APARATURA
BADAWCZA I DYDAKTYCZNA

A didactic stand for testing the erosion process

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ABSTRACT:

The paper presents a design of a mobile stand for testing the erosion process. The construction of the device makes it possible to conduct tests in closed rooms, and some of the measurement activities have been automated. The device enables the assessment of the influence of the impact angle of abrasive on the intensity of erosive wear. Parameters that can be adjusted are: the impact angle of the abrasive stream, the distance of the nozzle from the tested surface, the abrasive velocity, the type of abrasive. In this paper the concept and principle of operation of the stand are provided.

Stanowisko dydaktyczne do badania procesu erozji

Słowa kluczowe: erozja, stanowisko badawcze, zużycie

STRESZCZENIE:

W pracy przedstawiono projekt mobilnego stanowiska do badań procesu erozji uderzeniowej. Konstrukcja urządzenia pozwala na prowadzenie badań w zamkniętych pomieszczeniach, a niektóre czynności pomiarowe zostały zautomatyzowane. Urządzenie umożliwia ocenę wpływu kąta padania ścierniwa na intensywność zużycia erozyjnego. Parametrami, którymi można sterować, są: kąt padania strugi ścierniwa, odległość dyszy od badanej powierzchni, prędkość ścierniwa, rodzaj ścierniwa. W poniższej pracy została opisana koncepcja i zasada działania stanowiska.

1. INTRODUCTION

For many generations, people have struggled with the wear process in the machine environment. Wear is defined as the process of changes that occur in the surface layer of the solids, such as loss of mass or surface deformation resulting in wear [1, 2]. This process may not only lead to a loss of mass, but also to a change in the size of the object; for metals, it occurs both in contact with metals, non-metal solids, flowing liquids or droplets of liquids and residues of solids contained in gas [3].
The main criterion for the division of wear is the occurrence. In such a case, the tribological wear and non-tribological wear are distinguished [1]. Erosive wear is one of the non-tribological reasons which most commonly occurs in pipelines, pneumatic conveying systems, pumps and various types of flow systems. The principle of erosive wear is the action of solids, liquids or gases that hit the surface of the material, causing destruction [4]. One of the definitions provided by I. M. Hutchings describes the erosive wear as a process of abrasive wear consisting in repeated hitting the surface with the solid particles contained in the fluid. The result of this effect is the removal of material from the surface [5, 6]. In this process, there are several mechanisms leading to wear, such as: ridging, microcutting, fatigue wear, formation of adhesive joints, cracking, spalling, chemical, electrochemical and thermal wear [4, 7, 8].

2. FACTORS AFFECTING THE INTENSITY OF THE EROSIVE WEAR PROCESS

Erosive wear occurs due to exposure to different media. The main factors affecting the process intensity are: abrasive impact angle, abrasive particle velocity, particle shape, particle size and properties, and properties of the material subject to erosion [1, 2, 5]. The abrasive impact angle, dependent on the particle size, has a different impact on the surface being eroded. Due to aerodynamic effects, the maximum intensity is reached by small particles at higher impact angles. At dust velocity of 0.4 Ma, aerodynamic effects begin to be significant for particle size above 20 μm. High wear of plastic materials is reached at angles below 30° [2].

The velocity of abrasive particles impacting the material surface and causing loss of mass and volume is a power function of velocity affecting the erosive intensity. A change in the index exponent may occur when the velocity rises beyond a certain critical value, given the crushing of the abrasive and the absorption of energy by fragments of particles formed during the impact. Parameters describing the erosion process, such as the impact angle and particle size, also affect the value of the index exponent. For quartz sand, the exponent is 1.5 at up to 200 m/s, whereas at higher speeds it amounts to 0.3 [2, 11]. The particle shape influences the erosion intensity and type of wear mechanisms. If the shape of the abrasive, e.g. cullet, is changed into glass balls, then the angle at which the maximum wear intensity occurs (for steel) is changed from 30° to 90° [1]. The particle size, up to a certain value, also plays an important role, which is related to the crushing of the abrasive grain occurring with large diameter particles and high velocity particles. The movement path depends on their inertia. With larger particles, a smaller amount is sufficient to separate a portion of the material from the test surface [2].
There are different links between the properties of the materials and their erosion resistance. The dependencies between the type of material and resistance to erosive wear are presented below [1, 2]:
- **metals** — there is good correlation between the strength and hardness of the material for pure metals; crushing, shaping of the appropriate grain size, strengthening of the fixed solution does not significantly increase the erosion resistance;
- **composites** — composites based on fibre reinforced polymers are usually characterised by a greater wear of warp material than the reinforcement. Thermosetting materials are subject to wear such as fragile materials, and thermoplastic materials such as plastic materials; metal warp composites have a lower warp wear intensity.

