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Development of a Methodology for Processing of Drilling Operations

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***Abstract*—**Drilling is the most common machining operation and it forms the highest machining cost in many manufacturing activities including automotive engine production. The outcome of this operation depends upon many factors including utilization of proper cutting tool geometry, cutting tool material and the type of coating used to improve hardness and resistance to wear, and also cutting parameters. With the availability of a large array of tool geometries, materials and coatings, is has become a challenging task to select the best tool and cutting parameters that would result in the lowest machining cost or highest profit rate. This paper describes an algorithm developed to help achieve good performances in drilling operations by automatically determination of proper cutting tools and cutting parameters. It also helps determine machining sequences resulting in minimum tool changes that would eventually reduce machining time and cost where multiple tools are used.

***Keywords*—**Cutting tool, drilling, machining, algorithm.

I. INTRODUCTION

INCREMENTS of the productivity and quality of machined parts are main challenges of metal-machining. Drilling is an important operation in manufacturing industry which is the process of producing round holes in solid materials or enlarging existing holes by use of multi-tooth cutting tools such as drills, drill bits and inserts. The various types of cutting tools are available for drilling but the most common tool is the twist drill. The ratio between quality and costs of products has to be monitored in each production stage as well as immediate corrective actions have to be taken in case of deviation from desired trend. But the same action should be taken before the deviation has occurred. Every manufacturing company needs to develop a methodology for its particular task. Here methodology means how to analyze the information and data in order to select proper tools and conditions. It is a one kind of automation steps for series of choices. The methodology works as an indicator to control the cutting performance which improves the optimization process. The choice of optimized cutting parameters is very important for controlling the geometry of workpiece. The orthogonal array, process planning, selection of cutting tools, fluids and machines with required cutting parameters are employed to study the performance characteristics in drilling operations. Automated process planning has been the main target of researchers and many computer-based systems have been developed in the past [1-2]. Machining sequence planning is an essential part of computer aided process planning. The goal of machining sequence planning is to minimize the sum of machine set-ups, and tool changes. However, it should be noted that machining sequence planning is known as the most complex task of process planning. In most developed systems the precedence relations between machining features are specified by the users. Attempts have been made to automate this function [3-4].

The optimization of machining operations has also been of interest in recent years. The lack of developing realistic optimization strategies may be attributed to the complex nature of the economic machining problem. As well as the lack of quantitatively reliable machining performance equations relating the tool-life, forces, power and surface finish to the many process variables. It has been a tendency of some researchers to use mathematical programming and numerical search algorithms in the optimization of cutting conditions in machining operations [5-9]. These strategies can highlight the effects of the machining to performance data. Moreover, these strategies provide both optimal and feasible solutions provided comprehensive machining performance information and equations as well as known machine tool specifications. Yet the requirement for continuously updating and improving the reliability of the information and allowing for the new development of tool and work materials are re-emphasized in an international survey conducted by the International Institution of Production Engineering Research (CIRP).

This paper describes a methodology for automatic selection of cutting tools and cutting parameters such as cutting speed, feed rate and depth of cut with respect to the specified workpiece geometry, on the basis of an algorithm developed. The paper also presents a method for machining sequence planning on the basis of a method published in the literature [10] which results in minimum tool changes reducing the time and cost of machining significantly.

II. DRILLING TERMINOLOGY AND BACKGROUND

Drilling in simple terms is the mechanism of making a cylindrical hole in a workpiece by removing the solid metal from it. In order to make a hole on the workpiece either the drill is rotated and the workpiece stays fixed but in some cases for example, lathe, the drill stays stationary and the workpiece rotates. Fig. 1 represents terminology and introduces geometrical parameters of drill bits; and Table 1 represents

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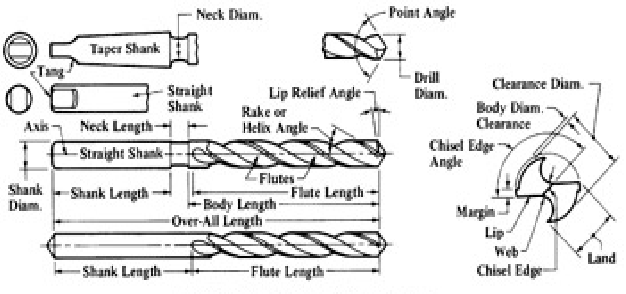
values of important parameters on the basis of workpiece material used which play an important role in the outcome of the drilling operation.



