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Review Article

Review of Parameters for Enhancing the Deep Hole Drilling Process Using Cutting Fluids

Dharmendra J. Patel[1], Pravin P. Rathod[2], V. M. Makwana[3], P.K. Jaradi[4], M M. Chandrala[5]

[1]*Gujarat Technological University, Ahmedabad, Gujarat, India.*
[2,3,4,5]*Department of Mechanical Engineering, Government Engineering College-Bhuj, India.*

[1]*Corresponding Author : dharmeetpatel@gmail.com*

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Abstract *- The paper presents a summary of research conducted on deep hole drilling processes using cutting fluids in manufacturing processes. Deep hole drilling is a process having a great L/D ratio. The hole produced by the deep hole drilling process is greatly impacted by a number of variables, including cutting speed, feed, depth of cut, drill diameter, point angle, and cutting fluid. Numerous challenges, including heat production, friction, tool wear, built-up edge and tool deflection, cutting fluid supply, chip removal, surface roughness, and hole roundness, arise throughout the deep hole drilling process. Heat generation in metal cutting operations is caused by friction between the workpiece and tool, as well as metal deformation. Cutting fluid is removing heat by friction.*

Keywords *- Cutting fluid, Deep hole drilling, Frictional heat, Tool wear and Surface roughness.*

1. Introduction

Deep hole drilling involves specialized tools and equipment designed to deliver high-pressure coolant, efficiently remove chips, and create deep, narrow holes in metal. Major problems with deep hole drilling are, first, removing chips with good surface finish, second, supplying cutting fluid to tool-work piece contact surface. Third reducing machining time, four disposals of heat. Also, a high L/D ratio results in issues in obtaining straightness, surface finishing, and roundness of holes [14]. Deep hole drilling process success is contingent upon several factors, including tool torsional rigidity, geometry, coating, chip disposal, cutting edge preparation, and cutting fluid delivery [18]. Cutting fluid is crucial because it removes heat from the cutting zone and lowers heat production by using less cutting force. Cutting fluid is applied in the cutting zone.

- On the back of the chip
- On narrow opening between the chip and rake face of the tool
- On a narrow opening between the finished surface and the clearance flank of the tool.

2. Research Motivation

Cutting fluid enters in elastic zone by capillary effect but does not enter in plastic zone. With the increase in cutting velocity, the plastic zone gradually increases and covers almost all cutting zones, which are unable to cut fluid from lubricating and cooling done by bulk external cooling. The effectiveness of the deep hole drilling process is also influenced by proper tool geometry, including elements such as cutting lips, web thickness, point angle, chisel edge, rake angle, and helix angle.

Therefore, the goal of this study is to present a summary of the literature on the subject of utilizing conventional manufacturing techniques to create small, deep holes. The main emphasis of attention will be on selecting efficient parameters to optimize the deep hole drilling process. These parameters include cutting-edge preparation, tool geometry and its effects on cutting forces, the function of cutting fluid, and the chip removal process.

3. Literature Review

Spur G. et al. (1981) acknowledged in their work that for the correct balance between the accuracy of cross section area and flute area, it is necessary to plan the cross-sectional shape of the twist drill. Moreover, the chips and heat produced in drill operations are by-products.[1]

According to Matthews, et al. (1984) state that the drilling operation generated heat, which was caused by the geometry of the drill bit. In his studies, the author primarily recognized three causes of heat generation.

(a) Friction between chip and cutter rake face. (b) Friction between the cutter flank face and finished surface (c) the principal shear component of heat produced during the drilling process. [2]

Frazao et al. (1986) conclude that it is always a big problem in the machining of holes with accurate size, parallelism, straightness and surface finish in deep hole drilling. It is difficult to obtain efficiency and economy for difficult to cut material due to low machinability. There are two primary methods for doing traditional deep hole drilling: BTA drilling and gun drilling. The use of a BTA tool with two pads causes grooves on the workpiece surface, while the use of three pads increases the stiffness of the tool, improves chip breaking effect and produces good quality deep hole. [3]

Jozef Jurkoa et al. (2012) conclude that drill penetration is most important in the success of the cutting process. In angled and irregular surfaces where cutting edges are unevenly loaded, causing the drill to wear off prematurely, drills can be made to punctured convex and concave shapes into angled and irregular surfaces in contrast to the conventional method where the drill penetrates perpendicular to the work surface, ensures good quality of hole. Convex penetration is often good. The feed should be decreased to one-third of the prescribed amount if there is a surface inclination of more than three degrees. Since the concave penetration radius is smaller than the hole diameter, the drill mesh first and feed must be reduced to a third of the acceptable value in order to prevent the tool from deviating from its starting position due to gradient. [4]

