6th International DAAAM Baltic Conference
INDUSTRIAL ENGINEERING
24-26 April 2008, Tallinn, Estonia

IMPACT WEAR TESTER FOR THE SUDY OF ABRASIVE EROSION AND MILLING PROCESSES

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Abstract: *Impact wear is common in crushing and mining equipment. For the determination of wear resistance of materials in such conditions the centrifugal type mill based on a disintegrator was developed. Results obtained by the tester enable to analyse impact wear of various materials as well as grindability and abrasivity of used materials simultaneously. This paper focuses on the development of the testing route and parameters for the tester to obtain results with tolerable uncertainty. Three different groups of materials: steels, cermets and coatings were tested. The velocity of the abrasive particles was varied from 40 m/s to 80 m/s and impact angle was close to normal. Used abrasive was granite gravel, classified according to the standards EN 13043, EN 13450 and EN 12620. Additional tests with different abrasives were made for comparison. The size of abrasive particles was 4/5.6 mm in all tests.*

The tests proofed that cermets have superior wear resistance in such conditions, but their uncertainty may be rather big. Feasible amount of abrasive for the most of materials to obtain results with moderate uncertainty was concluded to be 15 kg.

The grindability tests demonstrated that the main size reduction of mineral materials as brittle materials takes place after impact with 1st circle of pins.

Key words: impact wear, abrasive wear, wear resistance, uncertainty, grindability

1. INTRODUCTION

According to [1], wear is defined as either mass or volume of material, removed or displaced from a body which is repeatedly stressed in mechanical contact with another body or bodies.

Abrasion is sometimes indiscriminately associated with erosion, so that the erosive particles are often referred to as "abrasives" [1].

Erosive wear in which the relative motion of the solid particles is nearly normal to the solid surface is called impingement erosion or impact erosion [2]. To constraint this term is good to claim additionally that impact wear is present then abrasive particles are bigger than 2 mm.

Mechanical contact between solids may result from various basic models of relative motion and impact is one of them. Other models are sliding, and rolling. In each case, large contact stresses may arise, but their character, distribution and variation in time are unique. Fig. 1 shows wear characterization based on contact stresses.

Impact wear is characterized by narrow and high peak of stress because of very short duration of impact. The force F is very big and this is the reason for using momentums instead of forces in kinematical calculations of impacts:

$$I = \int_{t_i}^{t_f} \mathbf{F} dt = \Delta p$$ [3], where

$\Delta p = p_f - p_i$,
p – momentum of a particle,
I – momentum of the particle,
t_i – time initial,

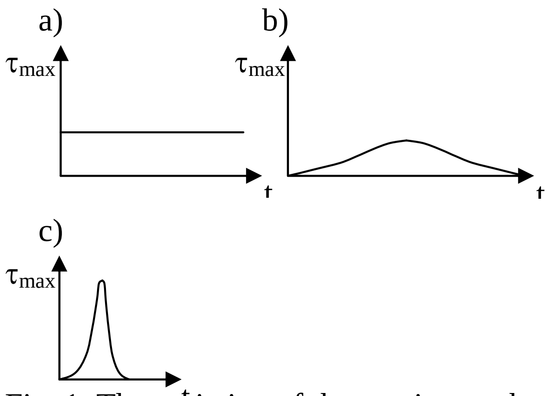


Fig. 1. The variation of the maximum shear stress at a point, in three types of contact: a – sliding (the shear stress on the slider is shown); b – rolling; c – impact [1]

t_f – time final.

Test equipments can be distinguished by the way how the erosive particles are accelerated in them. The main options are by gas stream, gravitational acceleration (Fig. 2) or centrifugal acceleration (Fig. 3). Gas stream acceleration (Fig. 2 b) is very common and used by many researchers in different countries and is the basis for German standard DIN 50332.

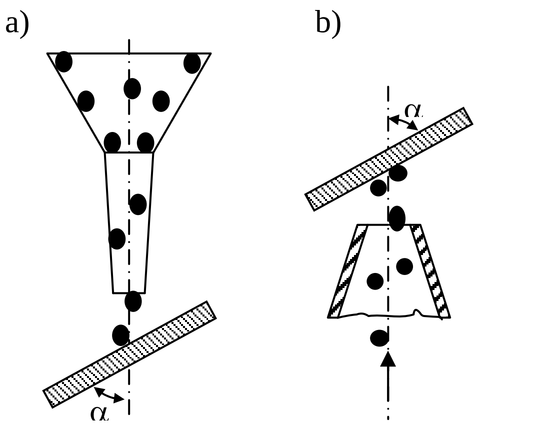


Fig. 2. Erosion testers where particles are accelerated: a – by a gravitation; b – by a gas stream [3]

Centrifugal acceleration principle is used in disintegrator mills. Erosive particles in disintegrators can be relatively big. Their maximum size depends from the model of a disintegrator and can be more than 10 mm. Their main disadvantage is that they are built for refining abrasive material and not for investigating wear phenomena of working parts.

