[1.] Peter OMONIYI

STUDY OF THE OPTIMIZATION OF MACHINING PARAMETERS AND NANO–LUBRICANT EFFECTS ON DRILLING, GRINDING, AND TURNING MACHINING PROCESS – CHALLENGES AND FUTURE TRENDS

[1.]Department of Mechanical Engineering Science, University of Johannesburg, Johannesburg, SOUTH AFRICA

Abstract: Any machining operation that generates heat must adequately dissipate it to minimize thermal stresses on the tool–workpiece contact. This inescapable heat production phenomenon, caused by using suboptimal machining parameters and a lack of long–lasting machining lubricant, adversely impacts the finished surface quality, tool destruction rate, and workpiece structure. Therefore, this review focuses on optimizing machining parameters and nano–lubricant effects on the various response parameters such as surface finishing, materials removal rate, tool wear rate, and cutting forces under drilling, grinding, and turning machining. The study reviewed reputable articles from Elsevier, Springer, and other quality outlets. This review cut across the impact of machining parameters and nano–lubricants on drilling processes and the impact of machining parameters and Nano–Lubricants on the grinding process. Also, this review studied machining parameters and Nano–Lubricants in the turning process. The study discusses the challenges of optimizing machining parameters during the drilling, grinding, and turning. It is anticipated to improve the capacity for heat transfer; surface structure, tool wear, and temperature are anticipated to be the machining parameters affected by nanofluid MQL in various machining processes, such as drilling, turning, and grinding. From the study, it will be recommended that a multi–optimization model with a flow rate of the MQL nano–lubricant and the machining parameters should be built under hybrid cryogenic–MQL machining conditions.
Keywords: Machining, Nano–Lubricant, Drilling, Grinding, Turning, Parameters Optimisation

1. INTRODUCTION

Manufacturing entails different processes or methods for producing mechanical and industrial components [1]. Various processes are employed, such as milling, grinding, turning, and shaping. However, in this article, the focus is on the drilling, grinding, and turning procedure for the optimization of machining parameters with different machining conditions such as nano–lubrication, flood cooling, vegetable cutting fluid, and mineral oil cutting fluid via minimum quantity lubrication, and dry cutting process [2–5]. Drilling mechanical components is one of the most widely used processes in the manufacturing industry. Drilling a particular hole dimension requires a lot of mechanical power relative to the drilling parameters during the machining process [6–7]. Parameters include the hole depth, the machine's movement during drilling (feed rate), and the cutting speed of the spindle that carries the drilling tools [8–10]. Also, some features contribute to the performance of the drilling process, such as the flute, helix angle, drilling axis, drilling diameters, the shank, and the materials used to develop the drilling tools. This analysis is presented in Figure 1 [9–11]. Tool path optimization techniques are frequently applied to Computer Numerical Control Machines to minimize energy consumption, production time and cost, etc. Several artificial intelligence systems based on the Traveling Salesman Problem (TSP) have been put into practice sectors to maximize tool trajectory length in diverse manufacturing processes, mostly the procedure of drilling holes [12]. Dhouib and Zouari [13] employed the Adaptive–Dhouib–Matrix–3 (A–DM3) to predict an iterated stochastic Dhouib–Matrix–3 (DM3) metaheuristic (T.S.). To verify the A–DM3 method's capacity and stability to determine the shortest drilling tool path, it was tested using a rectangular grid of holes in six real–world case studies. Additionally, it is contrasted with some widely employed techniques, including the hybrid Cuckoo Search Genetic Algorithm (CS–GA), modified Shuffled Frog Leaping Algorithm (mSFLA), Ant Colony Optimization (ACO) and several of its derivatives, and Genetic Algorithm (G.A.). According to computational results, the suggested A–

DM3 outperformed these well-known metaheuristics in the literature, especially in a medium and large number of holes. As a result, A-DM3 beat rival algorithms to produce a new record for the shortest path length, often improving upon it by almost 100%. Several modeling tools have been employed in various machining processes, which have proven viable for the parameter's optimization and assisted in identifying the significance of the nano-lubrication in the drilling procedure. In turning operations, the cutting model is different from drilling and grinding.

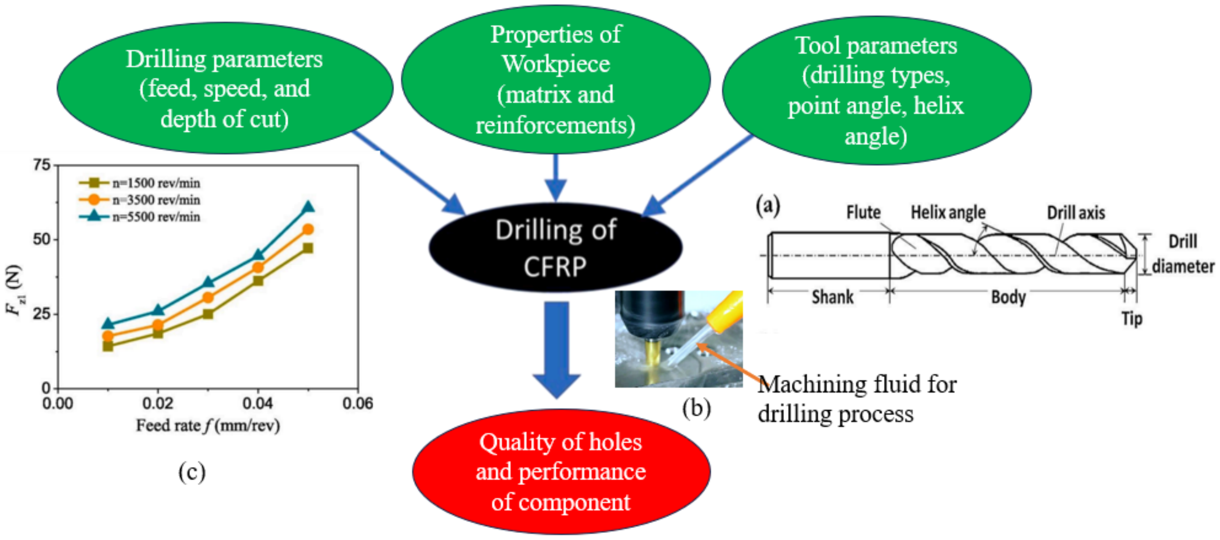

Figure 1: Key characteristics of the drilling process in the manufacturing industry, (a) the drilling bit, (b) setup of the drilling process, (c) performance analysis of the machining parameters

Turning process, the cutting tool can be employed to cut through high depth of cut, by using a lathe to spin the metal and a cutting tool moving linearly along the diameter to remove metal. Turning is a machining operation that results in a cylindrical shape [14–16]. Cylindrical materials employed to build mechanical systems are dimensioned via turning, as illustrated in Figure 2a. The application of optimization models for predictions for turning parameters and the study of the cutting fluid on the workpiece's chemical, mechanical, and thermal properties have been transformed from a raw product to a finished product [17–25]. However, suppose the workpiece's surface is unsuitable for mechanical operations. In that case, the developed component or part of the component will be taken for grinding operation to obtain the desired surface roughness. The grinding process, commonly called surface grinding, is a type of machining where the material is removed to achieve surface finishes and precise finish tolerances using a powered abrasive wheel, stone, belt, paste, sheet, and compound [21–30]. Rekha et al. [31] use the Taguchi technique and Grey Relational Analysis as the primary tools used in this study to choose the best cylindrical grinding process variables for austenitic stainless steel 304. The input elements in a grinding operation are the process parameters, which, when combined, significantly impact the output responses. The workpiece speed, longitudinal feed, transverse feed, and coolant flow rate are the variables related to the grinding process examined in this study. Surface roughness and material removal rate are the performance metrics on which the impact of various grinding parameters is examined. The L9 orthogonal array, produced using the Taguchi technique, served as the basis for the experiments. Additionally, the ideal settings for the grinding process (longitudinal feed = 6 m/min, work speed = 20 m/min, coolant flow rate = 1.43 l/min, and transverse feed = 0.02 mm), which meet both requirements (surface 189.37 mm^3 of material removal rate and 0.395 lm of roughness) were forecast with Grey Relationship Evaluation. Also, Awale et al. [32] researched MQL optimization of the machining fluid during the grinding process with grinding parameters. Yang et al. [33] show that optimising machining fluid and its parameters in the grinding process is highly needed for advanced manufacturing for sustainable production of engineering components, as shown in Figure 2b.

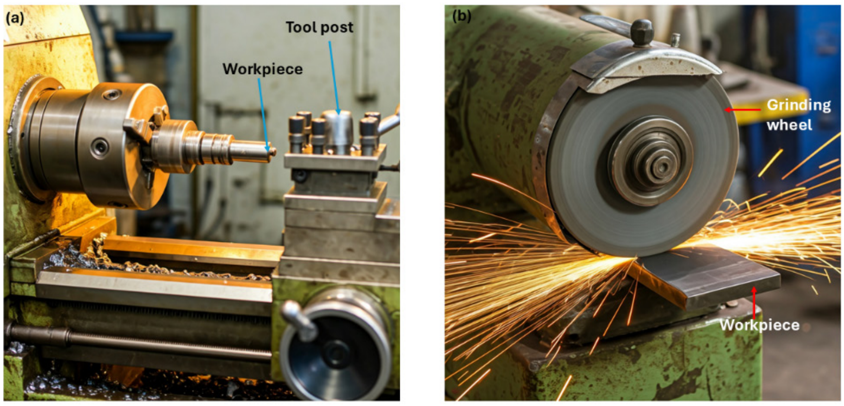

Figure 2: (a) Turning characteristics and (b) grinding operations

The application of several optimization tools is promise–able for the machining process, such as drilling, grinding, and turning operations [34–37]. However, there are still challenges with the end product during manufacturing when it comes to the complex production of mechanical systems [38–41]. Therefore, this study reviews the optimization of machining parameters and the effects of nano–lubricants on grinding, drilling, and turning operations. Also, to identify the challenges and suggest possible solutions to the existing problems identified in this review study.

2. IMPACT OF MACHINING PARAMETERS AND NANO–LUBRICANTS ON DRILLING PROCESSES

The minimum quantity lubrication (MQL) approach and cutting fluid with a blend of vegetable oil and Al_2O_3 were used in research by Pal et al. [42]. The primary goal of the study was to examine how drilling AISI 321 stainless steels using HSS drilling instruments performed in different lubricants and coolant settings (dry, flood, unadulterated MQL, and nanofluid MQL). Drilling actions, surface roughness, drilling tip temperatures, and tool wear process were among the factors examined. The air pressure was set at 6 bar, and the coolant supply rate was 120 mL/hr for the MQL conditions. Different amounts of nano–Al_2O_3 (0.5, 1.0, and 1.5 weight percent) have been added to the nanofluids to assess the cooling abilities of sunflower oil. In light of the results, drilling with pure, wet, and dry MQL was exceeded by cutting fluids using vegetable oil and Al_2O_3 in MQL drilling. When using nanofluid MQL drilling, the 30th hole showed a considerable reduction in thrust force, torque, surface roughness, and drill tip temperature of around 44%, 67%, 56%, and 26% compared to flood circumstances—additionally, drilling with nanofluid MQL settings significantly reduced tool wear. The more significant chilling impact caused by NFMQL owing to the lubricating qualities of nanoparticles may be the cause of the improved results of nanofluid MQL drilling. Using Pal et al. [43], Another study used the MQL drilling method to test the cooling and lubrication capabilities of several nanofluids made of vegetable oil combined with different nanoparticles (including Al_2O_3, MoS_2, SiO_2, CuO, and Graphene). The primary goal of this study was to compare the drilling efficiency of various cooling conditions, such as dry, flood, unadulterated MQL (PMQL), and the nanofluid MQL (NFMQL), in terms of cutting traits like thrust effect, torque, roughness of the surface, drill tip temperatures, and wear mechanism when drilling AISI 321 stainless steel. The experiment showed that NFMQL techniques had superior performance and better machining characteristics. The cooling strategy utilizing 1.5 percent by weight Al_2O_3 offered better cooling and lubricating effects, improving machining qualities among the NFMQL conditions. In comparison to flood drilling at the 30th hole, the thrust force, torque, roughness of the surface, and drill tip temperature obtained from 1.5 weight percent Al_2O_3 NFMQL drill significantly 1035 N, 10.8 Nm, 2.902 m, and 56.5 °C, respectively. These values were decreased by around 42.81%, 64.7%, 53.84%, and 20.97%. In addition, comparable to other drilling circumstances, the 1.5 weight percent Al2O3 NFMQL condition showed the smallest amount of tool wear. The nanoparticles of Al_2O_3 mixed with soybean oil showed several tribological enhancement mechanisms, including self–repairing or fixing processes, picking or ball–bearing processes, polishing processes, and tribo–film creation among contacting surfaces, which improve drilling characteristics. These mechanisms may be responsible for the outstanding performance of Al_2O_3 NFMQL.

