



Chapter 2
Literature Review

CHAPTER-2

LITERATURE REVIEW

This chapter presents the previous research and theories on the difficult-to-cut materials under environmentally friendly cooling techniques and parametric optimization techniques with different software & tools. Also, this chapter includes research gaps and research objectives.

2.1 Literature Review

During the past decades, several authors / researchers tried to give the explanation of improve the machinability through different types of cooling techniques and also, parametric optimization, and modelling of process parameters through different types of tools or software. The study of past researchers is very much necessary before starting new research. It helps us to determine the correct methodology as well as the principles related to various processes, parameters and machining conditions.

2.1.1 Literature Review on Cooling Techniques

Sartori et al., (2017).To evaluate the effect of hybrid lubricating/cooling strategies to reduce tool wear when finishing machining the wrought Ti6Al4V titanium alloy, commonly regarded as a DTC alloy. It was proved that the adoption of hybrid lubricating/cooling strategies is a viable alternative to the conventional ones, leading to a drastic reduction of the crater wear as well as good surface integrity given an optimized positioning of the lubricant/coolant nozzles.

Danish et al., (2021).Explored the milling performance of CFRPs in sustainable lubri-cooling mediums, i.e., dry, minimal lubrication (MQL), cryogenic-liquid nitrogen (LN₂), and carbon dioxide (CO_{2ice}). Eventually, the performances of the adopted approaches are compared in this manuscript, which reveals the prediction made by NSGA-II and PSO is quite consistent with the experimental results. However, in view of convergence characteristics and computational time, the PSO is shown to surpass the NSGA-II approach. Furthermore, the lubri-cooling medium was the most critical factor affecting the response parameters with a 49%

contribution in minimizing Fr, 46% contribution in decreasing VB, 38.89% contribution in Ra, and 50.21% contribution in reducing the T value.

Pereira et al., (2020). Achieved suitable machining processes to deal with this kind of alloy and high worldwide competitiveness. In the work here presented, cryogenic cooling with external MQL lubrication (Cryo-MQL) working along with CO₂ as internal coolant is proposed for milling Inconel 718 with the aim of not only improving from a technical point of view but also environmental. The results show that internal Cryo-MQL improves tool life by 57% in comparison with emulsion coolant, achieving 120% if it is compared with MQL in stand-alone mode.

Sterle et al., (2021). Investigated the effects of liquid carbon dioxide (LCO₂) cooling, minimum-quantity lubrication (MQL), and cutting speed in drilling. The resulting empirical models are used to quantify the individual contributions of the controlled parameters on drilling performance, and to facilitate temperature-based process optimization.

Shah et al., (2020). Analyzed the different cooling and lubrication techniques namely without coolant (i.e. dry), with coolant (i.e. flood), and cryogenic with LCO₂ and LN₂ when drilling titanium alloy. The number of holes drilled for dry, with coolant (flood), and cryogenic with LCO₂ and LN₂ were 20, 140, 202, and 293 respectively before reaching tool wear criteria. Also, better results of surface finish, power consumption, hole quality indicators, microhardness, and chip analysis were observed for cryogenic machining with either LCO₂ or LN₂ in contrast with dry and flood machining.

Gupta et al., (2022). Examined cryogenic-LN₂, minimum quantity lubrication (MQL), and hybrid cryogenic LN₂-MQL were applied and compared against a dry medium in perspective of in-depth analysis of tool flank wear, EDS mapping, and intensity of tool wear. Additionally, the SEM and EDS analysis depicted relatively less severe wear and chemical elements adhesion on the tool's main cutting edge, while turning titanium alloy under a hybrid LN₂-MQL lubricating environment. In addition, the dry condition has a maximum value of tool

wear progressions i.e., 1.04 mm and hybrid LN₂-MQL has 0.06 mm while machining titanium alloys. When tool wear was evaluated from a tribological point of view, the reduction in flank wear value compared to dry machining is 89.4 %, 92.3 %, and 94.2 % owing to MQL, LN₂, MQL, and hybrid LN₂-MQL cutting strategies.

Shah et al., (2021). Studied thrust force, power consumption, flank tool wear using FE-SEM and line scan EDS analysis; hole quality indicators and hole surface analysis using FE-SEM, microhardness and chip morphology for drilling Ti-6Al-4V using cryogenic coolants (LN₂ and LCO₂) and flood coolant were comprehensively investigated. 72% and 50% lesser tool wear is observed for LCO₂ and LN₂ respectively, compared to flood machining. The adhesion wear mechanism was found to be the predominant factor leading to higher tool wear during flood machining. The demonstrated superior performance of LCO₂ for all the machinability indicators in this research was a significant finding for machining Ti-6Al-4V in high-value manufacturing industries.

Khan et al., (2021). New empirical models were proposed to assess sustainable indicators. The embodied energy, environmental burden, and cost of coolant/lubricant have been added to the proposed models. Based on optimal technological parameters, experiments were performed under the same cutting conditions (machining parameters) for MQL and cryogenic LN₂-assisted external turning of Ti6-Al-4V titanium alloy. The electric power and energy consumption, production time/cost, and CO₂ emissions were assessed for a unit cutting-tool life. However, cryogenic LN₂ extended tool life by nearly 70% and incurred 4.12% less specific costs with 11.1 % better surface quality. In summary, after Energy–Economy–Ecology–Engineering technology (4E)-based analysis, cryogenic LN₂ is sustainable economically but not environmentally and there is a need to improve the sustainable production of LN₂ at an industrial scale to achieve environmental sustainability.

Danish et al., (2021). A hybrid lubri-cooling environment for turning Inconel 718 alloys was proposed, incorporating the theory of cryogenic cooling and

minimum quantity lubrication (Cryo-MQL). For an improved lubri-cooling effect, Cryo-MQL integrates the application of a minimum quantity of vegetable oil and liquid nitrogen from two distinct nozzles in the cutting zone. Surface roughness, cutting temperature, tool wear, chip morphology, and micro-structure of the machined surface were evaluated for different lubri-cooling mediums: dry, MQL, Cryogenic, and Cryo-MQL. In comparison to a dry medium, the Cryo-MQL environment decreases surface roughness, cutting temperature, and tool wear by 60.6%, 37%, and 19.5%, respectively. However, during processing with Cryo-MQL, the grain structure of the working material was found to be smaller as compared to other mediums.

Khanna et al., (2020).Analysed the dry, flood, MQL (Minimum Quantity Lubrication), and cryogenic machining with LCO₂ in terms of tool wear for the turning tests of 15-5 PH SS. The performance of sustainable cryogenic machining was found superior in terms of lower tool wear, power consumption, and subsurface microhardness. The relatively finer grain size and helical chip with a smaller diameter were produced in the cryogenic machining while the better surface finish was observed for the flood machining in contrast to other cutting fluid strategies.

Nimelet al., (2019).Investigated the machining of Nimonic 80A under the effect of cryogenic liquid carbon dioxide ($-79.5\text{ }^{\circ}\text{C}$) using PVD-TiAlN coated tungsten carbide (WC) insert, which was compared with the conventional dry, flood, and MQL environments. The results admitted that cryogenic cooling lessens the average roughness by 42–47% over dry cutting, 24–27% over wet cutting, and 16–21% over MQL. It was proved that cryogenic cooling produces greater compressive stress on the machined surface and brings down the flank wear by decreasing the temperature in the cutting zone.

Sanchez et al., (2010).In this work, a new approach to the elimination of fluids in grinding is presented. The technology is based on the use of a hybrid Minimum Quantity of Lubricant (MQL)-a low-temperature CO₂ system that reduces lubrication consumption. Abrasive grits are protected by the layer of frozen oil,

resulting in a significant improvement in grinding wheel life and surface quality of the machined component.

Eskandari et al., (2022). Studied, using the medium cutting parameters, the LN₂ cutting performance was as good as that of the flooded cutting both showing a cutting force of 90 N, 60 μm of flank wear, and 0.5–0.6 μm of surface roughness (Ra). These parameters were further optimized using the desirability function of RSM to determine the set of parameters that provided the lowest cutting force, flank wear, and Ra values and the highest material removal rate (MRR) under cryogenic cutting. Feed rate and depth of cut were significant factors both affecting Ra. Multi-objective optimization showed that a cutting speed of 87 m/min, a feed rate of 0.06 mm/rev, and a depth of cut of 0.37 mm constituted the optimum cutting parameters for achieving a cutting force of 78 N, flank wear of 58 μm, Ra of 0.49 μm and the MRR of 1.97 cm³/min under the cryogenic cutting condition.

