STUDY ON CUTTING OPERATION IN TURNING PROCESS BY 3D SIMULATION USING DEFORM 3D

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ABSTRACT

Understanding of the fundamentals of metal cutting processes through the experimental studies has some limitations. Metal cutting modelling provides an alternative way for better understanding of machining processes under different cutting conditions. Using the capabilities of finite element models, it has recently become possible to deal with complicated conditions in metal cutting. Finite element modelling makes it possible to model several factors that are present during the chip formation including friction at the chip tool interface. The aim of improved understanding of metal cutting is to find ways to have high quality machined surfaces, while minimizing machining time and tooling cost. Friction behaviour at the chip-tool interface is one of the complicated subjects in metal cutting that still needs a lot of work. Several models have been presented in the past with different assumptions. In the current model, the Coulomb friction model, which assumes a constant friction coefficient, is used to model the friction in order to simplify the model. The effect of the constant friction model is considered by analyzing the result for several friction coefficient values and comparing them to the previous work.As simulation tool for the purpose of this study, the FEM software used is DEFORM 3D. DEFORM 3D is a robust simulation tool that uses the FEM to model complex machining process in three dimensions. The simulation results on cutting forces and thrust forces, and shear angle are compared with experimental data in order to indicate the consistency and acccuracy of the results when conducting the comparison.

ABSTRAK

Dalam memahami asas proses pemotongan logam, ia adalah terbatas jika melalui uji kaji. Terdapat cara alternatif untuk memahami dengan lebih baik proses pemesinan di bawah keadaan pemotongan yang berbza. Dengan menggunakan kemampuan *"finite element model (FEM)",* ia telah dibuktikan untuk menjadi salah satu cara sesuai untuk menangani masalah pemotongan logam yang timbul dalam keadaan yang rumit. FEM telah merealisasikan kemungkinan untuk memodelkan beberapa faktor yang hadir dalam pembentukan chip termasuk geseran pada permukaan chip. Tujuan memahami dengan lebih mendalam mengenai pemotongan chip adalah untuk mencari cara untuk mendapatkan permukaan mesin yang mampunyai kualiti yang tinggi di samping meminimumkan masa pemesinan dan kos peralatan. Salah satu subjek yang rumit dalam pemoongan logam adalah sifat geseran antara permukaan alatan dan chip yang memerlukan kerja yang banyak. Beberapa model telah dibentangkan sebelum ini dengan pelbagai andaian. Daripada model yang sedia ada, Coulumb model dengan andaian pembolehubah malar telah digunakan untuk mereka model geseran sebagai usaha unutk memudahkan model tersebut. Kesan daripada model geseran malar itu dipertimbangkan dengan menganalisa keputusan daripada beberapa nilai model geseran dan membuat perbandingan dengan ujikaji yang telah dijalankan sebelum ini. Sebagai alat dalam simulasi dalam kajian ini, FEM software yang telah digunakan adalah DEFORM3D. DEFORM 3D adalah alat simulasi yang kuat yang menggunakan FEM untuk mereka proses pemesinan yang kompleks dalam tiga dimensi. Keputusan yang diperolehid daripada cutting force, thrust force dan shear angle telah dibandingkan dengan data yang diperolehi daripada experiment yang telah dijalankan sebelum ini untuk menunjukkan konsistensi dan ketepatan dalam keputusan yang diperolehi apabila membuat perbnadingan.

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CHAPTER I

INTRODUCTION

1.0 Introduction

Machining process such as turning, milling, boring and drilling are among others the most important process for discrete part manufacturing. Researchers have been studying machining processes for more than a century to gain better understanding and develop more advanced manufacturing technology.

The study of turning has lasted more than a century, but it still attracts a large amount of research effort. This is because turning is not only most frequently used machining operation in the modern manufacturing industry, but also because it is typical single-point machining operation. Other machining operations, such as milling, drilling and boring are multiple-point machining operation that can be investigated based on the combinations of single-point machining operation. Thus, the study of turning can contribute greatly to the knowledge of metal cutting principles and machining practice.

1.1.1 Turning process

Turning is the process whereby a single point cutting tool is parallel to the surface. It can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using a computer controlled and automated lathe which does not. This type of machine tool is referred to as having computer numerical control, better known as CNC, and is commonly used with many other types of machine tool besides the lathe.

When turning, a piece of material (wood, metal, plastic even stone) is rotated and a cutting tool is traversed along two axes of motion to produce precise diameters and depths. Turning can be either on the outside of the cylinder or on the inside (also known as boring) to produce tubular components to various geometries. Although now quite rare, early lathes could even be used to produce complex geometric figures, even the platonic solids; although until the advent of CNC it had become unusual to use one for this purpose for the last three quarters of the twentieth century. It is said that the lathe is the only machine tool that can reproduce itself.

The turning processes are typically carried out on a lathe, considered to be the oldest machine tools, and can be of four different types such as straight turning, taper turning, profiling g or external grooving. These types of turning processes can produce various shapes of materials such as straight, conical, curved, or grooved workpiece. In general, turning uses simple single-point cutting tools. Each group of workpiece materials has an optimum set of tools angles which have been developed through the years. The bits of waste metal from turning operations are known as chips.

1.2 Background of the Project

This research work is executed to compare the orthogonal cutting data from FEM Deform 3d software with experiments by creating numerical model to simulate the orthogonal metal cutting. AISI 1045 is used as the workpiece material in this study because it has been the focus of many recent modeling studies and well machinability.

