Recent research status on modern friction materials—an Overview

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Abstract. Modern friction materials have application in automotive, aerospace and industrial brake systems. It should also possess various resistance to water and heat, low wear rate and high thermal stability, but it is quite impossible to achieve all this in practical conditions. To meet these requirements, composite friction materials have been designed often based on experience or a trial and error method to make a new formulations. Selection of Binders, fibers, fillers, and modifiers plays key role in deciding new formulation of friction composite. Listing out these ingredients from literature give rise to idea for selection of suitable ingredient of new formulation which can be acceptable worldwide. Inferences and discussions are drawn from fact revealed of modern friction materials. In this Paper, A through literature survey of work carried out so far in field of manufacturing and characterization of friction materials is presented. It reports various methods of evaluation of friction performance, thermal stability of test samples. Types of mechanical, physical, thermal, morphological properties of test samples are reported and optimum formulation among other test samples is predicted. This gives idea about friction materials which fulfills the need of future.

1. Introduction

Discovery and application of friction materials dates back to approximate 117 years ago. Due to advantages such as light weight and easy processing conventional materials are being replaced by modern composite materials in many fields [1, 2, 3, 4]. Asbestos reinforced composites was used in the first generation of composites which are used in brake friction materials [27]. Asbestos fiber reinforced polymeric composites are used in brake couplings, brake pads and brake linings; however, asbestos has been found to be hazardous to the environment and to human health [11, 14, 15, 16]. Characteristics of friction materials, classification and factors affecting the friction and wear behavior of friction materials are presented. A Modern friction material is a multi-component polymer matrix composite. In general more than 10 ingredients are used for obtaining high friction materials Researchers have been working on improving the properties of existing friction materials varying the composition of their Ingredients. Types and proportions of various ingredients used by researchers are listed and studied in this paper. In a nutshell, Manufacturing methods, types and proportions of...
ingredients used in new formulation, characterization methods of friction materials are discussed in
detailed and an approach towards developing eco-friendly organic friction composite is investigated.

2. Present status on research work done related to natural fiber reinforced polymer composite
A wide range of published work relating to the development of new eco-friendly friction materials and
their characterization is critically survey and summarized. Present status discusses some of the
important findings of literature under headings listed as preparation method of composites, types of
characterization methods used, types of matrix used, types of reinforcement used, types of fillers used,
types of friction modifiers used to give exact direction of working for future researchers.

2.1. Preparation method of composites
Manufacturing methods of composites depend on types of ingredients involve in the preparation of
friction composites. 70% of Investigators have used Powder metallurgy technique to fabricate the
friction samples. 20% researchers have used Compression molding methods for fabrication wherein
only 10% researchers have preferred the casting method. Homogeneity and compactness of various
ingredients is assured by powder metallurgy method. With the help of Powder metallurgy technique,
samples can be made with a great variety of compositions. It is therefore very easy to have samples of
desired mechanical and physical properties like hardness, density, stiffness, toughness, etc
compression molding method is used to shape the raw material with the help of mould. Figure 1 shows
manufacturing methods of friction composites.

2.2. Types of characterization methods used
In order to evaluate the performance of friction material testing methods are employed and test are
conducted using different Test equipment and Test rigs. Generally Pin on disc test rig is used as to
check the coefficient of friction and wear rate , Brake Dynamometer, Friction assessment and
screening Test machine (FAST), Krauss Machine, CHASE machine, Tribometer are the optional
equipments found in literature to check friction and wear performance of friction material following
different standard procedures Mechanical Properties such as Compression test, Hardness test carried
out using Universal testing machine, Rockwell and Brinell hardness Tester. Density of samples is
measured by taking weight of sample and Archimedes principle is applied. Thermal stability of
samples is checked with help of thermogravimetric analysis. Infra red Thermometers are used to check
and control the temperature of samples. Morphology and microstructure of sample is checked by
scanning electron microscopy and elemental composition is checked with the help of Energy
dispersive X ray spectroscopy method. Figure 2 shows different characterization methods used by researchers in the literature.

![Figure 2 Types of characterization methods used.](image)

2.3. Types of matrix used
Binders are mainly responsible for holding all ingredients of composite together. It should possess resistance to high temperature [6, 10]. Investigators have used different matrices based on adhesion and compatibility with other ingredients. 60% researchers have given their preference to Phenolic resin/Phenol Formaldehyde [26, 28, 30]. Figure 3 shows different matrices used in literature.

