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IDENTIFICATION OF INSTABILITIES OF CHIP FORMATION BY IMAGE PROCESSING TECHNIQUE

M. A. U Patwari[1,2], A.K.M. Nurul Amin[2], W. Faris[3]

[1]Department of Mechanical and Chemical Engineering, Islamic University of Technology, Dhaka
[2]Department of Manufacturing and Materials Engineering, [3] Department of Mechanical Engineering,
Faculty of Engineering, International Islamic University Malaysia

ABSTRACT

Metal cutting is a chip forming process. Different types of chips are formed during machining. The nature of chip formation process is extremely complicated. This paper includes the findings of an experimental study on instabilities of the chip formation process during end milling operation of Ti6Al4V alloy at different cutting conditions. The instabilities of chip formation process are expressed in terms of primary or secondary serrated frequency. The chip formed at different cutting conditions is analyzed considering the chip cross-section and microstructure under the optical microscope and scan electron microscope. The image obtained from the microscope is further analyzed to identify the serrated teeth elements by detecting the edge using image processing technique. The developed technique can detect the serrated element identifying the boundary of the each teeth element. It has also been observed that the primary serrated frequency is more prominent in end milling of Ti6Al4V alloy compared to other materials. This developed technique will be useful to calculate the chip serration frequency during machining operation which is the primary cause of chatter formation.

Keywords: Image Processing, Chip Formation, Instabilities of Chip

1. INTRODUCTION

In metal cutting, the term “chip formation” has been used since the nineteenth century. Its initial meaning is the formation of the chip in the primary and secondary deformation zones. Primary attention was devoted to the kinematics relationships, cutting force and contact processes at the tool–chip interface. Later on, the chip-breaking problem became increasingly important with increasing cutting speed, the development of new difficult to-machine materials. Even though the term “chip formation” is still in use, its original meaning has been transformed. The modern sense of this term implies the chip, which just left the tool–chip interface and is yet to be broken [1-2]. The chip is enormously variable in shape and size in industrial machining operations. Chip morphology and segmentation play a predominant role in determining machinability and chatter during the machining operation of materials. In metal cutting, the present tendency is toward achieving increased material removal rates with a high degree of automation and without close human supervision. This requires very reliable machining processes, where the predictability of chip formation is very important.

Much research work has been done on the chip formation in turning, drilling and face milling. Komanduri [3-4] has made some remarkable progress in the research of chip segmentation and instability in chip formation. Nevertheless it appears that very few works have been done to investigate the nature of chip formation in end milling because of its complexity and geometrical difficulty. Toenshoff [5] proposed the basic chip formation mechanism as “adiabatic shear” at high cutting speed. Amin [6] earlier established that the instability of chip formation could be lowered by preheating the work material during turning. . Ekinoviˆc et.*al* [7] mentioned in their work that cutting speed has significant effect on chip formation models. Similar influence of the cutting speed on the chip structure and chip compression ratio was revealed in the experiments conducted by Tonshoff et al. [8].Problems with surface finish, work-piece accuracy, chatter and tool life can be caused even by minor changes in the chip formation process. At lower cutting speeds the chip is often discontinuous, while it becomes serrated as the cutting speeds are increased. But to maintain stable machining, much attention must also be paid to the formation of the desired type of chip and chip controls to facilitate its easy removal. This is because the chip formation and breaking aspect is very significant in machining.

2. EQUIPMENT

Cutting tests was conducted mainly on Vertical Machining Center (VMC ZPS, Model: 1060) powered by a 30 KW motor with a maximum spindle speed of 8000 rpm. SANDVIK grade PM1030 Insert code: R390-11 T3 08E-PL, Insert coating material: carbide, Working condition: light to medium milling is used for cutting. Insert shape and geometry with their values are shown in Fig.1 and Table 1.