Biermann et al. (2011) determined that tool geometry has an impact on surface integrity in deep hole drilling. Wear between guiding pads, contact area, and radial forces all affect surface quality. Conventional design is capable of producing high-quality bores; modifications in the drill head's conicity and peripheral shape are inappropriate for improving surface quality since they undermine process stability. A newly designed tool with a coating, a protective chamfer at the tool tip, and a more ductile material can achieve greater feed rates. A high level of mechanical load and the influence on the peripheral zone with the new tool are equivalent to the outcomes of studies conducted with the regular tool. [5]

Feng Ke et al. (2005) acknowledged that when drilling length increases in deep hole drilling, chips cannot retain their uniform shape. The chip has a spiral shape at first, but as depth increases, it gets harder to rotate, and the spiral shape of the chip unwinds. Eventually, the unwound spiral shape of the chip turns into a string shape of the chip. When spiral chips turn into string chips, there are a variety of intermittent shapes that can occur depending on drill size, type of material and chip thickness.

The researcher used the process of drilling AICI 1038 at 3000 RPM with a 150 mm/min feed and a 3.2 mm drill bit. The three pecks of 0-5,5-15 and 15-30 mm completed the hole. They saw that every peck of chips showed a change in shape from spiral to sting to uneven short chips.[6]

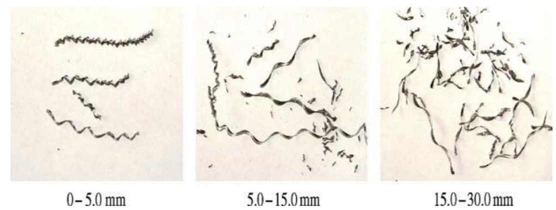

Fig. 1 Chip shape change in deep hole drilling [6]

William J. Endres et al. (2002) noticed a growing tendency to stop the cutting edge from chipping in the application of cutting instruments with a sharpened edge radius. Their results show that tool wear is significantly influenced by corner radius. More specifically, wear at the tool tip and lead edge is significantly decreased by a corner radius of approximately 0.8 mm.

Furthermore, the wear-minimizing corner radius tends to move near 1.2 mm at lower feed rates. In comparison to another corner radius, the wear is less impacted by feed rate when the corner radius is around this wear-minimizing value. [7]

Nakayama et al. (1985) suggested the application of the twist drill bit's cutting-edge nicks. Drill chips break into smaller pieces that are easily removed from the hole through the drill's flutes. This leads to reduced drilling torque, improved surface polish, longer tool life, and less burr at the hole outlet; yet, the issue of continuously mining chips persists.[8]

Sushanta et al. (2003) created a groove on the drill's rake face close to the cutting lip to facilitate chip breaking, lessen drilling force, and prevent the blocking of the chip. Using an aluminum oxide grinding wheel (MA150-KV) and a linear contour grinding process, they produced this groove. Because of the grinding process and the rake face's space limitations, the groove tapered at both ends.

The researchers drilled into 1018 steel workpieces using two-fluted conical point High-Speed Steel (HSS) drills with specifications of 32° helix angle, 118°-point angle, 10.72 mm diameter, 7.5 mm overall length, and 4.25 mm flute length.

They investigated the groove geometry characteristics, including groove radius, depth, width, back wall height, and groove entrance angle, to determine the optimal parameters.

Experiments involved drilling 60 mm deep holes under various combinations of drill geometry parameters and process conditions. Results showed that an ungrooved drill failed after 43 holes, while a grooved drill successfully drilled 67 holes, marking a 55% improvement in drill life. Additionally, grooved drills produced small, fractured chips that exited the hole easily without clogging the flute.[9]

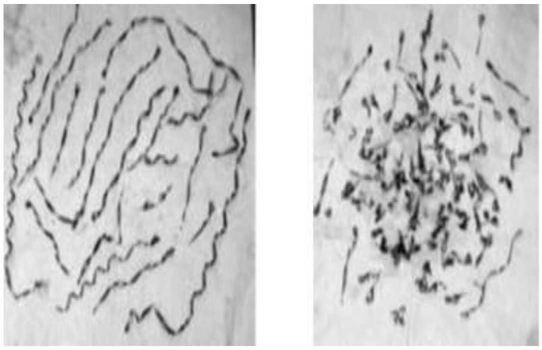

Fig. 2 Chips produce with ungrooved drill and grooved drill [9]

