Experimental Analysis on Wear Behaviour of PTFE and Bronze Composite

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Abstract - *PTFE is a thermoplastic polymer, which is a white solid at room temperature. Due to its low co-efficient of friction; it is used for applications where sliding action of parts is needed like plain bearings, gears, slide plates, etc. The wear behavior of polytetrafluroethylene (PTFE) filled with 40% bronze particles was studied on a pin on disc test rig.The wear parameters considered for the study were applied load, sliding speed and sliding distance and weight percentage of bronze. The dominant interactive wear mechanisms during sliding of PTFE and its composites are discussed in this paper. The results obtained after carrying out experimentation at optimum setting shows improvement in the wear resistance. The objective of the present work is to develop self-lubricating bronze filled PTFE composite, combining the low friction of PTFE with the high strength of alloy. This work is believed to be helpful for understanding dry friction and wear behavior of bronze filled PTFE composite under various loading conditions.*

Key Words: **PTFE, Bronze, Wear, Weight percentage, Self-lubricating, Dry friction.**

1. INTRODUCTION

Polytetrafluroethylene (PTFE) is polymer based compound with white or gray in color. It is a fluorocarbon solid, high molecular weight compound consisting wholly of carbon and fluorine. Bronze is an alloy of copper and tin. It is hard and tough. The low-friction characteristics of PTFE were largely responsible for the inception of this project. This resin is waxy in appearance gray in color. It is a crystalline solid with good stability from -454°F to +500° F (-270°C to +260°C), and is chemically inert to known reagents and solvents except molten alkaline metals and gaseous fluorine under pressure. PTFE is technically superior and economically cheaper friction material as compared to conventional bearing materials. Because of the relative softness of PTFE, it is logical to expect that its load-carrying ability and its wear resistance might be improved by the addition of suitable fillers

1.1 Aim of the Research

The present research work is aimed at developing a new bearing material, which consists of composition of bronze and PTFE, which is cost effective and superior in properties to the conventional bronze bearing materials.

1.2 Scope of Present Investigation

Practically in all cases a plain bearing material is a non-ferrous alloy or a mixture. With the development of Pharmaceutical industry, engineering industries, the amount of bearing metal requirement is increasing at a very fast rate. Until very recently, most common type of 'bushing' and 'bearing' materials has either been bronze, copper and lead mixture and lead or tin based white metals. As such, bearing industries consume large qty. of copper, lead, tin, silver and antimony etc. apart from the cost factor of these materials, some of these materials are not available or not produced in India or produced negligibly in small quantity and consequently can be termed rare in relation to present day requirements of the industries. These considerations lead the metallurgists to search for alternative bearing material with special attention to metal which are more easily available both at time of emergency and in normal times. Naturally attention should be given to low cost high potential no-ferrous bush bearing materials and from 1992. Extensive research has been carried out in various countries for the development of composite polymer materials like PTFE and PTFE with carbon, glass fiber, carbon coke, graphite etc. Bearing materials are special type of materials, which carry a moving or rotating component with least friction or wear.

2. LITERATURE SURVEY

In the paper entitled "Study Of PTFE Composites Tribological Behavior" they have explained that a comparative analysis of seven PTFE composites is presented showing how properties of PTFE can be improved even if the most attractive characteristic of low friction is lost due to the presence of hard particles in the polymer matrix. How the use of both soft and hard phases in a polymer matrix enhances the self-lubricating and the load-carrying properties of the matrix improving the tribological properties of the PTFE is presented.[1]

In the paper entitled "Friction and wear of PTFE composites at cryogenic temperatures" they have explained that presents investigations on the tribological behavior of PTFE composites against steel at cryogenic temperatures. The results showed that the friction coefficient decreases with temperature down to 77 K, but did not follow a linear evolution further down to extreme low temperatures. It can be stated that the cryogenic environment has a significant influence on the tribological performance of the polymer composites.[2]

In the paper entitled " A Study On Tribological Behavior Of Transfer Films Of PTFE/Bronze Composites" they have explained that Transfer films of PTFE/bronze composites with 5–30% volume content of bronze were prepared using a RFT friction and wear tester on surface of AISI-1045 steel bar by different sliding time (5–60 min). Tribological properties of these transfer films were studied using a DFPM reciprocating tribometer in a point contacting configuration under normal loads of 0.5, 1.0, 2.0 and 3.0 N. Thickness and surface morphology of the transfer films were investigated. It was found thickness of the transfer films slightly increased along with the increase of bronze content of corresponding composites.[3]