Gupta et al., (2021). Analyzed, sustainable hybrid cryogenic MQL cooling/lubrication techniques viz. The tool wear, surface roughness, micro-hardness, specific cutting energy, and chip morphology were considered under sustainable cooling conditions and compared with the dry condition. The outcome revealed that the N₂+MQL reduced the tons of annual coolant consumption attaining smooth surface quality, minimum built-up-edges of chips, and tool wear. Besides, minimum specific cutting energy and surface hardness was achieved under N₂+MQL among all cooling conditions. This endeavor is peculiar in integrating sustainability and machining perspectives under advanced cooling techniques for the industrial application of Ti–6Al–4V.

Chenetal., (2021). In the precision machining of in-situ TiB₂/7075 composite, the feasibility of cryogenic minimum quantity lubrication (CMQL) was explored considering the requirements of environmental protection and prolonging tool life. In the supercritical CO₂ (scCO₂) jet, water-based cutting fluid further improved the cooling performance, while the soluble vegetable oil greatly improved the lubrication performance. The milling experiment verified that the scCO₂-OoWMQL condition was prominent in inhibiting adhesive wear and slowing down

abrasive wear, due to the combination of excellent cooling and lubrication performance, so the tool life was extended by 198.08% compared with dry conditions.

Jebaraj et al., (2019). The research work was carried out on the end milling of Al 6082-T6 alloy with cryogenic LCO₂, LN₂, and wet conditions. The highest axial force (F_z), normal force (F_y), and feed force (F_x) values were recorded on cryogenic LN₂ machining. The conventional fluid coolant offered a better surface roughness value (Ra) over cryogenic coolants at a feed rate of 0.015 and 0.02 mm/tooth and a cutting speed of 100 m/min. The workpiece surface quality degraded in cryogenic machining conditions during the slot-end milling operation of the aluminum alloy under the given machining parameters.

An et al., (2020). Investigated the tool wear, surface topography, cutting torque, and surface profile in side milling Ti6Al4V under four sustainable conditions, i.e., dry, supercritical carbon dioxide (scCO₂), scCO₂ with antifreeze water-based minimum quantity lubrication (scCO₂-WMQL), and scCO₂ with oil-on-water based MQL (scCO₂-OoWMQL) conditions. A theoretical model of flank wear width VB with an average prediction error of 15.87% was established. scCO₂-OoWMQL reduced VB by 67.2% compared to scCO₂ alone due to improved lubricity. Detailed characteristics of the machined surface profile are investigated using continuous wavelet transform. The performance of scCO₂-OoWMQL as a new sustainable and efficient cooling/lubrication technique was superior to scCO₂ alone.

Ross et al., (2022). Studied some flaws in mist lubrication techniques when utilized under high-speed cutting circumstances, thus nanoparticles with a higher thermal conductivity than the base fluid are now being used in minimum quantity lubrication (MQL) systems. This research focused on a deeper exploration of Hastelloy C276's tribological behavior and machinability under various cutting approaches (dry, MQL cryo CO₂, and N-MQL). Outcomes showed that 0.8 with soybean oil reduces the surface roughness by 56–69 %, 15–24 %, and 15–26 % over dry, MQL, and cryo CO₂ environments.

Khanna et al., (2021).The cutting force, energy consumption, surface roughness (Ra), and chip breakability index (C_{in}) have been analyzed for MQL, cryogenic and Cryo-MQL techniques with variations in process parameters. By considering the average value of all turning tests, 64.65% and 40.39%; 11.49% and 7.13% higher value of cutting force and energy consumption was found correspondingly for cryogenic and Cryo-MQL machining respectively as compared to MQL technique respectively. Overall, 25.59% and 18.35% lower values of Ra have been observed for the Cryo-MQL technique as compared with MQL and cryogenic machining respectively.

Kaynak et al., (2018).This study illustrated that carbon dioxide-assisted cryogenic machining alone and with minimum quantity, lubrication does not contribute to decreasing the progression of wear within selected cutting conditions. This study also showed that carbon dioxide-assisted cryogenic machining helps to increase chip breakability. Liquid nitrogen-assisted cryogenic machining results in a reduction of tool wear, including flank and nose wear, in the machining process of AISI 4140 steel material. It was also observed that in the machining process of this material at a cutting speed of 80 m/min, built-up edges occurred in both cryogenic cooling conditions. Additionally, chip flow damage occurs in particularly dry machining.

Gupta et al., (2020).The effectiveness of dry, liquid nitrogen (LN_2) and hybrid cryogenic and minimum quantity lubrication ($LN_2 + MQL$) conditions were evaluated in terms of important machinability indicators for instance surface roughness, cutting forces, and temperature. The environmental parameters such as total cycle time, productivity, economic analysis, energy consumption, and carbon emissions were also analyzed under these cooling conditions. Findings have exhibited a superior cooling/lubrication effect under $LN_2 + MQL$ conditions lowering the machining as well as environmental indices. The improvement in cycle time and productivity of LN_2 and $LN_2 + MQL$ appeared to be 29.01% and 34.21% as compared with dry turning.

Jamil et al., (2019).The key objective of this experimental research was to compare the influence of cryogenic CO₂ and hybrid nanofluid-based MQL techniques for turning Ti-6Al-4V. The design variables were cutting speed, feed rate, and cooling technique. Results showed that the hybrid Nano additives reduced the average surface roughness by 8.72%, cutting force by 11.8%, and increased tool life by 23% in comparison with cryogenic cooling. Nevertheless, the cryogenic technique showed a reduction of 11.2% in cutting temperature compared to the MQL-hybrid nanofluids at low and high levels of cutting speed and feed rate.

Grguraš et al., (2021).Investigated the tool delivery of LCO₂ + MQL was used in the robotic drilling of Ti6Al4V with carbide tools. The flow rate of both LCO₂ and MQL were individually varied to study the effect of coolant and lubricant flow rates on thrust force and torque values in comparison to dry drilling. The results indicate a strong relation between LCO₂ flow rate and thrust force due to material hardening and a strong relation between torque and MQL flow rate due to the combined effects of lubrication in the cutting zone and chip evacuation process.

Korkmaz et al., (2022). Investigated the machining-based tribological characteristics of TiC rollers during hard turning under sustainable cooling/lubrication conditions. Surface quality, power consumption, tool wear, microstructural changes, microhardness after machining, and SEM-EDX analysis were evaluated under dry, minimum quantity lubrication (MQL), cryogenic, and hybrid cryo+ MQL environments. However, the best surface quality, the smallest tool wear, and the power consumption were obtained in the hybrid cryo+ MQL lubrication/cooling method.

Rodriguez et al., (2022).To evaluate the influence of environmentally friendly liquid carbon dioxide (LCO₂) based cooling/lubricating conditions and Polycrystalline Diamond (PCD) drill bit geometries (point angle) on the delamination when drilling CFRP composites. The results showed a significant influence of the tool geometry and cooling condition on the surface integrity of CFRPs, especially in the case of the former.

Karim et al., (2021). The effect of various process parameters on the surface roughness and cutting temperature was analyzed. Analysis of variance (ANOVA) shows that cutting speed and depth of cut were the most prominent factors for surface roughness and cutting temperature. Apart from this, to address the sustainability aspect, a life cycle assessment (LCA) of MQL-assisted and dry machining has been carried out. Energy consumption, CO₂ emissions, and processing time have been determined for MQL-assisted and dry machining. Moreover, very little energy consumption is required in MQL machining to achieve high material removal and very low tool change.

Manimaran et al., (2021). The focus was on the surface modification (roughness, topography, residual stress, microhardness) and wear phenomenon of the tools under the hybrid cryogenic minimum quantity lubrication (CMQL) approach. Compressive residual stress, increased microhardness (4–9%), and less tool wear (22–71%) were a few benefits of CMQL compared to the traditional approach.