3. TEST STAND

Due to the type of erosion, different methods of testing the erosive wear of structural materials are used. Two basic methods for reproducing the erosion process are impact erosion and cavitation erosion. The proposed concept of the test stand concerns impact erosion.

The design of the didactic stand for the erosion process study was developed using the CAD 3D Solid Works system [9, 10]. The following assumptions were adopted in the design works:
• the station should allow for testing the intensity of erosive wear depending on the impact angle of the abrasive stream;
• test samples should have dimensions and geometry determined;
• automation of maintenance and measurement activities, such as: measurement of the mass of the abrasive used, setting of the abrasive impact angle, dedusting system;
• stand mobility.
Figure 1 presents the design of the equipment based on the above assumptions.

Figure 1 Diagram of mobile didactic stand for testing the erosion process
1 — chamber, 2 — mechanism for setting the sample angle relative to the spray nozzle, 3 — abrasive container with weighing system, 4 — spray nozzle, 5 — dedusting cyclone, 6 — frame, 7 — fan, 8 — filter

The main component of the test stand is the chamber (1) mounted on the mobile frame (6). The chamber (1) contains a sample attachment set and a mechanism for setting its position angle (2). The stand also includes the sand container with weighing system (3), the spray nozzle (4), the cyclone with the container for the sand used (5), the fan (7) and the air filter (8).
The sample attachment (Fig. 2) has been designed to be able to achieve the same position at any time (the sample is removed every time to determine its mass and mass loss).

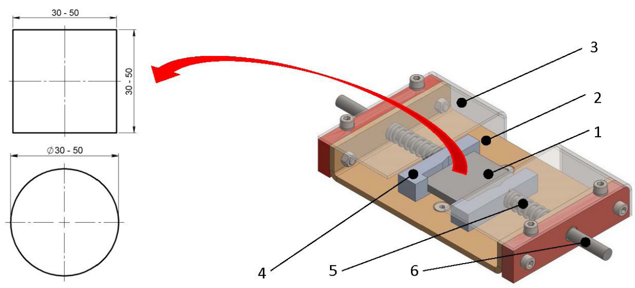

Figure 2 Diagram of the sample attachment:
1 — sample (may be a rectangle or a circle with dimensions from 30 to 50 mm), 2 — body, 3 — cover, 4 — sample positioning handle, 5 — compression spring, 6 — pin

During the test, the mass loss *u* of the sample exposed to abrasive stream impacting the surface at a specified angle is determined. To determine this loss, the sample should be weighed before and after the test.

$$u = M_1 - M_2 \quad (1)$$

where:
M_1 — mass of the sample before the test;
M_2 — mass of the sample after the test.
The intensity of erosive wear may be determined depending on:
• time t

$$I_t = \frac{u}{t} \quad (2)$$

• pressure P

$$I_t = \frac{u}{P} \quad (3)$$

• mass of sand used M_3

$$I_t = \frac{u}{M_3} \quad (4)$$

4. CONCLUSIONS

The designed stand, whose visualisation is shown in Figure 3, can be used in the didactic process.

Figure 3 Visualisation of the design of the didactic stand for testing the erosion process developed in SolidWorks

The structure of the stand is installed on a frame equipped with wheels, so that it can be transported quickly and easily to any place. Automation of some measurement activities (measurement of the weight of the used abrasive, setting of the angle of the abrasive stream) reduces test duration and eliminates the possibility for the operator to make an error. Owing to the use of dual air filtration, the installed dedusting system enables tests to be carried out in a closed room.
To sum up, the stand meets the assumptions and allows for the performance of tests that will be repetitive.

Conflict of interest:
The authors do not raise any conflict of interest.

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