Numerical simulation of dynamic impact spall of ultra high strength 7055 aluminum alloy

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Abstract

In order to fill the 7055 Aluminum Alloy dynamic impact damage evolution mechanism, this paper takes 7055 Aluminum Alloy T6 heat treatment state as the research object, through the method of experiment and simulation analysis of the free surface profile of the process speed of spallation process, explores the cohesive zone model parameters and 7055 Aluminum Alloy constitutive parameters the free surface velocity profile characteristics. The results of spall analysis show that the free surface velocity profile has a positive correlation with the ambient temperature, and the higher the ambient temperature is, the greater the free surface velocity is. The free surface velocity response amplitude and ambient temperature profile showed a significant negative correlation, the free surface velocity profile changes generally show a sine relation, the lower the temperature is, the larger the amplitude; free surface velocity profiles of initial peak slope and critical failure displacement show negative correlation, and between the first peak slope cohesion the viscous parameters and free surface velocity profiles showed significant positive correlation; the initial free surface velocity profile of the slope elastic loading history and 7055 Aluminum Alloy yield strength showed significant negative correlation, material initial yield strength increases, the slope of the smaller elastic loading history.

Keywords

7055 aluminum alloy; Damage evolution; Spallation; Cohesive force model; Free surface velocity.

1. Introduction

7055 aluminum alloy is a new type of ultra-high strength aluminum alloy produced by Alcoa, and has been successfully applied in aerospace and automobile manufacturing industry because of its many advantages. At present, the 7055 aluminum alloy research has been favored by domestic and foreign experts and scholars, because of the impact of the floating environment caused by the impact of the complex environment and the floating effect caused by the surface flow characteristics. And made a series of results. In this paper, the thermal deformation of 7075 aluminum alloy was studied and simulated[1]; Wang Qi studied the hot forming performance of 7075 aluminum alloy HFQ based on meso-damage [2] .The microstructures and cyclic deformation characteristics of fatigue damage of high strength 7075 aluminum alloy were studied[3]; Zhuang Weimin et al. studied the thermal imprinting limit diagram of 7075 aluminum alloy based on continuous dielectric damage mechanics[4]The influence of temperature and strain rate on the critical damage factor of 7075 aluminum alloy[6]; Xu Dexin has studied the damage behavior of 7050 aluminum alloy under high speed impact condition[5,7]; abroad, L. KrÜger et al. Studied the flow stress and dynamic mechanical properties of aluminum alloys under normal temperature and high temperature environment [8]; Dalton et al. Studied the dynamics of aluminum alloys with strain rates higher than 2106s-1 Microstructure dependence of fracture and yield[9]. Although the study of 7XXX aluminum alloy has been increasing year by year, most of them have been studied in the aspects of fatigue damage and damage factor. The research on dynamic impact stratification of 7055 aluminum alloy is still few. Therefore, in this paper, The study on the response characteristics of the free surface velocity profile under different factors is proved by the method of experiment and simulation, which is of great significance for the study of the damage evolution of 7055 aluminum alloy.

2. layering model

Stratification is a theoretical model that describes the rapid nucleation, growth and penetration of materials. Cracking process with the damage, therefore, describe the material spalling phenomenon is mostly based on material damage to analyze. There are many models that describe material damage, the most common being the Johnson model and the NAG model, but the above two models largely ignore the effects of thermo-mechanical coupling [10]. However, the cohesive force model can make up for the above defects. Therefore, this paper will use the method of cohesion model to analyze the spallation of 7055 aluminum alloy by dynamic impact.

Figure 1 is a model of the cohesion model established in this paper. In order to simplify the calculation, this paper will select a small part of the sample area to study, and define the length of the bullets and target ratio of 1: 2.

