International Journal For Technological Research In Engineering
Volume 3, Issue 10, June-2016 *ISSN (Online): 2347 - 4718*

MODELING AND SIMULATION OF MECHANICAL CUTTING BY SINGLE POINT CUTTING TOOL

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ABSTRACT: The commercial success of a new product is influenced by the time to market. Shorter product lead times are of importance in a competitive market. Metal cutting is the one of the most widely used manufacturing techniques in the industry and there are lots of studies to investigate this complex process in both academic and industrial world. Prediction of important process variable such as temperature cutting force and stress distribution play significant role in designing tool geometry and optimizing cutting conditions. The thesis focuses on the development of a finite element model for the cutting process, which can predict chip formation, cutting forces, temperature and pressure distribution on the tool –chip interface and the residual stresses of the work piece. The work is concentrated to handle the large and localize deformation, chip format-ion and contact and friction. Two basically different modelling approaches have been used for the chip separation, geometrical and physical model. The physical model has been found to be more suitable to simulate the chip formation. The geometrical model is based on the separation of a pre- defined crack path at the certain limit of stresses. The excessive element distortion is handled by frequently updating the finite element mesh, using the advance front technique for generation of quadrilateral elements. At this point, finite element modelling and simulation becomes main tool. These important cutting variables can be predicted without doing any experiment with finite element method. The effect of previous cutting on chip formation and surface residual stresses has been studied. The chip formation is not affected much. The influence of the cutting speed and feed on the residual stresses has been computed and verified by the experiments. It is shown that the state of residual stresses in the work piece increases with the cutting speed.

KEYWORDS: Adaptively, Contact algorithm, Finite element method, Friction, deformation, Mechanical cutting, Paving, Residual stresses

I. INTRODUCTION

1.1 About simulation, virtual manufacturing, and finite element analysis

Finite element method (FEM) theory mostly emerged during the 1950 and 60, while during the 1970s and 1980s, theories and methods were further developed and implemented in CEA software. The development of modern finite element technology can be divided in to four stage, each with a duration of eight to ten years, starting in 1950s. The first period is characterized by the method being mainly applied to structural mechanics problem. In the second stage, the approach was expanded to address multifoldproblem while mathematical foundation were also give a great deal of attention, specifically on new efficient solution algorithms as well as techniques for solving large problem. The third stage, much of the effort by researcher was directed towards the development of new elements capable of handling unbounded domains. The fourth stage characterized by new application fields, efficient algorithm for new computing system (parallel computing) and availability of the FE-software on personal computer and work stations, as well as technique of adaptive refinement of the mesh. A number distinctions can be made here as to what is the purpose of using FEA: Operation impact focus-The use of FEA mainly aim to improve the design of a product or a components by analyzing the effect of the loading (mechanical, thermal, or other) the structure will be subjected to during use. The result from the analysis is used to improve the design

Virtual manufacturing(VM) response focus- The use of FEA aim to investigate the response of the structure due to a manufacturing operation affecting the structural or Global behavior of a car body due to spot welding (no distinction is here made as to how the weld are molded)

1.2 Background

The commercial success of a new product is strongly influenced by the time to market. Shorter product lead-time are of importance for industry in a competitive market. This can be achieved only if the product development process can be realized in a relatively small time period. Usually, the material removal occurs in a highly hostile environment with high temperature and pressure, in the cutting zone. This make the study of cutting process very complicated. The objective of metal cutting studies is to establish a predictive theory that would enable us to predict cutting performance such as chip formation, cutting force, cutting temperature, tool wear, and surface finish.

1.3 The cutting process

Metal cutting is a process where component are arranged so that applied external force causes the fracture 1.1. This fracture Occurs due to the combined bending stress, the components S, and the shearing stress due to compression, Q. System consideration of the metal cutting process reveals that the competition between deformation hardening and thermal softening in the deformation zone constitutes a cyclical character of the chip formation process. As a result. The parameters of the cutting system vary over each chip formation cycle.

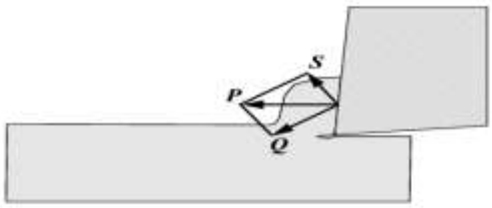

Figure 1.1 The interaction between tool rake face and the chip. The penetration force p acts on the chip, causing the compressive force Q and bending force S.

The orthogonal metal cutting process, is the focus in the present work, Figure 1.2 The chosen geometry provides a reasonably good modeling of the chip formation on the major cutting edge of many metal remove processes such as turning, milling, drilling, sawing, grinding, etc.

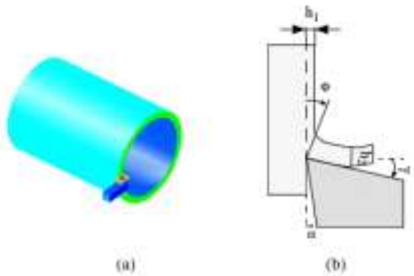

Figure 1.2 Schematic sketch of orthogonal cutting with used notations

1.4 MECHANICAL CUTTING

Mechanical cutting is defined as a number of method to separate material from a work piece in the form of chip. Methods included in this definition are, e.g. milling, turning, drilling and grinding. Mechanical cutting and primarily turning operation are very common in the manufacturing of aerospace components, since most components are rotational symmetric. Applying external force to work piece by rotating either the work piece or the tool while moving the tool or the work piece in the direction of the material cause the formation of a shear zone (primary deformation zone). The deformation is localized to this shear zone, and the formation of a chip begins.

