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Dynamic Fracture of Ductile Materials

Dynamic characterization and modeling of ductile failure of sintered aluminum alloy through shear-compression tests

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Abstract

This work presents an experimental method using shear-compression tests allowing the study of the temperature and strain rate sensitivities of the failure mechanisms of sintered metallic materials presenting low intergranular cohesion. Indeed, the classical approach using tensile tests cannot be used for such materials because only the intergranular resistance of the grains powder is therefore measured. The shear-compression tests allow the deformation of the grains powder and prevent the failure by decohesion. In this study, the failure behaviors of a sintered 7020 and laminated AA7020-T651 aluminum alloys are thoroughly investigated by means of shear-compression tests (several geometries) and specific expressions leading to modeling are provided and discussed. The modeling of the temperature sensitivity of the strain at initiation of failure is performed with a specific physical expression which takes into account the change of microstructure and present a temperature-strain rate coupling. Furthermore, it is linked to the thermal evolution of the stress and uses the same set of parameters determined for the stress modeling. Finally, a method using this expression is suggested in order to uncouple the phenomena responsible of the increase of the strain at initiation of the failure: the effect of the strain rate alone and the softening due to the adiabatic heating.

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Keywords: shear-compression, aluminum alloy, failure modeling, sintered metal, high strain rate

1. Introduction

The study of the failure mechanisms in metallic materials is a classical method for constitutive modeling of the mechanical behavior of structures in many industrial fields (e.g. aeronautic, automotive …). The traditional approach consists in the study of the sensitivities of the strain at initiation of failure (or another criterion) with the

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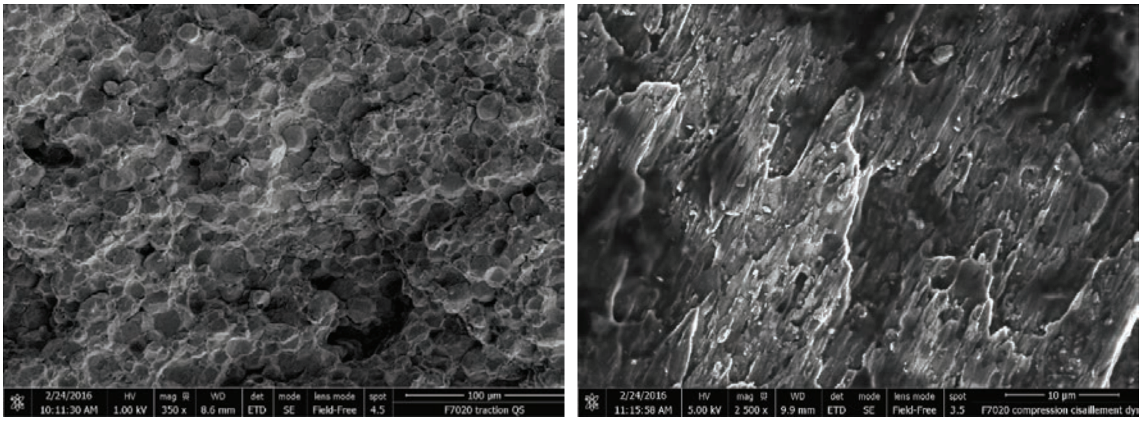
state of stress, the temperature and the strain rate [1, 2]. The latter two are generally identified from tensile tests. However, some sintered metallic materials shows grains powder decohesion in state of stress presenting a positive triaxiality (Figure 1.a). Due to this effect, tensile tests are therefore not suited to evaluate the evolution of the strain at initiation of failure with the temperature and the strain rate. Indeed, in these conditions, the results are measuring mainly the response of the intergranular structure and not of the material itself. The tests which has been chosen to overcome this problem is the shear compression test [3, 4] which leads to the shearing of the grains and prevents grains decohesion (Figure 1.b). The method to obtain the temperature and strain rate dependencies of the failure behavior for a sintered aluminum alloy is explained in this study.
The particular geometry of the shear-compression samples is also modified in order to obtain different states of stress at negative triaxiality for the sintered aluminum alloy.



(a) (b)

Figure 1 - SEM picture of 7020 sintered aluminum (F7020) alloy fracture profile in (a) tensile condition and (b) shear-compression condition

In this work, two different 7020 aluminum alloys are tested with the same tests: one has been sintered using Spark Plasma Sintering process (F7020) with failure by decohesion and the other is a commercial laminated AA7020-T651 presenting no decohesion. The stress behavior of both materials has already been thoroughly investigated [5] and the most interesting difference in their behavior can be seen through the observation of the calorific ratio Ω [5] in the Figure 2 (it corresponds to the evolution with the temperature of the thermal stress and normalized with its value at room temperature). It can be seen for both alloys a drop of the stress around 500 K caused by the change of microstructure due to the dissolution of the $MgZn_2$ and Al_6Mn precipitates in the aluminum matrix. This drop of stress differs according to the microstructure. Another aim of this study is to present a link between the thermal stress and thermal failure behaviors through an accurate modeling using the calorific ratio.