Ezilarasan et al. [44] attempted to simulate, evaluate, and investigate the machining properties of an alloy throughout the drilling process. The subject of the inquiry was using a silver nanoparticle fluid in a Minimal Quantity Lubrication (MQL) setting. The authors examined several variables: thrust force, drill cutting edge temperature, side wear, and surface polish. The study also investigated the residual stress under various combinations of process factors. Multi–response optimization using RSM and empirical approaches for these variables were created. The results showed that feed rate (which contributed 60%), spindle speed (which contributed 88.63%), feed rate (which contributed 71.42%), and spindle speed (which contributed 67.76%) were, respectively, the primary effects on thrust effect, drill cutting temperature, roughness of the surface, and tool wear, with additional variables having a smaller impact. Utilizing a cutting fluid made from vegetable oil and several Minimal Quantity Lubrication (MQL) techniques, both with and without the inclusion of graphene nanoparticles, the hole drilling efficiency for stainless steel AISI 321 was evaluated in the study by Pal et al. [45]. The experimental findings showed that, in comparison to pure MQL settings, the MQL drill with 1.5 wt% nanoparticles of Graphene dramatically decreased the thrust force (by 27.4%) as shown in Figure 3, pressure (by 64.9%), the roughness of the surface (by 33.8%), and coefficients of resistance (by 51.7%) at the 30th hole. Additionally, it increased tool life. In conclusion, adding sufficient graphene nanoparticles to the fluid MQL drill process improved the drilling characteristics by enhancing lubrication performance and film stability.

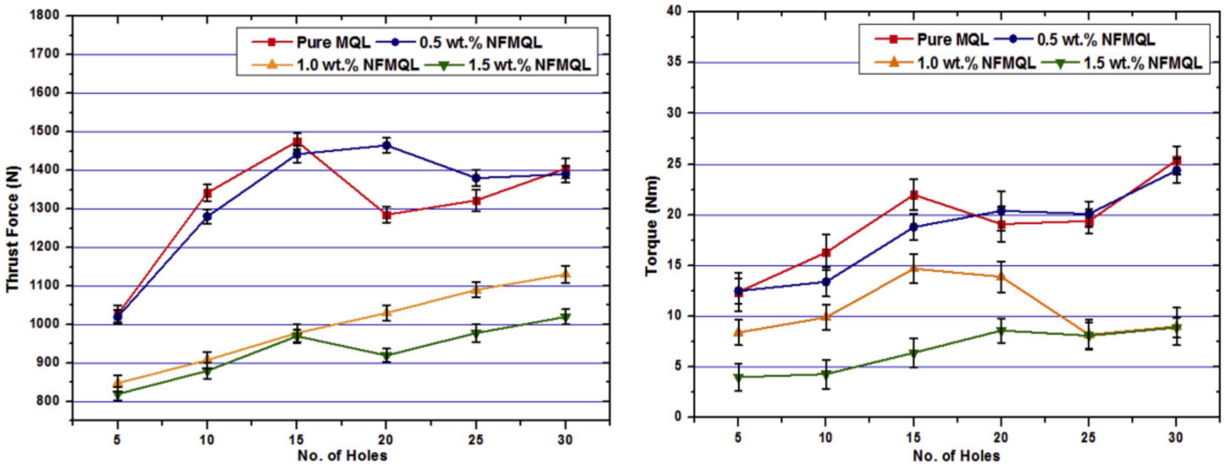

Figure 3: Drilling analysis of AISI 321 stainless steel, (a) differences in thrust force (N) values, and (b) Disparity in torque (Nm) varied depending on the lubrication environment. Source: [45]

High–speed stainless (HSS) drill bits were used to drill Aluminium 6063 alloy, and tests were done to examine how well they performed under various lubrication conditions, including dry, flooded, unadulterated minimum amount lubricant (MQL), and the MQL with nanofluid. The analysis was restricted to measuring the forces of cutting (thrust force and torque), tool wear, and surface roughness. A 200 ml/h oil flow rate and a 70–psi air pressure were maintained by both MQL procedures (pure MQL and MQL containing nanoparticles). The nanofluid in question comprised the fundamental oil (soybean oil) and 1.5 percent of the volume of 20 nm–sized nanoparticles (Al_2O_3). Compared to alternative coolant–lubrication systems, the testing findings show that the nanofluid MQL (NFMQL) substantially boosts the number of drilled holes while decreasing drill torques and thrust forces. The improved cooling capacity and decreased friction forces at the tool, chip, and workpiece interfaces of NFMQL are responsible for its excellent performance. Additionally, the nanofluid MQL successfully removes burrs and chips, improving hole surface circumstances and lengthening tool life by reducing tool wear. The effects of the cutting fluid comprising nanoparticles of Aluminium oxide and mineral oils on tool life and roughness of the surface during the drilling process of the stainless steel 304 were examined by Subhedar et al. [47].

In a two–step process, the researchers produced the nano–cutting fluid by adding Al_2O_3 nanoparticles to the cutting metal fluid at fractions of the volume of 0.3, 0.8, and 1%. The stability of the nanofluid is achieved using ultrasonic agitation force and drilling on a vertical CNC machine at speeds of 1000 and 1500 rpm with a constant feed rate of 0.050 mm per revolution. The results demonstrated that nano coolants lengthen tool life and lessen surface roughness. When using Nano cutting fluid, which has a 1% volume percentage and has the least surface roughness at 1000 rpm, tool life is shown to be the longest. The resulting results demonstrate how useful nano–coolant is. The tool undergoes rotational force from interacting with the workpiece throughout the drilling process. This rotational force can lead to imperfections or even the complete malfunction of the tool. Nam et al. [48] presented the drilling rotational forces observed in micro–drilling experiments under various drilling conditions. The drilling rotational forces for each set of 10 holes were averaged and depicted according to the number of holes drilled. When utilizing compressed air lubrication, the micro–drill failed at the 87th hole. It is important to note that 150 holes were considered for the other conditions, as the micro–drill did not break during the drilling of 150 holes. Conventional minimum quantity lubrication (MQL) and nanofluid MQL reduce the magnitude of the rotational force compared to compressed air (C.A.) lubrication. Furthermore, using nanofluids decreases the drilling rotational force compared to standard oils.

Table 1: Summary Analysis of the Literature Review for Drilling Machining

Authors Details	Base lubricant	Nanoparticles /% conc.	Method of delivery	Workpiece materials	Machining Parameters	Findings
Nam et al. [52]	Vegetable Oil	0.4wt% of Diamond nanoparticles	Two–Step Method	Titanium alloy (Ti–6Al–4V)	Drill diameter, Feed Rate, Spindle Speed	The optimal process is achieved with the weight concentration
Muthuvel et al. [53]	Ethylene Glycol	1g of 70nm C.U. nanoparticles for every 500 ml	Two–Step Method	AISI 4140 Steel	Cutting Speed, Feed Rate	The chosen concentration has decreased flank wear and surface roughness by 71% and 53%, respectively.
Babu et al. [54]	Ethylene Gycol	1g of 50nm white C.U. nanoparticles for every 500 ml	Two–Step Method	AA 5052 alloy	Surface Roughness, Cutting Speed, Tool Wear	When contrasted with dry and oil lubrication, it was shown that using copper nanofluid under MQL Tool wear reduces by 36 and 24%, and surface roughness reduced by 92 and 76%.
Shalimba et al. [55]	Jatropha Oil	1wt%–10wt% of Iron nanoparticles	Two–Step Method	Steel ČSN 11 523	Cutting Temperature, Depth of Cut	The efficacy of lubrication and cooling is enhanced when nanoparticle concentration is added to jatropha oil.
Liew et al. [56]	Water	4wt% of Cu nanofiber particles	Two–Step Method	Titanium Alloy	Cutting Speed, Feed Rate	The findings demonstrate that, in comparison to pure deionised water, carbon nanofiber nanofluid provides a superior surface finish and a lower cutting temperature.
Nam & Lee [57]	Vegetable Oil	0.4wt% of Diamond particles	Two–Step Method	Titanium alloy (Ti–6Al–4V)	Feed Rate, Drill diameter, Spindle Speed	The nano–MQL successfully reduces drill tool chip adhesion and hole burr.
Cetin et al. [58]	Rapeseed Oil (Canola)	0.5wt% Silver nanoparticles	Two–Step Method	AISI 304 Austenitic Stainless Steel	Cutting Speed, Feed Rate	Vegetable oils enhanced with nano–silver and boron did not perform well in lowering cutting forces.
Gomez–Merino et al. [59]	Taladrine, T	0.03vol of silica nanoparticles	Two–Step Method	Steel	Cutting Speed, Depth of Cut	The application of phase–change substances, including solid particles in drilling, as a sustainable, environmentally
Pal et al. [60]	Vegetable Oil	1.5wt% of MoS2 Nano–particles	Two–Step Method	AISI 321 stainless steel	Cutting Speed, Feed Rate	High surface activity nano–MoS2 particles readily adsorb to the interacting surfaces, sustaining the lubricating effect.
Hoang et al. [61]	Caltex Aquatex 3180	0.1wt% of graphene nanoparticles	Two–Step Method	AISI SUS 304 Stainless Steel	Spindle Speed, Feed Rate	The method of using nano–lubricant can be applied to deep drilling of other hard–to–cut materials.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

Several scientists have employed experimental methodologies to explore the utilization of nanofluids in drilling operations. Mosleh et al. [49] performed experiments under high–pressure conditions using cutting fluids improved by incorporating MoS_2 and diamond nanoparticles to assess the characteristics of these liquids in a typical drilling process. The results of the experiments demonstrated that nanofluids containing 2–4% MoS_2 nanoparticles amplified the load–bearing capability by up to 16% while significantly reducing the transfer of materials from smoother stainless–steel balls to the harder tungsten carbide ball. Conversely, nanofluids containing a 1% concentration of diamond nanoparticles led to a decrease in load–bearing capacity of approximately 10%. Nam et al. [50] conducted a comprehensive assessment of the characteristics of a micro–drilling procedure employing the nano Minimum Quantity Lubrication (MQL) technique. In this context, diamond nanoparticles measuring 30 nm in diameter were employed alongside vegetable oil and paraffin as the base fluids. The study revealed that the nano MQL significantly enhances the quantity of drilled orifices while simultaneously reducing the forces exerted on the drill and the torque required for drilling, as opposed to conventional approaches. Additionally, the nanofluid MQL effectively eliminates the undesired protrusions and fragments formed during drilling. Liew et al. [51] empirically assessed the effects of the carbon nanofiber nanofluid on the drilling process of AISI 304 steel. The efficiency of drilling was evaluated by examining the roughness of the hole surfaces, the precision of the hole dimensions, and the occurrence of burrs. Furthermore, a comparison was made between the drilling performance of the nanofluid and that of distilled water. The findings indicated that the nanofluid improves the surface's smoothness and the hole's accuracy while reducing burr formation. Table 1 debit summary study of drilling application via the nano–lubrication process.