Pusavec et al., (2014). Presented the experimental work of sustainable high-performance machining of Inconel 718 with the development of performance-based predictive models for dry, near-dry (MQL), cryogenic, and cryo-lubrication (cryogenic + near-dry) machining processes using response surface methodology (RSM). The results showed that the cooling/lubrication condition has an influence on machining performance and that optimum machining conditions have to be determined, at which an improved overall machining performance can be achieved, while sustainability directions are followed in terms of reducing cutting forces/power consumption, the prolonging of tool-life, and increasing productivity.

Jebaraj et al., (2020). The performance and the influence of LCO₂, LN₂, and Wet coolants on cutting zone temperature (T_c), feed (F_x), normal (F_y) and thrust (F_z) forces, tool wear, chip morphology, surface morphology and roughness (R_a) in the machining of die steel were examined. The use of LCO₂ and LN₂ caused a reduction of 50.49% and 53.97% respectively in T_c in comparison with the wet coolant. Similarly, the application of cryogenics during the end milling operations

reduced the tool wear, and chip width and produced lower cutting forces. The Ra value obtained was in the range of 0.17 μm to 0.22 μm by CO₂ cooling. Likewise, it was about 0.22 μm to 0.39 μm in LN₂ cooling.

Isakson et al., (2018). Investigated the influence of flank wear and cutting fluid (emulsion vs. liquid nitrogen) on surface integrity in the turning of titanium alloy Ti-6Al-4V. The flow rate of liquid nitrogen was therefore limited and as a result, tool wear development was observed to be faster for cryogenic cooling than emulsion-based flood cooling. However, the results showed limited differences in terms of achievable residual stresses when comparing cryogenic and conventional cooling at similar levels of tool wear. Despite an increase in tool wear rate, the cryogenic cooling conditions thus provide similar surface integrity results as emulsion cooling.

Jebaraj et al., (2020). Analysed 3D and 2D roughness profiles, surface morphology, residual stress, and microhardness of 55NiCrMoV7 die steel after end milling operation under dry, wet, cryogenic CO₂, and LN₂ cooling environments. Among different cooling methods, the cryogenic CO₂ was seen to enhance the surface topography and morphology due to the presence of a minimal wear track. The surface microhardness values were higher under cryogenic conditions compared to dry and wet conditions. Cryogenic LN₂ provided the highest microhardness value among the four cooling methods.

Isakson et al., (2018). The aim of this work was to investigate the influence of the flank wear and cutting fluid (emulsion vs. The flow rate of liquid nitrogen was therefore limited and as a result, tool wear development was observed to be faster for cryogenic cooling than emulsion-based flood cooling. However, the results show limited differences in terms of achievable residual stresses when comparing cryogenic and conventional cooling at similar levels of tool wear. Despite an increase in tool wear rate, the cryogenic cooling conditions thus provide similar surface integrity results as emulsion cooling.

Patel et al., (2021). Compared LCO₂ and conventional mineral oil-based flood coolant on the basis of machining performance while turning Nimonic 90. The effect of turning process parameters (cutting speed (v_c), feed (f), and depth of cut (a_p)) and cutting fluids have been identified by analyzing the machinability indicators like cutting forces, flank tool wear, power consumption, surface roughness in terms of Ra, and chip morphology. Increment of 34%, 25%, and 24% in cutting forces has been observed for cryogenic turning using LCO₂ in comparison with wet machining when the values of a_p are 0.75, 0.50, and 0.25 mm, respectively. The superior surface finish has been found in wet machining, while lesser power consumption was recorded for LCO₂ as a cutting fluid.

Shah et al., (2021). This novel study compared the drilling of Inconel 718 using two cryogenic cutting environments i.e., liquid carbon dioxide (LCO₂) and liquid nitrogen (LN₂) based on parameters like tool wear, power consumption, surface roughness; and Life Cycle Assessment (LCA) results at three cutting speeds. As compared to LN₂, 25–300% more holes were drilled using LCO₂ due to restricted growth of wear mechanisms like chipping and abrasion. Overall, 14%, 19%, and 11% increases in thrust force, power consumption, and surface roughness, respectively, were found with LCO₂ as compared to LN₂.

Kim et al., (2021). Examined the economic and environmental impact of cryogenic cooling conditions on hard-turning machining. The nozzle of internal angle 45° has the highest distance and narrow width of spray shape in the results of computational fluid dynamics analysis and the experimental observation. The cryogenic-assisted process improved ceramic cutting tool life by 3–6 times compared to dry and wet conditions. The improved tool life of the ceramic cutting tool by the cryogenic process reduced the total machine operation time; it thus reduced the electricity, and carbon dioxide emissions of machine operations. The implementation of cryogenic cooling can be suitable for the green manufacturing process with the improvement of the environmental impact.

Shah et al., (2021). Machining performance indicators like surface roughness in Ra, Active Cutting Energy (ACE), Active Energy Consumed by

Machine Tool (AECMT), and Energy Efficiency (EE) have been analyzed for each three cutting conditions. The increased values of ACE and AECMT with lesser values of EE have been found for flood machining in comparison with cryogenic machining. The results of LCA suggest that 67–99% of the whole impacts on ecology due to three cutting conditions are generated by flood machining only. Thus, cryogenic machining using LCO₂ and LN₂ has emerged as a sustainable cutting fluid strategy as a substitute for polluted mineral-based flood coolant.

Cai et al., (2021). Studied the machinability of Ti-6Al-4V in the finish milling process under four green cutting environments (CEs), i.e. dry, scCO₂, supercritical CO₂-based MQL with scCO₂-WMQL, supercritical CO₂-based MQL with scCO₂-OoWMQL. The experiment results showed that the minimum cutting force and its coefficients, cutting temperature and surface roughness were obtained in the scCO₂-OoWMQL environment because of its excellent cooling/lubrication and chip evacuation performance, whereas the worst friction in the tool-workpiece interface leads to the worst performance under scCO₂ CE. The fundamental frequency of the machined surface profile was equal to that of the cutting force envelope under dry and scCO₂ CEs, which was also called beat frequency, therefore scCO₂-WMQL and scCO₂-OoWMQL CEs can improve the milling stability. The result indicated that scCO₂-OoWMQL provides the best performance with regard to cutting force, cutting temperature, surface finish, and clean production.

Aslantas et al., (2016). A hybrid system was designed for cooling and lubrication in the micro-milling of Ti6Al4 V alloy. The effect of the hybrid system on cutting performance was evaluated in terms of tool wear and burr formation in the machining of Ti6Al4 V alloy. The efficiency of the designed hybrid system was compared with other cooling/lubrication methods (wet, chilled air, and MQL) and dry-cutting conditions. The experimental results showed that the hybrid system gave the minimum tool wear and burr size. In addition, it was found that the chilled air with a lower temperature of –30°C led to chipping-type damage on the cutting edge of the micro-tool.

Bagherzadeh et al., (2018). A new cooling technique was proposed to improve the effectiveness of the minimum quantity lubrication (MQL) and cryogenic carbon dioxide (CO₂) cooling in high-performance machining of hard-to-cut materials. The combination of minimum quantity carbon dioxide and oil (CMQL) supplied from the rake face is compared with CO₂ and MQL supplied from the rake and flank faces, respectively, as well as only CO₂ supplied from the rake face, in turning of Ti6Al4V and Inconel 718. Tool wear, surface roughness, and temperature measurements were performed to quantify the cooling impact of the various methods.

Ayed et al., (2017). Investigated the impact of these parameters on tool wear and surface integrity when machining the titanium alloy Ti-6Al-4V. Several nozzle diameters have been therefore employed in order to vary the pressure and the flow rate. The machining tests have allowed drawn attention to the impact of the pressure and the flow rate of the liquid nitrogen jet not only on tool life but also on surface integrity. Indeed, the increase in flow rate and pressure increases tool life. Moreover, surface integrity has been greatly improved notably at the highest pressure and the highest flow rate.

