Journal of Manufacturing Engineering, December 2020, Vol. 14, Issue.4, pp 118-123

EXPERIMENTAL STUDY OF TRIBOLOGICAL BEHAVIOR OF ALUMINUM OXIDE(Al_2O_3)USING PIN-ON-DISC WEAR TESTING APPARATUS

*Yathish Narayana Rao K N[1] and Mohamed Kaleemulla K[2]

[1]Department of Mechanical Engineering, S J C Institute of Technology, Belgaum, Karnataka- 562 101, India
[2]Department of Mechanical Engineering, UBDTVE, Davanagere, Karnataka -577 004, India
https://doi.org/10.37255/jme.v15i4pp118-123

ABSTRACT

Aluminium oxide ceramics have a good thermal conductivity, high strength and stiffness, low coefficient of expansion, these major properties made them adopt in the critical structural designs of aerospace and in advanced machinery. Ceramics is having wide applications in all the structural designs and developments, because of its properties like higher density, hardness, resistance to corrosion and it can stand with very high temperatures. Ceramics is mainly used as reinforcement with aluminium oxide in order to enhance its stiffness and strength. The particles of ceramics can easily combine with aluminium oxide (Al_2O_3) and it gives an identical property throughout the composite material.

Keywords: *Aluminum oxide (Al_2O_3),* Ceramics, Wear and Tribology

1. Introduction

Generally, the fabricated composite from the sintering casting process is having considerably improved properties as compared to the other methods of manufacturing the matrix composites [1]. The microstructural images of aluminium oxide matrix composites have clearly indicated fewer amounts of defects and identical distribution of the particulate reinforcements [2]. Mechanical properties of the AMMC are investigated by Vickers Hardness Test Rig, Impact Strength Test Rig, UTM (Universal Testing Machine) for compression test and Pin on Disc Machine for tribological behavior [3]. The fractured test specimens are further investigated for their fracture analysis using Scanning Electron Microscope (SEM) [4]. The experimental procedure proposed is presented in the form of a Flow Chart as below in Fig. 1 [6].The main objectives of the research works are to prepare aluminum oxide specimen as per ASTM standards by sintering ISO static pressing(ASTM Std-E9) (L/D:1.66) and evaluate the tribological characterization properties of Al_2O_3 [7].

2. Experimental Set Up

Isostatic squeezing is a powder metallurgy (PM) framing process that applies equivalent pressure in all sides on a powder minimized along these lines accomplishing most extreme consistency of density and microstructure without the geometrical confinements of uniaxial squeezing [8]. This type of operation is used for compaction of powders. The process is similar to pressing using cupped hands for making snow balls [9]. As Shows in Fig. 2.Types of Isostatic pressing are as follows:

i. Hot Isostatic Pressing.
ii. Cold Isostatic Pressing.