3. IMPACT OF MACHINING PARAMETERS AND NANO–LUBRICANTS ON THE GRINDING PROCESS

To serve as a coolant (cutting fluid) during the grinding process, Kananathan et al. [62] examine recent developments and applications of nanoparticles in lubricants. Coolants are employed during grinding to lessen workpiece thermal deformation, minimize wheel wear, flush chips, and improve surface smoothness. Flood cooling, a traditional method, disperses much fluid and mist, endangering people and the environment. Thus, as an alternative, a cutting–edge cooling method called Quantity Lubrication (MQL) has been developed to improve surface smoothness, lower costs, lessen negative effects on the environment, and use less metal–cutting fluid. A study of the use of different nanoparticles and their effectiveness in grinding processes was carried out in addition to implementing sophisticated cooling techniques. The study also discussed how nanoparticle performance relates to cutting forces, surface quality, tool wear, and cutting zone temperature. According to the study, the nanofluid's exceptional qualities can cool and lubricate machinery during production [62]. Experimental research determined the impacts of minimum quantity nano–lubrication (MQNL) on the surface grinding of tungsten carbide grade YG8. The studies used two distinct base oils—mineral (paraffin) and vegetable (sunflower)—to distribute MoS_2, graphite, and Al_2O_3 nanoparticles in varied concentrations. The process efficiency was assessed using the grinding outputs, like specific energy, cutting force, and surface quality. Additionally, the effectiveness of MQNL in grinding W.C. material was assessed by contrasting the outputs of grinding in various environments, including dry, wet, and MQL. The findings demonstrate that the MQNL technique successfully increases process efficiency by lowering the grinding force and specific energy and improving surface quality if nanoparticles are chosen effectively [63].

Zhang et al. [64] have discussed the dangers of traditional flood cooling techniques and the difficult circumstances that might arise during dry grinding, highlighting the relevance of minimal volume lubrication (MQL) as the only workable way for grinding cemented carbide. The impact on the residual tension in the cemented carbide is complicated by the introduction of force and heat changes brought about by the inclusion of nanoparticles during grinding. The arrangement of the particles on the grinding wheel's surface was analyzed using a single abrasion grinding force model to calculate an effective number of abrasive particles. The workpiece was then subjected to a stress fracture model developed and used in a method of step–by–step attenuation. The heat field model was the foundation for creating a thermal stress model. A final model for forecasting the residual stress was developed by evaluating the grinding process outcomes and performing stress loading and relaxation. Four distinct YG8 grinding settings were used, and a minimum frictional coefficient of 0.385 was attained using tiny fluids minimum quantity lubrication (NMQL). This allowed the model to be experimentally validated. Precision analysis was used to establish the validity of the stress residual model. During dry grinding, a minimum error value of 5.9% was found in the orthogonal direction to the workpiece feed direction. Comparatively, MQL applications using unadulterated oil as a base and flooding cooling based on water–grinding fluids fared worse than those using nano lubricants. By lowering the tangential grinding power, particularly grinding energy, and offering high grinding (G)–ratios, nano lubricants demonstrated superior grinding results. Through methodical tribological testing, modeling a machining contact combining rough crystals and the workpiece in a surface grinding technique (as shown in Figure 4), a thorough evaluation of the enhanced efficiency of nano lubricant in MQL grinding was carried out. By continually delivering active lubricant additives and generating a durable, low–friction tribo–film at the sliding interface between the rough grit and the workpiece surface, it was shown in Figure 4b that nano lubricants efficiently reduce sliding frictional losses [65].

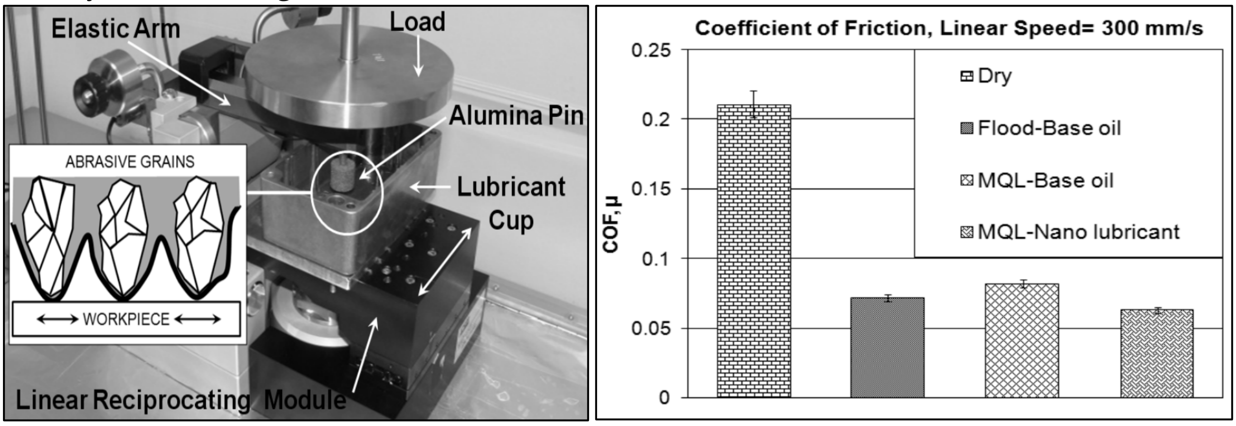

Figure 4: (a) Experimental Setup of the Tribological Testing and (b) A Graph Comparing the Coefficient of Friction ss Regard to the Lubricant Used Source: [65]

Using a vortex tube to create a low–temperature grinding atmosphere to increase heat transfer and a combination of nanoparticles used as a nano–lubricant to reduce friction in tungsten carbide ultra–precision grinding, Zhang et al. [66] propose a reduced temperature nano–lubrication approach. The outcomes demonstrate that the technique greatly lowers wheel deterioration and raises workpiece surface integrity. Compared to conventional minimal quantity lubrication, the arithmetical average height (Sa) and the maximum height (Sz) were lowered by 50.8% and 65.3%, respectively, and wheel degradation was reduced by 57.8%. These outcomes were achieved using a 1:2 mix–ratio MoS_2/Fe_3O_4 nano–lubricant and an optimized lower–temperature gas at 20 °C. Multiwall carbon nanotubes are combined with SAE 20W 40 oil to create nanofluids for the grinding process. The surface coarseness and microcracks are examined in this experimental investigation. The most popular material for molds and dies is AISI D3 tool steel, which was chosen to analyze the surface properties. According to experimental findings, the surface smoothness of the machined workpiece improves from micro to nanoscale. Using Minitab 15 software, the L8 orthogonal array was employed to optimize the machining settings in the Taguchi design of the experimentation technique. Regression analysis was used to build an empirical framework for forecasting output parameters, and the outcomes for the grinding process, both with and without nanofluids, were empirically evaluated. The significant parameter influencing surface roughness was identified using the analysis of variance and the F test. Analysis using atomic force microscopy showed that adding carbon nanotube to nanofluid during the grinding process improved surface properties, including surface roughness and microcracks [67]. Gao et al. [68], the aerospace industry now favors carbon fiber–reinforced polymer (CFRP), which makes it simple to manufacture integrated components with a high degree of specific strength and stiffness. The main technique used to produce precision components and ensure exact assembly location is grinding. However, because of its hygroscopicity, flood lubrication is only sometimes used in CFRP grinding, whereas dry grinding produces unwanted results, including increased forces, deteriorated surfaces, and blocked wheels. To get beyond these technological limitations, this work used grinding and friction–wear testing to analyze the grindability and resistive behavior of the CNT biological lubricant MQL. Compared to the dry state, the coefficient of friction was reduced by 53.47% thanks to the outstanding and long–lasting anti–friction capabilities of the CNT biological lubricant, according to the testing findings. The novel lubricant has also shown benefits regarding tribological characteristics and removing material behavior. Effectively reducing tensile breakage and tensile–shear fracture and eliminating material from multifiber blocks. Notably, compared to dry grinding, the tangential, normal, and specific grinding forces were all minimized by 40.41%, 31.46%, and 55.78%, respectively. The proposed approach minimized surface roughness and produced the ideal surface morphology by avoiding scratches, fiber pull–out, and resin spreading. Wheel clogging was also avoided by lowering the temperature and forming a lubricating oil film. Compared to dry grinding, Sa and Sq of the CNT biological lubricant decreased by 8.4% and 7.9%, respectively.

García et al. [69], an experimental strategy to improve the Ra–measured machining surface roughness is developed. The goal is to create a grinding lubricant with nanoparticles as the primary component. An investigation is made into how titanium dioxide (TiO_2) nanoparticles affect the surface roughness of cutting tools used in the metal–mechanics industry, emphasizing slitting knives. The literature demonstrates that nanoparticle concentrations less than or equal to 0.1% in weight have a substantial impact. A reaction surface statistical analysis was conducted using manufacturing variables like the spindle speed and rate of feed on grinding machines and control variables like nanoparticle concentration. According to the analysis of slitting knives, spindle speed, and feed rate have no discernible impact on surface quality. In contrast, the weight % of nanoparticles in the oil–based lubricant was the sole important factor. Utilizing response surface methods, the use of nanoparticles significantly improves the value of Ra. The initial Ra value of a fluid without nanoparticles is 0.9449, but the Ra value for a fluid with the ideal number of nanoparticles (0.055%) increases noticeably to 0.2805. The response has increased by an astounding 69% due to this improvement. As a useful cooling lubricant throughout grinding operations, the grinding fluid contains nanoparticles with qualities that minimize friction and wear. The grinding studies included nanoparticle jet MQL, minimal lubrication (MQL), dry grinding, and flood grinding. The grinding energies were distinct for each method, with an average of 84, 29, 8, and 45.5 J/mm3 for dry grinding, dry flooding grinding, MQL, and nanoparticles MQL, respectively. Notably, while utilizing nanoparticle MQL, the grinding energy reduced noticeably to 32.7 J/mm3. Flooding grinding, MQL, and nanoparticles jet MQL all resulted in appreciable decreases in surface roughness levels compared to dry grinding. The ten–point height of microcosmic unevenness values reduced by 1.5%, 0.5%, and 1.3%, whilst the overall topographic pattern values decreased by 11%, 2.5%, and 10%, respectively. These findings support the effectiveness of MQL nanoparticles as lubricants. The study also added MoS_2, Carbon Nanotube (CNT), and nanoparticles of ZrO_2 to the nanoparticle jet MQL's grinding fluid to examine their effects on lubrication. MoS_2 nanoparticles had a particular grinding energy of 32.7 J/mm^3, 8.22% and 10.39% lower than the other two varieties. The MoS_2 nanoparticles also decreased the workpiece's surface roughness, demonstrating their remarkable lubricating abilities. Various MoS_2 nanoparticle volume concentrations were investigated to determine their contribution to grinding surface greasing. The experiment used 1%, 2%, and 3%, and the findings showed that a volumetric concentration of 2% MoS_2 particles had sufficient lubricating effects. It was noted that when the volume amount of MoS_2 nanoparticles rose, the surface's particular grinding energy and roughness initially increased and later reduced [70].

