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Numerical Simulation on Impact Response of Plain-woven C/SiC Composite

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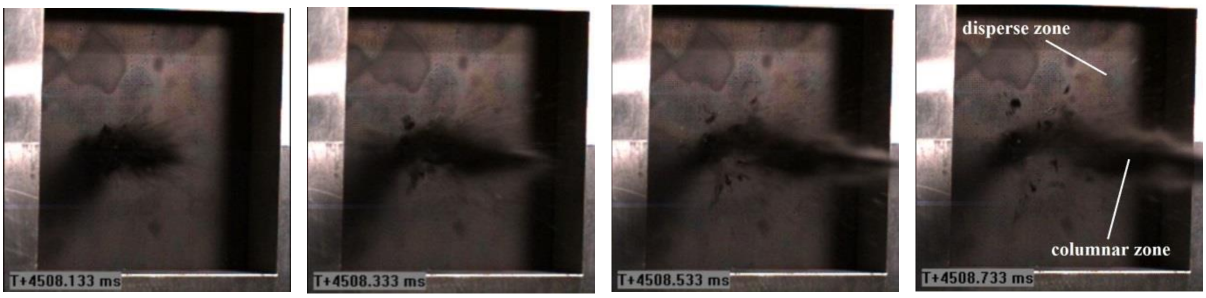
2D plain-woven C/SiC (2D-C/SiC) is a typical ceramic-matrix composite, which has been widely applied in the Thermal Protection Structure (TPS)[1]. In service, 2D-C/SiC plate in TPS will inevitably suffer low-speed external shocks, such as hailstones, tools fall off and so on. This paper will focus on the experimental and numerical study on the low-speed impact to 2D-C/SiC composite plate, which is of great significance for the design of TPS in engineering. First, the experiments that the steel balls impact to 2D-C/SiC composite under the velocity of 79 m/s ~ 219m/s are investigated by using the air gun, and the development of the debris clouds are recorded by using the high-speed camera. From the screenshots of the records shown in Fig.1, it can be clearly found that the structure of 2D-C/SiC debris cloud could be divided into two parts, i.e. the columnar zone and the disperse zone. In the columnar zone, fragments have smaller size and move along the axis. While in the disperse zone, fragments have bigger size and move along some angles. This is the special damage characteristic of 2D-C/SiC under impact load.



(a) (b) (c) (d)

Fig.1 Expansion of the debris cloud

Second, the material parameters of 2D-C/SiC are obtained [1-2] based on an orthotropic constitutive material model in Autodyn[3-4], and numerical simulations corresponding to experimental conditions are carried out based on Smooth Particle Hydrodynamics method.

(1) Debris cloud structure. It is shown in Fig.2 that, (a) the two parts structure of debris cloud can be also clearly found in the numerical results. (b) The velocity directions of fragments in these two parts shown in numerical results are consistent with that in experimental results.

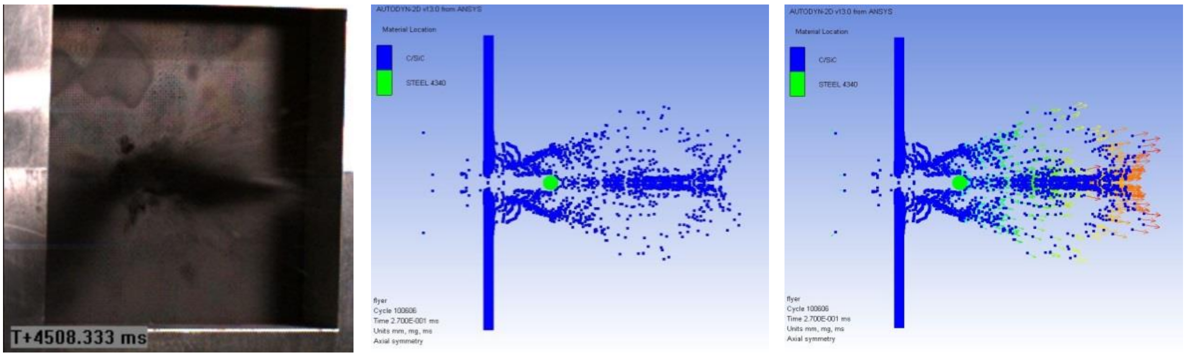
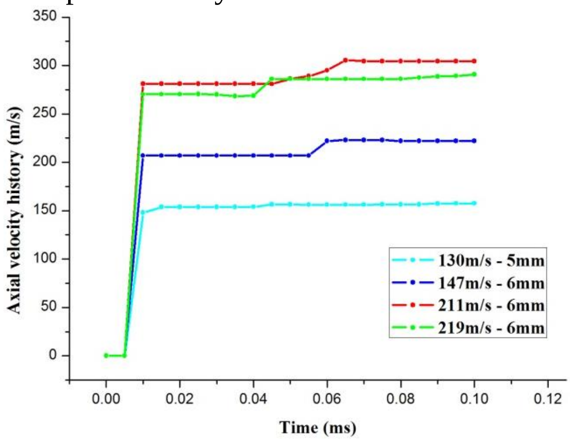


Fig.2 Comparison between simulation and experiment

(2) Axis velocity of debris cloud. The history of axis velocity of debris cloud under different impact velocities are shown in Fig.3, and the results of the axis velocity are compared with experimental results (Fig.4), which shows a good agreement and the error is just 2.25% when the impact velocity is 219m/s.



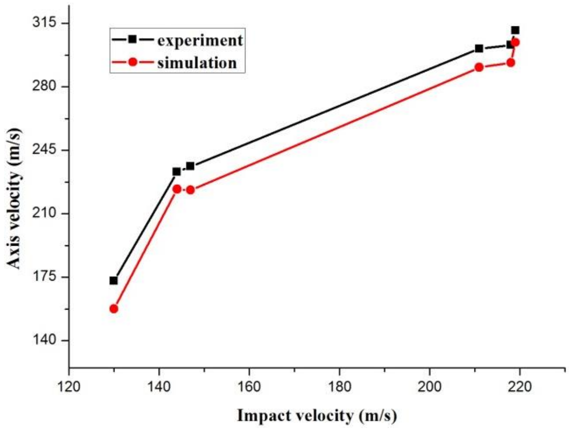


Fig.3 Axial velocity history under different impact velocities   Fig.4 Comparison of the axial velocity

Finally, the limit penetration depth of 2D-C/SiC under the impact load is predicted based on the numerical results and the following formula can be derived:

$$T = 0.0005362\ln(1 + 0.756v^2)$$

At this point, if the plate thickness has been determined in engineering, the ballistic limit velocity can be predicted as the inverse solution of the above formula.

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