REFERENCES

[1] R. Carnes and G. Maddock, “Tool steel selection: the effectiveness of a tool in service begins with selection of the proper tool steel alloy,” *Adv. Mater. & Process.*, vol. 162, no. 6, pp. 37–41, 2004.

[2] D. Bombac, M. Fazarinc, A. S. Podder, and G. Kugler, “Study of carbide evolution during thermo-mechanical processing of AISI D2 tool steel,” *J. Mater. Eng. Perform.*, vol. 22, no. 3, pp. 742–747, 2013, doi: 10.1007/S11665-012-0340-Y/FIGURES/5.

[3] Y. Isik, “Investigating the machinability of tool steels in turning operations,” *Mater. Des.*, vol. 28, no. 5, pp. 1417–1424, 2007, doi: 10.1016/j.matdes.2006.03.025.

[4] S. Malkin and C. Guo, *Grinding technology : theory and applications of machining with abrasives*. Industrial Press, 2008.

[5] W. B. Rowe, *Principles of modern grinding technology*. 2013. doi: 10.1016/C2013-0-06952-6.

[6] A. K. Biswas and S. Das, “Comparative Study of force Analysis and Heat Generation in Grinding,” *Reason. Tech. J.*, vol. 10, no. 0, p. 17, 2011, doi: 10.21843/reas/2011/17-20/108206.

[7] A. Sharma, A. Chaudhari, M. Z. K. Yusufzai, and M. Vashista, “An Experimental Study on Improving Grindability with LN2 Coolant for Grinding AISI D2 Tool Steel,” *J. Mater. Eng. Perform.*, pp. 1–15, 2023, doi: 10.1007/s11665-023-07958-7.

[8] R. Choudhary, H. Kumar, and S. Singh, “Machining performance and surface integrity of AISI D2 die steel machined using electrical discharge surface grinding process,” *J. Mater. Eng. Perform.*, vol. 22, no. 12, pp. 3665–3673, 2013, doi: 10.1007/S11665-013-0679-8.

[9] S. J. Pande and G. K. Lal, “Wheel wear in dry surface grinding,” *Int. J. Mach. Tool Des. Res.*, vol. 16, no. 3, pp. 179–186, 1976, doi: 10.1016/0020-7357(76)90003-2.

[10] M. S. Najiha, M. M. Rahman, and A. R. Yusoff, “Environmental impacts and hazards associated with metal working fluids and recent advances in the sustainable systems: A review,” *Renew. Sustain. Energy Rev.*, vol. 60, pp. 1008–1031, 2016,

doi: 10.1016/j.rser.2016.01.065.

[11] C. A. Smits, *Performance of metalworking fluids in a grinding system*. 1994.

[12] S. Pervaiz, S. Kannan, and H. A. Kishawy, “An extensive review of the water consumption and cutting fluid based sustainability concerns in the metal cutting sector,” *J. Clean. Prod.*, vol. 197, pp. 134–153, 2018, doi: 10.1016/j.jclepro.2018.06.190.

[13] A. Hosseini Tazehkandi, F. Pilehvarian, and B. Davoodi, “Experimental investigation on removing cutting fluid from turning of Inconel 725 with coated carbide tools,” *J. Clean. Prod.*, vol. 80, pp. 271–281, 2014, doi: 10.1016/j.jclepro.2014.05.098.

[14] G. Byrne, E. S.-C. Annals, and U. 1993, “Environmentally clean machining processes—a strategic approach,” *CIRPAnnals—Manufacturing Technol.*, 1993.

[15] M. Soković and K. Mijanović, “Ecological aspects of the cutting fluids and its influence on quantifiable parameters of the cutting processes,” *J. Mater. Process. Technol.*, vol. 109, no. 1–2, pp. 181–189, 2001, doi: 10.1016/S0924-0136(00)00794-9.

[16] S. A. Lawal, I. A. Choudhury, and Y. Nukman, “Application of vegetable oil-based metalworking fluids in machining ferrous metals - A review,” *Int. J. Mach. Tools Manuf.*, vol. 52, no. 1, pp. 1–12, 2012, doi: 10.1016/j.ijmachtools.2011.09.003.

[17] A. D. Jayal, F. Badurdeen, O. W. Dillon, and I. S. Jawahir, “Sustainable manufacturing: Modeling and optimization challenges at the product, process and system levels,” *CIRP J. Manuf. Sci. Technol.*, vol. 2, no. 3, pp. 144–152, 2010, doi: 10.1016/j.cirpj.2010.03.006.

[18] S. Ebbrell, N. H. Woolley, Y. D. Tridimas, D. R. Allanson, and W. B. Rowe, “Effects of cutting fluid application methods on the grinding process,” *Int. J. Mach. Tools Manuf.*, vol. 40, no. 2, pp. 209–223, 2000, doi: 10.1016/S0890-6955(99)00060-7.

[19] C. H. Li, W. Mao, Y. L. Hou, and Y. C. Ding, “Investigation of hydrodynamic pressure in high-speed precision grinding,” *Procedia Eng.*, vol. 15, pp. 2809–2813, 2011, doi: 10.1016/j.proeng.2011.08.529.

[20] S. K. Lee, Y. Miyamoto, T. Kuriyagawa, and K. Syoji, “Effects of minimizing

hydrodynamic pressure in ultra-precision mirror grinding," *Int. J. Mach. Tools Manuf.*, vol. 44, no. 10, pp. 1031–1036, 2004, doi: 10.1016/j.ijmachtools.2004.03.004.

[21] G. Guerrini, E. Landi, K. Peiffer, and A. Fortunato, "Dry grinding of gears for sustainable automotive transmission production," *J. Clean. Prod.*, vol. 176, pp. 76–88, 2018, doi: 10.1016/j.jclepro.2017.12.127.

[22] M. Li *et al.*, "Experimental evaluation of an eco-friendly grinding process combining minimum quantity lubrication and graphene-enhanced plant-oil-based cutting fluid," *J. Clean. Prod.*, vol. 244, p. 118747, 2020, doi: 10.1016/j.jclepro.2019.118747.

[23] A. Bordin, S. Sartori, S. Bruschi, and A. Ghiotti, "Experimental investigation on the feasibility of dry and cryogenic machining as sustainable strategies when turning Ti6Al4V produced by Additive Manufacturing," *J. Clean. Prod.*, vol. 142, no. 2017, pp. 4142–4151, 2017, doi: 10.1016/j.jclepro.2016.09.209.

[24] H. A. Çetindağ, A. Çiçek, and N. Uçak, "The effects of CryoMQL conditions on tool wear and surface integrity in hard turning of AISI 52100 bearing steel," *J. Manuf. Process.*, vol. 56, pp. 463–473, 2020, doi: 10.1016/j.jmapro.2020.05.015.

[25] A. Chaudhari, M. Z. K. Yusufzai, and M. Vashista, "Grindability study of hard to cut AISI D2 steel upon ultrasonic vibration-assisted dry grinding," *Proc. Inst. Mech. Eng. Part E J. Process Mech. Eng.*, vol. 236, no. 3, pp. 915–925, 2022, doi: 10.1177/09544089211051635.

[26] A. Awale, A. Srivastava, M. Vashista, and M. Z. K. Yusufzai, "Surface integrity characterization of ground hardened H13 hot die steel using different lubrication environments," *Mater. Res. Express*, vol. 6, no. 2, pp. 983–997, 2019, doi: 10.1088/2053-1591/aaeae8.

[27] X. Cui, N. Sun, J. Guo, J. Ma, and P. Ming, "Green multi-biomimetic spontaneous oil-transport microstructure and its effects on energy consumption in sustainable intermittent cutting," *J. Clean. Prod.*, vol. 367, p. 133035, 2022, doi: 10.1016/j.jclepro.2022.133035.

[28] N. S. Ross, N. Srinivasan, P. Amutha, M. K. Gupta, and M. E. Korkmaz, "Thermo-physical, tribological and machining characteristics of Hastelloy C276 under

sustainable cooling/lubrication conditions," *J. Manuf. Process.*, vol. 80, pp. 397–413, 2022, doi: 10.1016/j.jmapro.2022.06.018.

[29] X. Cui, Y. Guo, J. Guo, and P. Ming, "Bio-inspired design of cleaner interrupted turning and its effects on specific cutting energy and harmful gas emission," *J. Clean. Prod.*, vol. 271, p. 122354, 2020, doi: 10.1016/j.jclepro.2020.122354.

[30] G. Manimaran, M. Pradeep Kumar, and R. Venkatasamy, "Influence of cryogenic cooling on surface grinding of stainless steel 316," *Cryogenics (Guildf).*, vol. 59, pp. 76–83, 2014, doi: 10.1016/j.cryogenics.2013.11.005.

[31] R. SAXENA, A. SONI, S. N. SAXNA, S. S. RATHORE, and P. BARNWAL, "Cryogenic Grinding: a Physical Technique To Retain Volatile Content in Natural Products," *Int. J. Mod. Phys. Conf. Ser.*, vol. 22, pp. 589–592, 2013, doi: 10.1142/s2010194513010714.

[32] Y. Kaynak, T. Lu, and I. S. Jawahir, "Cryogenic machining-induced surface integrity: A review and comparison with dry, mql, and flood-cooled machining," *Mach. Sci. Technol.*, vol. 18, no. 2, pp. 149–198, 2014, doi: 10.1080/10910344.2014.897836.

[33] K. V. B. S. Kalyan Kumar and S. K. Choudhury, "Investigation of tool wear and cutting force in cryogenic machining using design of experiments," *J. Mater. Process. Technol.*, vol. 203, no. 1–3, pp. 95–101, 2008, doi: 10.1016/j.jmatprotec.2007.10.036.

[34] S. Y. Hong and Z. Zhao, "Thermal aspects, material considerations and cooling strategies in cryogenic machining," *Clean Technol. Environ. Policy*, vol. 1, no. 2, pp. 107–116, 1999, doi: 10.1007/s100980050016.

[35] S. Paul, N. R. Dhar, and A. B. Chattopadhyay, "Beneficial effects of cryogenic cooling over dry and wet machining on tool wear and surface finish in turning AISI 1060 steel," *Journal of Materials Processing Technology*, vol. 116, no. 1. pp. 44–48, 2001. doi: 10.1016/S0924-0136(01)00839-1.

[36] M. K. Sinha, R. Madarkar, S. Ghosh, and V. R. Paruchuri, "Some investigations in grindability improvement of Inconel 718 under ecological grinding," *Proc. Inst. Mech. Eng. Part B J. Eng. Manuf.*, vol. 233, no. 3, pp. 727–744, 2019, doi:

10.1177/0954405417752513.

[37] A. Mohamed Mahmoud IBRAHIM *et al.*, “Cooling and lubrication techniques in grinding: A state-of-the-art review, applications, and sustainability assessment,” *Chinese J. Aeronaut.*, 2023, doi: 10.1016/j.cja.2023.03.026.

[38] Y. Yildiz and M. Nalbant, “A review of cryogenic cooling in machining processes,” *Int. J. Mach. Tools Manuf.*, vol. 48, no. 9, pp. 947–964, 2008, doi: 10.1016/j.ijmachtools.2008.01.008.

[39] G. Rotella and D. Umbrello, “Finite element modeling of microstructural changes in dry and cryogenic cutting of Ti6Al4V alloy,” *CIRP Ann. - Manuf. Technol.*, vol. 63, no. 1, pp. 69–72, 2014, doi: 10.1016/j.cirp.2014.03.074.

[40] A. Sharma, M. Z. Khan Yusufzai, and M. Vashista, “A comparative analysis of grinding of AISI D2 tool steel under different environments,” *Mach. Sci. Technol.*, vol. 26, no. 2, pp. 183–202, 2022, doi: 10.1080/10910344.2022.2044853.

[41] K. H. Song, D. W. Lim, J. Y. Park, S. J. Ha, and G. S. Yoon, “Investigation on influence of hybrid nozzle of CryoMQL on tool wear, cutting force, and cutting temperature in milling of titanium alloys,” *Int. J. Adv. Manuf. Technol.*, vol. 110, no. 7–8, pp. 2093–2103, 2020, doi: 10.1007/s00170-020-05646-7.

[42] S. Guo *et al.*, “Experimental evaluation of the lubrication performance of mixtures of castor oil with other vegetable oils in MQL grinding of nickel-based alloy,” *J. Clean. Prod.*, vol. 140, pp. 1060–1076, 2017, doi: 10.1016/j.jclepro.2016.10.073.

[43] C. Birleanu, M. Pustan, M. Cioaza, A. Molea, F. Popa, and G. Contiu, “Effect of TiO2 nanoparticles on the tribological properties of lubricating oil: an experimental investigation,” *Sci. Rep.*, vol. 12, no. 1, pp. 1–17, 2022, doi: 10.1038/s41598-022-09245-2.

[44] H. Younes, M. Mao, S. M. Sohel Murshed, D. Lou, H. Hong, and G. P. Peterson, “Nanofluids: Key parameters to enhance thermal conductivity and its applications,” *Appl. Therm. Eng.*, vol. 207, p. 118202, 2022, doi: 10.1016/j.applthermaleng.2022.118202.

[45] X. Cui *et al.*, “Grindability of titanium alloy using cryogenic nanolubricant minimum quantity lubrication,” *J. Manuf. Process.*, vol. 80, pp. 273–286, 2022, doi:

10.1016/j.jmapro.2022.06.003.

[46] M. A. Makhesana, K. M. Patel, G. M. Krolczyk, M. Danish, A. K. Singla, and N. Khanna, “Influence of MoS2 and graphite-reinforced nanofluid-MQL on surface roughness, tool wear, cutting temperature and microhardness in machining of Inconel 625,” *CIRP J. Manuf. Sci. Technol.*, vol. 41, pp. 225–238, 2023, doi: 10.1016/j.cirpj.2022.12.015.

[47] M. K. Sinha, D. Setti, S. Ghosh, and P. V. Rao, “An investigation on surface burn during grinding of Inconel 718,” *J. Manuf. Process.*, vol. 21, pp. 124–133, 2016, doi: 10.1016/j.jmapro.2015.12.004.

[48] S. Prabhu and B. K. Vinayagam, “Fractal dimensional surface analysis of AISI D2 tool steel material with nanofluids in grinding process using atomic force microscopy,” *J. Brazilian Soc. Mech. Sci. Eng.*, vol. 33, no. 4, pp. 459–466, 2011, doi: 10.1590/S1678-58782011000400009.

[49] E. Bennett, “Water based cutting fluids and human health,” *Elsevier*, 1983.

[50] J. Davim, *Green manufacturing processes and systems*. 2013. doi: 10.1007/978-3-642-33792-5.

[51] Chetan, S. Ghosh, P. R.-M. and M. Processes, and U. 2016, “Environment friendly machining of Ni–Cr–Co based super alloy using different sustainable techniques,” *Taylor Fr.*, vol. 31, no. 7, pp. 852–859, 2016, doi: 10.1080/10426914.2015.1037913.

[52] K. Kishore, M. K. Sinha, A. Singh, M. K. Gupta, and M. Erdi Korkmaz, “A comprehensive review on the grinding process: advancements, applications and challenges,” *Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci.*, vol. 236, no. 22, pp. 10923–10952, 2022, doi: 10.1177/09544062221110782.

[53] G. Manimaran and M. Pradeepkumar, “Investigation of liquid nitrogen (LN2) as coolant in grinding of AISI D3 steel,” *Adv. Mater. Res.*, vol. 341–342, pp. 400–405, 2012, doi: 10.4028/www.scientific.net/AMR.341-342.400.

[54] T. Tawakoli, M. J. Hadad, M. H. Sadeghi, A. Daneshi, S. Stöckert, and A. Rasifard, “An experimental investigation of the effects of workpiece and grinding parameters on minimum quantity lubrication-MQL grinding,” *Int. J. Mach. Tools Manuf.*, vol. 49, no. 12–13, pp. 924–932, 2009, doi: 10.1016/j.ijmachtools.2009.06.015.

[55] V. Diwakar, A. Sharma, M. Z. K. Yusufzai, and M. Vashista, "Barkhausen Noise Signal Analysis of IS 2062 Steel and AISI D2 Tool Steel with Different Range of Magnetizing Frequency and Intensity," *Russ. J. Nondestruct. Test.*, vol. 58, no. 9, pp. 821–832, 2022, doi: 10.1134/S1061830922090054.

[56] A. K. Shrivastava, A. Sharma, A. S. Awale, M. Z. K. Yusufzai, and M. Vashista, "Assessment of Grinding Burn of AISI D2 Tool Steel Using Barkhausen Noise Technique," *J. Inst. Eng. Ser. C*, vol. 102, no. 4, pp. 885–896, 2021, doi: 10.1007/s40032-021-00721-8.

[57] W. P. Ogden, "Detection of subsurface tensile stress in an aircraft engine mainshaft bearing using Barkhausen noise," *NDT E Int.*, vol. 29, no. 5, p. 338, 1996, doi: 10.1016/s0963-8695(97)81531-9.

[58] A. Ktena *et al.*, "Barkhausen noise as a microstructure characterization tool," *Phys. B Condens. Matter*, vol. 435, pp. 109–112, 2014, doi: 10.1016/j.physb.2013.09.027.

[59] M. Vashista, A. Gaddam, and S. Paul, "Study of surface integrity of ground bearing steel using Barkhausen noise technique," *Int. J. Adv. Manuf. Technol.*, vol. 63, no. 5–8, pp. 771–783, 2012, doi: 10.1007/s00170-012-3918-5.

[60] A. Sahebalam, M. Kashefi, and S. Kahrobaee, "Comparative study of eddy current and Barkhausen noise methods in microstructural assessment of heat treated steel parts," *Nondestruct. Test. Eval.*, vol. 29, no. 3, pp. 208–218, 2014, doi: 10.1080/10589759.2014.914207.

