Material Behavior Modeling for High Speed Machining Simulation of 6061-T6 and 7075-T651 Aluminum Alloys

Modelisation du comportement du matériau pour la simulation de l’usinage à haute vitesse des alliages d’aluminium 6061-T6 et 7075-T651

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Abstract: The present study proposes an original method to identify the Marusich’s constitutive equation (MCE) for finite element simulation of the high speed machining of aluminum alloys. The coefficients of the MCE, for the aluminum 6061-T6 and 7075-T651, were identified inversely using orthogonal machining tests and dynamic tests.

Strain rate sensitivity of aluminum alloys

Marusich’s constitutive equation (Marusich, 1995)

\[
\begin{align*}
(1 + \frac{\varepsilon_p}{\varepsilon_0}) & = \left( \frac{\sigma}{g(\varepsilon_p)} \right)^{m_1} \quad \text{if } \varepsilon_p < \varepsilon_t \\
(1 + \frac{\varepsilon_p}{\varepsilon_0}) \left(1 + \frac{\dot{\varepsilon}_p}{\dot{\varepsilon}_0} \right)^{m_2-1} & = \left( \frac{\sigma}{g(\varepsilon_p)} \right)^{m_2} \quad \text{if } \varepsilon_p > \varepsilon_t
\end{align*}
\]

\[g(\varepsilon_p) = [1 - \alpha_{NL} (T - T_0)] \sigma_0 \left(1 + \varepsilon_p/\varepsilon_0 \right)^{1/n_{NL}}\]

Hybrid approach for the identification of the material constants

Dynamic tests

7075-T651 (Li, 2014)

Machining tests

Low strain rate constants: \(\sigma_0, n_{NL}, \text{and } m_1\)

High strain rate constants: \(m_2\) and \(\alpha_{NL}\)

Material constants

<table>
<thead>
<tr>
<th>Material</th>
<th>(\sigma_0) [MPa]</th>
<th>(m_1)</th>
<th>(m_2)</th>
<th>(n_{NL})</th>
<th>(\alpha_{NL})</th>
</tr>
</thead>
<tbody>
<tr>
<td>6061-T6</td>
<td>278</td>
<td>4.3</td>
<td>150.7</td>
<td>3.3</td>
<td>0.0022</td>
</tr>
<tr>
<td>7075-T651</td>
<td>529</td>
<td>2.6</td>
<td>168.9</td>
<td>11.2</td>
<td>0.0017</td>
</tr>
</tbody>
</table>

Results: finite element simulation of high speed machining 6061-T6 and 7075-T651 alloys

Dry cutting conditions, Speed=1145 m/min, Feed=0.15 mm/rev, and uncoated carbide inserts

Conclusions: The Marusich’s constitutive equations for 6061-T6 and 7075-T651 aluminum alloys were identified. The obtained material models were successfully implemented into an finite element modeling (FEM) of high speed machining using DEFORM 2D software. The FEM was validated using experimental data such as cutting force.