Table 2: Summary Analysis of The Literature Review for Grinding Machining

Authors Details	Base lubricant	Nanoparticles used/% concentration	Method of developing the Nano–lubricant	Workpiece materials	Machining Parameters and Responses	Findings
Lee et al. [72]	Paraffin Oil	1%–4% Nanodiamond and Al_2O_3	Two Step Method	Steel	Surface Roughness, Grinding Force	It is conclusively shown that the volumetric concentration, type, and size of nanoparticles are crucial factors that affect how well the micro–grinding process works.
Zhang et al. [73]	Synthetic Lipids	6wt% MoS_2/CNT hybrid nanoparticles	Two–step method	GH4169 Ni–based alloy (Inconel 718)	Principal axis power, grinding scope	The results demonstrate that the MoS_2/CNT mixed nanoparticles outperform single nanoparticles in terms of lubricating effect and that the ideal MoS_2/CNT mixture ratio and nanofluid concentrations are 2:1 and 6 wt%, respectively.
Jia et al. [74]	Soybean Oil	4% mass fraction of MoS_2, ZrO_2 and polycrystal diamond nano–particles	Two–Step Method	Hardened 45 Steel	Feed Speed, Cutting Depth, Nozzle angle/ distance	When the nanoparticle mass fraction was larger than 6%, the lubricating effects of the nanoparticle jet MQL decreased as the mass fraction rose.
Kumar et al. [75]	Deionised Water	0.5wt% of Al_2O_3, ZnO, B_4C, MoS_2 and h–BN nanoparticles respectively	Two–Step Method	Silicon Nitride	Wheel Speed, Workpiece Infeed Speed, Depth of Cut, Grinding width	The experimental findings showed that MoS_2 nanoparticle–based nanofluids have improved lubricating capabilities.
Zhang et al. [76]	Bluebe #LB–1 synthetic lipid oil	2wt% of Al_2O_3 nanoparticles + SiC nanoparticles	Two–Step Method	Hard Ni–based alloy (Inconel 718)	grinding power, removing material Workpiece Rate, Surface Roughness (Ra)	When the ratio of N.P. sizes in the Al_2O_3/SiC mixture was 70:30, the maximum workpiece removal rate (189.05 mm3/(s N)) and the smallest RSm (0.0381 mm) were attained.
Zhang et al. [77]	Liquid paraffin, palm oil, rapeseed oil, and soybean oil	2–5wt% of MoS_2 nanoparticles	Two–Step Method	45 steel	Grinding pattern, Wheel Speed, Feed Speed, Cutting depth	The optimum addition amount of molybdenum disulfide nanoparticles in the experiment was 6% mass fraction.
Shabgard et al. [78]	Distilled water + 20wt.% canola oil	0.15, 0.25, 0.35vol% of CuO nanoparticles	One–Step Method	AISI 1045 Steel	Cutting Speed, Table Speed, Depth of Cut	The findings demonstrate that manufactured nanofluids efficiently lower temperatures and grinding forces, particularly under difficult machining circumstances.
Kalita et al. [79]	Paraffin (mineral–based) oil and soybean (vegetable–based) oil	8 wt% of emulsified MoS_2 nanoparticles	Two–Step Method	EN 24 Steel and Ductile Cast Iron	Wheel Speed, Workpiece Speed, Depth of Cut, grinding width, Grinding passes	The process efficiency of MQL grinding using nano–lubricants is increased by results demonstrating energy consumption, friction loss at the wheel–workpiece interface, and decreased tool wear.
Khatai et al. [80]	Water	4% vol. of Al_2O_3	Two–Step Method	AISI 52100 steel alloy	Grinding Force, Surface Roughness, Cutting Depth	Utilising the ZrO_2 nanoparticle as a nanotechnology lubricant in grinding is restricted by its lower heat conductivity and greater density.
Mao et al. [81]	Water	0.75 wt% Al_2O_3 nanoparticles	Two–Step Method	AISI 52100 Steel	Wheel diameter, Wheel speed, Cutting depth	According to experimental data, utilising the nanofluid mist is significantly influenced by the spraying direction of the MQL nozzles.

The negative environmental effects of machining lubricants are the main reason for using minimal quantity lubrication (MQL) technology instead of conventional techniques. The MQL technique is less successful than conventional approaches because of greater heat production while grinding and greater specific energy for cutting. However, including nanoparticles in the base oil may improve the lubricating efficacy in grinding. This study used the MQL approach to analyze the steel grinding procedure of the AISI D2 cold work tool. To assess their impacts on the forces that cut (typical and tangential) and roughness of the surface, two types of vegetable–based oils—colza and soybean. To with various quantities of MoS_2 and CuO nanoparticles. The findings showed that adding 4% CuO nano–powder and 2% MoS_2 nano–powder to soybean base oil reduced normal and tangential forces by 19% and 35%, respectively. Additionally, using 2% CuO nano–powder in colza base oil resulted in a considerable reduction of 77% in surface roughness compared with pure oil as a grinding fluid [71]. Table 2 presents a relevant literature summary to determine the challenges in grinding applications with nano–lubricants. Table 2 discusses several methods for preparing the nano–lubricant, its application, and its findings.

4. STUDY OF MACHINING PARAMETERS AND NANO–LUBRICANTS ON TURNING PROCESS

Due to its remarkable properties, ceramics are frequently used when machining extreme temperature alloys like Haynes 25 alloy. The effectiveness of a cutting tool composed of whisker–reinforced ceramics (WRCCT) in combination with the minimum amount of lubrication (MQL) technique was investigated in a study by Sarkaya et al. [82]. This was accomplished in particular by employing solid lubricants spread in nanofluid–MQL. Several cutting conditions, including dry cutting, turning with the base fluid MQL (BF–MQL), MQL employing hBN–based nanofluid (hBN–NMQL), MQL with MoS_2–based the nanofluid (MoS_2–NMQL), and MQL with graphite–based nanofluid (Gr–NMQL), were used in this work to investigate the Co–based Haynes 25 alloy. The feed rate (0.1 percent by weight and 0.15 mm/rev) and cutting speed (200 and 300 m/min) were modified. Before using the microscopic particles in the machining experiments, the researchers evaluated their stickiness and heat conductivity. Compared to the base cutting fluid, the results showed that the thermal conductivity coefficient increased by 11.90% in hBN–nanofluid, 16.29% in MoS_2–nanofluid, and 14.12% in Gr–nanofluid. Gr–NMQL showed the best machining performance regarding surface roughness, whereas hBN–NMQL successfully reduced notch wear and nose wear values. The temperature decrease reached 27.18% using hBN–doped nanofluids, 34.95% using MoS_2–doped nanofluids, and 29.32% using graphene–doped nanofluids compared to dry turning. To better understand novel approaches for extending the useful life of cutting tools and improving the calibre of final surfaces while turning difficult alloys, Sartori et al. [83] investigated the application of Minimum Quantity Cooling (MQC) and Minimum Quantity Lubrication (MQL) techniques. Solid Lubricants (S.L.) for additives were proposed and analyzed for two different MQL and MQC solutions. Among the solutions was a water–based solution with variable amounts of graphite and an MQL technique using vegetable oil enhanced with PTFE particles. The research proved that the newly created techniques improved tool longevity and the precision of machined surfaces. The MQC techniques, with the help of Solid Lubricants, showed the best results, as shown in Figure 5a–d.

The turning process has been subjected to several attempts to regulate cutting force, temperature, roughness of the surface, and tool wear. However, it might be difficult to constrain these parameters directly with dry machining. Numerous lubricants have so far been used to solve this problem. Nanofluids were produced in the work by Rao et al. [84] by adding 6% and 8% of Al_2O_3 nanoparticles by volume to the vegetable fluid. These nanofluids were used to mill EN–36 steel, and the variables were assessed using conventional dry machining and lubricants made from MQL nanofluids. The studies used the Taguchi methodology, and an analysis for variance (ANOVA) was used to examine the results.

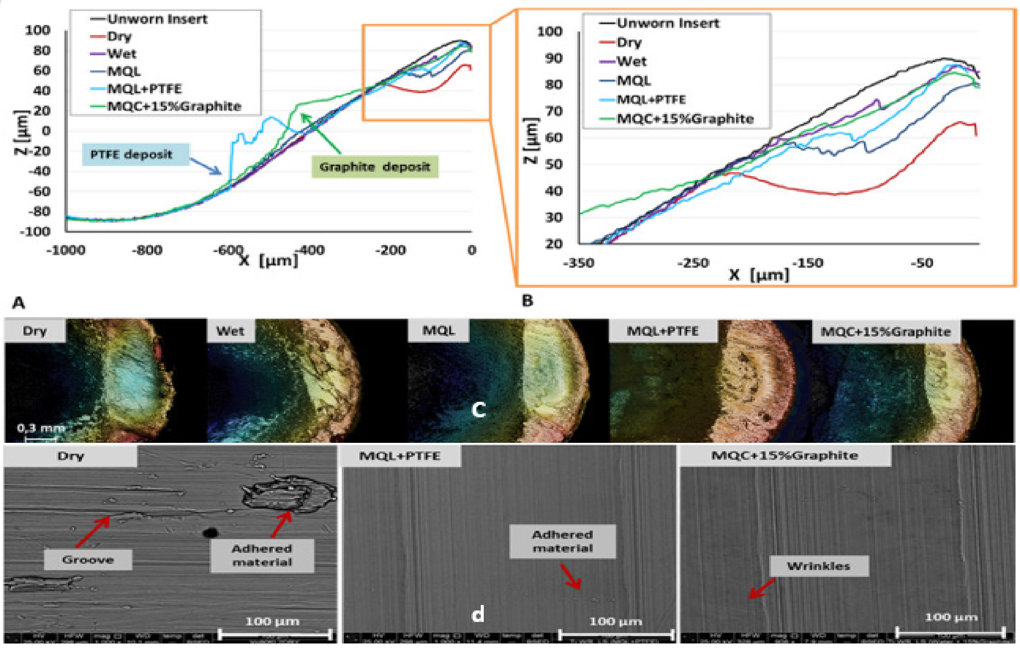

Figure 5: Cutting tool rake faces under the various machining conditions: (A) overall 2D profiles, (B) the zone of the damaged cutting edge, (C) 3D tool images, and (d) surface defects detected on samples machined, dry, SL–assisted MQL, and SL–assisted MQC. Source [83]

The experimental and anticipated values were compared and analyzed. Roughness, temperatures, cutting force, and tool wear were much better with 8% nanofluid with MQL than they were with 6% volume of nanofluid using MQL or dry machining, according to the analysis of the findings. For example, the cutting force was 280.46 N, the temperature was 44.16 °C, the roughness was 0.1 m, and the tool wear was 0.0031 mm. The results showed that, in comparison to dry milling, the application of 8% volume of nanofluid using MQL increased machining performance. Optimizing the MQL methodology for the hard turning process of 90CrSi steel (60–62 HRC) is the main objective of Duc et al.'s [85] study. In order to achieve this, Al_2O_3 and MoS_2 nanoparticles are added to the base fluids, which include soybean oil and a water–based emulsion. The researchers use analysis of variance (ANOVA) to determine how MQL factors affect the force of cutting and surface roughness. The results show that coating carbide insert performance is enhanced when MQL uses Al_2O_3 and MoS_2 nanofluids. Additionally, the fluid type, nanoparticles, and their concentration highly impact the cutting performance. Future studies using Al_2O_3 and MoS_2 nanofluids will benefit greatly from the study's understanding of the interactions between these factors. By mixing cutting fluid comprising alumina and multi–walled carbon nanotube (MWCNT) nanoparticles at different volumetric percentages of 0.25, 0.75, and 1.25 vol%, Sharma et al. [86] created a hybrid nano–cutting fluid. The basic nanofluid (Alumina nanofluid) and the generated hybrid nanofluids' thermophysical characteristics were studied. Additionally, pin–on–disc tests were used to evaluate the tribological properties of all nanofluid samples, and contact angle measurements were used to determine their spreadability. Figure 6(a–b) shows dramatically how rising temperatures and concentrations of nanoparticles both improve the thermal conductivity and viscosity of nanofluids and hybrid nanofluids. Al–MWCNT hybrid nanofluid exhibits a noteworthy increase of 11.13% in temperature over the base fluid spreadability. The results showed that a reduction in wear was caused by a rise in the concentration of nanoparticles in the cutting fluid, having the hybrid nanofluid showing the least wear, as shown in Figure 6c.

