FINITE ELEMENT METHOD MODELING OF THE STAINLESS STEEL CUTTING PROCESS USING DIFFERENT MACHINING PARAMETERS

GALĪGO ELEMENTU METODES PIELIETOŠANA NERŪSĒJOŠO TĒRAUDU APVIRPOŠANAS PROCESA MODELĒŠANAI AR DAŽĀDIEM APSTRĀDES PARAMETRIEM

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Annotation - For the past fifty years metal cutting researchers have developed many modeling techniques including analytical techniques, empirical approaches and finite element techniques. In recent years, the finite element method has particularly become the main tool for simulating metal cutting processes. Finite element models are widely used for calculating the stress, strain, and temperature distributions. In consequence, temperatures in the tool, chip and work piece, as well as cutting forces, plastic deformation, chip formation and possibly its breaking can be determined faster than using costly and time consuming experiments. It is especially important that FEM analysis can help to investigate some thermo dynamical effects occurring in the cutting zone which, as so far, cannot be measured directly. An example for such effects is the influence of cutting tool coatings on the heat transfer and friction, and resulting cutting temperature distribution in the chip and the tool. In our days, the finite element method based on upgraded - Lagranian formulation has been developed to analyze the metal cutting process The accuracy of the solution can be improved by increasing the number of elements, although with associated increases in the computing power and time required for the simulation.

Introduction

For the past fifty years metal cutting researchers have developed many modeling techniques including analytical techniques, slip-line solutions, empirical approaches and finite element techniques. In recent years, the finite element method has particularly become the main tool for simulating metal cutting processes [1]. Finite element models are widely used for calculating the stress, strain, strain-rate and temperature distributions. In consequence, temperatures in the tool, chip and work piece, as well as cutting forces, plastic deformation (shear angles and chip thickness), chip formation and possibly its breaking can be determined faster than using costly and time consuming experiments. It is especially important that FEM analysis can help to investigate some thermo dynamical effects occurring in the cutting zone which, as so far, cannot be measured directly [2]. An example for such effects is the influence of cutting tool coatings on the heat transfer and friction, and resulting cutting temperature distribution in the chip and the tool. The numerical simulation of chip formation during the metal cutting process has been a challenging research topic due to the difficulty in accurate modeling of the contact and work-material deformation with large plastic strain and friction, high temperature and strain-rate, and their coupling effects. In our days, the finite element method based on upgraded - Lagranian formulation has been developed to analyze the metal cutting process [1]. Several special finite element techniques, such as the element separation, modeling of worm cutting tool geometry, mesh rezoning, friction modeling, etc. have been implemented to improve the accuracy and efficiency of the finite element modeling. The finite element simulation results have also been validated by comparing with experimental measurements [3]. During the orthogonal metal cutting of 420L stainless steel using 5^o rake angle cutting tool at 90 m/min and 112 m/min cutting speed and feeding 0,1 mm/Rpm and 0,35 mm/Rpm the Third Wave AdvantEdge program's finite element simulation results show the work-material deformation zone and temperature in the cutting tool and workpiece contact zone (from to 700 to 1150 ^oC) .

Finite element modeling principle and description of the simulation model

The basis of all finite elements methods is the approximation of a material continuum by an assembly of small finite elements for which the relevant variables and quantities are determined only at the nodes of the elements. The accuracy of the solution can be improved by increasing the number of elements, although with associated increases in the computing power and time required for the simulation. In modeling the plastic material flow there are two basic approaches for assigning elements, both of which have advantages and disadvantages (figure 1a, b):

1. Fixing the elements in space and allowing material to flow through them (Eulerian technique) (figure 1a.).

2. Dividing the material into elements that move with the flow (Lagranian technique) (figure 1b.).

The main advantage of the Eulerian technique is that the shapes of the elements do not alter with time, so associated coefficients require computing only once and this considerably reduces the computational complexity. This presents a problem in the Eulerian technique since placement of the fixed elements is not obvious and an iterative approach to locating the element mesh boundaries is therefore necessary. For this reason the Eulerian technique is inherently more suitable for analysis of steady flow conditions. Thus, in machining, the modeling of intermittent cutting, transition conditions at tool entry and exits and cyclic chip formation mechanisms are difficult or not possible. Another problem to be faced is the description of material property changes with strain, strain rate, and temperature as the material slows through the element mesh.

