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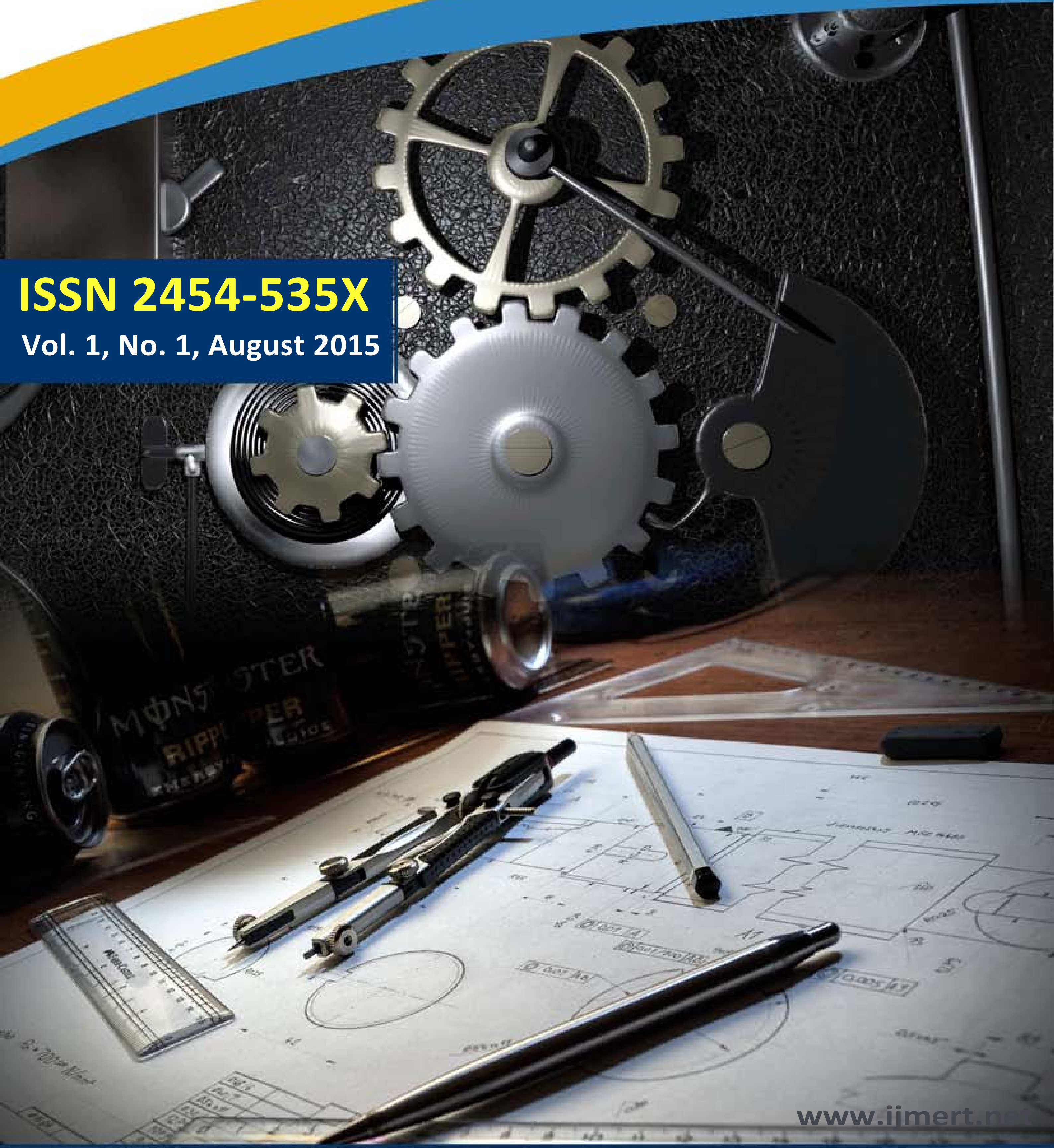

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Research Paper

ANALYSIS OF TOOL LIFE DURING DRILLING

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Drilling is a cutting process that uses a drill bit to cut or enlarge a hole of circular cross-section in solid materials. The drill bit is a rotary cutting tool, often multipoint. The bit is pressed against the work piece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the work piece, cutting off chips (swarf) from the hole as it is drilled. Exceptionally, specially-shaped bits can cut holes of non-circular cross-section; a square cross-section is possible. The basic aim of this project was to find out the drilling tool life by using different tool materials. So we used here Solidwork Modeling and Experimental Analysis to analyze the Factor of Safety for different tool material (3 different variant of steel tool material) by applying the constant force on the tool surface.