Also, Figure 6d shows that the smallest coefficient of friction is held by Al–MWCNT next to the alumina nanofluid. This decreased coefficient of friction decreased the cutting forces by reducing the contact force. Additionally, using the minimal quantity lubrication (MQL) approach, these nanofluids' effectiveness as cutting fluids was assessed while turning AISI 304 steel. Measurements of the cutting forces and surface roughness created regression models. The results show that the hybrid nanofluid performs better than the alumina nanoparticle mixed cutting fluid regarding machining forces and surface roughness.

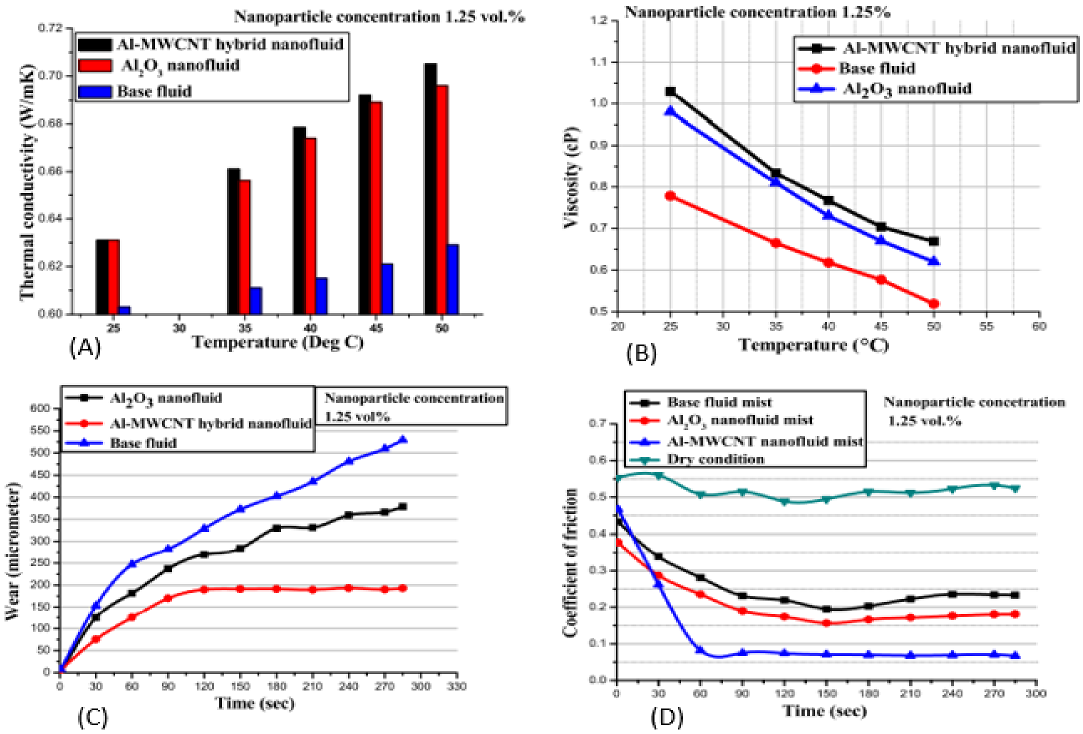

Figure 6: the study of the effect of the Al_2O_3 and Al–MWCNTs on (a) Thermal conductivity, (b) viscosity, (c) Wear analysis, and (d) coefficient of friction on the base fluid. Source: [86]

Turning is a procedure that is regularly used in machining and is widely applied. However, when it involves turning high–strength materials, much heat is produced, which has detrimental impacts, including accelerated tool wear, erratic chip formation, and tinier variations in physical attributes. Synthetic coolants, sometimes known as flood–type coolants, are used in excess to solve these problems, but controlling and getting rid of the extra coolant is difficult and quite expensive. The Minimum Quantity Lubrication (MQL) approach is used in conjunction with Water Soluble Cutting Oil that has been injected with nanoparticles (particularly Graphene) to address this problem. The goal of this strategy is to improve machining quality. To achieve a surface roughness of 0.462 μm while maintaining a cutting tool temperature of 55 °C using the MQL–GO (Graphene Oxide) process, the experimentation focused on the turning process of Monel K500 while taking into account various parameters, including cutting speed, feed, and depth of cut [87]. Singh et al. [88] found that increasing the concentration of nanoparticles increases both thermal conductivity and viscosity. At the same time, the hybrid nanofluid has a lower thermal conductivity than its constituent parts and a viscosity in the middle of the two. The tribological analysis confirms that wear decreases with increasing nanoparticle concentration, with the hybrid nanofluid showing the smallest amount of wear. In addition, the hybrid nanofluid outperforms the base fluid and the alumina–based nanofluid regarding wetting properties. Hybrid nanofluid surpasses cutting fluid combined with alumina nanoparticles, as demonstrated by turning AISI 304 steel using the minimal quantity lubrication (MQL) approach. The study shows that the efficiency of hybrid nanofluids is improved when GnP and alumina are combined. When combined with MQL, using a hybrid nanofluid significantly lowers the force needed to cut, thrust, and feed force by 9.94%, 17.38%, and 7.25%, respectively, and the surface roughness by 20.28%. To reduce the negative effects of friction and heat on the tool and the workpiece, nanofluids are frequently used. Water and Al_2O_3 nano–powder are combined with mustard oil to create the Nanofluid mixture. The goal is to determine how cutting parameters and nanofluids affect the temperature of the tool bit, workpiece, surface roughness, material removal rate, and cutting forces during the turning of mild steel. High–Speed

Stainless Steel was used as the cutting tool for the cutting processes carried out on a conventional lathe machine while altering the spindle speeds (N), feeds, and depth of cut. It was shown that employing Al_2O_3 and mustard oil compared to Al_2O_3 with water nanofluids resulted in a better material removal rate. Additionally, it was discovered that the surface roughness in the latter scenario was inferior [89].

Table 3: Summary Analysis of the Literature Review for Turning Machining

Authors Details	Base lubricant	Nanoparticles used/% concentration	Method of developing the Nano–lubricant	Workpiece materials	Machining Parameters	Findings
Sayuti et al. [91]	Mineral Oil	0.2–1.0wt% of SiO2 nanoparticles	Two–Step Method	AISI4140 Steel	Feed Rate, Cutting Velocity, Depth of Cut	With a 0.5–weight percent concentration in the mineral oil, a reduced air stream pressure, and a 30–nozzle orientation angle, the roughness of the surface can be increased.
Prasad et al. [92]	Water Soluble Oil	0.5wt% of nano graphite powder	Two–Step Method	AISI 1040 Steel	Cutting Speed, Surface Roughness, Depth of Cut	In comparison to dry machining, MQL nanofluids routinely outperform Flood lubrication.
Patole et al. [93]	Ethylene Glycol	0.2wt% of MWCNT nanoparticles	Two–Step Method	AISI 4340 Steel	Cutting Speed, Surface Roughness	The study of the results also shows that ethylene glycol–nanofluid is one of the most important variables impacting surface roughness.
Padmini et al. [94]	Vegetable Oils	0.5wt% of MoS_2 nanoparticles	Two–Step Method	AISI 1040 Steel	Cutting Speed, Feed, Depth of Cut	Except for absorbance, basic characteristics have increased as NPI has grown. Compared to all other lubricant conditions, 0.5%CC+nMoS_2
Patole et al. [95]	Ethylene	MWCNT nanoparticles	Two–Step Method	AISI 4340	Feed Rate, Depth of Cut, Cutting speed, Tool Nose radius	Compared to a traditional flood system, good surface and tool wear roughness may be achieved while preserving cutting forces with the right process parameters in MQL modes with nano coolant.
Shuang et al. [96]	Mineral Oil+Saponified natural oil+water	0.5wt% of Grapheme Oxide nanoparticles	Two–Step Method	TI–6AL–4V Titanium alloy	Cutting temperature, cutting Speed, Cutting depth, Feed Rate	When smaller velocities, lower feed, and greater coolant pressure were used, the cutting temperatures were lowered by 27.16 ℃, 30.42 ℃, and 31.8 ℃, respectively.
Yildirim et al. [97]	Vegetable Oil	0.5wt% of white graphite nanoparticles	Two–Step Method	Nickel–based Inconel 625	Speed of the cut, Feed Rate	According to the findings, 0.5 vol% hBN nanofluid has given results that are encouraging in terms of tool wear being reduced and good tool lifespan.
Yan et al. [98]	Grease	10wt% of copper nanoparticles	Two–Step Method	AISI 1045 Steel	Cut's Depth, Speed and Feed Rate	The experiment's findings demonstrated that the highest machining performance came from using liquid nitrogen and a 0.5 vol% hBN cooling technique.
Yildirim et al. [99]	Vegetable Oil	0.5wt% Alumina	Two–Step Methd	Inconel 625	Feed Rate, Cutting Speed	The 0.5% of alumina nano–vegetable–lubricant performed better than the base fluid
Krishna et al. [100]	Vegetable Oil	0.5% wt% of boric acid solid lubricant	Two–Step Method	AISI 1040 Steel	Feed Rate, Depth of Cut, Cutting Velocity	With a percentage rise in nano–boric acid in the base fluid.

To identify acceptable solutions with a minimum quantity of lubrication and cooling (MQCL) aided turning of Ti–6Al–4V ELI, Rahman et al. [90] studied 18 distinct nanofluids. They created two nanofluids by mixing canola and extra virgin olive oils with three different types of nanoparticles (0.5%, 2%, and 4% by volume): Al_2O_3, MoS_2, and rutile–TiO_2. A canola nanofluid with a 0.5% Al_2O_3 concentration produced an improved surface polish. On the other hand, it was discovered that canola nanofluid with 0.5% MoS_2 concentration substantially lowered temperature and increased chip removal. The nanofluids also displayed advantageous tool wear properties and reduced friction–related wear. SEM and x–ray dispersive analysis of the completed surface demonstrated the existence of tribo–film production and the effects of nano–polishing. The shape of the machined surface, the reduction in surface defects brought about by the manufactured nanofluids,

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

as well as the degree of viscosity (kinematic and dynamic), angle of contact, interaction area, and heat conductivity of the nanofluids were also included in this analysis. Table 3 shows the breakdown of some selected literature for the turning process via nanoparticle implementation in manufacturing.

5. DISCUSSION ON THE CHALLENGES AND FUTURE TRENDS IN THE OPTIMIZATION OF MACHINING PARAMETERS DURING DRILLING, GRINDING AND TURNING PROCESSES

The intricacy of interrelated factors offers a severe barrier to optimizing machining parameters. Changing one parameter can frequently cause ripple effects in others, necessitating a sought–after careful balance. When we evaluate parameters, such as cutting speed, feed rate, and tool shape during a milling operation, we learn they are not independent; as pointed out, searching for an optimum combination is more difficult [101]. This problem is exacerbated by the wide variety of materials and machining processes, which introduce different interactions and reactions to achieve optimal outcomes. A thorough grasp of these complicated interactions and a methodical strategy for determining the most efficient and effective parameter choices are required. For example, in the aviation and aerospace industries, carbon fiber–reinforced polymers (CFRP) show enormous potential among the array of fiber–reinforced polymer (FRP) composites [102]. However, drilling CFRP composites presents issues due to delamination, which affects structural integrity, all compounded by the composites' heterogeneous and anisotropic character. Because these characteristics are interrelated and somewhat interdependent, achieving delamination–free machining necessitates paying attention to how they are combined. Striking a balance between both would undoubtedly become critical for the holes' outstanding quality, polish, and dimensional precision [103]. Moving forward, drilling parameter optimization can be enriched by experimenting with advanced optimization methods such as Grey Relational Analysis, Artificial Neural Networks (ANN), Fuzzy Logic, and Genetic Algorithms, which can help yield more profound insights into parameter interactions. Furthermore, extending the use of fabricated composites to other machining operations such as wire EDM and milling can help uncover valuable data, as can performing a comprehensive suite of destructive and non–destructive tests (including tensile, compression, impact, liquid penetrant, magnetic particle, eddy current, ultrasonic, radiography, and thermography tests). This multidimensional approach can push the machining parameter optimization area toward more complete and robust solutions [104].

