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DELINEATION OF ABRASIVE WEAR TESTING EQUIPMENTS

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ABSTRACT: When we are testing the wear we have to measure the loss of the tested material with the same testing circumstances that cannot be easily ensured. Therefore a relative abrasion resistance is usually measured (wear of an etalon material / wear of the tested material). When somebody searches abrasive wearing properties, it is always a significant question, how to select appropriate wear testing equipment. If the chosen method is the model testing of simple specimens, lots of obtainable tribotesters will be found on the market, and there is a good chance for developing one, too. Many well-designed testing machines exist and are available. For classification my chosen main aggregate is the movement of the specimen. Here is a short summary of the advantages and disadvantages of the different kind of abrasive wear testers where the contact surfaces of the worn and the abrasive materials have relative speed difference.
KEYWORDS: Wear, wearing test, tribotester

INTRODUCTION - ABRASIVE WEAR

What is wear? Material particles are separating step by step from the interacting, frictioning surfaces as a result of the mechanical, thermal and chemical stresses. Several wearing types are named: abrasive wear, fatigue wear, tribochemical wear, cavitation wear, etc., but abrasive wear is the most common wearing type in the technical practice. In the course of abrasive wear between the surfaces moving on each other the peaks of the harder material gouges grooves into the softer material, peeling some material, so it is a groove-proceeding process (appearances: craters, scores, scratches, scrape traces). Typical occurring area: active tools of agricultural machines (e.g. plough). [1]

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The abrasion resistance (AR) hangs on many factors and circumstances but two material-features have to be highlighted [3.]:

- *AR is related linearly to the hardness of the material. AR can be increased significantly better by alloying softened metals than hardening by heat treatment.*
- *AR is influenced by the modulus of elasticity (Young-modul). The tougher material the more resistant.*

Influence of the wearing material [2]

- *Hardness: If the hardness of the abrasion grain is at least twice of the worn material's than occurs mainly abrasion wear. As it decreases, the abrasion wearing effect decreases too. From experience: the rate of the wear is not influenced if the hardness of the grain is more than 50% harder than the worn material.*
- *Brittle grain: when the grain breaks easily that decreases the wear on one hand because of the smaller grain size, on the other hand increases the wear due to the sharp ledges of the fresh break of grain.*
- *Grain size: the smaller then 10μm grains' abrasion effect is minor, as the size grows, the wear increases, degressive heading to a limited value.*
- *Shape: the influence of the shape is hardly traceable.*

ABRASIVE WEAR TESTING EQUIPMENTS

Many well-designed testing machines exist and are available. For classification my chosen main aggregate is the movement of the specimen.

Moving specimens: „sand-slurry" equipments

These are rather real-life than scale models and these rigs are mostly self-designed constructions. It gives opportunity to test the real abrasive material (e.g. agricultural use). Successful tests rely on close control of the abrasive material's features (particle size, shape, toughness and their fracture) and the contact temperature.[5]

The main difference is the driven path of the specimen:

1. *Rotating movement: barrel / drum design. Simple, space-saving construction, where the specimen is rotated around a fixed, vertical shaft, in a standing cylinder-shaped vessel filled with abrasive material.*

2. Rectilinear movement: trough design. The specimen is driven straight in a long trough filled with abrasive material. It needs more place and cost than the previous design but the movement resembles more to the real circumstances (e.g. plough). It is not introduced through an example below.

Fixed specimens

These machines are widely used because they are cost-effective. In each case the specimen geometry is simple and relatively easy and cheap to manufacture. Their principal advantage is that it is easy to cover wide load and speed ranges. Former there were rather three-body abrasion testers, where the stationary specimen was loaded against a rotating body with non- or recirculated abrasive particles introduced into the contact. Nowadays the two-body testers come to the front, where the abrasive particles are mounted on a carrying surface (e.g. abrasive paper). Here the main problem is how to ensure the stationary conditions of the abrasion (contact temperature, abrasive particles).[5]
The classification is driven by the principle of the contact:

1. Ball-plane contact:
   a. fixed-ball,
   b. rolling ball,
   c. rambling ball tribotesters
2. Cylinder-plane contact
3. Plane-plane contact: Pin-on-disk equipment
4. Cylinder-cylinder contact

The advantages and disadvantages are introduced by the following samples.

