

## Chapter 3

# Tribological Behavior of Ni-Based Self-Lubricating Composites at Elevated Temperatures

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### ABSTRACT

*This chapter illustrates the effect of the addition of solid lubricants on the high temperature friction and wear behavior of Ni-based composites. Ni-based composites containing solid lubricant particles both in nano and micrometer range have been fabricated through powder metallurgy route. In order to explore the possible synergetic action of a combination of low and high temperature solid lubricant, nano or micro powders of two or more solid lubricants were added in the composites. This chapter introduces the fabrication of the Ni-based self-lubricating composites containing graphite and/or MoS<sub>2</sub>, Ag and/or rare earth, Ag and/or hBN as solid lubricants and their friction and wear behavior at room and elevated temperatures. The chapter also includes information on some lubricating composite coatings such as electro-deposited nickel-base coating containing graphite, MoS<sub>2</sub>, or BN and graphene and their tribological characteristics.*

### 1. INTRODUCTION

High temperature wear presents difficulties when conventional lubrication fails to prevent direct contact between metallic surfaces due to degradation of lubricant at higher temperature

and consequently, the components encounter accelerated wear. The wear at elevated temperatures is a serious problem in many situations (power generation, transport, materials processing and turbine engines) and gets accentuated due to faster kinetics of surface oxidation; loss of mechanical

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hardness and strength of the materials constituting the contacting surfaces and change in adhesion between these surfaces caused by the joint action of temperature and tribological parameters.

Space bearing, seal ring, bearing retainer and other parts working under frictional conditions are required to work for longer hours at high temperatures, high loads, high vacuum, strong radiation and high corrosion etc. Conventional oil and grease are not able to meet these requirements, so the need of the hour is to develop self-lubricating composite materials that can fulfill the above mentioned requirements. Among the various solid self-lubricating composites, it has been found that nickel-based composites doped with solid lubricants offer great opportunity as these have excellent mechanical properties and high temperature oxidation resistance. Apart from these the Nickel base composite coatings have also been found to possess good friction and wear properties and different coatings have been synthesized by adding MoS<sub>2</sub>, BN, graphite, Si<sub>3</sub>N<sub>4</sub>, carbon nanotubes, diamond powder and other composite particles to the bath solution, to obtain composite coatings with high hardness and excellent wear resistance. The particles are uniformly distributed in the matrix metal, which significantly improve the friction properties of the coatings.

### **1. 1 Friction and Wear at Elevated Temperatures**

Apart from the study of surface interactions when two bodies are in relative motion, the elevated-temperature friction and wear behavior of metals and alloys is an important consideration in the effective performance of certain moving parts in internal combustion engines, bearings in aerospace propulsion systems, cutting tools, and metalworking processes. Sometimes the interfacial temperature is caused by external sources of heat, and at other times, the temperature results from frictional contact. At high temperatures, changes

occur in bulk mechanical properties, bulk thermo-physical properties, and surface reactivity. Since there are few viable liquid or solid lubricants that work well at temperatures beyond 500 °C, a number of elevated temperature applications for contacting metals depend on the ability of the bearing surfaces to self-lubricate, based on reactions with their environments and their ability to form protective glazes (tribo-layers) during the contact process (Inman, Datta, Du, Burnell-Graya, Pierzgalski & Luo, 2005).

Scientific and technological progress needs new structural materials capable of withstanding high temperatures in various fluids. The applicability of materials in high-temperature rubbing conditions also depends upon their mechanical behavior at high temperatures (Stott, 2002). Studies on metals have shown that for the metals the relationship of temperature with friction coefficient,  $f$ , is determined by their place in the periodic table and by their crystalline structure. Metals with body-centered cubic and face-centered cubic crystal lattices show the greatest friction and those with a hetro polar lattice show the least. Polymorphic transformations into body-centered or, even more so, into face-centered structures, yields a sharp increase in friction coefficient and the reverse transformation reduces it. Studies of friction of a number of metal-like compounds, such as carbides (Ti, V, Nb, Cr, Mo, and W) and several borides, have shown that the friction coefficient as a function of temperature is close to that demonstrated by metals.

The nickel based coating have higher wear resistance than cobalt based coating at high temperature due to the compacted oxide layers, nickel based hard facing alloy have good resistance to corrosion and oxidation, so if the operating temperature is high enough to induce oxidative wear, nickel based hard facing alloy can be used for nuclear power plant applications (Stott & Jordan, 2001).

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