Gajrani(2020). Analysed the Feed and cutting forces, workpiece surface roughness and microhardness, sliding-sticking regions contact length, and tool morphology were assessed for three distinct lubrication/cooling environments; dry, MQL, and cryo-MQL. The assessment indicated a significant improvement in machining performance; the cryo-MQL environment shows a reduction in machining forces and workpiece surface roughness by 27 % and 46 % over the dry environment. Morphology of the tool rake surface showed a significant reduction in sliding-sticking regions' contact length. Elemental composition confirms the reduction of workpiece material adhesion on the tool rake surface compared to dry and MQL environments.

Ayed et al., (2017). Investigated the impact of these parameters on tool wear and surface integrity when machining the titanium alloy Ti-6Al-4V. Several nozzle diameters have been therefore employed in order to vary the pressure and the flow rate. The machining tests have allowed drawn attention to the impact of the pressure

and the flow rate of the liquid nitrogen jet not only on tool life but also on surface integrity. Indeed, the increase in flow rate and pressure increases tool life. Moreover, surface integrity has been greatly improved notably at the highest pressure and the highest flow rate.

Halim et al., (2019).The experimental results showed that cryogenic and dry cutting conditions reported approximately similar tool wear patterns. The tool wear started with smooth abrasion and chipping around the depth of the cut line, which then progressed into flank wear and finally notching and flaking via mechanisms of abrasive and adhesive wear. The strong influence of cutting conditions and tool wear patterns on the chip morphology was also evident. Compared to cryogenic cutting, the shape and colour of the chips were found to be severe, distorted, and darker in dry cutting, which confirmed that it was thermally affected by the high cutting temperature.

Sartori et al., (2017).Evaluated the effect of hybrid lubricating/cooling strategies to reduce tool wear when finishing machining the wrought Ti6Al4V titanium alloy, commonly regarded as a DTC alloy. It was proved that the adoption of hybrid lubricating/cooling strategies was a viable alternative to the conventional ones, leading to a drastic reduction of the crater wear as well as good surface integrity given an optimized positioning of the lubricant/coolant nozzles.

Busch et al., (2016).Optimal and efficient machining of high-temperature alloys was one of the main goals set by manufacturing technology, considering the unique properties of these materials, the required performance, and the process parameters. One of the most important parameters investigated and presented in this paper is the optimal cooling and lubrication strategy. The paper introduces fundamental functions, cooling systems, and relationships that characterize the efficient utilization of standard machine tools. Based on fundamental investigations conducted using high-temperature alloys with poor machinability such as Titanium alloy Ti6Al4 V and Inconel 718, relevant influencing parameters were derived and optimization options were presented for the cooling strategies.

Pereira et al., (2016).The use of heat-resistant alloys was growing worldwide in aeronautical One of the most used materials is Inconel 718. The material was featured by high resistance to corrosion and oxidation while keeping However, low machinability of this material results in poor material removal rates and premature tool wear, Consequently, mineral cutting fluids were injected in the cutting zone in order to improve machining. as an ecological alternative. In order to achieve better results when milling Inconel 718, a LCO₂ cryogenic regulation system and a nozzle adaptor have been developed to use cryo-MQL and a comparative analysis was performed with regard to other coolant alternatives.

Muhamad et al., (2019).This paper presented the effects of cutting parameters on the cutting force when machining AISI 4340 steel in a dry speed, feed rate, axial depth of cut and radial depth of cut) to cutting force. For the experiment, using a straight-line machining strategy. The radial depth of cut was the dominating factor exerted on cutting force, followed by speed and feed rate, for both cutting environments. The experiment showed that the cryogenic application was able to reduce the cutting force cryogenic LN₂ effect efficiently reduced the cutting the main factor contributing to an improvement in cutting force.

Danish et al., (2017).Studied the effect of both cryogenic and dry machining of AZ31 magnesium alloy on temperature and surface roughness was examined. The cutting parameters (cutting speed, depth of cut, and feed rate) were varied, and their effect on the results were identified. A finite element model was developed to predict the temperature distribution at the machined surface. After analysing the temperature distribution, the model also suggested that cryogenic-assisted machining removes heat at a faster rate than dry machining. An arithmetic model using the response surface method was also developed to predict the maximum temperature at the surface during cryogenic and dry machining.

Kaynak et al., (2019).Presented the machining performance of new generation near-beta alloys, namely, Ti-5553, by focusing on a high-speed cutting process under cryogenic cooling conditions and dry machining. The experimental data on the cutting temperature, tool wear, force components, chip breakability, dimensional accuracy, and surface integrity characteristics were presented and

analysed to evaluate the machining process of this alloy and the resulting surface characteristics. This study showed that cryogenic machining improved the machining performance of the Ti-5553 alloy by substantially reducing the tool wear, cutting temperature, and dimensional deviation of the machined parts. Cryogenic machining also produced shorter chips as compared to dry machining.

Mahalil et al., (2019).Analysed that the cryogenic coolant in machining was a very significant effect on the surface quality. Flood coolant in existing finishing processes and lubricant techniques give a less effective performance to the machine tool, temperature, and surface integrity. Dry condition trust force higher cryogenic condition was more effective in order to decrease the thrust force compared with dry and MQL conditions. The application of cryogenic conditions in the burnishing process reduces the amount of thrust force against dry condition and MQL condition. Cryogenic condition recorded the lowest average thrust reduction compared to dry and MQL, respectively.

Pušavec et al., (2019).A comparative analysed of the heat-transfer rate was made utilizing the cooling of a controlled heat source with an integrated temperature sensor. The analysis was coupled with experimental in-process temperature measurements in cryogenic milling of titanium alloy Ti-6Al-4V (β).

Fernández et al., (2019).A cryogenic milling system was integrated within the tool holder and was used for milling Gamma TiAl, Inconel 718, and grade EA1N steel using carbon dioxide as a coolant. This system has been compared with the traditional cooling method (emulsion) in terms of tool life to check if it is possible to improve the machining operation in terms of efficiency by supplying the cryogenic coolant directly to the cutting zone. The resultshowed that by replacing traditional pollutant cooling fluids with other more ecologically-friendly alternatives, it is possible to improve tool life by 100% and 175% in the cases of Gamma TiAl and grade EA1N steel, respectively, when using the new delivery system for the coolant.

Iqbal et al., (2019). The paper experimentally investigated the effects of employing a cryogenic coolant (CO₂ snow), micro-lubrication, and hybridization of

the two on the performance measures, such as tool damage, machining forces, and specific cutting energy in the cutting of two commonly used high-strength alloys, Ti-6Al-4V and 40NiCrMo6. Hybrid subcooling and CO₂ snow cooling proved to be the most effective options for machining 40NiCrMo6 and Ti-6Al-4V, respectively.

Kim et al., (2018).A numerical model for the hard-turning process under the cryogenic cooling condition was implemented. The minimum and maximum errors in predictions were 1.8 and 15.2% for cutting force (P1), 1.6 and 33.7% for thrust force (P2), and 2.3 and 7.9% for feed force (P3), respectively, under the cryogenic cooling condition. It was observed that the cryogenic coolant during the hard-turning process reduces the thermal softening effect and in turn increases the cutting forces. Flank wear was observed in both cryogenic cooling and dry conditions.

Khan et al., (2019).The use of cooling media contributes to the elevation of desired responses owing to its cooling and lubrication effects, especially in the case of hard-to-cut materials like Ti-6Al-4V. This study aims to analysed the effect of cooling media in addition to cutting speed on responses including tool wear and surface integrity during turning. Results highlighted the effectiveness of the cooling system in particular that of cryogenic media. Use of cryogenic media and cutting fluid enhanced tool life max by 33% and 21% respectively. At lower cutting speed surface roughness was improved by 13% and 8% by cryogenic media and cutting fluid respectively.

Ghamdi et al., (2015).Presented an experimental investigation, complemented with a fuzzy modeling approach, for comparing the efficacies of using various combinations of CO₂ snow and minimum quantity of lubrication in machining two tempers each of AISI 4340 and Ti-6Al-4V. A total of 144 experimental runs were performed for developing the fuzzy knowledge-based model, and additional 20 experiments are conducted for testing its prediction accuracy. This article claims novelty with regard to the machinability comparison of AISI 4340 and Ti-6Al-4V, application of cryogenic cooling to the machining of hardened steels, investigation of hybrid cooling (CO₂ snow plus minimum quantity

of lubrication), and intelligent modeling of cryogenic machining of AISI 4340 and Ti-6Al-4V combined.

