DEVELOPMENT OF A DRILLING BURR CONTROL CHART FOR STAINLESS STEEL

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Abstract — A control chart of drilling burr formation for stainless steel was developed. The chart, based on experimental data, is a useful tool for prediction and control of the drilling burr. Burr classification was carried out based on the geometric characteristics and the size of the burrs. New parameters consisting of cutting condition variables and drill diameter were developed, and used to show a special distribution of the burr types. Burr types, resultant burr size, showed great dependence on the new parameters regardless of the drill diameter. Through the chart, the burr type can be predicted for given cutting conditions, and alternatively, cutting conditions that are believed to create a preferred burr type can be selected.

Introduction

The drilling burr is one of the most commonly encountered problems in the drilling process. Burrs may interfere with the assembly of parts and can cause jamming and misalignment. They may cause short circuits in electrical components and may reduce the fatigue life of components. Furthermore, burrs can be a safety hazard to personnel because they are usually sharp [1]. Therefore, deburring – a process to remove the burr- that requires additional cost must be carried out. In most cases, a smaller burr is preferred because it requires less deburring cost. Depending on the application however, a specific type of burr is preferred. This is why we try to avoid the formation of a drilling burr or at least to minimize it, or sometimes, to control the type of the burr.

It is very difficult to develop reliable analytical models for prediction and control of drilling burr formation. Drilling burr formation is a very complicated phenomenon affected by many parameters such as drill geometry, material property and process conditions. The Drilling Burr Control Chart is a tool to predict and control the formation of drilling burrs under given drilling conditions. Alternatively, it can be used to select the cutting parameters that are believed to create a reduced burr for the application.

The chart is based on experimental results. Newly developed parameters consisting of the variables of the drilling process are used. As part of an introductory study, Stainless steel workpiece material (AISI304L) and split point twist drill were used. Cutting conditions, feed rate and cutting speed, were varied over a wide range of levels, and two different drill diameters were used to find the correlation between drill diameter and the burr created. The chart shows the specific distribution of burr shape and burr size as a function of the newly developed parameters consisting of feed rate, cutting speed and drill diameter.

Development of Parameters

The first parameter of the chart is related to the feed rate and drill diameter. The thrust force directly affects the amount of the plastic deformation of the material at the final stage of the drilling process, and as a result, influences burr formation. It is known that increase in the feed rate in drilling tends to increase the thrust force. Correlation between feed rate and thrust force with varying drill diameters can be approximated by applying the shear plane model to the drilling process.

Figure 1 shows the shear plane model applied to a fraction of the cutting edge of a drill. Together with the Merchant equation, $j = p/4 + (a - l)/2$, and the expression for the rake angle varying with relative radius, r/R [2], we can calculate the thrust force that is exerted on a fraction of the cutting edge. Finally total thrust force can be expressed as

$$F_t = \sum \left(\Delta F_{t,ChiselEdge} + \Delta F_{t,CuttingEdge} \right) = \sum \left(k \cdot f \cdot R \cdot fn(j \cdot l \cdot t \cdot h \cdot k) \right) \tag{1}$$

where, k is the shear strength of material, f is feed rate (mm/rev), h is the helix angle, $2k$ is the point angle of the drill and t is the ratio of web thickness to the drill diameter. Since it is stress that directly influences the burr formation, an effective stress is considered and can be represented as the following.

$$\tilde{s} = \frac{F_t}{\tilde{A}} \propto \frac{F_t}{d^2} = \frac{f}{d} \cdot fn\left(Material(k, l), Geometry(j, t, h, k) \right) \tag{2}$$

Since the same drill geometry and material are being considered, it is believed that the effective stress is determined only by f/d. As a result, f/d influences the final burr formation and can be used as a parameter for the chart.

Another important parameter is cutting speed, defined as the product of drill diameter and spindle speed, N. Depending on the cutting speed, the amount of heat generated at the cutting edge changes greatly, influencing some

properties of the workpiece material. It also affects the rate of tool wear, specially for the corner wear which is believed to have a large influence in drilling burr formation.

Finally, the parameters for the chart are: $F_n = \frac{f}{d}$, $S = a \cdot d \cdot N$

Classification of Drilling Burrs in Stainless Steel

Two different shapes of drilling burr were observed, Figure 2. Figure 3 shows the proposed burr formation mechanisms for each burr type. Uniform burr has relatively small and uniform burr height and thickness around hole periphery. A drill cap is formed in the final step of burr formation and it can remain attached to the workpiece or can be separated from it. The crown burr has large and non-uniform burr height.

More detailed classification has been made by the burr height, thickness and height/thickness ratio. Table 1 shows the final burr classification. Type I is a uniform burr with smaller burr height, and Type II is also a uniform burr with relatively large burr height. Burr height of both types is drill diameter independent. Type III is a crown burr, which has no drill cap and the height is drill diameter dependent.

