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Tribological behavior of alumina (Al_2O_3) and zirconia (ZrO_2) plungers used in high pressure pumps

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Abstract
Ceramic materials are commonly used in plungers due to high resistance to wear, abrasion, and low coefficient of thermal expansion. Also, they are commonly used in dry conditions without permanent damage, ceasing of pump head and better corrosion resistance than metals due to their inert characteristics. Zirconia (ZrO_2) ceramic is used due to its high strength whereas, alumina (Al_2O_3) is commonly used in industries for high pressure pumps. The toughness of zirconia ceramics is higher than alumina ceramics as it overcomes the inherent brittleness of ceramic materials. It also has higher wear resistance and extends the life of the product. Whereas alumina has better mechanical characteristics such as hardness compared to Zirconia. In this research work tribological behavior of Alumina and Zirconia ceramics used in high pressure pumps have been studied. The wear test using end face wear testing apparatus has been conducted under flat contact for both alumina and ceramic material considering a mean contact pressure of 10 N, 20 N, 30 N and 40 N and sliding velocity of 40 mm/s. The wear test was conducted for 30 min considering a total sliding distance of 1500 m and 3000 m. The wear test results indicate that both alumina and ceramic exhibit lower wear factors and superior mechanical properties. The findings also reveal that the wear rates of Al_2O_3 and ZrO_2 are influenced by friction forces, subsequently impacting the overall wear rate. Also, as the load increases the surface contact area also increases which in turn increases the wear rate. However, zirconia could be a potential substitute for alumina due to its high strength and fracture toughness.

Article Highlights

- The tribological behavior of Alumina and Zirconia composite material used in pressure pumps has been tested.
- The above material has been tested for contact pressure and sliding velocity.
- From the results it is shown that the above material has less wear and has good mechanical properties.

Keywords Ceramics · Composites · Alumina · Zirconia · Wear rate · Toughness

1 Introduction

The properties such as unique molecular composition, chemical, physical along with mechanical properties such as high hardness, high stiffness and chemical stability have made ceramics distinct from other material and are most used for wider technical applications at elevated temperatures [1–3]. These materials are produced by either

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modification of raw material, refinement or even synthesized to form new enhanced ceramic materials properties and often called technical, advanced, engineering, or fine ceramics [4]. These new ceramics material is commonly used for faster, lighter, and more efficient machines for automotive and aircraft industries despite having high friction and high wear at elevated temperatures. Zirconia and alumina stand out as highly robust materials in ceramics, owing to their enhanced mechanical properties such as load-bearing capacity and resistance to wear [5, 6]. These materials find widespread applications in both medical and engineering fields. Out of these two ceramic materials, the wear resistance of zirconia is better as compared to wear resistance of alumina. Apart from wear resistance properties, the density of zirconia is more as compared to density of alumina. The major drawback of zirconia is the thermal shock resistance [7, 8] and hence it requires higher sintering temperatures as compared to alumina which in turn increases the manufacturing cost. Hence, zirconia and zirconia coated alumina are more commonly used in medical applications [9, 10]. In addition to the above, Zirconia and alumina have chemical inertness and good tribological properties and hence have a mechanical advantage as compared to metals and ceramics [11]. The properties of these commercially available structural ceramics like alumina and zirconia ceramics are given in Table 1. These ceramic material components are commonly used in moving or rotating parts such as pistons and rotors due to their ability to withstand higher temperature, good machinability, low manufacturing costs and ease of shaping [12].

The wear patterns observed in case of Al_2O_3 and ZrO_2 depends upon the tensile stress of the contact surface and considered to be predominant factor in fracture wear of ceramics and commonly occurs due to fine grains, compressive residual stresses, and low elastic moduli [13, 14]. In case of dry sliding at lesser velocity range (less than 0.75 m/s), it is observed that stick–slip plays an important role which depends upon coefficient of friction during the running condition [15]. From the literature it is also observed that during the higher speed range (Speed range above 0.75 m/s and the corresponding wear rate is less than 0.15 percent) the wear rate of alumina increases depending upon speed and load which in turn fails by plastic deformation, shear and grain pull out [16, 17]. From the above literature mentioned earlier, it can be inferred that numerous researchers have extensively investigated ceramic materials, particularly alumina and zirconia, as well as alumina–zirconia composites. These studies have focused on aspects such as friction forces, wear rates, and sliding velocities. But the literature corresponding to plungers used in high pressure pumps considering alumina and zirconia is not available. Hence, in this research work plungers made of alumina and zirconia ceramics have been considered and the friction force, wear and specific wear rate have been measured.