Keywords: Drill, Drilling tool, Drilling Bid

INTRODUCTION

A drill is a tool fitted with a cutting tool attachment or driving tool attachment, usually a drill bit or driver bit, used for boring holes in various materials or fastening various materials together with the use of fasteners. The attachment is gripped by a chuck at one end of the drill and rotated while pressed against the target material. The tip, and sometimes edges, of the cutting tool does the work of cutting into the target material. This may be slicing off thin shavings (twist drills or auger bits), grinding off small particles (oil drilling), crushing and removing pieces of the workpiece (SDS masonry drill), countersinking, counterboring, or other operations.

There are many types of drills: some are powered manually, others use electricity (electric drill) or compressed air (pneumatic drill) as the motive power. Drills with a percussive action (hammer drills) are mostly used in hard materials such as masonry (brick, concrete and stone) or rock. Drilling rigs are used to bore holes in the earth to obtain water or oil. Oil wells, water wells, or holes for geothermal heating are created with large drilling rigs.

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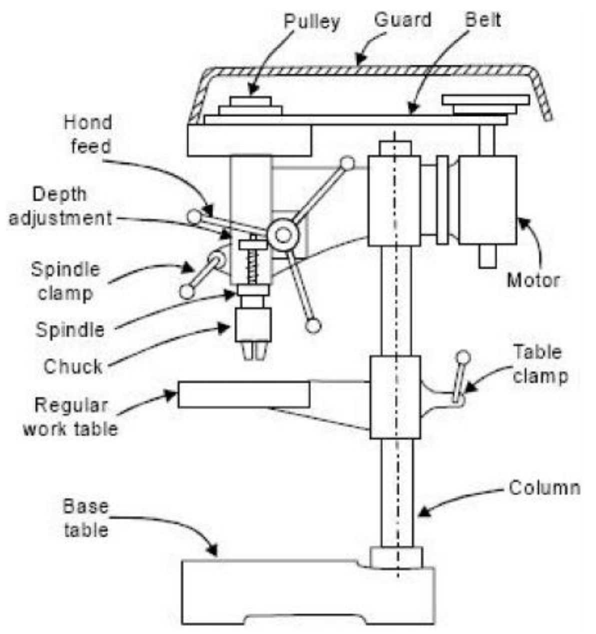
Drilling Machine: A Drilling Machine (also known as a pedestal drill, pillar drill, or bench drill) is a fixed style of drill that may be mounted on a stand or bolted to the floor or workbench. Portable models with a magnetic base grip the steel work pieces they drill. A Drilling Machine consists of a base, column (or pillar), table, spindle (or quill), and drill head, usually driven by an induction motor. The head has a set of handles (usually 3) radiating from a central hub that, when turned, move the spindle and chuck vertically, parallel to the axis of the column. The size of a Drilling Machine is typically measured in terms of swing. Swing is defined as twice the throat distance, which is the distance from the center of the spindle to the closest edge of the pillar. For example, a 16-inch (410 mm) Drilling Machine has an 8-inch (200 mm) throat distance.

Drilling Capacity: Drilling capacity indicates the maximum diameter a given power drill or Drilling Machine can produce in a certain material. It is essentially a proxy for the continuous torque the machine is capable of producing. Typically a given drill will have its capacity specified for different materials, i.e., 10 mm for steel, 25mm for wood, etc.

Figure 1: Schematic of Drilling Machine



For example, the maximum recommended capacities for the DeWalt DCD790 cordless drill for specific drill bit types and materials are as follows:

Table 1: Capacity of Drilling Bit

Material	Drill bit type	Capacity
Wood	Auger	⅞ in (22 mm)
	Paddle	1 ¼ in (32 mm)
	Twist	½ in (13 mm)
	Self-feed	1 ⅜ in (35 mm)
	Hole saw	2 in (51 mm)
Metal	Twist	½ in (13 mm)
	Hole saw	1 ⅜ in (35 mm)