Jeff et al. (2005) examined the shortcomings identified in Sushanta et al. (2003) work that had shaped the grooves on 10.72 mm drills using a linear grinding technique but had trouble maintaining shape control, causing damage to the chisel fringe and drill margin. They overcome these difficulties by creating grooves with exact control over the geometry thanks to a ram-style Electrical Discharge Machining (EDM) technique. They used two drills, each with a diameter of 3.18 mm and 6.35 mm, for their investigations. By varying two parameters in a two-level factorial design, such as flute shape (normal and parabolic) and the presence or absence of a groove, they were able to examine the performance of the groove. The outcomes showed that chip length was successfully decreased by chip breaker groove drills. To increase drill strength, they suggested a groove depth of 0.4 mm for drills with a 6.35 mm diameter and 0.3 mm for drills with a 3.18 mm diameter.[10]

Fang et al. (2005) emphasized the formation of chips during chamfered tool cutting. It highlights how the friction between the tool and the chip, along with the negative rake angle of the tool chamfer, causes distinct plastic deformation zones to emerge when machining with a chamfered tool. These are specific to tools with chamfers. Additionally, this model suggests that, while dealing with worn edges, cutting forces are distributed between the tool's rake and flank sides in addition to predicting the force ratio and chip thickness. Under various cutting settings, the projected results show good agreement with experimental data. When the tool shape and cutting speed determine a threshold value that is smaller than the uncut chip thickness, the thrust force can be greater than the cutting force for both chamfered and honed tools.

A tight relationship exists between this phenomenon of machining and the negative rake angle of sharpened and chamfered tools. The type of work materials employed and the thickness of the uncut chip have a significant impact on how cutting speed affects thrust force. Although a chamfered tool produces a narrower chip, it produces higher cutting forces.[11]

Denkena et al. (2011) acknowledged that wear behavior and tool life are significantly influenced by cutting edge microgeometry, which plays a crucial role in cutting processes. Today's difficult-to-machine materials have more mechanical qualities than ever before, which is why high-performance cutting tools with unique cutting edges are becoming more and more necessary. Furthermore, sharpening the cutting edge improves coating adhesion on the drilling bit, potentially extending tool life. A specific microgeometry can be designed based on the existing cutting tool wear behavior and the anticipated thermo-mechanical stress profile.[12]

Dirk Biermanna et al. (2012) focused on optimizing cutting-edge preparation to enhance tool efficiency. It was observed that rounding the leading edge with 20 μm increased the mechanical load on the tool. This deflection of the leading edge significantly affected surface roughness. Drilling time was reduced by almost an hour with the revised leading edge when the feed rate was raised from 0.03 to 0.05 millimeters per revolution. [13]

Endres et al. (2002) explored the impact of tool flank wear on nose radius. According to their research, tool flank wear at the tool tip and lead edge was lessened when a moderate nose radius was used. The application of coating materials to the instrument, which had yielded encouraging results in the past, was not addressed by the author, nevertheless.[7]

F Y Chang et al. (2004) concentrated on how cutting-edge preparation affects the wear and life of HSS drills. The experiment used magnetic polishing, an unusual but economical technique, to prepare the cutting edges of HSS drills. When compared to sharp-coated drills that were not polished, the drills coated with TiN that were magnetically polished before coating had twice as long of a drill life. According to their findings, the optimal drill life was found at cutting-edge radii of 24 to 27 micrometers. Additionally, they stated that for all drills, the surface roughness and thrust force of the drilled holes increased with feed rate. However, drills with larger edge radii were more likely to produce undersized holes. Thrust force and torque were found to be highly correlated with flank wear. Drills with radiused edges may be able to withstand greater wear and have a longer drill life because they have smaller thrust and torque increments per unit of flank wear.[15]

Dirk Biermann et al. (2008) state that high-performance cutting is characterized by high material removal rates, aggressive cutting parameters, and, consequently, significant cutting forces. These conditions demand cutting tools with enhanced strength and wear resistance, often requiring advanced coatings. The researchers used water jet blasting with abrasive particles to develop several cutting-edge carbide twist drill designs. This preparation included the chisel edge, primary leading edge, and corner. They found that twist drills with prepared leading edges were easier to handle and significantly improved the quality of drilled boreholes, leading to longer tool life.[16]

Galloway et al. (1957) acknowledged that minor alterations in the drill tip geometry can profoundly influence the drill's performance. Therefore, when aiming to enhance machining performance and the quality of drilled holes, careful attention to drill point geometry is crucial. Four main characteristics of this geometry are (1) Chisel Edge, (2) Clearance Angle and Rake Angle, (3) Cutting Lips, and (4) Point Angle. [17]

Todd et al. (1994) recognized that the characteristics of the material being drilled decide the most straightforward tool form to use. The table below includes suggested geometry for a few commonly drilled materials.