ANSI Standard Twist Drill Nomenclature

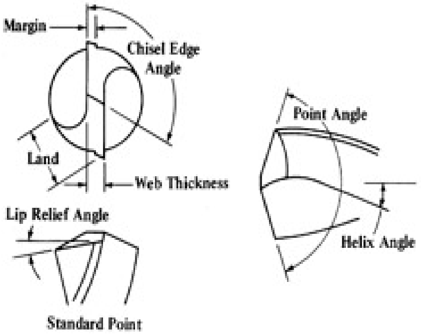


Fig. 1 Geometrical characteristics of drill bits [11]

TABLE I
TOOL GEOMETRY CRITERIA [11]

Tool Geometry Table			
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

A. Quick facts in Relation to Drill Bits

The point angle: As shown in Figs. 2 the standard point angle is 118˚ which is used for general purpose drill bits suitable for drilling soft or mild materials such as cold rolled steel, aluminum, plastic and wood. Most standard drill bits are made from high speed steels. For high performance split-point drill bits the point angle is 135˚ which are used for drilling harder or tougher materials such as hard alloys or cast metals, and tempered steels. Masonry drill bits have a point angle of 130˚ to 135˚ are typically used with a hammer drill which is more effective for installing wiring and plumbing in existing buildings. They are usually available in diameters ranging from 5mm to 40mm [12].

Split point: Split point drill bits are designed to self-centering which are not allowed to walk around on the material before commencing to cut. As well as it can commence to cut immediately due to additional cutting lips along the chisel edge.

Lip relief angle: As shown in Fig. 1 this relief angle is the angle between cutting lips and heel on the drill point. If the cutting lips are higher than heel then the drill will not cut properly.

Chisel edge angle: This is the line across the point of dill bit as shown in Fig. 1. It can be identified by imagining the drill point as a clock face with the chisel angle pointing to an around one o’clock position.

Web: It is the core thickness of a drill point. The size of web is approximately 10% of the drill bit diameter. Thinning the web will maintain the performance of the drill bit.

Carbide drill bits: In the case of carbide tool materials, which are harder and more brittle than high speed steels, the point angle is typically ranging from 130˚ to 135˚. Carbide drill bits can be used for drilling tempered steels, alloys, and glasses.

Parabolic and cobalt drill bits: These types of drill bits have thicker webs than regular drill bits. Cobalt drill bits are designed to increase efficiency and parabolic drill bits are designed to make deep holes.

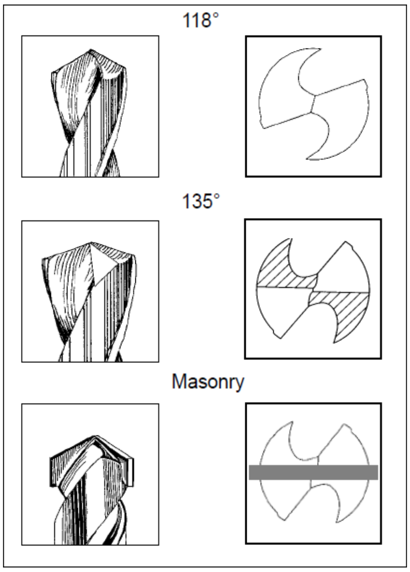


Fig. 2 Typical point angles of drill bits [13]

B. Classifications of Cutting Tools

There are two common types of cutting tools used in drilling processes: general and insert type. General drill bits are often provided with internal and external coolant supply. Insert type drill bits, as shown in Fig. 3, make use of carbide or other types of inserts which are generally harder than the previous type. There are four geometry types of inserts [14]:

1) GM: Can be used for most materials at medium feed rates.
2) LM: Has the first priority for long chipping materials such as low carbon steels. It is suitable to use at medium feed rates and insert has sharp positive edge.

3) GR: Has the choice of high feed rates for steels and cast irons. It is suitable for rough cutting and the is strong at reinforced edge.
4) GT: Mainly used for unstable machining conditions and interrupted cuts. It is suitable for use on materials with low to high cutting speeds.