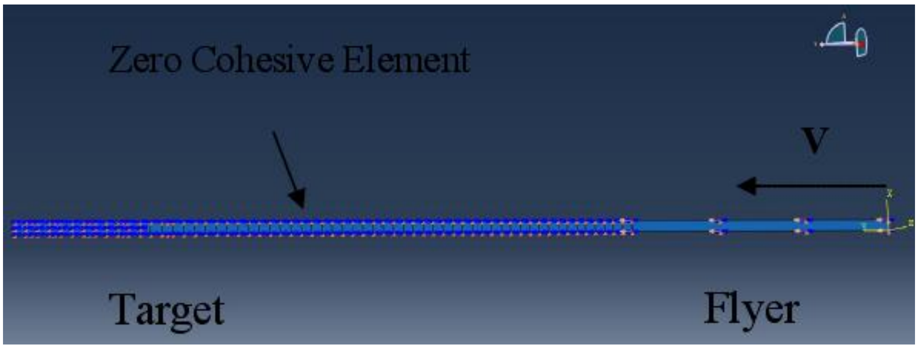

Figure 1 Cohesive force model

The material properties are the key to the numerical analysis. The definition of the material properties in the numerical analysis is defined according to the J-C equation. The J-C constitutive attribute of the 7055 aluminum alloy is shown in (1).

$$\bar{\sigma} = (542.24 + 273\varepsilon^{0.194})(1 + 0.136\ln(\frac{\dot{\varepsilon}}{\dot{\varepsilon}_0}))(1 - (\frac{T - T_{room}}{T_{melt} - T_{room}})^{0.271}) \qquad (1)$$

3. Analysis of layer cleavage process

3.1 Analysis of free surface velocity profile

Figure 2 shows the experimental and simulated values of free surface velocity profiles of 7055 aluminum alloys at different temperatures. It can be seen from Fig. 2 that the free surface velocity profile of 7055 aluminum alloy exhibits a high consistency with the experimental value and the simulated value at each temperature. At the same time, it can be seen that the free surface velocity profile and the ambient temperature The higher the ambient temperature, the greater the free surface velocity. The response amplitude of the free surface velocity profile shows a significant negative correlation with the ambient temperature. The change of the free surface velocity profile shows a significant change in the relationship between the positive temperature and the ambient temperature [11].

Fig. 3 shows the response time chart of the cohesive stress and the free surface velocity profile of the layered region. It can be seen from Fig. 3 that the spallation process of 7055 aluminum alloy material can be divided into five stages, namely, elastoplastic loading stage, complete shaping loading stage, shaping compression unloading stage, tensile loading stage and tensile unloading Stage [12]. In the elastoplastic loading stage, the free surface of the specimen is rapidly increasing due to the influence of the forward wave of the impact load. The time of the 7055 aluminum alloy in the process of full shaping loading is mainly due to the yield deformation. The cohesive stress of the free surface in the unloading stage shows a tendency to decrease obviously. The reason is that the surface reflected wave of the bullet is interfering with the sparse wave reflected from the surface of the specimen, and the partial reflection is carried out. The cohesive stress changes from negative to zero. During the tensile unloading stage, the cohesive stress of the 7055 aluminum alloy material begins to decrease, and when it is reduced to zero, the damage process of the material ends.

