WEAR TESTING AND CHARACTERIZATION OF ALUMINA CERAMIC TO PREDICT EROSION RATE

[1]VINAYAKUMAR R, ^{2}H RAMAKRISHNA, [3]B K CHAYAPATHY

[1]Asst Professor, [2]Professor and Head, [3]Professor,
Dept of IEM, DSCE,Bangalore
E-mail: [1]rsv.vinaya@gmail.com, [2]Hrkrishna1963@gmail.com, [3]chayapathybidar@gmail.com

Abstract— In aerospace applications electric thruster's wall material is made of ceramics. Alumina is one of preferred ceramics materials since it can withstand very high temperature and has excellent insulation properties at high properties. The life time of electric thruster is mainly limited by the erosion of the ceramics materials protecting the thruster's circuits. Thus understanding the wall erosion rate and its dependence on the ceramic material is very important.

In the present project work five samples of the ceramics material consisting of alumina and silicon dioxide are prepared. The test samples are prepared by mixing the various proportions of alumina with silica. Samples of 92%, 94%, 96%, 98% and 99.5% Al2O3 is mixed with 8%, 6%, 4%, 2% and 0.5% silica as additives. The samples are moulded using hydraulic press moulding. Wear test, compression test, flexural test and hardness test are conducted on these samples. The results are tabulated and the sample which gave minimum wear was selected as a suitable material for thruster wall material.

I. INTRODUCTION

Ceramics are often used as structural components where erosive wear occurs. Due to the operational requirements the study of solid particle erosion characteristics of the ceramics becomes highly relevant.

Alumina is a compound of Aluminum and potassium disulphate- (KAl (SO4)2, 12 H2O) – and it forms wherever schistose or clayed earth comes in contact with sulphuric acid as a result of sulphurated minerals or volcanic smoke and gas.

Fused alumina is identical in chemical and physical properties with natural corundum. It is a very hard material and its hardness is exceeded only by diamond and a few synthetic substances such as carborundum, and silicon carbide. This property of alumina lends itself for use as an abrasive material. Another useful property of the material is its high melting point, i.e., above 2000°C (3632°F), which makes it useful as a refractory and as linings of special furnaces

II. PROBLEM STATEMENT

Hall thrusters (HETs), stationary plasma thrusters (SPTs) are characterized by the use of a dielectric insulating wall in the plasma channel.

The wall is typically manufactured from harder materials. These dielectric materials have a low sputtering yield. The wall gets bombarded by the ions produced in the thruster and the walls get eroded. The life of the thruster is determined by the wall thickness eroded. The oldest methods for studying Hall thruster channel wall erosion are weight loss and profilometry.

Life estimation is based on the sputtering and erosion of the material. Wear tests and other mechanical properties of alumina are determined to predict the life of electrical thruster.

III. OBJECTIVES

The main objectives of research work is:

- Fabrication of alumina with different compositions.
- Characterization of mechanical properties such as hardness, compression strength, flexural strength and wear rate

IV. LITERATURE REVIEW

L.E.G. Cambronero, , E. Sánchez, J.M. Ruiz-Roman, J.M. Ruiz-Prieto stated in one of their journal titled "Mechanical characterisation of AA7015 aluminium alloy reinforced with ceramics" Journal of Materials Processing Technology Volumes 143–144, 20 December 2003, Pages 378–383

Manufacturing of metal matrix composites (MMCs) through powder metallurgy route and their characterisation are the objects of the present work. Thus a light alloy reinforced with 5% of ceramics is obtained after attrition milling of mixed powders, die pressing, lubrication of compacts and hot extrusion into 10 mm diameter bars. Since 7xxx series of aluminium alloys show high mechanical properties, AA7015 alloy was chosen as metallic matrix and B4C, TiB2 and Si3N4 ceramics were added. After process optimisation, the microstructure of these materials shows a uniform distribution of ceramics in the aluminium alloy matrix. Physical properties like

density, conductivity and coefficient of linear dilatation were determined on extruded MMCs samples. Hardness and tensile strength properties on machined samples according to ISO 2740 standard were evaluated. Also wear behaviour using a pin-on disk test was studied, within a microstructure study, which was carried out using optical and scanning electron microscopy.

W. Tabakoffstated in one of their journal titled "Erosion resistance of superalloys and different coatings exposed to particulate flows at high temperature" Journal of Materials Processing Technology Volumes 120–121, November 1999, Pages 542–547

The design and development of high performance turbomachinery operating in an ambient with solid particles require a thorough knowledge of the fundamental phenomenon associated with particulate flows. Because of the serious consequences of turbomachinery erosion on their performance and life, it is important to have reliable methods for predicting their erosion when solid particles are ingested with the incoming flow. Several studies, which are essential to predicting blade surface erosion intensity and pattern, have been conducted at the University of Cincinnati's Propulsion Laboratory over the past 25 years. This paper describes only some of the work done on erosion testing at high temperatures and velocities for different materials and coatings. The testing has been performed with a special high temperature erosion wind tunnel, which simulates the aerodynamic conditions on the blades. The coatings investigated are produced by chemical vapor deposition (CVD), physical vapor deposition (PVD), and other methods. Experimental studies were conducted at the University's high temperature erosion wind tunnel to investigate the erosion behavior of coatings exposed to different types of solid particles. Some of the following coatings were evaluated: rhodium platinum aluminized, SDG-2207 (super D-gun product), CVD coatings, including TiC, TiN, Al2O3 and PVD coatings. The erosive wear of the samples was studied experimentally by exposing them to a particle-laden flow at velocities from 180 to 305 m s−1, temperatures from ambient to 815°C and impingement angles from 15 to 90°