![Figure 3 Matrices used.](image)

2.4. Types of Reinforcement used
Reinforcement is generally provided in the form of fibers to mechanically strengthen the composite. Fig. 4 shows types of reinforcing fibers used in literature. 23% researchers have used Steel fiber as reinforcement fiber. 13% of investigators have used natural fiber such as Coconut powder [9, 12, 13, 17, 21, 22]. Baryte is also used as reinforcing fiber by 13% of the researchers mentioned in the literature. Remaining investigators have used other reinforcing fibers shown in below figure 4. Selection of reinforcing fiber mainly depends on strength requirement of friction composite [30, 31].
2.5. Types of Fillers used

The role of fillers is to increase the ease of manufacturing and reduce the cost of manufacturing [18, 20, 25]. Several types of fillers such as Barytes, Vermiculites, Graphite, Coconut, Cashew, Coca Bean Shell, Latex rubber are used as Fillers in given literature. 20% of Investigators have used Vermiculite as filler material whereas Baryte is used as Filler by 16% of researchers. Five of the researchers have not used any type of Filler in their formulations. Figure 5 shows all types of fillers used by number of Researchers in their research.

2.6. Types of Friction modifiers

Friction modifiers raises the friction and react with oxygen to control interfacial films. Friction additives like abrasives which increases friction and controls the build up of friction films, included in the friction modifiers. Lubricants are also come under friction modifiers. Friction modifiers such as Carbon, Aluminum oxide, Alumina, Brass, Zirconium silicate/ oxide, Silicon, Titanium, Magnesium, Lead, Copper, Antimony sulphide have used by Investigators as shown in fig. 6. 43% of researchers have used Carbon as Modifier whereas Aluminum oxide have been used by 26% of researchers.
3. Inferences drawn from research overview

From the research overview of recent years, Approximate 32 papers on Development of modern friction composites are taken under consideration and inferences are drawn, based on it this section discusses some of the important findings in the area of fabrication and characterization of friction materials and possible future research directions as mentioned below.

3.1. It is found that most of the researchers are working on developing asbestos free organic friction material used in Brake pad of automobiles. Powder metallurgy technique is used by most of the researchers. Powder metallurgy technique to fabricate composite friction material includes mixing, hot pressing, sintering and curing of mixture. This technique has its own advantages, namely it is easy to mix various composite elements in powder form, homogeneous mixing is achieved. So Powder metallurgy method could be used to develop friction material in future research.

3.2. Many investigators have focused on using Phenolic resin as a matrix to bind and hold together other elements in composite formulation. Phenolic resin is used as binder which gives good bonding action to the various constituents. The disadvantage of phenolic resin is brittle, Low impact resistance, highly toxic and decomposes at relatively low temperatures. Phenolic resin is selected as Matrix for future research due to brittleness property since brake pad is made up of Brittle material.

3.3. Due to carcinogenic nature of Asbestos fiber current trend in fabrication of friction material is to use non asbestos organic fibers in manufacturing of friction materials. Steel fibers have been used by maximum researchers as a reinforcement in the literature. However the aim of future research would be to use natural fibers as reinforcement due to their biodegradable and eco friendly nature [5, 7]. It is shown in literature that many researchers have been using Coconut shell powder, Flax like natural fibers as substitute natural fiber for asbestos. These materials may find their application in future research work.

3.4. Several Testing methods and equipment have been used by investigators to check performance of newly formulated friction materials. Coefficient of friction and wear is measured under different loading, temperature, pressure and environmental condition in the literature. Various types of characterization methods are available to check quality and properties of friction material [9, 19, 23, 24, 29, 32]. According to our proposed research application Pin on Disc, XRD, EDX, Microhardness, microstructure and compression test can be perform by considering testing standard of friction brake pad material.

4. Conclusion
For each and every literature introduced and employed in development of friction material and characterization, the objectives are critically studied and based on some some important conclusions are derived and summarized as given below.

4.1. The brake friction material selected for the design and manufacturing should not release any toxic substances in to the atmosphere.

4.2. It is required to develop a friction material by selecting a proper reinforcing fiber and Chemical treatment method on fiber to use it more effectively as reinforcement in polymer matrix composites.

4.3. There is also need to develop a friction material by selecting a proper resin which will bind all ingredients of composites firmly and should have excellent heat resistance all the time.

4.4. There is also need to concentrate on types of filler materials and friction modifiers which can lead to fabrication of high performance friction materials.

4.5. The interfacial adhesion, and bonding strength between fiber and matrix for a friction material to achieve better mechanical and tribological properties needs to be considered.

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