Thus, this software is used to simulate the cutting process from the initial to the steady state of cutting force. The orthogonal turning data is verified and a comparison is made between experimentally and simulations to investigate the cutting forces, thrust forces and chip shear plane angles as a practical tool by researchers, machine and tool makers. This is the reason why the application of FEM 3d software to cutting operations is quite common nowadays.

To simulate deformation in a three-dimensional environment makes it possible to see the process more in detail and to make more accurate predictions even for processes that are well represented by a plane model (such as orthogonal cutting). Moreover, it allows simulating more complex operations that need to be studied by a three-dimensional model (such as oblique cutting).

1.3 Problem Statement

In recent years, the application of finite element method (FEM) in cutting operations is one of the effective way to study the cutting process and chip formation. In particular, the simulation results can be used as a practical tool, both by researchers and tool makers to design new tools and to optimize the cutting process.

Facing in metal cutting of turning process, it is very complicated to determine the optimization of cutting conditions due to a lot of cutting experiments need to be execute. Further, these experimental also consider in risks condition because not all the results from the experiments could be achieved as desired. For the results which are not fulfill the optimized cutting condition, the experiments should be repeated and this will lead to high costing to the industry manufacturer worldwide in terms of time demanding, human energy and work material respectively. In order to reduce the costs and time, FEM in machining is widely used nowadays and has become main tool for simulating metal cutting process.

Based on cutting experiments, the simulation were carried out to verify using FEM to indicate that the simulation result are consistent or not with the experiments. This study aims to simulate three-dimensional cutting operations and the FEM software used for this study is DEFORM 3D.

1.4 Objective of study

The overall goal of this proposal is to develop methodologies using finite element simulations and to differentiate the actual value from the previous experimental result with the deform 3D simulation result. The data that have been taken into computation are cutting force, thrust force and shear angle. Thus, the objectives are to:

Study and determine the influence of process parameters (feed rate, cutting speed and shear friction factor) upon cutting forces, thrust forces and shear angle.

(i) To compare between simulation and experiment cutting test to indicate the results are consistent or inconsistent.

(ii) Demonstrate the use of FEM for 3D simulation in turning processes.

1.5 Scope of Study

(i) Simulation 3D cutting test is using deform 3D software.
(ii) Work piece are use is mild steel of 45% carbon (AISI 1450).
(iii) Tool material use is uncoated carbide with rake angle 5^o.
(iv) To differentiate between the simulation conducted by using Deform 3d software with the results obtained by the previous researcher as follow:
  - Experiment result; and
  - Results from advantEdge software.

1.6 Importance and Significance of Study

The significance of this research work is that Finite Element Analysis (FEA) in machining process will be a great help for the researchers to understand the mechanics of metal cutting process. Furthermore, the FEA technique has proven to be an effective technique for predicting metal flow and selecting optimum working conditions such as tool and workpiece temperatures and cutting force.

In addition, the influence of several parameters such as cutting speed and friction factor has been studied. This simulation will not involve chip elimination before the real material cutting which indirectly lead to time and cost saving.

1.7 Expected Result

In this study, the investigation indicates the results from simulation cutting test in terms of thrust force, cutting force, and shear plane angle which dependent on the cutting parameters such as shear friction factor and cutting speed.

In addition, this research also includes the analysis for the results and graphs from simulation machining such as cutting force versus time, thrust force versus time and shear angle versus cutting speed. Later, make a comparison between the simulation and experiment result to predict whether the results are consistent or inconsistent.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

For years, researchers in the area of metal cutting have attempted to develop model of cutting processes that described the mechanisms involved and predict the important behaviours in the process without requiring a large amount of cutting test. Various models have developed for this purpose. In this chapter, previous publication relating to the metal cutting is reviewed. The reviewed topics are organized as follows:

(i) Fundamental of metal cutting
(ii) Friction models
(iii) Cutting force models
(iv) Finite element models

2.2 Fundamental of Metal Cutting

The most widely used metal cutting operation is turning, milling and drilling. Turning is a process of using a single point tool that removes unwanted material to produce a surface of revolution. Figure 2.1 shows a cylindrical surface being generate on a workpiece and the movement of the cutting tool along feed direction [Kalpakjian, 2001].

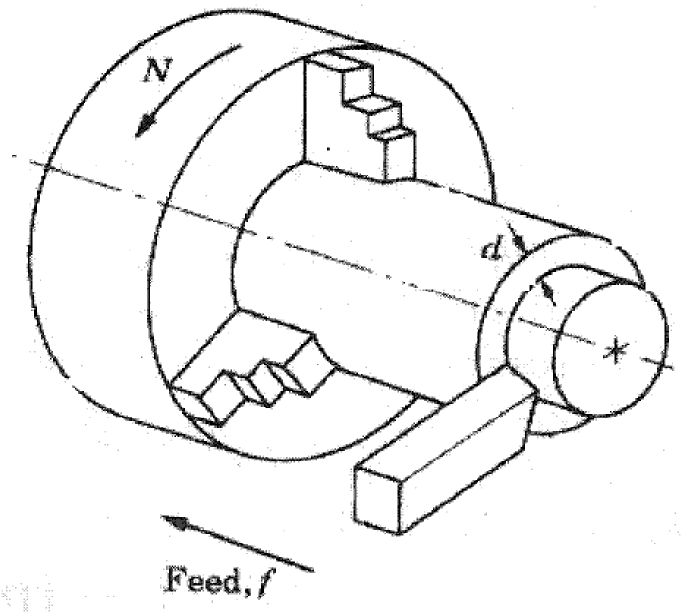


Figure 2.1: Three dimensional view of turning operation [Kalpakjian, 2001]