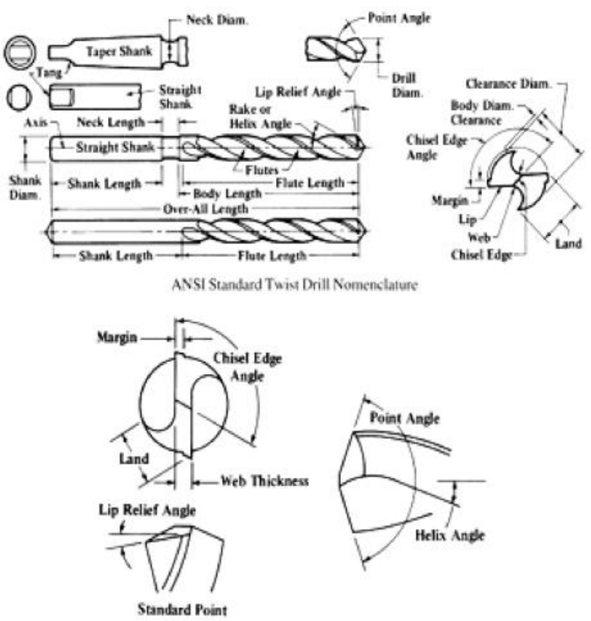
Drill Bit: Drill bits are cutting tools used to create cylindrical holes, almost always of circular cross-section. Drill bits come in many sizes and have many uses. Bits are usually connected to a mechanism, which rotates them and provides torque and axial force to create the hole.

The shank is the part of the drill bit grasped by the chuck of a drill. The cutting edges of the drill bit are at one end, and the shank is at the other.

Drill bits come in standard sizes, described in the drill bit sizes article. A comprehensive drill bit and tap size chart lists metric and imperial sized drill bits alongside the required screw tap sizes.

- The spiral (or rate of twist) in the drill bit controls the rate of chip removal. A fast spiral (high twist rate or "compact flute") drill

Figure 2: Tool Geometry



bit is used in high feed rate applications under low spindle speeds, where removal of a large volume of swarf is required. Low spiral (low twist rate or "elongated flute") drill bits are used in cutting applications where high cutting speeds are traditionally used, and where the material has a tendency to gall on the bit or otherwise clog the hole, such as aluminum or copper.

- The point angle, or the angle formed at the tip of the bit, is determined by the material the bit will be operating in. Harder materials require a larger point angle, and softer materials require a sharper angle. The correct point angle for the hardness of the material controls wandering, chatter, hole shape, wear rate, and other characteristics.
- The lip angle determines the amount of support provided to the cutting edge. A greater lip angle will cause the bit to cut more aggressively under the same amount of point pressure as a bit with a smaller lip angle. Both conditions can cause binding, wear, and eventual catastrophic failure of the tool. The proper amount of lip clearance is determined by the point angle. A very acute point angle has more web surface area presented to the work at any one time, requiring an aggressive lip angle, where a flat bit is extremely sensitive to small changes in lip angle due to the small surface area supporting the cutting edges.
- The length of a bit determines how long a hole can be drilled, and also determines the stiffness of the bit and accuracy of the resultant hole. Twist drill bits are available in standard lengths, referred to as Stub-length or Screw-Machine-length (short), the extremely common Jobber-length (medium), and Taper-length or Long-Series (long).

The diameter-to-length ratio of the drill bit is usually between 1:1 and 1:10. Much higher ratios are possible (e.g., "aircraft-length" twist bits, pressured-oil gun drill bits, etc.), but the higher the ratio, the greater the technical challenge of producing good work.

The best geometry to use depends upon the properties of the material being drilled. The

Table 2 Different Angles for Different Materials

Tool Geometry			
Workpiece Material	Point Angle	Helix Angle	Lip Relief Angle
Aluminum	90 to 135	32 to 48	12 to 26
Brass	90 to 118	0 to 20	12 to 26
Cast iron	90 to 118	24 to 32	7 to 20
Mild steel	118 to 135	24 to 32	7 to 24
Stainless steel	118 to 135	24 to 32	7 to 24
Plastics	60 to 90	0 to 20	12 to 26

following table lists geometries recommended for some commonly drilled materials.

Twist Drill Bits: The twist drill bit is the type produced in largest quantity today. It comprises a cutting point at the tip of a cylindrical shaft with helical flutes; the flutes act as an Archimedean screw and lift swarf out of the hole.

The twist drill bit was invented by Steven A. Morse of East Bridgewater, Massachusetts in 1861. The original method of manufacture was to cut two grooves in opposite sides of a round bar, then to twist the bar to produce the helical flutes. Nowadays, the drill bit is usually made by rotating the bar while moving it past a grinding wheel to cut the flutes in the same manner as cutting helical gears.