Fig. 2 Iso static pressing Machine

*Corresponding Author - E- mail:yathish73@gmail.com

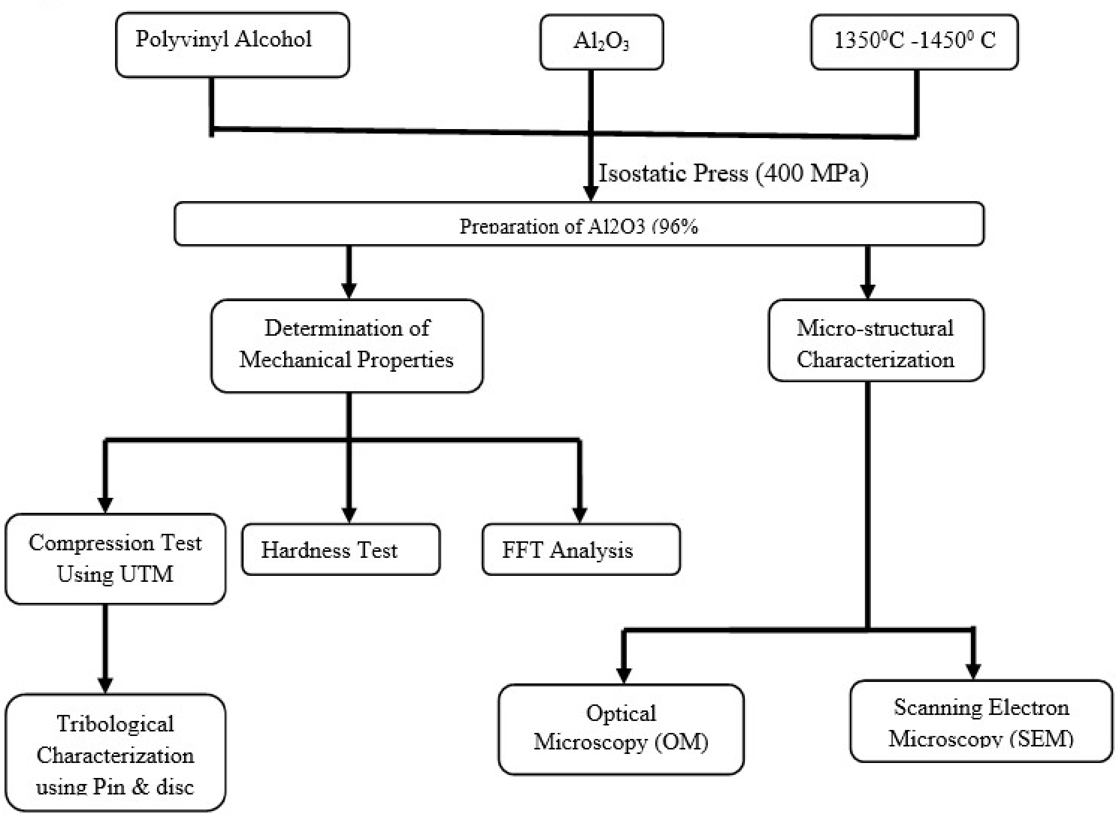

Fig .1Pure Al_2O_3material testing flow chart

2.1 Cold Isostatic pressing (CIP)

It is a material preparing method in which high pressure is applied to metal powder in a fixed elastomer holder formed for the applications. There are two varieties of the CIP procedure relying upon the manner in which the elastomer mold is used. The powder is changed over from loose aggregates into moderately dense conservative that has sufficient green strength to allow cautious handling with and exchange to the going with process activities. The usual pressure medium is the water treated with corrosion inhibitor. The pressure applied is the range of 207 to 414 MPa (30 to 60 ksi), and maximum pressure as high as 758 MPa (110ksi). The compacting procedure is carried out at ambient temperature. By this way the density of the loose powder is increases theoretically from 50 to 60% where nominal range will be 70 to 85% of the 100% theoretical density of the processed metal. The CIP process is of two variations which depends on the way of the elastomer mold is used. In the dry bag process, the elastomer mold is attached to the pressure vessel and the device is intended for a high rate of production of small sized parts. This is more suitable for the ceramics rather than metals is shown Fig. 3.

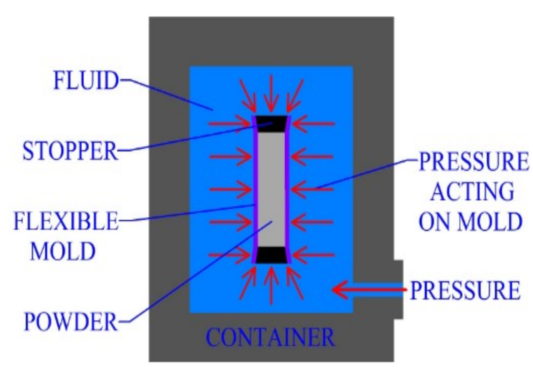

Fig. 3 Principle of Iso static pressing

2.2 Preparation of Specimens

Aluminum is the mainly used matrix material in metal matrix composite. Aluminum composites were very alluring because of their lower density, their ability to be strengthen by precipitations, their great erosion obstruction, higher thermal and electrical conductivity, and their higher vibrational damping capacity. They offer an enormous assortment of mechanical properties relying upon the concoction arrangement of the aluminum matrix. They are generally reinforced by alumina, SiC, silicon dioxide, graphite, boron nitride, B_4C and so on. The properties of Al_2O_3 and its photographic view are shown in Table 1 and Fig. 4.

