Title
Drilling Burr Control Chart -Adding a Material Property Axis

Authors
Reich-Weiser, Corinne
Dornfeld, David A

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DRILLING BURR CONTROL CHART – ADDING A MATERIAL PROPERTY AXIS

Corinne Reich-Weiser
corinne@me.berkeley.edu

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ABSTRACT

A 2-dimensional drilling burr control chart was developed by Jinsoo Kim (2000, 2001) which quantifies the effects of feed rate and speed on burr size; but, each chart is only useful for a specific type of material, and many materials have yet to be studied. What is needed is an understanding of how material properties and their dependence on temperature effect burr formation, to avoid the necessity of creating a burr control chart for every type of material. The goal is to use previous studies of material properties and burr formation to develop a third axis on the burr control chart. Ideally, one could create a dimensionless number that is a function of the material properties that most effect burr formation.

Keywords: burr, control chart, drilling, material properties

OBJECTIVES

Burr control charts are extremely useful for industry applications, because a designer can look at the control chart and see the type (i.e. size and shape) of burr formation that is expected under specific cutting conditions. The downside of these burr control charts is that they have been created for specific material types, and these charts do not apply for materials with vastly different properties. Rather than create a new, experimentally based, control chart for each material type used in industry, the objective is to create a third axis on the drilling burr control chart, which will include the effect of material properties.

BACKGROUND

A drilling burr control chart was developed by Jinsoo Kim (2000, 2001) for low alloy steel AISI 4118 and stainless steel AISI 304L. The control charts were established from experimental data on burr heights, where the material and drill geometry (135^o split point twist drill, HSS, 32.5^o helix angle) were fixed; the controllable parameters of drilling are feed and speed. A dimensionless feed parameter, equal to the feed (mm/rev) divided by tool diameter (mm), is used along the horizontal axis of the chart. Along the vertical axis the feed parameter (S) is represented. These parameters are given byequations 1 and 2.

$$F_n = \text{(feed)/(tool diameter)} \quad (1)$$

$$S = \text{(spindle speed)(drill diameter)}10^{-5} \quad (2)$$

Three burr types were observed while creating the drilling burr control chart: Type I, Type II, and Type III. These burr types are described in table 1 (S. Min, 2001). A line was fit through the data, using the method of least squares, to determine where the shift occurs from one burr type to another. The resulting drilling burr control charts are shown in Figure 1 (Kim, 2001).

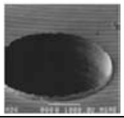
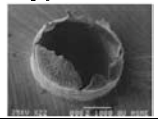
	Type I 	Type II 	Type III 
Burr Type	Small Uniform Burr	Large Uniform Burr	Crown Burr, Transient Burr
Burr Height	~0.18mm	~0.18-1mm	(1.1-1.5)(0.5d)

TABLE 1. OBSERVED BURR TYPES.

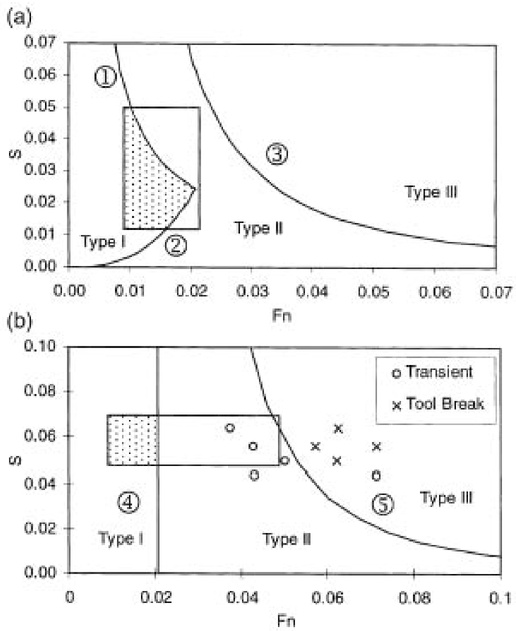


FIGURE 1. DRILLING BURR CONTROL CHART FOR (a) STAINLESS STEEL (b) LOW ALLOW STEEL.

ADDING MATERIAL PROPERTIES

There are many parameters that effect burr formation during drilling. These include feed, speed, drill geometry, and workpiece material properties (strain hardening, ductility, tensile strength, thermal expansion, etc). The influence of material properties on burr formation has been mentioned by many previous papers on burr formation, but Link was the first to quantify this effect.