Modified sand-slurry tribotester

The following equipment was developed by SZIE Gépipari Technológia Intézet for testing hot-dip galvanized elements. [2]

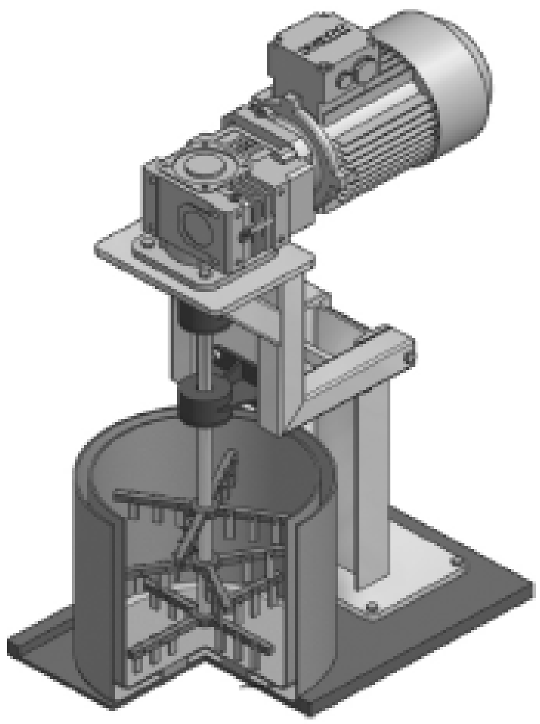


Figure 1. Modified san-slurry tribotester [2]

Advantages:

- Fast comparing tests for simple specimens.
- Testing by different speed and pressure circumstances.
- In this model there is a double wall drum filled with cooling liquid, so the heat circumstances can be influenced.

Problems:

- Heat cumulating due to friction – cooling of the system is tough. Only low speed can be used or only a few specimens can be tested side by side.
- The abrasive medium is susceptible to stratification that leads higher drag in the lower stratum.
- The system is sensible to the applied abrasive medium (mould can burn on the worn surface, grain size influence the heat).
- The steady conditions are hard to be ensured during the test (grain break, making even the former way's trace, pressure conditions).

Fixed-ball tribotester

The abrasive ball is fixed in a holder and loaded onto the rotating disk's surface. An increasingly deeper and wider crater comes into existence on the surface of the disk. By a steady load as the crater becomes deeper, the contact pressure increases, so the surface pressure decreases. During the wearing process the shape and roughness of the ball changes significantly. The fixed-ball tribotester is used rather for short time experiment and needs practice to evaluate right the wear picture. [4]
I have not found an example for adding plus abrasive medium to the system.

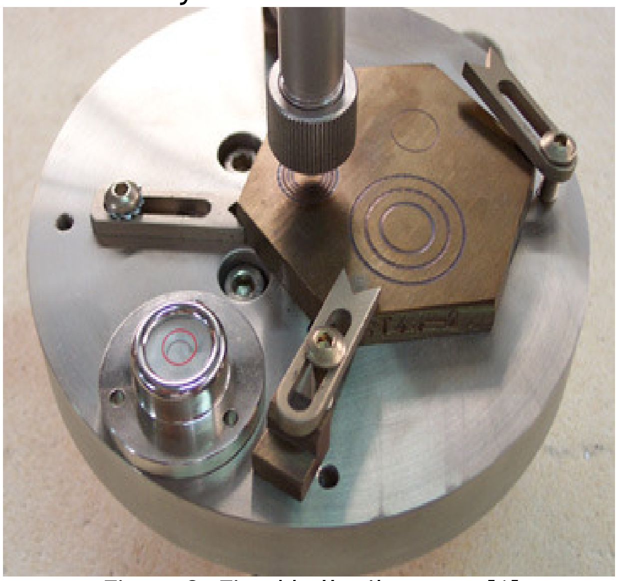


Figure 2. Fixed ball tribotester [6]

Rolling-ball tribometer

The specimen is fixed and loaded to the rotating ball. The ball is fixed on a driving shaft, and abrasive medium is poured between the contacting surfaces. If the abrasive medium is non-recirculated that ensures steadier conditions in the contact.
As the wear progresses it causes higher touching surfaces that decreases the force per unit of surface. [1, 6]
We have to count with the change of the ball's shape too, since the contact is localized on a narrow strip of the ball, so the contact line becomes wider as time passes.

