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Contact Phenomena in Micromachining: Modelling and Simulation

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Abstract: The chip development process is an active procedure that is frequently nonlinear. A chip resolve not arrangement once the cutting penetration is a smaller amount than the smallest chip width available. This research shows a series of simulation results that work with finite element methods in a sophisticated radius conclusion on micromachining. A prototypical is industrialised by considering a method, this method is arbitrary Lagrangian - Eulerian (ALE). Popular this study analyzed and simulated chip development, chip progress and the mechanism of material distortion that occurs throughout micromachining AISI D2.

1. Introduction

Microscopic in this field has a difference from the existing macroscopic cutting process, in other words, in relations of the process of chip development, operating conditions and when cutting the level of force. There are differences that occur, these differences have several factors, namely in the mechanism when cutting and microscopic machining processes are included in a smallest chip thickness measure to enable chip development process, the process of cutting radius properties along with micro structure besides tussle dimensions of workpiece solid. The last influence is a factor that applies in the double stage or twin stage [1], wherever the workpiece used cannot stand considered isotropic with the regular grain size of the material having the same order as the feature size in the machining process. The process of forming a chip is a process of characteristic smallest chip thickness or about the depth of a cutting process where the thickness is only micrometer in micromachining so that in principle earnings that chip development can occur in several or level only micro-material scraps, unlike processes that occur in scale macro, as shown in Figure 1 [2]. In a study conducted by Bisacco et al. [3], the effect of chip thickness on microcutting compared to macromachining was demonstrated through experimental means to investigate the correlation between grain size. This shows the occurrence of shear deformation in one grain, while the orientation of individual grains affects the tool, which can result in higher frequency fluctuations than cutting strength because the microstructure of the material is not the same.

Dynamic processes are often nonlinear chip formation processes. Understanding the accurate chip making process is very important for predictive material about cutting strength. If the thickness is



fewer than the smallest chip width, the chip will not be designed, observing the thickness of the chip has been observed by many previous researchers. But the main difference in mechanical cutting among conservative methods and micromachining is the outcome of a sharp radius [4]. Technology that is developing especially in the world of simulation and software has made a development for researchers to develop the results of studies through simulation results using finite element modeling (FEM) and they also try to use it in the field of micromachining, with software and technology they use it to see simulation results and see the development of the chip formed due to cutting, heat formation, friction force between objects and cutting tools.

In the research conducted, the software uses the finite element method, ABAQUS, connecting the Johnson-Cook material model castoff toward analyze then put on the chip development that occurs, chip development and material distortion instrument through micromachining. The Lagrangian-Eulerian (ALE) technique stays arbitrarily castoff to more show the formation of the AISI D2 chip. However, the main focus on sophisticated radius effects on connection singularities is below three standards for instance are a/r greater than 1, a/r smaller than 1 and a/r equal 1 at positive and negative prodigal angles.

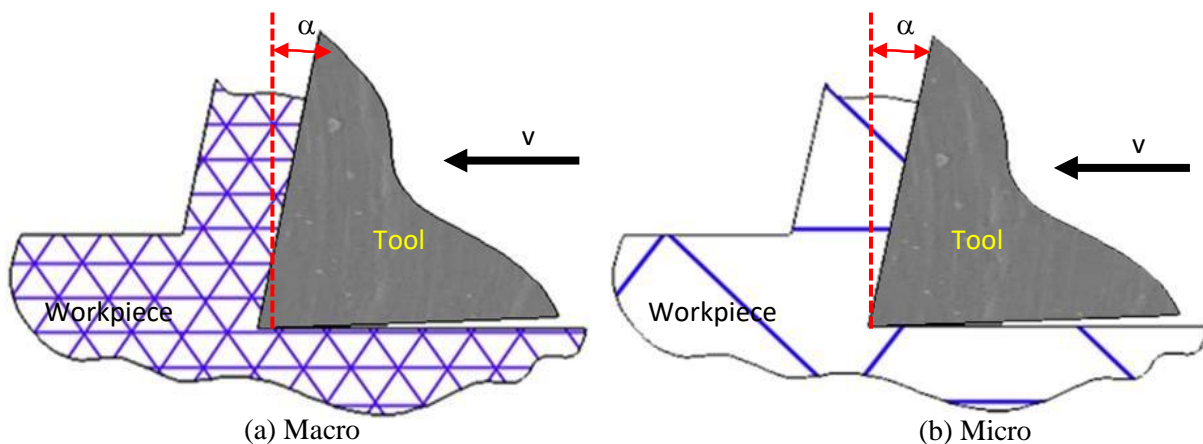


Fig 1: Relative amongst grain size and chip width for macrocutting and microcutting