[61] J. A. Pérez-Benitez, L. R. Padovese, J. Capó-Sánchez, and J. Anglada-Rivera, "Investigation of the magnetic Barkhausen noise using elementary signals parameters in 1000 commercial steel," *J. Magn. Magn. Mater.*, vol. 263, no. 1–2, pp. 72–77, 2003, doi: 10.1016/S0304-8853(02)01536-6.

[62] A. Srivastava, H. Kumar, M. Z. K. Yusufzai, and M. Vashista, "On the role of magnetising frequency and magnetic field intensity on hysteresis loop characteristics," *Int. J. Microstruct. Mater. Prop.*, vol. 12, no. 1–2, pp. 104–115, 2017, doi: 10.1504/IJMMP.2017.087701.

[63] S. Kahrobaee and T. H. Hejazi, "A RSM-based predictive model to characterize heat treating parameters of D2 steel using combined Barkhausen noise and hysteresis

loop methods," *J. Magn. Magn. Mater.*, vol. 433, pp. 131–140, 2017, doi: 10.1016/j.jmmm.2017.03.015.

[64] H. Ilker Yelbay, I. Cam, and C. Hakan Gür, "Non-destructive determination of residual stress state in steel weldments by Magnetic Barkhausen Noise technique," *NDT E Int.*, vol. 43, no. 1, pp. 29–33, 2010, doi: 10.1016/j.ndteint.2009.08.003.

[65] M. Neslušan, J. Čížek, K. Kolařík, P. Minárik, M. Čilliková, and O. Melikhova, "Monitoring of grinding burn via Barkhausen noise emission in case-hardened steel in large-bearing production," *J. Mater. Process. Technol.*, vol. 240, pp. 104–117, 2017, doi: 10.1016/j.jmatprotec.2016.09.015.

[66] K. Mandal, T. Cramer, and D. L. Atherton, "Study of a racetrack-shaped defect in ferromagnetic steel by magnetic Barkhausen noise and flux leakage measurements," *J. Magn. Magn. Mater.*, vol. 212, no. 1, pp. 231–239, 2000, doi: 10.1016/S0304-8853(99)00595-8.

[67] J. Anglada-Rivera, L. R. Padovese, and J. Capó-Sánchez, "Magnetic Barkhausen Noise and hysteresis loop in commercial carbon steel: Influence of applied tensile stress and grain size," *J. Magn. Magn. Mater.*, vol. 231, no. 2–3, pp. 299–306, 2001, doi: 10.1016/S0304-8853(01)00066-X.

[68] S. Malkin and C. Guo, *Grinding technology: theory and application of machining with abrasives*. Industrial Press Inc., 2008.

[69] M. B. Da Silva and J. Wallbank, "Lubrication and application method in machining," *Ind. Lubr. Tribol.*, vol. 50, no. 4, pp. 149–152, 1998, doi: 10.1108/00368799810225082.

[70] S. Debnath, M. M. Reddy, and Q. S. Yi, "Environmental friendly cutting fluids and cooling techniques in machining: A review," *J. Clean. Prod.*, vol. 83, pp. 33–47, 2014, doi: 10.1016/j.jclepro.2014.07.071.

[71] J. M. Vieira, A. R. Machado, and E. O. Ezugwu, "Performance of cutting fluids during face milling of steels," *J. Mater. Process. Technol.*, vol. 116, no. 2–3, pp. 244–251, 2001, doi: 10.1016/S0924-0136(01)01010-X.

[72] H. Sharma and M. Sharma, "Influence of Cutting Fluids on Quality and Productivity of Products in Manufacturing Industries," *Int. J. Eng. Manag. Sci.*, vol. 1, no. 11, pp.

8–11, 2014.

[73] K. Zheng Yang *et al.*, “Application of coolants during tool-based machining – A review,” *Ain Shams Eng. J.*, 2022, doi: 10.1016/j.asej.2022.101830.

[74] F. Engineer, C. Guo, and S. Malkin, “Experimental Measurement of Fluid Flow Through the Grinding Zone,” *J. Eng. Ind.*, vol. 114, no. 1, pp. 61–66, 1992, doi: 10.1115/1.2899759.

[75] C. Guo and S. Malkin, “Analysis of Fluid Flow through the Grinding Zone,” *J. Eng. Ind.*, vol. 114, no. 4, pp. 427–434, 1992, doi: 10.1115/1.2900694.

[76] J. W. Powell, “The application of grinding fluid in creep feed grinding,” *PhD Thesis, Univ. Bristol*, 1979.

[77] J. L. Metzger, “Superabrasive grinding,” Butterworth, Oxford.

[78] M. R. Schumack, J. B. Chung, W. W. Schultz, and E. Kannatey-Asibu, “Analysis of fluid flow under a grinding wheel,” *J. Manuf. Sci. Eng. Trans. ASME*, vol. 113, no. 2, pp. 190–197, 1991, doi: 10.1115/1.2899677.

[79] F. Klocke, A. Baus, and T. Beck, “Coolant induced forces in CBN high speed grinding with shoe nozzles,” *CIRP Ann. - Manuf. Technol.*, vol. 49, no. 1, pp. 241–244, 2000, doi: 10.1016/S0007-8506(07)62937-0.

[80] P. Hryniewicz, A. Z. Szeri, and S. Jahanmir, “Application of lubrication theory to fluid flow in grinding: Part I - Flow between smooth surfaces,” *J. Tribol.*, vol. 123, no. 1, pp. 94–100, 2001, doi: 10.1115/1.1331277.

[81] C. H. Li, Y. L. Hou, Z. Fang, and Y. C. Ding, “Analytical and experimental investigation of grinding fluid hydrodynamic pressure at wedge-shaped zone,” *Int. J. Abras. Technol.*, vol. 4, no. 2, pp. 140–155, 2011, doi: 10.1504/IJAT.2011.041608.

[82] S. Ganesan, M., Guo, C., Rafael, R.A. and Malkin, “Measurement of hydrodynamic forces in grinding,” *Trans. NAMRI/SME*, 1996.

[83] B. Zhang and A. Nakajima, “Hydrodynamic fluid pressure in grinding zone during grinding with metal-bonded diamond wheels,” *J. Tribol.*, vol. 122, no. 3, pp. 603–608, 2000, doi: 10.1115/1.555408.

[84] V. Gviniashvili, J. Webster, and B. Rowe, "Fluid flow and pressure in the grinding wheel-workpiece interface," *J. Manuf. Sci. Eng.*, vol. 127, no. 1, pp. 198–205, 2005, doi: 10.1115/1.1830051.

[85] A. Vesali and T. Tawakoli, "Study on hydrodynamic pressure in grinding contact zone considering grinding parameters and grinding wheel specifications," *Procedia CIRP*, vol. 14, pp. 13–18, 2014, doi: 10.1016/j.procir.2014.03.053.

[86] Y. Hwang, G. Ha Kim, Y. B. Kim, J. H. Kim, and S. K. Lee, "Suppression of the inflection pattern in ultraprecision grinding through the minimization of the hydrodynamic force using a toothed wheel," *Int. J. Mach. Tools Manuf.*, vol. 100, pp. 105–115, 2016, doi: 10.1016/j.ijmachtools.2015.10.009.

[87] Y. M. Shashidhara and S. R. Jayaram, "Vegetable oils as a potential cutting fluid-An evolution," *Tribol. Int.*, vol. 43, no. 5–6, pp. 1073–1081, 2010, doi: 10.1016/j.triboint.2009.12.065.

[88] Y. M. Shashidhara and S. R. Jayaram, "Vegetable oils as a potential cutting fluid-An evolution," *Tribol. Int.*, vol. 43, no. 5–6, pp. 1073–1081, 2010, doi: 10.1016/j.triboint.2009.12.065.

[89] A. Zeman, A. Sprengel, D. Niedermeier, and M. Späth, "Biodegradable lubricants-studies on thermo-oxidation of metal-working and hydraulic fluids by differential scanning calorimetry (DSC)," *Thermochim. Acta*, vol. 268, no. C, pp. 9–15, 1995, doi: 10.1016/0040-6031(95)02512-X.

[90] A. Shokrani, V. Dhokia, and S. T. Newman, "Environmentally conscious machining of difficult-to-machine materials with regard to cutting fluids," *Int. J. Mach. Tools Manuf.*, vol. 57, pp. 83–101, 2012, doi: 10.1016/j.ijmachtools.2012.02.002.

[91] E. Brinksmeier, D. Meyer, A. G. Huesmann-Cordes, and C. Herrmann, "Metalworking fluids - Mechanisms and performance," *CIRP Ann. - Manuf. Technol.*, vol. 64, no. 2, pp. 605–628, 2015, doi: 10.1016/j.cirp.2015.05.003.

[92] U. Dixit, D. Sarma, and J. Davim, *Environmentally friendly machining*. 2012.

[93] L. R. da Silva, E. C. Bianchi, R. Y. Fusse, R. E. Catai, T. V. França, and P. R. Aguiar, "Analysis of surface integrity for minimum quantity lubricant-MQL in grinding," *Int. J. Mach. Tools Manuf.*, vol. 47, no. 2, pp. 412–418, 2007, doi:

10.1016/j.ijmachtools.2006.03.015.

[94] K. Ishfaq, I. Anjum, C. I. Pruncu, M. Amjad, M. S. Kumar, and M. A. Maqsood, "Progressing towards sustainable machining of steels: A detailed review," *Materials (Basel).*, vol. 14, no. 18, pp. 1–47, 2021, doi: 10.3390/ma14185162.

[95] A. Moldavska and T. Welo, "The concept of sustainable manufacturing and its definitions: A content-analysis based literature review," *J. Clean. Prod.*, vol. 166, pp. 744–755, 2017, doi: 10.1016/j.jclepro.2017.08.006.

[96] R. Sharma, B. K. Jha, V. Pahuja, and S. Sharma, "Role of environmental friendly machining on machinability," *Mater. Today Proc.*, vol. 50, pp. 640–648, 2021, doi: 10.1016/j.matpr.2021.03.652.

[97] F. Klocke and G. Eisenblätter, "Dry cutting," *CIRP Ann.*, vol. 46, no. 2, pp. 519–526, 1997.

[98] S. Debnath, M. M. Reddy, and Q. S. Yi, "Environmental friendly cutting fluids and cooling techniques in machining: A review," *J. Clean. Prod.*, vol. 83, pp. 33–47, 2014, doi: 10.1016/j.jclepro.2014.07.071.

[99] K. Weinert, I. Inasaki, J. W. Sutherland, and T. Wakabayashi, "Dry machining and minimum quantity lubrication," *CIRP Ann. - Manuf. Technol.*, vol. 53, no. 2, pp. 511–537, 2004, doi: 10.1016/S0007-8506(07)60027-4.

[100] S. Alves and J. De Oliveira, "Vegetable based cutting fluid–an environmental alternative to grinding process," *15th CIRP International Conference on Life Cycle Engineering*. pp. 1–5, 2008.

[101] N. R. Dhar, M. W. Islam, S. Islam, and M. A. H. Mithu, "The influence of minimum quantity of lubrication (MQL) on cutting temperature, chip and dimensional accuracy in turning AISI-1040 steel," *J. Mater. Process. Technol.*, vol. 171, no. 1, pp. 93–99, 2006, doi: 10.1016/j.jmatprotec.2005.06.047.

[102] A. E. Diniz and R. Micaroni, "Cutting conditions for finish turning process aiming: The use of dry cutting," *Int. J. Mach. Tools Manuf.*, vol. 42, no. 8, pp. 899–904, 2002, doi: 10.1016/S0890-6955(02)00028-7.

[103] A. Devillez, F. Schneider, S. Dominiak, D. Dudzinski, and D. Larrouquere, "Cutting forces and wear in dry machining of Inconel 718 with coated carbide tools," *Wear*,

vol. 262, no. 7–8, pp. 931–942, 2007, doi: 10.1016/j.wear.2006.10.009.

[104] J. Zhao, Z. Liu, B. Wang, Q. Song, X. Ren, and Y. Wan, "Effects of Al content in TiAlN coatings on tool wear and cutting temperature during dry machining IN718," *Tribol. Int.*, vol. 171, p. 107540, 2022, doi: 10.1016/j.triboint.2022.107540.

[105] A. Chaudhari, M. Z. K. Yusufzai, and M. Vashista, "Grindability study of hard to cut AISI D2 steel upon ultrasonic vibration-assisted dry grinding," *Proc. Inst. Mech. Eng. Part E J. Process Mech. Eng.*, p. 095440892110516, 2021, doi: 10.1177/09544089211051635.

[106] A. Devillez, G. Le Coz, S. Dominiak, and D. Dudzinski, "Dry machining of Inconel 718, workpiece surface integrity," *J. Mater. Process. Technol.*, vol. 211, no. 10, pp. 1590–1598, 2011, doi: 10.1016/j.jmatprotec.2011.04.011.

[107] A. Balasuadhakar, S. T. Kumaran, R. Kurniawan, and F. Ahmed, "a Comprehensive Review on Minimum Quantity Lubrication in Turning Process," *Surf. Rev. Lett.*, vol. 29, no. 8, 2022, doi: 10.1142/S0218625X22300088.

[108] M. N. Morgan, L. Barczak, and A. Batako, "Temperatures in fine grinding with minimum quantity lubrication (MQL)," *Int. J. Adv. Manuf. Technol.*, vol. 60, no. 9–12, pp. 951–958, 2012, doi: 10.1007/s00170-011-3678-7.

[109] N. Boubekri, V. Shaikh, and P. R. Foster, "A technology enabler for green machining: Minimum quantity lubrication (MQL)," *J. Manuf. Technol. Manag.*, vol. 21, no. 5, pp. 556–566, 2010, doi: 10.1108/17410381011046968.

[110] S. K. Patra and S. Swain, "Effects of minimum quantity lubrication (MQL) in grinding: Principle, applications and recent advancements," *Mater. Today Proc.*, vol. 69, pp. 96–106, 2022, doi: 10.1016/j.matpr.2022.08.157.

[111] T. Tawakoli, M. Hadad, M. H. Sadeghi, A. Daneshi, and B. Sadeghi, "Minimum quantity lubrication in grinding: Effects of abrasive and coolant-lubricant types," *J. Clean. Prod.*, vol. 19, no. 17–18, pp. 2088–2099, 2011, doi: 10.1016/j.jclepro.2011.06.020.

[112] M. M. A. Khan, M. A. H. Mithu, and N. R. Dhar, "Effects of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil-based cutting fluid," *J. Mater. Process. Technol.*, vol. 209, no. 15–16, pp. 5573–5583, 2009, doi:

10.1016/j.jmatprotec.2009.05.014.

[113] M. Hadad and B. Sadeghi, "Minimum quantity lubrication-MQL turning of AISI 4140 steel alloy," *J. Clean. Prod.*, vol. 54, pp. 332–343, 2013, doi: 10.1016/j.jclepro.2013.05.011.

[114] J. Sharma and B. S. Sidhu, "Investigation of effects of dry and near dry machining on AISI D2 steel using vegetable oil," *J. Clean. Prod.*, vol. 66, pp. 619–623, 2014, doi: 10.1016/j.jclepro.2013.11.042.

[115] S. Niketh and G. L. Samuel, "Drilling performance of micro textured tools under dry, wet and MQL condition," *J. Manuf. Process.*, vol. 32, pp. 254–268, 2018, doi: 10.1016/j.jmapro.2018.02.012.

[116] A. Pal, S. S. Chatha, and H. S. Sidhu, "Experimental investigation on the performance of MQL drilling of AISI 321 stainless steel using nano-graphene enhanced vegetable-oil-based cutting fluid," *Tribol. Int.*, vol. 151, p. 106508, 2020, doi: 10.1016/j.triboint.2020.106508.

[117] A. Pal, S. S. Chatha, and H. S. Sidhu, "Assessing the lubrication performance of various vegetable oil-based nano-cutting fluids via eco-friendly MQL technique in drilling of AISI 321 stainless steel," *J. Brazilian Soc. Mech. Sci. Eng.*, vol. 44, no. 4, pp. 1–26, 2022, doi: 10.1007/s40430-022-03442-w.

[118] S. B. Kedare, D. R. Borse, and P. T. Shahane, "Effect of Minimum Quantity Lubrication (MQL) on Surface Roughness of Mild Steel of 15HRC on Universal Milling Machine," *Procedia Mater. Sci.*, vol. 6, pp. 150–153, 2014, doi: 10.1016/j.mspro.2014.07.018.

[119] A. Khatri and M. P. Jahan, "Investigating tool wear mechanisms in machining of Ti-6Al-4V in flood coolant, dry and MQL conditions," *Procedia Manuf.*, vol. 26, pp. 434–445, 2018, doi: 10.1016/j.promfg.2018.07.051.

[120] H. Sun *et al.*, "Effect of MQL condition on cutting performance of high-speed machining of GH4099 with ceramic end mills," *Tribol. Int.*, vol. 167, 2021, p. 107401, 2022, doi: 10.1016/j.triboint.2021.107401.

[121] C. Mao, X. Tang, H. Zou, Z. Zhou, and W. Yin, "Experimental investigation of surface quality for minimum quantity oil-water lubrication grinding," *Int. J. Adv.*

Manuf. Technol., vol. 59, no. 1–4, pp. 93–100, 2012, doi: 10.1007/s00170-011-3491-3.

[122] E. A. Rahim, R. Ibrahim, Z. Mohid, M. F. Ahmad, and M. Shahrudin, "Study on Temperature, Force and Specific Energy of AISI 1020 under MQL Grinding Process," *Appl. Mech. Mater.*, vol. 465–466, pp. 1119–1123, 2014, doi: 10.4028/WWW.SCIENTIFIC.NET/AMM.465-466.1119.

[123] H. Adibi, H. Esmaeili, and S. M. Rezaei, "Study on minimum quantity lubrication (MQL) in grinding of carbon fiber-reinforced SiC matrix composites (CMCs)," *Int. J. Adv. Manuf. Technol.*, vol. 95, no. 9–12, pp. 3753–3767, 2018, doi: 10.1007/s00170-017-1464-x.

