 \cdot R \cdot F_N} \quad (1)$$

Thus, this device is able to measure the coefficient of friction between a plastic disc and sand. However, the use of the rotary rheometer for the assessment of the associated abrasion is not an option. After 20 minutes no measurable loss of weight is detected by a scale with 0,01 µg accuracy, since axial forces up to 30 Newton can be applied.

3.2 Device to measure Abrasion

As shown in chapter 2.2 the wear of the taber abraser depends on the width of the abrasive wheel. Thus, instead of the taber abraser a belt sander is used to analyze the abrasion resistance of the plastic compounds. Therefore, the belt sander is fixed upside down on a desk. The grain of the belt is chosen by the particle size of the sand. Thus, based on the norm [10] the required grain is P 120. A specimen is placed upon the belt and loaded with a weight. The specimen is fixed by a wire to hold position (Figure 3.2).

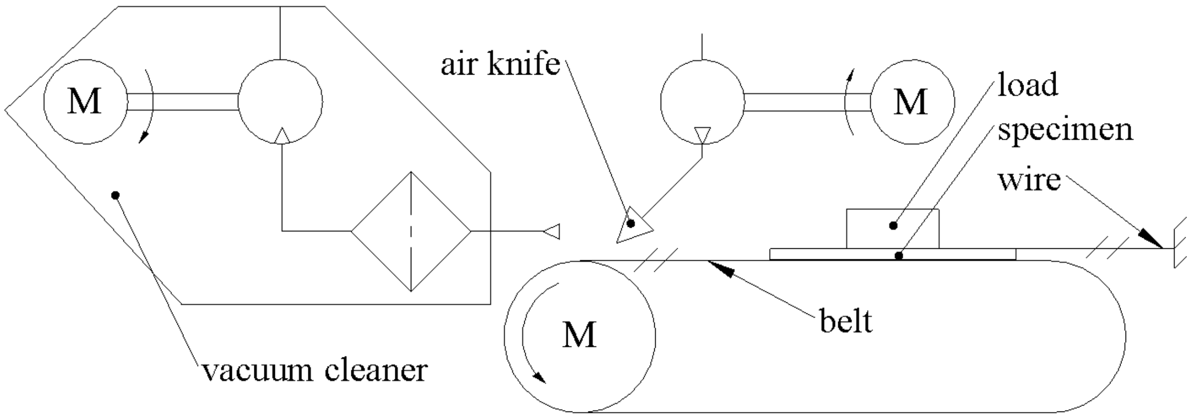

Figure 3.2: Abrasion measurement device

To avoid lubrication on spilled plastic material, an air knife and a vacuum cleaner is used. Behind the specimen the compressed air of the air knife detach the spill and the vacuum cleaner removes it. After a minute the test stops and the loosed weight is measured by a scale with 0,01 µg accuracy. The pre-tests resulted in a weight loss of approx. 70 mg per minute. To avoid failure caused by the different densities of the fillers, the loss of weight is correlated to the specimen weight.

3.3 Concept for Correlation of friction and wear

With the measuring devices of chapter 3.1 and 3.2 it is possible to measure abrasion and friction. Based on the results, a multi linear regression is applied to obtain an equation, which describes the correlation between input and output parameters by specific linearized values. For the verification of the equation, a correlation factor is derived. The factor implicates the reliability of the formula by its value. [4]

The effects to the sliding surface involve mechanical properties like hardness, strength, strain and elongation. Roughness, young's modulus, yield strength, ball hardness, elongation at break, elongation at yield are measured by ball hardness measurement [6], impact resistance [7], tensile test [8] and roughness measuring [9].