In 1992 Link proposed the burr tendency equation (G, Equation 3), which provides a value related to the material's tensile strength (σ_t), yield strength (σ_y), percent elongation at fracture (Z), and percent reduction of area (A) (Kim, 2001). This formula is essentially a measurement of ductility. K is a constant used to create a dimensionless number.

$$G = K^{-1}(\sigma_t - \sigma_y)(A + Z) \quad (3)$$

If Link's burr tendency equation is applied to the two materials studied for the Drilling Burr Control Charts, a trend can be seen. This is shown in Figure 2, where the stainless steel is $G = 146K^{-1}$, and the low alloy steel has a value of $G = 279K^{-1}$. Clearly, as the G value increases, the tendency to form large burrs moves towards lower feed and speed rates.

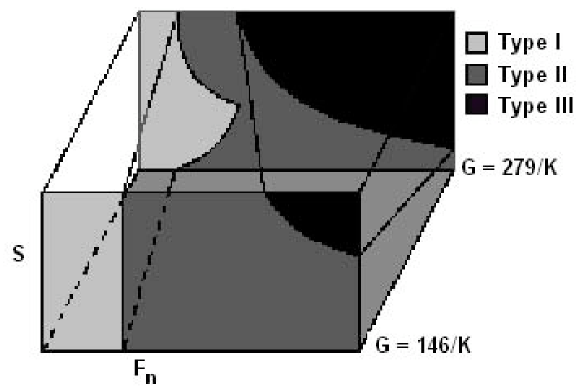


FIGURE 2. EFFECT OF BURR TENDENCY [G] ON DRILLING BURR CONTROL CHART.

As seen in Figure 2, the G value provides some understanding of how the chart will shift to the left (i.e. burrs are created more easily) with increasing workpiece ductility; however it does not indicate how the divisions between burr types will look. For example, the shift between type I and type II is linear for the lower G value and S-shaped for the higher G value. This is because the G value does not consider any change in material property with temperature.

It is known that with increasing speed rates, the workpiece temperature will increase; thus effecting material properties. This can be seen in the burr control chart for Stainless Steel, where for a constant feed value, there is a specific range of speeds that minimize the burr height.

The increase of temperature with feed and speed has been understood intuitively for many years, and was studied more recently by Koichi Kitajima (2004), who also investigated changing material properties. His graphical results are provided as figures 3, 4, and 5 for ASTM 5056 Aluminum Alloy (G value is approximately 30/K).

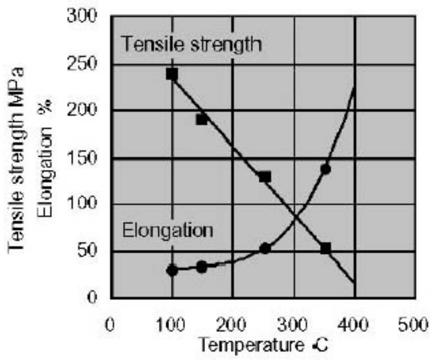


FIGURE 3. MATERIAL PROPERTY VARIATION WITH INCREASING TEMPERATURE.

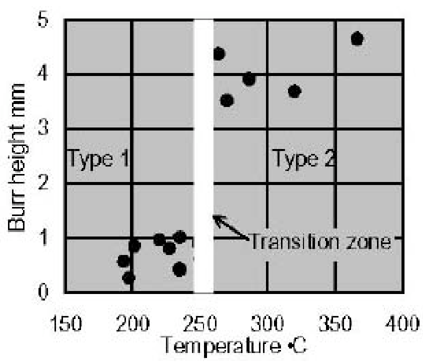


FIGURE 4. BURR HEIGHT VARIATION WITH INCREASING TEMPERTAURE.

By investigating the relationship between material properties and temperature for a variety of materials, and comparing this with the material's G-value, it should be possible to create a third axis to the drilling burr control chart.

FUTURE WORK

- Investigate all relevant material properties (strain hardening, thermal expansion, thermal conductivity, ductility) and establish a testing criterion to determine their influence on burr formation.
- Determine a dimensionless number that is a function of material properties to complete the 3rd axis of the drilling burr control chart.
- Complete experimental testing to verify the hypothesized 3-D drilling burr control chart.

REFERENCES

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