Fig. 3 Insert types for drill bits [15]

III. METHODOLOGY

The methodology developed for processing drilling operations is presented in the flowchart shown in Fig. 4. Also the algorithm presented below in 9 steps is applied to all drilling operations in order to determine machining sequence planning.

Start Algorithm

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Step 1:
Get the characteristics of available drilling machine
Step 2:
Receive work piece geometry and workpiece material information
Step 3:
Open the workpiece data file
Step 4:
Extract drilling features and divide them into similar hole size groups
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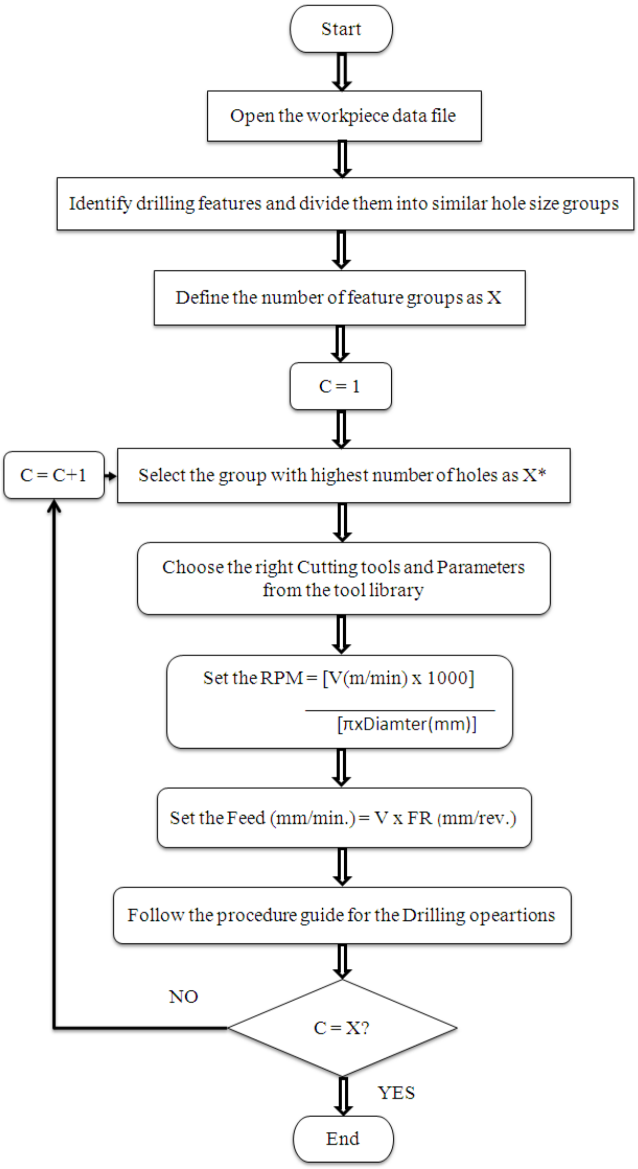

Fig. 4 Process sequence in flowchart for drilling operations

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Step 5:
For-each operation
    Set X as the number of feature groups
end for-each
Step 6:
For-each operation in list X
    Select the group with highest number of holes as X* and select counter C = 1
end for-each
Step 7:
For-each operation in list X*
    Select right cutting tools and parameters from the tool library and set RPM and feedrate
end for-eeach
Step 8:
Follow the procedure guide for drilling operations
Step 9:
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For-each operation in list $X^*$
        if $C < X$
          then set $C = C+1$ and repeat steps 7 to 8
           if $C = X$
             then terminate
           end if
     end if
end for-each

end algorithm
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IV. CASE STUDY

The workpiece shown in Fig. 5 is a base plate of a fixture. The material for this workpiece is cast iron and the required quantity is 10 samples. As shown in the flowchart of Fig. 5, processing of this part begins with receiving the geometrical information of the workpiece from a CAD file. It is noteworthy that characteristics of the drilling machine and production requirement will be entered by the user which is not shown in the flowchart. Then it identifies X as number of drilling features required which corresponds to the number of drilling features available in the workpiece. Then the system forms drilling groups by putting all of the similar hole sizes on the same plane in a one group. Then it arranges drilling feature groups from the highest to the lowest number of drilling features and sets the first group as X^* with the value of 1. Table II represents that this workpiece has five types of drilling features with different hole sizes.