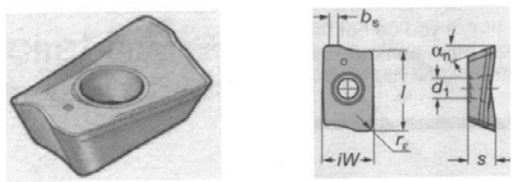

Fig 1. Insert Shape and Geometry

Table1 Insert Geometry Values

L	iW	d_1	s	b_s	r_ε	α_n°
11	6.8	2.8	3.59	1.2	0.8	21

3. OBSERVATION OF SEM TOP VIEW OF CHIP

The chip morphology at different cutting conditions is different. The primary and the secondary serrated teeth are observed under the scan electron microscope. A sample view of the chip (SEM) at particular cutting condition is shown in Fig 2.

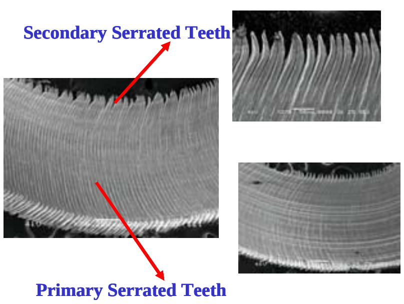

Fig 2. Sample SEM View of the chip showing the primary and secondary serrated teeth.

3.1 Observation of Primary Saw Tooth Formation:

Fig 3.below shows a schematic of the chip showing where the chips were sectioned (along the line A-A) to be observed under the microscope. This sectioning is done in order to observe more clearly the primary chip serration. The lengthwise cross-section view of the chips under optical microscope is shown in Fig 4.

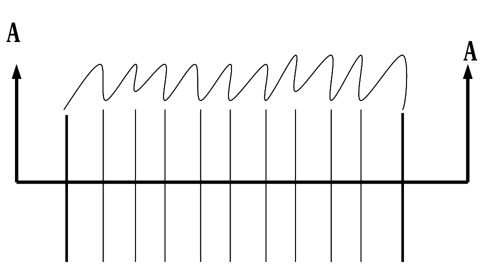

Fig 3. Schematic of chip showing sectioning for viewing side cross sectional view

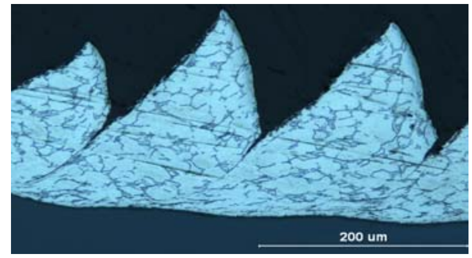

Fig 4. Section of chip formed by cutting the specimen at certain cutting conditions

4. IMAGE PROCESSING TECHNIQUE: CHIP ANALYSIS

Image processing is any form of signal processing for which the input is an image, such as photographs or frames of video; the output of image processing can be either an image or a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it. Image processing usually refers to digital image processing, but optical and analog image processing are also possible. The whole image process of the chip analysis for identifying the serrated teeth is divided into three steps. They are image acquisition, image editing, edge identifications and extraction. A visual basic code is used to analysis the chip for serrated teeth identification. The steps are described below:

4.1 Image Acquisition:

A color image of a chip is acquiesced by optical microscope or scan electron microscope, has different mode of dot per inch. Image editors can resize images in a process often called image scaling, making them larger, or smaller. High image resolution can produce large images which are reduced in size for use in the image processing code. Image editor programs use a mathematical process called resampling to calculate new pixel values whose spacing is larger or smaller than the original pixel values. Acquiesced image is resized 15% both horizontally and 25% vertically. The resized chip picture is opened in the specified area for further processing of the image as shown in Fig 5.

4.2 Image Pre-processing/Editing:

Image editing encompasses the processes of altering images, whether they be digital photographs, traditional analog photographs, or illustrations. Traditional analog image editing is known as photo retouching, using tools such as an airbrush to modify photographs, or editing illustrations with any traditional art medium. Due to the popularity of cameras, image editing programs are readily available. The more powerful programs contain functionality to perform a large variety of advanced image manipulations.

