Hot Deformation Behavior of Squeeze Casting SiC_p/2A50 Matrix Composites

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Abstract: The flow stress behaviors of squeeze casting SiC_p/2A50 matrix composites were investigated by means of compression tests on a Gleeble 1500 thermal mechanical simulator at isothermal constant strain rates ranging from of 0.001 to 1.0 with the testing temperature ranging from 350 to 500 ℃. The experiments showed that the relationship between stress and strain was obviously influenced by the strain rate and temperature. Dynamic recrystallization generally occurred at a higher temperature and a lower strain rate. A linear equation could be fitted between the Zener-Hollomon parameter Z and stress in the experiments. The mean value reciprocal of temperature at every true strain had a linear relation with natural logarithm of Z parameter, and the correlation coefficient, R=0.99, which was very significant by examination. The hot deformation activation energy of SiC_p/2A50 matrix composites was 163.47 KJ/mol by calculation.

Key words: SiC_p/2A50 matrix composites; deformation activation energy; stress and strain; dynamic recrystallization

1 Introduction

Due to their desirable properties of the high specific stiffness or strength, superior creep resistance, wear resistance, increased fatigue resistance, availability of cheaper reinforcement and comparatively low cost, high volume, production methods and good thermal stability, Al matrix composites have attracted great attention with regard to their application in transportation, electronics and aerospace industries[1-3]. However, compared with the aluminum alloy, the Al matrix composites show a lower hot ductility than that of the monolithic alloy owing to the presence of reinforcement SiC_p, which brings the difficulties for the plastic process of the matrix composites. Many results have been reported on the hot deformation behaviors of Al-based composites reinforced with ceramic reinforcement[4,5]. It is found that hot deformation mechanism and matrix flow behaviors of Al-based composites are quite different from those of unreinforced monolithic alloy. Thus, it is necessary to understand the hot deformation behaviors and the effects of deformation conditions on deformed microstructure and hot-ductility during the processing to improve the hot workability of the Al-based composites. Byung-chul Ko[6] studied the SiC_p/Al2024 composite, and found 40-50% efficiency in the dynamic recrystallization region (370-460 ℃, 0.1-0.5/sec), and it also indicated that that the deformation efficiency obtained at high temperature and low strain rate was larger than that of at low temperature and high strain rate. N P Cheng[7] indicated that the deformation behavior of SiC_p/Al composites strongly depended on the properties of matrix alloy. The present works are, therefore, in an attempt to study the hot working behaviors and the effect of hot deformation on hot deformation behavior of the aluminum reinforced with silicon carbide particulate. Many researchers have established deformation maps, which were based on the dynamic material models[8], to reveal the relationships between deformation efficiency.

Up to now, besides a certain degree applications of the matrix composites in the aerospace field in the advanced countries, such as American, Japan, western
Europe, and so on, the characteristics of the matrix composites restrict their use widely. By these reasons, further researches of the plastic deformation behaviors at high temperature should be required to extend the application of matrix composites.

This paper focused on the hot deformation behaviors of the SiCp/Al matrix composites which were prepared using the squeeze casting. The tests of SiCp/Al matrix composites were carried through the hot deformation experiment under the condition of the temperature 350-500 °C and the strain rate 0.001-1 s⁻¹. In addition, the deformation behaviors were discussed in hope to find the influencing characteristics of the preparation technology on the matrix composites.

2 Experimental

The material used in the study was SiCp/2A50 matrix composites prepared by squeeze casting. The reinforcement phase was SiCp, and its mean size and volume fraction were 20 μm and 15%, respectively. The chemical compositions of 2A50 were (mass fraction, %) Mg0.62, Si0.93, Cu2.21, Mn0.52, Fe0.13, Zn0.08, Ni0.06, and Ti0.07.

Every specimen was cut along squeezed direction of the billet and machined into small cylinder sample of φ10 mm×15 mm. Deformation tests were conducted on Gleeble 1500D thermal mechanical simulator at the temperature range from 350 to 500 °C and at strain rates of 0.001 to 1 s⁻¹. The biggest pre-deformation was set by 60%. Graphite flakes were located on the end surfaces of specimens in order to decrease lubrication. Final true strain values of all specimens were 1.0. The test data was recorded automatically. Specimens for metallographic examination were sectioned along axial direction, mounted, polished and then etched in acetic picral.

As the optical micrographs in Fig.1 showed, the distribution of the 15% SiCp particles reinforced 2A50 matrix composites were relatively uniform with a few small cellular regions.

3 Results and discussion

3.1 Flow stress characteristics of SiCp/2A50 matrix composites

The flow stress-strain curves of SiCp/2A50 matrix composites at different temperature and various strain rates were illustrated in Fig.2, which reflected the influences of temperatures, strain rate and strain on the flow stress. From Fig.2, every curve exhibited a sharp increase at the initial stage of strain, then slowly increased up to a transient equilibrium, when stress arrived at the maximum value. Subsequently stress decreased, then was driven to a steady value with increasing strain. With the same strain ratio, the higher the deformation temperature, the lower the corresponding flow stress. At the primary deformation stage which was the stage of the plastic deformation, the quantity of deformation was very little, but the ratio of the stress increased very quickly. In this stage, the materials would not harden. With increasing of the quantity of deformation, the increasing ratio of the stress got slower because of increasing of the deformation resistance which was caused by the work-hardening. With the increasing of the work-hardening, the speed of the dynamic recovery at high temperature and the dynamic recrystallization would quickened up, and the work-hardening and softening process would arrive at dynamic equilibrium in the end. With further increasing of the quantity of deformation, the softening preponderated over work-hardening gradually, and the flow stress began to decline and got stabilization eventually. From Fig.2, in the condition of fixed strain, the Al matrix composites took on the obvious steady flow characteristics in the process of deformation, that was to say that with the definite temperature and strain rate, the true stress σ did not change distinctly with the continuative increase of the true strain ε when the true strain exceeded a certain value; with regard to the same strain rate, the true stress decreased with the increase of the deformation temperature; with the same deformation temperature, the flow stress decreased with the increase of the strain rate. From Fig.2, it could be also seen that the curves of SiCp/2A50 matrix composites exhibited the dominant role of typical dynamical crystalline characteristics during the tests of compression.

The flow peak stress basically corresponded with those of the aluminum alloys under the same