[124] N. E. Arun kumar, A. Suresh Babu, M. Subramanian, and N. Arunkumar, "Influence of MQL on performance evaluation of EN19 steel under centreless grinding," *Mater. Manuf. Process.*, vol. 37, no. 14, pp. 1618–1629, 2022, doi: 10.1080/10426914.2022.2032142.

[125] I. S. Jawahir *et al.*, "Cryogenic manufacturing processes," *CIRP Ann. - Manuf. Technol.*, vol. 65, no. 2, pp. 713–736, 2016, doi: 10.1016/j.cirp.2016.06.007.

[126] R. Naveen Anthuvan, S. Pratheesh Kumar, R. Arun Prakash, B. Arunkarthik, and A. Akhilesh, "Machinability study in milling of Ti-6Al-4V using cryogenic treated and coated tool," *Mater. Today Proc.*, vol. 46, pp. 8417–8428, 2021, doi: 10.1016/j.matpr.2021.03.451.

[127] F. Pušavec, A. Stoić, and J. Kopač, "Sustainable machining process - Myth or reality," *Strojarstvo*, vol. 52, no. 2, pp. 197–204, 2010.

[128] S. Y. Hong and Z. Zhao, "Thermal aspects, material considerations and cooling strategies in cryogenic machining," *Clean Technol. Environ. Policy*, vol. 1, no. 2, pp. 107–116, 1999, doi: 10.1007/s100980050016.

[129] T. Nguyen, I. Zarudi, and L. C. Zhang, "Grinding-hardening with liquid nitrogen: Mechanisms and technology," *Int. J. Mach. Tools Manuf.*, vol. 47, no. 1, pp. 97–106, 2007, doi: 10.1016/j.ijmachtools.2006.02.010.

[130] A. Shokrani, V. Dhokia, P. Muñoz-Escalona, and S. T. Newman, "State-of-the-art cryogenic machining and processing," *Int. J. Comput. Integr. Manuf.*, vol. 26, no. 7,

pp. 616–648, 2013, doi: 10.1080/0951192X.2012.749531.

[131] A. Aramcharoen, "Influence of Cryogenic Cooling on Tool Wear and Chip Formation in Turning of Titanium Alloy," *Procedia CIRP*, vol. 46, pp. 83–86, 2016, doi: 10.1016/j.procir.2016.03.184.

[132] T. C. Jen *et al.*, "Investigation of heat pipe cooling in drilling applications. Part I: Preliminary numerical analysis and verification," *Int. J. Mach. Tools Manuf.*, vol. 42, no. 5, pp. 643–652, 2002, doi: 10.1016/S0890-6955(01)00155-9.

[133] A. N. Haq and T. Tamizharasan, "Investigation of the effects of cooling in hard turning operations," *Int. J. Adv. Manuf. Technol.*, vol. 30, no. 9–10, pp. 808–816, 2006, doi: 10.1007/s00170-005-0128-4.

[134] Z. Y. Wang and K. P. Rajurkar, "Cryogenic machining of hard-to-cut materials," *Wear*, vol. 239, no. 2, pp. 168–175, 2000.

[135] S. Paul and A. B. Chattopadhyay, "A study of effects of cryo-cooling in grinding," *Int. J. Mach. Tools Manuf.*, vol. 35, no. 1, pp. 109–117, 1995, doi: 10.1016/0890-6955(95)80010-7.

[136] S. Paul and A. B. Chattopadhyay, "Effects of cryogenic cooling by liquid nitrogen jet on forces, temperature and surface residual stresses in grinding steels," *Cryogenics (Guildf).*, vol. 35, no. 8, pp. 515–523, 1995, doi: 10.1016/0011-2275(95)98219-Q.

[137] N. Fredj, H. Sidhom, C. B.-S. and C. Technology, and U. 2006, "Ground surface improvement of the austenitic stainless steel AISI 304 using cryogenic cooling," *Surf. Coatings Technol.*, vol. 200, no. 16–17, pp. 4846–4860, 2005, doi: 10.1016/j.surfcoat.2005.04.050.

[138] C. Li, Y. Ding, B. Lu, G. C.-A. M. Research, and undefined 2009, "Analytical and experimental investigation of the nickel based superalloy using cryogenic cooling grinding," *Trans Tech Publ*, 2009, doi: 10.4028/www.scientific.net/AMR.69-70.354.

[139] S. K. Soni, V. Singh, A. K. Sahoo, and S. Ghosh, "Improvement in grinding of composite ceramic by using cryogenic cooling technique," *Int. J. Manuf. Technol. Manag.*, vol. 25, no. 1–3, pp. 60–77, 2012, doi: 10.1504/IJMTM.2012.047718.

[140] G. Manimaran and M. P. Kumar, “Investigation of cooling environments in grinding en 31 steel,” *Mater. Manuf. Process.*, vol. 28, no. 4, pp. 424–429, 2013, doi: 10.1080/10426914.2013.763957.

[141] D. Setti, N. Kumar Yadav, and S. Ghosh, “Grindability improvement of Ti-6Al-4V using cryogenic cooling,” *J Eng. Manuf.*, vol. 228, no. 9, pp. 1131–1137, 2014, doi: 10.1177/0954405414534660.

[142] L. Zhou, S. Huang, and X. Yu, “Machining characteristics in cryogenic grinding of SiCp/Al composites,” *Acta Metall. Sin. (English Lett.*, vol. 27, no. 5, pp. 869–874, 2014, doi: 10.1007/s40195-014-0126-3.

[143] J. Elanchezhian, M. Pradeep Kumar, and G. Manimaran, “Grinding titanium Ti-6Al-4V alloy with electroplated cubic boron nitride wheel under cryogenic cooling,” *J. Mech. Sci. Technol.*, vol. 29, no. 11, pp. 4885–4890, 2015, doi: 10.1007/s12206-015-1036-7.

[144] E. A. Kumar, K. P. Rao, and A. Johnrajan, “LN2 Grinding of Ti 6Al-4V Using Novel Bondless Diamond Grinding Wheel,” *Appl. Mech. Mater.*, vol. 754–755, pp. 812–816, 2015, doi: 10.4028/WWW.SCIENTIFIC.NET/AMM.754-755.812.

[145] P. K. Singh, S. Kumar, and P. K. Jain, “Effect of cryogenic grinding on surface characteristics of additively manufactured Ti-6Al-4V alloy,” *Surf. Topogr. Metrol. Prop.*, vol. 11, no. 1, 2023, doi: 10.1088/2051-672X/acad16.

[146] A. K. Singh, A. Kumar, V. Sharma, and P. Kala, “Sustainable techniques in grinding: State of the art review,” *J. Clean. Prod.*, vol. 269, p. 121876, 2020, doi: 10.1016/j.jclepro.2020.121876.

[147] M. Liu *et al.*, “Cryogenic minimum quantity lubrication machining: from mechanism to application,” *Front. Mech. Eng.*, vol. 16, no. 4, pp. 649–697, 2021, doi: 10.1007/s11465-021-0654-2.

[148] A. Damir, B. Shi, and M. H. Attia, “Flow characteristics of optimized hybrid cryogenic-minimum quantity lubrication cooling in machining of aerospace materials,” *CIRP Ann.*, vol. 68, no. 1, pp. 77–80, 2019, doi: 10.1016/j.cirp.2019.04.047.

[149] Y. Seid Ahmed and L. W. H. González, “Ti6Al4V grinding using different

lubrication modes for minimizing energy consumption," *Int. J. Adv. Manuf. Technol.*, pp. 2387–2405, 2023, doi: 10.1007/s00170-023-11203-9.

[150] M. Danish, M. K. Gupta, S. Rubaiee, A. Ahmed, and M. E. Korkmaz, "Influence of hybrid Cryo-MQL lubri-cooling strategy on the machining and tribological characteristics of Inconel 718," *Tribol. Int.*, vol. 163, 2021, doi: 10.1016/J.TRIBOINT.2021.107178.

[151] A. He, B. Ye, and Z. Wang, "Experimental effect of cryogenic MQL cutting 304 stainless steel," *Key Eng. Mater.*, vol. 621, pp. 3–8, 2014, doi: 10.4028/www.scientific.net/KEM.621.3.

[152] K. K. Gajrani, "Assessment of cryo-MQL environment for machining of Ti-6Al-4V," *J. Manuf. Process.*, vol. 60, pp. 494–502, 2020, doi: 10.1016/J.JMAPRO.2020.10.038.

[153] N. Lahari, N. Khanna, and K. K. Gajrani, "Energy and economic assessment of machining Ti-6Al-4V in cryo-MQL environment," *Sustain. Mater. Manuf. Technol.*, pp. 16–28, 2023, doi: 10.1201/9781003291961-3.

[154] O. Pereira, A. Rodríguez, I. Ayesta, J. B. García, A. I. Fernández-Abia, and L. N. L. De Lacalle, "A cryo lubri-coolant approach for finish milling of aeronautical hard-to-cut materials," *Int. J. Mechatronics Manuf. Syst.*, vol. 9, no. 4, pp. 370–384, 2016, doi: 10.1504/IJMMS.2016.082872.

[155] Y. Seid Ahmed and A. Ryon, "Tribological performance of a hybrid CryoMQL system on Ti6Al4V milling," *Int. J. Adv. Manuf. Technol.*, vol. 120, no. 11–12, pp. 8185–8199, 2022, doi: 10.1007/s00170-022-09249-2.

[156] Ş. Şirin, Ç. V. Yıldırım, T. Kıvak, and M. Sarıkaya, "Performance of cryogenically treated carbide inserts under sustainable cryo-lubrication assisted milling of Inconel X750 alloy," *Sustain. Mater. Technol.*, vol. 29, 2021, doi: 10.1016/j.susmat.2021.e00314.

[157] J. A. Sanchez *et al.*, "Machining evaluation of a hybrid MQL-CO2 grinding technology," *J. Clean. Prod.*, vol. 18, no. 18, pp. 1840–1849, 2010, doi: 10.1016/j.jclepro.2010.07.002.

[158] A. S. S. Balan, L. Vijayaraghavan, R. Krishnamurthy, P. Kuppan, and R.

Oyyaravelu, “An experimental assessment on the performance of different lubrication techniques in grinding of Inconel 751,” *J. Adv. Res.*, vol. 7, no. 5, pp. 709–718, 2016, doi: 10.1016/j.jare.2016.08.002.

[159] M. Rafiq *et al.*, “Use of vegetable oils as transformer oils-A review,” *Renew. Sustain. Energy Rev.*, vol. 52, pp. 308–324, 2015, doi: 10.1016/j.rser.2015.07.032.

[160] M. A. Maleque, H. H. Masjuki, and S. M. Sapuan, “Vegetable-based biodegradable lubricating oil additives,” *Ind. Lubr. Tribol.*, vol. 55, no. 2–3, pp. 137–143, 2003, doi: 10.1108/00368790310470976.

[161] M. A. Islam and N. R. Dhar, “Effects of Minimum Quantity Lubrication By Vegetable Oil- Based Cutting Fluid on Temperature , Chip Morphology and Surface Finish in Grinding Aisi 1060 Steel,” *Proc. 4th BSME-ASME Int. Conf. Therm. Eng. Dhaka, Bangladesh*, pp. 861–866, 2008.

[162] M. Emami, M. H. Sadeghi, A. A. D. Sarhan, and F. Hasani, “Investigating the Minimum Quantity Lubrication in grinding of Al 2O3 engineering ceramic,” *J. Clean. Prod.*, vol. 66, pp. 632–643, 2014, doi: 10.1016/j.jclepro.2013.11.018.

[163] B. Li, C. Li, Y. Zhang, Y. Wang, D. Jia, and M. Yang, “Grinding temperature and energy ratio coefficient in MQL grinding of high-temperature nickel-base alloy by using different vegetable oils as base oil,” *Chinese J. Aeronaut.*, vol. 29, no. 4, pp. 1084–1095, 2016, doi: 10.1016/j.cja.2015.10.012.

[164] R. F. Damasceno *et al.*, “Performance evaluation of various cooling-lubrication techniques in grinding of hardened AISI 4340 steel with vitrified bonded CBN wheel,” *Int. J. Adv. Manuf. Technol.*, vol. 92, no. 9–12, pp. 3795–3806, 2017, doi: 10.1007/s00170-017-0434-7.

[165] A. Jha and S. Paul, “Surface integrity in grinding of Ti-6Al-4V using monolayer superabrasive wheel,” *Taylor Fr.*, vol. 5, no. 2, pp. 213–225, 2019, doi: 10.1080/2374068X.2018.1564866.

[166] A. S. Awale, M. Vashista, and M. Z. Khan Yusufzai, “Application of eco-friendly lubricants in sustainable grinding of die steel,” *Mater. Manuf. Process.*, vol. 36, no. 6, pp. 702–712, 2021, doi: 10.1080/10426914.2020.1866187.

[167] S. Chakraborty and P. K. Panigrahi, “Stability of nanofluid: A review,” *Appl. Therm.*

Eng., vol. 174, no. March, 2020, doi: 10.1016/j.applthermaleng.2020.115259.

[168] D. K. Devendiran and V. A. Amirtham, "A review on preparation, characterization, properties and applications of nanofluids," *Renew. Sustain. Energy Rev.*, vol. 60, pp. 21–40, 2016, doi: 10.1016/j.rser.2016.01.055.

[169] R. Saidur, K. Y. Leong, and H. A. Mohammed, "A review on applications and challenges of nanofluids," *Renew. Sustain. Energy Rev.*, vol. 15, no. 3, pp. 1646–1668, 2011, doi: 10.1016/j.rser.2010.11.035.

[170] W. Yu, H. Xie, L. Chen, and Y. Li, "Investigation of thermal conductivity and viscosity of ethylene glycol based ZnO nanofluid," *Thermochim. Acta*, vol. 491, no. 1–2, pp. 92–96, 2009, doi: 10.1016/j.tca.2009.03.007.

[171] L. S. Sundar, M. K. Singh, and A. C. M. Sousa, "Thermal conductivity of ethylene glycol and water mixture based Fe3O4 nanofluid," *Int. Commun. Heat Mass Transf.*, vol. 49, pp. 17–24, 2013, doi: 10.1016/j.icheatmasstransfer.2013.08.026.

[172] Y. Li, J. Zhou, S. Tung, E. Schneider, and S. Xi, "A review on development of nanofluid preparation and characterization," *Powder Technol.*, vol. 196, no. 2, pp. 89–101, 2009, doi: 10.1016/j.powtec.2009.07.025.

[173] C. Mao, H. Zou, X. Zhou, Y. Huang, H. Gan, and Z. Zhou, "Analysis of suspension stability for nanofluid applied in minimum quantity lubricant grinding," *Int. J. Adv. Manuf. Technol.*, vol. 71, no. 9–12, pp. 2073–2081, Feb. 2014, doi: 10.1007/S00170-014-5642-9/METRICS.

[174] C. T. Wamkam, M. K. Opoku, H. Hong, and P. Smith, "Effects of pH on heat transfer nanofluids containing ZrO2 and TiO2 nanoparticles," *J. Appl. Phys.*, vol. 109, no. 2, 2011, doi: 10.1063/1.3532003.

[175] R. Choudhary, D. Khurana, A. Kumar, and S. Subudhi, "Stability analysis of Al2O3/water nanofluids," *J. Exp. Nanosci.*, vol. 12, no. 1, pp. 140–151, 2017, doi: 10.1080/17458080.2017.1285445.

[176] E. C. Okonkwo, I. Wole-Osho, I. W. Almanassra, Y. M. Abdullatif, and T. Al-Ansari, "An updated review of nanofluids in various heat transfer devices," *J. Therm. Anal. Calorim.*, vol. 145, no. 6, pp. 2817–2872, 2021, doi: 10.1007/S10973-020-09760-2.

[177] B. Shen, A. J. Shih, and S. C. Tung, “Application of nanofluids in minimum quantity lubrication grinding,” *Tribol. Trans.*, vol. 51, no. 6, pp. 730–737, 2008, doi: 10.1080/10402000802071277.

[178] C. Mao, X. Tang, H. Zou, X. Huang, and Z. Zhou, “Investigation of grinding characteristic using nanofluid minimum quantity lubrication,” *Int. J. Precis. Eng. Manuf.*, vol. 13, no. 10, pp. 1745–1752, 2012, doi: 10.1007/s12541-012-0229-6.

[179] Y. Zhang, C. Li, D. Jia, D. Zhang, and X. Zhang, “Experimental evaluation of MoS2 nanoparticles in jet MQL grinding with different types of vegetable oil as base oil,” *J. Clean. Prod.*, vol. 87, no. C, pp. 930–940, 2015, doi: 10.1016/j.jclepro.2014.10.027.

[180] Y. Wang *et al.*, “Experimental evaluation on tribological performance of the wheel/workpiece interface in minimum quantity lubrication grinding with different concentrations of Al2O3 nanofluids,” *J. Clean. Prod.*, vol. 142, pp. 3571–3583, 2017, doi: 10.1016/j.jclepro.2016.10.110.

[181] R. L. Virdi, S. S. Chatha, and H. Singh, “Experiment evaluation of grinding properties under Al2O3 nanofluids in minimum quantity lubrication,” *Mater. Res. Express*, vol. 6, no. 9, 2019, doi: 10.1088/2053-1591/ab301f.

[182] T. Le Manh, J. A. P. Benitez, and M. Alberteris, “Future trend and applications of Barkhausen noise,” *Barkhausen Noise Non-destructive Test. Mater. Charact. Low Carbon Steels*, pp. 239–253, 2020, doi: 10.1016/B978-0-08-102800-1.00009-5.