2 Methodology

The manufacturing technology used with ceramic components is very similar to that used for powder metallurgical technologies. The main steps in the manufacturing process are raw material, preparation, shaping, drying, probably pre-firing, firing (sintering) and finishing. Very often, the component is pre-fired and compressed. It can be finished using simple appliances or coated (glazed). The components are then fired (sintering process) and further compressed through shrinkage and increasing mechanical strength. Fired components are finished by sawing, grinding, polishing, and lapping. Ceramics are very brittle. Therefore, they cannot be reshaped during the manufacturing process, i.e., after shaping, apart from finishing after firing; the outlines of a ceramic component cannot be modified. Finishing is time-consuming

Table 1 Properties of commercially available ceramics (Al_2O_3 and ZrO_2) [18]

Property	Symbol	Unit	Al_2O_3	ZrO_2
Grain size	D	μm	10	0.18
Fracture Toughness	K	MPa. $\sqrt{m}$	3.5	7
Young's modulus	E	GPa	390	210
Poisson's ratio	Y	–	0.23	0.3
Density	ρ	Kg m^{-3}	3.9	6.05
Thermal expansion coefficient	α	$10^{-6}/K^{-1}$	8	9
Thermal conductivity	K	$W(m\ K)^{-1}$	29	2.5
Specific heat	C	$J/(kg\ K)^{-1}$	600	460
Thermal shock resistance	ΔTs	K	200	280
Hardness	H	GPa	18	12.3

and diamond tools are often the only tools that can be used in this process. During constructive planning and design, it is therefore essential to look for options that avoid a finishing operation.

The pin samples prepared were 25 mm in length and 10 mm in diameter. The pin was held against the counter face of a rotating disc (EN31 steel disc) with a wear track diameter 60 mm. The pin was loaded against the disc through a dead weight loading system. The experiments were conducted on a pin on disc tester (Wear & Friction Monitor TR-20, Ducom Instruments) considering a load of 10N, 20 N, 30 N and 40 N and the corresponding friction force and wear rate were measured. These experiments were conducted considering a sliding velocity of 40 mm/s and the corresponding machine speed used were 300 rpm and 600 rpm. Increased rpm in turn increases the sliding wear rate and surface interactions. The alumina and zirconia specimen were tested for a period of 30 min considering a sliding distance of 1500 m and 3000 m. Typically, zirconia and alumina samples are manufactured by shaping them into the desired forms through common methods such as pressing, slip casting, tape casting, or injection molding. In our research studies the samples of alumina and zirconia material plungers have been purchased and then the machining operations have been performed on these samples to reduce the diameter of the specimen so that it can be fixed in the pin on disc tester.

3 Experimental procedure

The experiments were conducted on pin on disk machine [19] and the experimental setup is as shown in Fig. 1. This machine can be operated in a speed range of 10–1500 rpm, and the maximum sliding speed range is from 0.1 m/sec to 10 m/sec and the maximum friction force has a range of 0–200 N. Generally, the wear of the specimen is usually measured using weight loss and has an accuracy range of 0.1 mg. The ceramic specimen was tested using a procedure followed as per ASTM standard. The specimen is securely held in the pin of machine and loaded against a rotating disk. Then this specimen is held perpendicular (90°) to the disc surface and motor is switched on and the corresponding speed and desired number of revolutions is adjusted. The load is applied to the system lever or bale to develop the force so that specimen can be pressed against the disc. Then the coefficient of friction is calculated by considering the ratio of friction force and the loading force on the pin which is directly displayed on the machine along with the wear loss. The machine is switched off after the desired number of revolutions is achieved. Three samples of each specimen were tested for replicability, and the average of these readings was recorded for further processing. Then, the specimen is removed from the machine and cleaned thoroughly and observed for wear scars such as protrusions, displaced metal, discoloration, micro cracking, and spotting. This wear scar such as protrusions or displaced metal have been observed and then it is cleaned thoroughly using emery paper. The identical procedure is applied across different loads and specimens, with readings duly recorded. Figures 2, 3 shows the investigation samples prepared for the experiments consisting of alumina and zirconia.