V. METHODOLOGY

The different composition of powdered form alumina and additive (SiO_2) as shown in table 1.1 is subjected to hydraulic moulding (compression moulding) pattern and size of the specimen is as shown in the figure 1.1

Table number 1.1 Sample compositions

SL.NO	Al2O3%	SiO2%
1	92%	8%
2	94%	6%
3	96%	4%
4	98%	2%
5	99.3%	.03%

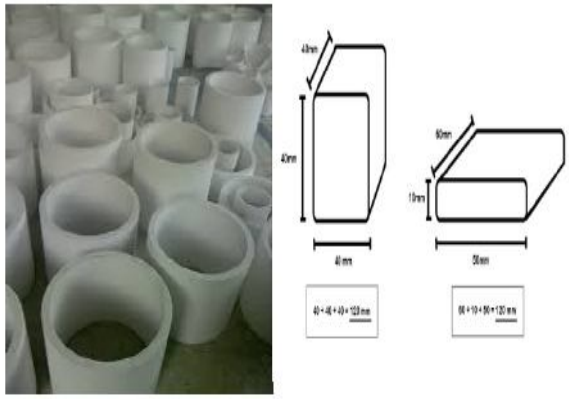

Figure 1.1 size and specimen

Then the specimen is subjected to the following test to determine the characteristics and properties

a. Wear test: Wear can also be defined as a process where interaction between two surfaces or bounding faces of solids within the working environment results in dimensional loss of one solid, with or without any actual decoupling and loss of material

Wear test is carried out to predict the wear performance and to investigate the wear mechanism. The test is performed to evaluate the wear property of a material so as to determine whether the material is adequate for a specific wear application.

Setup for wear test is as shown in the figure 5.1The unique 'X' pattern of Taber® Abrasers is produced by the rotary action of the abrasive wheels. The wear action occurs as the wheels are turned by the rotating specimens. The axis of rotation of the wheels is displaced from that of the turntable, creating an abrasive 'sliding' action as the specimen rotates. An area of 300 mm² (4.5 in²) is subjected to the abrasive action, and a complete circle on the sp ecimen surface is abraded at all angles and direction of grain or weave, effectively simulating 'real life' conditions. This high quality, durable instrument determines the precise point at which a specimen shows unacceptable wear



Fig 5.1 Wear test apparatus and mechanism

b. Compression test: Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate**.** Instran 5561 apparatus used for compression test is as shown in the figure 5.3



Figure 5.3 Apparatus for compression test

C. Hardness test: The Mohs scale of mineral hardness is a qualitative ordinal scale that characterizes the scratch resistance of various minerals through the ability of a harder material to scratch a softer material. Setup used for hardness test is as shown in the figure 5.4



Fig 5.4 Mohs scale of hardness

d. Flexural test: The **three point bending flexural test** provides values for the modulus of elasticity in bending E_f, flexural stress σ_f, flexural strain ϵ_f and the flexural stress-strain response of the material.Equipment used for this test is ashown in the figure 5.5



Figure 5.5 Flexural testing

VI. RESULTS

➢ Wear test result for the samples are determined and summarized as shown in the figure 6.1

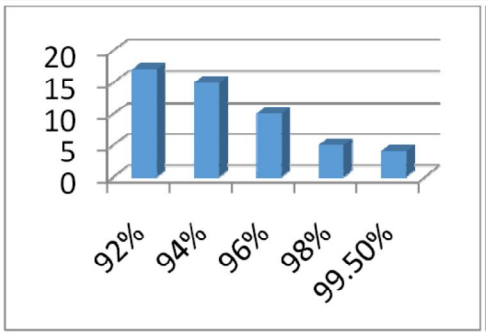

Fig 6.1 wear test result

Wear test Samples results 92%- 17mm^3, 94%-15mm^3, 96%-10mm^3, 98%-5mm^3, 99.5%-4mm^3

➢ Compression test result for the samples are determined and summarized as shown in the figure 6.2

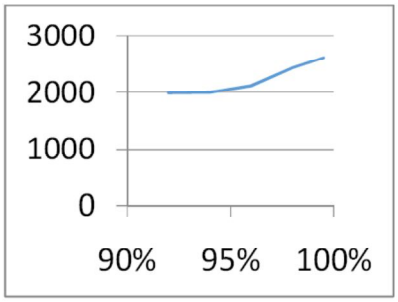

Figure 6.2 Compression test result

Samples results : 92%-1984mpa, 94%-1995mpa, 96%-2115mpa, 98%-2435mpa, 99.5%-2615mpa

➢ Hardness Scale Results: Wear test result for the samples are determined and summarized as shown in the Table 6.1

Table 6.1

% of sample	Mohr scale
92%	7
94%	8
96%	8
98%	9
99.5%	9

CONCLUSION

On the basis of test results that are conducted on the test specimen of different proportions of aluminum oxide and silica we got the test results 99.5 % proportion of Al_2O_3 give the best results which has less wear rate and maximum mechanical strength.

SCOPE OF THE STUDY

In the present paper alumina is taken or selected as the reference material, however other ceramics materials like boron nitride, zirconium when mixed in

different proportions exhibits similar wear resistance properties. This material can withstand high temperature .extensive experimental work has to be carried out to characterize this material.

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