Dawid ROMEK, Dariusz ULBRICH, Jarosław SELECH, Konrad WŁODARCZYK, Jakub KOWALCZYK
Politechnika Poznańska, Instytut Maszyn Roboczych i Pojazdów Samochodowych
ul. Piotrowo 3, 60-965 Poznań, Poland
e-mail: dariusz.ulbrich@put.poznan.pl

EVALUATION OF WEAR OF MACHINE PARTS MADE OF ARMOX 600, RAMOR 500 AND S355 STEEL WITH THE USE OF THE ROTATING BOWL UNIT

Summary

Application of materials of adequate hardness and abrasion resistance is important from the point of view of the exploitation of agricultural and heavy-duty machinery, especially the components of those machines that work in the ground. Therefore, the main goal of the studies is to determine the mass loss of 7 and 8 mm thick samples made of Armox 600, Ramor 500 and S355 steel. The study was carried out in abrasives such as quartz sand in a rotating bowl unit, and the distance after which the specimens were examined was 33.3, 66.6 and 100 km. Samples were made in the shape of a chisel. The largest loss of material over a distance of 100 km was recorded for a Ramor 500 steel sample, while the smallest for the Armox 600 steel sample.
***Key words**: abrasive wear, armored steel, rotating bowl unit, agricultural machinery, wear of machine parts*

BADANIE ZUŻYCIA ELEMENTÓW MASZYN WYKONANYCH ZE STALI ARMOX 600, RAMOR 500 ORAZ S355 Z WYKORZYSTANIEM METODY WIRUJĄCEJ MISY

Streszczenie

Zastosowanie materiałów o odpowiedniej twardości oraz odporności na ścieranie jest istotne z punktu widzenia eksploatacji maszyn rolniczych i do robót ziemnych, a w szczególności elementów tych maszyn, które pracują w gruncie. Dlatego celem badań, przedstawionych w niniejszym artykule, jest określenie ubytku masowego próbek o grubości 7 i 8 mm, wykonanych ze blach Armox 600, Ramor 500 i S355. Badanie prowadzono w środowisku ściernym (piasek kwarcowy), na stanowisku typu „wirująca misa”, a dystans po którym badano ubytek masowy próbek wynosił 33,3, 66,6 oraz 100 km. Próbki wykonane były w kształcie dłuta do pługa. Największy ubytek materiału na dystansie 100 km zanotowano dla próbki ze stali Ramor 500, natomiast najmniejszym zużyciem podczas badań laboratoryjnych cechowała się próbka ze stali Armox 600.
***Słowa kluczowe**: maszyny rolnicze, stanowisko wirująca misa, zużycie części maszyn, blacha pancerna*

1. Introduction

Agricultural machines and heavy-duty machinery are exposed to intensive abrasive wear, which occurs when very hard abrasive particles in the soil interact with the surface of the machine elements. In abrasive wear, the roughness of the surface of the materials, their hardness, the moisture and acidity of the medium in which the wear occurs is significant, as a result of micro-cutting and corrosion wear. The consequence of this process is minor or major mass loss of the part. In the test case of metal wear in the abrasive mass, the action of the abrasive grains depends mainly on their hardness and grain size. Also the direction of movement relative to the material and the force of gravity that the grain exerts is important.

The granulometric composition of the soil so the grain size is also an important factor which affects the intensity of abrasive wear. As indicated by the studies [1], grains of 0.25-1.00 mm are the most harmful. The size of the abrasives affects the type of wear (for example micro-cutting or ridging). The intensity of wear also results from the compactness of the soil, but it is closely related with hardness of soil. Determination of soil compactness refers to the force that should be used to cut the soil. Moisture is also significant for wear as the firmness of soil. If the smaller percentage of water is in the soil, the friction is much smaller, and the friction differences can be 2-3 times higher for more moist soils [1].

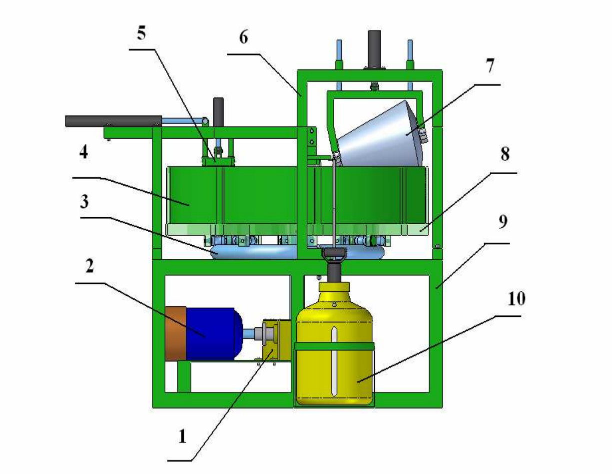
Abrasive wear of machine parts is carried out in both: field and laboratory conditions. The abrasive wear test results are different when the test item will often change the environment in which it works. Each element that will work in environment temperature from low to high or in compact to loose soil will have different abrasion properties. This confirms the assumption that the field test will be significantly different from laboratory tests where the temperature is constant and the humidity as well as conciseness of the soil is also at a controlled level.

