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Modeling of a Turning Process in Deform-3d Software

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Abstract

This article describes the process of high-speed machining of an aluminum alloy. The used method is the computer modelling of the process of an aluminium alloy. The results of the modeling compare well with those of the experiments.

Keywords: simulation of turning process, aluminium alloy, JIS-2024, high speed machining

1. Introduction

Aluminium alloys (or aluminum alloys) are alloys in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminium is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminium alloys yield cost-effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast aluminium alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to good casting characteristics. Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required.

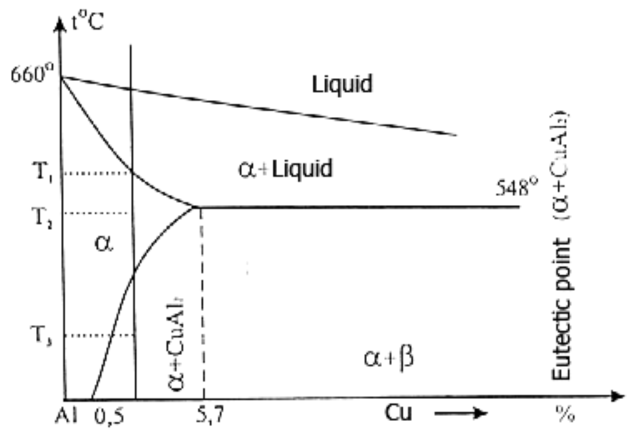

Fig. 1. Phase diagram of “aluminum – copper” where T1 – melting temperature; T2 – hardening temperature; T3 – artificial aging temperature.

2. Simulation

The process of turning was simulated with Deform-3D software [1]. The workpiece shape is of a parallelepiped of 15 mm length (Fig. 1) and made from JIS-2024. To treat the workpiece it was fixed on bottom and profile planes. The convection coefficient is 0.04 $W/m^2 \cdot K$, the ambient temperature is 20°C. In the modeling software the carbide cutting insert was considered as a rigid body. The material of the cutting piece was carbide. The carbide cutting insert has the following material properties and features:

- thermal conductivity – 71.176 W/m·K;
- coefficient of specific heat – 0.052 kkal/kg·K;
- radiance coefficient – 0.7;

Geometrical parameters of cutting part of a plate:

- front rake, γ =0°;
- cutting edge inclination, λ=0°;
- nose radius, rв=0.4 mm;
- nose angle, β =60°;
- tool edge radius, r=0.02 mm;
- main clearance angle, α =10°;
- approach angle, φ =80°;
- minor cutting edge angle $\varphi 1$=15°.

Table 1 - cutting conditions

Cutting speed (mm/sec)	Feed (mm/rev)	Cutting depth (mm)
20		
40		
60		
80		
100	0.08	0.5
120		
140		
160		
180		

Contact between the objects follows the law of sliding friction and the heat transfer coefficient. To describe the

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processes of friction of the carbide cutting insert used Siebel's law of friction, the friction coefficient is set to 0.6 [2]. The heat transfer coefficient of the workpiece and tool is 45 $W/m^2 \cdot K$. Table 1 contains the cutting conditions employed.

3. Properties of alloy JIS-2024

This alloy is a heat treated alloy with high and standard strength. The density of the alloy is 2500-2800 kg/m^3, the melting temperature is 650°C. Duralumin can be hardened with heat treatment, which consists of a hardening and subsequent aging stage. The part of the phase diagram of "aluminum – copper" and "aluminum – alloying element" is shown in Fig. 2. Tables 2 and 3 contain the chemical and physical properties.

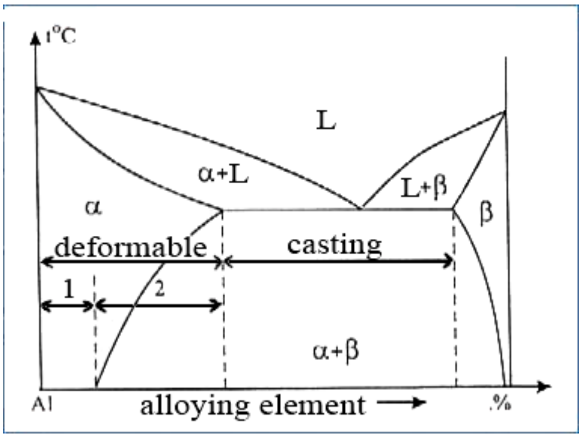

Fig. 2 Phase diagram "aluminum – alloying element": 1– deformable non–heat–treatable alloys; 2– deformable thermally hardenable alloys.

