Sample of Level 3 Editing

(Manufacturing)

Target Tutor included, Content Ideas included

The Effect of Uncut Chip Thickness on Edge Chipping and Grinding Ratio in Groove Grinding of Single Crystal Silicon

1. Introduction

~~With the growing of~~ ~~As~~Due to the growth of the semiconductor and optics industries~~ have grown~~, demand has increased for enhanced~~ing~~ manufacturing quality and reduced~~ing~~ machining costs~~ is increasing~~. Most mechanical machining of ~~the~~ semiconductor materials and optic glass requires the use of a diamond-impregnated wheel for grinding~~ with diamond-impregnated wheel~~. Groove grinding is extensively used for separating small sized components ~~or~~ and for cutting grooves. Edge chipping is a major issue ~~D~~during the precision groove grinding of brittle materials~~,~~ ~~the serious edge chipping is a major issue~~ due to the brittleness of the workpiece. In addition, the ~~G~~grinding wheel ~~additionally~~ often comprises a~~up to~~ majority of the manufacturing cost, ~~because~~ due to the large utilization of the diamond wheel during manufacture, and its' high unit price. For these reasons, an improved ~~better~~ understanding of ~~what happens during~~the groove grinding process should provide a technologicaly~~y~~ basis~~e~~ for engineers to enhance the process efficiency ~~enhancement~~ and ~~point way for the~~guide equipment manufacturers ~~to~~in ~~future~~ improving~~ement~~ their

Commented [M1]: IDEA: Your readers may find it interesting to read more regarding the increasing need for the machining process, so it may be helpful to include references.

Commented [M2]: IDEA: It would improve your article to elaborate on the uses of this process and the industries, in order to demonstrate its relevance.

Commented [M3]: IDEA: It may be useful to identify the more commonly used materials, to highlight the need for this research. (i.e. your research focuses on single crystal silicon, but if you highlight other materials that are also commonly used, it will serve to demonstrate how large an issue edge chipping is).

Commented [M4]: IDEA: Cite a reference for this statement.

Commented [M5]: CHECK: "large utilization" refers solely to the fact that the diamond wheel is used greatly during the manufacturing process. Is this your intention? Or were you intending to imply the large running costs of the wheel, due to power consumption, or other factors? (Utilization does not necessarily imply costs, particularly if power costs are small, so it may be helpful to elaborate on this point).

products.

Efficient production~~vity~~ is achieved in the groove grinding of brittle materials ~~requires~~ through the selection~~ing~~ of suitable grinding conditions, and by consideration~~ing~~ of material properties, in order to maximize the wheel life while controlling edge chipping. The fundamental grinding parameter ~~for~~ in a grinding process is the cutting geometry.~~,~~ ~~which is also called~~In particular, it is the uncut chip thickness ~~or~~ (also known as the grit depth of cut) [1, 2]. In general, the uncut chip thickness is well known to play an important role relative to the surface finish and ~~to~~the wheel life. ~~For the~~ In regards to the surface finish, controlling the uncut chip thickness ~~by varying~~through the modification of grit size, grit density, wheel dimension, cutting speed, feed speed, and/or wheel depth of cut can improve the surface roughness [1-7]. In past studies ~~on~~ of surface finish, ~~some~~ researchers have undertaken ~~to~~ experiments to investigate ~~experimentally what happen during~~the effects of ~~changing~~ altering the uncut chip thickness. The surface roughness ~~is indicated in experimental investigations~~ can be improved ~~effectively with~~ by decreasing the feed rate, abrasive grit size and/or increasing cutting speed, as reported by some authors [1-4]. For very hard materials~~,~~ such as silicon nitride [5], silicon carbide~~on~~ [6] and granite [7], the roughness of the grinding surface also decreases ~~with decreasing~~as the uncut chip thickness decreases. ~~Besides characterizing for surface finish~~In addition to its' effect ~~up~~on the surface finish, the uncut chip thickness can be a factor ~~to characterize~~in determining the wheel wear for a cutting process. For instance, it has been experimentally shown that ~~the behavior in~~ during the sawing of granite, there is evidence that suggests a transition in the predominant diamond wear mechanism, from~~or~~ attrition at a smaller uncut chip

Commented [M6]: CHECK: "controlling" or "minimizing?"

Commented [M7]: CHECK: Normally I've only seen 'cutting geometry' used to refer to a group of cutting tool parameters. I have changed the sentence to reflect this, however, feel free to alter it if you feel that your usage is correct.