In the Lagranian [4] technique the elements change shape and orientation as they flow through the deformation zone. Thus, the coefficients associated with each element must be continually updated, increasing the computational complexity considerably and this can also lead to problems of geometric nonlinearity. A finite element analysis can be made more accurate by using smaller elements, but computation times are increased dramatically as the number of elements is increased. For modeling of the machining process, a finer mesh is generally needed in the primary and secondary deformation zones. Using the Eulerian technique, this is straightforward as the elements in the fixed array can be made smaller in appropriate regions. For the Lagranian technique, in order to improve the computational efficiency, the mesh should be made course to start with and then be refined as the material pases through the deformation zones, before being made course again. This progressive mesh refinement in additional complication and is particularly a problem near to the cutting edge of the tool, where the work material divides and the chip is formed (figure 2, 3, 4). For Eulerian technique the separation of material at the tool edge presents problems.

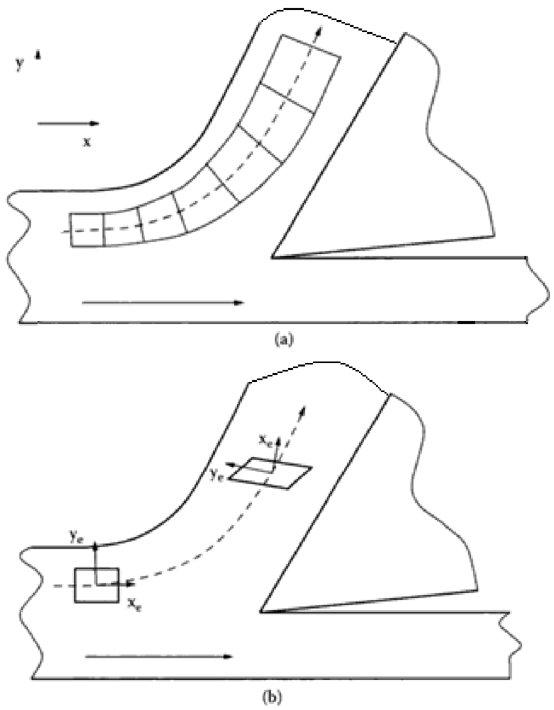

Fig.**1**. Approaches to finite element modeling of machining. Eulerian approach, material flows through a fixed element mesh (a); Lagranian approach, elements move with material and distort and rotate with position (b).

Material and cutting tool selection

As technical progress going forward and in our days metal cutting tools evolution going fast we chosen new Duratomic TM4000 nanocoated turning insert for medium/finish cutting operations with chip breaker MF4 (Chipbreaker intended for medium/finishing of stainless steels. Machining range: feeding = 0.15 – 0.5 mm/rev, depth of cut = 0.5– 4 mm. According to martensitic structure of this hard machining material (420L), carbon (0.15 %) and high Chrome (13 %) containing, manufacturer (SECO) recommendations for this type of cutting insert and possibilities of the lathe 16K20, such as 315 Rpm and 400 Rpm for feeding 0,1 mm/Rpm and 0,35 mm/Rpm, on which experiment was done, we chosen cutting parameters for our experiment (table1).

Simulation and experimental results

During the simulation of the orthogonal metal cutting of 420 L stainless steel using 5^{o} rake angle cutting tool at 90 m/min and 112 m/min cutting speed and feeding 0,1 mm/Rpm and 0,35 mm/Rpm the Third Wave AdvantEdge program's finite element modeling results are received to be compared to the experimental data.

The simulation processed in the Helsinki University of Technology (TKK) by V. Gutakovskis, S.Laakso and professor E.Niemi. In result four cutting parameters combinations was made and graphical results are received. Comparing to experimental data which were received in RTU by V. Gutaovskis, G. Bunga and G.Pikurs, the temperature flow through the cutting insert is correct and is 280 ^{o}C at the distance of 1,5 mm from the cutting edge. Chip formation process during metal cutting is well seen in Fig.2. The heat results in a rise in temperature and the contours of the temperature field and rate of temperature during this cutting process are shown in Fig. 2, 3, 4. On the simulation results (Fig.3, 4) we can see, that sometimes on the cutting edge temperature changes from base cutting temperature (600 to 700 ^{o}C) to the maximum mark of 1100 ^{o}C – 1200^{o}C.