[183] O. Ortega-Labra, T. Le Manh, P. Martinez-Ortiz, J. M. Hallen, and J. A. Perez-Benitez, “A novel system for non-destructive evaluation of surface stress in pipelines using rotational continuous magnetic Barkhausen noise,” *Meas. J. Int. Meas. Confed.*, vol. 136, pp. 761–774, 2019, doi: 10.1016/j.measurement.2019.01.018.

[184] S. Santa-aho, A. Sorsa, A. Nurmikolu, and M. Vippola, “Review of railway track applications of Barkhausen noise and other magnetic testing methods,” *Insight Non-Destructive Test. Cond. Monit.*, vol. 56, no. 12, pp. 657–663, 2014, doi: 10.1784/insi.2014.56.12.657.

[185] M. Rößler, M. Putz, C. Hochmuth, and J. Gentzen, “In-process evaluation of the grinding process using a new Barkhausen noise method,” *Procedia CIRP*, vol. 99,

no. July 2020, pp. 202–207, 2021, doi: 10.1016/j.procir.2021.03.028.

[186] J. A. Avila, F. F. Conde, H. C. Pinto, J. Rodriguez, and F. A. F. Grijalba, "Microstructural and Residuals Stress Analysis of Friction Stir Welding of X80 Pipeline Steel Plates Using Magnetic Barkhausen Noise," *J. Nondestruct. Eval.*, vol. 38, no. 4, pp. 1–9, 2019, doi: 10.1007/s10921-019-0625-2.

[187] M. Diegel, R. Mattheis, and E. Halder, "Multiturn counter using movement and storage of 180° magnetic domain walls," *Sens. Lett.*, vol. 5, no. 1, pp. 118–122, 2007, doi: 10.1166/sl.2007.038.

[188] G. Bertotti and I. Mayergoyz, *The Science of Hysteresis: 3-volume set*. 2005.

[189] V. Moorthy, B. A. Shaw, and J. T. Evans, "Evaluation of tempering induced changes in the hardness profile of case-carburised EN36 steel using magnetic Barkhausen noise analysis," *NDT E Int.*, vol. 36, no. 1, pp. 43–49, 2003, doi: 10.1016/S0963-8695(02)00070-1.

[190] V. V. Filinov, P. G. Arakelov, N. T. Kunin, and D. A. Golovchenko, "To the Question about the Thickness of Informative Layer in Magnetic-Noise Testing," *Russ. J. Nondestruct. Test.*, vol. 55, no. 1, pp. 31–38, 2019, doi: 10.1134/S1061830919010054.

[191] S. S. Singh, A. S. Awale, A. Chaudhari, and B. Nahak, "Monitoring the microstructural changes of heat treated medium carbon steel by Barkhausen noise and hysteresis loop techniques," *Mater. Today Proc.*, vol. 26, pp. 1198–1202, 2019, doi: 10.1016/j.matpr.2020.02.241.

[192] H. Gupta, M. Zhang, and A. P. Parakka, "Barkhausen effect in ground steels," *Acta Mater.*, vol. 45, no. 5, pp. 1917–1921, 1997, doi: 10.1016/S1359-6454(96)00315-1.

[193] D.C. Jiles, "Dynamics of domain magnetization and the Barkhausen effect," *Czechoslov. J. Phys.*, vol. 50, no. 8, pp. 893–924, 2000.

[194] V. Moorthy, B. A. Shaw, P. Mountford, and P. Hopkins, "Magnetic Barkhausen emission technique for evaluation of residual stress alteration by grinding in case-carburised En36 steel," *Acta Mater.*, vol. 53, no. 19, pp. 4997–5006, 2005, doi: 10.1016/j.actamat.2005.06.029.

[195] V. Moorthy and B. A. Shaw, "Magnetic Barkhausen emission measurements for

evaluation of material properties in gears," *Nondestruct. Test. Eval.*, vol. 23, no. 4, pp. 317–348, 2008, doi: 10.1080/10589750802275980.

[196] M. Vashista, S. Ghosh, and S. Paul, "Application of micromagnetic technique in surface grinding for assessment of surface integrity," *Mater. Manuf. Process.*, vol. 24, no. 4, pp. 488–496, 2009, doi: 10.1080/10426910802714456.

[197] S. Santa-Aho *et al.*, "Development of Barkhausen noise calibration blocks for reliable grinding burn detection," *J. Mater. Process. Technol.*, vol. 212, no. 2, pp. 408–416, 2012, doi: 10.1016/j.jmatprotec.2011.10.003.

[198] M. Čilliková, B. Mičieta, M. Neslušan, and D. Blažek, "Nondestructive Magnetic Monitoring of Grinding Damage," *Procedia Mater. Sci.*, vol. 12, pp. 54–59, 2016, doi: 10.1016/j.mspro.2016.03.010.

[199] A. Lasaosa, K. Gurruchaga, F. Arizti, and A. Martinez-De-Guerenu, "Induction Hardened Layer Characterization and Grinding Burn Detection by Magnetic Barkhausen Noise Analysis," *J. Nondestruct. Eval.*, vol. 36, no. 2, pp. 1–7, 2017, doi: 10.1007/s10921-016-0388-y.

[200] A. Srivastava, A. Awale, M. Vashista, and M. Z. K. Yusufzai, "Monitoring of thermal damages upon grinding of hardened steel using Barkhausen noise analysis," *J. Mech. Sci. Technol.*, vol. 34, no. 5, pp. 2145–2151, 2020, doi: 10.1007/s12206-020-0435-6.

[201] A. K. Shrivastava, A. Sharma, A. S. Awale, M. Z. K. Yusufzai, and M. Vashista, "Assessment of Grinding Burn of AISI D2 Tool Steel Using Barkhausen Noise Technique," *J. Inst. Eng. Ser. C*, vol. 102, no. 4, pp. 885–896, 2021, doi: 10.1007/S40032-021-00721-8.

[202] J. Heinzel, R. Jedamski, J. Epp, and B. Karpuschewski, "In-process measurement of Barkhausen noise and resulting productivity increase potential in grinding of case hardened steel," *CIRP J. Manuf. Sci. Technol.*, vol. 32, pp. 37–45, 2021, doi: 10.1016/j.cirpj.2020.11.011.

[203] R. Choudhary, H. Kumar, and S. Singh, "Machining performance and surface integrity of AISI D2 die steel machined using electrical discharge surface grinding process," *J. Mater. Eng. Perform.*, vol. 22, no. 12, pp. 3665–3673, 2013, doi:

10.1007/s11665-013-0679-8.

[204] M. A. S. Bin Abdul Rahim, M. Bin Minhat, N. I. S. B. Hussein, and M. S. Bin Salleh, "A comprehensive review on cold work of AISI D2 tool steel," *Metall. Res. Technol.*, vol. 115, no. 1, 2018, doi: 10.1051/metal/2017048.

[205] Y. H. Guu, "AFM surface imaging of AISI D2 tool steel machined by the EDM process," *Appl. Surf. Sci.*, vol. 242, no. 3–4, pp. 245–250, 2005, doi: 10.1016/j.apsusc.2004.08.028.

[206] A. Chaudhari, A. Sharma, A. S. Awale, M. Z. K. Yusufzai, and M. Vashista, "Modeling and Simulation Study of Dry Ultrasonic Vibration-Assisted Grinding of Tool Steel With Single Alumina Abrasive Grit," *J. Manuf. Sci. Eng.*, vol. 144, no. 11, pp. 1–11, 2022, doi: 10.1115/1.4054602.

[207] J. Zhang *et al.*, "Experimental assessment of an environmentally friendly grinding process using nanofluid minimum quantity lubrication with cryogenic air," *J. Clean. Prod.*, vol. 193, pp. 236–248, 2018, doi: 10.1016/j.jclepro.2018.05.009.

[208] D. Zhang, C. Li, D. Jia, Y. Zhang, and X. Zhang, "Specific grinding energy and surface roughness of nanoparticle jet minimum quantity lubrication in grinding," *Chinese J. Aeronaut.*, vol. 28, no. 2, pp. 570–581, 2015, doi: 10.1016/j.cja.2014.12.035.

[209] P. H. Lee, J. S. Nam, C. Li, and S. W. Lee, "An experimental study on micro-grinding process with nanofluid minimum quantity lubrication (MQL)," *Int. J. Precis. Eng. Manuf.*, vol. 13, no. 3, pp. 331–338, 2012, doi: 10.1007/s12541-012-0042-2.

[210] C. H. Li, Y. C. Ding, B. H. Lu, and G. Q. Cai, "Analytical and experimental investigation of the nickel based superalloy using cryogenic cooling grinding," *Adv. Mater. Res.*, vol. 69–70, pp. 354–358, 2009, doi: 10.4028/www.scientific.net/AMR.69-70.354.

[211] G. Manimaran and M. Pradeep Kumar, "Effect of cryogenic cooling and sol-gel alumina wheel on grinding performance of AISI 316 stainless steel," *Arch. Civ. Mech. Eng.*, vol. 13, no. 3, pp. 304–312, 2013, doi: 10.1016/j.acme.2013.03.002.

[212] A. B. Chattopadhyay, A. Bose, and A. K. Chattopdhyay, "Improvements in grinding

steels by cryogenic cooling," *Precis. Eng.*, vol. 7, no. 2, pp. 93–98, 1985, doi: 10.1016/0141-6359(85)90098-4.

[213] S. Paul, P. P. Bandyopadhyay, and A. B. Chattopadhyay, "Effects of cryo-cooling in grinding steels," *J. Mater. Process. Tech.*, vol. 37, no. 1–4, pp. 791–800, 1993, doi: 10.1016/0924-0136(93)90137-U.

[214] S. Y. Hong, "Economical and ecological cryogenic machining," *J. Manuf. Sci. Eng. Trans. ASME*, vol. 123, no. 2, pp. 331–338, 2001, doi: 10.1115/1.1315297.

[215] I. D. Marinescu, W. B. Rowe, B. Dimitrov, and I. Inasaki, *Tribology of abrasive machining processes*. 2004.

[216] A. S. Awale, A. Srivastava, M. Vashista, and M. Z. Khan Yusufzai, "Influence of minimum quantity lubrication on surface integrity of ground hardened H13 hot die steel," *Int. J. Adv. Manuf. Technol.*, vol. 100, no. 1–4, pp. 983–997, 2019, doi: 10.1007/s00170-018-2777-0.

[217] A. Srivastava, A. Awale, M. Vashista, M. Zaheer, and K. Yusufzai, "Monitoring of thermal damages upon grinding of hardened steel using Barkhausen noise analysis," *Springer*, vol. 34, no. 5, p. 2020, May 2020, doi: 10.1007/s12206-020-0435-6.

[218] B. Griffiths, *Manufacturing Surface Technology. Surface Integrity & Functional Performance*. 2001.

[219] F. Kara, U. Köklü, and U. Kabasakaloğlu, "Taguchi optimization of surface roughness in grinding of cryogenically treated AISI 5140 steel," *Mater. Test.*, vol. 62, no. 10, pp. 1041–1047, 2020, doi: 10.1515/mt-2020-621013.

[220] Whitehouse DJ, *Handbook of surface metrology*. CRC Press, 1994. doi: 10.1016/0042-207x(95)80060-3.

[221] K. Deepak Lawrence, R. Shanmugamani, and B. Ramamoorthy, "Evaluation of image based Abbott-Firestone curve parameters using machine vision for the characterization of cylinder liner surface topography," *Meas. J. Int. Meas. Confed.*, vol. 55, pp. 318–334, 2014, doi: 10.1016/j.measurement.2014.05.005.

[222] B. Rajmohan and V. Radhakrishnan, "A study on the thermal aspects of chips in grinding," *Int. J. Mach. Tools Manuf.*, vol. 32, no. 4, pp. 563–569, 1992, doi: 10.1016/0890-6955(92)90045-I.

[223] S. E. Dutra Xavier, S. Delijaicov, A. De Farias, M. S. Filho, and G. F. Batalha, “Investigation on the surface integrity and tool wear in cryogenic machining,” *AIP Conf. Proc.*, vol. 1315, no. February 2015, pp. 1199–1204, 2010, doi: 10.1063/1.3552345.

[224] F. Klocke, L. Settineri, D. Lung, P. Claudio Priarone, and M. Arft, “High performance cutting of gamma titanium aluminides: Influence of lubricoolant strategy on tool wear and surface integrity,” *Wear*, vol. 302, no. 1–2, pp. 1136–1144, 2013, doi: 10.1016/j.wear.2012.12.035.

[225] M. J. Jackson and J. P. Davim, *Machining with abrasives*. Springer, 2011. doi: 10.1007/978-1-4419-7302-3.

[226] G. Manimaran, M. Pradeep kumar, and R. Venkatasamy, “Surface modifications in grinding AISI D3 steel using cryogenic cooling,” *J. Brazilian Soc. Mech. Sci. Eng.*, vol. 37, no. 4, pp. 1357–1363, 2015, doi: 10.1007/s40430-014-0241-0.

[227] P. Pawlus, R. Reizer, and M. Wieczorowski, “Functional importance of surface texture parameters,” *Materials (Basel).*, vol. 14, no. 18, 2021, doi: 10.3390/ma14185326.

[228] R. Deltombe, K. J. Kubiak, and M. Bigerelle, “How to select the most relevant 3D roughness parameters of a surface,” *Scanning*, vol. 36, no. 1, pp. 150–160, 2014, doi: 10.1002/sca.21113.

[229] H. Chen, J. Tang, W. Shao, B. Z.-T. I. J. of Advanced, and undefined 2018, “An investigation on surface functional parameters in ultrasonic-assisted grinding of soft steel,” *Springer*, vol. 97, no. 5–8, pp. 2697–2702, 2018, doi: 10.1007/s00170-018-2164-x.

[230] J. P. Davim, *Mechanical and Industrial Engineering*. in Materials Forming, Machining and Tribology. Springer, 2022. doi: 10.1007/978-3-030-90487-6.

[231] A. Chaudhari, A. Sharma, A. S. Awale, M. Z. K. Yusufzai, and M. Vashista, “Effect of ultrasonic vibration assisted dry grinding on hysteresis loop characteristics of AISI D2 tool steel,” *Sadhana - Acad. Proc. Eng. Sci.*, vol. 46, no. 4, pp. 1–12, 2021, doi: 10.1007/S12046-021-01771-5.

[232] K. K. Gajrani, “Assessment of cryo-MQL environment for machining of Ti-6Al-

4V," *J. Manuf. Process.*, vol. 60, pp. 494–502, 2020, doi: 10.1016/j.jmapro.2020.10.038.

[233] F. Li, M. V. Hanson, and R. C. Larock, "Soybean oil-divinylbenzene thermosetting polymers: Synthesis, structure, properties and their relationships," *Polymer (Guildf).*, vol. 42, no. 4, pp. 1567–1579, 2001, doi: 10.1016/S0032-3861(00)00546-2.

[234] S. Guo *et al.*, "Analysis of volume ratio of castor/soybean oil mixture on minimum quantity lubrication grinding performance and microstructure evaluation by fractal dimension," *Ind. Crops Prod.*, vol. 111, pp. 494–505, 2018, doi: 10.1016/j.indcrop.2017.11.024.

[235] C. S. M. F. Costa, A. C. Fonseca, J. Moniz, M. Godinho, A. C. Serra, and J. F. J. Coelho, "Soybean and coconut oil based unsaturated polyester resins: Thermomechanical characterization," *Ind. Crops Prod.*, vol. 85, pp. 403–411, 2016, doi: 10.1016/j.indcrop.2016.01.030.

[236] A. S. Awale, A. Chaudhari, A. Kumar, M. Z. Khan Yusufzai, and M. Vashista, "Synergistic impact of eco-friendly nano-lubricants on the grindability of AISI H13 tool steel: A study towards clean manufacturing," *J. Clean. Prod.*, vol. 364, 2022, doi: 10.1016/j.jclepro.2022.132686.

[237] S. Khandekar, M. R. Sankar, V. Agnihotri, and J. Ramkumar, "Nano-cutting fluid for enhancement of metal cutting performance," *Mater. Manuf. Process.*, vol. 27, no. 9, pp. 963–967, 2012, doi: 10.1080/10426914.2011.610078.

[238] C. Mao, Y. Huang, X. Zhou, H. Gan, J. Zhang, and Z. Zhou, "The tribological properties of nanofluid used in minimum quantity lubrication grinding," *Int. J. Adv. Manuf. Technol.*, vol. 71, no. 5–8, pp. 1221–1228, 2014, doi: 10.1007/s00170-013-5576-7.

[239] A. Gupta, A. Pandey, H. Kesarwani, S. Sharma, and A. Saxena, "Automated determination of interfacial tension and contact angle using computer vision for oil field applications," *J. Pet. Explor. Prod. Technol.*, vol. 12, no. 5, pp. 1453–1461, 2022, doi: 10.1007/S13202-021-01398-6.

[240] A. Sharma, A. Tiwari, R. Singh, A. D.-M. T. Proceedings, and U. 2016,

“Tribological investigation of TiO2 nanoparticle based cutting fluid in machining under minimum quantity lubrication (MQL),” *Elsevier*, vol. 3, pp. 2155–2162, 2016.

[241] C. T. Wamkam, M. K. Opoku, H. Hong, and P. Smith, “Effects of pH on heat transfer nanofluids containing ZrO2 and TiO2 nanoparticles,” *J. Appl. Phys.*, vol. 109, no. 2, pp. 1–6, 2011, doi: 10.1063/1.3532003.

[242] H. Zhu, C. Zhang, Y. Tang, J. Wang, B. Ren, and Y. Yin, “Preparation and thermal conductivity of suspensions of graphite nanoparticles,” *Carbon N. Y.*, vol. 45, no. 1, pp. 226–228, 2007, doi: 10.1016/j.carbon.2006.07.005.

[243] A. Roushan, U. S. Rao, K. Patra, and P. Sahoo, “Performance evaluation of tool coatings and nanofluid MQL on the micro-machinability of Ti-6Al-4V,” *J. Manuf. Process.*, vol. 73, pp. 595–610, 2022, doi: 10.1016/J.JMAPRO.2021.11.030.