The need to understand and model the metal cutting process is driven by a number of technological requirements. Basically, the operation should be feasible to achieve the required quality of machined part and efficiency. Knowledge of the cutting process is also important for improvement of machine tool design. Researchers have been conducting experiments and developing models to explain the underlying mechanism of the cutting process for more than fifty year. Most of the proposed models can be classified as analytical, experimental and numerical as listed in table 2.1

Table 2.1: History of Cutting Process Modelling

	Analytical Methods	Experimental Methods	Mechanistic and Numerical methods
Before 1960	1941 Martellotti 1944 Merchant 1951 Lee et.al. 1956 Dio, Salje 1958 Tobias	1944 Kasharin 1946 Sokalov 1956 Trigger	-
1960's	1960 Albrecht 1961 Gurney, Albrecht 1963 Trusty, Zorev 1965 Tobias et.al 1966 Cook 1967 Das 1969 Kegg	1963 Zorev,Oxley 1964 Pekelharing 1965 Cumming, wallace 1966 Das, Thomas 1969 Peters	1961 Koenigsberger 1961 Sabberwal 1962 Sabberwal
1970's	1974 Hannas, Oto 1976 Szakovits	1970 Knight 1971 Peters 1972 Nigm 1973 Cook, Moriwaki 1974 Tlusty 1975 Baily, Pandit 1977 S.M Wu	1971 Okushima 1973 Klamecki 1974 Tay, Shirakasi 1975 Tlusty 1979 Gygax
1980's	1981 Trusty 1985 Rubenstein 1986 D.W. Wu 1989 Oxley	1981 Komanduri 1984 Shi, Shin 1985 Ahn, et.al 1986 Pandit 1987 Ahm	1980 Lajczok 1982 Usui 1983 Natrajan, Stevenson 1986 Carrol, Strenkowski 1987 Riddle 1988 Carroll 1989 Yang
1990 to	1990 Minis, Parthimos	1998 Arcona, Dow	1991 Komvopoulos

present	1993 Minis 1995 Altintas 1996 Arsecularatne 1998 Waldorf 1999 Moufki 2002 Becze, Elbestawi		1992 Yang 1993 Wayne 1994 Athavale 1995 Shih 1999 Ng et. Al

The importance of machining process modeling has been universally recognized in industry. Basic and applied research result has been employed to provide reliable predictions of the performance of the cutting process and the impact of the process on produce quality and process productivity [Ehmann, 1997].

In a simple way, most metal cutting operations can be described in terms of a wedge-shaped cutting tool that is constrained to move relative to the workpiece in such a way that a layer of metal is removed in the form of a chip. When the cutting edge of the tool is arranged to be perpendicular to the direction of cutting velocity, it is called orthogonal cutting. Oblique cutting involves an inclination angle [Boothroyd, 1989].

2.2.1 Orthogonal Cutting

Orthogonal cutting, as illustrated in Figure 2.2 is the simplest machining process and rarely used in industrial practice. The significance of orthogonal cutting is serving as an ideally simple cutting process model in theoretical and experimental work. It can be modelled as a two dimensional process. In orthogonal cutting, effects of independent variables have been eliminated as much as possible so that influences of basic parameter can be studied more accurately. Most of the further studies on machining process are based on the achievement from orthogonal cutting analysis. The assumptions Shaw [Shaw, 1984] on which orthogonal cutting is based to achieve simplicity include as follow:

(i) The tool is perfectly sharp and there is no contact along the clearance face.
(ii) The shear surface is a plane extending upward from the cutting edge.
(iii) The cutting edge is a straight line extending perpendicular to the direction of the cutting velocity and generates a plane-machined surface.
(iv) The chip does not flow to either side.
(v) The depth of cut is constant.
(vi) The width of cut is constant.
(vii) The workpiece moves relative to the tool with uniform velocity.
(viii) A continuous chip is produced with no build-up edge.
(ix) The shear and normal stresses along shear plane and tool are uniform.

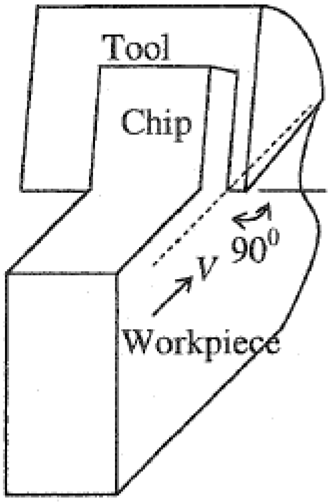


Figure 2.2: Orthogonal cutting

2.2.2 Oblique Cutting

In practice, most cutting operations involve oblique cutting, where the cutting edge is inclined. In the oblique arrangement shown in figure 2.3, the cutting edge inclines at an angle *i*. This angle makes the cutting process modelling more complicated than that for orthogonal cutting. Three-dimensional analysis needs to be performed to study oblique cutting.