In the paper entitled "The Mechanism of Tribological Wear of Thermoplastic Materials" they have explained that Sliding machine elements made of plastics co-operate mostly with metals. The friction of these materials engages several processes like mechanical and adhesion interactions, tribo-chemical and tribo-electrical reactions etc. In this paper, processes involved with the tribological wear of polymer materials under conditions of dry friction were discussed. Fundamental modes of wear characteristic for polymer materials were described. These include adhesion wear, abrasive wear, fatigue wear, thermal and chemical wear, asperities melting, creep wear, and fretting. A wear mechanism for different polymer materials (including composites) was presented. The mechanism includes chemical activity of the mating metals, the role of fillers in the transfer of load and creation of the polymer film. A mechanism accounting for additional heating of the material as a result of fluctuating friction force loading of the sliding metal/polymer pair and additional heating due to internal friction of the polymer materials was also presented.[4]

In the paper entitled "Sliding wear behavior of PTFE composites" they have explained that tribological behavior of polytetrafluroethylene (PTFE) and PTFE composites with filler materials such as carbon, graphite, E glass fibers, Glass and poly-*p*-phenyleneterephthalamide (PPDT) fibers, was studied. The present filler additions found to increase hardness and wear resistance in all composites studied. Wear testing and SEM analysis showed that three-body abrasion was probably the dominant mode of failure for PTFE + 18% carbon + 7% graphite composite, while fiber pull out and fragmentation caused failure of PTFE + 20% glass fiber + 5% Glass composite. The composite with 10% PPDT fibers caused wear reduction due to the ability of the fibers to remain embedded in the matrix and preferentially support the load.[5]

In the paper entitled "Taguchi method applied to parametric appraisal of erosion behavior of GF-reinforced polyester composites" they have explained that an investigation of Polyester composites reinforced with three different weight fractions of woven E-glass fiber reinforcement are developed. To study the effect of various operational and material parameters on erosive wear behavior of these composites in an interacting environment erosion tests are carried out. For this purpose, air jet type erosion test rig and the design of experiments approach utilizing Taguchi's orthogonal arrays are used. The findings of the experiments indicate that the rate of erosion of composites by impact of solid erodent is greatly influenced by the control factors.[6]

3. PROBLEM DEFINITION

3.1 Objectives of Dissertation

1. To find the effect of composition of bronze in PTFE on wear.
2. To Study the wear behavior of the selected materials and the effect of various Speeds, loads and sliding distance on wear.

3.1 Problem Definition

Study of effect of Bronze particles as a filler material on PTFE and analysis of its properties for various applications like bearing material. The study of PTFE + Bronze composite material includes -

1. Analysis of effect of 15%. 25%, 35%, 45%, 55% and 65% composition of Bronze on PTFE and. Evaluation of wear of above PTFE + Bronze composites.
2. Study of effect of load, sliding distance, percentage of Bronze, velocity and various parameters on friction and wear behavior of composite.
3. Comparison of different materials for their suitable application.

4. SYSTEM DEVELOPMENT

It is methodology based on statistics and other discipline for arriving at an efficient and effective planning of experiments with a view to obtain valid conclusion from the analysis of experimental data. Design of experiments determines the pattern of observations to be made with a minimum of experimental efforts. To be specific Design of experiments (DOE) offers a systematic approach to study the effects of multiple variables / factors on products / process performance by providing a structural set of analysis in a design matrix. More specifically, the use of orthogonal Arrays (OA) for DOE provides an efficient and

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effective method for determining the most significant factors and interactions in a given design problem.
While there are many standard orthogonal arrays available, each of the arrays is meant for a specific number of independent design variables and levels. Standard notation for orthogonal Arrays is, L_n (X^m) Where,
n=Number of experiments to be conducted
X=Number of levels
m= Number of factors
Common Orthogonal Arrays are listed below for quick reference -

- 2- Level arrays - L_4 (23), L_8 (27), L_{12} (211), L_{16} (215), L_{32} (231), L_{64} (263) etc.
- 3- Level arrays - L_9 (34), L_{18} (21*37), L_{27}(3*13), L_{54} (21*325), L_{81} (340) etc.
- 4-Level arrays - L_{16} (45), L_{32} (21*49) etc.

