CHARACTERIZATION OF CARBONACEOUS MATERIALS WITH RESPECT TO SLURRY-ABRASION

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Introduction

Physical wear caused by slurry-abrasion is assigned to the tribological exposure "flowing" with the structure "solid body, particle, liquid" and appears, whenever a solid-containing liquid is present in a system [1]. Typical examples for such a kind of wear mechanism can be found in the field of hydraulic conveyance, crystallization, electrolysis of aluminum, liquid heat exchangers or extrusion processes and can determine lifetime of equipment as well as complete installations [2,3].

In various fields of technology, carbon and graphite are the materials of choice, due to their resistance against aggressive chemical attack. Nevertheless, the application of carbon materials is often limited when abrasive wear mechanisms heavily occur.

The present fundamental study deals with the aspect to rank different carbonaceous materials with respect to slurry-abrasion and to identify possible routes to improve wear behavior, respectively.

Experimental

The response of different carbon materials to the abrasivity of a slurry, i.e. wear exposure in a flowing liquid, which contains abrasive particles, was determined with a newly developed test method (Fig. 1). A so-called "wear pot" is filled with a sand water mixture (sand-slurry), composed of 7 kg silica sand and 3 kg water.

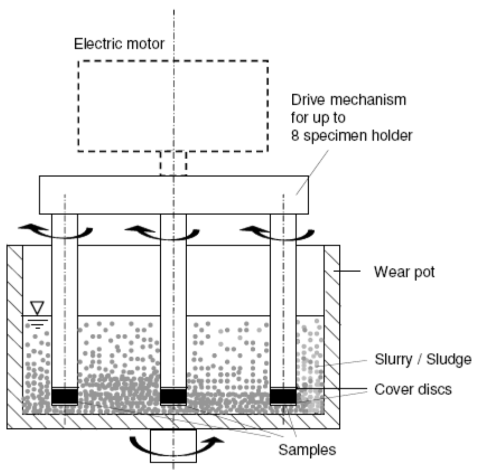

Fig. 1 Principal drawing of test equipment

Eight cylindrical samples with an outer diameter of 50 mm and a height of 30 mm are measured in parallel (sample rotation speed 1500 1/min, pot rotation speed 30 1/min). Top and bottom surfaces of the cylindrical samples are covered with stainless and hardened steel disks, to exclude the influence of sample edges as well as to realize a constant circumferential velocity. The specimens pass three abrasive test intervals, each with a duration of 60 minutes. For every abrasion interval, a new slurry with identical composition, regarding sand-to-water ratio, is prepared. This minimizes the rounding/passivation of sand particles and their covering with abraded carbon material. After each test run, the mass loss is determined by comparing the mass of the specimens before and after the individual runs. Before every weighing, the samples are carefully cleaned with water and dried. For each tested material, this provides eight individual data points of slurry-abrasive mass losses, after 60, 120, and 180 minutes. The mean cumulative mass loss is plotted against its respective cumulative abrasion time and the slope of this line is defined as (mass-based) abrasion rate (Fig. 2).

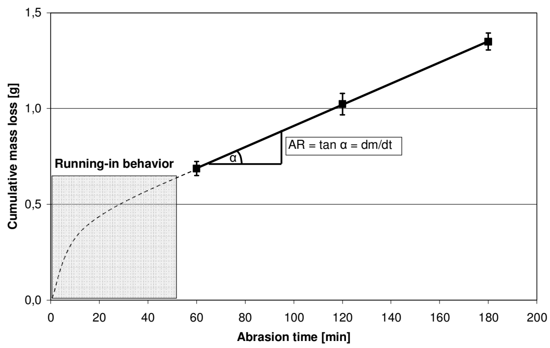

Fig. 2 Exemplary result of a typical slurry-abrasion test with free extrapolation to short abrasion times; error bars reflect one standard deviation

Altogether, 33 different materials were taken under consideration, out of various fields of applications: cathode materials for aluminum electrolysis, blast furnace lining materials for metallurgical processes, process technology applications, i.e. materials for heat exchanger pipes and rotary pump wheels as well as iso-graphite materials for bearings and sealings. The above mentioned materials were additionally characterized by measuring the universal hardness. A hard metal ball with a diameter of 10 mm is pressed into the specimen surface with an applied force of 1000 N, the indentation depth is measured and the surface area of the indented spherical cap is calculated (Hardness = F/A_{cap} [MPa]).

Results and Discussion

Fig. 3 gives an overview of the measured abrasion rates of all tested 33 materials and their respective graphite content, sorted by specific application fields.