Commented [M8]: CHECK: Depending on the journal to which you are submitting, it may be unnecessary to use "by some authors [1-4]." Instead you may be able to simply use "by [1-4]."

Commented [M9]: CHECK: Do you mean "silicon carbon" or "silicon carbide?"

Commented [M10]: IDEA: Consider stating how much of a factor it is. Is it the critical factor? Or only a minor factor?

Commented [M11]:
TUTOR – word choice:
Incorrect: "…to characterize the wheel wear…"
Correct: "…determining the wheel wear…"
Reason: "characterize" indicates that the uncut chip thickness is a symptom of wheel wear while "determining" is used to indicate that the uncut chip thickness is a factor in the degree of wheel wear.

thickness to fracture at a larger uncut chip thickness [7].

In addition to the uncut chip thickness, the material properties of the workpiece may also be a crucial factor. ~~The material removal process d~~During the grinding of a brittle material, the material removal process results in brittle fracture and leads to ~~the~~an undesirable ~~worsens~~decrease of surface roughness. This occurs~~,~~ to a greater degree ~~more ease~~ than would occur in conventional metal cutting. ~~But~~ However, if the cutting parameters ~~were~~ are chosen adequately, ~~the~~ brittle materials can deform ~~plastic~~plastically, without brittle fracture, at room temperature under conditions of large hydrostatic compressive stress [8, 9]. Research in ~~S~~scribing [10-12], turning [13], vibration cutting [14], and grinding [15-17] ~~also~~ have~~s~~ also observed ductile chip ~~respectively~~formation. In order to ensure~~get~~ a ductile-to-brittle transition~~al~~ depth during the~~in~~ cutting of brittle materials, analysis~~zing~~ of fracture mechanics [15, 18] ~~or~~ and dislocation theory [19] ~~further~~ can aid in estimat~~ing~~e the transition~~al~~ depth~~,~~ ~~that is called~~known as the critical depth of cut (CDC). The CDC can be formulated as a function of the geometry of the tool and the material properties of the workpiece [18]. The CDC model for a grinding process ~~on~~ used for various hard and brittle materials has been presented [15].

Commented [M12]: **CHECK**: Does "worsens" means reduces surface roughness or increases it? This is a little ambiguous here.

Commented [M13]: **IDEA**: Include a reference to demonstrate that this statement is accurate.

Commented [M14]: **CHECK**: "Plastic" is a noun or adjective. Do you intend to say that the brittle materials can deform another plastic material? Or that they themselves deform plastically? Or do you mean in a ductile manner? I have assumed your intention was that the brittle material deforms in a plastic manner.

Commented [M15]: **IDEA**: It may be useful to discuss how this research relates to your focus on grinding.

Commented [M16]: **CHECK**: It would be clearer here to state either “The CDC model... has been presented in [15]." Or alternatively, to state “The CDC model... has been presented by Bifano, Dow and Scattergood [15]."

~~A logical methodology forto optimizatione of the grinding parameters, in order and to reduce total manufacturing cost in groove~~

~~grinding of brittle materials (given for consideration~~ing the for ~~wheel life and groove edge chipping)~~ ~~in groove grinding of brittle materials is still lacking,~~ AAlthough several grinding studies have been reported, a logical methodology for the optimization of the grinding parameters, in order to reduce total manufacturing cost in groove grinding of brittle materials (given consideration for wheel life and groove edge chipping), is still lacking. An experimental investigation of edge chipping and performance in the grinding of a single crystal silicon (SCS) wafer over a range of uncut chip thickness (5 nm – 32 nm) has been undertaken in this study~~, over a range of uncut chip thickness (5 nm – 32 nm)~~ ~~in this process of a commercial single crystal silicon (SCS) wafer is then attempted in this study~~. The results show that ~~the~~ edge chipping and wheel performance ~~for~~ in a groove grinding process can be characterized by a newly defined value, i.e. the cutting depth ratio (CDR). This dimensionless parameter can be used ~~for~~ to explain~~ing~~ the effect of uncut chip thickness on ~~the~~ edge chipping and the grinding ratio ~~in~~during groove grinding of SCS. Evidence derived ~~form~~from both of these approaches ~~can~~ provides important insights into the groove and cutoff grinding mechanism for ceramics.

Commented [M17]: **CHECK**: Please ensure that this retains your desired meaning.

Commented [M18]: **CHECK**: Please clarify what they have reported. Have they reported possible sub-optimum methodologies, the necessity for a study into optimization of parameters, or the effects of paramater optimization? (Or some mix). Or are you referring to those studies already cited in your paper? (If this last is the case, then it is unnecessary to include "although several grinding studies have reported."