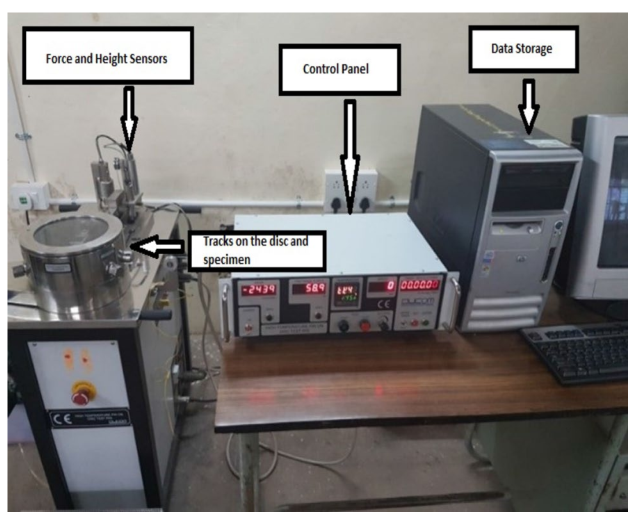

Fig. 1 Experimental setup of wear test

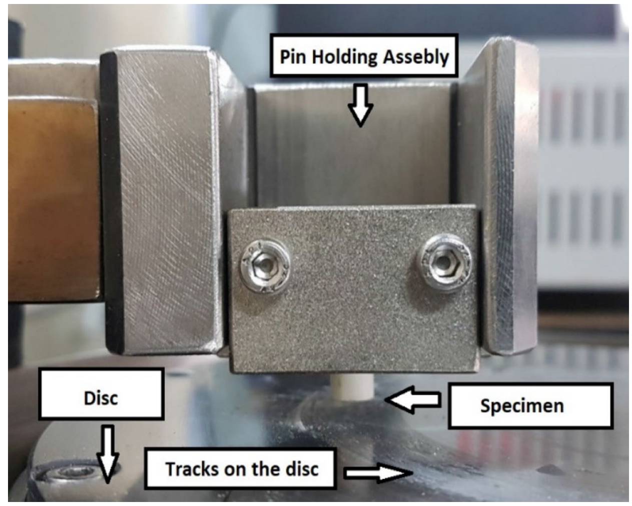

Fig. 2 Sample specimen disc arrangement

Fig. 3 Investigation of samples prepared for testing

4 Results

4.1 Investigation for a load of 10 N

The wear of a material can be predicted either by loss of weight or wear rate. The wear coefficient study is more suitable during wear of the materials and the wear rate considers the applied load and the hardness of the wear pin. Wear rate is the amount of volume loss per unit sliding distance. The wear rate observed in ceramic structure cannot be predicted accurately as it depends on many factors which involves physics, chemistry and contact mechanics and depends upon environmental and operating parameters and hence there is only few theoretical models to study ceramics [20, 21].

In this research work wear rate of alumina and zirconia have been studied considering a load of 10 N, 20 N, 30 N and 40 N. Figure 4 shows the wear rate of Al_2O_3 and ZrO_2 for 300 rpm at a load of 10 N [22]. From this figure it is observed that wear rate of Al_2O_3 and ZrO_2 is 1.51 mm^3/m and 0.48 mm^3/m for 100 s. Also, the wear rate of ZrO_2 is 6.05 mm^3/m at 200 s which is more as compared to Al_2O_3 (1.05 mm^3/m). It is known that zirconia ceramics exists in three different phases such as monoclinic, tetragonal, and cubic structure and the structure of zirconia is monoclinic at room temperature and pressure, and it retains its monoclinic temperature up to 1170 °C [23]. In general zirconia ceramic retains its high strength and fracture toughness in tetragonal structure and any crack propagating during this phase will change from tetragonal to monoclinic phase. The high amount of wear rate observed in case of Zirconia is due to its monoclinic structure and hence the wear rate observed initially is more in this case as compared to Alumina [24]. But alumina has several allotropic forms, and it exists at room temperature as α-Alumina. The wear rate observed in this case at this load of 10 N is less and has showed excellent wear resistance.

From Fig. 4a it is observed that the wear rate of ZrO_2 continuously decreases after 200 s and after some period of run time the wear rate of both Al_2O_3 and ZrO_2 continuously increases. However, it is observed that the wear rate of Al_2O_3 is more as compared to ZrO_2. This occurs due to high coefficient of friction at elevated temperatures in turn wear rate will be higher in case of Al_2O_3 as compared to ZrO_2 for the same load [12]. Examining the graph reveals that the wear rate is elevated during the initial stage of sliding distance, experiences a slight reduction [25], and subsequently continues to rise continuously. This phenomenon is attributed to variations in friction levels and the microstructural form of the composite, impacting the transition between mild and severe wear and vice versa. Figure 4b shows the friction force of Al_2O_3 and ZrO_2 for 300 rpm at the same load of 10 N. From Fig. 4b it is observed that the friction force in case of Al_2O_3 is more as compared to ZrO_2 which in turn clearly shows that the wear rate is higher in case of Al_2O_3 as compared to ZrO_2 (refer Fig. 4). This frictional force values and temperature obtained is a result of combination of load and speed values during sliding. Figure 5a shows the wear rate of Al_2O_3 and ZrO_2 at 150° C for a load of 10 N. From Fig. 5a it is observed that the wear rate of Al_2O_3 is more as compared to wear rate of ZrO_2. This clearly shows that the coefficient of friction is more in case of Al_2O_3 as compared to ZrO_2 and occurs at elevated temperatures.

Figure 5b shows the wear rate of Al_2O_3 at 600 rpm for a load of 10 N. From Fig. 5 it is also observed that the wear rate of Al_2O_3 is more as compared to wear rate of ZrO_2. Similarly, Fig. 6a shows the friction force of Al_2O_3 and ZrO_2 for a load of 10 N for 600 rpm. From Fig. 5a it is observed that the friction force is more at initial stage, and it remains constant after some period of sliding. It is also observed that the friction force is slightly higher in case of ZrO_2 as compared to Al_2O_3 however, the wear rate is more in Al_2O_3 as compared to ZrO_2. The grain size in the case of ceramics testing plays an important role in the analysis of the wear. It is established by many researchers [26, 27] that if the grain size is tiny then the ability of the material to resist wear is higher as compared to larger grain size. Also, from Fig. 6b it is observed that the wear rate of Al_2O_3 is more as compared to ZrO_2 at 150 °C at 600 rpm.