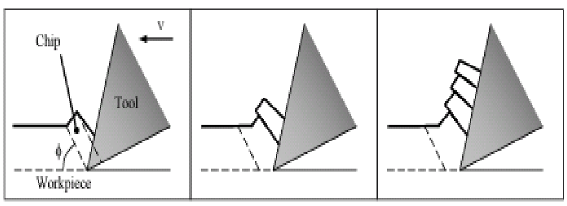

Figure 1.3 chip evolution principle in a cutting operation.

There are also other zones in the vicinity of the tool that are extensively affected in the cutting operation [14]. Zone A in fig 1.4 (left) secondary deformation zone where heat is generated due to both plastic deformation and friction between the chip side of the tool and the work piece. Looking to fig 1.4 (right). Of the total amount of heat generated in the cutting process.

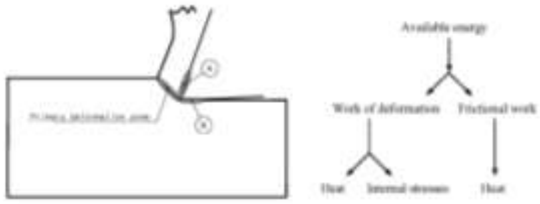

Figure 1.4 deformation zones and energy distribution in a cutting process

Trent [21] states that cutting speed are the limiting factor to decrease process time in many cutting operation and that the determination of temperature and temperature distribution in the region near the cutting edge is critical for the future development of cutting inserts geometries and coatings. Trent believes that even though recent research has clarified some principles, the work done so far is only the beginning of the fundamental survey required

1.5 MODELING AND SIMULATION CUTTING

One focus of this thesis is to highlight issues important an extended integration of manufacturing processes simulation and engineering design/product development this section will highlight issues modeling and simulation of these processes, and particularly computational issues impeding the use of FEA to model a sequence of manufacturing processes. Other issues needed to be solved to take full advantage of the possible using virtual manufacturing e.g. communication of engineering analysis data, will be discussed in the appropriate section of the thesis. A number of computational issues are important to address regarding simulation of mechanical cutting. This section briefly describes the computational aspects to consider. Discussions abound regarding which integration scheme to use in what situation with results being presented in a number of papers supporting both schemes depending on the situation.

II. REVIEW OF LITERATURE

Determination of optimal cutting condition through cost – effective mathematical complex research endeavor, and over the years, the techniques of modeling and optimization have undergone substantial development and expansion.

Biegler and Grossmann (2004) provided a general classification of mathematical optimization problems. Followed by a matrix of applications that shows the areas in which these problems have been typically applied in process systems engineering.

Mukherjee and Roy (2006) discussed the application potential of several modeling and optimization techniques in metal cutting processes and suggested a generic framework for parameter optimization in metal cutting processes.

Godfrey and Kumar (2006) performed experiment using a three level full factorial design on a CNC drilling machine. Mathematical model for correlating the interactions of control parameters such as speed, feed rate and drill diameter and their effects on some responses such as axial force and torque acting on the cutting tool is developed using Response surface methodology. The significance of the mathematical model developed is ascertained regression analysis. The results obtained show that the mathematical model is useful not only predicting optimum process parameters for achieving the desired quality but for process optimization too. Tsao (2008) presented the prediction and evaluation of thrust force and surface roughness in drilling of composite material using candle stick drill. In this study, the objective and control parameters correlation is established by multi-variable regression analysis and radial basis function network (RBFN) and compared with the experimental results. Jeong et al. (2007) proposed a geometric simulation model of EDM drilling process with cylindrical tool to predict the geometries of tool wear in the fabrication of a blind hole. Jayabal and Natarajan (2010) studied the effect of process parameters on thrust force, torque, and tool wear in drilling of coir fiber reinforced composites. The optimal setting of the parameters are determined through experiments planned, conducted and analyzed using genetic algorithm methods. Tzeng et al. (2009) investigated the optimization of CNC turning operation parameters using the Grey relational analysis method. Nine experimental runs based on an orthogonal array of Taguchi method were performed. An optimal parameter combination of the turning operation was obtained via Grey relational analysis. Gupta et al. (2011) presented the use of fuzzy logics to the Taguchi method in optimization of the high speed CNC turning with multiple performance characteristics. It is concluded that the optimization methodology developed in this study is useful in improving multiple performance characteristics in high speed CNC turning. Aggarwala et al (2008) used RMS for modelling the responses namely tool life, cutting force, surface roughness and power consumption in CNC turning of AISIS P-20totla steel using liquid nitrogen as a coolant. The development models were adequate in explaining the effect of independent parameters on responses.

Shrikanthand kamala (2008) developed a real coded genetic algorithm (RCGA) approach for optimization to get the optimum solution faster. This would be helpful for a manufacturing engineering to choose machining conditions for desired machining performance of a product.

