PREFACE

The adjacent surfaces in relative motion bring about energy losses due to the release of frictional heat. The loss of mass associated with friction results in surface wear. The presence of a lubricant between the proximal moving surfaces ensures a reduction in friction and wear. Nanomaterials, due to their small size and fast tribo-action, are favored as lubricant additives over conventional organic compounds. The vital role of graphene, a 2D material, in lubrication is accredited to the very low friction coefficient due to the ease of shearing of nanosheets under sliding motion. Functionalization of graphene is performed to overcome the demerits of graphene during lubrication, such as the agglomeration and repiling of nanosheets, poor dispersibility in the base lube, poor adhesion to the surface, inadequate friction and wear reducing characteristics, and last abysmal load-carrying ability.

In the current investigation, graphene-based nanohybrids have been synthesized to improve the tribological properties of graphene by covalent/non-covalent functionalization or both together using their synergistic effects. The thesis is spread into the major heads; Introduction, Experimental procedures, Results & Discussions, Summary, and References.

In **Chapter 1** introduction, at first tribology, a significant field related to the longevity of the mechanical systems has been introduced. The phenomena of friction, wear, lubrication have been elaborated. Types of lubrication, lubricants, and their classification, different categories of additives in general and antiwear/antifriction additives in particular, have been described. A detailed literature survey of graphene and graphene-based nano additives in tribology is also presented in this section. The statement of the problem has been clearly defined. At last, the aims and objectives of the present investigation have been outlined.

Chapter 2 describes the instrumentation details regarding the techniques, Fourier Transform infrared spectroscopy (FTIR), electronic absorption spectroscopy (UV/visible), Raman spectroscopy (RS), scanning electron microscopy (SEM)/high resolution scanning electron microscopy (HR-SEM) with energy-dispersive X-ray spectroscopy (EDX), transmission electron microscopy (TEM)/high-resolution transmission electron microscopy (HR-TEM), powder X-ray diffraction (p-XRD), and X-ray photoelectron spectroscopy (XPS) employed for characterization of the synthesized additives as well as lubricated surfaces. The computational methodology has been narrated in brief. The details of the test sample (steel balls), characteristics of base lube paraffin oil (PO), experimental procedures for the tribological tests, ASTM D4172, ASTM D5183, wear rate determination, and notes on different tribological parameters such as mean wear scar diameter (MWD), coefficient of friction (μ), mean wear volume (MWV), wear rate, the load-bearing capacity have also been included in this chapter.

The results and discussion of the experimental data and inferences drawn from them have been spread over four chapters 3-6.

Chapter 3 includes the synthesis of reduced graphene oxide (rGO), Zinc oxide (ZnO), and magnesium-doped zinc oxide nanoparticles, $Zn_{0.88}Mg_{0.12}O$ (ZMO), and the nanohybrids; ZnO-rGO and ZMO-rGO. Morphologies of as-prepared nanoparticles/nanosheets and their nanohybrids have been studied. The tribological activity of these nano additives has been evaluated, and the spectacular performance of ZMO-rGO has been noted.

Chapter 4 contains the synthesis of polyaniline functionalized reduced graphene oxide (PANI-rGO) and its nanocomposite with yttrium-vanadium co-doped zinc oxide nanoparticles to yield Y-V-ZnO/PANI-rGO. The nanocomposites PANI-rGO and Y-V-ZnO/PANI-rGO were characterized thoroughly. The tribological activity of various additives has been assessed, and illustrious tribological performance of Y-V-ZnO/PANI-rGO was obtained.

Chapter 5 illustrates the synthesis and characterization of binary nanocomposites ZrO_2-rGO and ZCO-2/rGO (ZCO-2 is 20% cerium doped zirconia), and ternary nanohybrids, ZrO_2/rGO/MoS_2, and ZCO-2/rGO/MoS_2. As expected, ZCO-2/rGO/MoS_2 shows marvelous tribological activity among all tested additives.

Chapter 6 addresses the synthesis and characterization of CuPc-(ADB-rGO), where 2-aminoethyl diphenyl borate (ADB) has been used for covalent functionalization of graphene oxide (GO). At the same time, copper (II) phthalocyanine (CuPc) nanotubes are attached by non-covalent forces in the composite. Both have successfully improved the tribological performance of the nanohybrid.