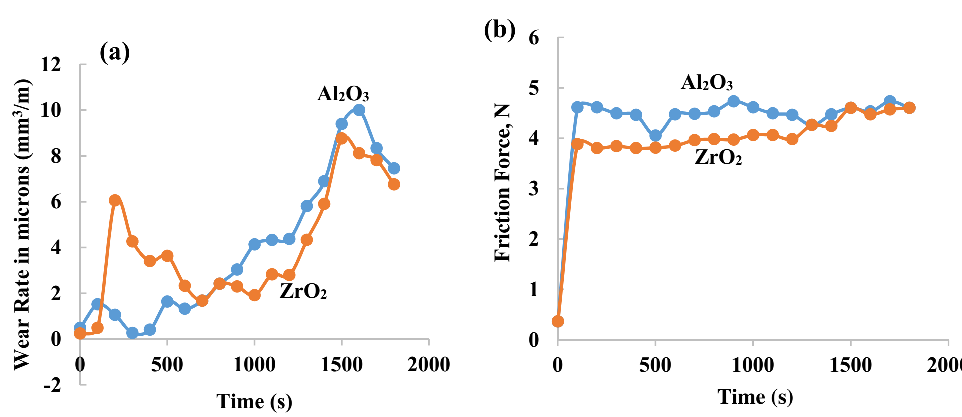

Fig. 4 **a** Wear rate of Al_2O_3 and ZrO_2 at 300 RPM –Load-10N. **b** Friction force of Al_2O_3 and ZrO_2 at 300 RPM –Load-10N

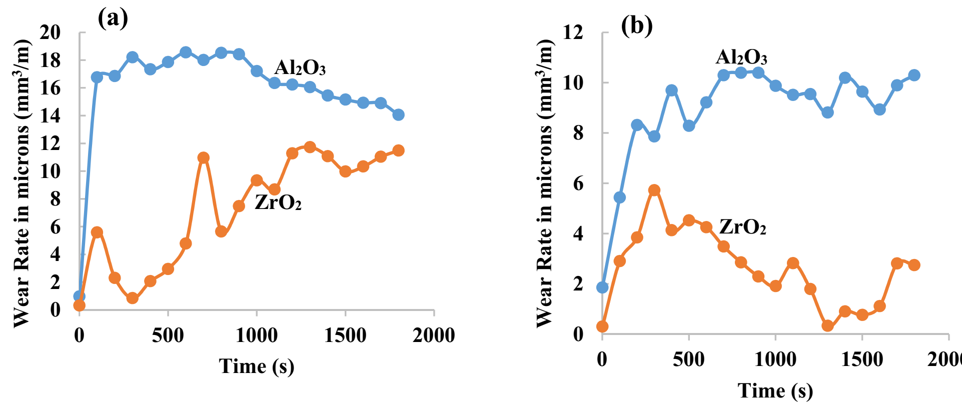

Fig. 5 **a** Wear rate of Al_2O_3 and ZrO_2 at at 150˚ C 300 RPM –Load-10N. **b** Wear rate of Al_2O_3 and ZrO_2 at 600 RPM –Load-10N

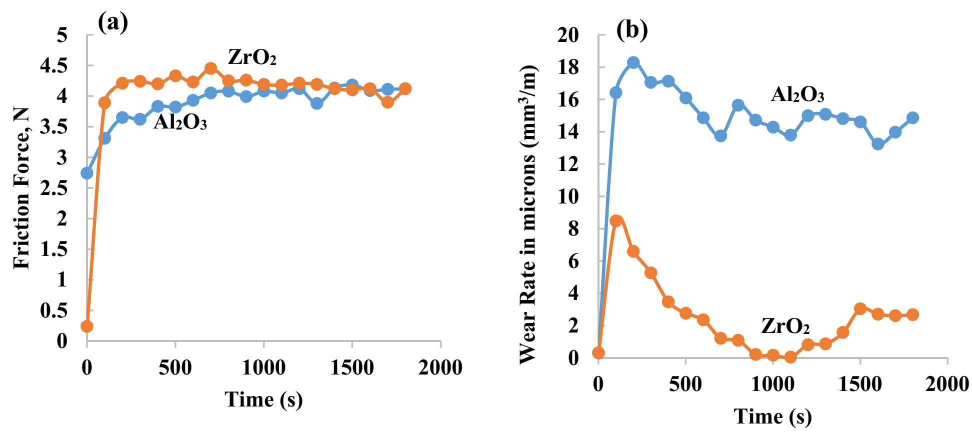

Fig. 6 **a** Friction force of Al_2O_3 and ZrO_2 at 600 RPM—Load-10 N. **b** Wear rate of Al_2O_3 and ZrO_2 at 150 °C (600 RPM)—Load-10 N

