

# Chapter 12

## A Finite Element Study of Chip Formation Process in Orthogonal Machining

**Amrita Priyadarshini**

*Indian Institute of Technology, Kharagpur, India*

**Surjya K. Pal**

*Indian Institute of Technology, Kharagpur, India*

**Arun K. Samantaray**

*Indian Institute of Technology, Kharagpur, India*

### ABSTRACT

*This paper examines the plane strain 2D Finite Element (FE) modeling of segmented, as well as continuous chip formation while machining AISI 4340 with a negative rake carbide tool. The main objective is to simulate both the continuous and segmented chips from the same FE model based on FE code ABAQUS/Explicit. Both the adiabatic and coupled temperature displacement analysis has been performed to simulate the right kind of chip formation. It is observed that adiabatic hypothesis plays a critical role in the simulation of segmented chip formation based on adiabatic shearing. The numerical results dealing with distribution of stress, strain and temperature for segmented and continuous chip formations were compared and found to vary considerably from each other. The simulation results were also compared with other published results; thus validating the developed model.*

### INTRODUCTION

Machining is a term that covers a large collection of manufacturing processes designed to remove material from a workpiece. This is one of the most important mechanical processes in industry

because almost all the products get their final shape and size by material removal either directly or indirectly. Although metal cutting process is commonplace, the underlying physical phenomena are highly complex. Therefore, this area has always been of great interest to the researchers. During the cutting process, the unwanted material is removed from the workpiece with the aid of a

DOI: 10.4018/978-1-4666-1867-1.ch012

machine tool and a cutting tool by straining a local region of the workpiece by the relative motion of the tool and the workpiece. As the tool advances, the material ahead of it is sheared continuously along a narrow zone called the shear plane; thus, removing the excess material in the form of chip that flows along the rake surface of the tool.

Chip formation and its morphology are the key areas in the study of machining process that provide significant information on the cutting process itself. The chip morphology depends upon the workpiece material properties and the cutting conditions. The main chip morphologies observed in cutting process are the continuous and the cyclic or serrated chips. Many parameters, namely, cutting force, temperature, tool wear, machining power, friction between tool-chip interface and surface finish are affected by the chip formation process and chip morphology. Thus, for determining the optimum cutting conditions, it is very essential to simulate the real machining operation by using various analytical and numerical models. Availability of an accurate model aids in the selection of optimal process parameters so that the metal removal process can be carried out more efficiently and economically.

With the advent of powerful computers and efficient commercial software packages, Finite Element Method (FEM) has become one of the most powerful tools for the simulation and analysis of cutting process. This not only allows studying the cutting process in greater detail than possible in experiments, but also takes into account the material properties and non-linearity better than analytical models.

Pioneering work in the analysis of metal cutting by using FEM has been carried out by Klamecki (1973) and Tay et al. (1974). Generally, application of finite element modeling to cutting process involves Eulerian, Lagrangian or Arbitrary Lagrangian Eulerian (ALE) formulations. Tay et al. (1974) used the Eulerian formulation technique that is often being used till date. In Eulerian approach, the reference frame is fixed in space that

allows for the material to flow through the grid (Raczy et al., 2004). As the mesh is fixed in space, the numerical difficulties associated with the distortion of elements are eliminated. In one of the recent works, an Eulerian finite element model has been applied to the simulation of machining which showed good overall correlation with the experimental results (Akarca et al., 2008). This approach permits simulation of machining process without the use of any mesh separation criterion. The main drawback of Eulerian formulation is that it is unable to model the unconstrained flow of material or free boundaries and may only be used when boundaries of the deformed material are known a priori. Hence, in this case, dimension of the chip must be specified in advance to produce a predictive model for chip formation (Mackerle, 1962). While in Lagrangian approach, no a priori assumption is needed about the shape of the chip. In Lagrangian approach, the reference frame is set by fixing the grid to the material of interest such that as the material deforms the grid also deforms. Lagrangian formulation is easy to implement and is computationally efficient. Difficulties arise when elements get highly distorted during the deformation of the material in front of the tool tip.

Therefore, many chip separation criteria have been used in the literature to simulate the cutting action at the cutting zone (Strenkowski & Moon, 1990). These criteria are grouped as geometrical and physical types. A geometrical criterion is based on a specified small distance from the tool tip, beyond which the separation of nodes is allowed along the predefined parting line. Komvopoulos and Erpenbeck (1991) used a distance tolerance of half of the length of the side length of the element in front of the tool tip. According to the physical criteria, the nodes get separated when the value of a predefined physical parameter, such as stress, strain or strain energy density, at nodes reaches a critical value that has been selected depending upon the work material properties and the cutting condition (Iwata et al., 1984). Strenkowski and

27 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage:

[www.igi-global.com/chapter/finite-element-study-chip-formation/67783](http://www.igi-global.com/chapter/finite-element-study-chip-formation/67783)

## Related Content

---

### Transcritical CO<sub>2</sub> Refrigeration System in Tropical Region: Challenges and Opportunities

Dileep Kumar Gupta and Mani Sankar Dasgupta (2015). *Handbook of Research on Advances and Applications in Refrigeration Systems and Technologies* (pp. 378-411).

[www.irma-international.org/chapter/transcritical-co2-refrigeration-system-in-tropical-region/136754](http://www.irma-international.org/chapter/transcritical-co2-refrigeration-system-in-tropical-region/136754)

### A Geometric Model for Tolerance Analysis with Manufacturing Signature and Operating Conditions

Wilma Poliniand Andrea Corrado (2019). *International Journal of Manufacturing, Materials, and Mechanical Engineering* (pp. 1-13).

[www.irma-international.org/article/a-geometric-model-for-tolerance-analysis-with-manufacturing-signature-and-operating-conditions/231655](http://www.irma-international.org/article/a-geometric-model-for-tolerance-analysis-with-manufacturing-signature-and-operating-conditions/231655)

### Strength Optimization of Infant Pop-Up Seat Frame Using Discrete Material and Thickness Optimization

YeongJo Juand Euysik Jeon (2021). *International Journal of Manufacturing, Materials, and Mechanical Engineering* (pp. 1-20).

[www.irma-international.org/article/strength-optimization-of-infant-pop-up-seat-frame-using-discrete-material-and-thickness-optimization/280123](http://www.irma-international.org/article/strength-optimization-of-infant-pop-up-seat-frame-using-discrete-material-and-thickness-optimization/280123)

### Modeling, Integration, and Automation of Degradation to Generate Asset Lifespan Analytics Using: AssessLIFE Software

Emenike Raymond Obiand Augustine O. Nwajana (2022). *International Journal of Manufacturing, Materials, and Mechanical Engineering* (pp. 1-40).

[www.irma-international.org/article/modeling-integration-and-automation-of-degradation-to-generate-asset-lifespan-analytics-using/300828](http://www.irma-international.org/article/modeling-integration-and-automation-of-degradation-to-generate-asset-lifespan-analytics-using/300828)

### Double Diffusive Convection in a Layer of Maxwellian Visco-Elastic Nanofluid in a Porous Medium

(2017). *Nanofluid Technologies and Thermal Convection Techniques* (pp. 201-220).

[www.irma-international.org/chapter/double-diffusive-convection-in-a-layer-of-maxwellian-visco-elastic-nanofluid-in-a-porous-medium/175605](http://www.irma-international.org/chapter/double-diffusive-convection-in-a-layer-of-maxwellian-visco-elastic-nanofluid-in-a-porous-medium/175605)