Note: Arrays L_{18} (21*37), L_{54} (21*325), L_{32} (21*49) etc. are for mixed level factors.

In this investigation work, which is carried out for 4 factors (Material, load, sliding velocity, and sliding distance), each factor at 3 levels, an L_{27} (3^{13}) orthogonal array is chosen for conducting the experiments.

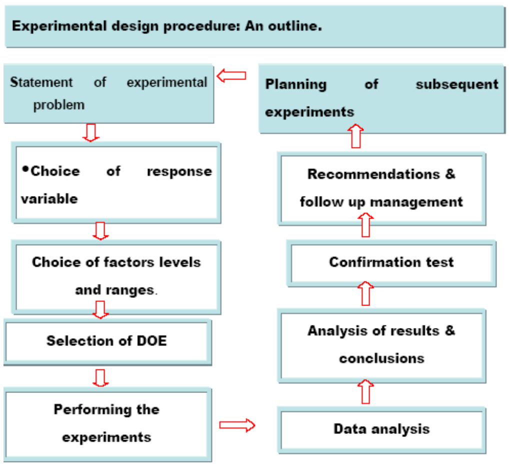

Fig -1: An Outline of Recommended Procedure for an Experimental Design

5. EXPERIMENTAL SETUP

In pin-on-disc tribometer TR-20, a flat pin is loaded onto the test sample with a precisely known weight of 17.63 kg. The pin is mounted on a stiff lever, designed as a frictionless force transducer. The deflection of the highly stiff elastic arm, without parasitic friction, insures a nearly fixed contact point and thus a stable position in the friction track. The friction coefficient is determined during the test by measuring the deflection of the elastic arm. Wear coefficients for the pin and disc material are calculated from the volume of material lost during the test. This simple method facilitates the study of friction and wears behavior of almost every solid-state material combination with or without lubricant. Furthermore, the control of the test parameters such as speed, contact pressure and varying time allow a close reproduction to the real life conditions of practical wear situations.

It also facilitates study of friction and wear characteristics in sliding contacts under desired conditions. Sliding occurs between the stationary pin and a rotating disc. Normal load, rotational speed and It wear track diameter can be varied to suit the test conditions. Tangential frictional force and wear are monitored with electronic sensors and recorded on PC.

For experimentation we used 4 group of materials which has material composition as follows -

Group I - Material 1-PTFE+15%Bronze

Material 2-PTFE+25%Bronze

Material 3-PTFE+35%Bronze

Group II - Material 1-PTFE+45%Bronze

Material 2-PTFE+55%Bronze

Material 3-PTFE+65%Bronze

6. OBSERVATIONS AND RESULTS

The experiments were conducted as per the standard orthogonal array. The selection of the orthogonal array was based on the condition that the degrees of freedom for the orthogonal array should be greater than or equal to sum of those wear parameters.
Variables used during experiment -
Speed : 200 rpm, 300 rpm, 600 rpm
Weight : 1 Kg, 2 Kg, 3 Kg
Wear track radius : 35 mm
Pin Diameter : 10 mm
Pin Length : 30 mm

Material	Wear (microns)		
	At 1 kg	At 2 kg	At 3 kg
PTFE + 15% Bronze	26.13	27.09	28.3
PTFE + 25% Bronze	22.98	24.07	25.04
PTFE + 35% Bronze	21.72	22.78	23.34
PTFE + 45% Bronze	19.73	20.11	21.7
PTFE + 55% Bronze	18.35	18.75	19.27
PTFE + 65% Bronze	16.18	16.93	17.9

Table -1: Wear at 200 rpm

Material	Wear (microns)		
	At 1 kg	At 2 kg	At 3 kg
PTFE + 15% Bronze	26.22	27.42	28.56
PTFE + 25% Bronze	23.06	24.36	25.27
PTFE + 35% Bronze	21.8	23.05	23.51
PTFE + 45% Bronze	19.81	20.35	21.91
PTFE + 55% Bronze	18.42	19.02	19.49
PTFE + 65% Bronze	16.24	17.14	18.06

