3D Finite Element Modelling of Drilling Process of Al2024-T3 Alloy with solid tooling and Experimental Validation

Davoudinejad, Ali; Tosello, Guido

Publication date: 2017

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.
3D Finite Element Modeling (3D FEM)

- Objective: Evaluate different drills geometry and material for drilling Aluminum 2024-T3.
- Reduction in cost and time, mainly with advance of powerful computers to predict parameters such as stress, cutting force, temperature, strain and strain rate, which are difficult or impossible to detect experimentally [1].
- Tool modeling and cutting configuration setup (Fig. 1).
- Different cutting tool geometries (Table 1).
- Tool and workpiece were meshed with the 4 node tetrahedral elements, type.
- Adaptive-meshing technique was applied constantly in the simulations.
- The Power Law constitutive material model, where \(\sigma_0\) is the initial yield stress, \(n\) is the plastic strain, \(\varepsilon_p\) is the reference plastic strain, \(\varepsilon_s\) is the reference plastic strain rate, \(c_0\) through \(c_5\) are the coefficients for the polynomial fit, \(T\) is temperature, \(n\) is the strain hardening exponent and \(m\) is the strain rate sensitivity coefficient [2].

\[
\frac{\sigma}{\sigma_0} = (1 + \varepsilon_p/n)\left(1 + \frac{\varepsilon_p}{c_0}\right)\left(1 + \frac{\varepsilon_p}{c_1}\right)\left(1 + \frac{\varepsilon_p}{c_2}\right)\left(1 + \frac{\varepsilon_p}{c_3}\right)\left(1 + \frac{\varepsilon_p}{c_4}\right)\left(1 + \frac{\varepsilon_p}{c_5}\right)
\]

The friction phenomenon at the chip-tool interface was modeled using the Coulomb law. Based on the experimental research results and related studies [3] a constant friction factor of 0.7 is used in the finite element (FE) model.

In order to validate model a comparison between numerical and experimental forces were carried out.

Experimental procedure for FEM validation

Table 1 Cutting tool specifications

<table>
<thead>
<tr>
<th>Tool A</th>
<th>Tool B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advance</td>
<td>0.8</td>
</tr>
<tr>
<td>Depth</td>
<td>2220</td>
</tr>
<tr>
<td>Hardness (HV)</td>
<td>260</td>
</tr>
<tr>
<td>Geometry</td>
<td>2 facet</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>6</td>
</tr>
<tr>
<td>No of Flutes</td>
<td>2</td>
</tr>
<tr>
<td>Flute angle</td>
<td>80°</td>
</tr>
<tr>
<td>Chamfer angle</td>
<td>150°</td>
</tr>
<tr>
<td>Lip relief angle</td>
<td>15°</td>
</tr>
<tr>
<td>Stem angle</td>
<td>30°</td>
</tr>
<tr>
<td>Web thickness (mm)</td>
<td>0.6</td>
</tr>
</tbody>
</table>

- Dry drilling experiments of Al2024 were carried out using CNC Deckel Maho DMC 835 [4].
- Cutting speed (94.2 m/min)
- Feed rates (0.04, 0.4 mm/rev) [4].

Fig. 1 Tool 3D model and experimental image (a) two facet HSSCo (b) four facet HSS (c) 3D FE model for drilling setup

Fig. 2 The schematic representation of the experimental set-up.

Fig. 3 Experimental thrust force (a) 3 facet drill and (b) 4 facet drill at \(f_r = 0.04\) mm/rev

Fig. 4 Comparison of thrust and experimental thrust force

Fig. 5 Stress values at different cutting conditions (a) \(f_r = 0.04\) mm/rev (b) \(f_r = 0.4\) mm/rev

Fig. 6 Chip formation and temperature distribution obtained at the end of simulations

Conclusion

3D finite element modeling of the drilling process of aluminum 2024-T3 alloy with two and four facet drills geometry were carried out at different cutting conditions. Comparable results of FE model and experimental thrust force were obtained. The performance comparison of the simulations result reveals the 4-facet drill geometry mainly in terms of thrust force and stress distribution along the cutting edges demonstrates a better performance. Higher force obtained at the same cutting condition with 2-facet drill and the maximum stress occurs on the chisel and cutting edges.

References