Rahim et al., (2016).The experiment was carried out using the orthogonal cutting process in which the efficiency of the ScCO₂ technique was compared to the MQL technique with respect to cutting temperature, cutting force, chip thickness, and tool-chip contact length. The experimental results showed that the application of SCCO₂ as the cutting fluid was more efficient for the machining process as it reduced the cutting temperature, cutting force, chip thickness, tool-chip contact length, and specific energy compared to the MQL machining technique

Halim et al., (2019).The tool life optimization of carbide-coated ball nose milling inserts using high-speed milling Inconel 718 under a cryogenic CO₂ environment. By using ANOVA, it was found that all factors have significant effects on tool life. After that, the relevant influencing parameters on tool life were derived in the form of a mathematical model which was then used to predict the response within the predetermined parameters. ANOVA also suggests a tool life of 23.40 min could be obtained at optimized parameters of; V_c : 120.06 m/min, F_z : 0.15 mm/tooth, a_p : 0.66 mm, and a_e : 0.53 mm under cryogenic CO₂ conditions.

Faga et al., (2017).Focused on the effects of dry and near-dry cutting conditions on machining process performance when turning Ti-6Al-4V. Minimum Quantity Cooling/Lubrication systems have been exploited to supply low-cutting fluid volumes to the cutting area in the form of a precision-metered droplet mist. Conventional flood cooling (i.e., wet cutting) has been assumed as a benchmark. Results were discussed with respect to tool wear/life, cutting forces, process power demand, surface quality, lubricant consumption, and human health hazards. All the main factors of influence are highlighted, and guidelines for identifying the trade-off between the minimization of environmental impact and the enhancement of process productivity are proposed.

Vishal et al., (2018).An eco-friendly minimum quantity lubrication technique was implemented by using a commercially available vegetable-based cutting fluid. An investigation was done on surface characteristics, chip

morphology, and intensity of cutting temperature evolved during the machining of H13 steel. The results obtained from vegetable oil-based minimum quantity lubrication showed a reduction in the cutting temperature by 52–57 % and 38–45 % and the average surface roughness is in the range of 53–64 % and 22–40 % compared to dry and wet machining.

Amini et al., (2019). Investigated the effect of the cooling method in the grinding process, surface roughness, and hardness were compared in the presence of lubricating fluid and cryogenic cooling with three speeds and three grinding depths. The results of this study showed that except for high depths of cut and cutting velocities, the obtained surface quality with liquid nitrogen and carbon dioxide gas was better in comparison to lubricating fluid. In addition, in high depths of cut and cutting velocities, the hardness obtained from liquid nitrogen and carbon dioxide gas is higher compared to lubricating fluid.

Bruschi et al., (2016). Investigated the feasibility of using dry cutting and cryogenic cooling in the semi-finishing turning of the Ti6Al4V titanium alloy produced by the Additive Manufacturing technology known as Electron Beam Melting when compared to standard flood cooling. The experimental findings showed that cryogenic cooling assures better performances than dry and wet machining by reducing the tool wear, and improving the surface finish and the chip breakability, whereas dry cutting provokes more surface defects and severe tool wear. Therefore, from an environmental point of view, cryogenic machining can represent a sustainable process for manufacturing surgical prostheses made of AM titanium alloys.

Sivaraman et al., (2019). Investigated the effect of molybdenum disulfide nanoparticle (nMoS₂) dispersed in castor oil, as a cutting fluid, sprayed using minimum quantity lubrication (MQL) technique on turning of AISI O1 cold worked tool steel. PVD-TiAlN coated tungsten carbide insert was used for the experimentation. The experimental results of the nMQL condition were compared with the dry and wet conditions. The results proved that application nMQL has given 15–49 % enhanced tool life with a better surface finish as compared with the

dry and wet conditions, respectively. No major phase change occurs in nMQL when compared with other conditions because of their low cutting temperature.

Gowthaman et al., (2022).A study of the machining performance of hardened AISI 4340 steel with cutting temperature, surface roughness, material side flow, flank wear, microhardness, and chip morphology has also been made. The experiment results revealed the effective lowering of the cutting temperature, better surface roughness, and reduced flank wear for LCO₂ and LN₂ coolant by cryogenic cooling against the dry cutting conditions. Compared to dry and cryogenic LCO₂ cutting environments, the machined zone of a cryogenic LN₂ exhibited the highest microhardness value. Overall, the performance of the cryogenic LN₂ environment condition was effective and efficient in the turning process compared to dry and cryogenic LCO₂.

Gupta et al., (2022).The sustainable machining approach was promoted by implementing the dry and minimum quantity lubrication (MQL) cooling conditions in the turning of duplex stainless steel. Initially, the turning experiments were performed under dry as well as MQL conditions, and then, the influence of different positions of MQL nozzles on the tribological and machining performance of 2205 duplex steel was investigated. The cutting parameters were kept fixed and the performance is evaluated in terms of surface roughness, micro-hardness, energy consumption, tool wear, machined surface microstructure, and chip morphology. Moreover, dual-jet MQL gives the lowest energy consumption (229 kJ) and tool wear (0.15 mm) with 23.67% and 52.38% enhancement, respectively.

Boy, (2022).To improve the machining performance of coated ceramic cutting tool under the turning of powder metallurgical hardened (from 30 to 60 HRC) Böhler K490 steel. The turning experiments were performed in dry, MQL, and nano-MQL environments using coated ceramic inserts. The average surface roughness of machined surfaces, the tool wear of coated ceramic inserts, total power consumption in machining, and chip morphology were evaluated for all cutting environments to see the effect of MQL, nano-MQL, and the positions of their nozzles. As a result, the best values of tool wear, surface quality, and power

consumption were obtained by using the nano-MQL conditions, especially the dual jet nano-MQL technique.

Salur, (2022).Examined the effect of different sustainable cooling/lubrication conditions on the machining performance, surface integrity, and accompanying tribological aspects of Inconel 718 superalloy. Tool wear mechanisms, surface roughness/profile/topography, cutting performance (tool-chip interface temperature and energy consumption), chip shapes, microstructures, and micro-Vickers hardness of the machined surfaces were thoroughly analysed to assess experimental observations. The Cryo medium reduces tool wear, surface roughness, cutting temperature, and cutting energy by 67 %, 61 %, 85 %, and 33 % in comparison with a dry environment, respectively.

A critical summary of the conducted literature on cooling techniques is persecuted further in the table 2.1.

Table 2.1 Brief overview of literature on cooling techniques

Author	Environmental Conditions	Operation	W/P Material	Response Variables
Danish et al., (2021)	Dry, MQL, & Cryogenic	Milling	CFRPs	Cutting force, surface roughness
Pereira et al., (2020)	Cryo-MQL	Milling	Inconel 718	Tool life
Sterle et al., (2021)	LCO ₂ & MQL	Drilling	2CrMo4steel	Cutting force & cutting temperature
Shah et al., (2020)	Dry, flood, & cryogenic	Drilling	Ti-alloy	Surface, power consumption, hole error, microhardness, & chip analysis.
Danish et al., (2021)	Cryogenic & MQL-Cryo	Turning	Inconel 718	Surface roughness, cutting temperature, tool wear, chip morphology, and micro-structure.