Twist drill bits range in diameter from 0.002 to 3.5 in (0.051 to 88.900 mm) and can be as long as 25.5 in (650 mm).

The most common twist drill bit has a point angle of 118 degrees, acceptable for use in wood, metal, plastic, and most other materials, although it does not perform as well as using the optimum angle for each material. In most materials it does not tend to wander or dig in.

LITERATURE REVIEW

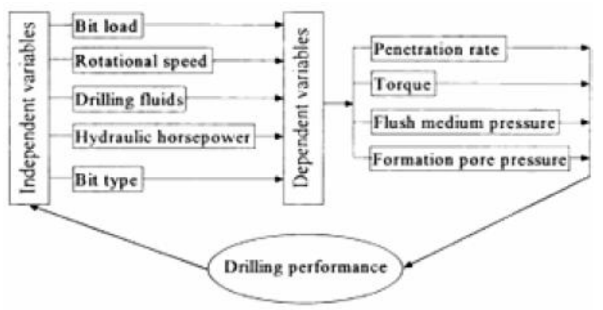
The drilling machine or drill press is one of the most common and useful machine employed in industry for producing forming and finishing holes in a workpiece. The unit essentially consists of:

1. A spindle which turns the tool (called drill) which can be advanced in the work piece either automatically or by hand.
2. A work table which holds the work piece rigidly in position.

Principles of Drilling: The rotating edge of the drill exerts a large force on the work piece and the hole is generated. The removal of metal in a drilling operation is by shearing and extrusion.

The drilling parameters, or variables, associated with rotary drilling have been analyzed and divided in two groups as independent and dependent parameters as shown in Figure 3, (Barr and Brown, 1983; Ambrose, 1987; and Shah, 1992).

Figure 3: Drilling Variables



Dependent Variables: The dependent variables associated with rotary drilling represent the response of the drilling system to the imposed conditions and are the penetration rate of the bit, the torque and the flush medium pressure.

- Penetration Rate
- Torque
- Flush Medium Pressure
- Formation Pore Pressure

Independent Variables: The independent variables are the drilling fluids, bit load, the bit rotational speed, bit type and the hydraulics horse power.

- Bit Load
- Rotational Speed

- Drilling Fluid
- Hydraulic Horsepower
- Bit Type

Literature Based on Tool Life

Luis Miguel Durao, Joao Manuel Tavares, Victor Hugo C. de Albuquerque, Jorge Filipe Marques and Oscar Andrade [1], analyzed the characteristics of carbon fiber reinforced laminates have widened their use from aerospace to domestic appliances, and new possibilities for their usage emerge almost daily. In many of the possible applications, the laminates need to be drilled for assembly purposes. It is known that a drilling process that reduces the drill thrust force can decrease the risk of delamination. In this work, damage assessment methods based on data extracted from radiographic images are compared and correlated with mechanical test results, bearing test and delamination onset test, and analytical models. The results demonstrate the importance of an adequate selection of drilling tools and machining parameters to extend the life cycle of these laminates as a consequence of enhanced reliability.

Peter Muchendu *et al.* [2], analyzed the performance of drilling bits has a direct influence on cost and increase in the rate of penetration translates significantly to cost and time saving. From a total sample of 56 wells, approximately 450 tri-cone bits were consumed at a cost of KSh 200Millions.

The primary objective of this study is to analyze and optimize 8½" tricone bits which were used to drill the 8½" diameter hole at Olkaria geothermal field. The pads had three wells each with the intention of exploring t in order to determine resource availability for massive power production. The exercise covered depth from 750 m to 3000 m using three rigs all with kelly drive systems. The data were compared in average between the daily and sectional drilling range for each well. Evaluation was on weight on bit, rev per minute and strokes in regard to their ROP. Olkaria formation is mainly trachytic and rhyolite with pyroclastic on surface. Also, occasional minor syenitic and deleritic dyke intrusive on bottom with temperatures above 250 degrees centigrade encountered at 3000 m total depth.