2. Methodology

In the research conducted, ABAQUS Software is a software used to analyze least chip width in micromachining AISI D2 steel tools. 2D obvious energetic algorithm added by Arbitrary Lagrangian-Eulerian (ALE) as a answer technique settled to pretend chip evolution that occurs, chip development and material distortion. This workpiece is analogous to the similar besides flexible movement performance about the cutting edge which is regulated through the Johnson-Cook material prototypical. Therefore, there is no category of chip departure followed. The work piece and microcutting solid of the prototypical are AISI D2 and WC steel tools singly. The workpiece is described as a four-sided block $50\mu\text{m}$ lengthy and $15\mu\text{m}$ thick. Uniforms blend with a temperature of four combined tones - displacement with an element dimension of $1\mu\text{m} \times 0.5\mu\text{m}$. The number of mesh produced for the prototypical is 4791 elements, although 4955 nodes have been determined as the area of chip development analysis. Figure below illustrates a threaded workpiece through predetermined limit situations where the position point is set at the end of the cutting tool. At the lowest and port positions on the work piece are modernised in vertical and horizontal purposes. The tool is nourished horizontally to a static stiff workpiece with a speed of cutting is 100 m / minute for as initial method of working tools and then the separation of material is done. The dislocation of this tool for the y axis and

rotation of the tool for the x axis and y axis is static but the cutting tool is left to change horizontally on the x axis.

Cutting tools by dissimilar types of edge radii are preserved as flawlessly stiff solids though workpieces are analogous to changes due to workpiece distortion studies only. Shrink and curved sharp edges are simulated on improved undeformed chip thickness ($a = 3\mu\text{m}$). The model developed in this study in the replication study was validated by a prototypical settled by Woon et al. [5]. Simulations are approved out with an angle of 5° negative rake and angle of permission, at dissimilar tool edge radii, $r = 0, 1, 5$, and $8\mu\text{m}$ under three criteria, $a/r < 1$, $a/r > 1$ and $a/r = 1$. On this situations, tool chatters and workpiece solid chatters are explained in Table 1.

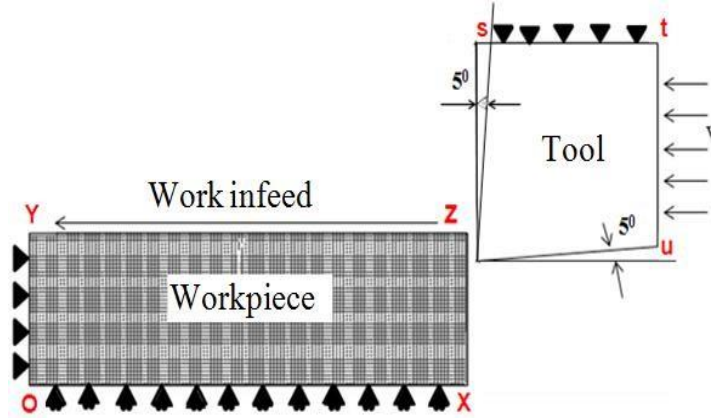


Figure 2: Finite Element Analysis prototypical

Table 1: FEM assets

<u>Cutting conditions</u>	
CS (m/min)	100
Undeformed chip thickness (μm)	3
<u>Tool properties (TiAlN)</u>	
Thermal conductivity (W/m.K)	46
Density (kg m^{-3})	15000
Elastic Modulus (Gpa)	800
Poisson's Ration	0.24
Specific heat (J/kg.K)	203
<u>Workpiece properties (AISI D2)</u>	
Yield strength (Mpa)	1776
Hardening modulus (Mpa)	904
Strain rate sensitivity	0.012
Thermal softening coefficient	3.38
Hardening coefficient	0.312
Reference strain rate	1
Melting temperature ($^\circ$)	1460
Density (kg m^{-3})	7750
Elastic Modulus (Gpa)	200
Poisson's Ration	0.3
Specific heat ($\text{Jkg}^{-1} \text{K}^{-1}$)	485
Thermal Expansion ($10^{-6}/^\circ\text{C}$)	10.4
Thermal conductivity (W/m.K)	21