4. EXPERIMENTAL IMPLEMENTATION AND RESULTS

The next step is to assemble a huge variety of fillers to calibrate the calculation model. Therefore, seven fillers are selected. Some fillers are chosen to increase the heat (h) and electrical (e) conductivity. Others are selected to increase mechanical properties such as tensile strength and hardness (s) or to reduce the friction coefficient (f) based on the knowledge of steel plastic combinations. These fillers are categorized as follows:

- talcum (s)
- hexagonal boron nitride (s, h)
- polytetrafluoroethylene (f)
- glass balls (h)
- short carbon fibers (h, e, s)
- titanium dioxide (s, f)
- graphite (h, e, s, f)

The named filler materials differ also in their particle geometry, between balls, fibers and disks. As a matrix material polyamide 6.6 is used, because it has a softening point at a higher temperature and decent tribological properties. First, each filler material is compounded by 20 weight per cent into the polyamide. In a second stage, mixtures of filler materials are made to a fill content of 20 weight per cent. Thus, thirty friction results are measured with eleven compounds. These results are correlated to eleven material properties. In Figure 4.1 a correlation with good results is displayed with less than ± 15 % of deviation towards calculated coefficient of friction.

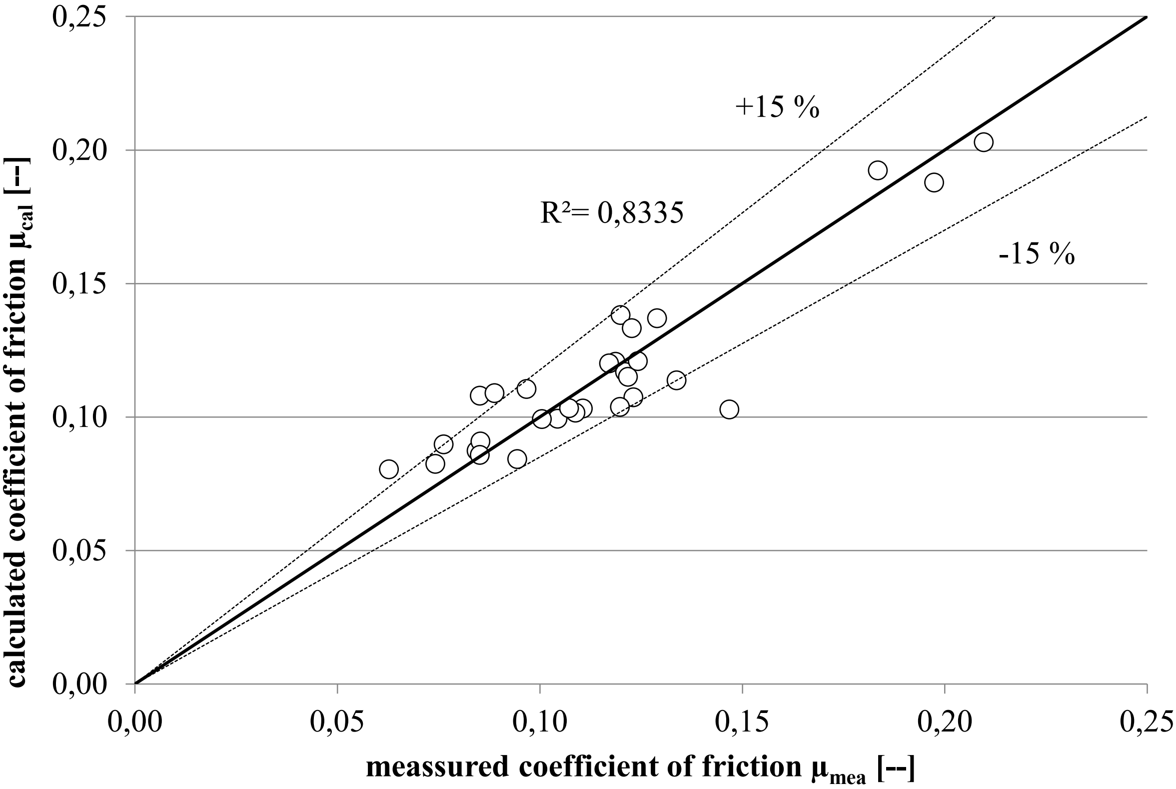

Figure 4.1: Correlation of measured and calculated coefficient of friction

The results of the calculated coefficients of friction in Figure 4.1 consist of the roughness R_a [µm], the yield strength σ_m [MPa] and the temperature T [K]. Further combinations did not increase the correlation above one per cent.