Commented [M19]: **CHECK**: Please ensure that this retains your desired meaning.

Commented [M20]: **IDEA**: If you are going to state what they have reported, please include some citations to ensure interested readers can pursue these avenues of thought.

Commented [M21]: **CHECK**: Are you referring to wear resistance or another measure of performance?

Commented [M22]:
TUTOR: - word choice:
Incorrect: “form” is a noun used for a number of things, such as appearance.
Correct: "from" is a preposition used to indicate a starting point.
This occurs a few times during this article, I felt it worth pointing out.

2.

Process~~ing~~ Modeling

The block diagram ~~in~~for a groove grinding system ~~can be~~is illustrated in~~as~~ Fig. 1. ~~Many~~ A variety of input parameters directly ~~affect~~affects the grinding mechanisms and their influence on the resulting edge chipping and wheel performance. This study reduces these input parameters to two characteristic parameters, the uncut chip thickness and the critical depth of cut (CDC), ~~A~~assuming that the thermal effect in the fracture removal process ~~more small~~is of negligible magnitude in comparison to the ~~than~~ cutting force effect [20].~~, this study therefore groups and reduces these input parameters into two characteristic parameters, uncut chip thickness and CDC.~~ The following section defines the uncut chip thickness and the CDC.~~Introducing uncut chip thickness, CDC, and how to define new characteristic parameter are described detailed on the following section.~~

Commented [M23]: CHECK: As before, please specify what performance refers to.

Commented [M24]: IDEA: In some instances, such as those in which you are highlighting the aims of the study, it may help to use the full term (i.e. critical depth of cut), rather than the acronym (CDC), in order to reinforce the meaning of the acronym to the reader. (Although this is not strictly necessary).

Commented [M25]: IDEA: What is the thermal effect? Will your readers understand this term? It could potentially help to explain this term and why your are neglecting it.

2.1 Uncut chip thickness

The uncut chip thickness ~~of~~ in grinding processes can be formulated as a function of the grinding conditions and the geometry of the wheel. The essential ~~parameter~~ variables include~~s~~ the cutting speed, feed rate, depth of cut, contact length of cutting, abrasive grit size, and active grit density, as shown in Fig. 2. The a~~A~~verage uncut chip thickness is given by ~~the following equation. [1]~~

$$\bar{t} = \left[\left(\frac{v}{VCr}\right)\left(\frac{d}{l}\right)\right]^{0.5}$$

(2)

Commented [M26]: CHECK: Equations 1 and 2 are out of order.

where C is active grit density (grits/mm^2); V is cutting speed (m/sec); v is feed rate (mm/sec); d is cutting depth (μm); l is contact length of cutting (μm) and r is the ratio of the mean scratch width to the mean scratch depth (10 - 20) [1].

2.2 Critical depth of cut

The d~~D~~uctile to brittle deformation transition has been shown to occur~~exist in~~ during the indentation and~~ in the~~ cutting~~ process~~ of brittle materials, as reported by some researchers [8-17]. This transitional depth is ~~called~~known as the critical depth of cut. An analytical model ha~~ve~~s been presented to predict the theoretical critical depth of indentation [18]; this model was later modified to estimate the CDC in the grinding of a brittle material, and is given by [15]

$$d_c = \alpha \frac{E}{H}\left(\frac{K_c}{H}\right)^2$$

(1)

where E, H and K_c are the Young's modulus, hardness and fracture toughness respectively. α is the grinding tool factor representing the combined effect of the tool geometry and the cutting conditions.

2.3 Cutting depth ratio

The removal mechanism in the cutting of brittle materials is deeply affected by the CDC of the work material and the uncut chip thickness. For thi~~s~~e~~ reason, th~~e~~is following investigation ~~is further then combining~~combines the CDC model of the work materials with the average uncut chip thickness~~,~~ in order to discuss ~~the~~ groove edge chipping and the ~~life of~~ wheel lifespan. The cutting process is then characterized by a newly defined value, the cutting depth ratio (CDR), or γ_c. The CDR is defined as the ratio ~~as~~of the maximum uncut chip thickness ~~and~~ to the CDC. As the depth of the cut is ~~very~~ far smaller than the diameter of the wheel, the maximum uncut chip thickness is ~~notedly~~notably around twice the average uncut chip thickness [1]. The CDR can be written as

Commented [M27]: IDEA: would readers know the terms scratch width and scratch depth? It may help to elaborate on these terms.

Commented [M28]: CHECK: As per previous comments.

