CHAPTER 1

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INTRODUCTION

Tribology is the study of interacting bodies in relative motion and includes three aspects i.e., friction, wear, and lubrication. It is a fascinating but highly complex and interdisciplinary subject involving many research fields such as physics, mathematics, chemistry, materials science, mechanical engineering, and, therefore, connects both basic and applied sciences. The origin of friction in an engineering system is attributed to the relative sliding motion between the components/links, leading to both losses of energy (to overcome friction) and material from the mating parts, known as wear, which may affect life, reliability, and efficiency of components. Most of instances, the failure of a machine is not mainly due to fracture of components, but wear (i.e., mechanical action leads to a gradual loss of material from the rubbing surface) which may leave the system idle and causes huge losses to the economy. Hence, there is a strong need for today's machines that have minimum friction and components that last longer in service. Tribology, as a discipline is expected to play a significant role in designing systems and selecting suitable materials that are able to minimize both friction and wear.

Wear results in catastrophic failures that lead to the shutdown of any system's productivity, which causes enormous losses to the economy. The latest worldwide energy consumption reports by Holmberg and Erdemir (2017) have reported that 23% of total energy accounts for tribological contacts and energy losses in transportation, manufacturing, power generation, and the residential sector. It has been indicated that nearly 20 % is used to overcome friction, and 3% is used to repair worn parts due to wear.

It has also been suggested that utilization of new materials, lubricants and surface modification technologies can help in saving up to 1.4% of the GDP annually and energy losses due to friction and wear may be reduced by 18% (21.5 EJ) in 8 years and 40% (46 EJ) in 15 years). Hence, the prime objective of tribology research is to design methods and materials to minimize friction and wear which may help in saving our resources, energy, and economic losses directly and indirectly. Direct measures pertain to friction reduction, fabrication of the new parts and, replacing the worn components whereas indirect savings pertain to the life of machinery.

A composite material is a manmade combination of two or more physically distinct materials, chemically dissimilar, and possessing different properties. The topologically continuous material is termed as a matrix, while the discontinuously distributed phase is known as reinforcement. The reinforcement phase can have other geometrical characteristics and scales ranging from micro to nano-meter, which govern the composite material's properties. The idea and the goal of this concept are to produce a material with a combination of properties superior to those attained with a single metal independently. Since the beginning of the development of composite materials, researchers have been trying different combinations to achieve the desired tribological performance, with or without solid lubricants. Hence, alternative approaches like surface modification (coatings) or the development of new composite materials have emerged as viable options to provide an effective replacement in such conditions to minimize friction and wear. However, between these two, the development of new composites is the best alternative as they offer desirable performance for an extended period of time compared to coatings, which have a limited life.

Much work has been done on Titanium, Aluminum, Copper, Magnesium, and Nickel matrix composites containing various hard/soft reinforcements, or a combination of them to attain the desirable tribological performance. But the quest continues. Titanium and its alloys are widely used in aerospace, medical implants, and the automobile industry [2,3]. However, the low hardness and strength, low friction properties, and wear resistance of pure Ti restrict its application in the components involving sliding contacts. The use of titanium matrix composites (TMCs) in the automobile, aviation, and biomedical sectors has attracted a great deal of attention [4-6]. Titanium boride (TiB) is supposed to be the most desirable reinforcement for TMCs because of its exceptional stiffness, excellent thermodynamic stability, and equivalent thermal expansion coefficient to the Ti matrix. Also, in-situ reactions of Ti with TiB_2 leads to the formation of TiB during the synthesis, resulting in the formation of a clean interface and excellent bonding with the Ti matrix [7,8]. It is being widely researched to be used in composites either singly or in combination with other reinforcement. However, the research on TiB is still not that mature, so, it would be good to analyze the behavior of Titanium-based composites containing a range of TiB volume percentages.

A number of processing techniques are available to fabricate the composites, and each one of them has its own benefits and limitations. The processing methods utilized to manufacture particulate-reinforced MMCs can be classified into three categories: (a) liquid-phase processes, (b) solid-state processes, and (c) two phases (solid-liquid) processes. However, over the last few decades, Powder Metallurgy (PM) has proven itself to be the most appropriate route to produce superior-quality products. Solid-state processing offers advantages like uniform dispersion, improved structural stability, good surface finish, dimensional control, and good bonding between matrix and reinforcement. However, the main drawback of conventional sintering processes is that it is a bit time-consuming, so advanced techniques like vacuum arc melting (VAM) and laser melting are being explored used to save time and energy. The properties of the product fabricated by these techniques are observed to be of superior to those manufactured by conventional sintering techniques. Vacuum arc melting offers some advantages like less time consumption, good densification due to the arc pressure, high heating, and simultaneous cooling, which is controlled to achieve different microstructures and properties for all the materials.

In view of the above, the goal of the present is to synthesize Ti-TiB composites containing different amounts of TiB via spark plasma sintering as well as vacuum arc melting and to evaluate their friction and wear characteristics by carrying out reciprocating wear tests at different loads and frequencies. The study also aims to elicit the effect of load, frequency, and the volume percentage of TiB on the tribological performance of these composites in order to reveal the optimum content and to establish the prevailing mechanisms of wear.

In summary, the present study has been carried out to explore the tribological performance of Ti-TiB composites, containing different amounts of TiB, synthesized via spark plasma sintering and vacuum arc melting process. The knowledge base generated through this study is expected to provide a better understanding of the friction and wear characteristics of these composites in determining the optimum TiB content for improved tribological performance and will be helpful in utilizing their potential for future tribological applications.