Table 1. Tool geometry for different work materials [18]

Tool Geometry			
Work Material	**Point Angle**	**Helix Angle**	**Lip Relief Angle**
Aluminium	90^0 to 138^0	34^0 to 48^0	12^0 to 26^0
Brass	90^0 to 116^0	0^0 to 22^0	12^0 to 26^0
Cast iron	90^0 to 119^0	26^0 to 34^0	7^0 to 20^0
Mild Steel	118^0 to 137^0	26^0 to 34^0	7^0 to 24^0
Stainless Steel	118^0 to 139^0	24^0 to 32^0	7^0 to 24^0
Plastic	65^0 to 95^0	0^0 to 20^0	12^0 to 26^0

Audy et al. (2008) observed that variations can occur between manufacturers as well as between batches in drill point parameters such as tip angle, angles, and web thickness. Depending on the sharpening technique used and the particular sharpener settings, Additionally, there are large variations in the chisel edge region's geometry. Recognizing the complexity of equations involved in predicting forces and power, it has been acknowledged that computer assistance is essential. [19]

Whitfield et al. (1986) explored the effects of drill geometric properties on thrust and torque forces during drilling, including point angle, chisel edge angle, and web thickness. Here are their key findings: [20]

- Increasing drill diameter expanded the area of the cut, resulting in higher torque and thrust forces.
- Greater web thickness correlated with increased thrust and torque ratings.
- While they had little effect on torque, increases in the wedge and chisel edge angles increased thrust values.
- Changes in point angle enhanced thrust force but had little influence on torque.
- Flute angle adjustments reduced both thrust and torque levels.
- Higher drilling speeds slightly reduced both thrust and torque.
- Increasing feed rates raised both thrust and torque.

During their experiments, the authors did not reduce cutting lip size to mitigate lead recovery and minimize thrust force.

Tuijthof et al. (2013) examined the effects of feed rate, point angle, cutting-edge sharpness, and flute shape on the maximal thrust forces during the drilling of animal cortical and trabecular bones. They originated that maximum thrust forces produced are significantly influenced by these drill bit properties. [21]

M. Sujan Kumar et al. (2021) Draw attention to the significant impact that cutting forces, cutting speeds, feed rates, and temperatures have on the drilling process and observe how closely these factors correlate with output characteristics like tool wear and surface roughness. High drilling forces resulting from excessive friction between the workpiece and the drill bit can cause chipping and wear on the tool. Drill breakage and chip blockage might also result from challenging chip removal. Drilling performance has been greatly improved by developments in coolant application techniques and cutting tool materials, such as coated solid carbide tools. Measurements of vibration, force, and temperature, along with process monitoring, are essential for estimating tool wear and surface roughness during drilling operations. [22]

G.L. Tnay et al. (2016) demonstrated that substantial mechanical and thermal strains are produced during deep hole drilling of high-temperature superalloys such as Inconel 718, which can lead to gun drill failure in the absence of efficient chip evacuation. Gun drilling chip evacuation efficiency is mostly determined by the geometry of the drill, which determines the hydraulic conditions for coolant and chip flow. Under high-pressure coolant, they measured the linear and rotational flow motion of gun drill chips with different dub-off angles using a CFD model that was calibrated experimentally. [23]

- It was discovered that greater dub-off angles raise the possibility of chips being stuck at the bottom of the hole since huge dub-off angles cause a significant expansion of the flow, which raises pressure loss and expands the regions of flow separation.
- To be more precise, when using standard tools for dub-off angles of 20° or more, Suction, also known as vacuum pressure, begins to build at the bottom of the

drilled hole. Chips stick to the bottom due to the pressure differential between the chip's front and back surfaces.

- The coolant flow is more effectively managed at the cutting edge for dub-off angles ranging between 0° to 10°.

Liming Shu et al. (2021) explored the impact of high thermomechanical loads generated during the drilling of CFRP (Carbon Fiber Reinforced Polymer) on cutting tools. They proposed a significant improvement in CFRP drilling performance through switching to shear cutting from crushing/compression fracture in the cutting model. This shift was achieved using a novel web thinning design aimed at reducing thermomechanical loads. They carried out a thorough comparison between the novel drill bit and traditional drill bits, paying particular attention to the mechanical, thermal, and chip formation characteristics. Our findings demonstrated that modifying the cutting mechanism had the potential to significantly impact the thermomechanical performance of CFRP drilling. With values of 56.3 N and 71.5°C, respectively, the maximum thrust force and average maximum temperature utilizing the suggested drill were much lower than those of the conventional drill, which had values of 136.7 N and 128.5°C, respectively. Furthermore, the study found that with the conventional drill bit, the average maximum temperature increased with rotation speed and decreased with feed rate. [24]