Zain et al. (2010) carried out experiments to observe the optimal effect of the radial rake angle of the tool, feed and feed rate cutting condition in influencing the surface roughness for an end milling machining process. Regression model is the development GA is then applied to find the optimal solution for giving the minimum value of surface roughness. Singh and Rao (2007) presented a multi-objective optimization technique based on GA to optimize the cutting parameters in turning processes. Multi- objective genetic Alogrithm (MOGA) efficiently searches the entire working range to give as a Pareto optimal solution. Ho et al. (2009) used an adaptive network-based fuzzy inference system (ANFIS) with the genetic learning algorithm to predict the work piece surface roughness for the end milling process. The hybrid Taguchi- genetic learning algorithm (HTGLA) is applied in the ANFIS to determine the most suitable membership functions and to simultaneously find the optimal premise and consequent parameters by minimizing the root-mean-squared-error performance criterion. Rao and Pawar (2010) presented optimization aspects of a multi-pass milling operation. The objective considered is minimization of production time (i.e. maximization of production rate) subjected to various constraints like arbor strength, arbor deflection, and cutting power.Optimization is carried out using three no –traditional optimization algorithms namely, artificialBee colony (ABC), particle swarm optimized multi-pass milling in terms of two objectives, i.e. machining time and production cost using an advanced search algorithm called parallel genetic simulated annealing(PGSA) to optimal cutting parameters. The aurthors have taken the benefit of Strength of both of these techniques and have successfully applied this hybrid parallel genetic simulated of annealing optimization technique to multi pass milling operation.

III. METAL CUTTTING MECHANICS

3.1 STRESESS ANALYSIS

Figure3.1. The work piece is subjected to large deformation at a high strain rate in this region. The plastic deformation. At the secondary deformation zone, heat is generated due to the plastic deformation and friction between the cutting tool and the chip. The major deformation during the machining process are concentrated in two regions close to cutting tool edge, These regions are usually called the primary and the secondary deformation zone, see figure 3.1

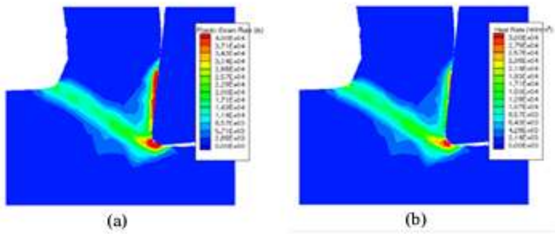

Figure 3.1 computed strain- rate (a) and heating (b) in deformation zones during orthogonal cutting of AISI 1045. The cutting speed is 198 m/min and feed is 0.25 mm.

The secondary deformation zone may be divided into two region, the sticking region and the sliding region, Figure 3.2. In the sticking region, the work piece material adheres to the tool and shear occurs within the chip, thefrictional force is high and so is also the heat generation.

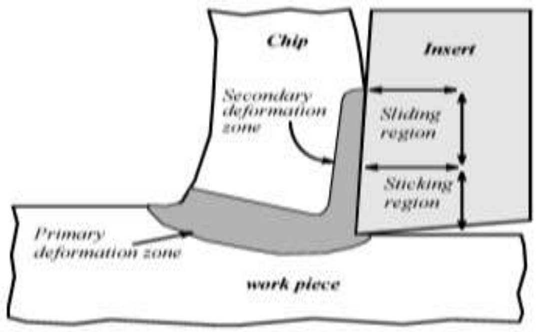

Figure 3.2 Definition of the primary and the secondary deformation zone and the sliding & sticking region.

3.2 Cutting forces

The cutting forces vary with the tool angles, feed and cutting speed. Figure 3.3. the component of the force acting on the rake face of the tool, normal to cutting edge, in the direction OY is called the cutting force, this is usually the largest force component, and acts in the direction of the cutting velocity. The forces component acting on the tool in the direction OX, parallel with the direction of feed, is referred to as the feed force, the third component, acting in OZ direction, push the cutting tool away from the work in the directions. The major concern in dealing with fracture of engineering material is to define conditions under which material should not fracture or fail in service. In contrast, in metal cutting, the opposite effect is desired, how to fracture the material with a minimum effort. Therefore, the studies of the fracture process in metal cutting applications should answer how the cutting parameters may be optimized to result in crack initiation and propagation in the work piece. Fracture consist of two phases, initiation and propagation.

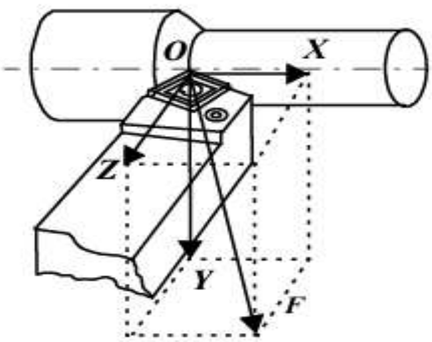

Figure 3.3 Cutting forces acting on the tool in a semi-orthogonal cutting

3.3 Influence of temperature on cutting process

The effect of temperature on the stress–strain relationship and the flow and fracture properties is well known. In general the strength of the material decreases and ductility increases as the temperature is increased. In the cutting operation the heat transfer is strongly dependent on the cutting velocity. At very low cutting speeds there may be adequate time for conduction to occur. At the other extreme, at very high cutting speeds there is nearly no time for heat conduction and adiabatic condition may exist with high local temperatures in the chip. The heat conduction can be neglected in the primary deformation zone and the average temperature T in this region are proportional to the specific work for metal removal Wc.