[244] M. A. Makhesana, K. M. Patel, and N. Khanna, “Analysis of vegetable oil-based nano-lubricant technique for improving machinability of Inconel 690,” *J. Manuf. Process.*, vol. 77, pp. 708–721, 2022, doi: 10.1016/j.jmapro.2022.03.060.

[245] B. Shen, A. J. Shih, and S. C. Tung, “Application of nanofluids in minimum quantity lubrication grinding,” *Tribol. Trans.*, vol. 51, no. 6, pp. 730–737, 2008, doi: 10.1080/10402000802071277.

[246] F. Gunan, T. Kivak, C. V. Yildirim, and M. Sarikaya, “Performance evaluation of MQL with AL2O3 mixed nanofluids prepared at different concentrations in milling of Hastelloy C276 alloy,” *J. Mater. Res. Technol.*, vol. 9, no. 5, pp. 10386–10400, 2020, doi: 10.1016/j.jmrt.2020.07.018.

[247] M. Winter, S. Thiede, and C. Herrmann, “Influence of the cutting fluid on process energy demand and surface roughness in grinding—a technological, environmental and economic examination,” *Int. J. Adv. Manuf. Technol.*, vol. 77, no. 9–12, pp. 2005–2017, 2015, doi: 10.1007/s00170-014-6557-1.

[248] U. Sridharan and S. Malkin, “Effect of minimum quantity lubrication (MQL) with nanofluids on grinding behavior and thermal distortion,” *Trans. North Am. Manuf. Res. Inst. SME*, vol. 37, pp. 629–636, 2009.

[249] D. Zhang, C. Li, D. Jia, Y. Zhang, and X. Zhang, “Specific grinding energy and surface roughness of nanoparticle jet minimum quantity lubrication in grinding,”

Chinese J. Aeronaut., vol. 28, no. 2, pp. 570–581, 2015, doi: 10.1016/j.cja.2014.12.035.

[250] D. Setti, S. Ghosh, and P. V. Rao, "Application of Nano Cutting Fluid under Minimum Quantity Lubrication (MQL) Technique to Improve Grinding of Ti – 6Al – 4V Alloy," *Int. J. Mech. Mechatronics Eng.*, vol. 6, no. 10, pp. 2107–2111, 2012.

[251] X. Cui *et al.*, "Grindability of titanium alloy using cryogenic nanolubricant minimum quantity lubrication," *J. Manuf. Process.*, vol. 80, pp. 273–286, 2022, doi: 10.1016/j.jmapro.2022.06.003.

[252] S. S. Rawat, A. P. Harsha, and O. P. Khatri, "Tribological Investigations of Two-Dimensional Nanostructured Lamellar Materials as Additives to Castor-Oil-Derived Lithium Grease," *J. Tribol.*, vol. 144, no. 9, 2022, doi: 10.1115/1.4054102.

[253] A. Chaudhari, A. Sharma, M. Z. K. Yusufzai, and M. Vashista, "Experimental Analyses into Dry Ultrasonic Vibration-Assisted Grinding of Difficult-to-Machine Tool Steel with Alumina Wheel," *J. Mater. Eng. Perform.*, 2022, doi: 10.1007/s11665-022-07444-6.

[254] H. Yue, J. Deng, and J. Schneider, "Development of a new topographical parameter set for characterizing textured rough surfaces," *Surf. Topogr. Metrol. Prop.*, vol. 9, no. 3, 2021, doi: 10.1088/2051-672X/ac1723.

[255] D. Setti, M. K. Sinha, S. Ghosh, and P. Venkateswara Rao, "Performance evaluation of Ti-6Al-4V grinding using chip formation and coefficient of friction under the influence of nanofluids," *Int. J. Mach. Tools Manuf.*, vol. 88, pp. 237–248, 2015, doi: 10.1016/j.ijmachtools.2014.10.005.

[256] M. Mia, M. K. Gupta, G. Singh, G. Królczyk, and D. Y. Pimenov, "An approach to cleaner production for machining hardened steel using different cooling-lubrication conditions," *J. Clean. Prod.*, vol. 187, pp. 1069–1081, 2018, doi: 10.1016/J.JCLEPRO.2018.03.279.

[257] S. Roy, R. Kumar, A. Panda, A. K. Sahoo, M. Rafighi, and D. Das, "A Comparative Performance Investigation of Single- and Double-Nozzle Pulse Mode Minimum Quantity Lubrication Systems in Turning Super-Duplex Steel Using a Weighted Pugh Matrix Sustainable Approach," *Sustainability*, vol. 15, no. 20, p. 15160, 2023,

doi: 10.3390/su152015160.

[258] S. Padhan, L. Dash, S. K. Behera, and S. R. Das, "Modeling and Optimization of Power Consumption for Economic Analysis, Energy-Saving Carbon Footprint Analysis, and Sustainability Assessment in Finish Hard Turning Under Graphene Nanoparticle–Assisted Minimum Quantity Lubrication," *Process Integr. Optim. Sustain.*, vol. 4, no. 4, pp. 445–463, 2020, doi: 10.1007/s41660-020-00132-9.

[259] H. Gürbüz and Y. E. Gönülaçar, "Experimental and statistical investigation of the effects of MQL, dry and wet machining on machinability and sustainability in turning of AISI 4140 steel," *Proc. Inst. Mech. Eng. Part E J. Process Mech. Eng.*, vol. 236, no. 5, pp. 1808–1823, 2022, doi: 10.1177/09544089221076243.

[260] B. Li, C. Li, Y. Zhang, Y. Wang, D. Jia, and M. Yang, "Grinding temperature and energy ratio coefficient in MQL grinding of high-temperature nickel-base alloy by using different vegetable oils as base oil," *Chinese J. Aeronaut.*, vol. 29, no. 4, pp. 1084–1095, 2016, doi: 10.1016/j.cja.2015.10.012.

[261] M. A. Meyers and K. K. Chawla, *Mechanical behavior of materials*. Cambridge university press, 2008.

[262] S. Kumar Gupta, A. R. Raja, M. Vashista, M. Zaheer, and K. Yusufzai, "Hysteresis loop analysis of gas metal arc welded ferritic stainless steel plate," *Mater. Res. Express*, 2019, doi: 10.1088/2053-1591/ab2f6e.

[263] D. C. Jiles, "Dynamics of domain magnetization and the Barkhausen effect," *Czechoslov. J. Phys.*, vol. 50, no. 8, pp. 893–924, 2000, doi: 10.1023/A:1022846128461.

[264] S. Santa-Aho *et al.*, "Development of Barkhausen noise calibration blocks for reliable grinding burn detection," *J. Mater. Process. Technol.*, vol. 212, no. 2, pp. 408–416, 2012, doi: 10.1016/j.jmatprotec.2011.10.003.

[265] E. Arzt, "Size effects in materials due to microstructural and dimensional constraints: a comparative review," *Acta Mater.*, vol. 46, no. 16, pp. 5611–5626, 1998, doi: 10.1016/S1359-6454(98)00231-6.

[266] K. Gurruchaga, A. Martínez-De-Guerenu, M. Soto, and F. Arizti, "Magnetic barkhausen noise for characterization of recovery and recrystallization," *IEEE*

Trans. Magn., vol. 46, no. 2, pp. 513–516, 2010, doi: 10.1109/TMAG.2009.2029069.

[267] Y. Wei, Y. Zhang, Y. Chen, and S. Du, "Impact of material permeability on friction and wear Properties under the interference of DC steady magnetic field," *Tribol. Int.*, vol. 57, pp. 162–169, 2013, doi: 10.1016/j.triboint.2012.07.019.

[268] L. Piotrowski, M. Chmielewski, and Z. L. Kowalewski, "The Dominant Influence of Plastic Deformation Induced Residual Stress on the Barkhausen Effect Signal in Martensitic Steels," *J. Nondestruct. Eval.*, vol. 36, no. 1, pp. 1–8, 2017, doi: 10.1007/s10921-016-0389-x.

APPENDIX-I

Table 1: Variations in tangential grinding force with downfeed.

Tangential grinding force, F_t (N)									
a_p (μm)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
10	19	20.5	22	15	16.4	17.5	9.5	11.2	12
20	33	38.3	41	25.5	26.5	27.5	12.5	14.4	15.5
30	50	52.7	55.5	33	35.8	38.5	18.5	20.5	22
40	67	70	73.5	41.5	45.2	50.5	23	25.7	27

Table 2: Variations in normal grinding force with downfeed.

Normal grinding force, F_n (N)									
a_p (μm)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
10	29.5	34.5	38	25	29.3	35	21	23.5	26
20	57	65.7	72.5	47	49.5	54.5	27.5	31	34
30	86	91	93	63	67	74	42	45.2	50
40	120	126	130.5	83.5	88	96.5	54	57	61.5

Table 3: Variations in specific grinding energy with downfeed.

Specific grinding energy, U_g (J/mm^3)									
a_p (μm)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
10	24.902	27.334	29.303	19.701	21.672	23.021	12.957	14.592	15.91
20	23.744	25.381	27.028	17.011	17.655	18.323	8.145	9.295	10.27
30	21.987	23.078	24.387	14.414	15.504	16.824	8.123	8.993	9.756
40	22.113	22.913	24.234	13.605	15.034	16.635	7.437	8.257	8.924

Table 4: Variations in grinding temperature with downfeed.

Grinding temperature, T_g (ºC)									
a_p (μm)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
10	456	470	488	289	301	315	138	149	163
20	530	550	566	326	340	353	156	169	179
30	586	608	633	398	415	435	178	191	208
40	607	635	650	430	451	474	206	221	237

Table 5: Variations in force ratio with downfeed.

Force ratio, F_t/F_n									
a_p (μm)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
10	0.5699	0.5999	0.6249	0.5199	0.5599	0.6099	0.4296	0.4696	0.5056
20	0.5577	0.5877	0.6177	0.5299	0.5399	0.5549	0.4367	0.4567	0.4967
30	0.5393	0.5793	0.5993	0.52	0.529	0.545	0.43	0.4525	0.4725
40	0.503	0.553	0.578	0.4935	0.5185	0.5385	0.4189	0.4389	0.4739

Table 6: Variations in surface roughness (R_a) with downfeed.

Surface roughness, R_a (µm)									
a_p (µm)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
10	0.585	0.61	0.64	0.4267	0.4537	0.4877	0.266	0.284	0.299
20	0.6581	0.6761	0.6961	0.4914	0.5194	0.5484	0.3141	0.3241	0.3361
30	0.687	0.732	0.792	0.5462	0.5652	0.5852	0.3685	0.3975	0.4225
40	0.7787	0.8237	0.8587	0.5709	0.6349	0.6899	0.4046	0.4396	0.4696

Table 7: Variations in surface roughness (R_q) with downfeed.

Surface roughness, R_q (µm)									
a_p (µm)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
10	0.7254	0.7554	0.7904	0.53	0.565	0.605	0.3401	0.3651	0.3851
20	0.8274	0.8504	0.8754	0.6004	0.6324	0.6674	0.395	0.415	0.435
30	0.8405	0.8905	0.9555	0.67	0.695	0.72	0.4599	0.4949	0.5249
40	0.9658	1.0158	1.0558	0.7282	0.7982	0.8582	0.4865	0.5265	0.5615

Table 8: Variations in surface roughness (R_z) with downfeed.

Surface roughness, R_z (µm)									
a_p (µm)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
10	3.8548	4.0248	4.2248	2.8962	3.0762	3.2962	1.9499	2.0799	2.1799
20	4.2422	4.3622	4.4922	3.0622	3.2522	3.4272	2.4425	2.5325	2.6225
30	4.3007	4.5907	4.8907	3.3047	3.4247	3.5447	2.492	2.692	2.862
40	4.7033	4.8533	5.1033	3.9877	4.4377	4.6577	2.6745	2.8945	3.0945

Table 9: Variations in tangential grinding force with LN_2 delivery pressure at various downfeed.

Tangential grinding force, F_t (N)												
P_{LN_2} (bar)	Downfeed											
	10 µm			20 µm			30 µm			40 µm		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
2	10	11.5	12.5	12.5	14.2	15.5	18.5	20.5	22.5	22.5	25.1	27.5
3	9.5	11.2	12.5	12	14	15	17	19.5	21.5	22.5	24.8	26.5
4	8.5	10.3	12	11.5	13	14.5	16.5	18.9	20.5	21	23.1	25.5

Table 10: Variations in the normal grinding force with LN_2 delivery pressure at various downfeed.

Normal grinding force, F_n (N)												
P_{LN_2} (bar)	Downfeed											
	10 µm			20 µm			30 µm			40 µm		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
2	21	23.7	25.5	27.5	31	34.5	41.5	45.5	50	54.5	57.2	61.5
3	20.5	22.5	24.5	26	29.5	32	41	45	48.5	51.5	55.7	58.5
4	21	22.2	23.5	27	29.1	31	39	42.6	45.5	50.5	53.8	56.5

Table 11: Variations in specific grinding energy with LN_2 delivery pressure at various downfeed.

Specific grinding energy, U_g (J/mm^3)												
P_{LN_2} (bar)	Downfeed											
	10 µm			20 µm			30 µm			40 µm		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
2	12.945	14.585	15.895	8.14	9.29	10.271	8.118	8.988	9.748	7.429	8.249	8.899
3	13.296	14.296	15.396	8.415	9.165	10.165	7.291	8.541	9.041	7.637	8.137	9.137
4	12.166	13.416	14.616	7.548	8.548	9.298	7.769	8.269	8.769	6.839	7.588	8.588

Table 12: Variations in surface roughness with LN_2 delivery pressure at various downfeed.

Surface roughness, R_a (µm)												
P_{LN_2} (bar)	Downfeed											
	10 µm			20 µm			30 µm			40 µm		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
2	0.27	0.284	0.296	0.3141	0.3241	0.3361	0.3875	0.3975	0.4125	0.4146	0.4396	0.4621
3	0.2536	0.2686	0.2846	0.2989	0.3039	0.3089	0.3594	0.3794	0.3944	0.406	0.4185	0.4335
4	0.2454	0.2594	0.2734	0.2866	0.2991	0.3141	0.3593	0.3693	0.3833	0.403	0.408	0.418

Table 13: Variations in tangential grinding force with table feed rate.

Tangential grinding force, F_t (N)									
V_w (m/min)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
6	52	55.5	58.5	31	34.5	39	19.5	21.2	22.5
9	67	69.8	73.5	41.5	45.6	50.5	22.5	25.1	27
12	75	78.2	81.5	55	59.5	63.5	33.5	35.3	38.5

Table 14: Variations in normal grinding force with table feed rate.

Normal grinding force, F_n (N)									
V_w (m/min)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
6	90.5	94.9	98.5	73	76.7	81	49.5	52.6	55
9	120.5	126.2	130.5	84	88	96.5	54.5	57	61.5
12	141.5	145.6	150	105	111.9	120	72.5	75.9	80

Table 15: Variations in surface roughness (R_a) with table feed rate.

Surface roughness, R_a (µm)									
V_w (m/min)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
6	0.5845	0.6095	0.6395	0.4461	0.4761	0.5111	0.2723	0.2963	0.3143
9	0.7787	0.8237	0.8587	0.5509	0.6149	0.6699	0.4046	0.4396	0.4696
12	0.9763	1.0213	1.0713	0.7404	0.7904	0.8454	0.5773	0.6023	0.6373

Table 16: Variations in surface roughness (R_q) with table feed rate.

Surface roughness, R_q (µm)									
V_w (m/min)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
6	0.7166	0.7516	0.7916	0.5536	0.5986	0.6386	0.357	0.382	0.409
9	0.9708	1.0158	1.0558	0.7282	0.7982	0.8382	0.4815	0.5265	0.5665
12	1.1995	1.2595	1.3145	0.9487	0.9937	1.0637	0.6966	0.7466	0.7916

Table 17: Variations in surface roughness (S_a) with table feed rate.

Surface roughness, S_a (nm)									
V_w (m/min)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
6	395	410	429	301	315	326	217	225	234.5
9	497.23	517.23	540.23	386.17	401.17	418.17	271.12	283.12	297.12
12	623	645	670	510	535	558	371	387	405

Table 18: Variations in surface roughness (S_q) with table feed rate.

Surface roughness, S_q (nm)									
V_w (m/min)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
6	461	480	500.5	344	359	373	231	243	256
9	664.47	690.47	720.47	442.07	464.07	485.07	331.05	344.05	359.05
12	826.6	855.6	888.6	607	629	654	448.5	469	492

Table 19: Variations in surface bearing index (*Sbi*) with table feed rate.

Surface bearing index, *Sbi* (µm)									
V_w (m/min)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
6	0.9430	0.9680	0.9880	1.085	1.11	1.14	1.1733	1.2133	1.2483
9	1.1944	1.2294	1.2694	1.387	1.422	1.467	1.5094	1.5594	1.6044
12	1.2411	1.2961	1.3411	1.506	1.551	1.601	1.7095	1.7595	1.8145

Table 20: Variations in core fluid retention index (*Sci*) with table feed rate.

Core fluid retention index, *Sci* (µm)									
V_w (m/min)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
6	1.3817	1.4217	1.4517	1.6132	1.6382	1.6832	1.8557	1.9007	1.9357
9	1.2040	1.2540	1.2940	1.4488	1.4838	1.5338	1.6376	1.6926	1.7376
12	1.0921	1.1521	1.1971	1.3561	1.4011	1.4461	1.5610	1.6110	1.6660

Table 21: Variations in grinding temperature with table feed rate.

Grinding temperature, T_g (ºC)									
V_w (m/min)	Dry			Wet			Cryogenic		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
6	592	605	619	420	431	443	184	192	198
9	617	633	645	439	451	465	211	221	229
12	632	645	650	453	466	482	218	230	239

Table 22: Microhardness variation along the depth beneath the ground surface at table feed rate of 6 m/min.