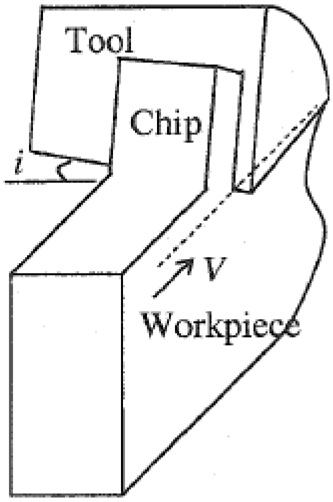
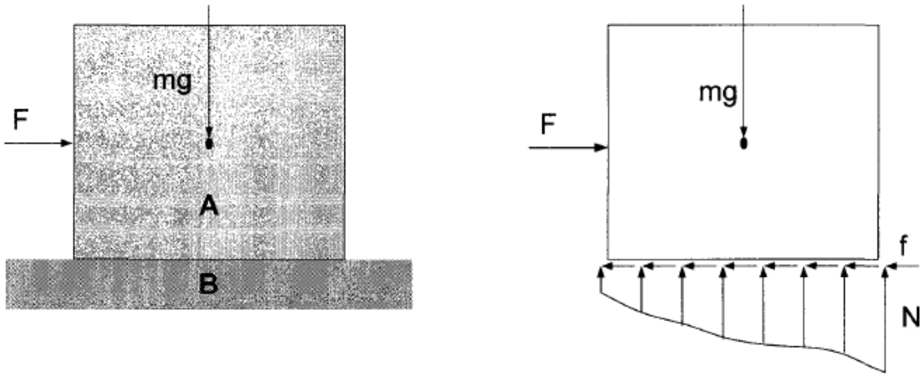


Figure 2.3: Oblique cutting

2.3 Friction model

A general conception of friction can be considered as the tangential force generated between two surfaces. Friction can be represented as a resistance force acting on the surface to oppose slipping. Figure 2.4 (a) shows a simple example of friction where a block is pushed horizontally with mass *m* over rough horizontal surface. As showing in the free body diagram, Figure 2.4 (b), the body has distributions of both normal force *N* and horizontal force *f* along the contact surface. From the equilibrium, the normal force *N* acts to resist the weight force of the mass *mg* and the friction force *f* acts to resist the force *F*.



(a) (b)

Figure 2.4: Explanation of contact between two surfaces:

(a) Two bodies with friction after applying the load

(b) Free body diagram for the block on a rough surface

Basically, there are two types of friction, which are static and kinetic as shown in Figure 2.5. By increasing the force *F,* friction force f increases too. The blocks cannot move until the force *F* reaches the maximum value. This is called the limiting static factional force. Increasing of the force *F* further will cause the block to begin to move. In the static portion, the limiting friction force can be expressed as:

$$F_{static} = \mu s\ N$$

where μs is called the coefficient of static friction

When the force F becomes greater than F_{static}, the frictional force in the contact area drops slightly to a smaller value, which is called kinetic frictional force. Machining models generally just consider the kinetic friction coefficient which can be calculated by the following equation:

$$F_{kinetic} = \mu k\ N$$

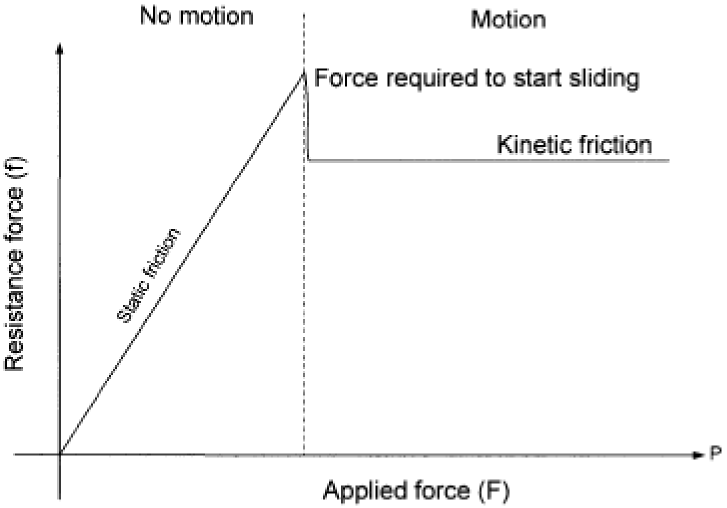


Figure 2.5: Static and kinetic friction

2.3.1 Albrecht's Coulomb friction coefficient

In the the Coulomb friction coefficient, Albrecht's analysis has been used to estimate the coefficient of friction along the chip-tool interface by eliminating the cutting edge effect [P. Albrecht,1960]. Figure 2.6 illustrates the basic concept of Albrecht's model.

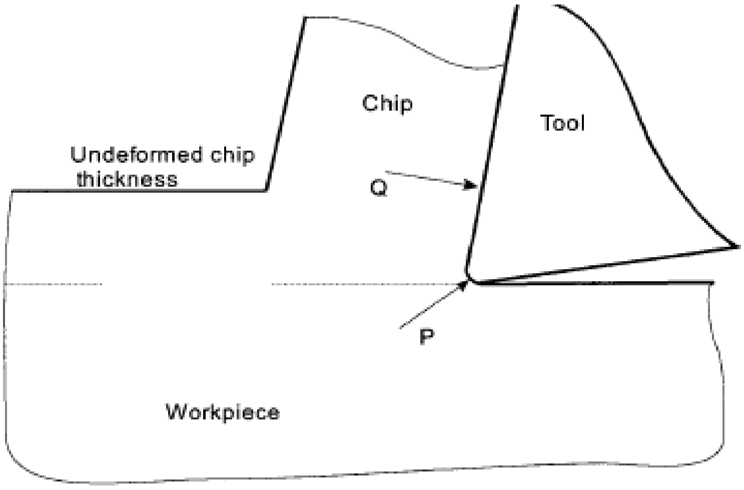


Figure 2.6: Force decomposition in the Albrecht's model

The forces are resolved into two components where *P* is close to the cutting edge and *Q* is applied on the rake face. With the sharp cutting tool, the ploughing force *P* has insignificant value. But for the tool that is not sharp, the force *P* will affect significantly the force model. For uncut chip thickness greater than the critical uncut chip thickness.

