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WEAR PROPERTIES OF CERAMIC BODIES PRODUCED WITH NATURAL ZEOLITE

VEDENJE KERAMIČNIH TELES, IZDELANIH IZ NARAVNEGA ZEOLITA, PRI OBRABI

Ayşe Şükran Demırkiran

Sakarya University, Faculty of Engineering, Department of Metallurgical and Materials Engineering, Esentepe Campus, 54187 Sakarya, Turkey
dkiran@sakarya.edu.tr

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In this study, the wear and friction behaviours of a ceramic disk produced from natural zeolite were studied using a ball-on-disk arrangement. Samples were fired in an electric furnace with a heating rate of 10 °C/min at 1150 °C for a period of 60 min. Friction and wear tests were carried out in dry test conditions under the (2.5, 5 and 7.5) N loads at the (0.1, 0.3 and 0.5) m/s sliding speeds.

Keywords: zeolite, friction, wear, ceramic

V tej študiji je predstavljeno vedenje keramične ploščice, izdelane iz naravnega zeolita, pri obrabi in trenju na napravi krogla na disku. Vzorci so bili žarjeni v električni peči s hitrostjo ogrevanja 10 °C/min, 60 min pri temperaturi 1150 °C. Preizkusi trenja in obrabe so bili izvršeni v suhih razmerah z obremenitvami (2,5, 5 in 7,5) N pri hitrostih drsenja (0,1, 0,3 in 0,5) m/s.

Ključne besede: zeolit, trenje, obraba, keramika

1 INTRODUCTION

At present, there is a large interest in the application of moving ceramic parts in the constructions without lubrication.[1] Ceramics have high mechanical properties, including hardness, general chemical inertness, excellent wear resistance, the ability to work in severe thermal conditions and relatively low densities in comparison with metallic or polymeric materials.[2,3] The wear of ceramics is one of the important issues for designers.[1] The wear of ceramics depends on operating conditions (such as normal load, sliding velocity, sliding distance and temperature), material properties (such as mechanical and thermal material properties) and structural properties (such as bulk density, impurity content, grain size, grain-boundary microstructure, porosity and glassy phase).[1,4,5]

In recent years, there has been a great demand for new materials produced using different raw materials. Zeolites are crystalline aluminosilicates with a three-dimensional framework structure based on the repeated units of silicon-oxygen (SiO_4) and aluminium-oxygen (AlO_4) tetrahedra. Natural zeolites are abundant raw materials in many countries. They can be used as raw material to produce ceramic, and the ceramics produced from natural zeolites have interesting properties.[6–9]

In this study, the wear behaviour of the ceramic bodies made of natural zeolite was investigated. The wear tests were carried out using an AISI 52100 ball by means of a ball-on-disc system in ambient and dry-friction conditions under the (2.5, 5 and 7.5) N loads with the (0.1, 0.3 and 0.5) m/s sliding speeds.

2 EXPERIMENTAL PROCEDURE

The zeolites used in the present study were supplied from ETİ Holding Company, located in Turkey. The chemical composition of zeolite as raw material is given in **Table 1**. The raw material was ground and sieved through a mesh 75 µm. Then, water was added as a binder and disc samples (Ø = 25 mm, 5 mm thick) were shaped by uniaxial dry pressing at a pressing pressure of 1.5 t. After shaping, the samples were dried at 110 °C for 24 h in an oven. Dried samples were fired in an electric furnace at a heating rate of 10 °C/min at 1150 °C for a period of 60 min and the fired samples were cooled down to room temperature in the furnace.

Before the wear test, the sintered disc samples were metallographically prepared and polished. Then, the balls and disc were ultrasonically cleaned in acetone. A ball-on-disc system was used for the friction and wear

Table 1: Chemical composition of zeolite as raw material
Tabela 1: Kemijska sestava zeolita kot surovine

Components (*w*/%)										
SiO_2	Al_2O_3	Na_2O	K_2O	Fe_2O_3	CaO	MgO	TiO_2	SrO	Rb_2O	ZnO
79.28	11.22	0.15	4.22	1.20	2.52	1.22	0.08	0.06	0.03	0.02

tests. The wear tests were carried out at ambient and dry-friction conditions under the (2.5, 5 and 7.5) N loads at the (0.1, 0.3 and 0.5) m/s sliding speeds. Hardened AISI 52100 steel balls with a 9 mm diameter against a ceramic disk were used in the system.

3 RESULTS AND DISCUSSION

The microstructural investigations, carried out by SEM, of the sintered samples revealed various features including very small cracks, undissolved quartz grains and porosity. In order to understand the microstructural changes and correlate them with the other results, an XRD analysis was performed. The XRD patterns of the samples sintered at 1150 °C for 60 min are shown in **Figure 1**. The XRD patterns consisting of kyanite, albite and silicon oxide peaks confirm the SEM results. In addition to these crystalline phases, a glassy phase also exists in the microstructure.

