ABSTRACT

Today's era is of eco-friendly materials. Copper around 10 wt. % is added invariably in friction materials (FMs) because of its unmatchable contribution to the performance of FMs. However, recently it is proven as an aquatic hazard, and global efforts are being focused on searching for an alternative, eco-friendly, and equally or more efficient than Copper. Copper, being a multi-purpose additive, its replacement is a Herculean task. Very recently, it has been claimed that fine particles of stainless steel of typical kind have shown full success in replacing Copper in FMs.

It is always desirable to find an alternative, which would be non-metallic, leading to a reduction in weight apart from fulfilling all other criteria for Copper- replacement.

The current research work was hence focussed on finding the non-metallic alternative to Copper in FMs.

Another issue, which is inadequately addressed in the literature, is the efforts to reduce the noise-vibration (NV) tendency of brake-pads by selecting appropriate ingredients in the formulation. Noise emission while braking is a serious concern, particularly in automotive industries, which can lead to high warranty costs and the customers' dissatisfied feedback. The ingredients need to be selected in such a way that they should not adversely affect tribo-performance, which is the most critical performance parameter.

Another critical issue that is never addressed in the open literature by the researchers is about the design of formulation of the underlayer. In commercial brake-pads, an underlayer is added to control NV characteristics of FMs. Underlayer (UD) is added for the following primary functions.

- reduces noise and vibration to a great extent
- acts as a thermal barrier to avoid the spongy brake phenomenon while braking
- assures high shear strength with a back-plate
- reduces the overall cost of the brake-pads

It is important to design the formulation of UD in such a way that its efficiency can be increased, leading to brake-pads with superior performance. Ingredients having a well-proven capability of noise-vibration (NV) can be investigated for performance enhancement. Interestingly these ingredients will be present only in UD and hence, will not affect the tribo-performance.

Another issue about FMs, which is not yet addressed adequately, is filler-matrix adhesion. Phenolic matrix has less adhesion for certain types of fillers such as abrasives, solid lubricants, metals, etc., and hence such ingredients are easily dug out during braking leading to high wear. In this thesis work, this issue was addressed by selecting abrasive particles and enhancing adhesion with matrix, and then study the effect on all performance properties.

With this in view, this research was focused on the following themes.

- To find a non-metallic and eco-friendly alternative, preferably polymeric for Copper in FMs.
- To investigate the influence of selected ingredients for their efficiency to reduce NV-related issues and simultaneous effect on tribo-performance.
- To explore various NV reducing ingredients in underlayer and to find its influence on overall NV related performance of brake-pads.
- To enhance filler (alumina abrasive particles) -matrix adhesion by siloxane treatment and to investigate its effect on wear performance and also on other performance properties.

The thesis work was divided into seven chapters as follows.

CHAPTER 1 INTRODUCTION

CHAPTER 2 MATERIALS AND METHODOLOGY

CHAPTER 3 EXPLORATION OF PARTICULATE PANI (POLYANILINE) AS A NON-METALLIC SUBSTITUENT FOR COPPER IN BRAKE-PADS

CHAPTER 4 SILOXANE FUNCTIONALIZATION OF ALUMINA PARTICLES FOR PERFORMANCE ENHANCEMENT OF BRAKE-PADS

CHAPTER 5 INFLUENCE OF VARIOUS TYPES OF RUBBER PARTICLES ON THE PERFORMANCE OF BRAKE-PADS

CHAPTER 6 INFLUENCE OF SELECTED INGREDIENTS IN UNDERLAYER ON THE PERFORMANCE OF BRAKE-PADS

CHAPTER 7 CONCLUSIONS AND SCOPE FOR FUTURE WORK

Chapter 1 includes an introduction to the braking system and various classes of FMs. It also includes a literature survey on key areas leading to the research gaps and motivation to the work. The chapter concludes with the objectives of the work and implementation overview.
Chapter 2 elaborates the details of ingredients used to develop various series of brake-pads apart from the fabrication procedure of brake-pads. It also describes the experimental techniques for performance evaluation such as physical, mechanical, chemical, tribological, and NV characterization of brake-pads.
Chapter 3 First part focuses on the synthesizing particles of PANI (Polyaniline) in the laboratory and then exploring its potential for replacement of Copper in brake pads. Particles of PANI were added in 10 wt. % amount as a theme ingredient keeping all parent ingredients identical. Performance was also compared with brake-pads containing 10 wt. % commercially available PANI and also with brake-pads with 10 % Copper particles. The Inclusion of PANI led to very promising results as a substituent for Copper entirely. It was also tried to explore if it shows synergism with stainless steel particles. All PANI-based pads proved superior to Copper- based and SS-based (without PANI) pads. These efforts led to still better results in Part B of the chapter.

Chapter 4 explored the potential of siloxane treatment to alumina particles to enhance adhesion with resin. A series of brake-pads with 2 % alumina particles (treated and untreated) was developed apart from one without alumina particles. The results showed that pads with treated particles excelled in all performance properties.
Chapter 5 pertains to the investigations on eight types of Copper-free brake-pads using various rubbers as a theme ingredient (9 vol.%). Five types of particles of NBR, two types of SBR, and also with commercially used crumb rubber with varying particle sizes and structures were used, keeping all the parent formulations identical. An additional type of brake-pads without rubber particles was also developed for comparison. The performance properties with special reference to NV were evaluated and analyzed with a conclusion that rubber particles not only improved NV performance but tribo-performance also. Liner structures performed better than cross-linked ones.
Chapter 6 focussed on designing underlayers using four types of noise controlling and vibration damping ingredients (particles of cork and crumb rubber apart from jute fibers and aramid pulp) in various amounts keeping parent ingredients of underlayer fixed. The brake-pads were then evaluated NV performance. The unique ingredients in the underlayer proved effective to multiple extents for improving NV performance. Cork and jute fiber-based under-layer had a capability to suppress high-frequency squeal, and hence an enhanced NV performance. Using natural ingredients in under-layer like cork, jute fiber, etc., a low-cost, light-weight, and eco-friendly under-layer can be designed to enhance the NV performance of brake pads without compromising the tribo-performance.
Chapter 7 is for conclusions on overall thesis work and scope for future possibilities in this area.