IV. NUMERICAL PROCEDURE

4.1 Finite element formulations

The finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problem for partial differential equation.it is obvious that the cutting process requires a large deformation analysis. The use of remeshing is discussed later is discussed later in this chapter. Furthermore, it requires the simulation calculation of temperatures. And deformations.it also referred to as finite element analysis (FEA). FEM subdivides a large problem into smaller, simpler, parts, called finite element. The simple equations that model these finite elements are then assembled into a larger systems are then assembled into a larger system of equations that models the entire problem. This assumption has been used in [27]. This approach cannot be used if the cooling to room temperature is needed in order to evaluate residual stresses of work piece. Some analyses have been done using a coupled thermal-mechanical analysis,then a heat conduction analysis is coupled with the mechanical analysis. A so-cold staggered approach is preferred and has been used in [8, 3,]. The mechanical analysis can be performed using different formulation. Each formulation has its advantages and disadvantages. There is the possibility to treat the material as a non- Newtonian fluid. This is called a flow formulation. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function. This approach has been used in [8]. The more general option is the solid formulation where the material is modelled by the usual constitutive equations for solid material.There exist two main types of methods for the temporal discretization. The explicit, conditionally stable, method.This a fast method but the limit on the step is related to the time it takes for an acoustic wave to pass through the smallest element. However, it has been used with success for solving thereby make it possible to take larger time step [30]. Heshemi [19] has used this approach, the other, more general option is to use an implicit finite element code. It has no problem in computing steady response. This type of formulation has been used in the cutting simulation in [22, 27, -28,].Different material models option have been in simulation of cutting using the solid formulation. The material has been treated as rigid-plastic by [19]. A high order element enforces a higher degree of continuity in the solution. The large incompressible plastic strains can give locking effects for low order triangular elements in 3-D. Therefore, well know codes like the public domain codes NIKE and DYNA from Lawrence Livermore national laboratory has only linear quad element in 2-D and hexahedron element in 3-D. The four quad element is also used in [8, 22, 28].

4.2 contact algorithms

Interaction between parts in an explicit dynamic simulation is modeled with a contact algorithm. Contact algorithms have to take into consideration many possibly complex interactions. Depending on the type of problem that is being simulated, special-purpose contact can be used to achieve a stable, accurate, yet efficient result. Two main algorithms for solving contact problems are presented; the penalty approach [11, 16, 20]. Laursen and simo[29] also describe b combined method called the augmented Lagrangian technique. The automatic contact is the easiest to use and can handle the overwhelming majority of problems, alternate special purpose contact can be useful and powerful. ANSYS LS–DYNA offer an extensive set of contact algorithms such as automatic, single face, spot weld, surface-to-surface-eroding, edge-to-edge, draw beads and many more. Addition special procedures have been developed for the explicit integration method [a6, 4, 17, 18], as momentum- related in which modifications are made to the acceleration, velocities and displacements. One of the aims of the latter is to avoid the penalizing effect on the time step of the explicit procedure, which can be introduced by the high stiffness, with penalty approaches. This may cause significant changes in surface behavior, which in turn cause divergence. A further disadvantage of the penalty approach is that, in the early iterations, while a node is oscillating between being in and out contact. The convergence characteristics can be very bad. This can be achieved using a methodproposed by zavarise. et al., which combines a penalty procedure with a barrier method [13].

4.3 Adaptivity and Re-meshing

The need of adaptive strategies for large deformation finite element computations is undeniable. For many cases, Adaptivity is an essential tool to obtain accurate numerical solutions. It will also reduce the required computational effort needed to achieve this z accuracy. This is the case, for instance with problem in non- linear mechanics involving localized large strains. Mesh adaptivity is divided in to three different type of categories, h- adaptivity, p-adaptivity and r-adaptivity. The error associated with the gradients which are discontinuous at interelementboundaries. This means that a mesh a mesh would be refind where large difference in the gradients exist between elements. marusich and Ortiz [13] proposed to use the plastic work rate in each element in order to refine the finite element mesh in cutting simulations. This option convey to capture the plastic deformation of the work piece material. All this criteria was followed by using the procedure originally proposed by Zienkiewicz and zhu. The Delaunay triangulation for generating six-noded quadratic elements was used by marusich et al.[23]. Hierarchical adaptive mesh scheme [15], used in this study, provides an efficient way to change the mesh density by refining/coarsening a given mesh and facilitates data transfer. Mesh adaptivity is also important for reducing the distortion of the elements as this is a large problem in simulation the mechanical cutting process, using a lagrangian finite element formulation. The most useful smoothing technique in the current application is the so-called opti-smoothing algorithm [24], where one tries to optimize the node position using an element distortion metric. One disadvantage for this method is the time consuming optimization procedure. These procedures are applied regularly during the simulation. However, it is also necessary to completely regenerate themesh now then. The advance front technique [6-7] for generating a quadrilateral FE-mesh was used for this.

4.4 LOCAL REFINEMENT

The graded quadrilateral element proposed by McDillis used in this study. The 4 to 8- noded grading quadrilateral is shown in figure 3.1. nodes1 to 4 are mandatory while nodes 5 to 8number are optinal mid edge nodes.