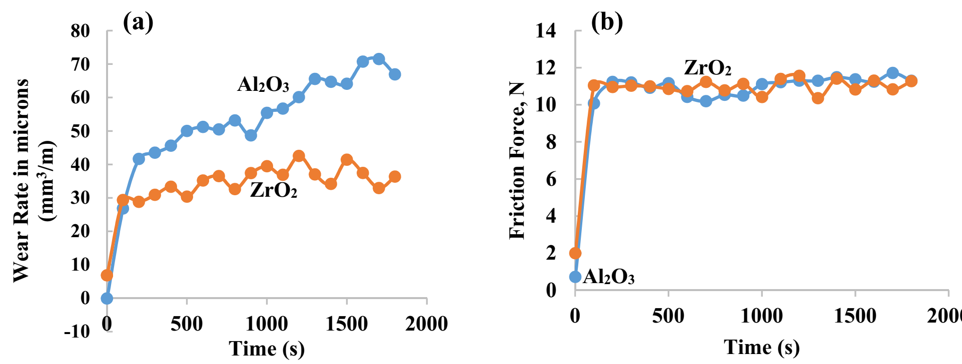

Fig. 7 **a** Wear rate of Al_2O_3 and ZrO_2 at 300 RPM—Load-20 N. **b** Friction Force of Al_2O_3 and ZrO_2 at 300 RPM—Load-20 N

4.2 Investigation for a load of 20 N

Figure 7a shows the wear rate of Al_2O_3 and ZrO_2 for a load of 20 N at 300 rpm. From Fig. 7a it is observed that the wear rate of Al_2O_3 is more as compared to wear rate of ZrO_2. The wear rate of Al_2O_3 and ZrO_2 is 26.79 mm^3/m and 29.3 mm^3/m for 100 s which is slightly higher in case of ZrO_2 as compared to Al_2O_3. After this point the wear rate of Al_2O_3 increases continuously as compared to ZrO_2. In general wear rate in case of ceramics depends upon asperities. These asperities deform elastically in the case of ceramics and in turn contact stress distribution depends upon radius of the asperity and hence it can be stated that ceramics is independent of the load applied. The effect of this load is to increase the density of the asperities which in turn increases the surface contact area [28]. The wear rate observed in case of 20 N is more as compared to wear rate observed in 10 N and this occurs due to increase in the contact surface area between the specimen and the disk. Also, as the load is increased from 10 to 20 N the wear rate is high due to high coefficient of

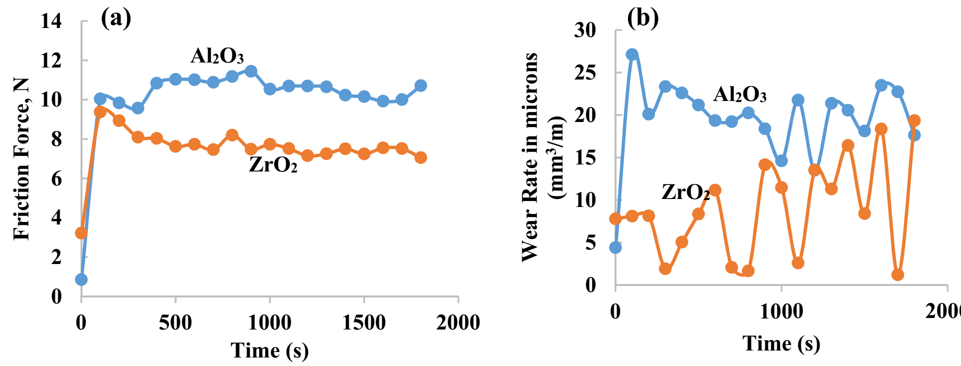

Fig. 8 **a** Friction force of Al_2O_3 and ZrO_2 at 600 RPM—Load-20 N. **b** Wear rate of Al_2O_3 and ZrO_2 at 150 °C (600 RPM)—Load-20 N

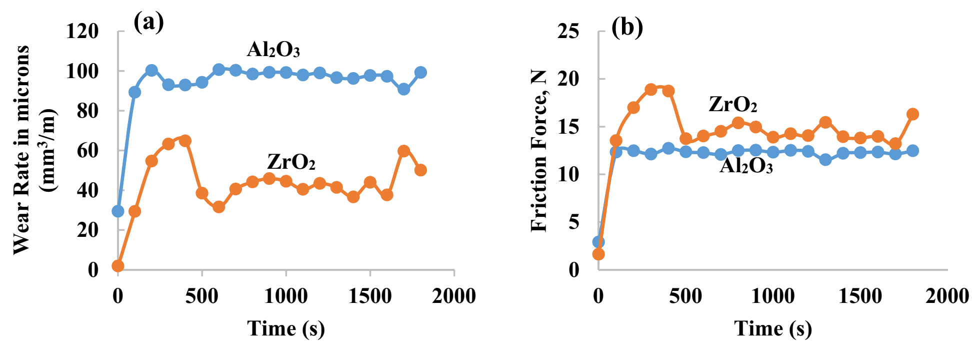

Fig. 9 **a** Wear rate of Al_2O_3 and ZrO_2 at 300 RPM—Load-30 N. **b** Friction Force of Al_2O_3 and ZrO_2 at 300 RPM—Load-30 N

friction. It is also observed that the wear rate is higher in case of Al_2O_3 as compared to ZrO_2. This clearly shows that as the load is increased from 10 to 20 N, ZrO_2 has higher toughness as compared to Al_2O_3 which reduces the spreading of crack and in turn reduces the microscopic fracture and the surface damage. Figure 7b shows the friction force of Al_2O_3 and ZrO_2 at 300 rpm. From Fig. 7b it is observed that friction forces are higher as compared to 10 N as the contact surface area is more. In this case also it is observed that the friction forces in case of Al_2O_3 and ZrO_2 approximately remains same. Figure 8a shows the graph of Friction force of Al_2O_3 and ZrO_2 at 150 °C for load of 20 N at 600 rpm. From Fig. 8a it is observed that the friction force of ZrO_2 is less as compared to Al_2O_3. This occurs due to thermal conductivity of ZrO_2 at elevated temperature is less which in turn the friction force is less as the atoms in the structure are more heated up due to less thermal conductivity.

