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It is certified that the work contained in the thesis titled “**Tribological study on mineral and vegetable oils–based greases with nanoadditives**” by **Mr. Sooraj Singh Rawat** (Roll No. 15131502) has been carried out under our supervision and this work has not been submitted elsewhere for a degree.

It is further certified that the student has fulfilled all the requirements of Comprehensive Examination, Candidacy and SOTA for the award of Ph.D. Degree.

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**DECLARATION BY CANDIDATE**

I, Sooraj Singh Rawat, certify that the work embodied in this thesis is my own bona fide work and carried out by me under the supervisions of Prof. A. P. Harsha and Dr. O. P. Khatri from December 2015 to July 2021, at the Department of Mechanical Engineering, Indian Institute of Technology (BHU), Varanasi. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not willfully copied any other's work, paragraphs, text, data, results, etc., reported in journals, books, magazines, reports dissertations, theses, etc., or available at websites and have not included them in this thesis and have not cited as my own work.

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*Dedicated to  
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## Abbreviations/symbols

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<b>Abbreviation/Symbol</b>	<b>Description</b>
AF	Antifriction
AFM	Atomic force microscopy
AISI	American Iron and Steel Institute
Al	Aluminum
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
AW	Antiwear
at%	Atomic percentage
BAC	Bearing area ratio curve
C	Carbon
Ca	Calcium
Cl	Chlorine
CO <sub>2</sub>	Carbon dioxide
COF	Coefficient of friction
cm	Centimeter
°C	Degree centigrade
d	Diameter
<i>d</i>	Interlamellar spacing
deg	Degree
E	Young's modulus
EDS	Energy dispersive spectroscopy
EHL	Electrohydrodynamic lubrication

EP	Extreme pressure
eV	Electron volt
Fe	Iron
FM	Friction modifier
FTIR	Fourier transform infrared
g	Gram
$\dot{\gamma}$	Shear rate
G'	Storage modulus
G''	Loss modulus
GO	Graphene oxide
GO-ODA	Chemically functionalized graphene oxide with long-chain octadecylamine
GPa	Giga pascal
h	Hour
H	Hydrogen
Hz	Frequency
H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid
HCl	Hydrochloric acid
JCPDS	Joint Committee on Powder Diffraction Standards
k	Consistency factor
<i>k</i>	Wear coefficient
KBr	Potassium bromide
kg	Kilogram
kgf	Kilogram force
KMnO <sub>4</sub>	Potassium permanganate

kV	Kilovoltage
l	Length
Li	Lithium
LWI	Load wear index
$\lambda$	Wavelength of incident X-ray radiation
$\lambda$	Film thickness parameter
m	Meter
mA	Milliampere
mm	Millimeter
$\mu$ L	Microliter
$\mu$ m	Micrometer
$\mu$	Coefficient of friction
min	Minute
MJ	Mega joule
MoS <sub>2</sub>	Molybdenum disulfide
MoS <sub>2</sub> -ODT	Chemically functionalized molybdenum disulfide with long-chain octadecanethiol
MWV	Mean wear volume
n	Shear thinning index
N	Nitrogen
$\eta$	Apparent viscosity
Na	Sodium
NaNO <sub>3</sub>	Sodium nitrate
NLGI	National Lubricating Grease Institute
nm	Nanometer

O	Oxygen
ODA	Octadecylamine
ODT	1–octadecanethiol
OPEC	Organization of the Petroleum Exporting Countries
P	Phosphorus
$P$	Cone penetration by test method D 217
$p'$	Cone penetration by $\frac{1}{2}$ scale
$p''$	Cone penetration by $\frac{1}{4}$ scale
%	Percentage
$P_{\max}$	Maximum contact pressure
pH	Potential of hydrogen
PAO	Polyalphaolefines
PTFE	Polytetrafluoroethylene
$\phi$	Diameter
R	Radius of steel ball before test
$R$	Correlation coefficient
$R_a$	Average line roughness
$R_q$	Root–mean–square line roughness
rGO	Reduced graphene oxide
rpm	Revolutions per minute
$\nu$	Poisson's ratio
s	Second
S	Sulphur
$S_a$	Average surface roughness
Si	Silica

$S_k$	Core roughness depth
$S_{ku}$	Kurtosis
$S_{pk}$	Reduced peak height
$S_q$	Root-mean-square surface roughness
$S_{r1}$	Peak material component
$S_{r2}$	Valley material component
$S_{sk}$	Skewness
$S_{vk}$	Reduced valley depth
SAOS	Small-amplitude oscillatory shear
SEM	Scanning electron microscope
$SiO_2$	Silicon dioxide
SPM	Scanning probe microscope
SRV	Schwingung reibung verschleiss (German) Oscillating, friction, wear, (English translation)
SWR	Specific wear rate
$T_{onset}$	Onset temperature
$T_{max}$	Maximum decomposition temperature
$t$	Thickness
$\tau$	Shear stress
$\tau_y$	Yield shear stress
TEM	Transmission electron microscope
TEOS	Tetraethoxysilane
TGA	Thermogravimetric analysis
TXP	Trixylyl phosphate
$\theta$	Incident angle

VI	Viscosity index
$W_q$	Planimetric wear
$W_v$	Total wear volume
WR	Wear rate
$WS_2$	Tungsten disulfide
WSD	Wear scar diameter
wt%	Weight percentage
% w/v	Weight by volume percentage
% w/w	Weight by weight percentage
WTW	Wear track width
WV	Wear volume
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffractometer
ZDDP	Dialkyldithiophosphate
2D	Two-dimensional
3D	Three-dimensional
↑	Increase
↓	Decrease