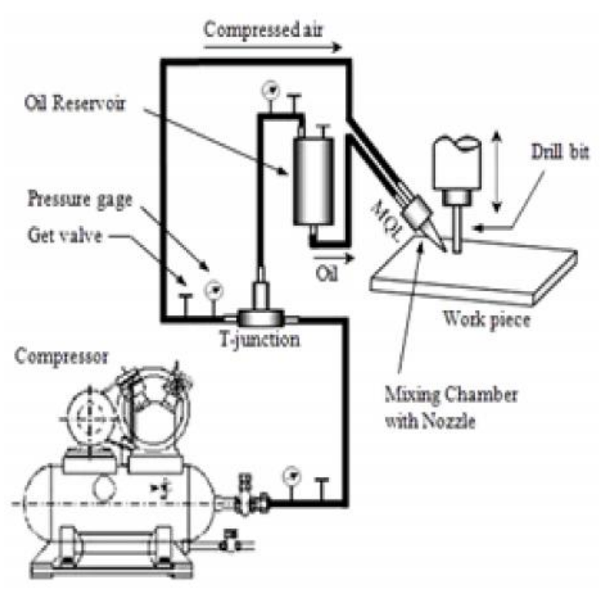
Yahiaouia *et al.* [3], found The quality of innovating PDC bits materials needs to be determined with accuracy by measuring cutting efficiency and wear rate, both related to the overall mechanical properties. Therefore, a lathe-type test device was used to abrade specific samples. Post-experiment analyzes are based on models establishing coupled relations between cutting and friction stresses related to the drag bits excavation mechanism. These models are implemented in order to evaluate cutting efficiency and to estimate wear of the diamond insert. Four main properties of PDC material were used to define quality factor: cobalt content in samples that characterizes hardness/fracture toughness compromise, other undesired phase as tungsten carbide weakening diamond structure, diamond grains sizes and residual stresses distribution affecting abrasion resistance. PDC cutters were submitted to wear tests and a comparison between all these cutters requires an overlap of information. Archard's linear model permits an evaluation of wear rate but a long bit life could be related to a poor cutting performance. For this purpose, an exponential law properly associates cutting efficiency to excavation distance and led to determine a cutting efficiency coefficient. The cutting efficiency coefficient on wear rate ratio establishes a quality factor and associate to sample wear, aggressiveness of the rock field and energy spent to cut it.

Kadam and Pathak [4], analyzed experimental investigation was conducted to determine the effect of the input machining parameters cutting speed, feed rate, point angle and diameter of drill bit on Hass Tool Room Mill USA made CNC milling machine under dry condition. The change in chip load, torque and machining time are obtained through series of experiments according to central composite rotatable design to develop the equations of responses. The comparative performance of commercially available single layer Titanium Aluminum Nitride (TiAlN) and HSS tool for T105CR1 EN31 steel under dry condition is done. The paper also highlight the result of Analysis of Variance (ANOVA) to confirm the validity and correctness of the established mathematical models for in depth analysis of effect of finish drilling process parameters on the chip load, torque, and machining time.

Nourredine Boubekri [5], analised the current trend in the metal-cutting industry is to find ways to completely eliminate or reduce cutting fluid use in most machining operations. Recent advances in technology have made it possible to perform some machining without cutting fluid use or with Minimum-Quantity Lubrication (MQL). Drilling takes a key position in the realization of dry or MQL machining. Economical mass machining of common metals (i.e., tool and construction- grade steels) requires knowledge of the work piece characteristics as well as the optimal machining conditions. In this study we investigate the effects of using MQL and flood cooling in drilling 1020 steel using HSS tools with different coatings and geometries. A full factorial experiment is conducted and regression models for both surface finish and hole size are generated. The results show a definite increase in tool life and better or acceptable surface quality and size of holes drilled when using MQL.

Nazmul Ahsan *et al.* [6], analised the growing demand for higher productivity, product quality and overall economy in manufacturing by drilling particularly to meet the challenges thrown by liberalization and global cost competitiveness, insists high material removal rate and high stability and long life of the cutting tools. However, high production machining with high cutting velocity, feed and depth of cut is inherently associated with the generation of large amount of heat and this high cutting temperature not only reduces dimensional accuracy and tool life but also impairs the surface finish of the product. The dry drilling of steels is an environmentally friendly machining process but has some serious problems like higher cutting temperature, tool wear and greater dimensional deviation. Conventional cutting fluids (wet machining) eliminate such problems but have some drawbacks. Thus machining under Minimum-Quantity Lubrication (MQL) condition has drawn the attention of researchers as an alternative to the traditionally used wet and dry machining conditions with a view to minimizing the cooling and lubricating cost as well as reducing

Figure 4: Schematic View of MQL Setup



cutting zone temperature, tool wear, surface roughness and dimensional deviation. In this work, improvements that were possible when minimum quantity lubrication was used in drilling AISI 1040 steel were examined. Results were compared with drilling under dry and wet conditions.