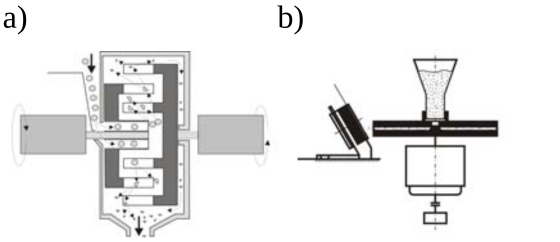


Fig. 3. Testers using centrifugal acceleration phenomena: a – disintegrator; b – centrifugal accelerator CAK

The force of centrifugal acceleration is exploited too in a centrifugal accelerator tester CAK, developed by I. Kleis [4]. However, it is not impact wear tester because its erosive particles must be smaller than 2 mm.

The aim of this work was to develop testing machine where is possible to test two-body wear process in the conditions of impact wear as well as grindability of abrasive materials to be used.

2. TEST METHODS

2.1 Impact wear tester

Impact tester DESI is centrifugal type and bases on a disintegrator. The main components are 2 rotors rotating at opposite directions (Fig. 4).

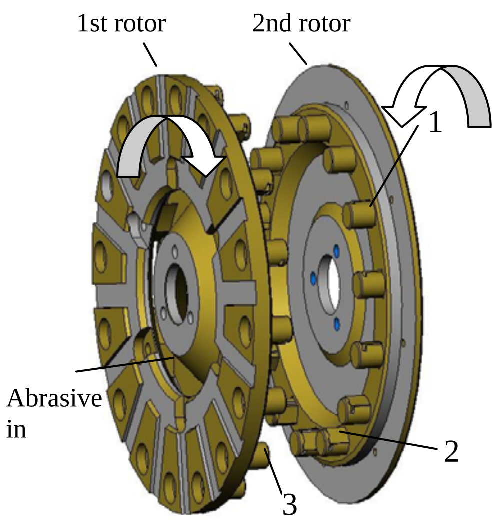


Fig. 4. The rotors of impact wear tester DESI in exploded view. 1 – 1st circle of pins; 2 – specimen; 3 – 2nd circle of pins

Crushing pins with the specimens are attached onto them. The attachment of the specimens is unique and protected by the Estonian utility model no U200600001.
Abrasive enters into the center of 1st rotor. After that it slides on impellers (Fig. 5) and gains velocity because of centrifugal force.

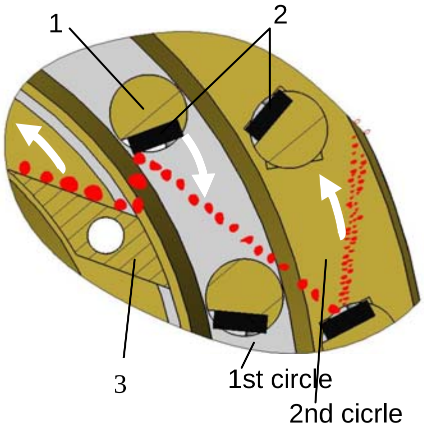


Fig. 5 Simplified scheme of particles moving in DESI: 1 – pin (specimen holder), 2 – specimen, 3 – impeller

In next step it hits the pins/specimens of the first circle. The 1st ring of specimens contains 14 pins or in other words, specimen holders. Two places are occupied by the reference specimens, i.e. 12 pins are free for specimens of materials to be tested. Impact angle between 1st circle of specimens and abrasive particles determined partly by the calculations and graphical method (Fig. 6), is close to normal. Impact angle between 2nd circle of specimens and abrasive particles originating from 1st circle of specimens cannot be determined so easily. The problem is that the impingement from the 1st circle of pins adds additional uncertainty factor, because the shape and the coefficient of restitution varies from particle to particle. That is why 2nd circle of pins is optional, i.e. these pins can be removed for the test.
Angular velocity of rotors is changeable by the belt drive mechanism. Possible is to have 5 different angular velocities on both rotor, which gives impacting velocities between abrasive particles and 1st circle of specimens from 40 m/s to 120 m/s. If both rotors turn with different angular velocities, is possible to have 20 additional speed combinations.