For drilling sequence planning an approach similar to the one developed by [10] is adapted. This approach would result in minimum number of tool changes. The methodology performs all the drilling sequencing by following these three rules:

1) Processing starts from drilling the feature with highest number of holes, and gradually descending to drilling the feature with lowest number of holes.
2) If all features have same number of holes, then one is chosen on a random basis.
3) Drilling process is started from the leftmost hole in a given feature.

The system chooses the right cutting tools and fluids with respect to the workpiece and operation characteristics and available cutting tools in the tool library. It also computes drilling parameters by use of information restored in the database and also some computations where needed, as represented in Table III for this particular workpiece.

Then, the methodology checks to see if $C = X?$ If the answer is negative then it adds 1 to the value of C and repeats all these steps until last feature is processed.

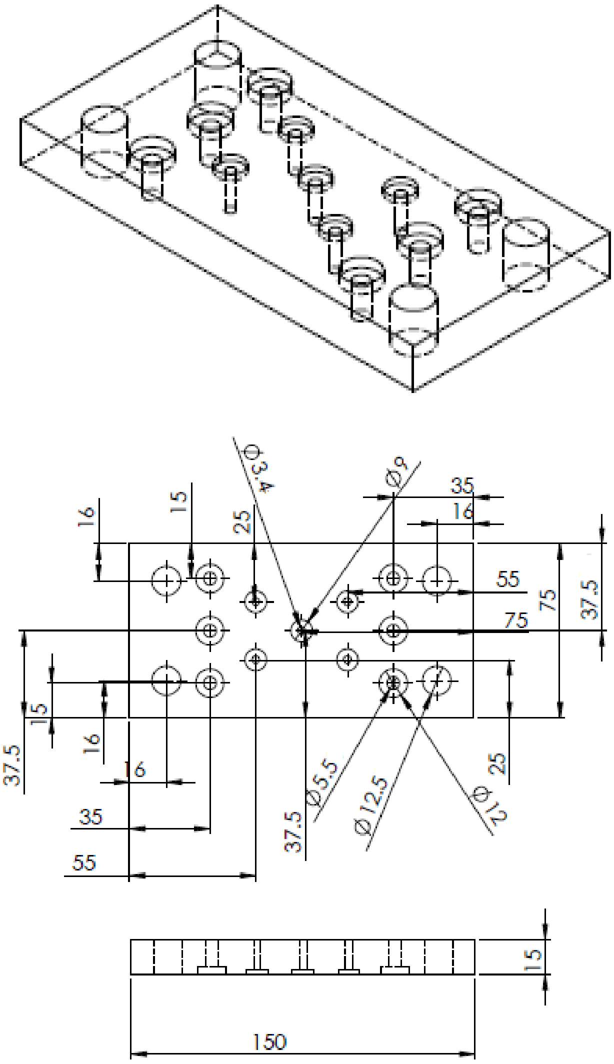

Fig. 5 The fixture base plate

TABLE II
DRILLING FEATURES

Feature group	Hole dia (mm)	Number of holes
1	12.00	6
2	5.50	6
3	9.00	5
4	3.40	5
5	12.50	4

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TABLE III
DRILLING PARAMETERS

Feature	Diameter		RPM	Feed mm/rev	Tolerances
	Drill	Hole			
1	20	12.0	2918	292	± 0.25mm
2	6	5.5	4051	810	± 0.20mm
3	10	9.0	3537	1061	± 0.20mm
4	6.0	3.4	6553	1311	± 0.20mm
5	20.0	12.5	3820	382	± 0.25mm

V. CONCLUSION

This paper described a methodology for processing drilling operations and explained an algorithm developed for automated machining sequence planning of drilling-related operations. The methodology concludes that properly defined operation sequences and an effective algorithm can minimize the time needed for machining, setting-up, and tool changing. It is also concluded that the choice of tooling and cutting conditions depend upon many factors that include workpiece and cutting tool materials, workpiece geometry, etc. The methodology developed has been used for a number of test parts and proved to be capable of handling drilling-related operations efficiently. It resulted in minimum tool changes reducing the time and cost of machining significantly. More work is needed to cover other operations such as turning and milling.

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Ankit Shah is a mechanical engineering student at Edith Cowan University in Perth, Western Australia. As the final year engineering project he worked on a challenging project on developing a new methodology for drilling operations.