The highest wear resistance (lowest abrasion rates) among all the investigated materials is shown by amorphous and coarse-grained blast furnace lining materials, which mainly consist out of gas- or electrically-calcined anthracite and which contain no graphite at all. The lowest wear resistance (highest abrasion rates) can be found for fully graphitized materials (graphitization temperatures can reach up to 3000 °C). As a common trend it can be summarized, that the slurry-abrasional wear rate is directly connected to the graphite content of the materials or the respective degree of graphitization. Possibilities to increase the abrasion resistance of a material with fixed composition are the replacement of carbon fractions by hard additives (e.g. hard ceramics) or by impregnating the material after graphitization (pitch, resin, metal). To give an example: the slurry-abrasion rate of a graphitized coke-based material can be decreased by 10 %, if the material is additionally pitch impregnated and rebaked after graphitization. If a resin-impregnation is applied after graphitization (but without rebaking), this effect is even stronger pronounced and can reduce the abrasion rate by more than half. This impressive effect can be explained by the raise in elasticity of the base material, which is caused by the resin impregnation. Such an positive effect of elasticity with respect to wear resistance can also be found for other material groups, e.g. if the slurry-abrasion behavior of elastic polymers with chrome-steels is compared [4].

With the present test equipment it was also observed, that even the production process or the route of forming has an influence on the wear behavior of carbon materials. Extruded materials were found to have a higher abrasion resistance than vibromoulded materials.

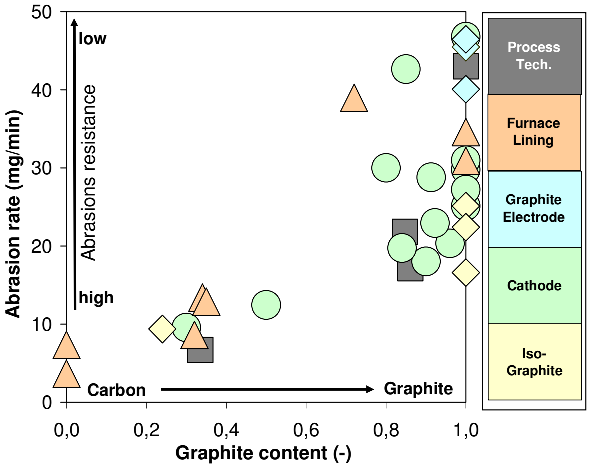

Fig. 3 Overview of abrasion rates for all 33 materials under investigation, sorted by specific application fields

Also the volumetric (mm³/min) and linear (mm/d) abrasion rates of all materials were checked and compared to each other, to reveal, if there is a possible influence of the respective apparent density on the qualitative and quantitative wear behavior. But the apparent density of the materials was found to have only a very minor and therefore negligible effect.

Fig. 4 presents a three-dimensional wear map, which illustrates the interrelation between graphite content, hardness and abrasion rates for carbonaceous materials. Beside the graphite content of a material, the abrasion rate is also highly depending on its material hardness. Hardness in principal correlates very well with decreasing graphite content. The universal hardness of pure graphite was found to be below 100 MPa, while for amorphous carbon materials the universal hardness was measured to be five times higher. To summarize: the lower the graphite content of an individual carbonaceous material, the higher in principal its hardness, which directly corresponds with lower abrasion rates. Exceptions for this trend during the present study were only found for materials impregnated with elastic substances.

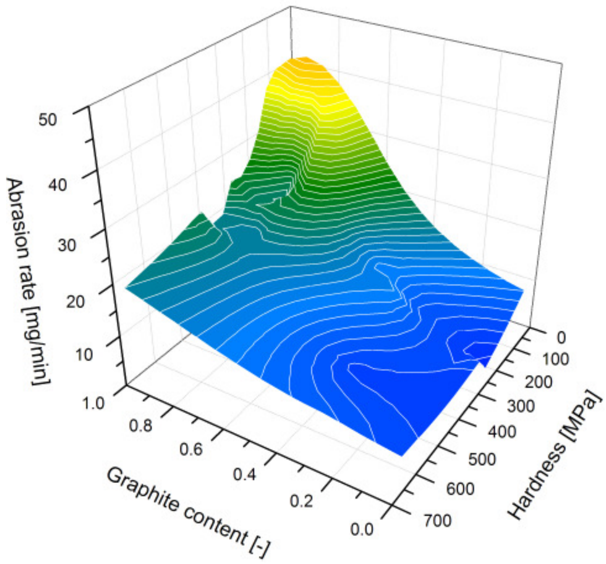

Fig. 4 3D-diagram for carbonaceous materials, for visualization of the dependency of slurry-abrasion rates on material hardness and graphite content

Conclusions

The most applicable material properties to forecast slurry-abrasional wear behavior of carbonaceous materials are the graphite content in the base material composition and/or graphitization degree/temperature, as well as material hardness. Beside the good correlation between the mentioned material properties and the measured slurry-abrasion rates, there are several possibilities to increase wear resistance of a material, whose composition/recipe is fixed, for whatever reason. An impregnation with pitch, elastic resin or an replacement of defined carbon fractions by hard ceramics can dramatically reduce the slurry-abrasive wear rates.

References

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