Fig 5. Image acquisition of the chip

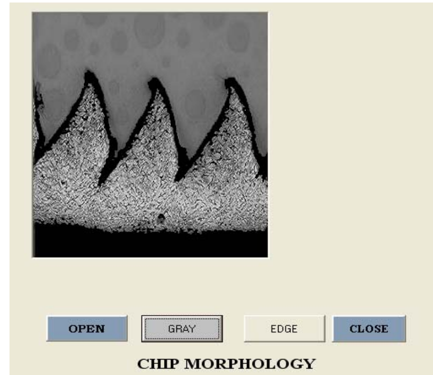

Fig 6. Image editing for chip analysis

4.3 Image orientation:

Image editors are capable of altering an image to be rotated in any direction and to any degree. Mirror images can be created and images can be horizontally flipped or vertically flopped. A small rotation of several degrees is often enough to level the horizon, correct verticality, or both. Rotated images usually require cropping afterwards, in order to remove the resulting gaps at the image edges. Image dimension may vary due to the irregularities in the image scanning and capturing process. A normalized size of 360×270 pixels has been used for all images. Subsequently, the color image is converted to a grayscale image. A color image consists of a coordinate matrix and three color channels. Coordinate matrix contains, *x*, *y* coordinate values of the image. The color channels are labeled as Red, Green and Blue. Since our approach demands chip images in gray scale, by converting the color image into gray scale. The color image is converted to gray scale using the equation (1) as shown in Fig 6.

$$\text{Gray color} = (\text{Red} + \text{Green} + \text{Blue})/3$$

4.4 Edge detection Technique:

Edge detection is a terminology in image processing, particularly in the areas of feature detection and feature extraction, to refer to algorithms which aim at identifying points in a image at which the image brightness or pixel coordinates changes sharply or more formally has discontinuities. The purpose of detecting sharp changes in image is to capture important events and changes in properties of the chip. It can be shown that under rather general assumptions for an image formation model, discontinuities in image are likely to correspond to:

1. discontinuities in depth,
2. discontinuities in surface orientation,
3. changes in material properties and
4. variations in scene illumination.

In the ideal case, the result of applying an edge detector to an image may lead to a set of connected curves that indicate the boundaries of objects, the boundaries of surface markings as well curves that correspond to discontinuities in surface orientation. Thus, applying an edge detector to an image may significantly reduce the amount of data to be processed and may therefore filter out information that may be regarded as less relevant, while preserving the important structural properties of an image. If the edge detection step is successful, the subsequent task of interpreting the information contents in the original image may therefore be substantially simplified. Subsequently, thick boundary (edge) outside the chip is generated using edge detection algorithm [9] given in following equation (2). The result is depicted in Fig 7.

$$X_n = (X_{n+2} + 2X_{n+3} + X_{n+4}) - (X_{n-4} + 2X_{n-3} + X_{n-2}) \quad \ldots (2)$$

Where, X_n is the new pixel value for the detected edge. For the edge detection the pixels of the image of the chip are considered as a 3 X 3 matrixes as shown below.

X_1	X_2	X_3
X_4	X_5	X_6
X_7	X_8	X_9

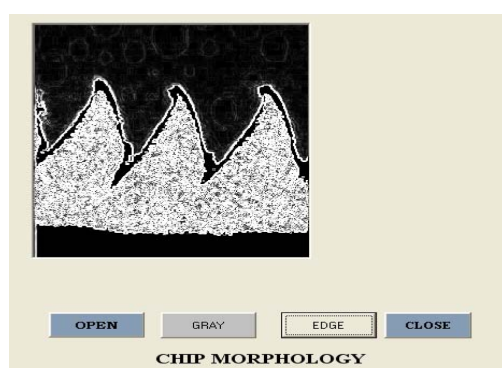

Fig 7. Edge detecting for chip analysis

5. CONCLUSIONS:

It can be concluded from the above analyses of chips that the chip formation process is accompanied with an inherent instability and the tendency to form discrete elements. In majority of the cases chips with primary/ secondary serrated teeth are formed. Each such tooth comprises a certain number of smaller sheared grains. The number of deformed grains forming a serrated tooth may identified by the image processing techniques. This technique will be useful for chip analysis and identification of the serrated elements.

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10. MAILING ADDRESS:

Md. Anayet U Patwari
Department of Mechanical and Chemical Engineering,
Islamic University of Technology, Dhaka.
E-mail:aupatwari@hotmail.com