Milton Luiz Polli et al. (2018) underlined the difficulties of deep drilling, including chip removal and effective cooling and lubrication of the cutting area. They proposed that although it has a lesser cooling impact and less efficient chip removal from the cutting zone, Minimum Quantity Lubrication (MQL) offers an environmentally friendly substitute for conventional wet machining by offering superior lubrication. They discovered that when deep drilling SAE4144 M under MQL, Split point design yielded the best chip shape and relatively low workpiece temperatures when combined with slower cutting speeds and greater feed rates. Amazingly, they were able to drill 800 holes (56 m) with MQL, which greatly increased tool life in comparison to drilling with pressurized oil conditions, which could only drill 21 m. Furthermore, in comparison to holes drilled with pressured oil, a metallographic cross-section of holes drilled under MQL showed more noticeable white surface layers and overlapping surface textures. Due to their propensity for fatigue failure, these surface flaws may restrict the use of MQL in deep drilling of high-pressure component placement. [25]

Ce Han et al. (2018) solve the problem of chip buildup in the drill flutes' enclosed area when drilling deep holes. These accumulating chips raise the drilling torque as the depth of the hole is drilled, which may eventually result in drill failure. A popular method that periodically lowers this torque is peck drilling, which involves stopping the process to remove chips. The longevity of the drill and the effectiveness of the machining process both depend on the depth of each drilling step. A chip evacuation torque model that shows how the torque changes with drilling depth was introduced by the researchers for single-step drilling. By using this model, the peck drilling process can be made more efficient, resulting in less drill breakage and more effective machining. [26]

Robert Schmidt et al. (2023) examine how to improve your understanding of machining operations by using in-process measurements. The contact region is inaccessible from the exterior for procedures such as boring, drilling, and deep hole drilling for the Boring and Trepanning Association (BTA). To measure from within the bore without damaging the workpiece, sensors must be built into the tool. They unveiled a cutting-edge sensor integrated tooling solution that combines a specially created micromagnetic sensor system with a BTA drill head. They also included commercial force sensors beneath the BTA drill head's guiding pad. In this configuration, the tool diameter is still a constraint. [27]

Wanzhong Li et al. (2023), Through a combination of regression analysis, cutting simulation, genetic algorithm, and experimental validation, the cutting criterion was adjusted for machining deep bottle holes. They examined the effects of various cutting criteria on temperature and cutting force using the Response Surface Method (RSM). They specifically looked at how the forces Fx, Fy, and Fz were affected by feed rate, cutting speed and depth of cut and discovered that depth of cut>feed rate>cutting speed was the order of influence. The sequence for cutting temperature (Tn) was v > ap > f. They determined the ideal cutting parameters by applying a genetic algorithm for multi-objective optimization, which were 139.41 m/min of cutting speed, 1.12 mm of cut depth, and 0.27 mm/rev of feed rate. With these specifications, they were able to successfully machine a complexly profiled TC4 tube, obtaining a straightness of 0.5 mm/1000 mm, a hole surface roughness of Ra 3.2 µm, and a length-to-diameter ratio of 36.36.[28]

Xu-Bo Li et al. (2019) glanced at the effects of several conditions on chip breakage and deformation during drilling. They looked into the impacts of tool wear, drilling radius, process variables, and chip breaker geometric factors. Their results demonstrated that chip thickness is strongly influenced by the teeth's cutting radius, with chip thickness rising as the cutting radius increases. The largest chip thickness ratios for the central, intermediate, and external teeth are 1.53:1.17:1, respectively. The maximum chip thickness for each tooth is measured at the edge with the maximum cutting radius. The chip thickness grows in tandem with the feed rate, which rises from 0.04 to 0.12 mm/rev. On the other hand, if you increase the drilling speed between 800 and 1600 r/min, the thickness of the chip decreases. Chip thickness can also be attributed to deeper drilling and wear on the tools. In the staggered teeth BTA deep hole drilling technique, the tool-chip contact length is roughly 1.65 times the chip thickness, contact length closely matching the thickness of the chip during drilling circumstances. The study also discovered that chip strain increases with the drilling feed rate. The chip strain increment for the three teeth reduces progressively from the center to the external to the intermediate tooth. [29]

Faraz et al. (2009) evaluated the impacts of leading edge rounding and flank wear when drilling Compound Fiber Reinforced Plastic (CFRP) composites using 4 different carbide tools using statistical rectilinear regression analysis. Among these instruments were [30]

- T1: A traditional helical-fluted bit ideal for abrasive materials such as CFRPs, featuring a fine and robust K30F grain structure.
- T2: The Ratio drill, which has three helical flutes with a 150°point angle and nearly zeros geometry.
- T3: A three-helix fluted drill with a spiral lead.
- T4: A modern design with four straight flutes and a sharp 20°point angle.

In comparison to the other drills, T2, with its 150°point angle, showed noticeably greater thrust forces and flank wear, according to the study. In contrast, T4 showed the lowest flank wear rate due to its smaller point angle.