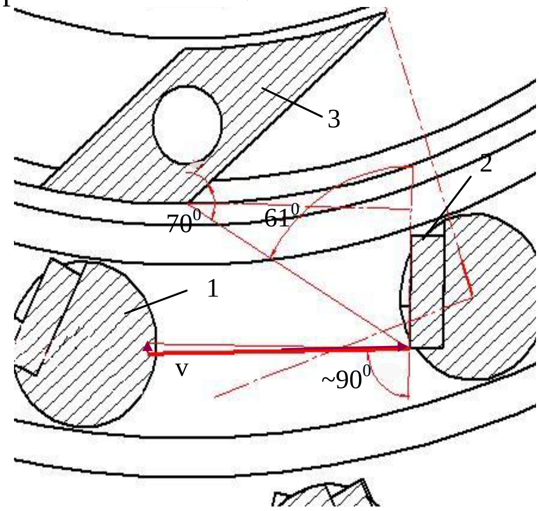


Fig. 6. Impact angle between particles coming from impellers and 1st circle of pins: 1 – pin, 2 – specimen, 3 – impeller, v – resultative velocity

2.2 Erosion wear resistance calculation

The specimens are weighed before and after each test. Mass losses of the specimens are determined. The mass loss of each specimen is divided by the working zone area of the specimen: mass loss to unit surface area is obtained. The outcome is divided by the density and volume loss is obtained, which is compared with volume loss of reference material. This is the route for calculating relative wear resistance (eq. 1).

$$\varepsilon = \frac{\Delta V_r}{\Delta V} \text{, where} \qquad (1)$$

ε - relative wear resistance of material under investigation;
ΔV - average volume loss per unit surface area of material under investigation;
ΔV_r - average volume loss per unit surface area of reference material.

$$\Delta V = \frac{\Delta m}{A\rho} = \frac{\Delta m}{bh\rho} \text{, where} \qquad (2)$$

Δm – average mass loss of material under investigation
A – average active surface area of the specimen (A = b*h, where b –width of the specimen, h –height of the specimen).

The formula for calculation of relative wear resistance is following

$$\varepsilon = \frac{\Delta m_r}{b_r h_r \rho_r}\frac{bh\rho}{\Delta m} = \frac{bh\Delta m_r \rho}{b_r h_r \Delta m \rho_r} \quad (3)$$

We started by searching of reasonable amount of abrasive from 3 kg per batch. It proved to be too less because the uncertainty of the results was too big. Finally we determined reasonable amount of abrasive to be 15 kg. In most cases such amount of abrasive gives good results with small uncertainty. Exceptions are especially materials of very high wear resistance, like hardmetals. Then uncertainty can still be very big (even up to 50% of their wear resistance value), but it is explainable by brittle materials wear nature. They are prone to spalling.

From each material is recommended to test 4 specimens in each batch.

Abrasive feed rate depends slightly from the abrasive and is usually kept 3 kg/min.

2.3 Grindability

The size of abrasives usable in DESI can be up to 7 mm.

Used gravels (Fig. 7) were 4/5.6 mm in particle size. Granite gravel is classified according to the standards EN 13043, EN 13450 and EN 12620.

Hard rock was used in additional tests.

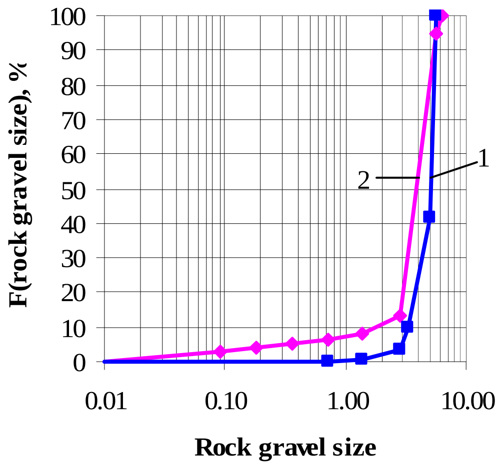
Fig. 7. Overall picture of abrasives: left side – granite gravel; right side – hard rock

The chemical composition of granite gravel is 70 vol % of quartz, 10 vol % of feldspar and 20 vol % of other ingredients. The impact value SZ is 18.