Khanna et al., (2020)	Dry, flood, MQL, & cryogenic machining	Turning	15-5PH SS	Tool wear, power consumption, & subsurface microhardness.
Nimel et al., (2019)	Dry, flood, MQL& cryogenic	Milling	Nimonic 80A	Roughness, flank wear
Gupta et al., (2021)	Hybrid cryogenic MQL	Turning	Ti-6Al-4V	Tool wear, surface roughness, micro-hardness, specific cutting energy, & chip morphology.
Grguras et al., (2021)	MQL & cryogenic	Drilling	Ti6Al4V	Thrust force, hardening
Korkmaz et al., (2022)	Dry, MQL, cryogenic & hybrid MQL-cryo	Turning	TiC rollers	Surface quality, power consumption, tool wear, micro hardness
Pusavec et al., (2014)	Dry, MQL, cryogenic & cryo-lubrication	Turning	Inconel 718	Cutting force, tool life.
Patel et al., (2021)	Flood & Cryogenic	Turning	Nimonic 90	Cutting force, flank tool wear, power consumption, surface roughness, chip morphology.
Gajrani (2020)	Dry, MQL, & cryo-MQL	Drilling	Ti6Al4V	Cutting force, surface roughness, microhardness, sliding-sticking regions contact length, & tool morphology.
Danish et al., (2017)	Dry & cryogenic	Turning	AZ31 magnesium alloy	Cutting temperature & surface quality.
Kaynak et	Dry & cryogenic	Turning	Ti-5553	Cutting

al., (2019)	machining			temperature, tool wear, force, chip breakability, dimensional accuracy, & surface integrity.
Halim et al., (2019)	Cryogenic Machining	Milling	Inconel 718	Tool life.
Faga et al., (2017)	Dry & near-dry cutting (MQL)	Turning	Ti-6Al-4V	Tool life, cutting force, surface quality, lubricant consumption, & human health hazards.
Gowthaman et al., (2022)	Dry & cryogenic machining	Milling	AISI 4340 steel	Cutting temperature, surface roughness, material side flow, flank wear, micro hardness, & chip morphology.
Gupta et al., (2022)	Dry, & MQL	Turning	Duplex stainless steel	Surface roughness, micro-hardness, energy consumption, tool wear, chip morphology.
Boy, (2022)	Dry, MQL, & MQL-Nano	Turning	Bohler K490	Average surface roughness, tool wear, power consumption, chip morphology.

2.1.2 Literature Review on Optimization and Modelling Techniques / Tools

Adalarasan et al., (2015).The quality characteristics of the cut surface were assessed by measuring the surface roughness and kerf width while cutting the 304 L stainless steel. The experimental trials were designed by Taguchi's L18 orthogonal array unlike the central composite design used with traditional response surface methodology (RSM), and an integrated approach of Grey Taguchi-based response surface methodology (GT-RSM) was disclosed for predicting the optimal combination of cutting parameters. The GT-RSM approach was found to improve the quality characteristics studied in the work significantly. The results will offer a good cutting database for the textile, chemical, and pharmaceutical processing industries.

Deswal et al., (2019).Investigated the significant process parameters (layer thickness, build orientation, infill density, and a number of contours) that were optimized for enhancing the magnitude/dimensional preciseness of fused deposition modeling (FDM) devise units. An attempt has been made to build up a mathematical model in order to set up an indirect correlation between various FDM process parameters and magnitude preciseness. Sequentially to verify the different developed models and the optimum process parameters setting validation tests were also performed. The results showed that various hybrid statistical tools such as RSM-GA, ANN, and ANN-GA are very adequate tools for FDM process parameter optimization.

Wu et al., (2021).Presented a robust design approach, TM-RSM-DF, for optimizing the multiple quality characteristics of the precision product. By the proposed TM-RSM-DF method, the relationship between design parameters, quality characteristics, and desirability was addressed, and the significant parameters were also sorted out.

Laouissi et al., (2019).A comparative study was undertaken in terms of the surface roughness criterion (Ra), the tangential cutting force (F_z), the cutting power (P_c), and the material removal rate (MRR) in turning EN-GJL-250 cast iron using both coated and uncoated silicon nitride ceramics (Si₃N₄). The artificial neural

network approach (ANN) and the response surface methodology (RSM) were adopted to develop the mathematical prediction models applied in the optimization procedure that used a genetic algorithm (GA). The predictive capabilities of the ANN and RSM models were further compared in terms of their mean absolute deviation (MAD), mean absolute error in percent (MAPE), mean square error (RMSE), and coefficient of determination (R²). Moreover, the coated ceramic tool has been found to lead to better surface quality and a minimum cutting force compared to those obtained by uncoated ceramic.

Sen et al., (2021). In the minimum quantity lubrication (MQL) technology, a small lubricant mist was inserted into the tool-workpiece interface to achieve better lubrication. Therefore, explore the viability of alumina-reinforced palm oil as a lubricant in the MQL environment. A diverse volume fraction of aluminium (0-1.4%) was mixed with palm oil, and the optimal concentration of nanoparticles (0.8%) was chosen through spectroscopic analysis. Subsequently, twenty-seven milling operations were carried out on Inconel 690 material under the best lubricating medium. Finally, the Particle Swarm Optimization (PSO) approach was applied to achieve an optimal machining environment: cutting speed = 88.348m/min, feed rate = 0.108 mm/tooth, and depth of cut = 1 mm. The optimal machining conditions were confirmed by functional experimentation, which has shown that the mean error between the experimental and the predictive outputs is minimal (less than 2%).

Chen et al., (2021).Analysed the syngas yield from the two-stage optimization (Taguchi + RSM) is more efficient than from the single-stage. The syngas yield from the best combination of gas hourly space velocity (GHSV), the oxygen-to-methane molar ratio (O₂/C ratio), and CO₂-to- O₂ molar ratio (CO₂/O₂ ratio) was acquired by a two-stage optimization, namely, the Taguchi approach followed by response surface methodology (RSM). In the first stage, the Taguchi approach suggests that the influences of the factors on the syngas yield were ranked by O₂/C ratio > CO₂/O₂ ratio > GHSV, and the maximum syngas yield is 2.191 mol·(mol-CH₄)⁻¹. Thereafter, the ranges of the three operating parameters are narrowed, and RSM and analysis of variance were used in the second stage to obtain

a more precise optimization. Based on the Box-Behnken experimental design, RSM analysis leads to the maximum syngas yield of $2.304 \text{ mol} \cdot (\text{mol CH}_4)^{-1}$, lifting the syngas yield by 5.15% in the second stage.

Dambhare et al., (2015). Investigated sustainability issues pertinent to the turning process in the Indian machining industry. Parameters such as surface roughness, material removal rate, and energy consumption were considered sustainability factors. The effect of process parameters (speed/feed/depth of cut), the machining environment (dry/MQL/wet), and the type of cutting tool on the response was observed. The process was analysed using response surface methodology (RSM). The results of the study helped to understand the effect of the cutting parameters on surface finish, energy consumption, and material removal rate. The process was optimized from a power consumption point of view. An extended form of the model could be useful to predict the environmental impact of the machining process which will bring environmental concerns into conventional machining.

Zerti et al., (2019). The experimental work was to study the impact of the machining parameters (V_c , a_p , and f) on the surface roughness criteria (R_a , R_z , and R_t) as well as on the cutting force components (F_x , F_y , and F_z), during dry turning of martensitic stainless steel (AISI 420) treated at 59 hardness Rockwell cone. The response surface methodology and the artificial neural networks approach were used for output modeling. Finally, the optimization of the machining parameters was performed using the desirability function (DF) minimizing the surface roughness and the cutting forces simultaneously. Furthermore, artificial neural network and response surface methodology models correlate very well with experimental data. However, artificial neural network models show better accuracy. The optimum machining setting for multi-objective optimization is $V_c = 80 \text{ m/min}$, $f = 0.08 \text{ mm/rev}$, and $a_p = 0.141 \text{ mm}$.

Li et al., (2019). The combined Taguchi, response surface methodology and NSGA-II approach were proposed to optimize the fiber-reinforced composite injection molding process. On the basis of orthogonal experiment design, Moldflow software is applied in the short fiber-reinforced composite injection molding

process. Three response surface models are created on the basis of the simulation results to map the complex nonlinear relationship between design parameters and quality objectives. Based on the response surface model, the relationship between fiber parameters and quality objectives is further discussed. The nondominated sorting genetic algorithm II (NSGA-II) is interfaced with the predictive models to find the optimum design parameter values. The results showed that the hybrid method of response surface method (RSM) and NSGA-II is an effective method to solve the multi-objective optimization problem for the quality optimization of fiber-reinforced composite injection molding.