Albrecht assumes that the force *P* has a constant value. However, at feeds less than the critical uncut chip thickness, the force *P* will affect the thrust force significantly. After passing the critical chip thickness, the force *P* slightly affects the thrust force. Example feeds and chip thickness are shown in Figure 2.7. The sum of the two force components (cutting and feed) can be obtained by the sum of two vectors *P* and *Q*.

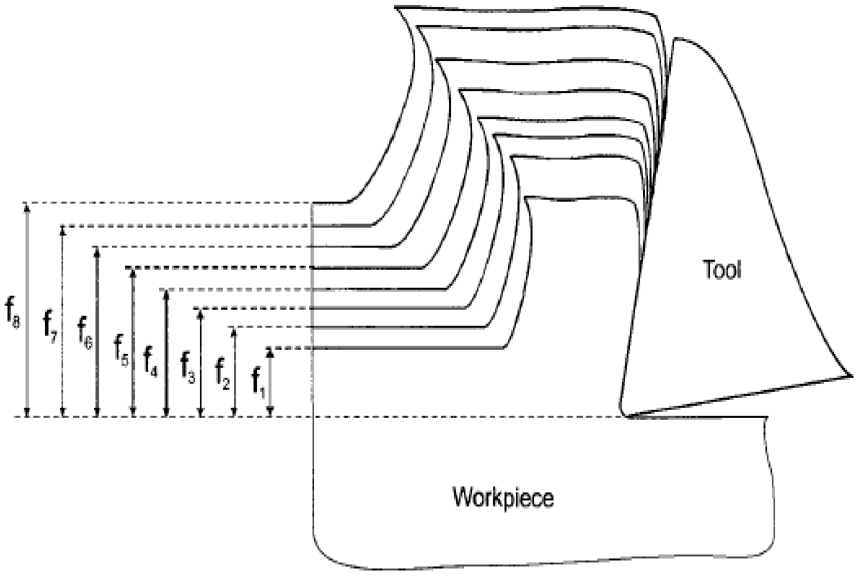


Figure 2.7: Corresponding cutting for different feeds

Figure 2.8 illustrates the cutting force and the thrust force relation at different uncut chip thicknesses. At the smallest feeds in Figure 2.8 *(A* and *B* sections), a non-linear relation will describe the behaviour of the cutting and thrust forces. Below the critical point, the *P* force will cause a relatively large thrust force. The section C where the relation takes a linear behaviour is used to approximate the value of the Coulomb friction coefficient. The friction coefficient along the chip tool interface can be defined by taking the slope of section C as tan (A - *a)* and then $\mu = \tan\gamma$.

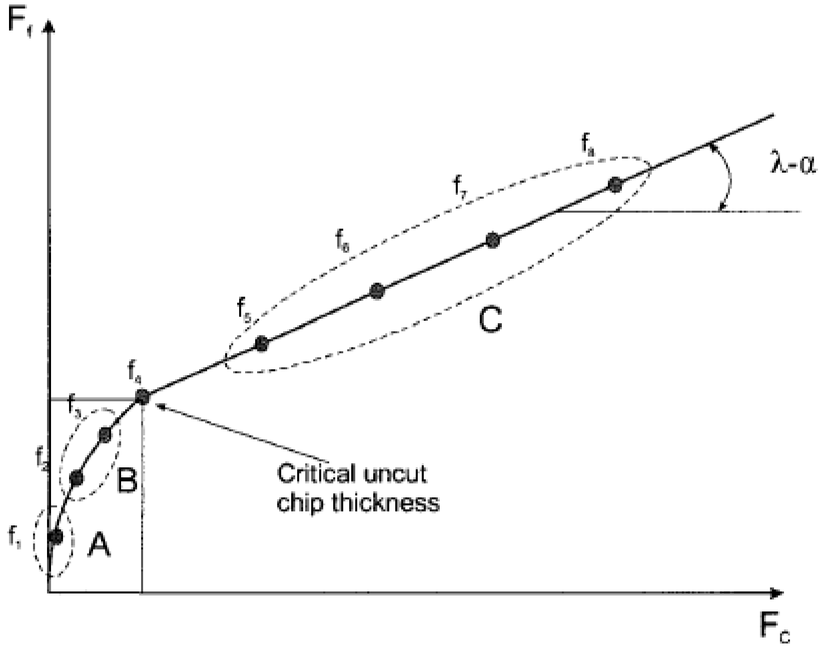


Figure 2.8: Thrust force versus cutting force are define of the critical feed rate

2.4 ANALYTICAL FORCE MODEL

Since 1930, many researchers have tried to understand the machining process under framework plasticity theory. The studies of chip formation were the main goal in order to know the cutting force, stresses and temperatures involved in the process. Various methods were proposed which are several of the study based on fundamentals of mechanical cutting process and others based on experimental Simplified analytical approaches of orthogonal cutting were first considered by Merchant [Merchant, 1945], who introduced the concept of shear plane angle.