Microhardness (HV)									
Depth from ground surface (µm)	**Dry**			**Wet**			**Cryogenic**		
	Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
0	731	736	739	715	720	723	708	711	713.5
30	729.5	733	737	710	713	718	704.5	708	710.5
80	718	721	726	703	705	708.5	694	698	701
130	709	713	716	683.5	686	690	675	678	681.5
180	681	685	688.5	670	675	679	665	669	672.5
230	668.1	671	674.5	662.5	665	668.5	660	663	665.5
280	659	663	666.5	658.5	661	663	655.5	659	662
330	659.5	661	663.5	657	660	662.5	660	662	665
380	659.5	662	665	660.5	663	665	656.5	659	662.5
430	657.5	660	663	655	658	660.5	656.5	661	663.5

Table 23: Microhardness variation along the depth beneath the ground surface at table feed rate of 9 m/min.

Microhardness (HV)									
Depth from ground surface (µm)	**Dry**			**Wet**			**Cryogenic**		
	Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
0	739.5	745	748.5	720.5	726	729.5	712	716	719.5
30	738	742	746.5	719.5	723	728.5	706.5	711	714
80	730.5	734	739.5	704	707	711	696.5	701	704.5
130	714.5	719	722	691.5	695	699.5	680.5	684	688
180	691.5	695	699	671.5	677	681.5	667.5	672	676
230	674.5	678	682	664.5	668	672.5	662.5	666	669
280	660.5	665	669	662	666	669.5	657	661	664.5
330	656.5	659	662	654.5	658	661	657.5	662	667
380	659.5	663	666.5	659.5	664	668	655.5	659	663
430	657	661	664.5	657.5	661	664	655.5	660	663.5

Table 24: Microhardness variation along the depth beneath the ground surface at table feed rate of 12 m/min.

Microhardness (HV)									
Depth from ground surface (µm)	**Dry**			**Wet**			**Cryogenic**		
	Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
0	750	755	759.5	729.5	735	738.5	717	722	725.5
30	745.5	751	755	725.5	729	734.5	710.5	715	718
80	745	749	755	718	721	725	700.5	705	708.5
130	724.5	729	734.5	699.5	703	707.5	680.5	686	689
180	691	695	699.5	675.5	681	685.5	670.5	675	679
230	675.5	680	685	665.5	669	673.5	664.5	668	671
280	660.5	665	670.5	662	666	669.5	660	664	667.5
330	655.5	659	663	654.5	658	661	655.5	660	665
380	659.5	663	667.5	659.5	664	668	657.5	661	665
430	657	661	664.5	654.5	658	661	657.5	662	666

Table 25: Variations in tangential grinding force under different lubricants.

Tangential grinding force, F_t (N)						
Lubricant	**MQL**			**Cryo-MQL**		
	Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
SO	37.5	39.3	41.5	37	37.8	39
SO+DW	46.5	48.5	50.5	41.5	44	46
Al_2O_3 (0.5 wt.%)	40	42.6	44	36.5	38.6	40
Al_2O_3 (1 wt.%)	33	34.9	37.5	25	26	27.5

Table 26: Variations in normal grinding force under different lubricants.

Normal grinding force, F_n (N)						
Lubricant	**MQL**			**Cryo-MQL**		
	Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
SO	76.5	80.1	84	72.5	77.3	80.5
SO+DW	86.5	91.2	94.5	83	86.9	91.5
Al_2O_3 (0.5 wt.%)	77.5	82.2	85	74.5	78.5	83
Al_2O_3 (1 wt.%)	70	71.8	74.5	60.5	62.5	65

Table 27: Variations in specific grinding energy under different lubricants.

Specific grinding energy, U_g (J/mm^3)						
Lubricant	**MQL**			**Cryo-MQL**		
	Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
SO	16.687	17.187	17.987	15.660	16.560	17.360
SO+DW	20.421	21.221	22.221	18.054	19.254	20.254
Al_2O_3 (0.5 wt.%)	17.750	18.650	19.150	15.798	16.898	17.598
Al_2O_3 (1 wt.%)	14.795	15.295	16.095	10.970	11.370	11.670

Table 28: Variations in surface roughness (R_a) under different lubricants.

Surface roughness, R_a (μm)						
Lubricant	**MQL**			**Cryo-MQL**		
	Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
SO	0.4172	0.4382	0.4622	0.3375	0.3525	0.3645
SO+DW	0.5435	0.5675	0.5875	0.4955	0.5175	0.5375
Al_2O_3 (0.5 wt.%)	0.461	0.479	0.499	0.3815	0.3975	0.4115
Al_2O_3 (1 wt.%)	0.3863	0.4053	0.4203	0.2899	0.3039	0.3149

Table 29: Variations in surface roughness (R_q) under different lubricants.

Surface roughness, R_q (μm)						
Lubricant	**MQL**			**Cryo-MQL**		
	Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
SO	0.5187	0.5397	0.5637	0.4254	0.4404	0.4524
SO+DW	0.6946	0.7146	0.7396	0.6136	0.6376	0.6586
Al_2O_3 (0.5 wt.%)	0.5845	0.6045	0.6265	0.4749	0.4949	0.5109
Al_2O_3 (1 wt.%)	0.4768	0.4958	0.5108	0.3749	0.3929	0.4079

Table 30: Variations in specific surface roughness (R_z) under different lubricants.

Surface roughness, R_z (μm)						
Lubricant	**MQL**			**Cryo-MQL**		
	Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
SO	2.6108	2.8308	3.0308	2.382	2.512	2.612
SO+DW	4.159	4.329	4.579	3.4586	3.6586	3.8786
Al_2O_3 (0.5 wt.%)	3.0422	3.2222	3.4422	2.542	2.692	2.882
Al_2O_3 (1 wt.%)	2.3601	2.5601	2.7301	1.9873	2.1373	2.2973

Table 31: Variations in grinding temperature under different lubricants.

Grinding temperature, T_g (ºC)						
Lubricant	**MQL**			**Cryo-MQL**		
	Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
SO	491	507	526	204	215	230
SO+DW	462	476	493	191	201	213
Al_2O_3 (0.5 wt.%)	440	458	473	179	191	201
Al_2O_3 (1 wt.%)	407	421	439	168	178	189

LIST OF PUBLICATIONS

1. **Sharma, A.,** Chaudhari, A., Diwakar, V., Awale, A. S., Yusufzai, M. Z. K., & Vashista, M. (2024). Implementation of hybrid CryoMQL sustainable lubri-cooling to enhance the grindability and surface integrity of tool steel. *Journal of Manufacturing Processes*, 119, 16-31.

   Link: https://doi.org/10.1016/j.jmapro.2024.03.040
2. **Sharma, A.,** Chaudhari, A., Yusufzai, M. Z. K., & Vashista, M. (2023). An experimental study on improving grindability with LN_2 coolant for grinding AISI D2 tool steel. *Journal of Materials Engineering and Performance*, 33(1), 64-78.

   Link: https://doi.org/10.1007/s11665-023-07958-7
3. **Sharma, A.,** Chaudhari, A., Yusufzai, M. Z. K., & Vashista, M. (2023). Effectiveness of using liquid nitrogen cryogen in grinding to enhance the grinding performance of hard steel. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 238(1-2), 315-327.

   Link: https://doi.org/10.1177/09544054221147622
4. **Sharma, A.,** Khan Yusufzai, M. Z., & Vashista, M. (2022). A comparative analysis of grinding of AISI D2 tool steel under different environments. *Machining Science and Technology*, 26(2), 183-202.

   Link: https://doi.org/10.1080/10910344.2022.2044853
5. **Sharma, A.,** Chaudhari, A., Awale, A. S., Yusufzai, M. Z. K., & Vashista, M. (2021). Effect of grinding environments on magnetic response of AISI D2 tool steel. *Russian Journal of Nondestructive Testing*, 57(3), 212-221.

   Link: https://doi.org/10.1134/S1061830921030062

Response to examiner's comments

Thesis Title: Sustainable Cryogenic Grinding of AISI D2 Tool Steel using Various Eco-friendly Lubricants with MQL Technique

Dear Examiner,

Thank you for your useful comments and suggestions on my PhD thesis. We have modified the thesis accordingly. Detailed corrections are listed below point by point:

Examiner I

Editorial issues & English errors:

Comment 1: The general English is acceptable. However, an overall polishing is still required. E.g., there are a few typos and grammatically errors should be edited as below:

- Page 17, last line: the research articles;
- Page 39, line 21: Nitrogen is a non-harmful,...;
- Page 43, line 10: The authors investigated the use....;
- Page 44, line 3: The authors suggested that...;
- Page 44, line 4: They also recommended controlling...;
- Page 59, line 18: To determine the stability of NFs;
- Page 76, the line before the last line: MQL;
- Page 85, line 9: 10×10 mm^2;
- Page 86, line 5: Metallographic and microhardness analyses;

- Page 86, line 10: 10 × 10 mm^2;
- Page 92, line 23: rubbing and ploughing actions;
- Page 98, line 11: Fig. 4.7 shows the 2D profiles;
- Page 99, line 11: Fig. 4.8 represents the SEM images of;
- Page 101, line 12: cryogenic cooling (refer to Fig. 4.10).
- Page 109, line 7. Fig. 4.14 indicates the;
- Page 112, line 16: Using cryogenic LN2;
- Page 119, line 6: 6 m/min, 9 m/min, and 12 m/min;
- Page 128, line 12: plays an important role;
- Page 137, line 1: Fig. 4.36 shows the grinding forces;
- Page 145, line 3: Fig. 4.40 (h) shows the best surface texture;
- Page 151, line 23: rubbing, ploughing, and shearing actions;
- Page 165, line 9: in sections 5.1.1, 5.1.2, and 5.1.3;

Response: Thank you for your thorough review of my thesis. I appreciate your feedback on the overall quality of the English and the identification of typos and grammatical errors. I corrected all above comments as per the examiner's suggestions and incorporated them in the revised thesis as well I also checked the thesis thoroughly for any other typos and grammatical errors. Page no. 20, 43, 47, 63, 81, 90, 91, 98, 103, 104, 107, 115, 119, 125, 134, 143, 152, 161, and 177.

Comment 2: Please re-arrange the "list of abbreviations" on page xviii in alphabetical order.

Response: Thank you for your suggestion. I appreciate you bringing to my attention the need to alphabetize the list of abbreviations. I have already corrected the list of abbreviations to ensure it is in proper alphabetical order in the revised thesis. Page no. xxv.

Comment 3: British and American spelling have been used simultaneously, such as "analyse & analyze, "mould & mold", "utilise & utilize", "optimise & optimize", "aluminium & aluminum", "minimise & minimize", "characterize & characterize", "behaviour & behavior", and "characterization & characterisation".

So, please only follow one of them.

Response: Thank you for your insightful review of my PhD thesis and pointing out the inconsistencies in spelling conventions between British and American English. I have meticulously revised the document and followed one in the revised thesis, such as analyze, mold, utilize, optimize, aluminum, minimize, characterize, behaviour, characterization.

Comment 4: Some sentences on pages 15, 48, 54, 68, 75, and 169 were written in Italic form. Please modify them.

Response: Thank you for your suggestion. Sentences have been modified according to the examiner's comment in the revised thesis. Page no. 18, 52, 58, 72, 80, and 181.

Comment 5: The abbreviation of a term should be brought at the first time that term is used in the text (and not e.g. at the second time). So, please consider this issue for magnetic Barkhausen noise (MBN).

Response: I recognize the importance of clarity in technical writing. To address this oversight, I revised the relevant sections to ensure MBN is defined and abbreviated at its first instance in the text. I have located all subsequent uses of the term and ensured they consistently utilize the abbreviation after that.

Comment 6: Some words have been written in different spellings, such as “online & on-line”, “environmentally friendly & environmentally-friendly”, “LN2 & LN_2”, as well as “microcrack &

micro-crack”. You should follow a unique spelling in your text.

Response: As per the examiner’s suggestion, I have written a unique spelling in the revised thesis, such as online, environmentally friendly, LN_2, and microcrack.

Comment 7: In the literature review, it is not usual to mention a researcher with his/her title (such as prof.). This is done in a few cases in this thesis. So, please modify them.

Response: Thank you for your comprehensive review of my thesis. I modified the relevant sentences to remove any unnecessary titles. Page no. 16.

Comment 8: The first paragraph of page 48 is unfinished.

Response: Thank you for flagging the mistake. The unfinished paragraph has been completed in the revised thesis. Page no. 52.

Comment 9: The first sentence of the third paragraph on page 90 is not clear and I cannot get the concept. Please rewrite it.

Response: I apologize for any confusion it may have caused. I modified the suggested sentence and incorporated it in the revised thesis according to the examiner's comment. Page no. 95.

Comment 10: The supply pressures of 2, 3, and 4 bars have been mentioned three times just in less than ten lines on pages 108 and 109. Please prevent extra repetitions.

Response: Thank you for your insightful review of my thesis. I appreciate you pointing out the repetitive mentions of supply pressures at 2, 3, and 4 bars, as excessive repetition can hinder readability. I have carefully reviewed Section 4.1.9 and Subsection 4.1.9.1 in the revised thesis to ensure clarity and avoid unnecessary repetition. Section 4.1.9 and Subsection 4.1.9.1 were mentioned on pages 108 and 109 in the previous thesis. Now, it is on Page no. 114 and 115 in the revised thesis.

Comment 11: The verb tenses should be defined exclusively throughout the thesis. In some cases, the simple present structure is being used for describing the conditions and in some cases the past present is being employed. For example, both of them have been used just in the first paragraph of subsection 4.1.9.2 or 5.1.

Response: Thank you for your careful review and for pointing out the inconsistency in verb tenses within subsection 4.1.9.2 or 5.1. I acknowledge the inconsistency in your identified subsection and have carefully reviewed the tense usage throughout the thesis. I have revised the thesis to ensure consistent use of the simple present tense for describing general conditions, principles, and techniques. I have also limited the use of the past perfect tense to instances where it is necessary to emphasize the completion of an action with ongoing relevance. Page no. 116, 117 and 177.

Comment 12: You should reconsider the first sentence of the second paragraph on page 114. It seems you meant "3D roughness of dry grinding was poor under various table feed rates". The current sentence transfers another meaning, which is not correct.

Response: Thank you for your review and for identifying the unclear sentence on page 114, which essentially needs revision. I corrected the sentence and incorporated it in the revised thesis. The incorporated sentence is "Poor surface roughness was noticed with an increased table feed rate during the dry grinding operation". Page no. 120.

Technical comments

Comment 1: In subsection 1.1, bring the equivalent of AISI D2 tool steel in other commonly used standards such as DIN, EN, and AMS.

Response: Thank you for your valuable feedback regarding the equivalents of AISI D2 tool steel in other standards within subsection 1.1 of my thesis. I added that AISI D2 tool steel is equivalent to DIN 1.2379, EN X153CrMoV12. This provided a clear and concise way for readers familiar with other standards to identify the material. Page no. 1.

Comment 2: Rubbing and ploughing are two machining mechanisms. However, there is almost no material removal in them, So, instead of introducing them as "the modes of removing metals" on page 5, please refer to them as the "machining mechanisms".

Response: Thank you for your insightful feedback regarding the terminology used to describe rubbing and ploughing on page 5. I agree; rubbing and ploughing are fundamental machining mechanisms but do not directly contribute to material removal. To address this, I incorporated the text "machining mechanisms" instead of "modes of removing metal" on page 5 in the revised thesis.

Comment 3: Not all the abrasive grains have the negative rake angle (as you also show in Fig. 1.2). Hence, modify your statement on page 5, number 2.

Response: Thank you for your valuable feedback. Figure 1.1 (updated figure no.) clearly illustrates that not all abrasive grains will have a negative rake angle. To address this, I revised the statement on page 5, point no. 2, to provide a more accurate representation: The grit rake angle may vary from positive to negative.

Comment 4: In chapter 1, you brought some explanation about cutting fluids and coolants in "subsection 1.3. background of the present research work". It is recommended to bring these explanations into another subsection, as you already did for other aspects (in subsections 1.1 and 1.2). In such a case, you can specifically focus on the research gap in subsection 1.3.

Response: Thank you for your valuable suggestion regarding the organization of Chapter 1. As per your suggestion, I separated the explanation about cutting fluids and coolants from subsection

1.4 (as per the revised thesis) into another subsection (Subsection 1.3: The role of cutting fluids and coolants in grinding process). After that, subsection 1.4: Background of the present research work is modified according to the examiner's comment. Page no. 9, and 14.

Comment 5: In subsection 2.1, you introduced gas-based lubricants as one of the cutting oils. By considering this, you should also bring solid lubricants (like powders, films, composite materials, etc.) in your classification.

Response: Thank you for your suggestion. I have incorporated your suggestion. Furthermore, I have added relevant information about solid lubricants at an appropriate location within the thesis. This section discusses their unique properties, including high-temperature stability and suitability for specific applications under high stress or load. Page no. 24 and 25.

Comment 6: Although a wide range of literature has been reviewed in section 2, there is no specific categorization in the subsections. You must specify the path and method you are going to narrate the literature in each subsection. Currently, the way of presenting previous research in some subsections is not based on year or any other specific division.

In addition, as a PhD student, you should not limit yourself to reviewing previous literature. Rather, you should also include your own analysis and criticism of them. For example, there are some contradictions about the effect of cryogenic on cutting forces. You could enter your own point of view and state your own analyses in this regard.

Response: Thank you for your valuable feedback regarding the organization of the literature review in Section 2. I recognized the importance of clearly presenting the reviewed research and aimed to improve the categorization within subsections. According to the examiner's suggestion, Section 2: Literature Review is categorized into conventional cutting fluids, sustainable techniques, vegetable oil-based MQL technique, nanofluid-based MQL technique, and magnetic

Barkhausen noise technique. These sections are divided into subsections, providing a path and method. After doing a literature survey, a research gap and objectives of the present work sections are added. Furthermore, relevant previous research articles are explained in Section 2: literature review based on the year, as per the examiner's comment.