Figure 8b shows the wear rate of Al_2O_3 and ZrO_2 at 600 rpm for a load of 20 N. From Fig. 8b it is observed that the wear rate of Al_2O_3 is more as compared to ZrO_2 even though the friction forces are higher which can be observed from Fig. 8a and occurs due to thermal conductivity at elevated temperature. Similarly, Fig. 8b shows the wear rate of Al_2O_3 and ZrO_2 at 150° C at 600 rpm for a load of 20 N. From this Fig. 8b it is observed that the wear rate of Al_2O_3 is more as compared to ZrO_2. This occurs due to the load is increased the alumina grains have become much coarser and uneven due to contact surface area and in turn wear rate is higher [27].

4.3 Investigation for load of 30 N

Figure 9a shows the graph of Al_2O_3 and ZrO_2 at 300 rpm for a load of 30 N. From this Fig. 9a it is observed that the wear rate of Al_2O_3 is more as compared to ZrO_2. From this it can be stated that zirconia ceramics can retain their grain structure even at high load and more contact surface area as compared to alumina ceramics. The wear rate in both these cases is higher as compared to previous load of 10 N and 20 N. It is also observed that the wear rate of Al_2O_3 is higher even though the friction force approximately remains constant (Refer Fig. 9b) as compared to load of 20 N. The wear rate in the case of 20 N is much higher as compared to wear rate in case of 30 N. The maximum wear rate in case of 20 N has reached around 25 mm^3/m for Al_2O_3 whereas the maximum wear rate in case of 30 N is 19 mm^3/m for Al_2O_3. Also, the maximum wear rate observed in case of ZrO_2 in case of 20 N and 30 N remains constant. Whereas the average wear rate is more in case of ZrO_2 in case of 20 N as compared to 30 N. Similarly, the wear rate of ZrO_2 has increased due to friction force also increased as compared to load of 20 N. Figure 10a shows the wear rate of Al_2O_3 and ZrO_2 at 300 rpm for a temperature of

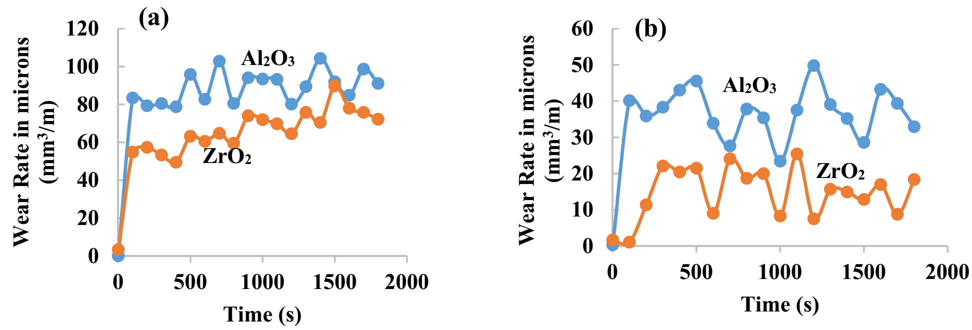

Fig. 10 **a** Wear rate of Al_2O_3 and ZrO_2 at 150 °C (300 RPM)—Load-30 N. **b** Wear rate of Al_2O_3 and ZrO_2 at 600 RPM—Load-30 N

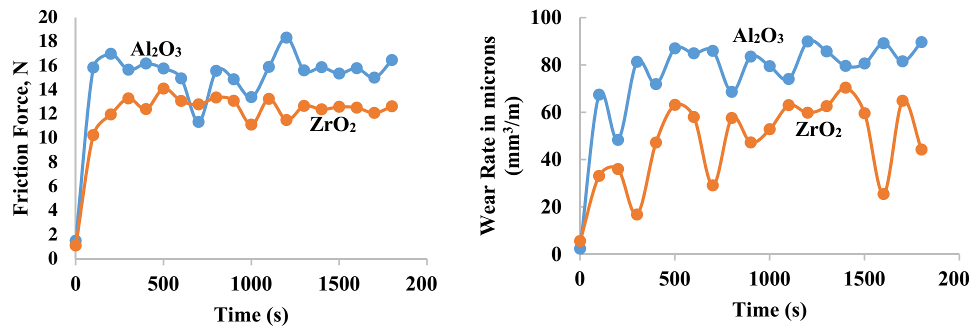

Fig. 11 **a** Friction force of Al_2O_3 and ZrO_2 at 600 RPM—Load-30 N. **b** Wear rate of Al_2O_3 and ZrO_2 at 150 °C (300 RPM)—Load-30 N