3. Result and Discussion

3.1 Chip formation and Von Mises Effective Stress Distributions

Figure 3 demonstrates the process of chip development that occurs and solid distortion at different a/r ratios. For a/r , 3 and 1, the chip is form at the beginning of the rake surface of the tool as given away on Figures 3 (a), (b), and (c) singly. The material below the permissible surface movements round the radius of the tool edge at $a/r > 1$. A minor portion of the solid can pass as a chip whereas the residual movement returns to mass solid which leads to the development of the engine exterior. Once $a/r < 1$, the early machining achievement is carried out by the cutting edge, see Fig 3 (d). This event causes hijacking, coarse superficial and flexible retrieval of the work piece. Liu et al. [6] and Kim et al. [7] explains that close remains flexible distortion of the workpiece throughout the micromachining procedure

Figure 3 illustrates the plastic deformation process that occurs in the workpiece at a dissimilar ratio a/r as replicated by the Von Misses flow stress in the simulation results. At $a/r > 1$ the flexible distortion that occurs is identified as the main shear zone. Primary shear sectors clearly arise at the Von Misses stress contour during the initial stages of the micromachining process by sharp cutters at $a/r = \infty$, 3 and 1 as seen in Figures 3 (a), 3 (b) and 3 (c).) each. Secondary shear zones occur along the rake surface as the primary shear zone red as seen in the stress spreading. When the a/r is lesser than 1, the workpiece will experience plain plastic distortion because the tool edge is round with a big plastic deformation zone. At $a/r = 0.2625$, the Von Misses voltage converts a high localized voltage as shown in Figure 3 (d). This illustration shows that Von stress Misses become a much-localized stress distribution when a/r decreases.