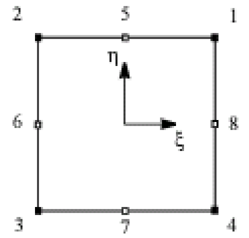

Fig 4.1 number of 4- to 8- noded graded element

Node	P (ξ , η)
8	$0.5\,(1+\xi)\,(1-\lvert\eta\rvert)$
7	$0.5\,(1-\lvert\xi\rvert)\,(1-\eta)$
6	$0.5\,(1-\xi)\,(1-\lvert\eta\rvert)$
5	$0.5\,(1-\lvert\xi\rvert)\,(1+\eta)$
4	$0.25\,(1+\xi)\,(1-\eta)-0.5\,(P_7+P_8)$
3	$0.25\,(1-\xi)\,(1-\eta)-0.5\,(P_6+P_7)$
2	$0.25\,(1-\xi)\,(1+\eta)-0.5\,(P_5+P_6)$
1	$0.25\,(1+\xi)\,(1+\eta)-0.5\,(P_5+P_8)$

Table 4.1 Shape function for a 2-D graded element

The presence of mid edge nodes affects the basis corner nodes on that edge. Therefore, the shape function should be evaluated in order from P8 to P1. Propagation of refinement in a graded mesh is illustrated in figure 4.2. if a vertex node in the element to be refined is also amid edge node in a neighbour refinement must propagation into the neighbor.

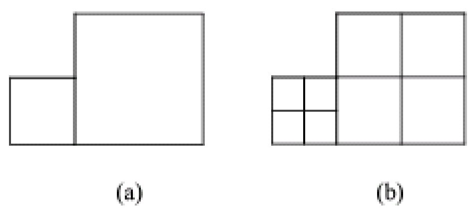

Fig 4.2 propagation of refinement. A) Original mesh b) Mesh after propagate

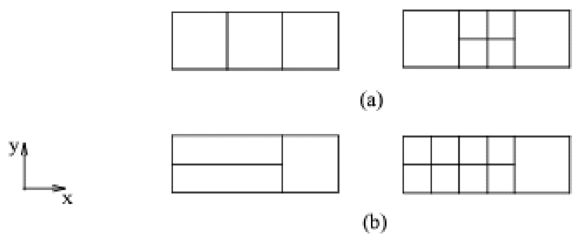

Fig 4.3 Refinement scheme in a) x-& y- directions) x-direction

4.5 ADAPTIV MESH MANAGEMENT

The adaptive remeshing is managed by using two different error estimation criteria simultaneously. The plastic work rate and a generic posterior error estimate based on the gradients in finite element mesh are used. The plastic work

rate criteria was used to capture the progression of the plastic deformation in the primary and the secondary zone, figure 3.4.itsneighboursetc. may in turn initiate propagation in.
Plastic power density in each primary and secondary zone$W_l^p = \sigma_{\varepsilon}{}^{-p}$
Average power of the finite element mesh$W_{avg} = \sum_{i=0}^{n} Wlp/n$
Property factor for each element $\beta_c = W_l^p / W_{avg}$

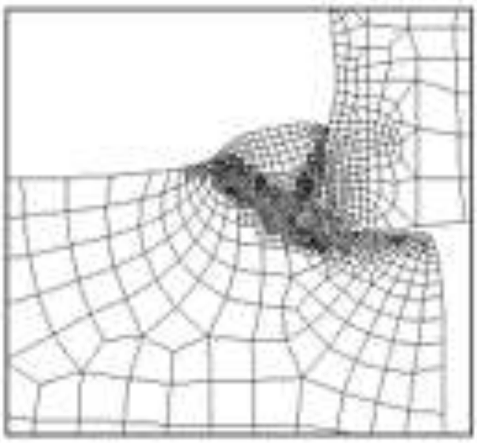

Fig 4.4 The mesh refinement using the plastic work rate criterion

The smoothed gradients are obtained by averaging the nodal gradients from the Gauss points.

$e_l = \sigma_{exact} - \sigma_{FE}$

$e_l = \sigma_{sm} - \sigma_{FE}$

$e_{g=} \sum_{i=0}^{n} ((el))^2$

The two error measure criteria are frequently used during the simulation simulation of mechanical cutting in the current studies, figure 4.5.

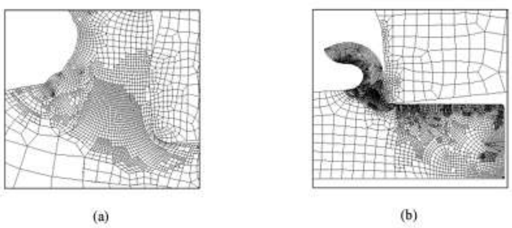

Fig 4.5 The refined finite element mesh based on a combination of the plastic work rate and the displacement gradients. A) Error based on the plastic work rate b) refined mesh

4.6 GLOBAL REMESHING

The advance front technique [6-7] for mesh generation has been found most convenient in simulating mechanical cutting. The need of mesh regeneration is evaluate at the start of each increment by computing the elements distortion with respect to the shear angle and elongation. This is managed by using the distortion metric proposed by Oddy [38]. It is given as.

$$D = C_{ij} = \frac{1}{del\ |j|} \sum_{k=1}^{n} J_{ki} J_{KJ} \ \ C_{ij} = \frac{1}{del\ |j|} \sum_{k=1}^{n} J_{ki} J_{KJ}$$

The advantage front technique, so called paving, is an iterative procedure. The elements are added one by one to the meshing area along the exterior paving boundaries, figure 3.6