Hard rock contains 100 vol % of quartzite.

Cumulative and distribution polygons of used abrasives are given in Fig. 8. They are based on sieve analysis.

a)



b)

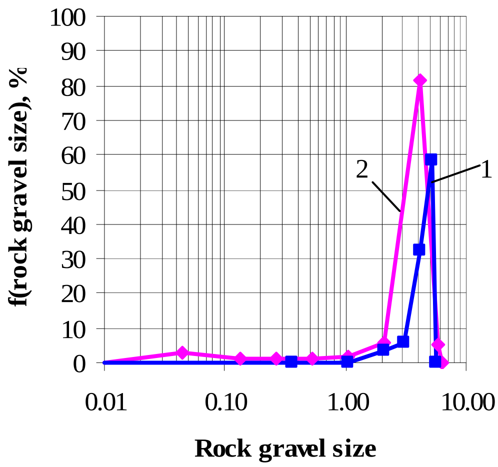


Fig. 8. Cumulative (a) and distribution (b) polygons of tested abrasives: 1 – granite gravel, 2 – rock gravel

3. RESULTS AND DISCUSSION

3.1 Wear resistance study

All tests were made at the velocity of 60 m/s between 1st circle of specimens and abrasive. 2nd circle of specimens was not in use.

As indicated by the studies of hardmetals and cermets of various type and composition, their behaviour differ under studied conditions of wear. The results of testing – relative wear resistance of the WC-Co hardmetals, TiC-NiMo and Cr3C2-Ni cermets are given in Fig. 9. It compares wear in DESI with wear in CAK.

In the case of abrasive erosion more wear resistant is WC-8Co hardmetal, in case of impact wear – WC-15Co hardmetal. The high binder content (30 wt%) TiC based cermets demonstrated also good resistance in impact wear conditions. The TiC-based cermets are preferable, especially considering the fact that their density is lower compared to hardmetals and weight wear rate is on the level of hardmetals.

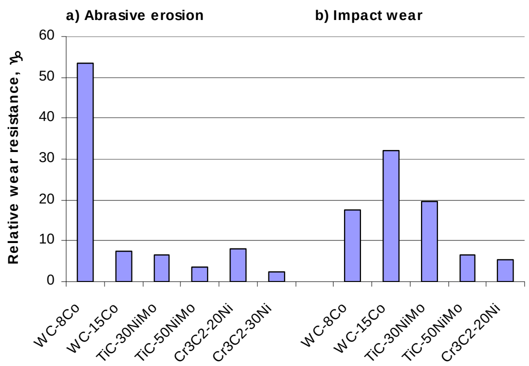


Fig. 9. Relative wear resistance of hardmetals and cermets at abrasive erosive (a) and impact wear (b)

The relative wear resistance of coatings made by Tafa’s HVOF system JP-5000 and compared with CAK tests is given in Fig. 10. As it follows from Fig. 10, the coatings do not suit into high-energy impact conditions presented in DESI.

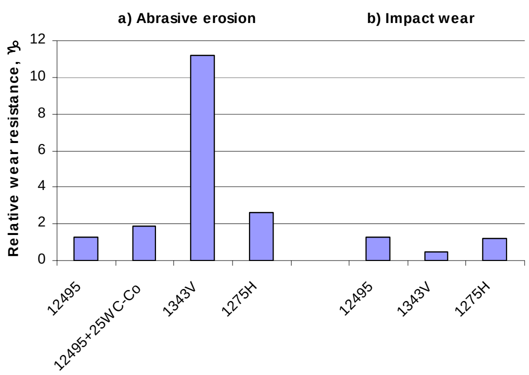


Fig. 10. Relative wear resistance of powder coatings at abrasive erosion and impact wear

Their main problem is too weak bonding strength. The coatings will spall from the substrate.

Hardmetal coating WC-17Co (1343V), which worked very well in CAK, was outperformed by fused NiCrSiB coating (1275H). Fused coatings having better bonding are more wear resistant.