Conclusion

The aim of this finite element modeling was to create a FEM simulation model in order to obtain and research: numerical solutions of cutting forces, temperature in the chip/tool contact region and plastic strain during turning the stainless steel. Program Thirdwave AdvantEdge has been

Table 1.
Finite element modeling cutting process parameters

Parameter comb. Nr.	1	2	3	4
Feeding, mm/Rpm	0,1	0,35	0,1	0,35
Cutting depth, mm	0,5	0,5	0,5	0,5
Cutting speed, m/min.	90	112	112	90

used in simulations of cutting process performed by means of TM4000 Duratomic coated carbide turning insert. Results show us how cutting parameters influence to the temperature distribution fields.

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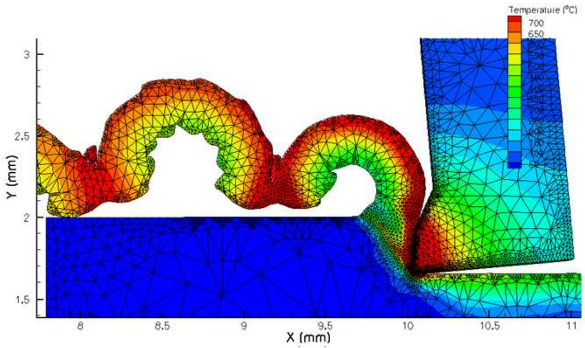
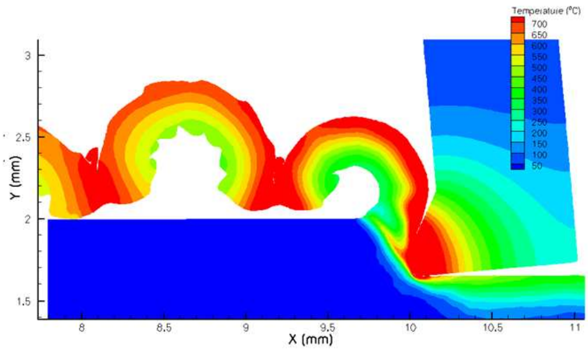
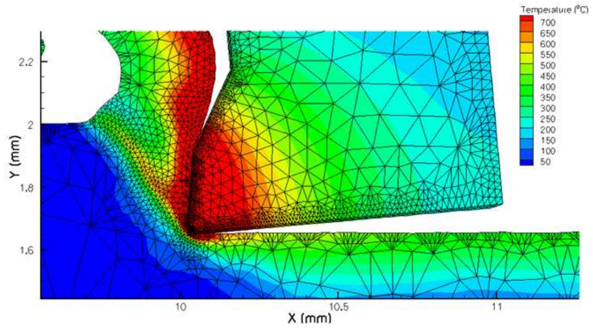


a



b

Fig.2. Simulation of cutting process, chip formation process, temperature field in the cutting tool and material



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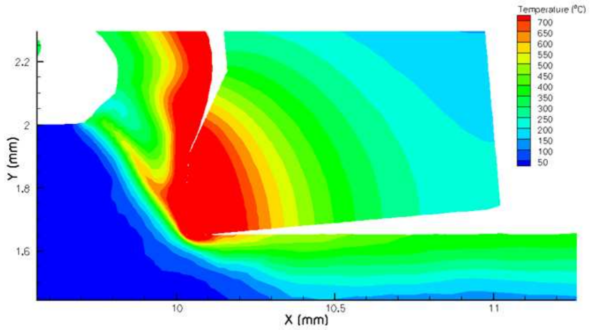
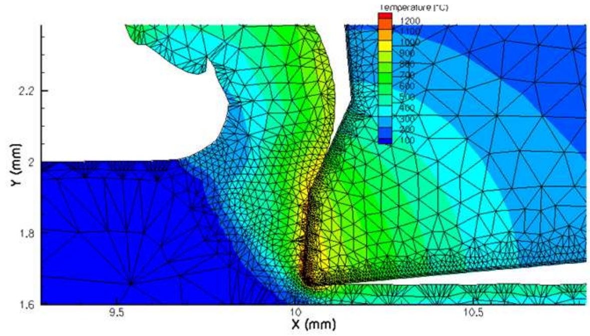


b

Fig.3. Simulation result of cutting process: temperature field in the cutting tool and material with meshing (a), without meshing (b)