2.4.1 Merchant's Model

Merchant's analysis is based on the two- dimensional process geometry as show in Figure 2.9[Shaw, 1984]. An orthogonal cutting is defined by cutting velocity V, uncut chip thickness t_{u}, chip thickness t_c, shear angle Ø, rake angle α, and width of cut w. The width of cut w is measured parallel to the cutting edge and normal to the cutting velocity.

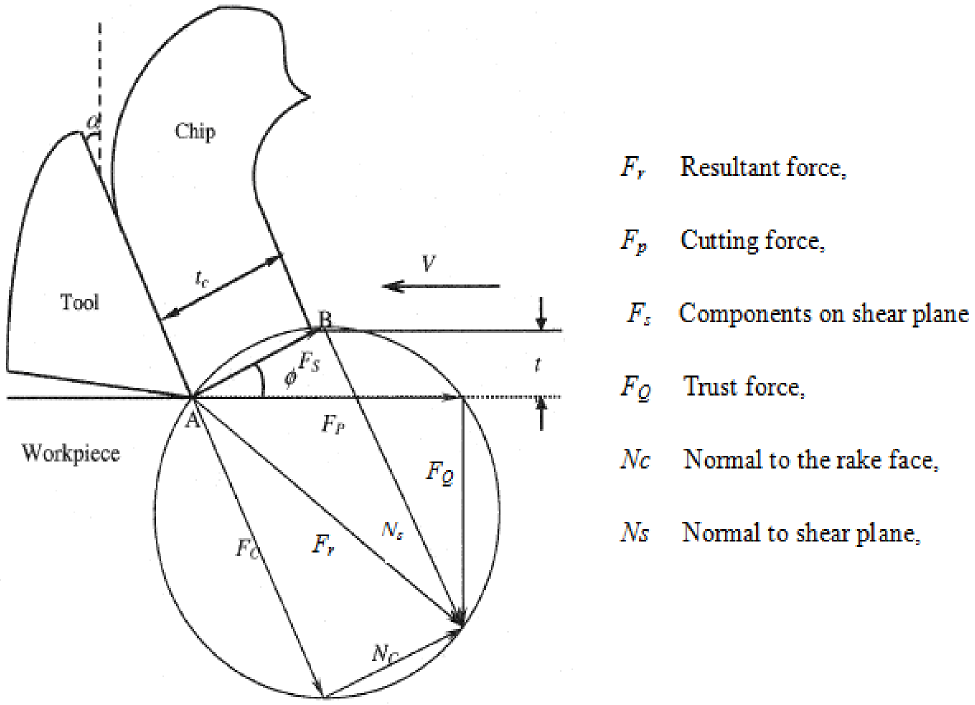


Figure 2.9: Merchant's orthogonal cutting Model [Shaw, 1984]

The workpiece material moves at the cutting velocity while cutting tool remains still. A chip is thus formed and is assumed to behave as a rigid body held in equilibrium by the action of the forces transmitted across the chip-tool interface and across the shear plane. The resultant force F_r is transmitted across the chip-tool interface. No force acts on the tool edge or flank. F_r can be further resolved into components on shear plane, rake face, on cutting direction depending upon research interest. Components on shear plane are F_s in the plane and N_s normal to shear plane. Cutting force F_p is in the cutting direction and a trust force F_Q normal to the workpiece surface. On the rake face, the friction force F_c is in direction of chip flow and the normal force Nc is normal to the rake face. The relationships between those components and resultant force can be defined by the following equations:

On the shear plane:

$$\begin{bmatrix} F_S \\ N_S \end{bmatrix} = \begin{bmatrix} \cos \emptyset & -\sin \emptyset \\ \sin \emptyset & \cos \emptyset \end{bmatrix} \begin{bmatrix} F_P \\ F_Q \end{bmatrix} \qquad (2.1)$$

On the rake face:

$$\begin{bmatrix} F_C \\ N_C \end{bmatrix} = \begin{bmatrix} \sin \alpha & \cos \alpha \\ \cos \alpha & -\sin \alpha \end{bmatrix} \begin{bmatrix} F_P \\ F_Q \end{bmatrix} \qquad (2.2)$$

Shear angle Ø can be experimental determined by:

$$\emptyset = \tan^{-1} \left(\frac{t_u \cos \alpha}{t_c - t_u \sin \alpha} \right) \qquad (2.3)$$

The concept of orthogonal cutting and all of the simplifying assumptions helped to build the fundamental cutting force analysis and left space for improvement in succeeding studies. Most analytical force models follow this shear plane theory or slip-line field theory.

2.4.2 Slip-line Field Theory

Slip-line field solution for shear angle Ø was derived based on two assumptions:

(i) The material cut behaves as an ideal plastic solid which does not strain-hardened.

(ii) The shear plane represents the direction of the maximum stress.

A slip-line field ABC in front of the cutting tool, shown in figure 2.10 [Waldrof, 1996], was assumed to be plastically rigid and subjected to a uniform state of stress.