Table 1 Properties of Al_2O_3

Melting point	2350°C
Grit Size(microns)	2-4
Odor	Odorless
Appearance	White small crystals

Fig. 4 Al_2O_3 powder.

2.3 Wear Test Specimen

The Sintering specimens were machined to the dimensions as per ASTM standards using Diamond cutting and tested using UTM machine. The dimension for wear test specimen is round to 20mm length and 10 mm diameter, 15 mm length and 9 mm square face as per ASTM standard with the aspect ratio 1.66 (l/d ratio)

Three different Specimens are prepared based on Sintering temperatures:

Specimen 1:1350°C

Specimen 2:1400°C

Specimen 3: 1450°C

The hardness specimen dimension 15mm length and 9mm square face it follows ASTM standard with the aspect ratio 1.66 (l/d ratio) is as shown inFig.5.

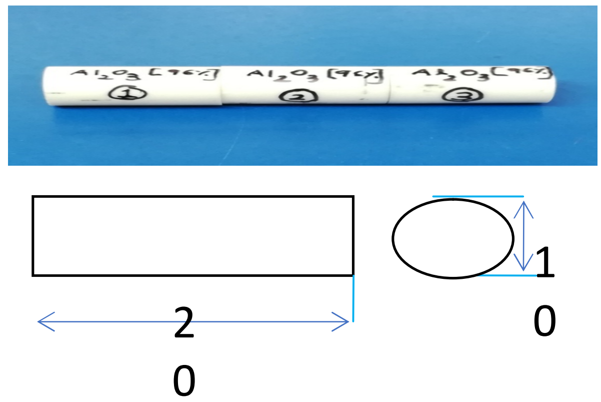

Fig. 5 Wear Test Specimen

3. Experimental Details

Fig. 6 Pin-on-Disc wear testing apparatus

Table 2 Parameter taken constant during sliding wear test

Pin material	**Al2O3**
Disc material	EN31 (165mm diameter and 8mm thick)
Pin dimension	Cylinder with diameter 10 mm height 20 mm
Sliding speed (m/s)	20-2000
Normal load (N)	2-200
Sliding distance (m)	100-3000

Wear tests were carried out on pin-on-disc equipment (Fig. 6) as per ASTM standards. (G99) The disc made of hard heat treated standard matrialEN31and Ra of 0.1 load of 0-200N were applied with a disc speeds of 200-2200 rpm. Wear along the length of the specimens to accuracy of one micron was measured. The end test specimen was given smooth finish first with abrasive paper of 600 Grade and then 1000 Grade.

The disc surface and the end of the test specimen were cleared with acetone. Dry sliding test were conducted with cumulative damage technique, where the same specimen was subjected to wear for different loads in the range. The sliding distances were kept constant and the loads were increased in predetermined steps.

The parameter taken during sliding wear test is presented in Table 2. Few preliminary tests were conducted to determine the range of parameters via load, sliding speeds and sliding distances with the requirement that does not occur, and then the tests were carried out at a sliding speed of 20 m/s and sliding distance of 1000 m for each load. The tribological response was expected to wear friction co-efficient and specific wear rates.

4. Procedure

The experiments are generally carried out by evaluating the wear rate under the following condition:

Wear against a fixed sliding distance

Wear against a fixed load

The sliding distance measured as follows

A diameter of sliding is fixed on the disc and their linear distance parameters were found out which gives the sliding distance for one revolution. The total sliding distance was converted onto a number of revolutions.

The Specimen has with its diametrical surface. Machined in such a way that it is perpendicular to the axis of the specimen and given a good polish. The specimen was weighed to 0.0001 gm level and was recorded (w1) its height was also recorded. The diameter of the sliding track was noted down and a number of revolutions for known sliding distance was found out and the required time was noted down.

Initially, pin surface was made flat such that it will support the load over its entire cross-section called first stage. This was achieved by the surfaces of the pin sample ground using emery paper (80 grit size) prior to testing.

Run-in-wear was performed in the next stage/ second stage. This stage avoids initial turbulent period associated with friction and wear curves.

Wear test result of cylinder shape.