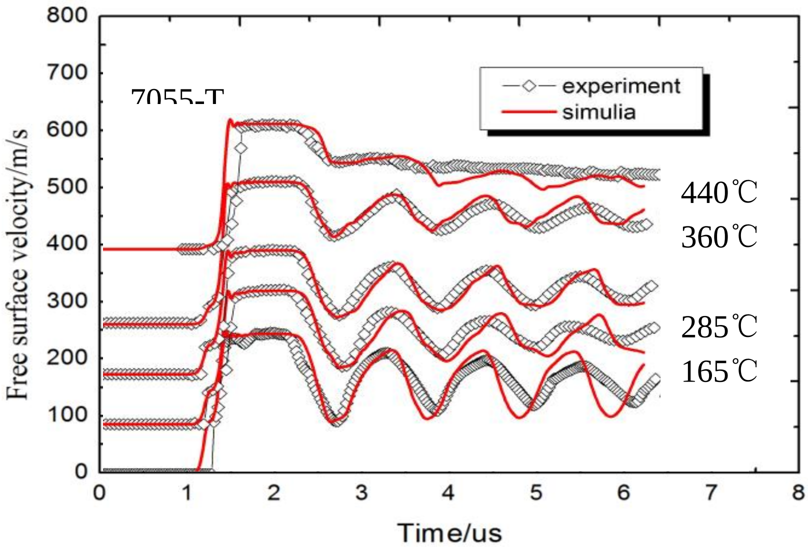

Figure 2 Free surface velocity experiment and simulation

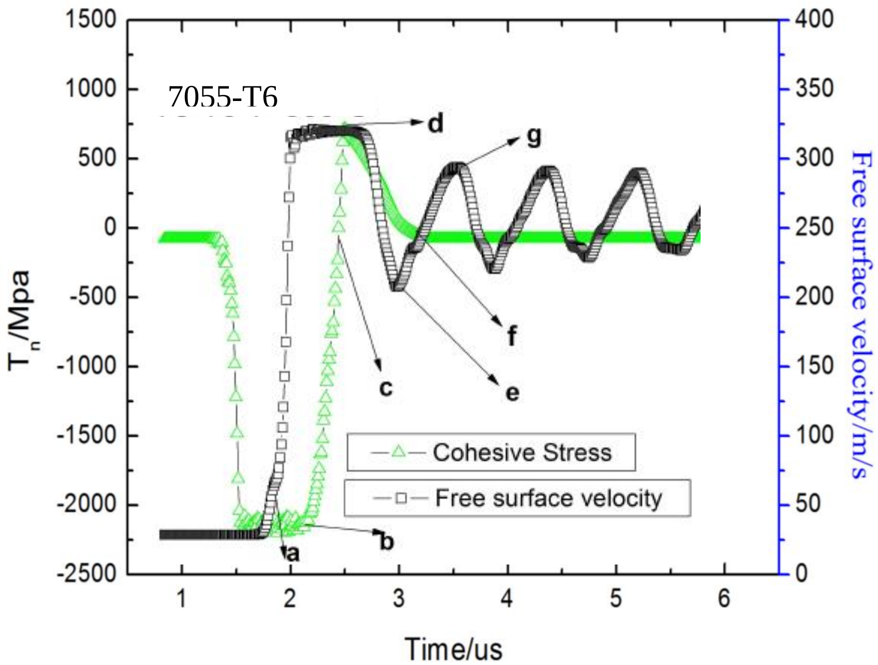

Figure 3 free surface profile speed history schedule

3.2 Effect of cohesion model parameters on free surface velocity profile

The cohesive force model has many parameters, and the influence of different parameters on the free surface velocity profile of the spalling process is different. Considering the influence of cohesion strength, critical failure displacement and cohesive force viscosity parameters on the spallation, Therefore, this paper chooses the above three parameters to study, in order to exclude thermal interference, the selected ambient temperature is 360 ℃.

Figure 4 depicts the influence of cohesive force on the free surface velocity profile. It can be seen from Fig. 4 that the cohesive force has little effect on the free surface velocity profile when the response time is less than 0.9 s. When the free surface response time is more than 1.8 s, the free surface velocity profile shows a tendency to change, The higher the cohesive strength, the greater the amplitude of the free surface velocity.

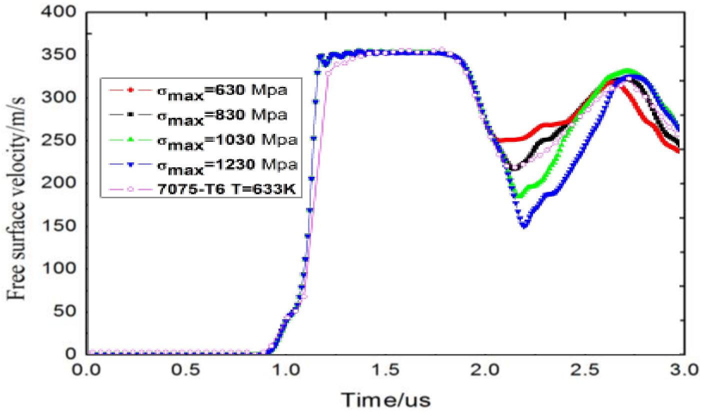

Figure 4 Effect of cohesive strength on free surface profile velocity

Figure 5 shows the effect of critical failure displacement on free surface velocity. According to Fig. 5, it can be seen that the free surface velocity is negatively correlated with the critical failure displacement, the greater the critical failure displacement is, the smaller the free surface profile velocity is.