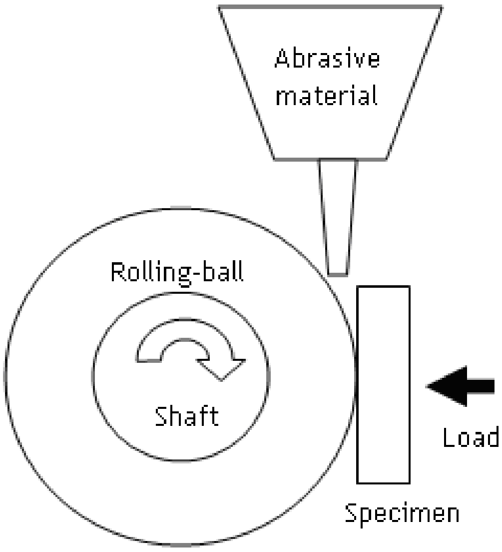
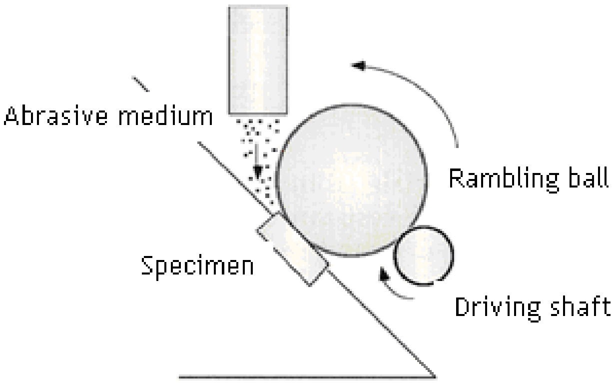


Figure 3. Rolling ball tribotester

Rambling-ball tribometer (free-ball)

The rambling ball is driven by a shaft by friction, so the speed of the ball is not steady. The normal power of the surface comes only from the weight of the ball, so this equipment is not able to test heavy loads. Even this smaller load is also not steady, since the ball can jump off from the surface. [6]

The ball moves on a rambling way, it touches the specimen with its whole surface, so it doesn't changes its shape significantly.



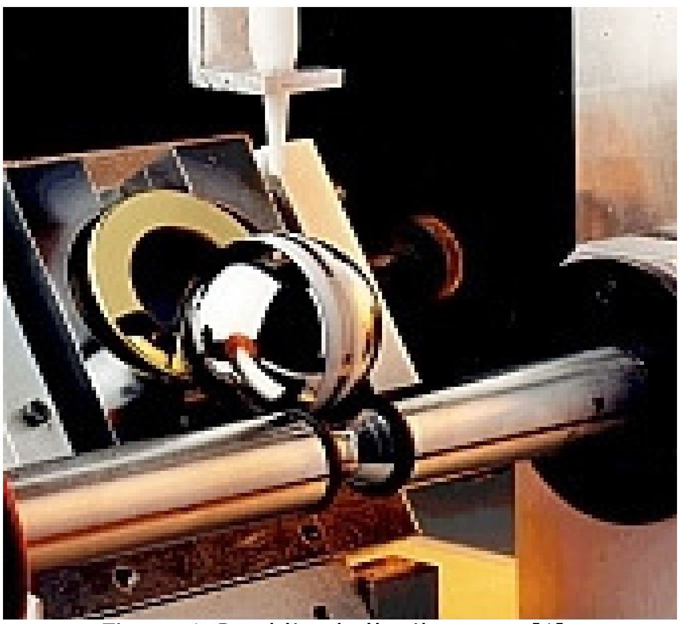


Figure 4. Rambling ball tribotester [6]

Cylinder-plane tribometer

Several arrangements of cylinder-specimen (horizontal, vertical) of this tribotester type are available on the market.