Drilling Burr Control Chart

Figure 4 shows the Drilling Burr Control Chart that contains all data and boundary lines between burr types. The exponential equation between Type II and Type II was found by least square fitting.

The 'conditions for general drilling' within the rectangle in the figure refers to the recommended conditions for general drilling of stainless steel with a high speed steel drill. The common area, dotted region in the figure, represents the range of conditions, which likely create holes with minimized burrs as well as acceptable productivity and hole quality.

With the chart, burr type and burr size can be predicted for given cutting conditions. And alternatively, cutting conditions that are believed to create preferred burr types can be selected.

Reference

[1] Kalpakjian, S., 1997, "Manufacturing Processes for Engineering Materials," 3rd Edition, pp607-608.

[2] William R.A., 1974, "A Study of the Drilling Process," Journal of Engineering for Industry, pp1207-1215

[3] Kim, J., Dornfeld, D., A., 1999, "Experimental Study of Burr Formation in Drilling of Intersecting Holes with Gun Drill and Twist Drills," Technical Papers of the NAMRC, SME, pp39-44

	TYPE I	TYPE II	TYPE III
Burr Type	Uniform with a drill cap		Crown
Burr Height(mm)	~0.15	0.15~1.0	(1.1~1.5)(d/2)
Height/Thickness	0.8~1.6	1.5~3.2	3.8~5.3

Table 1 Burr classifications.

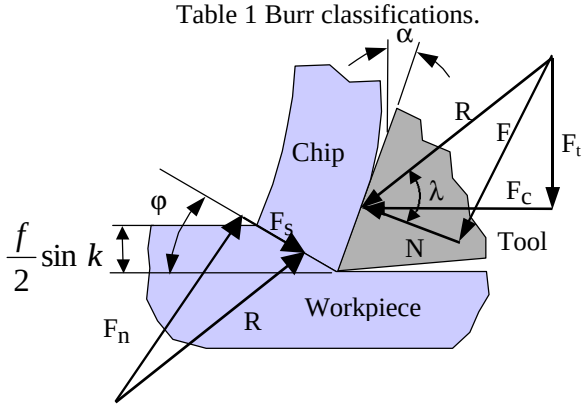

Figure 1. Shear plan model of the drill cutting edge

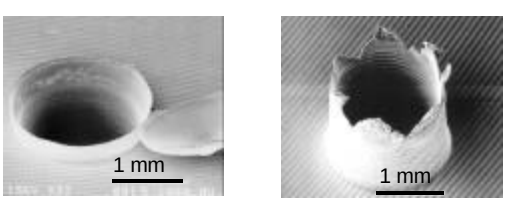

Figure 2 Two types of drilling burr of stainless steel
(a) Uniform burr with drill cap (b) Crown burr

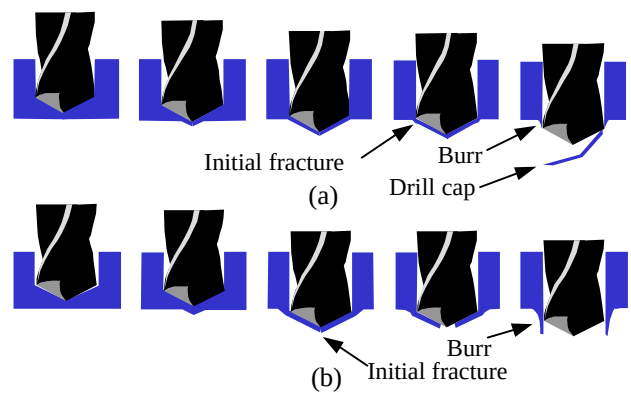

Figure 3 Proposed burr formation mechanism [3]
(a) Uniform burr with drill cap (b) Crown burr

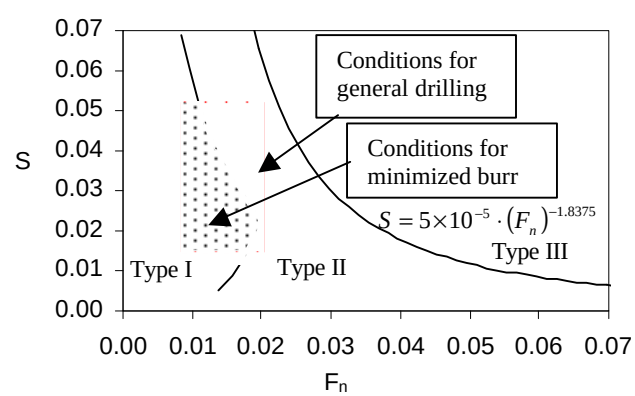

Figure 4 Drilling burr control chart.