In grinding, a shortage of qualified operators is one of the most significant challenges in optimizing machining parameters during a grinding operation. Human expertise is critical for interpreting subtle intricacies that automated methods may overlook, as demonstrated by Rudrapati et al. [105] when they used a multi–objective genetic algorithm (MOGA) to optimize vibration and surface roughness in traverse simultaneously cut cylindrical grinding of stainless steel material. Because of the complex interaction of many input parameters and their consequent varying impact on critical output responses, skilled operators with the experience and acumen to comprehend the complex relationships between machining parameters and desired outcomes become indispensable [106]. Therefore, while technological advancements pave the way for sophisticated optimization methodologies, the irreplaceable human touch remains paramount in navigating the intricate landscape of parameter optimization in a grinding process [107]. Therefore, a promising path forward would involve a synergy of human expertise and cutting–edge technology. By encouraging continuous training and knowledge enhancement among skilled operators, such as the review taken by Zolpakar et al. [108], their ability to decipher intricate parameter interactions can be further refined. Simultaneously, integrating advanced data analytics, artificial intelligence, and machine learning into the optimization process can augment the capabilities of skilled operators, as this collaborative approach empowers operators to make informed decisions supported by data–driven insights, thereby enhancing the efficiency and accuracy of parameter optimization

[109]. This way, the convergence of human skill and technological prowess can navigate the complexities of machining parameter optimization, encouraging even more streamlined and effective grinding processes.

In the turning process, mastering the delicate balance between tool, technique, and material characteristics becomes essential for successful machining outcomes in demanding manufacturing scenarios. One challenge in optimizing machining parameters is the unique and varying responses materials have with cutting tools under their individual turning process. Every material, from metals to advanced composites, has distinct mechanical behaviors or responses to any machining process. A good example is the Inconel 718 superalloys, which find application in components needing superior chemical and mechanical traits even at elevated temperatures. Still, these alloys are intricate, making them seem 'difficult to machine']110]. This diversity in material characterization under machining processes necessitates that operators grasp material science well before delving into parameter optimization. As a way forward, simulation software can create virtual machining environments to ensure the testing of various parameter combinations without physical setups. With this virtual setup, material wastage and production downtime could also be reduced greatly as an add–on advantage [111]. Additionally, machining processes could be equipped with real–time monitoring systems with several sensors that can provide crucial data during the process. This sensor information can help operators better understand the dynamic material–tool interactions and make necessary adjustments [112].

6. CONCLUSION AND RECOMMENDATIONS

The application of machining parameters optimization and nano–lubrication effects on drilling, grinding, and turning operations have been studied. In order to improve the economy, reduce idle time, reduce environmental pollution, and increase the safety of the end users during machining, the implementation of nano–lubricants is significant. However, without the study of optimization of the machining parameters, the risk of cutting tool substitution will be high. This study has reviewed literature that cut across the drilling, grinding, and turning machining process. From the reviewed study, the following conclusions were drawn for the three–machining process under study:

- Literature has proven that optimizing machining parameters such as speed, depth of drilling, and feed rate of the movement of the machine bed greatly assists drilling operations. However, according to statistics, due to the drilling mechanisms, the cutting tool faces high vibration challenges during the drilling process. In these terms, the application of nano–lubricants also helps in the reduction process of friction occurrences, flushing away the chips developed at the drilling region.
- The same phenomenon is obtained in grinding operations. However, most manufacturing processes deal with the grinding process's surface finishing. So, applying the optimized machining parameters and the nano–lubrication process assists in the material's deformation process during grinding. Because a high temperature has been generated in the grinding region. So, the nano–lubricant gives excellent protection to the surface of the workpieces for the grinding process.
- In the turning process, the nano–lubricant also had advantages. However, the depth of the cut is very significant, and if it is not optimized, it will result in the chartered vibration of the cutting tool. That is why, in the literature, the range of cut depth is between 0.5 to 1.5 mm. This enables the industry's production section to avoid chartered vibrations.

Therefore, this study will recommend that manufacturers work with researchers to conduct an experimental analysis and build a multi–optimization model with a flow rate of the MQL nano–lubricant and the machining parameters under hybrid cryogenic–MQL machining conditions. This will promote a sustainable and clean manufacturing process.

References

[1] A. Diniță, A. Neacșa, A.I. Portoacă, M. Tănase, C.N. Ilinca, I.N. Ramadan. Additive Manufacturing Post–Processing Treatments, a Review with Emphasis on Mechanical Characteristics. Materials. 2023 Jun 26;16(13):4610

[2] K. Kanishka, B. Acherjee. A systematic review of additive manufacturing–based remanufacturing techniques for component repair and restoration. Journal of Manufacturing Processes. 2023 Mar 3;89:220–83

[3] I.P. Okokpujie, O.M. Ikumapayi, U.C. Okonkwo, E.Y. Salawu, S.A. Afolalu, J.O. Dirisu, O.N. Nwoke, O.O. Ajayi. Experimental and mathematical modeling for prediction of tool wear on the machining of aluminium 6061 alloy by high speed steel tools. Open Engineering. 2017 Dec 29;7(1):461–9

[4] C.A. Ezugwu, O.S. Fayomi, M.K. Onifade, A.O. Adeoye, I.P. Okokpujie. Modelling the Effects of Workpiece Flexibility on Cutting Performance in Turning Operations. Journal Européen des Systèmes Automatisés. 2023 Sep 1;56(4).

[5] I.P. Okokpujie, L.K. Tartibu. Cutting Force Optimisation Under ANN and QRCCD. InModern Optimization Techniques for Advanced Machining: Heuristic and Metaheuristic Techniques 2023 Jul 22 (pp. 201–231). Cham: Springer Nature Switzerland.

[6] I.P. Okokpujie, L.K. Tartibu. Material Removal Rate Optimisation Under ANN and QRCCD. InModern Optimization Techniques for Advanced Machining: Heuristic and Metaheuristic Techniques 2023 Jul 22 (pp. 233–262). Cham: Springer Nature Switzerland.

[7] I.P. Okokpujie, L.K. Tartibu. Cutting Fluid and Its Application with Different Delivering Machining Techniques. InModern Optimization Techniques for Advanced Machining: Heuristic and Metaheuristic Techniques 2023 Jul 22 (pp. 25–39). Cham: Springer Nature Switzerland.

[8] S. Jia, W. Cai, C. Liu, Z. Zhang, S. Bai, Q. Wang, S. Li, L. Hu. Energy modeling and visualisation analysis method of drilling processes in the manufacturing industry. Energy. 2021 Aug 1;228:120567

[9] I.P. Okokpujie, L.K. Tartibu. A Multi–objective Optimisation Approach for Improving Machining Performance Using the General Algebraic Modelling System (GAMS). InModern Optimization Techniques for Advanced Machining: Heuristic and Metaheuristic Techniques 2023 Jul 22 (pp. 137–167). Cham: Springer Nature Switzerland.

[10] I.P. Okokpujie, L.K. Tartibu. A Multi–objective Optimisation Approach for Improving Machining Performance Using the General Algebraic Modelling System (GAMS). InModern Optimization Techniques for Advanced Machining: Heuristic and Metaheuristic Techniques 2023 Jul 22 (pp. 137–167). Cham: Springer Nature Switzerland.

[11] I.P. Okokpujie, L.K. Tartibu. Adaptive Neuro–Fuzzy Inference System for Prediction of Surface Roughness Under Biodegradable Nano–lubricant. InModern Optimization Techniques for Advanced Machining: Heuristic and Metaheuristic Techniques 2023 Jul 22 (pp. 289–311). Cham: Springer Nature Switzerland.

[12] I.P. Okokpujie, L.K. Tartibu. Multi–objective Ant Lion Optimizer for Improved Machining Performance. InModern Optimization Techniques for Advanced Machining: Heuristic and Metaheuristic Techniques 2023 Jul 22 (pp. 107–121). Cham: Springer Nature Switzerland.

[13] S. Dhouib, A. Zouari. Adaptive iterated stochastic metaheuristic to optimise holes drilling path in manufacturing industry: The Adaptive–Dhouib–Matrix–3 (A–DM3). Engineering Applications of Artificial Intelligence. 2023 Apr 1;120:105898

[14] I.P. Okokpujie, L.K. Tartibu. Multi–objective Grasshopper Optimizer for Improved Machining Performance. InModern Optimization Techniques for Advanced Machining: Heuristic and Metaheuristic Techniques 2023 Jul 22 (pp. 123–136). Cham: Springer Nature Switzerland.

[15] K. Dey, K. Kalita, S. Chakraborty. Prediction performance analysis of neural network models for an electrical discharge turning process. International Journal on Interactive Design and Manufacturing (IJIDeM). 2023 Apr;17(2):827–45.

[16] I.P. Okokpujie, L.K. Tartibu. Application of Hybrid ANN and PSO for Prediction of Surface Roughness Under Biodegradable Nano–lubricant. InModern Optimization Techniques for Advanced Machining: Heuristic and Metaheuristic Techniques 2023 Jul 22 (pp. 263–288). Cham: Springer Nature Switzerland.

[17] M.K. Gupta, P. Niesłony, M. Sarikaya, M.E. Korkmaz, M. Kuntoğlu, G.M. Królczyk. Studies on geometrical features of tool wear and other important machining characteristics in sustainable turning of aluminium alloys. International Journal of Precision Engineering and Manufacturing–Green Technology. 2023 Jan 10:1–5.

[18] N. Deswal, R. Kant. Hybrid turning process by interacting ultrasonic vibration and laser energies. Materials and Manufacturing Processes. 2023 Apr 4;38(5):570–6.

[19] J. Schlegel, Manufacturing Processes. In the World of Steel: On the History, Production and Use of a Basic Material 2023 Jan 4 (pp. 297–355). Wiesbaden: Springer Fachmedien Wiesbaden.

[20] B. Karpuschewski, G. Byrne, B. Denkena, J. Oliveira, A. Vereschaka. Machining Processes. Springer Handbook of Mechanical Engineering. 2021:409–60.

[21] K. Kishore, M.K. Sinha, A. Singh, Archana, M.K. Gupta, M.E. Korkmaz. A comprehensive review on the grinding process: advancements, applications and challenges. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science. 2022 Nov;236(22):10923–52.

[22] J. Yu, H. Sun, Y. An, P. Gao, X. Zhang, Y. Han. Energy conservation and consumption reduction in grinding operations through ceramic media stirring mill: An industrial validation test. Powder Technology. 2023 Nov 1;429:118943.

[23] N. Virivinti, B. Hazra, K. Mitra. Optimising grinding operation with correlated uncertain parameters. Materials and Manufacturing Processes. 2021 Apr 26;36(6):713–21.