As the wearing process progresses and the trace increases the force per unit of surface decreases as well, but there is no significant change in the shape of the cylinder that would influence the wearing picture on the specimen.

There is an ASTM Standard G65-04 (2010) is for using the dry sand / rubber wheel apparatus. [7]

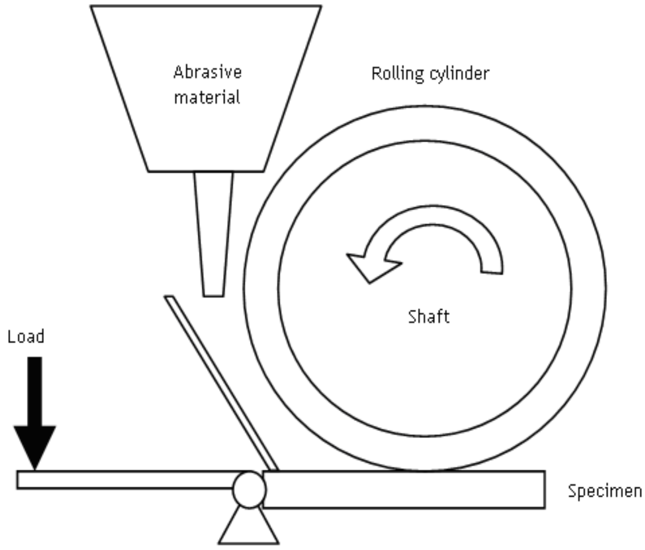


Figure 5. Cylinder-plane tribotester

Pin-on-disk construction

The specimen is a pin pushed by load on an abrasive disk. The linear loss of the pin shows directly the wear and the wear-resistance of the tested material. As the test progresses the abrasive paper degrades and becomes clogged so the loss of the worn material per time-unit reduces too.

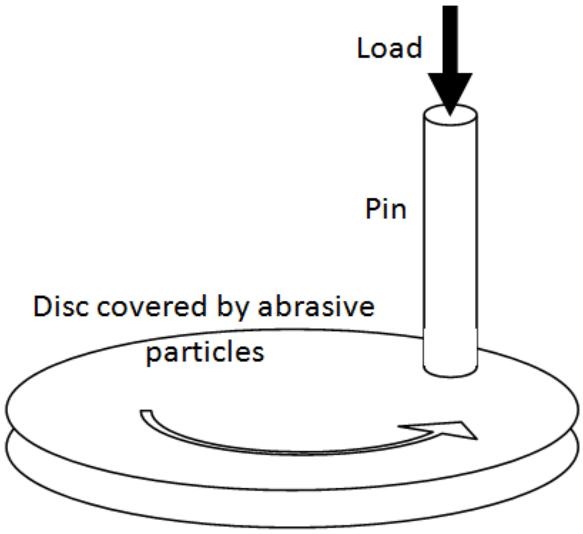


Figure 6. Pin-on-disk tribotester

There are some recommendations of standards for this type: ASTM G99 and DIN 50324. [5]

Cylinder-cylinder construction

There is a wear scar occurring by using this type of wearing test. The vertical dimension and the depth of scar can be measured.

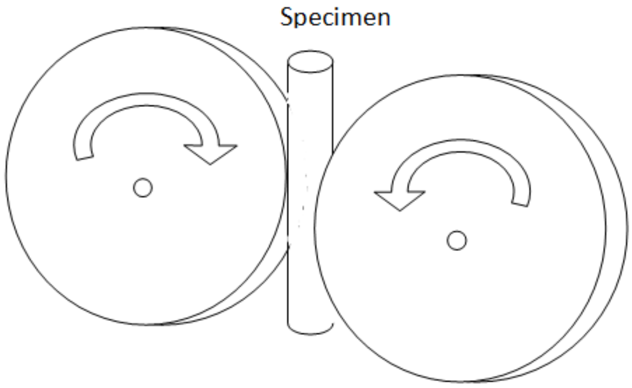


Figure 7. Cylinder-cylinder type

CONCLUSIONS

In technical practice it is more and more important to develop and use abrasive resistance materials. Therefore the modeling of wear is inevitable. Ensuring the adequate method and circumstances is the key for the success of testing.

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