Fan Zou et al. (2020) investigated how the drilling performance of 2D Cf/SiC composites using tools of PCD (polycrystalline diamond) is affected by the clearance angle and point angle. They evaluated variables such as hole surface quality, drilling torque, and thrust force. They discovered that while the drilling torque decreases, the drilling thrust force increases when the tip angle increases. On the flip side, decreasing the drilling thrust force and torque results from raising the clearance angle. Furthermore, there exists a direct proportionality between the degree of hole damage and thrust force at the exit. They concluded that cutting through holes is not a good use for a tool with a 180°point angle. Nonetheless, reducing exit damage can be achieved by suitably raising the clearance angle. Despite these changes, the size of the clearance angle does not affect surface roughness due to the inherent properties of Cf/SiC composites. [31]

Amjed M. Kadhim et al. (2021) used the finite element method and DEFORM-3D V.11 software to conduct a numerical analysis of the impact of drill tip angle and cutting parameters on temperature distribution when dry drilling AISI 304 stainless steels. They employed two cutting instruments, one at a 110° tip angle and the other at a 118° tip angle with a 10 mm diameter with 3 feed rates (0.15, 0.25, and 0.35 mm/rev) and 3 cutting speeds (100, 200, and 300 rpm). The findings demonstrated that, for both tools with differing tip angles, higher cutting rates considerably raised the temperature of the workpiece. At tool tip angle of 118°, feed rate of 0.15 mm/rev and cutting speed of 300 rpm, the highest temperature rise recorded was 797°C. On the other hand, at a tool point angle of 110°, feed rate of 0.15 mm/rev and speed of 100 rpm, the lowest temperature gain was 322°C. However, the biggest percentage rise in workpiece temperature due to the increase in cutting speed was 86.9% while increasing from 100 rpm to 200 rpm at a feed rate of 0.15 mm/rev and a tool point angle of 110°. Additionally, when converting the point angle from 110° to 118° at a feed rate of 0.15 mm/rev and at a speed of 100 rpm, the greatest percentage rise in workpiece temperature as a result of the point angle increase was 102.17%. These results suggest that the point angle is more important than the cutting speed in determining the highest temperature produced in the machined models. [32]

Robert Schmidt et al. (2020) investigate the relationship between residual stress and the structure of the process in boring and trepanning association deep hole drilling. Their findings demonstrated differences in the bore's beginning, middle, and end in terms of roundness and roughness. Specifically, they observed that both surface roughness and roundness errors were relatively high at the start and end of the bore. This suggests that the initial and final sections of the bore should be considered separately from the middle section when evaluating surface quality and accuracy.[33]

J. Rajaguru et al. (2021) discussed frequent problems that arise during deep hole drilling, including incorrect chip evacuation, a rough surface, uneven roundness, and excessive tool wear, all of which have a detrimental effect on the quality of the hole. They used Ultrasonic Vibration Assisted Deep Hole Drilling (UVADD) to lessen these issues. Chip morphology, cutting force, tool wear, machining time, torque, surface roughness, and hole quality were used to compare the effectiveness of UVADD with traditional deep hole drilling (CDD). As a result of producing small, discontinuous chips, UVADD dramatically diminished cutting force and torque, according to the data. Burr formation and surface roughness were significantly reduced, and the hole quality significantly improved with a more consistent radius surrounding the edge. Because of the efficient coolant penetration and lowered cutting temperature, an examination of tool wear revealed no built-up edge development along the cutting edge. This thorough investigation showed that, in comparison to CDD, UVADD improved machining performance. [34]

Mateusz Bronis, et al. [2023] investigate the impact of various drilling procedures on dimensional and geometrical correctness of through deep holes. Using cylindrical PA6 aluminium alloy specimens, each measuring length of 30 mm and diameter of 6 mm, VHM HPC TiAlN coated twist drill bits, the experiments were carried out on a 3-axis direct-drive turning centre. Through the spindle, cutting fluid was entered into the cutting zone. The four main output parameters that were analysed were diameter errors, cylindricity, straightness, and roundness. Three approaches to drilling were evaluated: [35].

- The tool operated in both rotary and reciprocating motions with the workpiece fixed.
- The tool moved in a reciprocating motion as the workpiece carried out the primary (rotary) motion.
- Tool reciprocated in addition to the workpiece rotating in opposite directions.

Outcomes demonstrated that the first technique, in conjunction with the greatest spindle speed (4775 rpm) and feed per revolution (0.14 mm/rev), yielded the minimum values for the outcome parameters: straightness (22.7 micrometre), roundness (8.6 micrometre), cylindricity (28.2 micrometre), and diameter error (9.9 micrometre). As a result, it was determined that the technique was the most successful at boring holes in PA6 aluminium alloy.