For a correlation of mechanical properties to an abrasion rate, only a limited number of results could be measured, because of the limited possibility by the temperature setting of the abrasion device. The best correlation is shown in Figure 4.2.

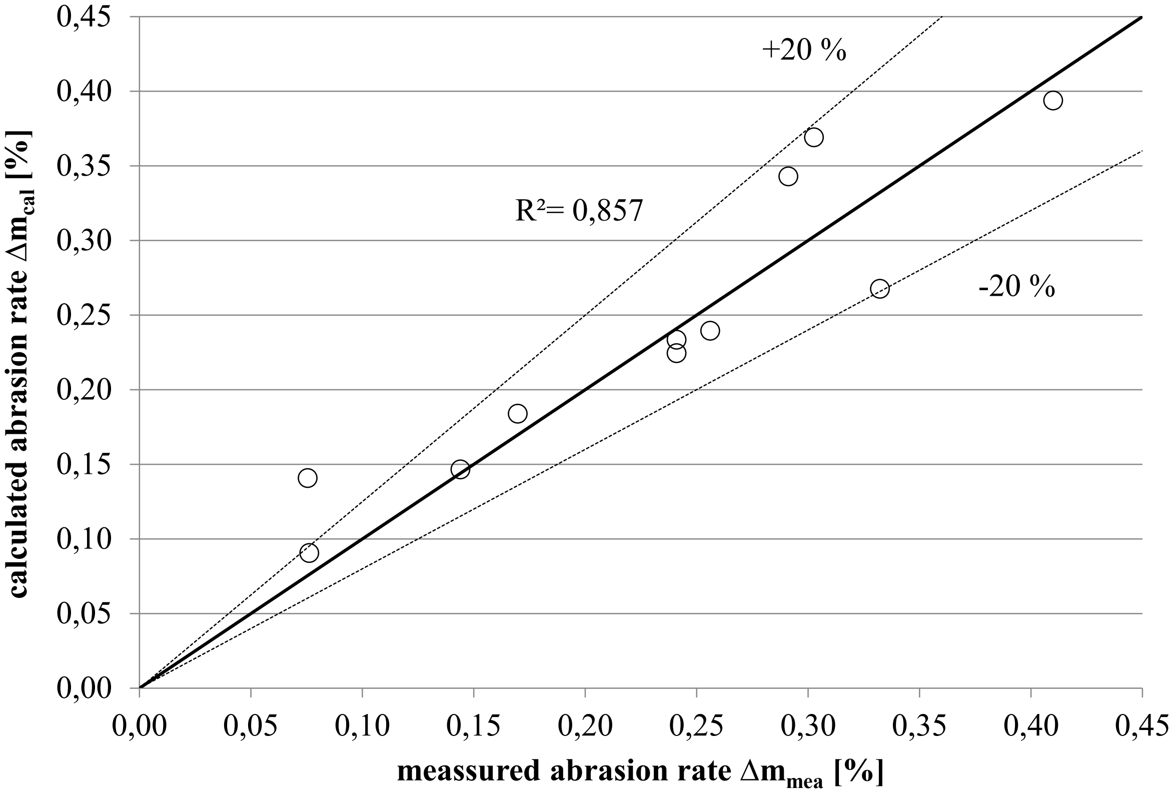

Figure 4.2: Correlation of measured and calculated abrasion rate

The abrasion rate has been correlated to the yield modulus E [MPa], the ball hardness HB [MPa], tensile strength σ_m [MPa], the elongation at break ε_b [%] and the yield strength at 0,5 % elongation $\sigma_{0,5}$ [MPa]. Because of the small number of results and five influencing parameters, the correlation between abrasion rate and these factors does not satisfy, yet.