As a PhD student, according to the examiner’s suggestion, I wrote my opinion from our PhD research work at the appropriate place in the revised thesis. Page no. 52.

Comment 7: In line with the above comment, some statements are repeatedly mentioned in the literature review. For example, “overheating the workpiece during the dry machining”, “bacteria growth in cutting fluids”, etc.

Response: Thankful to the examiner for this observation regarding the repetitive mention of certain statements in the literature review (e.g., “overheating the workpiece during dry machining” and “bacteria growth in cutting fluids”). I have thoroughly checked the literature review, and repetitions have been removed from the literature review section of the revised thesis.

Comment 8: In subsection 2.5.1, you referred to reference [93] and mentioned that the “dry machining enhances the machinability in comparison to the conventional methods involving cutting fluids”. This is a very challenging statement. Generally, cutting fluids are being used to increase the surface quality, decrease cutting forces, and improve dimensional accuracy; all of these refer to better machinability. Even in the referred reference, it was mentioned that the “dry machining will be acceptable only whenever the part quality and machining times achieved in wet machining are equalled or surpassed”.

Response: I apologize for the sentence mistake. I sincerely read the article (Ref. [93]) and thought of your opinion. I corrected the previous sentence, i.e., “dry machining enhances the machinability in comparison to the conventional methods involving cutting fluids", and incorporated it in the revised thesis. Also, I deleted the reference [93]. Page no. 35.

Comment 9: "Reduction in specific energy" has been introduced as one of the advantages of cryogenic cooling (by increasing the cutting speed). However, from a wider view, we would also need energy for producing LN2 as well as related activities (such as storage, circulation, etc.). So, we could not easily claim about the energy consumption in this regard.

Response: Thank you for pointing out the statement "Reduction in specific energy" under cryogenic cooling. I agree with the examiner's statement, "We could not easily claim about the energy consumption in this regard". In our research work, specific energy was calculated using the formula ($U_g = \frac{F_t \cdot V_s}{V_w \cdot a_p \cdot b}$). Details are given in Section 3.5.1 in the revised thesis. Several researchers used this formula to calculate the specific energy. Paul and Chattopadhyay reported a reduction in specific energy under cryo-grinding when compared with grinding dry and with soluble oil in their article "A study of effects of cryo-cooling in grinding".

Comment 10: For the Cryo-MQL experiments, it is mentioned that the flow rates of lubricant and compressed air were controlled by valves. So, was there no flowmeter in your experiments? If not, how you get sure about the constant experimental conditions during the different setups?

Response: Thank you for your query regarding the flow measurement in our Cryo-MQL experiments. In our experimental setup, the lubricant and compressed air flow rates were controlled using valves rather than flowmeters. While flowmeters could have provided direct real-time measurement of the flow rates, we employed a careful calibration and monitoring approach to maintain consistent experimental conditions throughout different setups. To be sure about the constant experimental conditions during the different setups:

Based on preliminary tests and established flow rate ranges suitable for our experiments, I calibrated the valves to achieve a specific flow rate. Once the desired flow rates were set using the valves, we maintained consistent operating parameters, including valve positions and system pressures, to minimize variability between experimental runs. After that, I continuously monitored the system performance and conditions throughout the experiments to detect deviations.

Comment 11: Please bring the specification of the coolant oil you used for wet grinding in subsection 3.4.2.

Response: I added the required information in the revised thesis. Page no. 84.

Comment 12: Units related to the equation 3.1 are not compatible. By considering the units you mentioned for P and Q_w, we cannot receive to J/mm^3. Moreover, the units of the second part of this equation (F_t, V_s, etc.) will not result in J/mm^3, too.

Response: Thank you for identifying the potential unit mismatch in equation 3.1. I modified equation 3.1 and checked the units for all variables (F_t , V_s , V_w , a_p and b) to ensure dimensional consistency and found a result in J/mm^3. Page no. 87

Comment 13: Based on the outputs (such as Fig. 4.1), downfeed of 10μm is also used. So, please bring this value to Table 3.4.

Response: Thank you for your suggestion. My research is divided into three parts: (1) Performance analysis of grinding parameters under cryogenic environment for ground AISI D2 tool steel, (2) Performance analysis of grinding parameters under Cryo-MQL environment for ground AISI D2 tool steel, and (3) Performance analysis of magnetic BN and HL parameters under various environments for ground AISI D2 tool steel. Part 1 is the main part of my research in which grinding experiments have been done at all parameters, as given in the details in Table 3.3 in the thesis. Fig. 4.1 belongs to Part 1. Table 3.4 provides details about the grinding parameters under Cryo-MQL grinding. In the case of Cryo-MQL grinding, experiments were carried out only at a higher downfeed (40 µm) because it was an additional part of my research.

Comment 14: Please add some quantitative evaluations to your analyses. For instance, when comparing the tangential and normal forces or the effect of downfeed in subsection 4.1.1, such quantitative comparisons can transfer a better sense.

Response: Thank you for your valuable feedback on incorporating quantitative evaluations into my analysis, particularly in subsection 4.1.1. I understand the importance of quantifying comparisons to enhance the clarity and impact of my findings. I incorporated some sentences to compare the tangential and normal forces and also showed how the downfeed affects things with some percentage changes in the revised thesis. Page no. 95.

Comment 15: Temperature has been introduced as the main factor for the sharpness variation of the grits in subsection 4.1.1. Generally, such strict statements without any evidence should be avoided. There are such claims in a few sections, too. Please review the thesis from this aspect and polish it.

Response: I agreed with the examiner’s opinion. I cited this sentence with a relevant article in subsection 4.1.1. Also, I checked the whole thesis and provided evidence where appropriate. Page no. 97.

Comment 16: In chapter 4 and the related subsections, you did not only focus on the cryogenic environment; and other environments have been investigated. So, instead of writing “effect of cryogenic environment" you can simply write "grinding environment”.

Response: Thank you for the examiner’s suggestion. Suggestions have been incorporated in

Chapter 4 and the related subsections of the revised thesis. Page no. 93, 97, 99, 100, 101, 104, 111, and 113.

Comment 17: The ratio of Ft to Fn was defined as the friction coefficient, in the beginning. Why did you change this to force ratio at subsection 4.1.4?

Response: In abrasive machining, the ratio F_t/F_n is known as the force ratio. Due to its similarity to a coefficient of friction, the same symbol, μ, is used:

$$\mu = \frac{F_t}{F_n}$$

In abrasive machining, like grinding, the friction coefficient and force ratio are interrelated concepts, but they represent distinct aspects of the cutting process. In grinding, the friction coefficient depends on workpiece material, grinding wheel material, and lubrication conditions. Factors influencing the force ratio include friction coefficient, grinding wheel properties, and grinding conditions. This ratio reflects the overall force distribution during the grinding process by relating the tangential force (F_t) acting in the cutting direction to the normal force (F_n) pressing the wheel into the workpiece.

Comment 18: How did you conclude that the virtually completely curled chips are evidence of oxidation and large heat production?

Response: Thank you for commenting on the connection between virtually completely curled chips and observations on oxidation and heat production. The statement, "The virtually completely curled chips are evidence of oxidation and large heat production", was justified by SEM micrographs of chips and EDS analysis of the ground surface under dry grinding. SEM micrographs showed that almost circular chips were noticed under dry grinding. Due to the absence of cutting fluid under dry grinding, more heat is generated in the grinding zone area. The EDS analysis concluded that the ground surface had undergone severe oxidation in dry grinding, reflected by the highest value of oxygen weight percentage.

Besides, many researchers (Sinha et al. [1], Rajmohan and Radhakrishnan [2]....etc.) also reported that almost complete curling of chips (i.e. almost circular chip) has been observed, which proves that high heat generation and severe oxidation occurred.

[1] *M. K. Sinha, R. Madarkar, S. Ghosh, and V. R. Paruchuri, "Some investigations in grindability improvement of Inconel 718 under ecological grinding," Proc. Inst. Mech. Eng. Part B J. Eng. Manuf., vol. 233, no. 3, pp. 727–744, Feb. 2019, doi: 10.1177/0954405417752513.*

[2] *B. Rajmohan and V. Radhakrishnan, "A study on the thermal aspects of chips in grinding," Int. J. Mach. Tools Manuf., vol. 32, no. 4, pp. 563–569, 1992, doi: 10.1016/0890-6955(92)90045-I.*

Comment 19: Please specify which downfeed has been used for the micrographs in Fig. 4.13.

Response: Thank you for your comment. Micrographs of ground samples under different environments in Fig. 4.13 were taken at 24 µm downfeed. A 24 µm downfeed has been incorporated in subsection 4.1.8 of the revised thesis. Page no. 113.

Comment 20: The size of Al2O3 NPs was defined between 20 and 50 nm in subsection 4.2.1. However, it seems bigger according to the scale bar in Fig. 4.26. Please bring more obvious micrographs to prove the statement.

Response: Thank you for your careful review and raising this important point. I agree that the scale bar in Fig. 4.26 might not clearly depict the actual size of the nanoparticles. I modified the size of Al_2O_3 nanoparticles in the text. The size of Al_2O_3 nanoparticles is written as 10-50 nm" in the revised thesis. To prove the size of Al_2O_3 nanoparticles, I added the TEM image of Al_2O_3

nanoparticles instead of the HR-SEM image of Al_2O_3 nanoparticles. Page no. 129.

Comment 21: It is hard to distinguish between the densities of different nanofluids in Fig. 4.32. Change the vertical axis bound to the limited range to get a better sense.

Response: Thank you for your feedback regarding Fig. 4.32. I acknowledge the difficulty in distinguishing between the densities of different nanofluids presented in the figure. The density of SO+DW emulsion and NFs with 0.5 wt.% and 1 wt.% concentration of Al_2O_3 NPs is 996.58, 1000.11, and 1003.62 kg/m^3, respectively. The value of these lubricants is very close to each other. After changing the vertical axis limit range, I did not get a better difference between them. So, I incorporated the density value of SO+DW emulsion and NFs with 0.5 wt.% and 1 wt.% concentration of Al_2O_3 NPs in the text of subsection 4.2.2.2.4 of the revised thesis. Page no. 138.

Comment 22: You have evaluated the different concentrations of Al2O3 nanofluids from different aspects. From different aspects, different nanofluids can be introduced as the ideal lubricant. E.g. since the lower pH would be preferred, 0.5 wt% was considered the best. in contrast, since the higher density of the nanofluid was preferred, the 1 wt% was introduced as the desired one. However, no conclusion has been made about this. In other words, considering all these studies, it is still not possible to determine which nanofluid is better. If the general trend of different lubricants was only considered, it could be found in the literature.

Response: I agree with your opinion. The thermophysical properties of nanofluids are measured by their thermal conductivity, dynamic viscosity, surface tension, density, pH value, and wettability analysis. These properties show the only characteristics of the nanofluids. According to the experimental investigation outcomes, i.e., grinding force, specific grinding energy, surface roughness, surface topography, chip morphology and grinding temperature, it was found that the optimum concentration of the eco-friendly nanofluid is 1 wt.% concentration of Al_2O_3 NPs which provided better results as compared to 0.5 wt.%. This result indicated that adding the NPs in vegetable oil-based deionized water emulsion impacts the grinding performance and that a specific concentration can optimize this effect. To determine which nanofluid is better, I also incorporated the paragraph in the Section 5.1.2 of the revised thesis. Page no. 181.

Comment 23: The grit sharpness has been a hypothesis for the reason of better surface quality under some conditions (such as employing Cryo-MQL coolant) in your thesis. Since there was no investigation from this point of view, you are not allowed to claim grit sharpness improvement as an output of your experiments in your conclusion on page 168.

Response: Thank you for your valuable feedback regarding the inclusion of grit sharpness improvement in the conclusion of my thesis (page 168). I understand your concern about the lack of direct investigation into this aspect. I deleted the sentence related to grit sharpness improvement from point no. 2 of the conclusion subsection 5.1.2 and modified the conclusion in the revised thesis. Page no. 180.

Comment 24: A main question that arises is that even without conducting experiments, the general trend of the graphs of chapter 4 (e.g. improvement of surface quality with Cryo-MQL coolant, reduction of machining forces under wet grinding, reduction of machining forces by increasing coolant pressure, reduction of specific machining energy by increasing machining speed, increasing in machining forces with an increase in feed rate, etc.) can be predicted.

Therefore, it would be better if you included other parameters in the investigation to show the efficiency of Cryo-MQL. For example, you could enter the cryogenic cost parameter and finally conclude whether this grinding is cost-effective or not considering the improvements it has achieved.

Response: Thank you for raising an important question regarding the predictive nature of the trends illustrated in Chapter 4 of our thesis. I appreciate the opportunity to clarify the methodology and justification behind the results presented in our research.

In our study, I conducted all grinding experiments to investigate and analyze the factors influencing surface quality, grinding forces, specific energy, etc., under different environments. I employed SEM (Scanning Electron Microscope) and AFM (Atomic Force Microscope) micrographs to justify our results. By analyzing these micrographs, I directly observe and quantify the effects of various process parameters, i.e., downfeed, coolant delivery pressure, and table feed rate.

As per the examiner's suggestion, I incorporated additional techniques to examine the efficiency of Cryo-MQL in the revised thesis. Page no. 157. In this technique, I kept all parameters (also included cost parameters) which affects the sustainability, grinding performance and productivity. This technique is explained below.

Sustainability Assessment: Pugh Matrix Approach

In modern manufacturing sectors, the use of cutting fluids plays a vital role in the efficient production of products with appropriate quality. Presently, various techniques for application of cutting fluid are available and a secure and eco-friendly manufacturing process requires a crucial evaluation of the sustainability of each technique before implementation. Sustainable manufacturing, characterized by green efficiency, entails adopting economically efficient and eco-friendly technologies with broader social implications. This approach minimizes waste, reduces negative environmental impacts, and helps in the development of a healthy working environment. It encompasses various manufacturing parameters such as environmental and worker safety, product quality, process efficiency, total cost, etc.

This section uses the Pugh matrix sustainability assessment on MQL and Cryo-MQL techniques to decide the best among these two cooling environments during the grinding operation of AISI D2 tool steel by considering environmental impact, operator safety, coolant cost, setup cost, surface finish, specific energy consumption, grinding temperature, grinding force, and coolant recycling and disposal. To assess sustainability in manufacturing processes, the Pugh matrix decision-making sustainability assessment technique is preferred by many researchers [253], [254], [255], [256] (as per thesis). According to the importance of each quality parameter, a weight criterion as mathematical numbers ranging from -2 to +2 was assigned. Here, dry grinding was referred to as a datum or reference line for comparing the other two conditions. Its factors are denoted by "S" and receive a total score of zero. Scores were allocated based on the worst-to-best criterion, with "-1" for inferior outcomes and" +1" for better results, and much superior and much inferior results were assigned a score of +2 for the best and -2 for the worst, respectively. Total scores for all conditions, i.e., MQL and Cryo-MQL grinding, are calculated by summing up the scores of all sustainability assessment factors, as represented in Table 4.4 (as per thesis). Compared to dry grinding, MQL and Cryo-MQL grinding scored "-1" regarding environmental impact. Because under the MQL and Cryo-MQL, the MQL uses a small quantity of lubricants at high pressure, which emits minimal emissions of harmful gases that harm the environment. At the same time, cryogenic coolant (LN_2) evaporates into the atmosphere and does not harm the environment due to its properties. As to operator safety scoring, MQL and Cryo-MQL were given a "+1" score, producing efficient cooling and debris-flushing capabilities. In the case of MQL, only a small amount of lubricant was used with compressed air; a score "-1" was given to the coolant cost. However, in Cryo-MQL grinding, the score "-2" was given for coolant cost due to the use of liquid nitrogen coolant and lubricants with compressed air. For setup cost, "-1" and "-2" scores were given to the MQL and Cryo-MQL, respectively. The MQL setup includes an air compressor, flow control valve, air control valve, lubricant reservoir, air atomizing spray nozzle, etc. On the other hand, the Cryo-MQL setup has two additional major parts, namely, dewar and nitrogen gas cylinder with MQL setup. Therefore, Cryo-MQL setup cost is high. When the graphs of experimental results were examined, it was seen that Cryo-MQL have better results than MQL grinding in terms of surface roughness, specific energy, grinding temperature and grinding force. Therefore, MQL and Cryo-MQL grinding were given "+1" and "+2" scores for surface finish, specific energy consumption, grinding temperature, and grinding force, respectively. Further, for coolant recycling and disposal, a score of "-1" was provided for MQL and Cryo-MQL because dry grinding has better results due to the absence of coolant. Also, in MQL and Cryo-MQL environments, cleaning, filtering, and minimizing the harmful effects of the coolant used, resulted in enhancement in manufacturing cost. Now, after the summation of positive and negative scores in both cases, the final scores are achieved. The MQL receives a final score of +1, and the Cryo-MQL gets a final score of +3. The technique with the highest total score is deemed the best. Thus, this clearly indicates that the Cryo-MQL technique is superior in terms of sustainability compared with the MQL. Therefore, from a sustainability point of view, Cryo-MQL grinding proves economically and socio-technologically beneficial. All these results are displayed in the Kiviat diagram in Fig. 4.44 (as per thesis) and sustainability assessment scores are plotted in Fig. 4.45 (as per thesis).

"In summary, the Cryo-MQL system is more efficient than the MQL, offering enhanced lubrication, cooling, and process adaptability, leading to improved grinding performance and productivity."

Table 4.4. Pugh matrix comparison for MQL and Cryo-MQL techniques.