Final stage/ third stage is the actual testing called constant/ steady state wear. This stage is the dynamic competition between material transfer processes (transfer of material from pin onto the disc and formation of wear debris and their subsequent removal). Before the test, both the pin and disc were cleaned with ethanol-soaked cotton. Before the start of each experiment, precautionary steps were taken to make sure that the load was applied in normal direction.

Table 3 Test condition of Variable load and constant load

SlNo	Sample ID	Maximum wear in µm	Average COF	Average Frictional Force in N	Mass loss, g
1	Cylinder 1-1	62	0.553	11.06	0.0004
2	Cylinder 2- 1	19	0.406	16.24	0.0006
3	Cylinder 3- 1	39	0.353	21.18	0.0014
4	Cylinder 3-2	19	0.480	19.28	0.0002
5	Cylinder 2- 1	20	0.403	16.12	0.0007
6	Cylinder 1-1	92	0.356	14.24	0.0003

The Wear test was conducted at 3 different temperatures and different phase on the specimens. It gives equal result but the temperature Specimen 3, the1450°C is high value then the other two temperature Specimens values of results, the experiments average readings were calculated and shown in Table3. The table below shows the results of the Wear test between Variable load and constant load and also shown in graph (Fig 2.)

Sl No	Sample ID	Load in N	Speed in rpm	Wear track Diameter in mm	Duration in Seconds	Sliding Velocity in m/sec
1	Cylinder 1-1	20	1089	70	500	4
2	Cylinder 2- 1	40	1089	70	500	4
3	Cylinder 3- 1	60	1089	70	500	4
4	Cylinder 3-2	40	953	40	1000	2
5	Cylinder 2- 1	40	953	80	500	4
6	Cylinder 1-1	40	953	120	333	6

The Wear test was conducted at 3 different temperatures and different phase on the specimens. It gives equal result but the temperature Specimen 3, the1450°C is high value then the other two temperature Specimens values of results, the experiments average readings were calculated and shown in Table 4. The table below shows the results of the Wear test between Variable load and variable load and also shown in graph (Fig 3.)

Cylinder 1-1

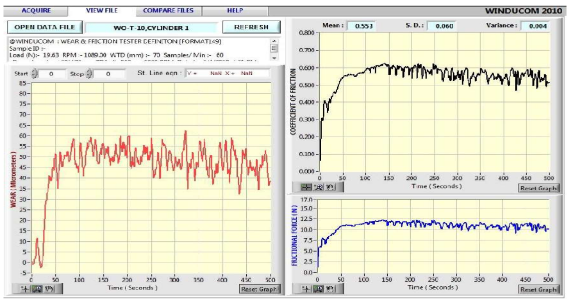

Fig. 7 Wear rate for Cylinder 1-1 (a wear v/s Time b.cof v/s Time c. frictional force v/s Time)

Cylinder 2-1

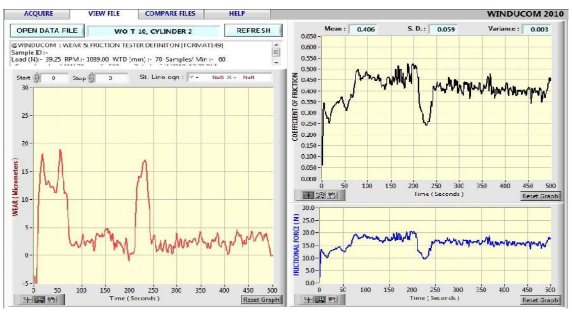

Fig. 8 Wear rate for Cylinder 2-1 (a.wear v/s Time b.cof v/s Time c. frictional force v/s Time)