[24] M. Hu, Y. Sun, Q. Gong, S. Tian, Y. Wu. Multi–objective parameter optimisation dynamic model of grinding processes for promoting low–carbon and low–cost production. Processes. 2019 Dec 18;8(1):3.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

[25] G. Xiao, H. Gao, Y. Zhang, B. Zhu, Y. Huang. An intelligent parameters optimisation method of titanium alloy belt grinding considering machining efficiency and surface quality. The International Journal of Advanced Manufacturing Technology. 2023 Mar;125(1–2):513–27.
[26] R. Roy, S.K. Ghosh, T.I. Kaisar, T. Ahmed, S. Hossain, M. Aslam, M. Kaseem, M.M. Rahman. Multi–response optimisation of surface grinding process parameters of AISI 4140 alloy steel using response surface methodology and desirability function under dry and wet conditions. Coatings. 2022 Jan 17;12(1):104.
[27] N.P. Vu, Q.T. Nguyen, T.H. Tran, H.K. Le, A.T. Nguyen, A.T. Luu, V.T. Nguyen, X.H. Le. Optimisation of grinding parameters for minimum grinding time when grinding tablet punches by CBN wheel on CNC milling machine. Applied sciences. 2019 Mar 6;9(5):957.
[28] C. Li, F. Jiao, X. Ma, Y. Niu, J. Tong. Dressing principle and parameter optimisation of ultrasonic–assisted diamond roller dressing W.A. grinding wheel using response surface methodology and genetic algorithm. The International Journal of Advanced Manufacturing Technology. 2023 Jul 17:1–8.
[29] R.K. Inapakurthi, P.D. Pantula, S.S. Miriyala, K. Mitra. Data driven robust optimisation of grinding process under uncertainty. Materials and Manufacturing Processes. 2020 Dec 9;35(16):1870–6.
[30] N. Shen, Y. Wu, J. Li, T. He, Y. Lu, Y. Xu. Research on procedure optimisation for composite grinding based on Digital Twin technology. International Journal of Production Research. 2023 Mar 19;61(6):1736–54.
[31] R. Rekha, S.V. Kumar, V.A. Raj, B.A. Baboo, P.G. Raj, A.J. Vignesh. Optimisation of cylindrical grinding process parameters on austenitic stainless steel 304 using Taguchi based Grey Relational Analysis. Materials Today: Proceedings. 2023 Jan 1;72:2569–73.
[32] A.S. Awale, M. Vashista, M.Z. Yusufzai. Multi–objective optimisation of MQL mist parameters for eco–friendly grinding. Journal of Manufacturing Processes. 2020 Aug 1;56:75–86.
[33] Z. Yang, Z. Huang, H. Wang, L. Wang, H. Yang. Process parameter optimisation model for robotic abrasive belt grinding of aero–engine blades. The International Journal of Advanced Manufacturing Technology. 2022 Dec 16:1–6.
[34] C.P. Selvan, L. Girisha, V. Koti, M. Madgule, M.B. Davanageri, A. Lakshmikanthan, M.P. Chandrashekarappa. Optimisation of stir casting and drilling process parameters of hybrid composites. Journal of Alloys and Metallurgical Systems. 2023 Sep 1;3:100023.
[35] A.T. Abbas, A.A. Al–Abduljabbar, M.M. El Rayes, F. Benyahia, I.H. Abdelgaliel, A. Elkaseer. Multi–Objective Optimisation of Performance Indicators in Turning of AISI 1045 under Dry Cutting Conditions. Metals. 2023 Jan 2;13(1):96.
[36] D. Popli, U. Batra, V. Msomi, S .Verma. A systematic survey of RUM process parameter optimisation and their influence on part characteristics of nickel 718. Scientific Reports. 2023 Jan 31;13(1):1716.
[37] F.Z. Abdelaoui, A. Jabri, A.E. Barkany. Optimisation techniques for energy efficiency in machining processes—a review. The International Journal of Advanced Manufacturing Technology. 2023 Apr;125(7–8):2967–3001.
[38] M.T. Ahmed, H. Juberi, A.M. Bari, M.A. Rahman, A. Rahman, M.A. Arefin, I. Vlachos, N. Quader. Investigation of the effect of vibration in the multi–objective optimisation of dry turning of hardened steel. International Journal of Industrial Engineering and Operations Management. 2023 Feb 7;5(1):26–53.
[39] S. Sharma, P.P. Das, T.Y. Ladakhi, B.B. Pradhan, R. Phipon. Performance Evaluation and Parametric Optimisation of Turning Operation of Ti6Al–4V Alloy Under Dry and Minimum Quantity Lubrication Cutting Environments. Journal of Materials Engineering and Performance. 2023 Jun;32(12):5353–64.
[40] B.M. Abdo, R. Almuzaiqer, M.A. Noman, S. Chintakindi. Investigation of Heat Annealing and Parametric Optimization for Drilling of Monel–400 Alloy. Journal of Manufacturing and Materials Processing. 2023 Sep 15;7(5):170.
[41] M.R. Qazani, S. Amini, S. Pedrammehr, M. Baraheni, A.H. Suhail. A machine learning method for cutting parameter selection in rotary ultrasonic–assisted end grinding. The International Journal of Advanced Manufacturing Technology. 2023 May;126(3–4):1577–91.
[42] A. Pal, S.S. Chatha, H.S. Sidhu. Performance evaluation of the minimum quantity lubrication with Al2O3–mixed vegetable–oil–based cutting fluid in drilling of AISI 321 stainless steel. Journal of Manufacturing Processes. 2021 Jun 1;66:238–49
[43] A. Pal, S.S. Chatha, 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. Journal of the Brazilian Society of Mechanical Sciences and Engineering. 2022 Apr;44(4):148
[44] C. Ezilarasan, M.S. Nagaraj, A.J. Kumar, A. Velayudham, R. Betala. Experimental analysis of process parameters in drilling nimonic C263 alloy under nano fluid mixed MQL environment. Manufacturing Review. 2021;8:2
[45] A. Pal, S.S. Chatha, 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. Tribology international. 2020 Nov 1;151:106508
[46] S.S. Chatha, A. Pal, T. Singh. Performance evaluation of aluminium 6063 drilling under the influence of nanofluid minimum quantity lubrication. Journal of Cleaner Production. 2016 Nov 20;137:537–45
[47] D.G. Subhedar, Y.S. Patel, B.M. Ramani, G.S. Patange. An experimental investigation on the effect of Al2O3/cutting oil based nano coolant for minimum quantity lubrication drilling of SS 304. Cleaner Engineering and Technology. 2021 Jul 1;3:100104
[48] J.S. Nam, D.H. Kim, H. Chung, S.W. Lee. Optimisation of environmentally benign micro–drilling process with nanofluid minimum quantity lubrication using response surface methodology and genetic algorithm. Journal of Cleaner Production. 2015 Sep 1;102:428–36
[49] M. Mosleh, M. Ghaderi, K.A. Shirvani, J. Belk, D.J. Grzina. Performance of cutting nanofluids in tribological testing and conventional drilling. Journal of Manufacturing Processes. 2017 Jan 1;25:70–6
[50] J.S. Nam, P.H. Lee, S.W. Lee. Experimental characterisation of micro–drilling process using nanofluid minimum quantity lubrication. International Journal of Machine Tools and Manufacture. 2011 Jul 1;51(7–8):649–52

[51] P.J. Liew, M.A. Syahida, S. Ainusyafiqah, S.M. Amri, R.R. Izamshah. Investigation of effects of carbon nanofiber nanofluid in drilling of AISI 304 stainless steel. Journal of Advanced Manufacturing Technology (JAMT). 2018;12(1 (2)):491–500.

[52] J. Nam, J.W. Kim, J.S. Kim, J. Lee, S.W. Lee. Parametric analysis and optimisation of nanofluid minimum quantity lubrication micro–drilling process for titanium alloy (Ti–6Al–4V) using response surface methodology and desirability function. Procedia Manufacturing. 2018 Jan 1;26:403–14.

[53] S. Muthuvel, M.N. Babu, N. Muthukrishnan. Copper nanofluids under minimum quantity lubrication during drilling of AISI 4140 steel. Australian Journal of Mechanical Engineering. 2018 Jul 3

[54] M.N. Babu, N. Muthukrishnan. Experimental analysis in drilling of AA 5052 using copper nanofluids under minimum quantity lubrication. Australian Journal of Mechanical Engineering. 2018 Mar 26

[55] V. Shalimba, B. Sopko. Nanofluids Application in the Drilling Process. Manuf. Technol. 2018 Jun 1;18(3):493–8.

[56] P.J. Liew, M.R. Yahaya, M.S. Salleh, R. Izamshah, J. Wang. Experimental investigation of drilling process using nanofluid as coolant. Journal of Advanced Manufacturing Technology (JAMT). 2018;12(1 (3)):11–22.

[57] J. Nam, S.W. Lee. Machinability of titanium alloy (Ti–6Al–4V) in environmentally–friendly micro–drilling process with nanofluid minimum quantity lubrication using nanodiamond particles. International Journal of Precision Engineering and Manufacturing–Green Technology. 2018 Jan;5:29–35

[58] M.H. Cetin, A. Kesen, S. Korkmaz, S.K. Kilincarslan. Performance evaluation of the nano–silver added vegetable–oil–based cutting fluid in drilling process. Surface Topography: Metrology and Properties. 2020 Jun 3;8(2):025029. **DOI** 10.1088/2051–672X/ab96dc

[59] A.I. Gomez–Merino, J.J. Jiménez–Galea, F.J. Rubio–Hernandez, I.M. Santos–Ráez. Experimental assessment of thermal and rheological properties of coconut oil–silica as green additives in drilling performance based on minimum quantity of cutting fluids. Journal of Cleaner Production. 2022 Sep 25;368:133104.

[60] A. Pal, S.S. Chatha, H.S. Sidhu. Tribological characteristics and drilling performance of nano–MoS 2–enhanced vegetable oil–based cutting fluid using eco–friendly MQL technique in drilling of AISI 321 stainless steel. Journal of the Brazilian Society of Mechanical Sciences and Engineering. 2021 Apr;43:1–20.

[61] T.D. Hoang, T.H. Mai, V.D. Nguyen. Enhancement of Deep Drilling for Stainless Steels by Nano–Lubricant through Twist Drill Bits. Lubricants. 2022 Jul 29;10(8):173.

[62] J. Kananathan, M. Samykano, K. Sudhakar, S.R. Subramaniam, S.K. Selavamani, N.M. Kumar, N.W. Keng, K. Kadirgama, W.A. Hamzah, W.S. Harun. Nanofluid as coolant for grinding process: An overview. InIOP Conference Series: Materials Science and Engineering 2018 Apr 1 (Vol. 342, No. 1, p. 012078). IOP Publishing

[63] S.F. Hosseini, M. Emami, M.H. Sadeghi. An experimental investigation on the effects of minimum quantity nano lubricant application in grinding process of Tungsten carbide. Journal of Manufacturing Processes. 2018 Oct 1;35:244–53

[64] Z. Zhang, M. Sui, C. Li, Z. Zhou, B. Liu, Y. Chen, Z. Said, S. Debnath, S. Sharma. Residual stress of grinding cemented carbide using MoS2 nano–lubricant. The International Journal of Advanced Manufacturing Technology. 2022 Apr;119(9–10):5671–85

[65] P.A. Kalita, A.P. Malshe, W.E. Jiang, A.J. Shih. Tribological study of nano lubricant integrated soybean oil for minimum quantity lubrication (MQL) grinding. Transactions of NAMRI/SME. 2010 May 25;38(313):137–44.

[66] F. Zhang, Y. Zhang, C.F. Cheung, A. Shokrani, S.T. Newman. A low temperature nano–lubrication method for enhancing machinability in ultra–precision grinding of binderless tungsten carbide (W.C.). *CIRP Annals*. 2023

[67] S. Prabhu, B.K. Vinayagam. AFM investigation in grinding process with nanofluids using Taguchi analysis. The International Journal of Advanced Manufacturing Technology. 2012 Apr;60:149–60

[68] T. Gao, Y. Zhang, C. Li, Y. Wang, Q. An, B. Liu, Z. Said, S. Sharma. Grindability of carbon fiber reinforced polymer using CNT biological lubricant. Scientific reports. 2021 Nov 18;11(1):22535.