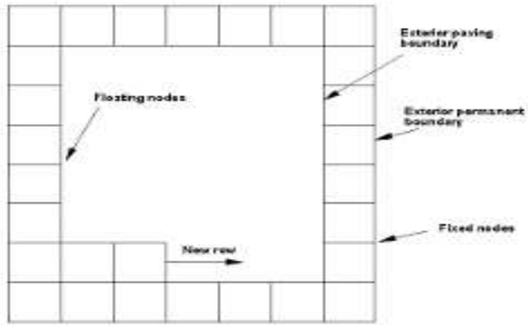

Fig 4.6 A Simple paving sequence and the paving boundaries

$$h = \frac{(d_1 + d_2)}{2\left(\sin\left(\frac{\alpha}{2}\right)\right)}$$

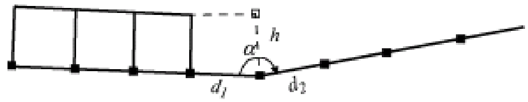

Fig. 4.7 calculation of desired element

These operation could be summarized as below Seam. Small interior angles in the paving boundary are seamed or closed by connecting opposing elements.
Clean up. The completed mesh is adjust where element deletion and/or addition improves the overall mesh quality.
Row choice. The beginning and ending node of the next sequence or row of element to be added is found.
Row generation. The next row of elements identified in the row choice step is incrementally added to the boundary.
Figure 4.8. This problem can be revolve by changing the size of element along the exterior paving boundary, figure 3.10. The coarser elements may be refind, figure 3.9. In this case both the average distortion metric for the FE mesh and maximum distortion metric, may be increased to 1.5 respective 15.0. It may also be useful to smooth the exterior paying paving boundary by the spacing function Eq.3.10.

$$= \frac{\sum_{i=1}^{n} h_i \left(\frac{h_i}{|X - X_i|}\right)}{\sum_{i=1}^{n} \left(\frac{h_i}{|X - X_i|}\right)}$$

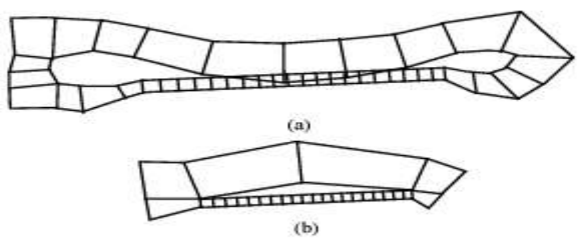

Figure 4.8 intersection between a finer and a coarser boundary section

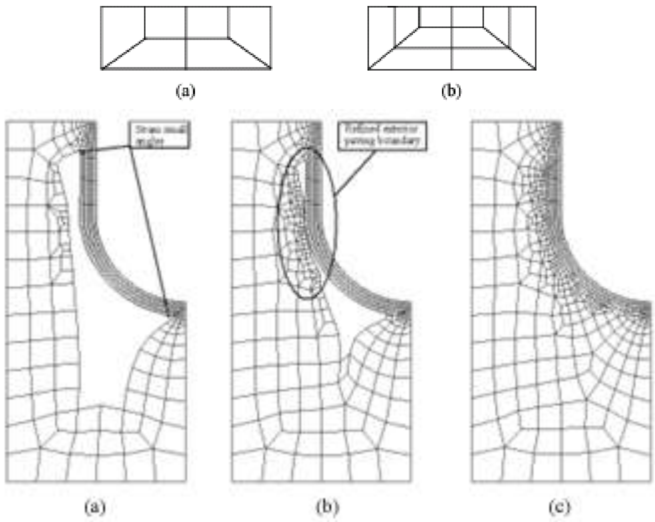

Fig 4.9 A paving sequence. The averaged metric for the final mesh is 1.2 and the maximum metric is 14.6 a) seaming of small interior angles b) the exterior paving boundary refinement c) the final mesh.

V. RESULT AND CONCLUTIONS

Design of the mechanical cutting process is mainly based on the empirical knowledge of the process. The primary object of the research presented in this the development of a finite element approach to provide a better understanding of the cutting process. As a result the chip morphology, cutting force, heat generation and the residual stresses in the work piece may be predicted.

5.1 RESULTS

Different finite element modeling approaches has been evaluated and implemented in a research FE-code Simple. This is an implicit finite element code based on the lagrangian formulation. The commercial FE-code standard was also used to simulate cutting process. In this section a brief review of the appended will be given.

NUMERIACAL AND EXPERIMENTAL ANALYSYS OF ORTHOGONAL METAL CUTTING.

As first step a simplified model of chip formation was used to simulate the cutting process. This is an implicit FE-code using the updated Lagrangian formulation. The computational result were compared with the experiments.

COUPLED THERMOMECHANICAL SIMULATION OF HOT ROLLING, USING AN ADAPTIVE MESH.

Coupled thermos-mechanical analysis of rolling was performed. The efficiency and accuracy when using an adaptive remeshing technique is compared with using a uniform, fine mesh. The accuracy has been confirmed by comparison with PALM2D and by using SIMPLE without remeshing. The overhead cost associated with the remeshing technique reduces the required computing time considerably.

FINITE ELEMENT MODELING OF ORTHOGONAL METAL CUTTING.

The objective of this study was to evaluate different modeling approaches for simulation of mechanical cutting. The latter is a commercial code developed especially for simulating mechanical metal cutting. Two basically different modeling approaches have been used for the chip separation, geometrical and physical model. The advance front technique for generation of quadrilateral element was implemented in the in-house code simple in order to maintain the mesh quality

EFFECT OF PREVIOUS CUTTING ON CHIP FORMATION.