Mia et al., (2017). The analysis of average surface roughness, cutting force, and feed force in turning of difficult-to-machine Ti-6Al-4V alloy by experimental investigation and performance modeling. Afterward, the models of responses have been formulated by the response surface methodology (RSM) and artificial neural network (ANN). Analysis of variance (ANOVA) determined the effects of cutting speed, feed rate, and insert configuration on the quality characteristics. The results revealed that a cutting speed not exceeding 110 m/min was likely to generate favorable machining responses. In addition, a higher feed rate was found to ensure better machining performances. Moreover, the desirability-based multi-response optimization determined that a cutting speed of 78 m/min, a feed rate of 0.16 mm/rev, and the use of the SNMM tool insert are capable of minimizing surface roughness at 1.05 μm , main cutting force at 315 N, and feed force at 208 N.

Lee et al., (2010). The Taguchi method was used to determine the rough region first, followed by the RSM technique to determine the exact optimum value during turning on a CNC lathe. A new region-reducing algorithm was introduced to narrow down the region of the Taguchi method for RSM. To achieve the goal, the result from the Taguchi method was fed to train the artificial neural network (ANN), whose optimum value was used to drive the region-reducing algorithm. Data located in the literature was also used to inspect the adequacy of the region-reducing algorithm. Both results show that the introduced algorithm has a good region-reducing capability. In a separate experiment, it was shown that the obtained cutting condition from RSM gives a better result than that from the Taguchi method.

Venkata et al., (2018). The statistical models were developed to investigate the effect of cutting parameters on surface roughness and root mean square of workpiece vibration in the boring of stainless steel. Surface roughness, tool wear, and vibration of the workpiece were measured in each experiment. A laser Doppler vibrometer was used to measure the vibration of the workpiece in the form of acousto optic emission signals. Analysis of variance was used to identify significant cutting parameters on surface roughness and root mean square of workpiece vibration. Predictive models like response surface methodology, artificial neural network, and support vector machine were used to predict the surface roughness and root means square of workpiece vibration. Cutting parameters were optimized for minimum surface roughness and root mean square of workpiece vibration using a multi-response optimization technique.

Kilickap et al., (2017). An experimental study was conducted to determine the effect of different cutting parameters such as cutting speed, feed rate, and depth of cut on cutting force, surface roughness, and tool wear in the milling of Ti-6242S alloy using the cemented carbide (WC) end mills with a 10 mm diameter. Data obtained from experiments were defined as both Artificial Neural Network (ANN) and Response Surface Methodology (RSM). Values obtained from the ANN and the RSM were found to be very close to the data obtained from experimental studies. The lowest cutting force and surface roughness were obtained at high cutting speeds and low feed rate and depth of cut. The minimum tool wear was obtained at low cutting speed, feed rate, and depth of cut.

Mondal et al., (2020). The experimental study has been performed according to L_{27} orthogonal array for burr formation in aluminium alloy using an HSS drill This model was optimized using Flower Pollination Algorithm, which helped to determine the optimal process parameters responsible for minimum burr height formation. The result shows that minimum burr height was formed for optimized values of speed 219 rpm, feed 0.04 mm/rev, and point angle 113° . Next, the ANN model has been developed to compare experimental, regression, and ANN

model predicted burr height. For validation, a new set of experiments were performed and validated with ANN and regression model with satisfactory accuracy.

Kumar et al., (2020). The Box Behnken design with a Simulation annealing algorithm were used for the development of the regression model and simultaneous optimization. The effect of machine parameters, namely, weight % of Graphene oxide (GO), spindle speeds, and feed rate, has been investigated for the quality of the drilled samples. The outcomes were validated through a confirmatory test that reveals a satisfactory agreement with actual ones. The findings reveal that the feed rate is the most prominent factor affecting delamination and thrust trailed by GO wt%. Also, a little error has been detected in the predicted results, which confirms the application potential of the proposed module.

Sharma et al., (2022). The recent work used the stir casting technique to develop the Al/SiC composite. The experiments were designed using Response Surface Methodology based Box-Behnken design. According to the available drilling parameters (discharge current, pulse on-time, and pulse off-time) and their level, for each experiment overall, fifteen experiments were performed, and the tool wear rate (TWR) and material removal rate (MRR) were evaluated. After that, empirical models were developed for MRR and TWR, which were further solved by the Multi-objective Grasshopper Optimization Algorithm (MOGOA). It was observed that the predicted solutions suggested by MOGOA produce excellent results and reproducibility. A small amount of burr formation was observed at the optimized setting. Energy dispersive spectroscopy (EDS) has been performed to determine the elements in the drilled composite.

Santhosh et al., (2021). The surface roughness of AISI 4340 alloy steel components in a typical CNC machine is minimized using CNC machining parameters such as feed rate, rotational speed, and depth of cut. The Coded and Actual Empirical model was generated using Face Centred Central Composite Design (CCD) approach in Response Surface Methodology (RSM) to forecast the predicted values. The Artificial Neural Network (ANN) approach was employed to increase the coefficient of regression (R^2) and to get the well-trained best fitness model for the Genetic Algorithm (GA). The confirmation test results explore experimental surface roughness value, and the percentage of error is less in the

Genetic Algorithm than in Response Surface Methodology for AISI 4340 alloy steel components. As a result, this research suggests using a combination of Artificial Neural Network (ANN) and Genetic Algorithm (GA) methodology to find the best machining process parameters and get a good performance response in practical applications.

Ortiz et al. (2021). Compared fundamental and industrial outputs when turning hardened steel 100Cr6 using Cubic Boron Nitride (CBN) inserts with wiper geometry in dry conditions and with cryogenic cooling. For this purpose, turning experimental tests were performed in both cooling conditions varying the cutting speed (150-550 m/min). Machining forces were measured during the tests, and then tool wear, microstructural damage, and residual stresses of the workpiece were characterized. A nose-turning (3D) FEM model was also developed to understand the influence of cooling strategy on the outputs measured experimentally.

A critical summary of the conducted literature on optimization techniques and modelling tools is persecuted further in the table 2.1.

Table 2.2 Brief overview of literature on optimization techniques & modelling tools

Author	Tools & Techniques	W/P material	Operation	Response variables
Adalarasan et al., (2015)	Taguchi, RSM, & GT-RSM	304 L	Turning	Surface roughness, kerf width
Laouissi et al., (2019)	RSM, GA, ANN	EN-GJL cast iron	Turning	Surface roughness, cutting force & power, MRR
Zerti et al., (2019)	Desirability function, RSM, ANN	AISI 420	Turning	Surface roughness, cutting force,
Mia et al., (2017)	RSM, & ANN	Ti-6Al-4V	Turning	Surface roughness, cutting force
Kilickap et al., (2017)	RSM, & ANN	Ti-6242S	Milling	Cutting force, surface roughness, tool wear
Mondal et al.,	Taguchi,	Aluminium	Drilling	Burr height

(2020)	ANN, flower pollination algorithm	alloy		
Santhosh et al., (2021)	RSM, ANN, GA	AISI 4340	Turning	Surface roughness

2.2 Critical Literature Review

Makhesana et al., (2023). The turning tests were conducted under dry, MQL, and nano fluid-MQL (nMQL) environments, and the findings were compared considering surface roughness, chip morphology, tool wear, cutting temperature, power consumption, and micro hardness. The sunflower oil blended with MoS₂ resulted in 56%, 42%, and 22% improved surface quality compared to dry, MQL, and nMQL (Graphite) conditions. Also, MQL, nMQL with MoS₂, and nMQL (Graphite) resulted in lower cutting temperatures by 18%, 35%, and 25%, respectively, compared to dry turning.

Airao et al., (2022). Combining different cooling and lubrication strategies to reduce the tool wear and enhance the machinability of Inconel 718 was a new approach to be studied. Six different approaches of cooling strategies, i.e., Cryo-MQL (LCO₂ delivers on rake and MQL on Flank), MQL- Cryo, EMQL- Cryo, and Cryo -EMQL, EMQL-MQL and MQL-EMQL are used for experiment. The tool wear, specific cutting energy, power consumption, surface roughness, and chip morphology were inspected. The flow of LCO₂ on the rake face and the EMQL on the flank face considerably reduce the tool wear, surface roughness, power and specific cutting energy consumption, in comparison to other strategies.