Abrasive wear tests in laboratory conditions are conducted applying a variety of methods. One of them consists in a continuous abrasion test. It involves continuous and steady supply of sand or abrasive material through feed hopper with a suitable outlet diameter on a rubber wheel. The sand adheres to the material being tested during operation. The study that is also included in the continuous test methods is CIAT testing. The stand in its construction has a slowly rotating outer drum that moves at a fairly low speed, while a rotor inside is contained. The rotor rotates at a much higher speed in the range of 60-650 rpm [2]. The view of CIAT machine is shown in Fig. 1.

Another method of material testing for wear involves using of the "rotating bowl" unit. In this method the round tank is filled with a soil mass. The tank is rotary, while the tested elements are stationary. Elements are subject to friction from the soil mass for monotonous wear. Behind tested element the soil is flattened by the shaft, and the machine also has an irrigation system. Such a construction of the unit causes closer laboratory conditions to field conditions [4]. The "rotating bowl" unit that was used during the study is shown in Fig. 2.

Fig. 1. CIAT machine for continuous abrasive testing [3]
Rys. 1. Maszyna typu CIAT do ciągłego badania ściernego [3]

a)



b)

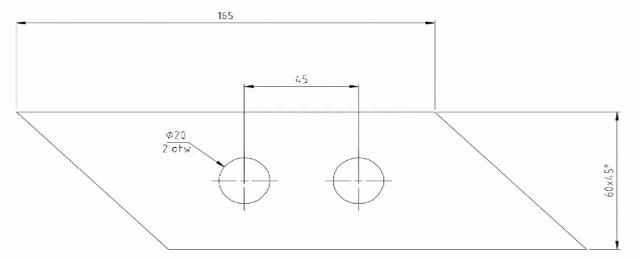
Fig. 2. The „rotating bowl" unit: a) scheme [5]: 1 - transmission, 2 - engine, 3 - running rail, 4 - bowl, 5 - holder of the sample, 6 - supporting frame, 7 - roller: 8 - frame of the bowl, 9 - main frame, b) view [6]
Rys. 2. Stanowisko badawcze „wirująca misa": a) schemat [5]: 1 - przekładnia ślimakowa, 2 - silnik, 3 - szyna jezdna, 4 - misa, 5 - uchwyt próbki, 6 - rama pomocnicza, 7 - walec ugniatający, 8 - rama misy, 9 - rama główna, b) widok [6]

The main goal of the studies presented in this article is to determine the mass loss of samples made of Armox 600, Ramor 500 and S355 steel. Samples are made in the shape of a chisel, due to the fact that this element is exposed to intensive abrasive wear during exploitation. Samples of 7 and 8 mm thickness were tested to determine the effect of material thickness on wear rate. The results of the research should provide an answer to question whether the use of very hard materials in the construction of agricultural machinery as well as heavy machinery may be justified? Such kind of material are commonly used in construction for military purposes.

2. Experimental study

The element used during the experiment was designed using AutoCAD and has the shape of a chisel (Fig. 3). The samples were made of Armox 600, Ramor 500 and S355 steel. The first two plates are used for the structural reinforcements of machines and vehicles (armored steel). Steel Armox 600 has a hardness of 590HBV, Ramor 500 has a hardness of about 500HBV, while the hardness of this two tested materials is higher than hardness of S355 steel (187 HBV). The chemical composition of steel used during the experiment is shown in Tab. 1.

a)



b)

Fig. 3. Sample tested in the abrasive test [7]; a) scheme, b) view
Rys. 3. Próbka poddana badaniu ściernemu [7]; a) schemat, b) widok

Tab. 1. Chemical composition of steel used during the experiment [7]
Tab. 1. Skład chemiczny stali wykorzystywanych podczas eksperymentu [7]

Steel	Chemical composition [%]								
	C	Si	Mn	P	S	Cr	Ni	Mo	B
Armox 600	0.47	0.7	1	0.01	0.003	1.5	3	0.7	0.005
Ramor 500	0.35	0.7	1.5	0.015	0.01	1	2	0.7	0.005
S355	0.2	0.55	1.6	0.4	0.4	0.3	0.3		