[69] G.E. García, F. Trigos, D. Maldonado–Cortés, L. Peña–Parás. Optimisation of surface roughness on slitting knives by titanium dioxide nano particles as an additive in grinding lubricant. The International Journal of Advanced Manufacturing Technology. 2018 Jun;96:4111–21

[70] D. Zhang, C. Li, D. Jia, Y. Zhang, X. Zhang. Specific grinding energy and surface roughness of nanoparticle jet minimum quantity lubrication in grinding. Chinese Journal of Aeronautics. 2015 Apr 1;28(2):570–81

[71] A. Azami, Z. Salahshournejad, E. Shakouri, AR. Sharifi, P. Saraeian. Influence of nano–minimum quantity lubrication with MoS2 and CuO nanoparticles on cutting forces and surface roughness during grinding of AISI D2 steel. Journal of Manufacturing Processes. 2023 Feb 3;87:209–20

[72] P.H. Lee, J.S. Nam, C. Li, S.W. Lee. An experimental study on micro–grinding process with nanofluid minimum quantity lubrication (MQL). International Journal of Precision Engineering and Manufacturing. 2012 Mar;13:331–8

[73] Y. Zhang, C. Li, D. Jia, D. Zhang, X. Zhang. Experimental evaluation of the lubrication performance of MoS2/CNT nanofluid for minimal quantity lubrication in Ni–based alloy grinding. International Journal of Machine Tools and Manufacture. 2015 Dec 1;99:19–33

[74] D. Jia, C. Li, D. Zhang, Y. Zhang, X. Zhang. Experimental verification of nanoparticle jet minimum quantity lubrication effectiveness in grinding. Journal of nanoparticle research. 2014 Dec;16:1–5

[75] A. Kumar, S. Ghosh, S. Aravindan. Experimental investigations on surface grinding of silicon nitride subjected to mono and hybrid nanofluids. Ceramics International. 2019 Oct 1;45(14):17447–66

[76] X. Zhang, C. Li, Y. Zhang, Y. Wang, B. Li, M. Yang, S. Guo, G. Liu, N. Zhang. Lubricating property of MQL grinding of Al2O3/SiC mixed nanofluid with different particle sizes and microtopography analysis by cross–correlation. Precision Engineering. 2017 Jan 1;47:532–45

[77] Y. Zhang, C. Li, D. Jia, D. Zhang, X. Zhang. Experimental evaluation of MoS2 nanoparticles in jet MQL grinding with different types of vegetable oil as base oil. Journal of Cleaner Production. 2015 Jan 15;87:930–40
[78] M. Shabgard, M. Seyedzavvar, M. Mohammadpourfard. Experimental investigation into lubrication properties and mechanism of vegetable–based CuO nanofluid in MQL grinding. The International Journal of Advanced Manufacturing Technology. 2017 Oct;92:3807–23.
[79] P. Kalita, A.P. Malshe, S.A. Kumar, V.G. Yoganath, T. Gurumurthy. Study of specific energy and friction coefficient in minimum quantity lubrication grinding using oil–based nanolubricants. Journal of Manufacturing Processes. 2012 Apr 1;14(2):160–6.
[80] S. Khatai, R. Kumar, A.K. Sahoo, A. Panda, D. Das. Metal–oxide based nanofluid application in turning and grinding processes: A comprehensive review. Materials Today: Proceedings. 2020 Jan 1;26:1707–13
[81] C. Mao, H. Zou, X. Huang, J. Zhang, Z. Zhou. The influence of spraying parameters on grinding performance for nanofluid minimum quantity lubrication. The International Journal of Advanced Manufacturing Technology. 2013 Feb;64:1791–9.
[82] M. Sarıkaya, Ş. Şirin, Ç.V. Yıldırım, T. Kıvak, M.K. Gupta. Performance evaluation of whisker–reinforced ceramic tools under nano–sized solid lubricants assisted MQL turning of Co–based Haynes 25 superalloy. Ceramics International. 2021 Jun 1;47(11):15542–60.
[83] S. Sartori, A. Ghiotti, S. Bruschi. Solid lubricant–assisted minimum quantity lubrication and cooling strategies to improve Ti6Al4V machinability in finishing turning. Tribology International. 2018 Feb 1;118:287–94.
[84] G.M. Rao, S. Dilkush, I. Sudhakar. Effect of cutting parameters with dry and MQL nano fluids in turning of EN–36 STEEL. Materials Today: Proceedings. 2021 Jan 1;41:1182–7
[85] T.M. Duc, T.T. Long, T.Q. Chien. Performance evaluation of MQL parameters using Al2O3 and MoS2 nanofluids in hard turning 90CrSi steel. Lubricants. 2019 May 8;7(5):40.
[86] A.K. Sharma, A.K. Tiwari, A.R. Dixit, R.K. Singh. Measurement of machining forces and surface roughness in turning of AISI 304 steel using alumina–MWCNT hybrid nanoparticles enriched cutting fluid. Measurement. 2020 Jan 1;150:107078
[87] A. Kulandaivel, S.K. Santhanam. Experimental investigation on turning of monel K500 alloy using nano graphene cutting fluid under minimum quantity lubrication. InASME International Mechanical Engineering Congress and Exposition 2019 Nov 11 (Vol. 59377, p. V02AT02A009). American Society of Mechanical Engineers.
[88] R.K. Singh, A.K. Sharma, A.R. Dixit, A.K. Tiwari, A. Pramanik, A. Mandal. Performance evaluation of alumina–graphene hybrid nano–cutting fluid in hard turning. Journal of cleaner production. 2017 Sep 20;162:830–45
[89] Lokanadham D, Sivasankara Raju R. Influence of Nano–Al_2O_3 Particulates with Mustard Oil as Cutting Fluid in Turning Operation. Journal of Engineering Sciences. 2019 Vol 10, Issue 12, 69–72
[90] S.S. Rahman, M.Z. Ashraf, A.N. Amin, M.S. Bashar, M.F. Ashik, M. Kamruzzaman. Tuning nanofluids for improved lubrication performance in turning biomedical grade titanium alloy. Journal of cleaner production. 2019 Jan 1;206:180–96
[91] M. Sayuti, A.A. Sarhan, F. Salem. Novel uses of SiO2 nano–lubrication system in hard turning process of hardened steel AISI4140 for less tool wear, surface roughness and oil consumption. Journal of Cleaner Production. 2014 Mar 15;67:265–76
[92] M.M. Prasad, R.R. Srikant. Performance evaluation of nano graphite inclusions in cutting fluids with MQL technique in turning of AISI 1040 steel. International Journal of Research in Engineering and Technology. 2013;2(11):381–93.
[93] P.B. Patole, V.V. Kulkarni. Parametric optimisation of minimum quantity lubrication in turning of AISI 4340 using nano fluids. Materials Today: Proceedings. 2018 Jan 1;5(5):12419–25
[94] R. Padmini, P.V. Krishna, G.K. Rao. Effectiveness of vegetable oil based nanofluids as potential cutting fluids in turning AISI 1040 steel. Tribology International. 2016 Feb 1;94:490–501
[95] P.B. Patole, V.V. Kulkarni. Optimisation of process parameters based on surface roughness and cutting force in MQL turning of AISI 4340 using nano fluid. Materials Today: Proceedings. 2018 Jan 1;5(1):104–12
[96] Y. Shuang, M. John, D. Songlin. Experimental investigation on the performance and mechanism of graphene oxide nanofluids in turning Ti–6Al–4V. Journal of Manufacturing Processes. 2019 Jul 1;43:164–74
[97] Ç.V. Yıldırım, M. Sarıkaya, T. Kıvak, Ş. Şirin. The effect of addition of hBN nanoparticles to nanofluid–MQL on tool wear patterns, tool life, roughness and temperature in turning of Ni–based Inconel 625. Tribology International. 2019 Jun 1;134:443–56
[98] J. Yan, Z. Zhang, T. Kuriyagawa. Effect of Nanoparticle Lubrication in Diamond Turning of Reaction–Bonded SiC. Int. J. Autom. Technol.. 2011 May 5;5(3):307–12.
[99] Ç.V. Yıldırım. Experimental comparison of the performance of nanofluids, cryogenic and hybrid cooling in turning of Inconel 625. Tribology International. 2019 Sep 1;137:366–78
[100] P.V. Krishna, R.R. Srikant, D.N. Rao. Experimental investigation on the performance of nanoboric acid suspensions in SAE–40 and coconut oil during turning of AISI 1040 steel. International Journal of machine Tools and manufacture. 2010 Oct 1;50(10):911–6.
[101] N.K. Sahu, M.K. Singh, B. Getrude Mutono–Mwanza, A.K. Sahu. Investigation of machinability characteristics of EDMed inconel 825 alloy under multidimensional parametric modeling by using holistic grey–PCA statistical models. Advances in Materials Science and Engineering. 2022 May 14;2022
[102] N. Bhanot, P.V. Rao, S.G. Deshmukh. Sustainable manufacturing: an interaction analysis for machining parameters using graph theory. Procedia–Social and Behavioral Sciences. 2015 May 15;189:57–63

[103] D.Y. Pimenov, M. Mia, M.K. Gupta, Á.R. Machado, G. Pintaude, D.R. Unune, N. Khanna, A.M. Khan, Í. Tomaz, S. Wojciechowski, M. Kuntoğlu. Resource saving by optimisation and machining environments for sustainable manufacturing: A review and future prospects. Renewable and Sustainable Energy Reviews. 2022 Sep 1;166:112660.

[104] G.R. Kumar, M. Sathishkumar, M. Vignesh, M. Manikandan, G. Rajyalakshmi, R. Ramanujam, N. Arivazhagan. Metal additive manufacturing of commercial aerospace components–A comprehensive review. Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering. 2023 Apr;237(2):441–54

[105] R. Rudrapati, P.K. Pal, A. Bandyopadhyay. Modeling and optimisation of machining parameters in cylindrical grinding process. The International Journal of Advanced Manufacturing Technology. 2016 Feb;82:2167–82

[106] K. Abhishek, S. Datta, S.S. Mahapatra. Optimisation of thrust, torque, entry, and exist delamination factor during drilling of CFRP composites. The International Journal of Advanced Manufacturing Technology. 2015 Jan;76:401–16

[107] J.U. Prakash, C.S. Rubi, S. Palani, S.J. Juliyana, A.D. Sadhana. Optimisation of machining parameters in drilling of LM6/B4C/Fly ash hybrid composites. Manufacturing Review. 2022;9:28

[108] N.A. Zolpakar, M.F. Yasak, S. Pathak. A review: use of evolutionary algorithm for optimisation of machining parameters. The International Journal of Advanced Manufacturing Technology. 2021 Jul;115:31–47.

[109] G. Kant, K.S. Sangwan. Predictive modelling and optimisation of machining parameters to minimise surface roughness using artificial neural network coupled with genetic algorithm. Procedia Cirp. 2015 Jan 1;31:453–8.

[110] C. Pinheiro, M.Y. Kondo, S.S. Amaral, E.S. Callisaya, J.V. De Souza, M.C. De Sampaio Alves, M.V. Ribeiro. Effect of machining parameters on turning process of Inconel 718. Materials and Manufacturing Processes. 2021 Sep 10;36(12):1421–37.

[111] M.E. Korkmaz, M.K. Gupta. A state of the art on simulation and modelling methods in machining: future prospects and challenges. Archives of Computational Methods in Engineering. 2023 Jan;30(1):161–89.

[112] M. Hassan, A. Sadek, H. Attia. A Real–Time Deep Machine Learning Approach for Sudden Tool Failure Prediction and Prevention in Machining Processes. Sensors. 2023 Apr 11;23(8):3894

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665