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INFLUENCE OF CUTTING PARAMETERS ON THRUST FORCE AND TORQUE IN DRILLING OF ALUMINUM, CAST IRON AND EN28.

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ABSTRACT

Understanding of the fundamentals of metal cutting processes through an experimental study 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 accuracy of the results when conducting the comparison.

Keywords*: Cast Iron.*

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1. 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 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 repeate 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. 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. To compare between simulation and experiment cutting test to indicate the results are consistent or inconsistent.

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 simulations conducted by using Deform 3d software with the results obtained by the previous researcher as follow:

- Experiment result; and
- Results from advantEdge software.

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Importance and Significance of Study

The significance of this research work is that Finite Element Analysis (FEA) inmachining 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 temperature

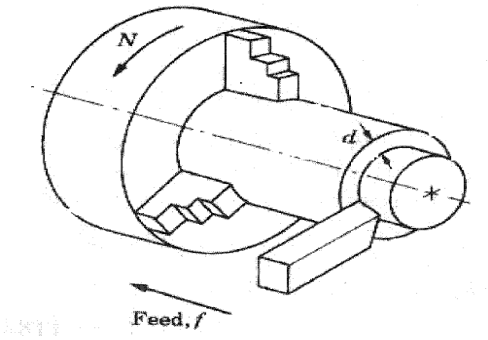
2. MODELS OF CUTTING PROCESS:

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

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. A cylindrical surface being generate on a workpiece and the movement of the cutting tool along feed direction.



Three dimensional view of turning operation

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 1 (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 1 (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*.

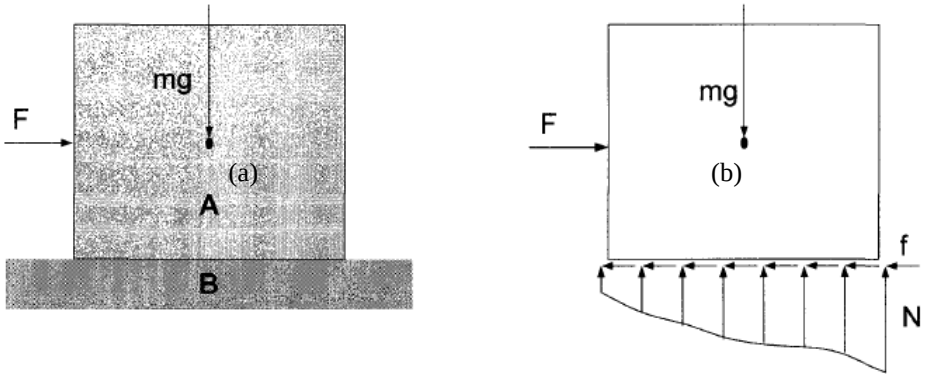


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Figure 1: Explanation of contact between two surfaces:
(a) Two bodies with friction after applying the load
(b) Free body diagram for the block on a rough surface

Basically, there are two types of friction, which are static and kinetic as shownin Figure 2. 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 *Fstatic*, 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:

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

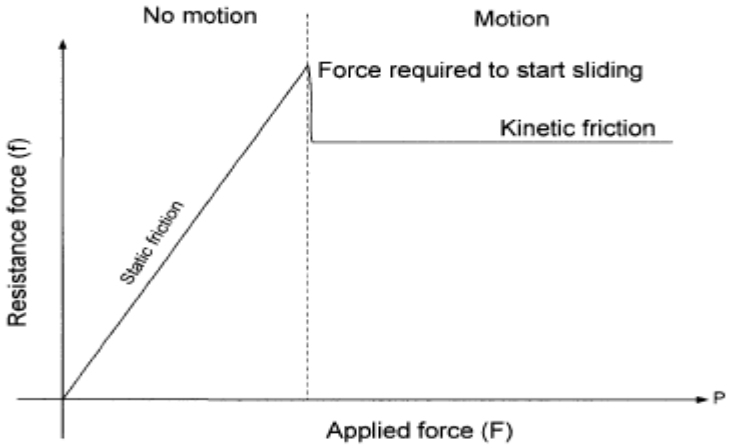

Figure 2: Static and kinetic friction

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.

FINITE ELEMENT MODELS (FEM):

With the development of numerical methods and advent of digital computers, omputational 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 thematerial 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.

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.

THE MANUFACTURE OF CAST IRON ALUMINUMAND FITTINGS:

Aluminum and fittings are manufactured of cast iron. Cast iron is a generic term for a series of alloys primarily of iron, carbon, and silicon. Cast iron also contains small amounts of other elements such as manganese, sulfur, and phosphorous. The chemical composition of the iron is determined by reg-ularly scheduled analysis of samples taken from test blocks or test specimens, or directly from cast-ings. Product standards require chemical and tensile testing to be performed a minimum of once every four hours during the course of production. The hardness of the iron is determined by its chemical composition and by the rate that the casting is cooled.

All CISPI member foundries utilize post-consumer recycled scrap iron and steel in the produc-tion of cast iron Aluminum and fittings. Recycling, through environmentally friendly, exposes the manufacturing foundry to an additional hazard: radiation from contaminated recycled materials. The use of scrap iron and steel in the

production process necessitated the introduction of radiation screening equipment for all scrap iron and steel used in the production process. (See Figure 3.)

Figure 3—Radiation Detector Screening Ferrous New Material for Radiation.

manufactured; the cleaning department where the pipe and fittings are cleaned, coated and prepared for storage or shipment; and the storage and shipping area for finished products.

Adjacent is an area for mold preparation, and a core room is provided to house coremaking machinery. The cleaning department contains abrasive shot-blast machinery and chipping and grind-ing equipment to remove sand, fins, gates, and risers from the pipe and fittings. Coating equipment is located in or adjacent to this section. The modern Aluminum foundry also includes a pattern shop and pattern storage room, a testing laboratory, a storage area for finished product inventories, and a packing and shipping section.

RAW MATERIALS AND MELTING DEVICES:

The cupola furnace is used as the principal method for obtaining the molten metal required for pro-duction. Electric melting equipment, such as coreless induction furnaces, may also be used. Regardless of the type of melting equipment employed, the make-up of the furnace charge determines the composition of the molten iron.

The basic raw materials used to produce cast iron Aluminum and fittings are scrap iron, steel scrap, alloys, coke, and limestone. These materials are stockpiled in the raw materials storage yard. The ratio between scrap iron and steel scrap for a given charge can vary over a wide range, depend-ing on the relative availability of these materials. Silicon and carbon may be added to the molten iron in predetermined amounts to provide the proper final chemical composition.

An overhead bridge crane is used to handle these materials for charging into the melting fur-nace, which is normally located in close proximity to the raw materials storage yard.

3. CONCLUSION:

This study showed that, when feasible process parameters are selected, BMG could be efficiently drilled using either the HSS or WC-Co tool. The WC-Co tool with better mechanical and thermal properties is the better choice for drilling BMG. The chip light emission, which is associated with high chip and tool temperatures, showed the detrimental effect on the drill life. For drilling without light emission, both HSS and WC-Co tools performed well in BMG drilling. The analysis of tool wear further confirmed such statement.

The research into machining of BMG is continuing in several fronts. The next step is the micro-milling, grinding, polishing and electrical discharge machining processes. In recent years, new Fe-, Al-, and Ti-based BMG materials have been developed. This has created the needs and opportunities for research into machining processes for precision shaping of these new, advanced engineering materials.

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