Simulation are performed with the purpose of investigate the chip formation process and to find the residual stresses on the surface of the work piece. The main conclusions in this study of the effect of previous cutting on subsequent layer are as follows. There is only a minor influence from the residual stress on the surface from the first cutting on the second pass chip formation. The residual stresses are affected more in current model. But this influence is expected to be smaller when an appropriate material model which includes rate-dependency and damage effects is implemented.

INFLUENCE OF CUTTING SPEED ON RESIDUAL STRESSES IN WORK PIECE

The influence of the cutting speed and feed on the residual stresses is studied is studied in this work. The material of the work piece is the stainless steel 3161. The explicit finite element code simple. The computational time was considerably shorter in simulations by simple, it is only the heat conduction that give a difference between different cutting speeds. It is assumed that the material will reach a constant hardening when the stress- strain reaches a certain value.

FINITE ELEMENT METHOD

A cutting tool is usually subjected multi- axial stresses in a cutting process such that each face may be subjected to the total force. Relatively lower tensile strength of modern cutting tools. (i.e., carbide tools) makes them prone to brittle failure due to chipping and fracture. Premature failure often results due to improper selection of cutting parameters, which causes excessive stress on the cutting edge.

Generally when the included stress in a cutting tool reaches a critical value, tool failure will occur. In cutting process, the surface is influenced by changes in tool geometry, chip flow, temperature generation, heat flow and tool wears. The understanding of theses interaction during the cutting process is done by static and dynamic analyses with the help of finite element analysis software, called ANSYS [6, 7]

Static analysis

A static analysis calculation the effect of steady loading conditions on a structure, while inertia and damping effects. It has assumed that the orthogonal machining process is in steady- state, a continuous chip is produced and the work piece material is elastic- visco plastic. In a static analysis a rigidity matrix is calculated for each element according to the given specifications. These matrices are aggregated and the rigidity matrix of the system is generated. The solution is the zero displacement of the nodes that are fixed to the tool holder. Inthis research, free meshes are used for the FEM of the cutting tool. The adopted mesh is an arrangement of solid 10 nodedelement.

Dynamic analysis

The dynamic analysis represents that the actual cutting forces depends on various other factors like natural frequency of the lathe, unusual noise and disturbance due to eccentricity of loading condition, excessive cutting velocity, etc. since only linear behavior is valid in this analysis, any non-linearity is ignored even if they are defined. For this reason, the cutting tool structure defined in this work is assumed to have linear behavior.

Finite element modeling

Steady state orthogonal machining

The cutting tool is modelled with a nose radius of o.6 mm. the geometry is 6-8-10-20-45-0.6 (table). The initial tool geometry was drawn in solidwork and imported into ANALYSIS in parasolid format. The work piece was assumed to be elasto-viscoplastica whilst the tool was assumed to be elastic. The spindle speed used for the simulation was 145rpm, federate 0.08382, 0.508 mm/rev, and depth of cut 0.127, 0.254, 0.381 mm to experimental condition. Material properties given in table

Table 5.1 secondary input parameters.

Inclination Angle	Top rake angle	Side relief angle	End relief angle	Auxiliary cutting edge angle	Approach angle	Nose radius
6°	8°	10 °	10 °	20°	45°	0.6mm

Table 5.2.material properties of the tool.

Tool	Density g/cc	Yung's modulus GPa	Poisson's Ratio	Thermal Expansion/k	Yield strength (MPa)
HSS	7.72	190	0.27	9.4*10^-6	380

Stress analysis of the cutting tool

During the orthogonal machining with the tool, the chip is formed by shearing in the primary deformation zone. As a result of very high shear stresses and pressure at the chip-tool interface, a secondary deformation zone along the chip-tool interface also occurs. The magnitude of the von Mises equivalent stress increases while the work piece element goes through the primary deformation zone. The result obtained from the experiment has been shown in table several input parameters were chosen by sampling and a few of the stress analysis done on ANLSYS are show below.