Figure 6 shows the effect of cohesive viscosity parameters on free surface velocity. It can be seen from Fig. 6 that the influence of cohesive viscosity parameters on free surface profile velocity is basically the same. However, the cohesive force viscosity parameter has a positive correlation with the free surface profile velocity. The greater the cohesive force viscosity parameter is, the greater the free surface profile velocity [13].

Compared with Fig. 5 and Fig. 6, it can be seen that the first peak slope of the free surface velocity profile is negatively correlated with the critical failure displacement, and there is a significant positive correlation between the cohesive viscosity parameter and the first peak slope of the free surface velocity profile The amount of fracture release is affected by the critical failure displacement and the cohesive viscosity parameter.

3.3 Effect of Material Constituents on Historical Characteristics of Free Surface Velocity Profile

7055 aluminum alloy mechanical properties and its temperature changes have a corresponding relationship between the temperature changes at the same time caused by changes in the microstructure of the material, the material received impact load will produce a certain degree of damage. Often damage evolution is the focus of stratification analysis, and often ignores the effect of elastoplasticity on the history of free surface velocity profile. The constitutive equation of the material is a physical model describing the properties of the material, which reflects the change of temperature, stress and strain. Therefore, it is very important to analyze the influence of material constitutive on the free surface velocity profile in the process of spalling.

Figure 7 shows the relationship between the initial yield strength and the free surface velocity profile. According to Fig. 7, it can be found that the slope of the historical elastic loading of the free surface velocity profile is negatively correlated with the initial yield strength of the 7055 aluminum alloy. The greater the initial yield strength of the material, the smaller the slope of the historical elastic loading.

Figure 8 shows the experimental and simulated values of the dynamic impact stratification process of 7055 aluminum alloy at different temperatures. It can be seen from Fig. 8 that the experimental value and the simulated value of the historical elastic loading slope of the free surface velocity profile at the same temperature are highly consistent, and the higher the temperature, the more the consistency of the historical elastic loading slope of the free surface velocity profile High, elastic.