Wong *et al.* [7], conducted an experimental investigation to determine the effect of drill point geometry and drilling methods on tool life and tool wear in drilling titanium alloy, Ti-6Al-4V. Uncoated carbide drills with different type of geometry under various cutting speeds and drilling methods were used in the investigation. Experimental results revealed that both the drill geometry and drilling techniques affect the tool wear and tool life performance when drilling Ti-6Al-4V. It was also found that peck drilling outperformed direct drilling in terms of tool life all cutting speeds investigated. Non uniform wear and chipping were the dominant failure mode of the tools tested under most conditions.

Table 3: Mechanical Properties of Ti-6AL-4V

Properties	Value
Tensile Strength (MPa)	960-1270
Yield Strength (MPa)	820
Elongation (%)	≥8
Reduction In Area (%)	≥25
Density (g/cm^3)	4.42
Modulus of Elasticity Tension (GPa)	100-130
Hardness (HV)	330-370

Hochenga and Tsao [8], analyzed that the fiber-reinforced composite materials possess advantage for structural purpose in various industries. Delamination is considered the major concern in manufacturing the parts and assembly. Drilling is frequently applied in production cycle while the anisotropy and no homogeneity of composite materials affect the chip deformation and machining behavior during drilling. Traditional and non-traditional drilling processes are feasible for making fine holes for composite materials by carefully selected tool, method and operating conditions. In this article, the path towards the delamination-free drilling of composite material is reviewed. The major scenes are illustrated including the aspects of the analytical approach, the practical use of special drill bits, pilot hole and back-up plate, and the employment of non-traditional machining method.

Jaromír Audy [9], analised experimentally the effects of TiN, Ti (Al, N) and Ti(C, N) as well as a M35 HSS tool substrate material on the drill-life of the GP-twist drills by drilling the Bisalloy 360 steel work material. All these experiments have been statistically planned in order to establish the 'empirical' drill-life-cutting speed equations for each of the three coatings as well as to compare statistically the effects of these different coatings on the drill-life. The results demonstrated that although the coated drills performed very well at conditions much higher than applicable for the uncoated drills, none of the three coatings offered any statistically significant advantage over another coating in terms of the drill life.

PROBLEMS DEFINITION

Nowadays there are several types of Drilling Tools with Different Tool Geometry and Various factors (Force, feeding Rate, MOQ, Tool Material, Tool Geometry, etc.), which are affecting the Drilling Tool Life. In this project will be focus only on Different tool Material with Constant Forces acting on the tool surface for analyzing the Deformation in Drilling Tool Geometry and Find out the Factor of Safety for optimizing the Drilling Tool Life. On Drilling Tool, there are many problems occur such as breakage, wear, rough surface finish, short tool life and so on. This problem affects finishing of machined product, life of cutting tool and reduces productivity of Drilling. Through this study, it will determine effects such as cutting forces and Tool Geometry on work pieces based on three different materials.

OBJECTIVE

The Objectives of the Solidwork Modeling and Experimental Analysis are,

1. To study the effect of Drilling Tool Material and Forces variation on the drilled work piece.
2. To compare the results obtained by the Computational Analysis (Solidwork Modeling) and Experimental Analysis.
3. To evaluate the Factor of Safety for Different material to analyze the Drilling Tool Life.

Thus we can optimize the drilling forces and tool geometry by analysis of deformation due to changing in drilling tool material. Finally we can analyze the deformation in drilling tool geometry and drilling tool life.

COMPUTATIONAL MODELING (SOLIDWORK ANALYSIS)

Table 4: Model Information

Document Name and Reference	Treated As	Volumetric Properties
Chamfer1 	Solid Body	Mass:0.0479244 kg Volume:6.14415e-006 m^3 Density:7800 kg/m^3 Weight:0.469659 N

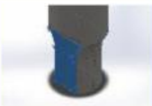
Table 5: Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	1.83193 mm
Tolerance	0.0915963 mm
Mesh Quality	High
Total Nodes	13788
Total Elements	8223
Maximum Aspect Ratio	24.354
% of elements with Aspect Ratio < 3	96.2
% of elements with Aspect Ratio > 10	0.0608
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:04

Table 6: Load Details

Load name	Load Image	Load Details
Force-1		**Entities** **2 face(s)** **Type** **Apply normal force** **Value** **200 N**

Table 7: Fixture Details

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities** **2 face(s)** **Type** **Fixed Geometry**

First Tool Material (44SMnPb28)