Margherita Pizzi et al. (2024) tackled the difficulties associated with deep micro drilling, including tool depreciation, size effects, high thrust forces, and restricted heat dissipation. To obtain an aspect ratio of 36, they experimented with micro drilling pure magnesium with a 0.138 mm diameter microdrill. The study looked at how changes in cutting speed and feed rate affected hole quality and thrust force, which had their burr height, entry, and inner diameters measured. Feed rate was found to have a substantial effect on hole quality. As the feed rate increased, the burr height decreased, and the inner diameter approached the nominal diameter. At the maximum cutting speed and lowest feed rate, the lowest thrust forces were noted. The best hole quality could be obtained with the feed rate of 0.0045 mm/tooth and a high cutting speed of 17.56 m/min, with short burrs and enhanced hole cylindricity. [36]

Enemuoh et al. (2001) studied how varying tool tip angles (varying between 75^0 and 160^0) impact surface roughness and trim at the drill exit when drilling CFRE composites. Their research showed that using a 75-degree tip angle resulted in minimal delamination attributed to lower thrust forces while achieving somewhat acceptable surface roughness. [37]

Uwe Heisel et al. (2012) examined how changes in the drilling tool's point angle affect drilling forces and the quality of boreholes in CFRP machining. They found that increasing the point angle notably influences the extent of delamination during drilling. [38]

Sergey Gorbatyuk et al. (2018) conclude that A drill steel guide for tools should be provided with intermediate support to prevent this from happening. A long, straight column loses precision and becomes unstable as the cutting force reaches a crucial value. How tools behave when subjected to an axial compression load can be analyzed. [39]

Bharani Chandar J et al. (2023) studied the use of an Abrasive Waterjet Machine (AWJM) for deep hole drilling on AISI 316L stainless steel. In order to ascertain the machining properties and quality of the holes generated, the study assessed the impact of different drilling parameters on the MRR (Material Removal Rate) and RD (Roundness Deviation) of the drilled holes. [40]

Key findings include:

- Waterjet Pressure (WP): Because of the increased kinetic energy, higher WP causes a faster erosion or cutting rate, which removes more material from the workpiece and increases MRR. Since the WP more effectively controls the changes in hole diameter, higher WP greatly reduces RD.
- Abrasive Mass Flow Rate (AFR): Since there are more abrasive particles available to forcefully impact the target material and remove more material, an increase in AFR also increases the MRR.
- Stand-off Distance (SoD): Greater SoD tends to increase RD, indicating that a larger distance between the nozzle and the workpiece can result in more significant variations in hole diameter.

The study found the ideal process parameters for deep hole drilling with AWJM by applying the Grey Wolf Optimization (GWO) method. An RD of 0.55 mm and an MRR of 31.08 mm³/min were attained with the ideal conditions. A confirmation trial yielded an MRR of 30.33 mm³/min and an RD of 0.545 mm, with corresponding variances of 2.49% and 1.28%.

Simon Strodick et al. (2024) conducted a study to identify correlations between the surface integrity that results from the BTA deep hole drilling operation using the modeling and experimental techniques. They examined how feed rate and cutting speed affected surface integrity and thermomechanical stresses. [41]

Key findings include:

- Feed Rate: Elevating the feed rate led to increased drilling torques and normal forces, which consequently elevated the temperatures at the workpiece-cutting edge contact and subsurface.
- Temperature Effects: Higher feed rates led to elevated temperatures, contributing to the formation of White

Etching Layers (WEL) due to a mix of elevated temperatures and plastic deformation.

- Cutting Speed: More feeds and higher cutting speeds caused elevated temperatures during drilling to exceed the transformation temperature, leading to the formation of WEL. X-Ray Diffraction (XRD) analysis revealed traces of austenite peaks when WEL was present on the bore surface, supporting the phase transformation mechanism for WEL formation.

According to the result, during the deep hole drilling process with boring and trepanning association, the combination of high temperatures and significant plastic deformation results in the creation of WEL, which compromises the integrity of the hole surface.

Dirk Biermann et al. (2024) reported that when deep hole drilling, the cutting edge first slices the bore. After that, a guide pad burnishes the surface of the just built bore wall. These two processes condition the bore wall and affect its surface integrity, depending on the treatment parameters. [42]

The study included a number of finite element models of the BTA deep hole drilling procedure. To shorten calculation times, the Coupled Eulerian-Lagrangian (CEL) approach and continuous remeshing were used.

Simulation Results: In order to verify the simulation results, measured data from earlier research were compared to the simulated results, which included temperatures, process forces, and surface characteristics. Enhancing Model Performance: The goal of the research is to improve the models' ability to replicate many interactions between the cutting edge and guide pad and the bore hole wall, simulating an actual process in which the area of the surface makes repeated contact with the cutting edge/guide pad. It is expected that three consecutive passages will be enough to simulate.