Sustainability assessment factors	Dry	MQL	Cryo-MQL
Environmental impact	S	-1	-1
Operator safety	S	+1	+1
Coolant cost	S	-1	-2
Setup cost	S	-1	-2
Surface finish	S	+1	+2
Specific energy consumption	S	+1	+2
Grinding temperature	S	+1	+2
Grinding force	S	+1	+2
Coolant recycling and disposal	S	-1	-1
Total +	0	+5	+9
Total -	0	-4	-6
Score	0	+1	+3

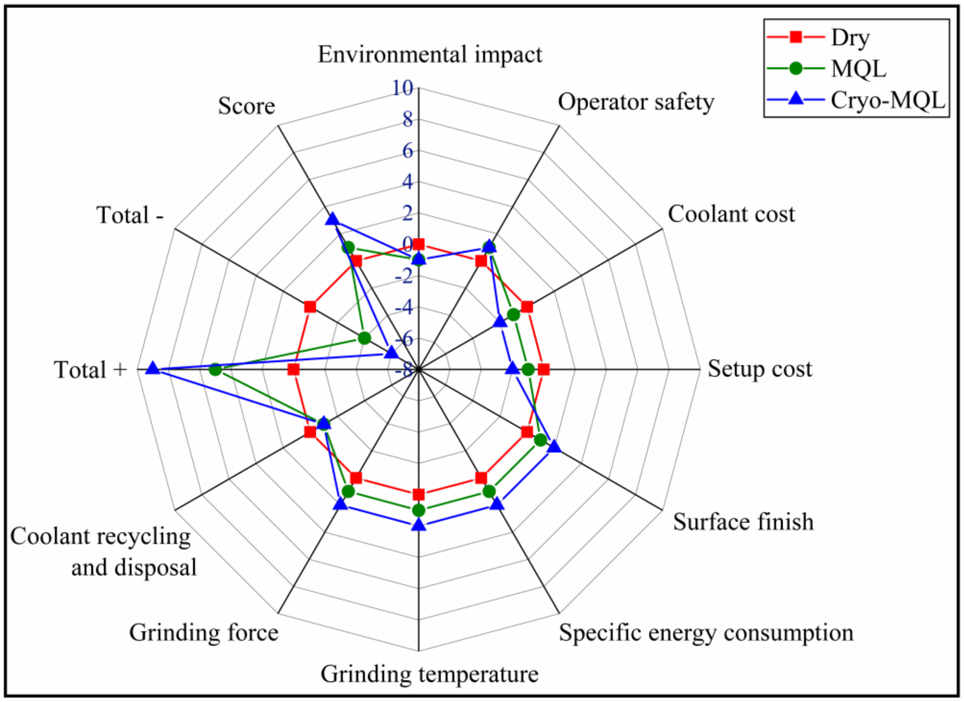

Fig. 4.44. Kiviat diagram based on the Pugh Matrix for sustainability assessment.

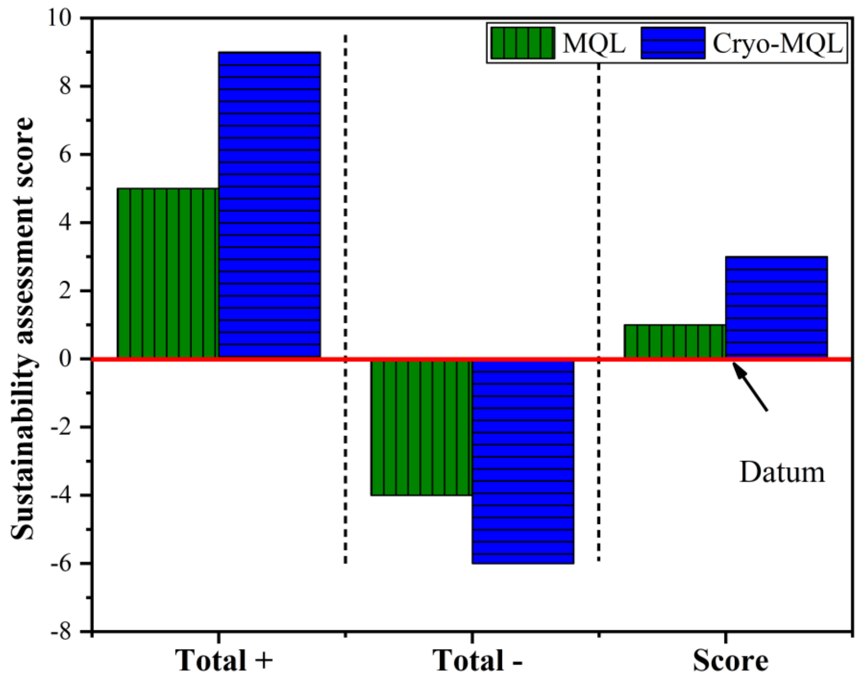

Fig. 4.45. Sustainability assessment scores.

Examiner II

Annexure (b)

Points for clarification:

Comment 1: Why are you using magnetic Barkhausen noise analyser for surface integrity? Is profilometer not enough?

Response: Magnetic Barkhausen noise technique is best for online monitoring of machined surface. It can be easily used to evaluate surface integrity for ferromagnetic materials such as all types of steel. Magnetic Barkhausen Noise (MBN) analysis offers some unique advantages.

Advantages of MBN Analysis:

- **Non-Destructive:** MBN analysis is a non-destructive testing (NDT) method, meaning it does not damage the workpiece surface during the measurement. This is crucial for ensuring the integrity of critical components.
- **Bulk Material Sensitivity:** MBN analysis is sensitive to the microstructure of the material below the surface. This can be particularly useful for detecting subsurface defects like cracks or residual stresses that might not be readily apparent with profilometry.
- **Fast and Efficient:** MBN analysis can be a relatively fast and efficient method for assessing surface integrity, particularly for large or complex components.

The MBN technique provides certain advantages, such as deep penetration, less energy consumption, and portability of equipment.

A profilometer is a very common and effective tool for measuring surface integrity, particularly when focusing on geometric features like roughness, waviness, and step height. They do not provide direct information about the microstructure/microhardness/residual stresses at surface and sub-surface level.

Comment 2: Why was the coolant deliver at 12º angle?

Response: Prior to the actual experiment, several pilot tests were performed to optimize the nozzle angle for grinding the AISI D2 tool steel workpiece in our research work. The coolant delivery angle might compromise between good cooling and chip evacuation. A 12° angle could represent a balance between directly targeting the heat source and maintaining a flow path that effectively removes chips from the grinding zone. This angle helps to effectively reach coolant in the grinding zone and minimize the effect of the hydrodynamic layer around the wheel.

Comment 3: Give more details of water-based coolant.

Response: A detailed explanation of water-based coolant is provided below:

Water: The primary component, typically comprising 80-95% of the coolant mixture. Water provides excellent heat transfer properties, which are crucial for absorbing heat generated during machining processes.

Additives: Various additives are incorporated in relatively small concentrations (5-20%) to enhance the coolant's performance and offer additional functionalities beyond simple cooling.

Water-based coolants have several classifications, depending on the type and concentration of additives: Mineral Oil-Based Emulsions, Synthetic-Based Coolants, Semi-Synthetic Coolants, and Soluble Oils.

Water-based coolants are widely used in various machining processes, including grinding, milling, turning, drilling, and tapping.

Advantages of Water-Based Coolants:

Cost-Effective: They are generally less expensive compared to oil-based coolants.

Environmentally Friendly: Water is the primary component that makes it more eco-friendly and easier to dispose of compared to oil-based coolants with stricter disposal regulations.

Good Cooling: Water possesses excellent heat transfer properties, effectively removing heat from the machining zone.

Biodegradable: Many synthetic-based water-based coolants are biodegradable, further reducing their environmental impact.

Easy Cleanup: Water-based coolants are generally easier to clean from workpieces and tools compared to oil-based coolants.

Comment 4: Better to provide more details of dynamometer.

Response: Thank you for your suggestion. As per your suggestion, some more information about the dynamometer has been incorporated at the appropriate place in subsection 3.5.1 of the revised thesis. Page no. 85.

Comment 5: How did you focus thermal imaging camera? What is the accuracy? Will chips and coolant will not hinder the correct measurement?

Response: After performing several trial experiments, the thermal imaging camera was fixed at a distance of 550 mm from the grinding zone using a tripod for proper focus on the grinding zone. The infrared thermal imager has 320 × 240 pixels infrared resolution and 30 Hz frame rate. It is set to a measurement range of -20 to 650 ºC, an emissivity of 0.95 with thermal accuracy of ±2%.

Thank you for your valuable comment regarding the potential impact of chips and coolant on temperature measurements using a thermal imaging camera in the grinding zone. Chips and coolant can hinder the accurate temperature measurement at the grinding zone using a thermal imaging camera. I used a chip evacuation system throughout the experiment to remove chips and maintain a clear line of sight between the camera and the grinding zone. On the other hand, coolant can coat the workpiece surface, altering its emissivity. Therefore, coolant should be chosen with minimal impact on emissivity. In my research, all coolants are provided in less quantity at the grinding zone area, which means they can not cover the workpiece surface, resulting in less impcat on emissivity.

Comment 6: How significant is thermal softening in your work? Cryogenic cooling and thermal softening are contradictory.

Response: The role of thermal softening in my work is related to the sharpness of grits, which results in grindability indices such as grinding forces, surface roughness, etc. Thermal softening and grit sharpness are interrelated factors in grinding, but their significance on each other varies depending on the grinding environment, i.e., dry, wet, or cryogenic with liquid nitrogen. In dry grinding, the absence of coolant leads to the highest grinding temperatures. This can significantly soften the workpiece material, especially with dull grits that generate more heat due to friction. The softened material might smear or adhere to the grinding wheel, further reducing grinding efficiency. Wet grinding introduces a coolant that absorbs some heat, reducing grinding temperatures compared to dry grinding. This can help minimize thermal softening, particularly when combined with sharp grits that promote efficient material removal with less heat generation. Cryogenic grinding with liquid nitrogen (LN_2) offers the most significant reduction in grinding temperatures. The extremely low temperature of LN_2 minimizes thermal softening, even with slightly dull grits. However, very sharp grits are still preferred for optimal grinding efficiency and minimizing overall grinding forces.

Comment 7: Section 4.1.4: It may be better to carry out hypothesis testing before making any conclusion.

Response: I completely agree with the examiner's opinion. For better justification, in subsection 4.1.4, I cited the conclusion statement, which was taken after studying the relevant research article in the revised thesis. Page no. 100 and 101.

Comment 8: Fig. 4.6: Some texts report that surface roughness improves with increasing down feed due to self-sharpening etc. Please comment.

Response: The statement "surface roughness improves with increasing down feed due to self-sharpening" is not entirely accurate. The influence of downfeed on surface roughness in grinding is not a simple linear relationship. Because it depends on the work material, wheel material, grinding parameters, environments, etc. While there can be an initial improvement at low downfeed, increasing the downfeed can improve surface roughness to a certain extent. This can be attributed to self-sharpening and the increased penetration of sharper grits into the workpiece material, resulting in a cleaner chip formation. However, increasing the down feed excessively can lead to a rougher surface due to chip size, wheel loading, redeposition material over the machined surface and deflection issues of the workpiece and grinding wheel. Selecting the optimal down feed is crucial for achieving the desired surface finish in grinding.

Comment 9: Bearing area curve can be explained in a better way. If needed, use Appendix.

Response: Thank you for your suggestion regarding further explanation of the bearing area curve (BAC). I appreciate your feedback and agree that a more detailed explanation would be beneficial.

I have revised the explanation of the bearing area curve in the main text (section 4.1.6.3) to provide a more precise and comprehensive understanding. Page no. 108 and 109.

Annexure (c)

Suggestions for Modification:

Comment 1: Please take permissions for all the figures taken from other sources. Write in caption "With permission from Ref. XYZ" as applicable. See for example, Fig. 1.1.

Response: Thank you for your time and consideration of my thesis. I have taken immediate action and secured written permission to use all figures from external sources. I have cited all figures taken from external sources at appropriate places and wrote" With permission from Ref. XYZ" in the caption. Page no. 5, 6, 13, 29, 30, 34, 36, 39, 44, 47, 56, 59, 64, 66, 69.

Comment 2: Section 1.3: Line 7: Change "grits" to "grains".

Response: Thank you for your suggestion. The suggestion has been incorporated into the revised thesis. Page no. 14.

Comment 3: Page 11: "hydrodynamic layer is inversely proportional to the smaller space.." is not clear and needs to be rephrased.

Response: Thank you for your insightful review of my thesis. This suggestion would improve the clarity of the sentence on page 11 regarding the hydrodynamic layer. The current sentence, "hydrodynamic layer is inversely proportional to the smaller space..," is unclear. Here is a revised version that better conveys the intended meaning: "The reason was that hydrodynamic pressure is inversely proportional to the minimum gap between the grinding wheel and the workpiece". The revised sentence has been incorporated into the revised thesis. Page no. 11.

Comment 4: Please use proper symbol for minus. You are using dash.

Response: I appreciate you bringing to my attention the use of dashes (-) in place of proper minus signs (-) throughout the document. As per the examiner's suggestion, I used the appropriate symbol for minus in the revised thesis.

Comment 5: Please describe the setup of Fig. 1.4 in text.

Response: Thank you for your review. As commented, a few descriptions of Fig. 1.3 (updated Fig. no.) are included at appropriate places in the revised thesis because detailed descriptions are given in Section 3.3.1. Page no. 12.

Comment 6: Page 18: "Chapter 2:" line: Change "article" to "articles".

Response: Thank you for your suggestion. The suggestion has been incorporated into the revised thesis. Page no. 20.

Comment 7: Page 22: Correct the grammar in the first sentences and explain Fig. 2.1 in text.

Response: Thank you for your thorough review of my PhD thesis. I appreciate your efforts for identifying the need for grammatical correction in the first sentences on page 22. I improved those sentences and incorporated a detailed description of Fig. 2.1 in the revised thesis. Page no. 24.

Comment 8: Page 29: In the pointwise description, remove grammatical errors.

Response: Thank you for reviewing my thesis and identifying grammatical errors in the pointwise description on page 29. I have carefully reviewed the thesis and made the necessary revisions to address the grammatical errors. Now, Page no. is 32.

Comment 9: Fig. 2.4: What about cultural impact?

Response: Thank you for highlighting the lack of cultural considerations in Fig. 2.4. I addressed this by adding a sentence in the revised thesis. Page no. 34.

Comment 10: Fig. 2.10: Improve it. Portion regarding Dewar is not clear.

Response: I am grateful for the examiner's suggestion. I updated Fig. 3.5 (updated Fig. no.) according to the examiner's comments in the revised thesis. Page no. 81.

Comment 11: Fig. 2.14 is not much useful.

Response: Thank you for your feedback on Fig. 2.14. I understand your concern that Fig. 2.14 is less valuable than other figures in the thesis, but it shows the importance of nanofluids in recent research. Page no. 64.

Comment 12: While writing a number, do not put space after decimal point. Thus, 3.1 is correct, not the 3. 1.

Response: Thank you for your suggestion. Suggestion has been incorporated in the revised thesis. Page no. 75.

Comment 13: Page 74: Change 1050ºC to 1050 ºC.

Response: Thanks for suggestion. I agree that the temperature on page 74 should be formatted as "1050 °C" with a space between the number and the degree symbol. I ensured that the temperature on page 74 is corrected to "1050 °C" and corrected all temperatures, as per the comment, throughout the revised thesis document. Page no. 76.

Comment 14: Repeated experiments have been carried out. Hence, range or standard deviation can be reported along with average value.

Response: Thank you for your suggestion. A range and average value are reported in tabular form and incorporated in the revised thesis. Page no. 215-221.

Comment 15: Along with Fig. 3.5, adding one schematic will look good.

Response: Thank you for giving valuable suggestions. I agree that adding a schematic diagram alongside Fig. 3.5 could be beneficial for further clarity. I clubbed a schematic diagram and a real image of the Cryo-MQL experimental setup and placed them in Fig. 3.5 in the revised thesis. Page no. 81.

Comment 16: Provide more details of coolant.

Response: Thank you for your suggestion. I added some details about the coolant in Section 3.4 because more details are given in Chapters 2, 3 and 4. Page no. 84 and 85.

Comment 17: Page 85: Change “environmental-friendly” to “environment-friendly”.

Response: Thank you for your valuable feedback. I updated all instances of “environmental-friendly” throughout the entire thesis and corrected them to “environment-friendly”, as per the examiner’s suggestion. Page no. 86.

Comment 18: Get rid of the habit of referring an equation number before it appears in the text. See Eq. 3.1, for example. The text should be written in different manner.

Response: Thank you for your valuable feedback regarding using equation number before the equation is introduced in the text. As per the comment, I modified the sentence. Page no. 87

Comment 19: Page 91: Line 8: Change “sections” to “Sections”.

Response: Thank you for your suggestion. The suggestion has been incorporated into the revised thesis. Page no. 93.

Comment 20: Fig. 4.2: Mention other parameters in a box or caption.

Response: Thank you for your valuable feedback regarding the presentation of additional parameters. I understand the suggestion to include them within a dedicated box or caption. However, I provided the other parameter in the caption of Fig. 4.2 in the revised thesis. Page no. 96.

Comment 21: Eq. 4.1: Change “Where” to “where”. Same in Eq. 4.2. Also, explain Eq. 4.2.

Response: Thank you for your attentive review. I have identified the capitalization errors in Eq. 4.1 and Eq. 4.2. After that, I revised them both to use lowercase "where" for proper equation formatting. Also, Eq. 4.2 was explained on page 122 of the revised thesis document.

Comment 22: Section 5.1.1: Point 4: Correct grammar. Points 10, 11 and 12 are not clear.

Response: Thank you for your thorough review of my thesis. I appreciate you identifying areas for improvement in Section 5.1.1. I read Section 5.1.1 and modified the point 10, 11 and 12 in the revised thesis according to the examiner's suggestion. Page no. 178 and 179.

We appreciate all your insightful comments. Thank you for taking the time and energy to help us improve the thesis.

Thank You.