150 °C. In this case it is observed that the wear rate of Al_2O_3 is more as compared to ZrO_2. Also, wear rate is more in case of 30 N as compared to 20 N. For instance, the wear rate of Al_2O_3 for 30 N at 100 s is 83.43 mm^3/m as compared to 38.97 mm^3/m in case of 20 N. This clearly shows that as the load increased from 20 to 30 N the ability of Al_2O_3 to resist load is less and in turn the wear is more. Also, it is observed that the wear rate of ZrO_2 is 54.83 mm^3/m in case of 30 N whereas, the wear rate in case of 20 N is 108.33 mm^3/m (Refer Fig. 10b). This shows that both Al_2O_3 and ZrO_2 at 30 N have less wear rate as compared to 20 N load. This occurs due to friction is less as the contact load is increased, which in turn the detached wear particle [29] will reattach to the specimen as the temperature is increased to 150 °C.

Figure 11b shows the graph of wear rate of Al_2O_3 and ZrO_2 at 600 rpm for a load of 30 N. From this plot it is observed that the wear rate in case of Al_2O_3 and ZrO_2 is less as compared to 20 N despite friction force is slightly higher (refer Fig. 11a). Similarly, Fig. 11a shows the graph of wear rate of Al_2O_3 and ZrO_2 for 600 rpm at 150 °C for load of 30 N. From this it is observed that the wear rate of Al_2O_3 and ZrO_2 is slightly higher as compared to load of 20 N. This occurs due to high elevated temperature and in turn more wear rate occurring in both cases of alumina and zirconia ceramics.

4.4 Investigation for a load of 40 N

Figure 12a shows the wear rate of Al_2O_3 and ZrO_2 at 300 rpm for a load of 40 N. From Fig. 12a it is observed that wear rate of Al_2O_3 is more as compared to wear rate of ZrO_2. Also, wear rate of Al_2O_3 is less in case of 40 N as compared to a load of 30 N. For instance, the wear rate at 40 N for 200 s is 72.44 mm^3/m whereas the wear rate is 100.22 mm^3/m for a load of 30 N. This is occurring due to the load is increased the contact surface is increased which in turn detached particle will attach back to the specimen and in turn wear rate is less. The same behavior is also observed for ZrO_2. The friction force in case of Al_2O_3 and ZrO_2 is slightly higher in case of 40 N (refer Fig. 12b) as compared to 30 N. Figure 13a shows the graph of wear rate of Al_2O_3 and ZrO_2 at 300 rpm for 150 °C. In this case it is observed that the wear rate is very less for Al_2O_3 as the particle is going to attach back to the specimen due to high temperature. Also, it is observed that the wear rate of ZrO_2 approximately remains constant as compared to 30 N. Figure 13b shows the wear rate of Al_2O_3 and ZrO_2 at 600 rpm for a load of 40 N. In this case the wear rate of ZrO_2 is more as compared to wear rate of Al_2O_3. From this graph it is also observed that the wear rate of Al_2O_3 is slightly higher as compared to load of 30 N. This clearly shows that Al_2O_3 has performed better in terms of wear rate as compared to ZrO_2.The wear rate of zirconia observed is more and it occurs due to low thermal conductivity at high sliding speeds and occurs due to frictional heating. This frictional heating increases the flash temperature and in turn high stresses are generated which increases the thermal shock and in turn

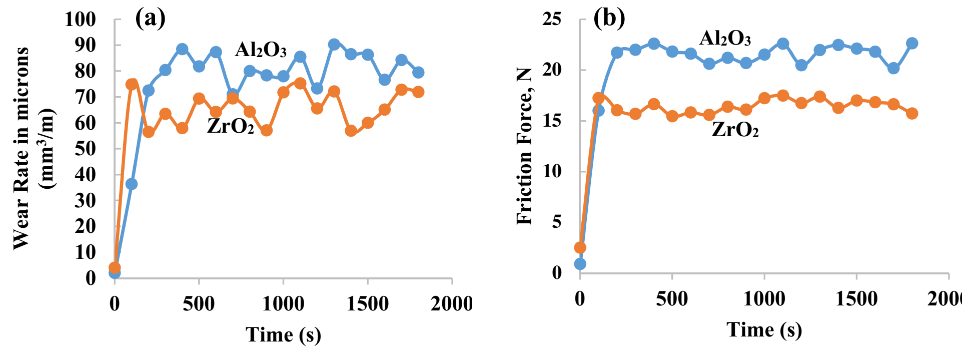

Fig. 12 **a** Wear rate of Al_2O_3 and ZrO_2 at 300 RPM—Load-40 N. **b** Friction force of Al_2O_3 and ZrO_2 at 300 RPM—Load-40 N

