CHAPTER 1

INTRODUCTION

The fundamental requirements of any engineering system are the reliability, efficiency and long life. When two components of an engineering system are in relative motion, the loss of material from the surface of both the materials occurs and this phenomenon is known as *"wear"*. The wear affects the reliability, efficiency and long life of an engineering system. In most of the circumstances, the failure of the machines is due to the wear and not due to the breakage of component. Wear is not an intrinsic property of a material but a characteristic of an engineering system. Wear is hardly ever catastrophic, but it diminishes the operating efficiency and increases power losses, oil consumption, and component replacement rates. So it is mandatory that the parts having sliding motion between them should be designed in such a way that wear can be minimized. The study of the complex phenomena occurring during rubbing and the need to minimize both energy and material losses in mechanical systems has resulted in the evolution of an interdisciplinary field named as "Tribology", the science of friction, wear and lubrication.

The necessity to develop newer wear resistant materials has forced the materials scientists worldwide to pay attention to this important aspect which causes huge loss to the economy. Exhaustive research work is continuing to explore the tribological behavior of composites based on copper, aluminum or magnesium alloys for the last five decades. The main purpose is to develop the composite materials that possess specific properties which cannot be obtained by the constituent materials. Composite materials containing the fibres, whiskers and ceramic particles have been developed for wear resistant applications. Among the composite materials, copper based composite materials are the potential candidates for a wide range of tribological applications such electrical sliding contacts, shipping hulls, bearings etc.

When two or more chemically dissimilar materials are combined at a microscopic scale it results in a composite material whose physical properties are quite different than that of the properties of the constituents due to their synergy. The continuous constituent material is called matrix and the other constituent, discontinuously dispersed in the matrix is called reinforcement. Due to the wide variety of matrix and reinforcement materials available, the design potentials are incredible (Rohatgi, 1995).

Discontinuously reinforced metal matrix composites (MMCs) generally refer to a kind of material in which rigid ceramic reinforcements are embedded in a ductile metal matrix. Therefore, MMCs combine metallic properties of ductility and toughness of the matrix with high strength and modulus of ceramic reinforcements, leading to a greater strength in shear and compression along with capability of retaining properties at higher service temperature. The attractive physical and mechanical properties that can be obtained in MMCs, such as high specific modulus, strength, better wear resistance and thermal stability have been exploited extensively. MMCs are employed in space, in aerospace and automotive industries and in other structural applications (Chung et al. 2017). The use of MMCs has increased over the past 30 years as a result of the availability of relatively inexpensive reinforcements and development of various processing routes which result in reproducible microstructure and properties. The discontinuously reinforced MMCs include particle as well as whisker or short fiber reinforced composites.

The particle-reinforced MMCs have attracted special attention due to ease of fabrication, lower costs, and isotropic properties. Traditionally, discontinuously reinforced MMCs have been produced by several processing routes such as powder metallurgy, spray deposition, and various casting techniques, i.e. squeeze casting, rheocasting and compocasting. All these techniques are based on addition of ceramic reinforcements to the matrix materials which may be in molten or powder form. For the conventional MMCs, the reinforcing phases are added separately prior to the composite fabrication. In this case, the scale of the reinforcing phase is limited by the starting powder size, which is typically of the order of microns to tens of microns and rarely below 1 μm. However, the main drawbacks of liquid metallurgy route that have to be overcome are the interfacial reactions between the reinforcements and the matrix, and the poor bonding between the reinforcements and the matrix due to surface contamination of the reinforcements. It is widely recognized that the properties of MMCs are controlled by the size and volume fraction of the reinforcements as well as the nature of bonding at the matrix-reinforcement interfaces. An optimum set of mechanical properties can be achieved when fine and thermally stable ceramic particles are dispersed uniformly in the metal matrix.

The powder metallurgy (P/M) technique which is a solid state process is one of the most appropriate technique to produce quality MMCs than the various processing routes mentioned above. P/M is a well-recognized and proven processing technique being used from the last seven decades for developing superior quality products which find numerous important applications in power tools industry, aerospace, house hold appliances, electronics and much more (Torralba et al., 2003)

Several advantages such as uniform distribution of reinforced particles which enhances its structural stability, dimensional control with an excellent surface finish, mitigation of reactions between the matrix and the reinforcement, and hence, improved bonding between the reinforcement and the matrix make this a powerful technique for producing near-net shape composites. The versatility of the P/M method is that it allows the synthesis of those materials which is difficult to be processed by any other processing route. For example graphite, Ti and carbon nano tubes can be easily reinforced in copper by using powder metallurgy route (Mallikarjuna et al., 2017). Powder metallurgy process generally consists of four basic steps as powder preparation, powder mixing and blending, compacting and sintering. Despite the recent developments of some special techniques like microwave sintering and spark plasma sintering, the conventional powder metallurgy is still the most useful technique for fabrication of near net shaped components.

In recent years, copper and its alloys are widely used because of their excellent electrical and thermal conductivities, better resistance to corrosion, ease of fabrication, good strength and fatigue resistance (Ayyappadas et al., 2017). For the electrical purpose, pure copper is used for making cables and wires, electrical contacts equipment and various other parts related to it. Copper and its alloys are not only finding their applications for electrical purpose but it also finds their use in automobile parts such as radiators, heat exchangers and where applications requiring rapid conduction of heat.

To address the above mentioned problem, particulate-reinforced metal matrix composites have been developed to produce high- strength and high wear-resistant materials by introducing hard ceramic particles and solid lubricant in the metal matrix. It is observed that addition of ceramic reinforcements such as SiC, Al_2O_3, TiC, B_4C, and ZrO_2 to copper matrix improve its hardness and thermal shock resistance.

Among the various reinforcements titanium carbide (TiC) is an attractive material for the reinforcement in metallic matrix due to its high modulus, hardness, melting temperature, and moderate electrical conductivity (Akhtar et al., 2009; Bagheri, 2016). Addition of TiC in copper matrix does not induce any detrimental effect on physical and electrical property of the resulted Cu–TiC composite.

In the light of the above, the objective of the present investigation is to synthesize the TiC reinforced Cu-4 wt.% Ni matrix composites using a powder metallurgy route. The addition of Ni is expected to promote the bonding between the copper and TiC particles. In the investigation, the effect of TiC reinforcement and effect of milling time on the Cu-Ni matrix alloy will be studied through various characterization techniques. The compressibility behavior of the milled powders will be analyzed by using Panelli and Ambrosio Filho, Heckel and Ge compaction equations. Further, physical, mechanical and tribological properties of the developed composites studied with the objective to find their potential as a tribological material for engineering applications under dry sliding contacts. Optimization of wear properties of the composites is performed by using response surface methodology (RSM).