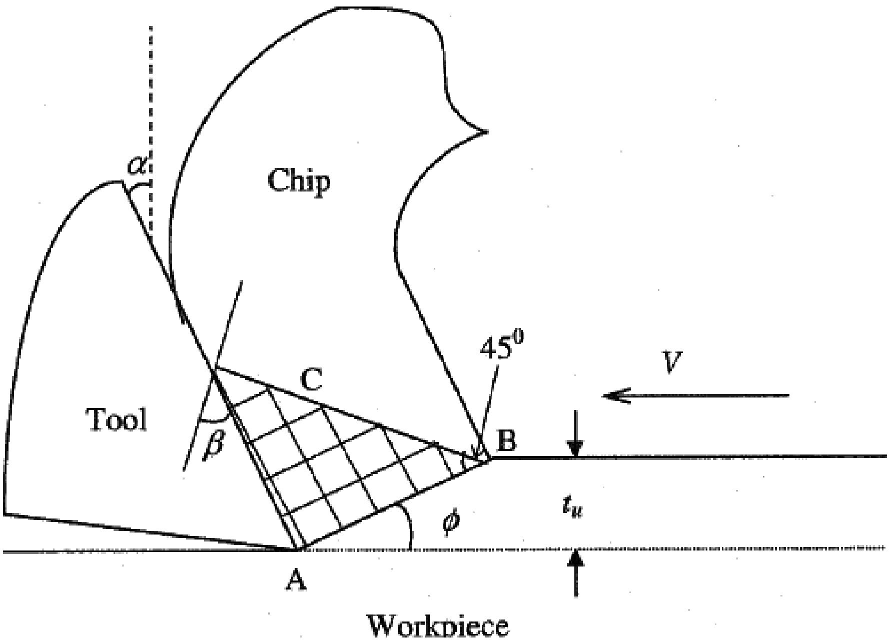


Figure 2.10: Slip-line fields in orthogonal Cutting [Waldrof, 1996]

Line BC is the line along which the stress is zero. *β* is the friction angle on the rake face of the cutting. Ø is shear angle. They can be determined by:

$$\beta = \tan^{-1}(F_c/N_c) \qquad (2.4)$$

$$\text{Ø} = 45^{o} - \beta + \alpha \qquad (2.5)$$

2.5 FINITE ELEMENT MODELS (FEM)

With the development of numerical methods and advent of digital computers, computational difficulties and model limitations were overcome. Since 1973, the finite element method has been applied to simulate machining with some successes [Komvopoulos, 1991]. Two different finite –element formulations, the Lagrangian and the Eulerian, are most commonly used in the modelling of cutting process. In the Lagrangian approach, the finite element must consist of material elements that cover the region of analysis exactly. These elements are attached to the material and deformed with the deformation of the workpiece. In the Eulerian approach, the mesh consists of elements that are fixed in space and cover the control volume, and the material properties are calculated at fixed spatial locations as the material flows through the mesh [Movahbedy, 2000].

In FEM, the material properties can be handled as functions of strain, strain rate and temperature. Interaction between chip and tool can be modelled as sticking and sliding. Nonlinear geometric boundaries such as the free surface of the chip can be represented as used. Stress and temperature distribution can be obtained as well [Zhang, 1994; Shih, 1995]. However, large deformation of the material results in the distortion of the elements and deterioration of simulation results. The numerical simulation of cutting process can be extremely difficult because of unconstrained flow of material that occurs over free boundaries. As a result, most of the previous analysis used simple models such as rigid-plastic/elastic-plastic and non-hardening material behaviour, or empirical models depending on experimental data, ignored interfacial friction and tool wear on the cutting process.

2.5.1 Deform Software

Deform is a commercial FEM software based process simulation system designed to analyze flow of various metal forming process. It is available in both Lagrangian (Transient) and arbitrary Lagrangian and the Eularian (ALE Steady-State) modeling. Additional, the software is currently capability of Steady-State function and it is required of running a transient simulation previous to steady state cutting simulation.

Ceretti and his colleague [Ceretti, 1996] conducted simulation of orthogonal plane strain cutting process using FE software Deform2D. To perform this simulation with relevant accuracy, they have been used damage criteria for predicting when the material starts to separate at the initiation of cutting for simulating segmented chip formation. Further, they also study about influence of cutting parameters such as cutting speed, rake angle and depth of cut. Later, the computed cutting force, temperature, deformations and chip geometry have been compared with cutting experiments.

In 2000, Ceretti and his colleague also study simulation using Deform3D. Their objective of this work is to set up two three-dimensional FEM reference models to study three-dimensional cutting operations: one model for orthogonal cutting, one for oblique cutting. This FEM code is based on an implicit lagrangian computational routine, the finite element mesh is linked to the workpiece and follows its deformation. To simulate the chip formation a remeshing procedure is performed very frequently, so that the workpiece mesh is frequently updated and modified to follow the tool progress. This technique makes possible to simulate chip separation from the workpiece without any arbitrary predefinition.

Mamalis, [mamalis, 2001] investigated FE simulation on chip formation in steady-state orthogonal metal cutting using finite element code MARC. The flow stress of the work material is taken as a function of strain, strain rate and temperature in order to know the effect of the large strain, strain rate and temperature associated in cutting process. Additional, the chip formation and the stress, strain and strain-rate distribution in the chip and workpiece, as well as the temperature fields in the workpiece, chip and tool are determined.

Referring to iqbal and friend [Iqbal. 2006], there were effects of workpiece flow stress models and friction characteristics at the tool-chip interface by predicting on different output parameters. Further, they have been performed 2D orthogonal cutting FE model by Deform2D simulation in order to predict accuracy of cutting force and shear angle. Flow stress models are used extensively in the simulations of deformation processes occurring at high strains, strain rates and temperature.

Jaharah and her colleague [Jaharah et al. 2009] performed the application of FE software Deform2D in simulating the effect of cutting tool geometries on the effective stress and temperature increased. They have been developed an orthogonal metal cutting model in order to study the effects on tool geometries with various rake angle, clearance angle and cutting parameters.