Commented [M29]: CHECK: Is this reference to "this model was later modified to estimate the CDC in the grinding of a brittle material" or for the following equation? If the former, insert the reference at the end of "the grinding of a brittle material", or if the latter, then insert it at the end of the sentence (after the equation, just before the first period).

Commented [WL30]: CHECK: Should this be here or is it an error?

Commented [M31]: CHECK: Please ensure that this sentence retains your original intended meaning, as the original sentence was difficult understand.

Commented [M32]: CHECK: Was this your intention?

Commented [Ozy33]:
TUTOR – grammar:
Incorrect: very far smaller
Correct: far smaller
Reason: 'very far' can be used in 'very far away', 'very far from here'. That is, 'very far' acts like one word meaning a long distance. To say 'very far smaller' is thus strange.

$$\gamma_c = \frac{t_{max}}{d_c} \square \frac{2\bar{t}}{d_c}$$

(3)

where t_{max} is the maximum uncut chip thickness, d_c is the cutting depth, and $\bar{t}$ is the average uncut chip thickness.

Commented [WL34]: CHECK: You may be missing a symbol in this equation from a lack of characters.

Commented [WL35]: CHECK: Again, is this symbol meant to be here?

3. Experimentation

3.1 Set up and cutting parameters

The experiments were ~~carried out on a~~undertaken using a grinding machine tool ~~using~~ incorporating a diamond-grinding wheel. A c~~C~~ommercial single crystal silicon wafer was used as the work material. Fig. 3 shows the schematic illustration of the groove grinding experiment, where *d* is the depth of cut and the wheel width ~~is~~ was 43 µm. The diameter of the wheel ~~is~~ was 55.56 mm. Fig. 4 shows the distribution of the participating grits for ~~a~~the wheel. Subsequently, using the abrasive grit size (#2000), diameter of wheel, and the distribution of the participating grits, the~~n could estimate~~ active grit density ~~could be~~was estimated~~, which is~~ ~~at~~to be 23885 grits/mm^2. Table 1 summarizes the experimental conditions used for studying ~~the~~ edge chipping and the performance. The experimental parameters were the depth of cut, feed rate and cutting speed. The c~~C~~utting length of every experiment ~~is~~ was 120 m. At the restricted range of experimental parameters, the ~~variable~~ average uncut chip thickness lies between 5.5 nm to 32 nm, as listed in Table 2.

Commented [M36]: CHECK: Please check this term. To a non-technical reader this would appear that the wheel was designed to grind diamond. The use of this term is fine if it is a commonly known technical term, otherwise, it may be clearer to state something along the lines of "a diamond-grit grinding wheel."

Commented [M37]: IDEA: Your readers may be interested to know where the SCS wafer that you have used would be commonly used in manufacturing. Also consider providing the manufacturer of the wafer.

Commented [WL38]: TUTOR:
Incorrect: "…could be estimated…"
Correct: "…was estimated…"
Reason: The use of "could be" suggests that it is not necessary to have that value. If however, the value is critical, you should use "was estimated".

Commented [M39]: CHECK: 120 meters seems very large given measurements for other variables. Is this correct?

Commented [M40]: CHECK: What do you mean by restricted range? Will your readers understand this terminology? Perhaps include a sentence to explain this term.

As ~~S~~shown in Fig. 5, ~~the method of~~ digital imaging was used to quantify ~~detect~~ the magnitude of groove edge chipping. A CCD camera was used to catch edge chipping images off-line. Each~~very~~ experiment took ~~at~~ minimum of 50 pictures ~~least~~. The ~~P~~pixel array ~~is~~ was 640X480~~-~~, the size of each image ~~is~~ was 300X225 μm ~~per picture~~, and the mode of image acquisition card ~~i~~was IMAQ PCI-1408. As stated ~~above~~previously, the resolution of the images was~~is~~ 300/640 μm.

Commented [M41]: CHECK: It may help to clarify to your readers what off-line is referring to (a simple explanation in brackets would suffice).

Commented [Ozy42]:
TUTOR – word choice:
Incorrect: every experiment
Correct: each experiment
Reason: ‘Every’ means ‘not just this one or that one, but all of them’. The emphasis is on ‘all of the’.
‘Each’ means ‘the first, second, third and fourth one etc’. The emphasis is on ‘the same applies to each experiment'
Example: I think there is some error in the result. Every (*all of the)* experiment has some measurement error.
Example: How much time will we need? Well, each (*the 1st, 2nd , 3rd etc)* experiment takes 10 min, so we need 2 hours in total.