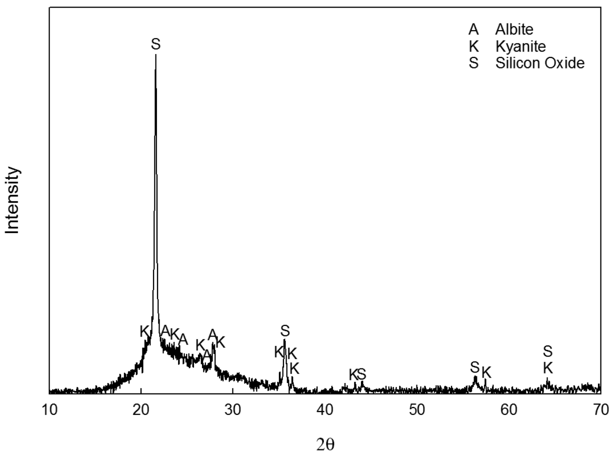

Figure 1: XRD pattern of the samples sintered at 1150 °C for 60 min
Slika 1: XRD-posnetek vzorca, sintranega pri 1150 °C, 60 min

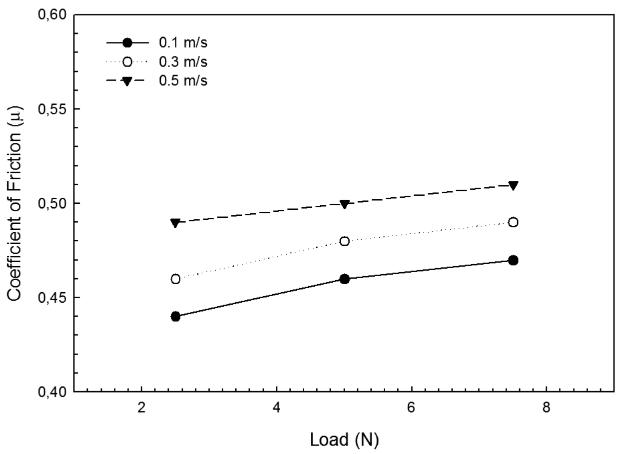

Figure 2: Variation of the friction coefficient with the applied load at different sliding speeds
Slika 2: Spreminjanje koeficienta trenja od uporabljene obtežbe pri različnih vrednostih hitrosti drsenja

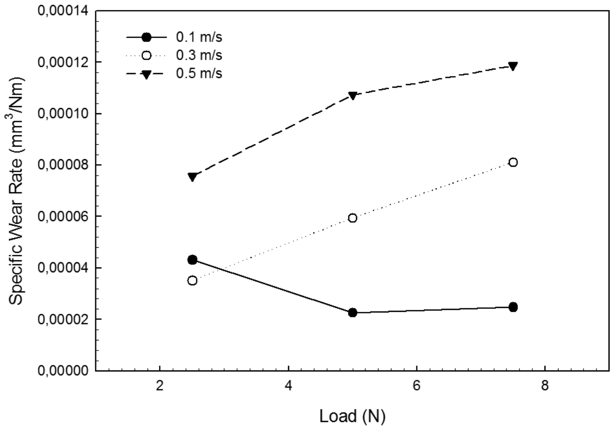

Figure 3: Variation of the specific wear rate with the applied load at different sliding speeds
Slika 3: Spreminjanje specifične hitrosti obrabe od uporabljene obtežbe pri različnih vrednostih hitrosti drsenja

Figure 2 presents a variation in the friction coefficient with an applied load at different sliding-speed values. It clearly shows that the friction coefficient increases linearly with an increase in the applied load and sliding speed. However, there is no significant change in the friction-coefficient values. **Figure 3** shows a variation in the specific wear rate with an applied load at different sliding-speed values. It is shown that specific-

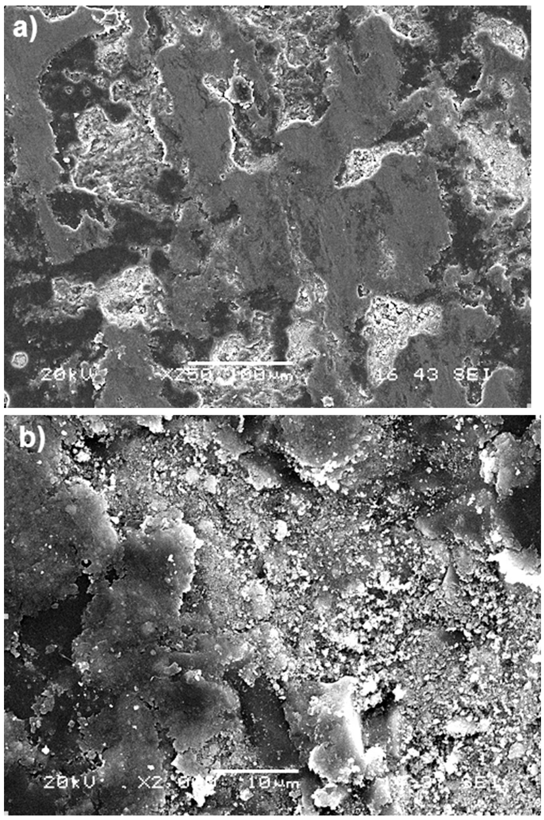

Figure 4: SEM micrographs of the worn surfaces at the 0.1 m/s sliding speed under the normal load of 5 N at different magnifications
Slika 4: SEM-posnetka obrabljene površine pri hitrosti drsenja 0,1 m/s pri obremenitvi 5 N pri različnih povečavah