Cooling Lubricant Integration: The second major improvement is the addition of the cooling lubricant used in BTA deep hole drilling. A solid basis for this integration is provided by the CEL technique, which facilitates fluid-structure interaction by applying the Finite Element method or the Smooth Particle Hydrodynamics (SPH) method.

Kamonpong Jamkamon et al. (2021) state that as machining depth increases, Electrical Discharge Machining (EDM) performance reduces while drilling holes. The reason for this reduction is that traditional cleaning methods and electrodes cannot completely eliminate debris particles from the machining region. To solve this, they developed an electrode modification with a step cylindrical shape to enhance deep hole drilling machining performance, the findings indicate that, in comparison to a standard electrode, the step cylindrical electrode considerably raised the MRR by about 215.7%, 203.8%, and 130.4% for hole sizes of 6 mm, 9 mm, and 12 mm, respectively. The electrode wear ratio decreased by approximately 47.2%, 63.1%, and 37.3% for the various sizes, indicating a longer electrode lifespan. Using the step cylindrical electrode decreased the gap clearance and side wall concavity of the drilled holes. Due to the electrode's limited high flank design, debris was able to escape from the machining area to a greater extent. There were consequently fewer secondary sparks on the electrode's side wall, which cut down on machining time and improved roundness with precise machining. [43]

Nils Felinks et al. (2022) found that chips were plagued due to chatter vibrations and worn guide pads in the deep hole drilling process of high alloyed materials. Several tool adjustment techniques were explored to improve process stability, feed rates and bore surface quality in single tube system deep hole drilling. They outline a novel method for creating tribologically best guide pads and explain how it affects guide pad forms by modifying the axial run-in chamber's shape with micro finishing, which enhances the quality of the bore hole. This was further enhanced by applying a coating such as Tin, TiAlN, and ta-c with applying cooling lubricant in the deep hole drilling process. A new Carbon Fiber Reinforced Plastic (CFRP) boring bar and a traditional steel boring bar were used to analyse the machining of austenitic steel AISI 304. The operation was stabilized by the CFRP boring bar's effective reduction of chatter vibrations of the drill head. Whereas the conventional drill tube showed oscillations with distinct eigen frequencies. Even when feeding more rapidly, up to f = 0.3 mm, the CFRP boring bar enabled for greatly reduced vibrations during the machining of austenitic, hard-to-cut materials. [44-46]

Robert Wegert et al. (2020) investigate that various properties like hardness, residual stresses and surface finishing have a high impact on machining processes. In some machining processes, to optimize these properties, it is followed by some heat treatment or other processes. The research tried to measure thermomechanical properties like temperature in the cutting zone during the process using multi sensor base tools in the deep hole drilling process, and cutting parameters have been controlled to control required surface and other properties with process simulations. They found that the temperature in the range from 600 ^{0}C to 800 ^{0}C during the process without cooling lubricant. The simulation date and temperature on the cutting edge have a similarity, but the cutting zone experienced remarkable distortion with high compressive stress. In the simulation feeding force was remarkably higher than the actual process, imputed more feed rate in the simulation. So, by regulating the feed rate in simulation to be closer to the actual condition, improvement has been made in feed forces.

4. Conclusion

Currently, many researchers are focused on developing cost-effective deep hole drilling processes. Based on the literature review, the following points have been noted down as a conclusion.

1. When drilling deep holes, several factors like drill tip shape, tool geometry, coolant supply, selection of process and coating of tool are crucial. However, for drilling small holes less than 1mm, where spindle/tool coolant is not feasible, an innovative approach is required for effective chip removal and coolant delivery.
2. To avoid vibration in the top and table, the machine must be stable; otherwise, it will lead the tool to malfunction. With the development of new composite materials to obtain the best mechanical properties, now today it is necessary to design new specialised machine tools for machine rigidity, especially in the deep hole drilling process due to large L/D ratio.
3. To reduce thrust force and friction force, improve surface smoothness, and ease of chip removal, a new design tool with optimized cutting-edge design must be used.
4. New environmentally and operator-friendly bio cutting fluids, made from synthetic or vegetable-based natural oils, are being explored as alternatives to petroleum-based water-soluble cutting fluids. Further research is necessary to enhance the use of biofuel as a cutting fluid medium, aiming to improve surface smoothness and reduce machining cycle time also MQL technique with Vegetable-based natural oil with high-pressure and low-pressure misting must be used in future work.
5. To achieve better results, further research into the effective use of flooding techniques and tool cleaning is needed.
6. Existing techniques for measuring interior stresses must be upgraded, especially when utilised for difficult to cut material
7. Use of modeling and analysis software must be increased for data selection and processing.

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