Table 8: Material Properties (44SMnPb28)

Model Reference	Properties
	Name: **1.0763 (44SMnPb28)** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **4.9e+008 N/m^2** Tensile strength: **7e+008 N/m^2**

Table 9: Study Results (44SMnPb28)

Name	Type	Min	Max
Stress	VON: von Mises Stress	57244.8 N/m^2 Node: 9992	3.56538e+007 N/m^2 Node: 10459
Displacement	URES: Resultant Displacement	0 mm Node: 707	0.0267083 mm Node: 599
Factor of Safety	Max von Mises Stress	13.7433 Node: 10459	8559.73 Node: 9992

Figure 5: Study-Stress-Stress (44SMnPb28)

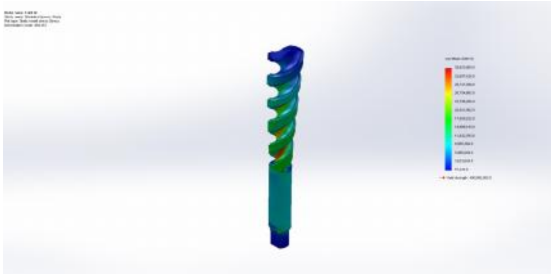
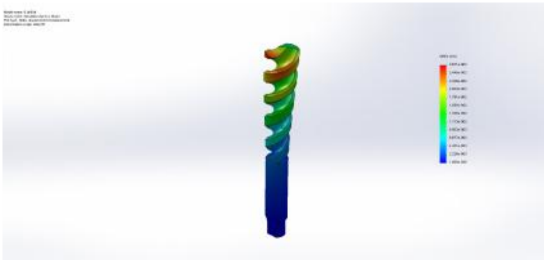


Figure 6: Study-Displacement-Displacement (44SMnPb28)



Second Tool Material (11SMn37)

Table 10: Material Properties (11SMn37)

Model Reference	Properties
	Name: **1.0736 (11SMn37)** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **3.05e+008 N/m^2** Tensile strength: **4e+008 N/m^2**

Table 11: Study Results (11SMn37)

Name	Type	Min	Max
Stress	VON: von Mises Stress	57244.8 N/m^2 Node: 9992	3.56538e+007 N/m^2 Node: 10459
Displacement	URES: Resultant Displacement	0 mm Node: 707	0.0267083 mm Node: 599
Factor of Safety	Max von Mises Stress	0 Node: 1	0 Node: 1

Figure 7: Study-Stress-Stress (11SMn37)

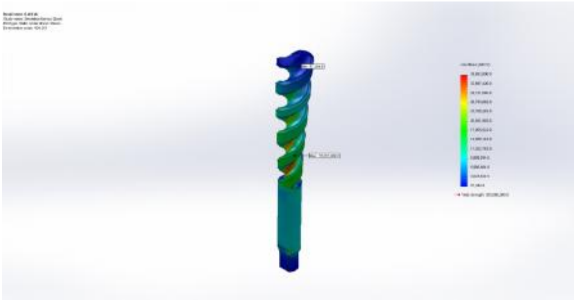
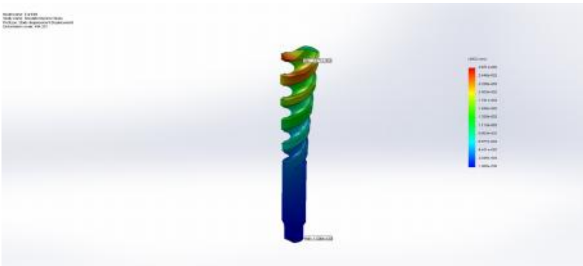


Figure 8: Study-Displacement-Displacement (11SMn37)



Third Tool Material (11SMnPb30)

Table 12: Material Properties (11SMnPb30)

Model Reference	Properties	
	Name:	**1.0718 (11SMnPb30)**
	Model type:	**Linear Elastic Isotropic**
	Default failure criterion:	**Max von Mises Stress**
	Yield strength:	**3.75e+008 N/m^2**
	Tensile strength:	**4.6e+008 N/m^2**

Table 13: Study Results (11SMnPb30)

Name	Type	Min	Max
Stress	VON: von Mises Stress	57244.8 N/m^2 Node: 9992	3.56538e+007 N/m^2 Node: 10459
Displacement	URES: Resultant Displacement	0 mm Node: 707	0.0267083 mm Node: 599
Factor of Safety	Max von Mises Stress	0 Node: 1	0 Node: 1