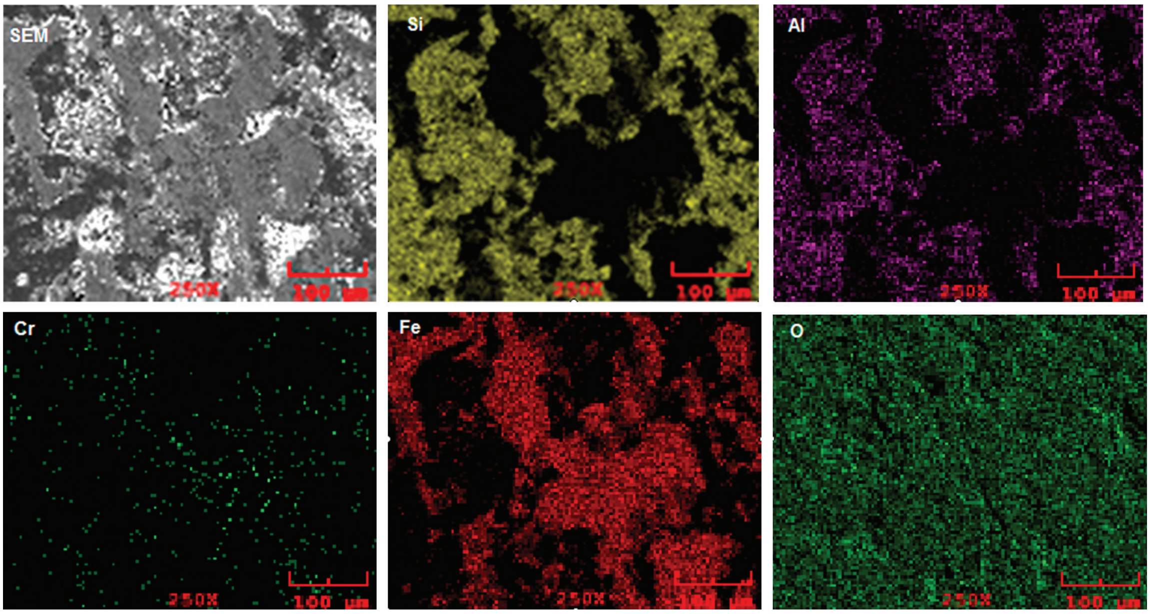

Figure 5: Elemental maps of the worn surfaces at the 0.1 m/s sliding speed under the normal load of 5 N
Slika 5: Razporeditev elementov na obrabljeni površini pri hitrosti drsenja 0,1 m/s pri obremenitvi 5 N

wear-rate values increase with the increasing applied load at the (0.3 and 0.5) m/s sliding speeds, but, at the 0.1 m/s sliding speed, the specific wear rate first decreases and then increases with the increase in the applied load.

Figure 4 shows SEM micrographs of the worn surfaces at the 0.1 m/s sliding speed under a normal load of 5 N at different magnifications. The worn surface of a sintered sample was covered by a layer formed with a densification of the oxidized wear debris from the steel ball on the sintered sample. However, a local spalling took place in this layer. Furthermore, the wear tracks consist of the wear debris as shown in **Figure 4b**. **Figure 5** presents elemental maps of the wear tracks of the sintered samples. It is clearly shown that the wear track of the disk includes iron, chromium and oxygen. However, as shown in **Table 1**, the chemical composition of the raw material does not include these elements. In this case, the wear debris from the AISI 52100 steel balls oxidizes with the heat resulting from the friction and then it adheres on the sample surfaces. In the light of these findings, it can be said that the wear mechanism of these samples is the adhesive wear. The wear mechanism of the AISI 52100 steel ball is also the abrasive wear.

4 CONCLUSIONS

The phases formed in the sintered samples are kyanite, albite and silicon oxide.

The coefficients of friction for all the combinations increase with an increase in the load.

The friction-coefficient values for the ceramic disks against the AISI 52100 steel balls vary between 0.44 and 0.51.

The specific wear rate also ranged between 2.267×10^{-5} mm^3/(N m) and 1.187×10^{-4} mm^3/(N m).

The wear mechanism of the sintered samples is the adhesive wear.

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