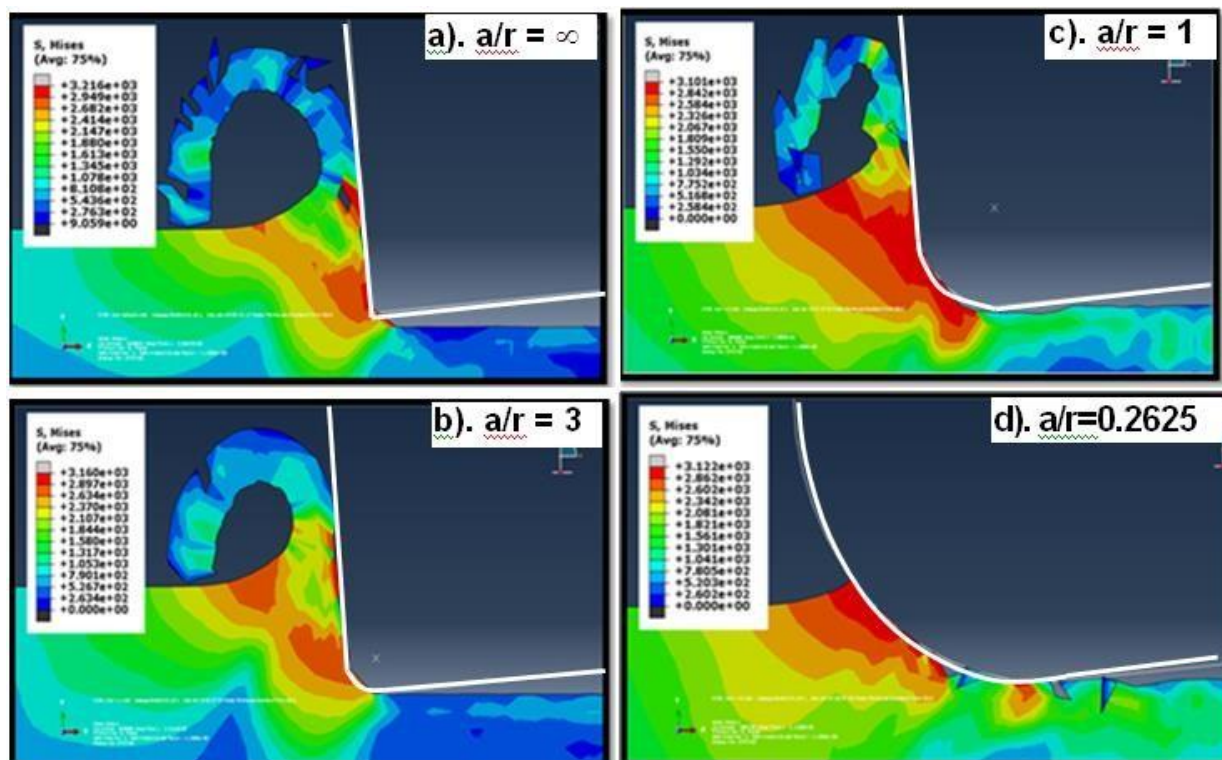


Figure 3: Material distortions at dissimilar

4. Contact length

Figure 4 shows a comparison among the negative rake angle and the positive profligate angle cutter. The result of this comparison rests on the effectiveness of different rake angles on the workpiece chip formation that occurs. The connection length among the mark and the rake from the negative rake angle is \leq the positive rake angle. Result can be seen in Figures 4 (a) and 4 (b) respectively. This occurs due to the displacement of the negative angle grinding tool equal to the friction action while the positive grinding wheel which cuts the cutting tool moves on the cutting action. Both types of orientation cutting tools have their respective advantages. For the cutting process, the positive rake angle is more efficient because it gets a smaller amount force to expurgate the workpiece while in the negative rake angle, the cutting tool has less contact with the workpiece and moves smoothly on the workpiece. The latest experimental settings extend the life of the cutter. In this numerical analysis, the types of chip formations between negative and positive rake angles are arranged. The chip formed by a negative rake angle cutter during machining simulation is a discontinuous chip where the positive rake angle forms a continuous chip. Both chips, for negative and positive rake angles occur at the $a / r1$ ratio while at $a / r < 1$, minimum or no cuts have been analyzed. This is because the thickness of the chip has reached its minimum level.

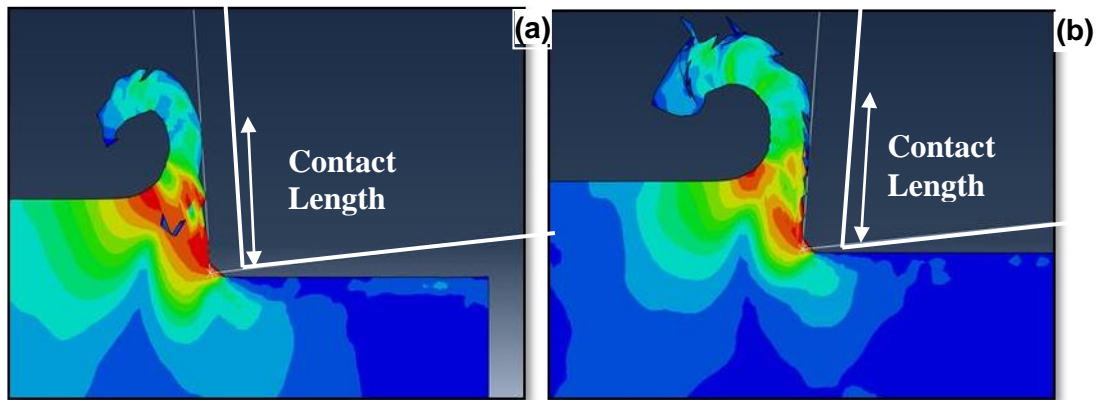


Figure 4: (a) Negative rake angle (b) Positive rake angle

5. Conclusions

In this research, chip development arises, chip development and the mechanism of material distortion that occurs in the micromachining process is carried out an investigation. The chip development machine is intentional quantitatively through the FEM method. Some conclusions are originate, as tracks:

- The smallest chip width is an important focus in calculating the presentation of chip development in the micromachining process.
- The prototypical shows that the mark is designed at a/r of additional than 1 while physical extrusion occurs after the ratio $/ r$ is less than one.
- The chip development machinery is characterized by a (-) rake angle that continues to fluctuate which becomes steady at a advanced phase after the process influences a constant connexion length of the chip. Considerate the passing behaviour of micromachining is very significant since it often forms done a continuous cycle of passing chip development in real preparation.
- The contact distance amongst the chip besides the rake face of negative angle is a \leq amount than the (+) angle

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