Figure 9: Study-Stress-Stress (11SMnPb30)

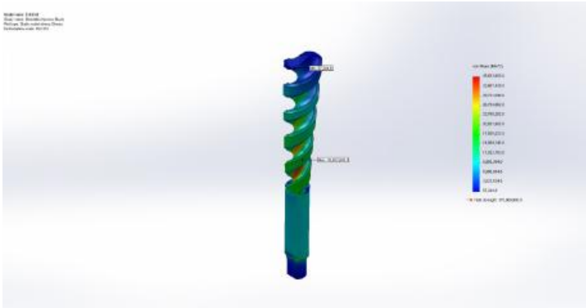
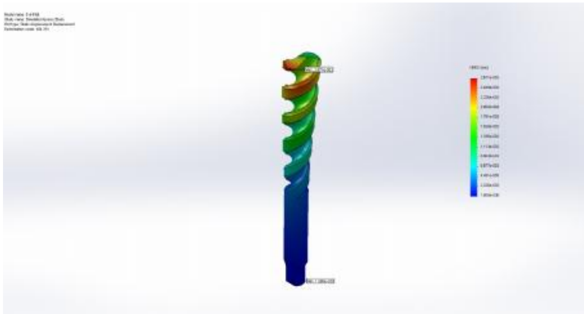


Figure 10: Study-Displacement-Displacement (11SMnPb30)



RESULTS AND CONCLUSION

We used here Solidwork Modeling and Experimental Analysis to analyze the Factor of Safety for different tool material (3 different variant of steel tool material) by applying the constant force on the tool surface.

In Experimental Analysis we can see that the deformation in drilling tool bodies (0.026 mm) is same as the computational Analysis (Solidwork Modeling). So we can say that the results obtained by the Solidwork Modeling will be accurate for other parameters (Deformation, Stress, Factor of Safety).

In Solidwork Modeling, There is each tool of different material body having 13788 nodes and two faces of holding points are fixed for holding the tool body, then we applied a constant load of 200 N on the tool body circumferentially. Now with the help of software, we analyzed the followings:

- In first tool (Material 44SMnPb28), we can see here that the maximum Von Mises Stress ($3.56538*10^7$ N/m^2) is obtained at node 10459, where the minimum Factor of Safety required is 13.7433 and the minimum Von Mises Stress (57244.8 N/m^2) is obtained at node 9992, where the maximum Factor of Safety obtained is 8559.73. We can also see here that the maximum displacement (0.0267083 mm) in tool body is obtained at node 599 and the minimum displacement (0 mm) at node 707.

  By analyzing the tool we can say that the minimum FOS for this tool material is 13.75 to maintain its performance and tool life without failure.

- In second tool (Material 11SMn37), we can see here that the maximum Von Mises Stress ($3.56538*10^7$ N/m2) is obtained at node 10459, where the minimum Factor of Safety required is 0 and the minimum Von Mises Stress (57244.8 N/m^2) is obtained at node 9992, where the maximum Factor of Safety obtained is 0. We can also see here that the maximum displacement (0.0267083 mm) in tool body is obtained at node 599 and the minimum displacement (0 mm) at node 707.

  By analyzing the tool we can say that there is no requirement of FOS for maintaining the tool life and performance.

- In third tool (Material 11SMnPb30), we can see here that the maximum Von Mises Stress ($3.56538*10^7$ N/m^2) is obtained at node 10459, where the minimum Factor of Safety required is 0 and the minimum Von Mises Stress (57244.8 N/m^2) is obtained at node 9992, where the maximum Factor of Safety obtained is 0. We can also see here that the maximum displacement (0.0267083 mm) in tool body is obtained at node 599 and the minimum displacement (0 mm) at node 707.

  By analyzing the tool we can say that there is no requirement of FOS for maintaining the tool life and performance.

Thus by comparing the both analysis (Computational and Experimental), we can validate the results and clearly define the Factor of Safety required the drilling tool material at that working conditions.

FUTURE ENHANCEMENT

By this project work and Analysis, we can optimized the Drilling Tool Life by considering the following factors,

- Drilling Tool Material.
- Drilling Tool Geometry
- Force on tool surface
- Drilling Rate
- Minimum Quantity of Lubrication.
- Types of Drilling Machine.

Thus, we can optimize the drilling process by Mathematical Modeling, Software Modeling and Experimental Analysis for Improving the Drilling Tool Life.

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