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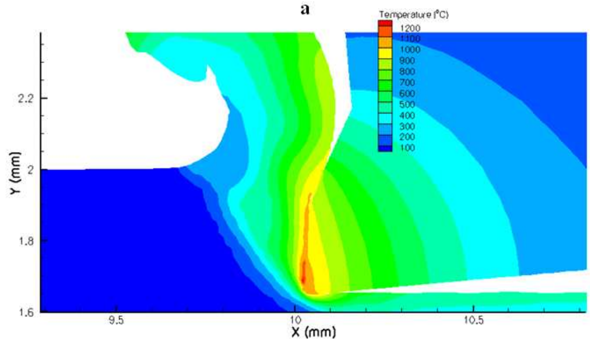

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Fig.4. Simulation result of cutting process: temperature field in the cutting tool and material with meshing (a), without meshing (b)

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Viktors Gutakovskis,Guntis Bunga, Esko Niemi, Sampsa Laakso. Galīgo elementu metodes pielietošana nerūsējošo tēraudu apvirpošanas procesa modelēšanai ar dažādiem apstrādes parametriem

Pēdējās piecdesmit gadu laikā metālapstrādes pētnieki atklāja vairākus modelēšanas paņēmienus , empīriskus paņēmienus un galīgo elementu metodi. Pēdējos gados galīgo elementu metode ir palicis galvenais simulācijas instruments metālapstrādes procesa modelēšanai. Galīgo elementu metode plaši pielietojas spriegumu, deformācijas un temperatūras sadalījuma aprēķināšanai. Tagad temperatūras griešanas instrumentā, skaidā un apstrīdamā detaļā, kā arī griešanas spēku vērtības, materiāla plastiskā deformēšana, skaidu veidošana un tās laušanas varianti, viss tas tagad var aprēķināt ātri un bez dārgo eksperimentu veikšanas. Galvenokārt ir svarīgi ka galīgo elementu analīze var palīdzēt izpētīt termodinamiskus efektus un tās ietekme

griešanās zonā, kuri nevar izmērīt pataisno. Ka tāda efekta paraugs var būt griešanas instrumenta pārklājuma ietekme siltumvadīšanai, vibrācijām un temperatūras lauka sadalījumam skaidā un griezējinstrumentā. Mūsdienās tiek pielietots uzlabots Lagranža formulējums metāla griešanas procesa modelēšanai. Aprēķināšanas precizitāte var paaugstināt ar sadalījuma elementu daudzuma palielināšanu, bet tas protams palielinās simulācijas izpildes laiku.

Виктор Гутаковский, Гунтис Бунга , Эско Ниеми, Сампса Лааксо. Применение метода конечных элементов для моделирования процесса токарной обработки нержавеющей стали при различных параметрах обработки.

За последние пятьдесят лет исследователи по металлообработке разработали много методов моделирования, включая аналитические методы, эмпирические методы и метод конечных элементов. За последние года метод конечных элементов стал основным инструментом для симуляции процесса металлообработки. Модели метода конечных элементов широко используются для расчета напряжений, деформаций и распределения температуры. Теперь температура в инструменте, стружке и обрабатываемой детали, также как силы резания, пластическая деформация, формирование стружки и её излом, всё это может быть определено быстро и без затрат на дорогостоящий эксперимент. Особенно важно, что теперь анализ методом конечных элементов может помочь в изучении влияния термодинамических эффектов в зоне резания, которые не могут быть измерены напрямую. Примером такого эффекта может быть влияние толщины покрытия режущего инструмента на теплопередачу, вибрации и распределение температурного поля в обрабатываемой детали и инструмента. В наши дни применяется метод конечных элементов улучшенной формулировки Лагранжа для анализа моделирования процесса резания металлов. Точность результата моделирования может быть повышена при помощи увеличения количества элементов, но это в свою очередь увеличит время процесса моделирования.