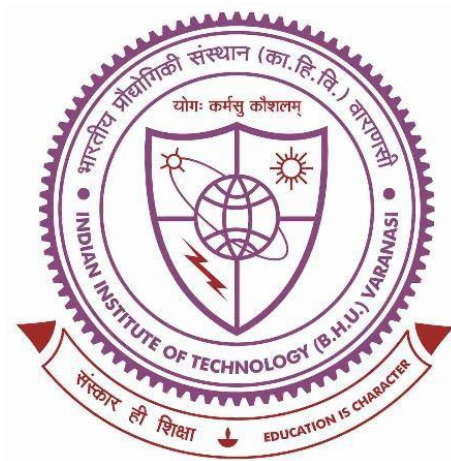


# **SUSTAINABLE CRYOGENIC GRINDING OF AISI D2 TOOL STEEL USING VARIOUS ECO- FRIENDLY LUBRICANTS WITH MQL TECHNIQUE**



Thesis submitted in partial fulfillment  
for the award of degree

**Doctor of Philosophy**

*By*

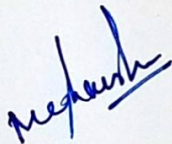
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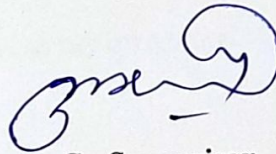
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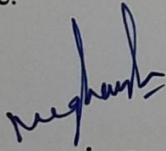
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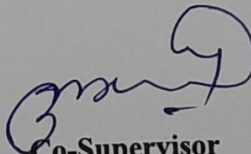
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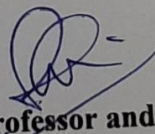
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*Ashwani  
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# LIST OF ABBREVIATIONS/SYMBOLS

## 1. Abbreviations

AFM	:	Atomic force microscope
Al <sub>2</sub> O <sub>3</sub>	:	Aluminum oxide
BAC	:	Bearing area curve
BN	:	Barkhausen noise
Cryo-MQL	:	Cryogenic minimum quantity lubrication
DLVO	:	Derjaguin–Landau–Verwey–Overbeek
EDS/EDX	:	Energy-dispersive X-ray spectroscopy
HL	:	Hysteresis loop
IEP	:	Isoelectric point
LN <sub>2</sub>	:	Liquid nitrogen
MBN	:	Magnetic Barkhausen noise
MQL	:	Minimum quantity lubrication
NFs	:	Nanofluids
NPs	:	Nanoparticles
RMS	:	Root mean square
SEM	:	Scanning electron microscope
SO	:	Soybean oil
SO+DW	:	Soybean oil-based deionized water emulsion
SQL	:	Small quantity lubrication
TEM	:	Transmission Electron Microscopy
XRD	:	X-ray diffraction

## 2. Symbols

$a_p$	:	Downfeed ( $\mu\text{m}$ )
$b$	:	Grinding wheel width (mm)
$F_n$	:	Normal force (N)
$F_t$	:	Tangential force (N)
$M_{r1}$	:	Smallest material ratio
$M_{r2}$	:	Greatest material ratio
$P_a$	:	Air pressure (bar)
$P_{LN_2}$	:	Liquid nitrogen pressure (bar)
$Q_e$	:	MQL mist flow rate of vegetable oil-based deionized water emulsion and nanofluids (ml/h)
$Q_{LN_2}$	:	Flow rate of liquid nitrogen (l/min)
$Q_o$	:	MQL mist flow rate of vegetable oil (ml/h)
$R_a$	:	Average surface roughness ( $\mu\text{m}$ )
$R_k$	:	Core roughness depth ( $\mu\text{m}$ )
$R_{pk}$	:	Reduced peak height ( $\mu\text{m}$ )
$R_q$	:	Root mean square roughness ( $\mu\text{m}$ )
$R_{vk}$	:	Reduced valley depth ( $\mu\text{m}$ )
$R_z$	:	Ten-point mean surface roughness ( $\mu\text{m}$ )
$S_a$	:	Average roughness ( $\mu\text{m}$ )
$S_{bi}$	:	Surface bearing index ( $\mu\text{m}$ )
$S_{ci}$	:	Core fluid retention index ( $\mu\text{m}$ )
$S_k$	:	Core roughness depth ( $\mu\text{m}$ )
$S_{mr1}$	:	Upper material ratio (%)

$S_{mr2}$	:	Lower material ratio (%)
$S_{mrk}$	:	Bearing area ratio (%)
$S_{pk}$	:	Reduced peak height ( $\mu\text{m}$ )
$S_q$	:	Root mean square roughness ( $\mu\text{m}$ )
$S_t$	:	Area peak-to-valley height ( $\mu\text{m}$ )
$S_{vk}$	:	Reduced valley depth ( $\mu\text{m}$ )
$T_g$	:	Grinding temperature ( $^{\circ}\text{C}$ )
$U_g$	:	Specific grinding energy ( $\text{J}/\text{mm}^3$ )
$V_s$	:	Alumina wheel speed (m/s)
$V_w$	:	Table feed rate (m/min)
$\mu$	:	Apparent friction coefficient
$\theta$	:	Contact angle ( $^{\circ}$ )