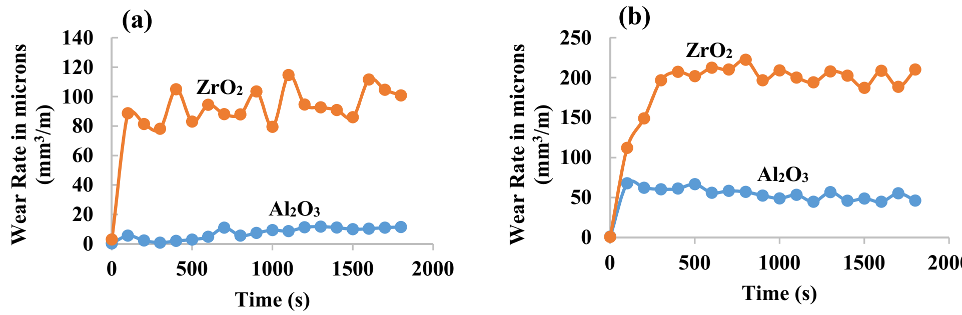

Fig. 13 **a** Wear rate of Al_2O_3 and ZrO_2 at 150° C (300 RPM)—Load-40 N. **b** Wear rate of Al_2O_3 and ZrO_2 at 600 RPM—Load-40 N

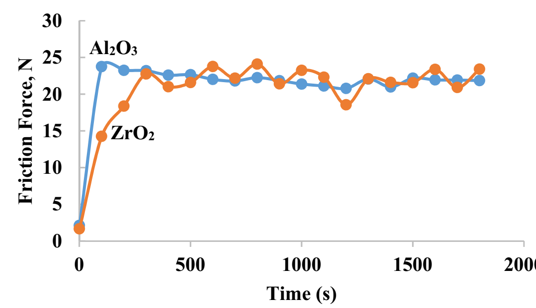

Fig. 14 Friction force of Al_2O_3 and ZrO_2 at 600 RPM—Load-40 N

wear [30]. Similarly, Fig. 14 shows the friction forces of Al_2O_3 and ZrO_2 at 600 rpm for a load of 40N. From this Fig. 14 it is observed that the friction forces approximately remain same for both Al_2O_3 and ZrO_2.

5 Discussions

From the previous results it is understood that the friction force of Al_2O_3 and ZrO_2 has an impact on wear rate having various types of loads, temperature, and different rpm. The ZrO_2 ceramic has less friction coefficient and contact temperatures with respect to alumina. However, zirconia has more energy dissipation as compared to alumina. So, the composites of Al_2O_3 and ZrO_2 has performed differently as compared to individual materials and the effects of various loads, temperature and sliding velocity discussed above clearly demonstrates the capability of these composites used in ceramics plungers which in turn enhances hardness and wear resistance [31]. The tailoring of Al_2O_3 and ZrO_2 can be designed and synthesized by reaction sintering shows that continuous homogeneous structures with improved physical, mechanical and thermal properties can be achieved [32]. The crater wear resistance of these structures is like that of ceramic tools [33]. Similar type of work considering dry sliding wear of ZrO_2 toughened Al_2O_3 considering different metal oxide additives for a similar type of load has showed that the lowest specific wear rate and less coefficient of friction [34].

6 Conclusions

In this research article the tribological behavior of alumina and zirconia plungers commonly used in high pressure pumps needs to be investigated for various types of loads and sliding velocity. To study the tribological behavior such as wear rate and frictional force, a load of 10 N, 20 N, 30 N and 40 N was used. From this study it is understood that the wear rate of Al_2O_3 and ZrO_2 depends on the friction forces and in turn wear rate. The material is more wear resistant if the grain size is tiny and vice versa. The wear rate for alumina in this case at the load of 10 N is less and has showed excellent wear resistance. The wear rate observed in case of ZrO_2 for a load of 10 N continuously decreases after 200 s and after some period of run time the wear rate of both Al_2O_3 and ZrO_2 continuously increases. Similarly, the wear rate of ZrO_2 for a load of 20 N is slightly higher as compared to wear rate of Al_2O_3. After this point the wear rate of Al_2O_3 increases continuously as compared to ZrO_2 for the same load conditions. The wear rate of Al_2O_3 observed in case of 30 N is more as compared to ZrO_2. This clearly shows that as the load increased from 20 to 30 N the ability of Al_2O_3 to resist load is less and in turn the wear is more. In the case of 40 N it is observed that the wear rate is very less for Al_2O_3 as the particle is going to stick back to the specimen due to high temperature. Also, it is observed that the wear rate of ZrO_2 approximately remains constant as compared to 30 N. Based on the above analysis, it can be asserted that the primary wear mechanisms influencing ceramics are closely linked to tribological contact surfaces. In instances of low contact stress on the surface, material removal is contingent upon plastic deformation at the microcontact surfaces. However, when the contact pressure surpasses the material's elastic limit, it results in an escalation of wear debris.

From the wear point of consideration zirconia ceramics have performed better compared to alumina ceramics and enhance the life of the plunger. From the load point of view, it is observed that as the load increases the surface contact area of the ceramics increases and in turn wear also increases. The major limitation of this study is the specimen would have been observed for more information to identify the various patterns of wear using Scanning electron microscope and can be considered as future scope of work.

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Data availability The authors declare that the data supporting the findings of this study are available within the paper. Should any raw data files be needed in another format they are available from the corresponding author upon reasonable request. Source data are provided with this paper.

Declarations

Ethics approval and consent to participate Not applicable.

Competing interests The authors declare no competing interests.

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