5. CONCLUSION AND FORECAST

The comparison of both tribological parameters, coefficient of friction and abrasion rate, offers the following option to influence the material properties (Table 5.1):

Table 5.1: Comparison of effects to reduce coefficient of friction and abrasion rate

Parameter	Reduces coefficient of friction by…	Reduces abrasion rate by …
Tensile Strength	↓	↓
Roughness	↓	-
Yield Modulus	-	↑
Ball Hardness	-	↑
Elongation at Break	-	↑
Strength at 0,5 % Elongation	-	↓

Both, low coefficient of friction and abrasion rate improve as the tensile strength of the material increases. All other parameters do not interact with friction and abrasion. Thus, the solution appears to be easy. Unfortunately all the parameters influence each other in a different way. To illustrate the needed modifications of the material the following picture describes the changes in a stress strain diagram.

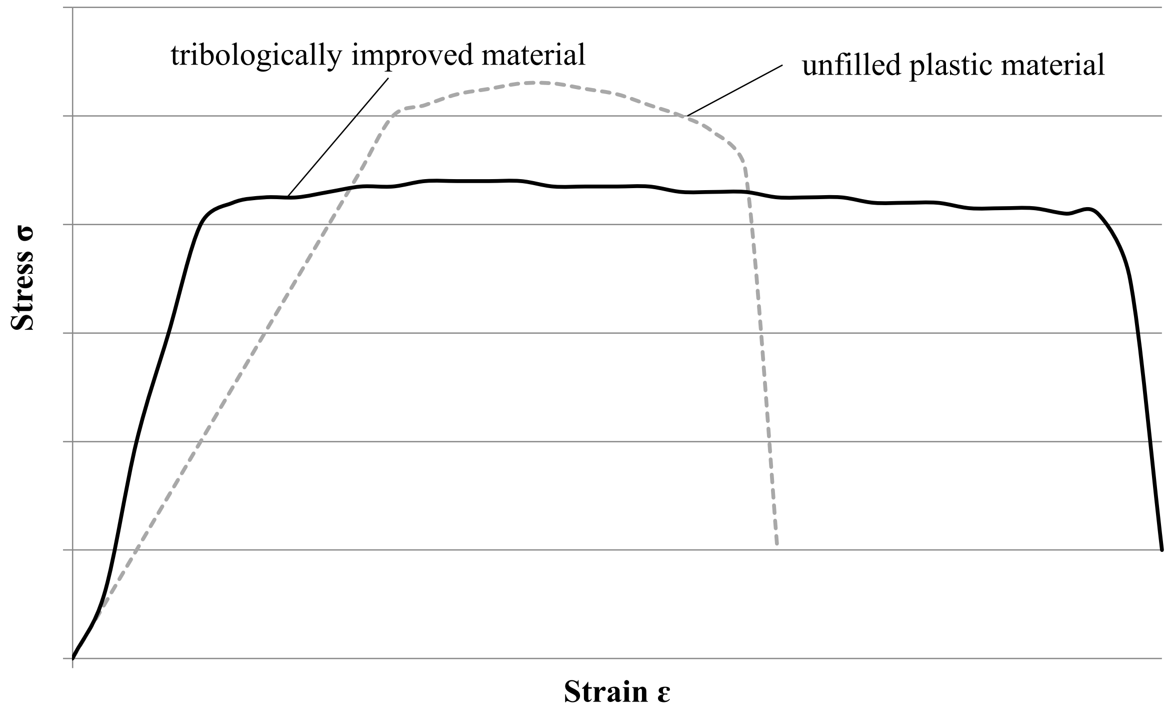

Figure 5.1: Demonstration of tribological improved to unfilled plastic material

Figure 5.1 displays the change in mechanical properties in a tensile strength test. Additionally, the ball hardness is expected to improve. The roughness can be influenced by the filler material and its size as well as by the surface of the mold.
The research shows best results with 20 wt.% of talcum as filler material in Polyamide 6.6. The high abrasion resistance and the indifferent friction coefficient have been observed to cause this result.

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