Table 2. Chemical composition

Fe	Si	Mn	Cr	Ti	Al	Cu	Mg	Zn	Addition
0.5	0.5	0.3–0.9	0.1	0.15	90.9–94.7	3.8–4.9	1.2–1.8	0.25	0.15

Table 3. Material properties

T, ^0C	$E \cdot 10^{-5}$ MPa	$\alpha \cdot 10^{6}$ $1/^0C$	λ $W/(m \cdot {}^0C)$	ρ kg/m^3	C $J/(kg \cdot {}^0C)$
20	0.72	22.9	130	2770	0.922

4. The machinability of aluminum and its alloys

These alloys cab be machined easily, because of their low melting temperature and the cutting temperature does not reach these. Long tool life can be obtained by using for most aluminum alloys cutting speeds up to 10 m/sec with carbide tools and 5 m/sec with high speed steel tools. For machining aluminum alloys the cutting forces are low. However, to cut commercially pure aluminum will show high cutting forces due to the large contact surface on the tool and will produce thick chips.

In the zone of plastic flow there is adhesion phenomenon of a chip on the tool surface. Newly formed bonds break shortly and this process results in additional rising of temperature in a chip. This area is the main source of heat, contributing to an increase in temperature of the tool and its wear. In this regard, aluminum differs from magnesium, but it is yet similar to many other pure metals.

5. Results

The results of experiments of cutting speed of the ultra high performance aluminum wrought alloy [3] are presented in Table 4, while the modeling results are shown in Table 5. The maximum difference between modeling and experimental temperature is about 235 K.

Table 4. Experiments

Cutting speed (m/sec)	Temperature (K)
20	838
40	870
60	895
80	910
100	925
120	928
140	928

Table 5. Modelling.

Cutting speed (m/sec)	Temperature (K)
20	833
40	873
60	970
80	898
100	1073
120	1073
140	1163

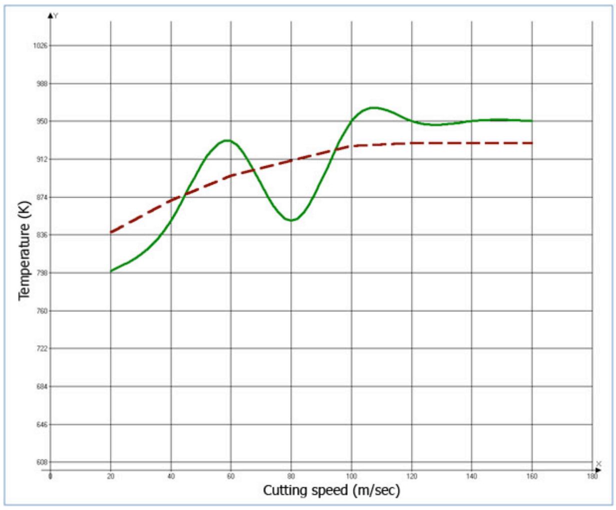

Fig. 3. Temperature change with cutting speed: full line – modelling, dotted line – experiments

6. Conclusion

Experimental results (dashed line) show that temperature increases with cutting speed , asymptotically approaching melting point. Modelling results show (solid line) a similar behavior, and at a speed of 80 m/sec temperature is sharply reduced to 898 K, and subsequently increases to reach a steady state. The simulation shows that the maximum temperature is 1163 K at a cutting speed of 140 m/sec, 160 m/sec. This can be explained by the accumulation of energy at speeds from 20 m/sec to 60 m/sec. The effect of high-speed processing is caused by structural changes in a material (due to plastic deformation carried out at high speed) at point of a chip separation. With increasing strain rate cutting forces grow initially, and then, once reaching a certain temperature within the chip, it suddenly begins to drop significantly. It should be noted that the time of contact with the cutting edge of the workpiece and the chip is so small and the lift-off speed of chips is so high that most of the heat generated in the cutting zone is removed along with the chips and the workpiece and the tool simply do not have time to heat up.

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