During the test, each sample was equally prepared for measurements. Samples were weighed after washing in an SB5200 DTD ultrasonic washing machine. Washing time was 10 minutes, and frequency was 40kHz. Then the material was dried at about 100°C in a WAMED dryer. After washing and drying, the components were weighed using a laboratory scale of 1/1000 [g] accuracy. The research was carried out using the "rotating bowl" unit in the Poznan University of Technology Heavy Machinery Laboratories. Research method consists in a continuous and steady rotation of the ring-shaped tank. The advantage of this method is that the conditions are constant during the test. The tank also has an irrigation system so the operating conditions are as close as possible to the field ones. The abrasive was extracted directly from the soil, thus the similar conditions occurring to those that are during field work were reflected. The bowl turned at a constant speed of 6.2 km per hour. Elements mounted on the unit had a change in fixing sequence every 33.33km, thus each one was driven to the same path. Thanks to this treatment each of the elements was subject to the same force that was exerted on it throughout the experiment.

3. Results of research

The results of abrasive wear of designed and made from three types of steel elements are set out in Tab. 2.

Tab. 2. Mass decrement of the sample depending on the distance traveled in the soil [7]
Tab. 2. Zmniejszenie masy próbki w zależności od odległości pokonanej w glebie [7]

Steel	Distance [km]				Mass decrement [g]
	0	33.32	66.66	100	
Armox 600	486.683	486.654	486.597	486.572	0.111
Ramor 500	516.521	516.374	515.976	515.671	0.850
S355	447.254	447.132	447.118	447.100	0.154

The biggest loss of mass after thorough washing was measured for samples with a thickness of 7 mm, made of steel Ramor 500. Armox steel 600 had the smaller loss. This is due to the nature of test, because wear in the soil not only extends frontally but also laterally. Very similar results were obtained for samples of 8 mm thickness (Fig. 4).

Hardness of the material has a significant impact on the abrasion but also price of the material is very important. The first factor makes Armox 600 steel the best material (of three tested) to use in agricultural and heavy machinery.

4. Conclusion

On the basis of the tests the following statements can be formulated:

- Armox 600 steel is the best material for work in the soil, which also has a high ballistic resistance and hardness, so it is suitable for difficult conditions.
- A sample of 7 mm thick Ramor 500 showed the largest weight loss of 0.850 g after overcoming distance of 100 km.
- Samples of Armox 600 and S355 steel are similar, so both materials are suitable for machine parts that work in the soil.

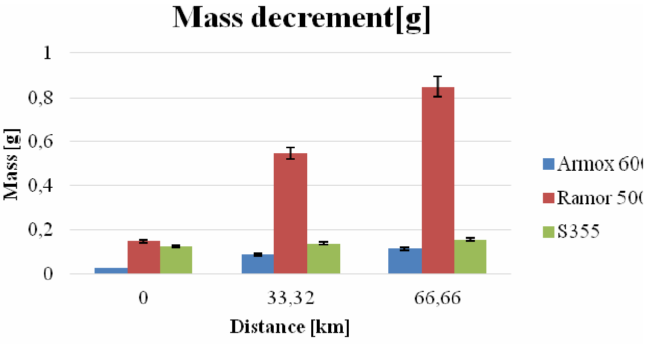


Fig. 4. Mass decrement of the sample depending on the distance traveled in the soil during the experiment [7]
Rys. 4. Zmniejszenie masy próbki w zależności od odległości pokonanej w glebie podczas eksperymentu [7]

5. References

[1] Napiórkowski J.: Zużyciowe oddziaływanie gleby na elementy robocze narzędzi rolniczych, Inżynieria Rolnicza, 2005, 12 (72).
[2] Napiórkowski J.: Badania i modelowanie procesów zużywania, Polska, 2014.
[3] http://www.ac2t.at/fileadmin/Bilder/FotosGeraete/db053-1-impeller-tumbler.png data dostępu: 15.06.2017 r.
[4] Selech J., Ulbrich D., Włodarczyk K., Kowalczyk J., Kęska W., Spiczak-Brzeziński P.: Experimental and simulation research of forces and stresses acting on the hoe coulter, „Journal of Research and Applications in Agricultural Engineering", 2016, Vol. 61(2).
[5] Biadała P.: Projekt stanowiska do badania zużycia elementów maszyn roboczych pracujących w ośrodku glebowym. Praca dyplomowa. IMRiPS, Poznań, 2007.
[6] Spiczak-Brzeziński P.: Zależność siły od głębokości i prędkości pracy narzędzia pracującego w ośrodku ściernym. Praca dyplomowa. IMRiPS, Poznań, 2014.
[7] Romek D.: Analiza porównawcza różnych rodzajów stali w maszynach do pracy w glebie. Praca dyplomowa. IMRiPS, Poznań, 2017.