Table -1: Wear at 300 rpm

Material	Wear (microns)		
	At 1 kg	At 2 kg	At 3 kg
PTFE + 15% Bronze	26.33	27.86	28.87
PTFE + 25% Bronze	23.15	24.74	25.55
PTFE + 35% Bronze	21.89	23.42	23.78
PTFE + 45% Bronze	19.86	20.67	22.15
PTFE + 55% Bronze	18.50	19.32	19.70
PTFE + 65% Bronze	16.31	17.40	18.26

Table -1: Wear at 600 rpm

From above observations we can present this data in graphical form as given below

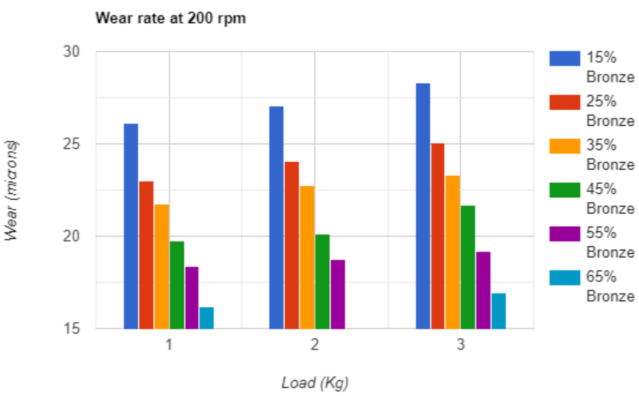

Fig -1: Wear of material at speed of 200 rpm

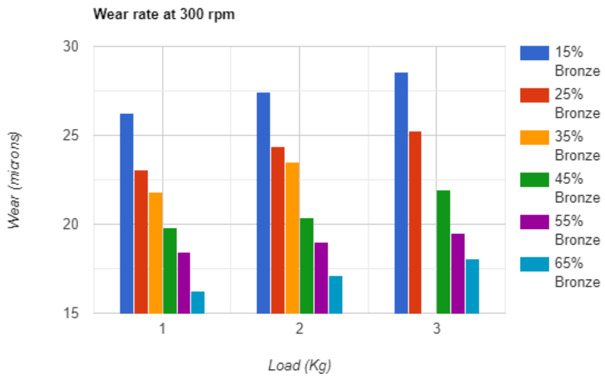

Fig -2: Wear of material at speed of 300 rpm

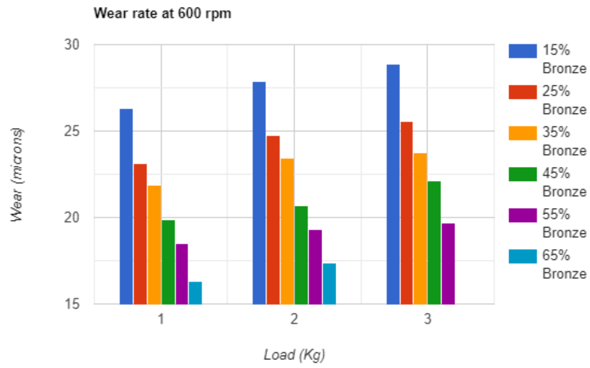

Fig -3: Wear of material at speed of 600 rpm

7. CONCLUSIONS

From the analysis on the results of dry sliding wear of the PTFE Filled with Bronze, the following conclusions can be drawn from the study.

1) Composite PTFE has much good mechanical and tribological properties as compared to Plain PTFE.
2) Wear rate is directly proportional to load applied.
3) Coefficient of friction is inversely proportional to the Load applied.
4) Composite with more percentage of Bronze in PTFE gives less wear rate as compared to other with low percentage of Bronze when tested under similar working condition.
5) As percentage of Bronze in PTFE increases, coefficient of friction also increases.
6) Wear increases as roughness of counter surface increases.
7) Hence, 15%, 25%, 35% Bronze filled PTFE are best suited for applications requiring less coefficient of friction, less cost of material and where moderate wear rate is tolerable.

8) 45%, 55%, 65% Bronze filled PTFE are best suited for bearing applications because of its low wear rate, low coefficient of friction, low cost & better mechanical properties than other materials

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