Shah et al., (2022). Analysed cryogenic coolants i.e., liquid nitrogen (LN₂) and liquid carbon dioxide (LCO₂) were proved to be the prominent alternatives to conventional carbon-based flood coolant pollutants. However, the comparison of these cryogenic coolants based on machining performance was still lacking to cut the materials having low machinability like Inconel 718 at various cutting speeds (v_c). However, the comparison of these cryogenic coolants based on machining performance is still lacking to cut the materials having low machinability like Inconel 718 at various cutting speeds (v_c). In this context, thrust force, tool wear,

and hole quality indicators using field emission scanning electron microscopy (FE-SEM) and Energy Dispersive X-ray Spectroscopy (EDS) analysis, microhardness, chip morphology for drilling Inconel 718 utilizing cryogenic fluids i.e., LCO₂ and LN₂ are extensively explored. By analysing the mean of thrust force, 14 %, 9 %, and 31 % reduced values of it have been observed for LCO₂ as compared to LN₂ when the same quantity of holes were considered for v_c as 10, 15, and 20 m/min correspondingly. Both cryogenic coolants reveal abrasion and chipping wear mechanisms on tools as significant at all v_c . A superior machining performance was observed for LCO₂ in comparison with LN₂ at all v . The superiority of LCO₂ over LN₂ makes it suitable for high-value machining industries.

Gupta et al., (2022). Experimental results showed that in comparison with dry, hybrid LN₂-MQL substantially reduced the tool flank and rake wear followed by LN₂, MQL, and dry conditions, respectively. Additionally, the SEM and EDS analysis depicted relatively less severe wear and chemical elements adhesion on the tool's main cutting edge, while turning titanium alloy under a hybrid LN₂-MQL lubri-cooling environment. In addition, the dry condition has a maximum value of tool wear progressions i.e., 1.04 mm and hybrid LN₂-MQL has 0.06 mm while machining titanium alloys. When tool wear was evaluated from a tribological point of view, the reduction in flank wear value compared to dry machining is 89.4 %, 92.3 %, and 94.2 % owing to MQL, LN₂, MQL, and hybrid LN₂-MQL cutting strategies.

Korkmaz et al., (2022). Surface quality, power consumption, tool wear, micro structural changes, micro hardness after machining, and SEM-EDX analysis were evaluated under dry, minimum quantity lubrication (MQL), cryogenic and hybrid Cryo+ MQL environments. Although the surface quality did not meet the expectations in dry cutting, MQL improved slightly than cryo methods. However, the best surface quality, the smallest tool wear, and power consumption were obtained in the hybrid Cryo+ MQL lubrication/cooling method.

Airao et al., (2022). A novel studied, applied ultrasonic vibration along with MQL and LCO₂, is proposed to enhance the machinability of Ti-6Al-4V. In this

regard, analysed machinability of Ti-6Al-4V in conventional and Ultrasonic Assisted Turning (UAT) under dry, wet, MQL, and LCO₂. Moreover, the LCO₂ and ultrasonic vibration significantly reduce specific cutting energy without compromising the surface roughness and tool life. Ultimately, the LCO₂, along with ultrasonic-assisted turning, promotes sustainability in the machining of Ti-6Al-4V.

2.3 Summary of literature

In the above section, various research's in the field of machining on difficult to cut materials through different types of cooling techniques and parametric optimization through different types of software or tools. After literature, and tables 2.1, 2.2 some research gaps are observed that few researches are available on drilling DSS with environmental friendly cooling techniques. Another is that compare of four types modelling of process parameters e.g. RSM, ANN, ANFIS, FLS are not available in past. For considered these factors some research gaps are formed, these are shows in next section.

The selection of process parameters e.g. input parameters and output parameters based on literature and machine specifications, these are available.

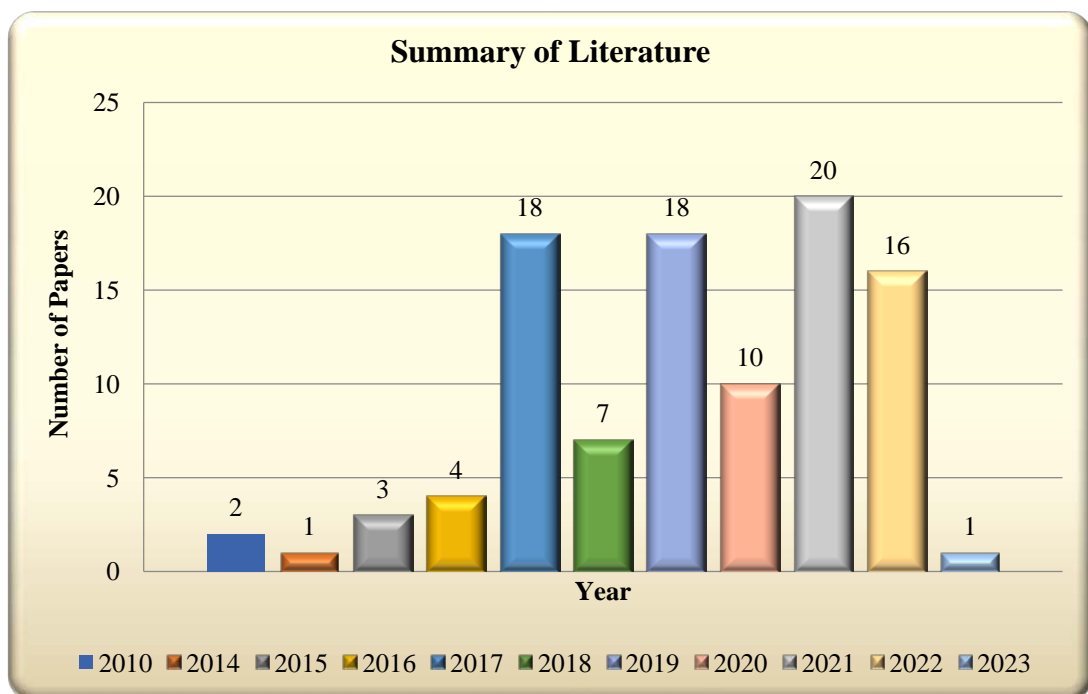


Fig. 2.1: Summary of Literature

Figure 2.1 is shows summary of literature survey year wise. As per figure, it was observed that total 100 papers review for current investigation. Further literature review, some gaps are observed that are below.

2.4 Research Gaps

The comprehensive study on existing work mentioned in an earlier section has highlighted the following statements as a research gap.

- The literature survey overviews difficult-to-cut materials by using different types of environmental friendly cooling techniques. As observed from the literature, few research articles have been found for machinability investigation on Duplex stainless steel with different types of cooling environments e.g. dry, flood, etc. Furthermore, none of the papers has reported on the drilling of DSS 2205 with hybrid MQL-LCO₂ cooling conditions. Thus, for improving the machinability a hybrid cooling technique is implemented for the present investigation.
- The literature survey also overviews parametric optimization and modeling of process parameters by using different types of modeling tools e.g. ANN, FLS, GA, etc. As per the observation, none of the papers has been reported on the comparison of experimental value to predicated model value e.g. RSM, ANN, FLS, ANFIS. In the present study, four modeling techniques were chosen to find the best model that provides the closest value to the experimental value.

2.5 Research Objectives

1. Develop the facilities for machining with a minimum quantity of lubrication (MQL) and liquid carbon dioxide (LCO₂).
2. Evaluation of machinability of duplex stainless steel 2205 under various environmental conditions, including dry, MQL, and liquid carbon dioxide (LCO₂) machining, as well as parametric optimization in terms of Ra and hole diameter error using the Taguchi method of design of experiment (DOE).

3. Implementation of a genetic algorithm (GA) for an optimum process parameter value, as well as Comparison of experimental results against predicted results.
4. Evaluation of machinability under a hybrid approach (MQL + LCO2) of machining in terms of hole diameter error, cylindricity error, and circularity error. Develop the mathematical model and parametric optimization by using the Response Surface Method (RSM) in the design of the experiment (DOE).
5. Compare experimental results to a Fuzzy logic system (FLS), artificial neural network (ANN), and ANFIS to determine the best techniques to use. Also, for multi-objective optimization, TOPSIS is used.