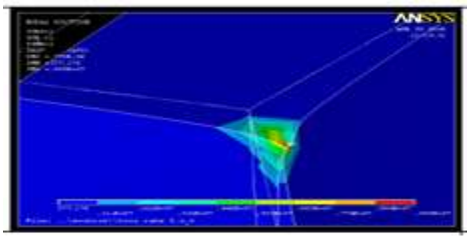

Fig 5.1 von mises stress when f = 0.0832mm/rev, n=145 rpm, d= 0.127mm

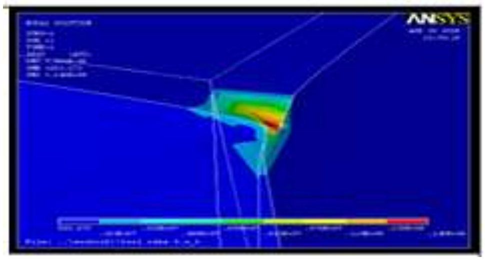

Fig 5.2 von mises stress when f = 0.08382mm/rev, n = 145 rpm, d = 0.254mm

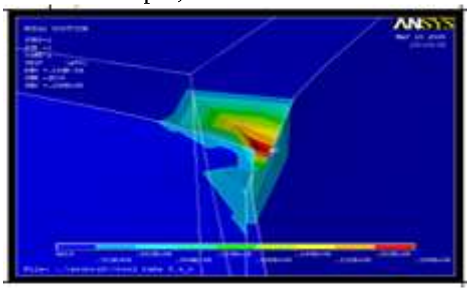

Fig 5.3 von mises stress when f = 0.508 mm/ rev, n = 145rpm, d = 0.127mm

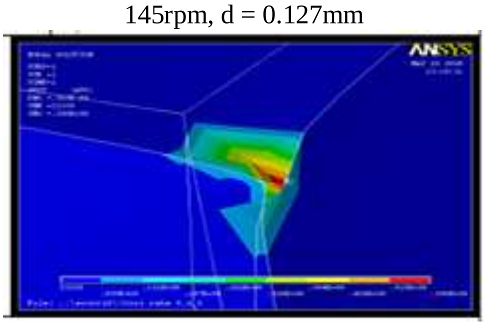

Fig 5.4 von mises when f = 0.508 mm/ rev n =145 rpm, d = 0.254mm

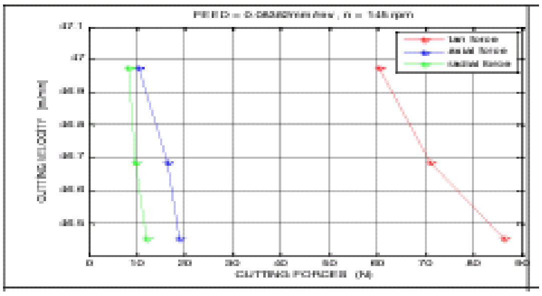

Fig 5.5 cutting force vs. cutting velocity at f = 0.08382mm/rev, n=145 rpm.

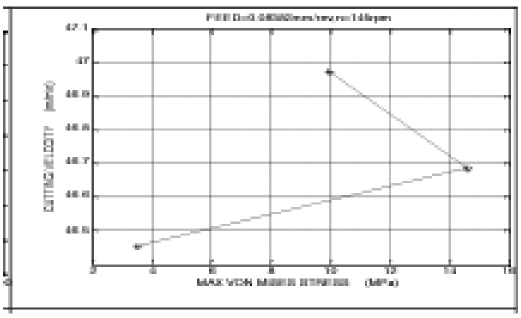

Fig 5.6Max von Mises vs. cutting velocity at f = 0.08382mm/rev, n = 145 rpm

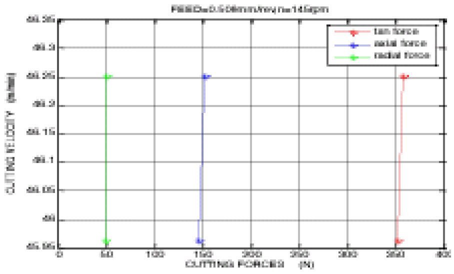

Fig 5.7 cutting forces vs. cutting velocity at f = 0.508mm/rev, n=145 rpm.

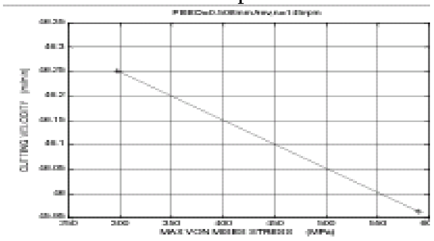

Fig 5.8 Max von Mises stress vs. cutting velocity at f = 0.508mm/rev, n =145 rpm.

5.2 Conclusions and discussion

Different modeling and simulation approaches for orthogonal cutting have been developed and evaluated, using the finite element method. Furthermore the chip formation process and residual stresses in the work piece can be studied. It is believed that the finite element simulation will improve the design of the cutting tools by reducing the testing. Thereby, it will also reduce the time to market for the new designs. Two basically different modelling approaches have been used for the chip separation, geometrical and physical model. The continuous remeshing has been used in the physical model. It is found that the use of continuous remeshing is more demanding but better than the use of a pre-defined crack path however, the Lagrangian finite element simulations of the cutting process using the physical model is obstructed by excessive element distortion, caused by the large, localized deformations. The adaptive remeshing can be used to obtain accurate results. This is done by using two error estimator criteria simultaneously. The error estimate based on the stress gradients in the finite element mesh is combined with quotient between the rate of plastic work in each element and the averaged plastic work rate of the whole mesh. The mesh generation procedure is also utilizing the distortion metric to provide well-shaped elements. It is believed that the lack of the damage mechanics in the material model and the rate –dependent material behavior in simple cause a non-lamina structure chip formation. The CPU time for simulation of residual stresses was considerably longer using the explicit code advantage. The simulation with advantage required 100-130 CPU hours (about 1 million time steps) where the simulation with simple only required 6-8 hours (about 500 time steps) than using the implicit code simple. Furthermore, the use of parallel computing is necessary be able to simulate the cutting processs using three dimensional models. In the course of this study we have found the cutting forces by a 2d strain gauge dynamometer and strain indicator. On the other hand the effect of cutting forces to that spindle speed, feed rate, depth of cut and cutting velocity are observed. It can be concluded from the study that the cutting forces are directly proportional to feed, spindle speed and depth of cut and inversely proportional to the cutting velocity. The von Mises equivalent stress also directly proportional to feed, depth of cut but inversely proportional to cutting velocity. The vulnerable region is identified from the stress contours. It is also observed that the von Miss equivalent stress is 590 MPa which is much higher than the yield strength 380 MPa resulting in tool wear.

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