Numerical Study on the Waveform Evolution in Metal Material

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Summary. In this paper we studied on the waveform evolution in metal material Fe utilizing a Lagrangian finite volume numerical simulation code. The metal material is impacted at a certain speed and shock wave occurs. The collision time is a sine wave with location and shock wave propagates in the metal sample. We studied two geometries, plane model and column model. In both cases, waveform evolution rules of shock wave in metal sample with different impacting speeds and amplitudes were analyzed. Simulation results show that the waveform evolution in metal material is close related to the geometry and the amplitude, while the impacting speed has less effect.

Introduction

The thermodynamic state and material character of metal material under high temperature and high pressure have a very important position in a lot of fields such as the celestial physics and physics of the earth. The high temperature and high pressure states of metal material are usually attained through impact compression. Under one dimensional plane impact compression, the state in the material can maintain steady for a certain interval, and the relation between state quantities can be described accurately by simple mathematical expressions. So one dimensional plane shock wave loading is a basic means of the experimental research. But in actual absolute one dimensional plane impact compression state is impossible to reach. By various restriction and disturbance, the propagation waveform of shock wave in test sample is a wave of curved surface. The study of waveform evolution in metal material has an important meaning for correct acknowledgement of the physical states of material and evaluation of uncertainties of experiment results.

Modeling

The calculation model is shown in figure 1 and figure 2. In the plane model as shown in figure 1, the Fe sample with the thickness of 5.0mm and the width of 16mm is impacted at a certain speed and shock wave occurs. The impacting speed is uniform at different locations, but the impacting time is a sine wave with location. The column model is similar with the plane model. In figure 2, the Fe sample has a thickness of 5.0mm and a width of 72° . Shock wave occurs when impacted at a certain speed. The impacting speed is uniform and the direction is pointing the center, but the impacting time is a sine wave with the angle. The impacting speed V0 is 12.0km/s, 16.0km/s and 20.0km/s. The waveform amplitude is 0ns, 70ns, 100ns, 200ns and 400ns.

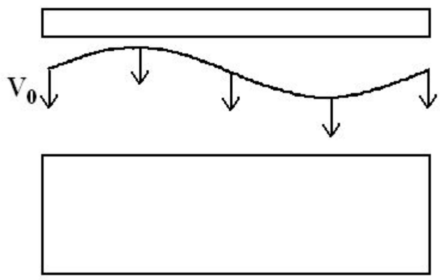

Figure 1. Plane model

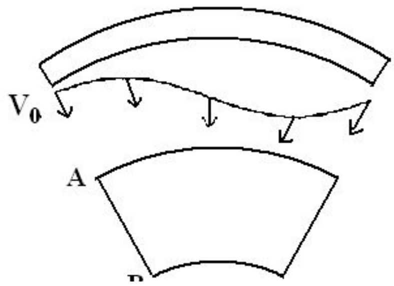

Figure 2. Column model

Calculation results

Figure 3 shows results of the plane model. The extreme difference of the waveform is reduced obviously as the shock wave propagates in the metal for some distance. Table 1 is the propagating time at different locations. Times at different locations are different, longer at the trough (leading waveform) and shorter at the peak (lagging waveform). The development of waveform and difference of propagating times at different locations enlarge with the increasing of the amplitude, while the impacting speed has less effect on the waveform evolution.

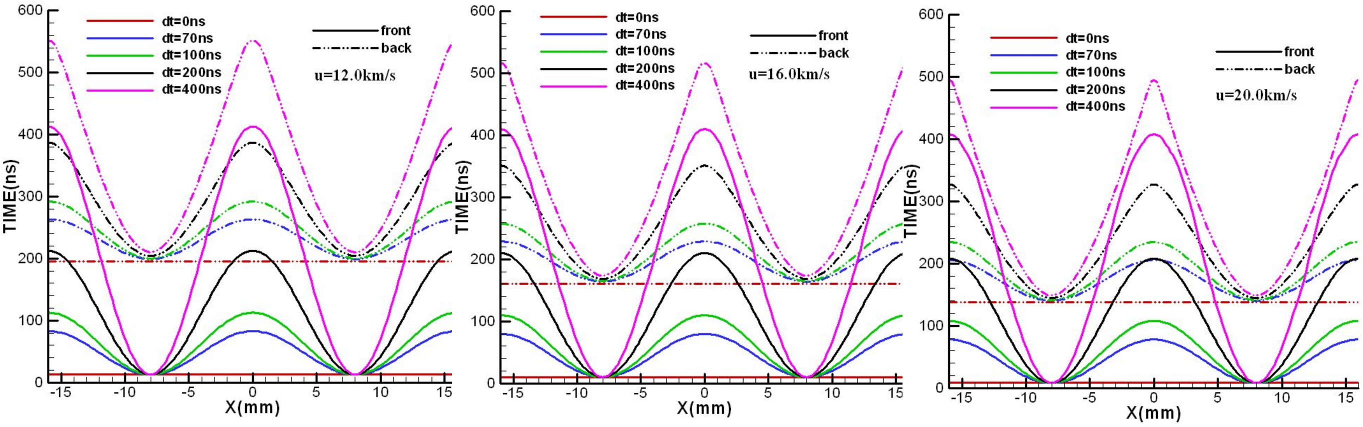

Figure 3. Wave results of the plane model

Table 1. Time results of the plane model Units: ns

Amplitude	V0＝12.0km/s			V0＝16.0km/s			V0＝20.0km/s		
	Trough	Peak	Δ t	Trough	Peak	Δ t	Trough	Peak	Δ t
70	186.2	180.4	5.8	154.2	148.9	5.3	132.4	127.6	4.8
100	187.4	179.3	8.1	155.3	147.8	7.5	133.4	126.6	6.8
200	191.2	174.0	17.2	158.7	141.8	16.9	136.3	119.1	17.2
400	197.1	138.3	58.8	163.8	106.5	57.3	140.6	87.1	53.5

Results of the column model are similar with the plane model. Difference of propagating times at different locations enlarges with the increasing of the amplitude. The evolution of the column model is more violent than the plane model with the same waveform amplitude, as shown in Table 2.

Table 2. Time results of the column model Units: ns

Amplitude	V0＝12.0km/s			V0＝16.0km/s			V0＝20.0km/s		
	Trough	Peak	Δ t	Trough	Peak	Δ t	Trough	Peak	Δ t
70	179.1	172.5	6.6	148.4	142.3	6.1	127.5	121.9	5.6
100	180.4	171.1	9.3	149.6	140.8	8.8	128.6	120.5	8.1
400	190.9	115.4	75.5	158.7	75.7	83	136.3	41.4	94.9

Concluding remarks

In this paper we studied on the waveform evolution in metal material Fe. Simulation results show that: The propagating times at different locations are different, longer at the trough and shorter at the peak. The waveform evolution is close related to the amplitude. Difference of propagating times at different locations enlarges with the increasing of the amplitude. The evolution of the column model is more violent than the plane model with the same waveform amplitude. The impacting speed has less effect on the waveform evolution.

Acknowledgments

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