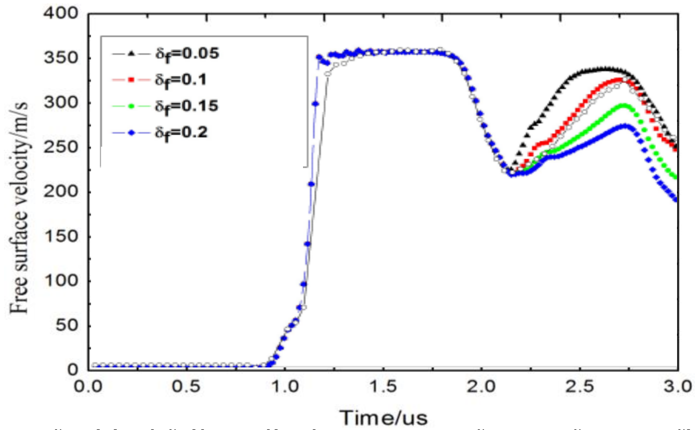

Fig.5 Effect of critical failure displacement on free surface profile velocity

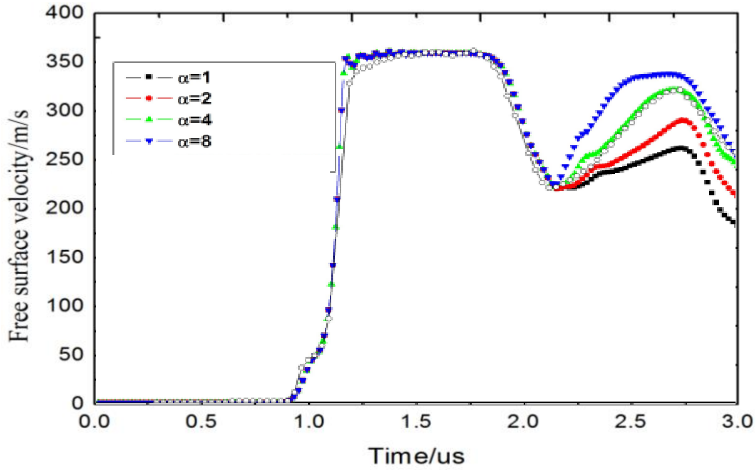

Fig.6 Effect of cohesive viscosity parameter on free surface profile velocity

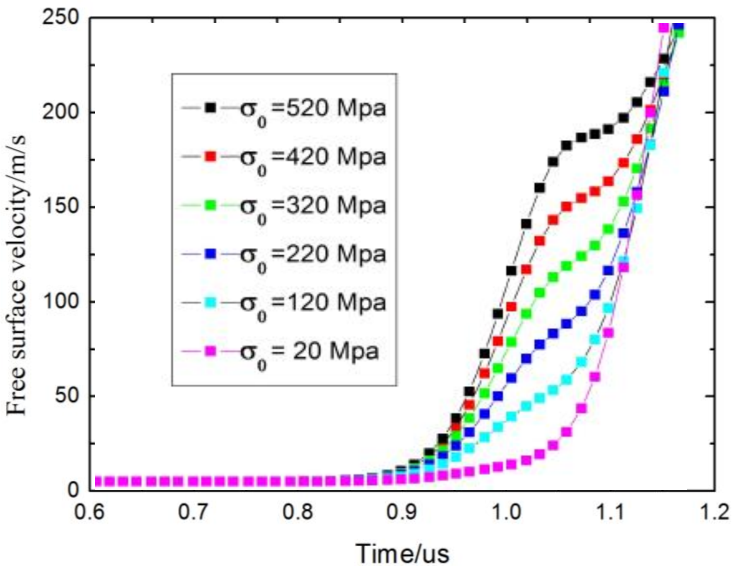

Fig.7 Effect of initial yield strength on free surface velocity profile

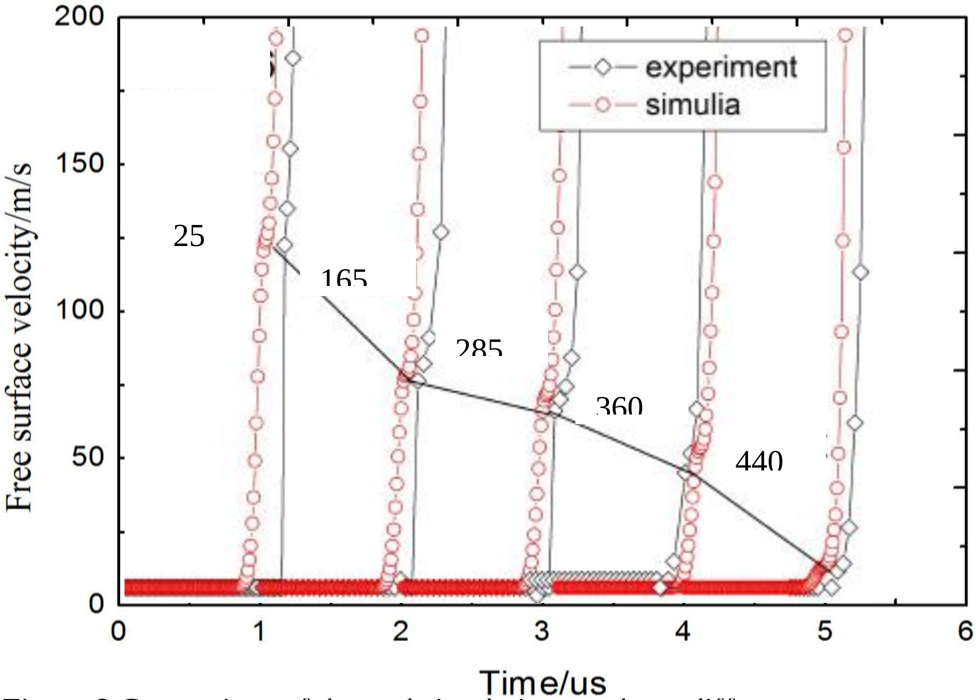

Figure 8 Comparison of thermal simulation results at different temperatures

Figure 9 depicts the correlation between the yield stress of the material and the free surface velocity profile. It can be seen from Fig. 9 that there is a significant negative correlation between the initial peak and the yield stress of the torsional wave of the cracked free surface velocity profile, and the greater the yield stress is, the smaller the initial peak of the free-surface velocity profile , And the change of yield stress plays a major role in the material after the damage evolution.

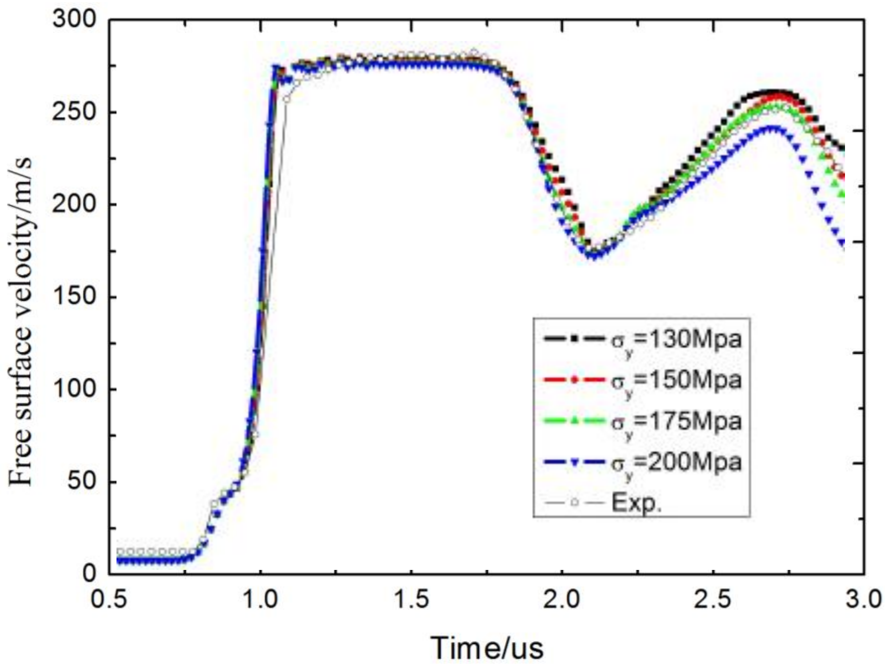

Fig. 9 Correlation between yield stress and free surface profile velocity

4. Conclusion

(1) The crack strength changes with the change of the ambient temperature. The numerical analysis shows that the size of the free surface profile is affected by the strength of the cohesive force, and the velocity of the free surface profile and the cohesive force are significantly And the trend is linearly increased.

(2) There is a significant negative correlation between the initial peak and the yield stress of the tail wave oscillations of the free surface velocity profile, and the greater the yield stress is, the smaller the initial peak value of the tail wave oscillation in the free surface velocity profile.

(3) The first peak slope of the free surface velocity profile is negatively correlated with the critical failure displacement, and there is a significant positive correlation between the cohesive viscosity parameter and the first peak slope of the free surface velocity profile.

(4) The slope of the historical elasticity of the free surface velocity profile is negatively correlated with the initial yield strength of the 7055 aluminum alloy. The larger the initial yield strength of the material, the smaller the slope of the historical elastic loading.

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