Well-known wear resistant steels were tested in DESI (Fig. 11). Their relative wear resistance was practically the same compared to reference steel 45 and did not depend considerably from their hardness: ** – the specimens were not heat treated; *** – average hardness after heat treating was 42 HRC; **** – average hardness after heat treating was 46 HRC

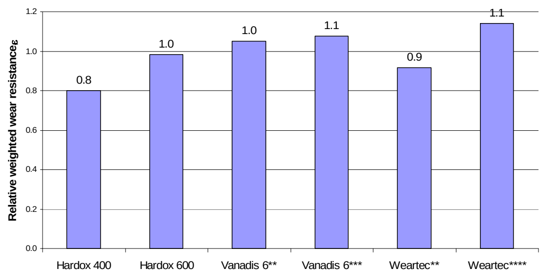
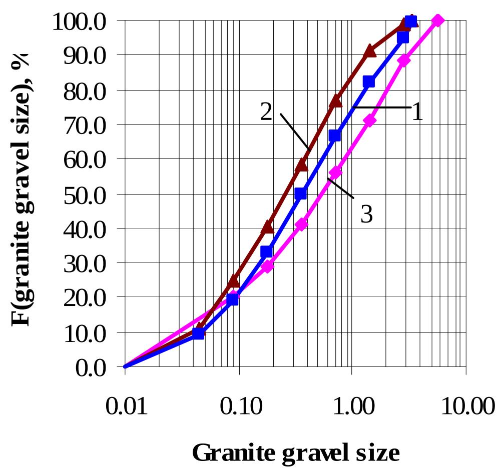


Fig. 11. Relative wear resistance of steels in DESI.

3.2 . Grindability study

Depending on the particle composition and initial defects, a significant size reduction takes place (Fig. 12). The initial particle

a)



b)

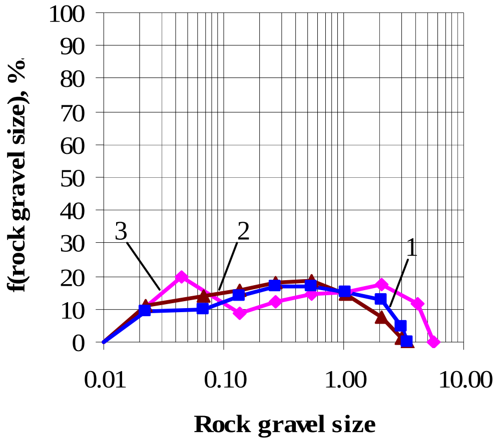


Fig. 12. Cumulative (a) and distribution (b) polygons of grinded abrasives: 1 – granite gravel after impact with 1st circle of pins; 2 – granite gravel after impact with 2nd circle of pins; 3 – hard rock after impact with 1st circle of pins

size decreases considerably after impact with pins of the first road, the mean particle size d_{50} of granite gravel decreases from 5 mm to 0.4 mm. 2nd circle of pins does not cause considerable size reduction (compare curves 1 and 2 in Fig. 12).

Similar size reduction behaviour was noticed for hard rock abrasive. In case of hard rock, additional velocities of 40 m/s and 80 m/s were studied (Fig. 13.). It was

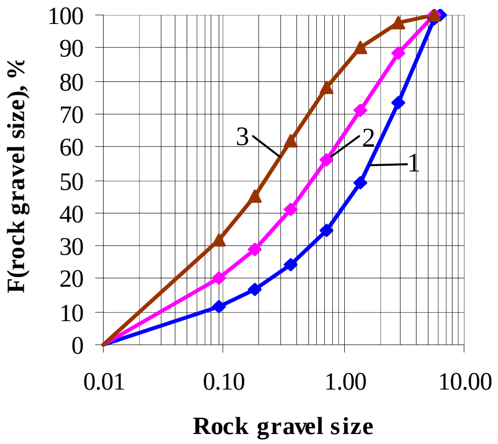


Fig. 13. Cumulative distribution polygon of hard rock grinded in various velocities between abrasive and 1st circle pins: 1 – 40 m/s; 2 – 60 m/s; 3 – 80 m/s

proofed that the increase of particles velocity 2 times decreases their size d_{50} 4 times (compare curves 1 and 3 in Fig. 13). It correlates with kinetic Work-energy theorem [3].

4. CONCLUSIONS

- The main advantage of impact wear tester DESI compared to erosive testers is simultaneous wear study of various materials as well as of grindability of abrasive materials.
- Reasonable amount of abrasive is 15 kg. Such amount of abrasive gives results with good uncertainty.
- DESI suits perfectly for testing hardmetals and cermets. In the case of steels and coatings, their wear resistance is practically same and is similar to reference steel (steel 45). Smaller angular velocities of rotors and/or lighter abrasives should be used.
- Impact wear tester DESI is suitable device for grindability study of brittle abrasive materials. Size reduction of abrasive material is considerable.

5. REFERENCES

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