Cylinder 3-1

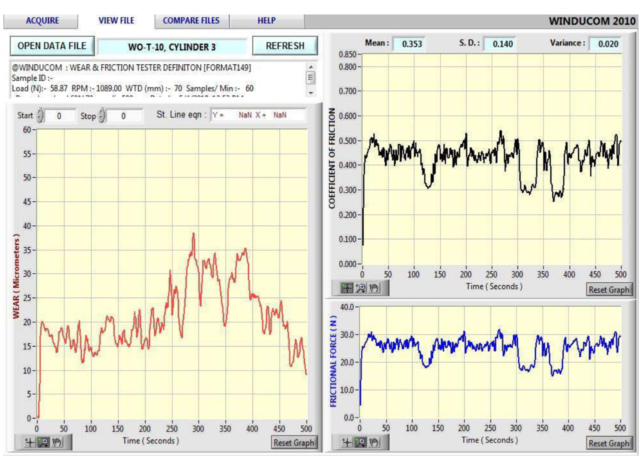

Fig. 9 Wear rate for Cylinder 3-1 (a. wear v/s Time b.cof v/s Time c. frictional force v/s Time)

Cylinder 3-2

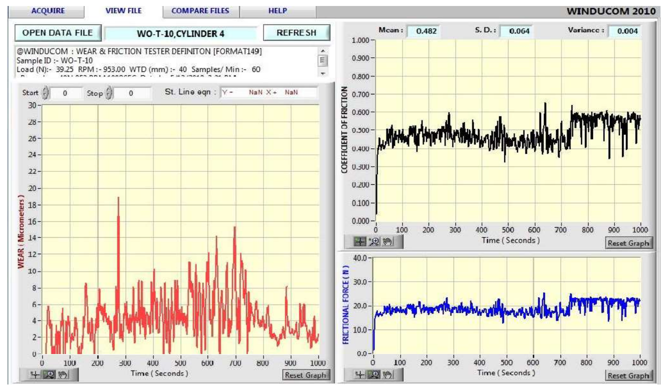

Fig.10 Wear rate for Cylinder 3-2 (a. wear v/s Time b.cof v/s Time c. frictional force v/s Time)

The 1st three specimens are tested for varying load by keeping speed, track diameter and time constant. And other three specimens are tested for constant load and speed, by varying the track diameter time. Coefficient of friction wear rate and frictional force are determined by conducting wear test and the graphs are obtained. By observing the result we can understand if the loading increases coefficient friction decreases and friction force increases Mass loss of the entire specimen is very less due to high hardness of the material.

5. Conclusions

i. Conduct wear test so find out wear properties of Al_2O_3 materials. When load is increased that wear rate is increased but the rpm is increased so wear rate of material is reduced

ii. Conducted wear test shows the result of Wear, Cof, Frictional force v/s time, initial stages value will be increasing and gradually decreases to a study stage which shows the Al_2O_3 material.

References

1. *Vencl A., Rac A., BobicI.'Tribological Behaviour of Al-Based MMCs and their Application in Automotive Industry', Tribology in industry, Volume 26, No. 3 &4, 2004, 31-38.*

2. *Razavi-Tousi S.S., Yazdani-Rad R., ManafiS.A. 'Effect of volume fraction and particle size of alumina reinforcement on compaction and densification behavior of Al–Al2O3 nanocomposites', Materials Science and Engineering A 528, 2011, pp 1105–1110*

3. *Veeresh Kumar G. B., Rao C. S. P., Selvaraj N.' Mechanical and Tribological Behavior of Particulate Reinforced Aluminum MetalMatrix Composites – a review', Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.1, 2011, pp.59-91.*

4. *E. Medvedovski, "Wear-resistant engineering ceramics", Wear 249 (2001) 821-828*

5. *F. C. Zhang, H. H. Luo, T. S. Wang, S. G. Roberts, R. I. Todd, "Influence factors on wear resistance of two alumina matrix composites, Wear 265 (2008) 27-33.*

6. *S. Kumar, A. R. Durai, T. Sornakumar, "Wear behaviour of alumina-based ceramic cutting tools on machining steels", Trib. Int. 39 (2006) 191-197.*

7. *L. Esposito, A. Tucci, "Microstructural dependence of friction and wear behaviours in low purity alumina ceramics", Wear 205 (1997) 88-96.*

8. *K. Mukhopadhyay, Y. W. Mai, "Grain size effect on abrasive wear mechanisms in alumina ceramics", Wear 162-164 (1993) 258-268.*

9. *E. Kostić, S. Bošković, S. J. Kiss, "Reaction sintering of* Al_2O_3 *in the presence of the liquid phase", Ceram. Int. 19 (1993) 235-240.*