2.6 Conclusion

According Merchant’s shear plane analysis, the concept of friction implies that friction force and normal force are uniformly distributed over the sliding interface. However, this is not the case of metal cutting and this approach provides coefficient of friction is too simple. Additionally, the friction formula is relevant only to sliding conditions that was probably bring weakness of this analysis.

Continuous to Lee and Shaffer with their slip line theory, the most likely sources of the poor agreement are the material assumption, that is work material is rigid-perfectly plastic and the simple friction assumption. As a result, a more recent approach in the studies of metal cutting has been employed. FEM has employed to conduct simulation of cutting processes. The FEM is more accurate due to ability to incorporate more realistic assumptions of material behavior and the influence of friction.

CHAPTER III

METHODOLOGY

3.1 Introduction

The software Deform 3D is used in this study to simulate the three-dimensional orthogonal with plane strain deformation metal cutting process. The finite element model is composed of a deformable workpiece and a rigid tool. Overall, there have been a series of cutting test that will be carried out for simulation in varies machining parameters of cutting speed, feed rate and depth of cut.

The relationship exist between cutting performance such as cutting forces, residual stresses, cutting temperature and cutting condition may be established theoretically by Finite Element Methods (FEM) analysis model. The proposed work focuses on the development model of Finite Element Analysis (FEA) procedures to achieve the research objectives as mentioned in section 1.4. Flow chart in Figure 3.1 indicates the flow of this simulation.

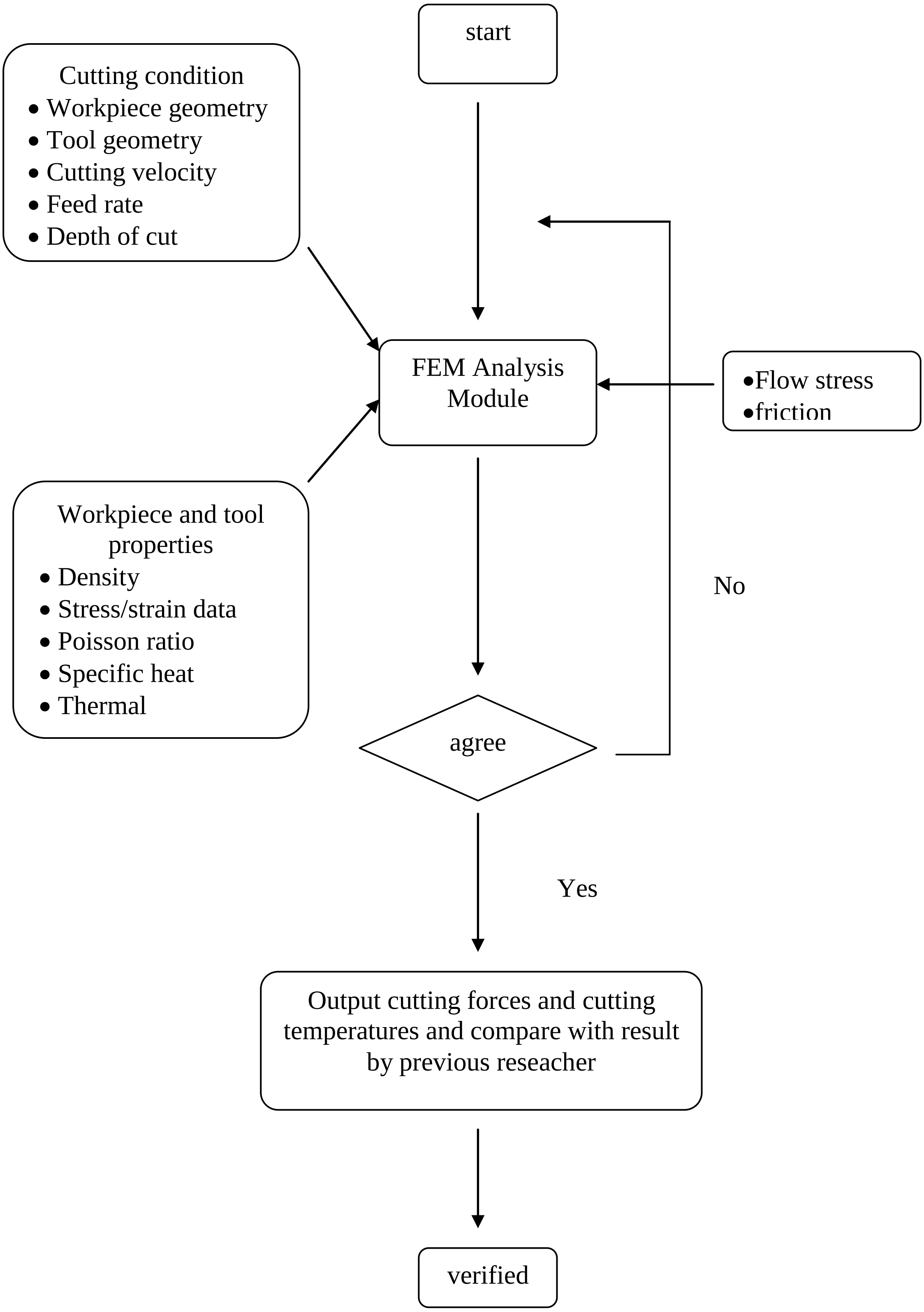


Figure 3.1: process flow chart for simulation

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