ANALYSIS OF ENTRY PROCESS AND INFLUENCE ON GROUND FOR SONGYUAN METEOROID

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Introduction

A meteoroid entered into atmosphere near Songyuan City, Jilin Province, China, at about 0:16 Beijing time, October 11, 2019. The bright fireball was observed by many people and recorded by many video instruments in the surrounding areas around Songyuan, such as Shenyang, Changchun, Harbin. After the event, NASA provided time, position, and velocity at peak brightness of fireball, as well as estimated total radiation energy and entry kinetic energy, at its NEO website (https://cneos.jpl.nasa.gov/fireballs/). Videos of the fireball were spread and discussed extensively at internet. Jilin Museum of China had organized scientists to seek meteorite and found no one.

In this paper, we carried out an analysis of deceleration, ablation, and break up during the meteoroid's atmospheric entry as well as ground damage using AICA(Asteroid Impact Consequence Analysis) code developed by CARDC. We also made an simple inference about material and structure of Songyuan meteoroid.

Computation and Results

Models in AICA code:

- Trajectory equations based on spherical and rotating Earth model;
- Equations of mass loss;
- Breakup criterion based on stagnation pressure;
- NASA's FCM model[1];
- Overpressure at ground based on Collins' empirical formulation[2];
- Heat radiation damage at ground based on Collins' empirical formulation[2].

Material, structure and entry parameters :

- The material of the meteoroid might be stony with an rubble pile structure in that airburst at high altitude of 47.3km given by NASA implyed low strength.
- The asteroid before entry was assumed to be composed by regolith and 4 groups of monoliths (Table.1). Computational results with this computational set matched observed data very well (Fig.1).
- Entry parameters were derived from NASA's data. Entry velocity and angle was respectively14.07km/s and -59.4°.

Table.1 Material and structural input parameters of Songyuan meteoroid before entry. The aerodynamic strength of asteroid was 0.018MPa. All rubbles were modeled with two fragments per discrete break split 50/50% by mass, a cloud dispersion coefficient of 1.8, and ablation coefficients of 7 $\times 10^{-9}$ kg/J for cloud components and 1 $\times 10^{-8}$ kg/J for fragment components.

Group ID	type	Group mass fraction	Bulk density (kg/m³)	Number of pieces	Strength (MPa)	Strength exponent	Cloud fraction
1	regolith	70%	2500	—	—	—	—
2	monolith	11%	3300	1	0.27	0.07	80%
3		9%		1	0.39	0.1	80%
4		7%		1	0.9	0.07	80%
5		3%		2	0.72	0.1	100%

Computational results of entry process :

- The pattern of energy deposition curve obtained from computation agreed well with total grey value from video.
- All mass was completely ablated above 30km. No meteorites fell to ground, which also agreed with observation.

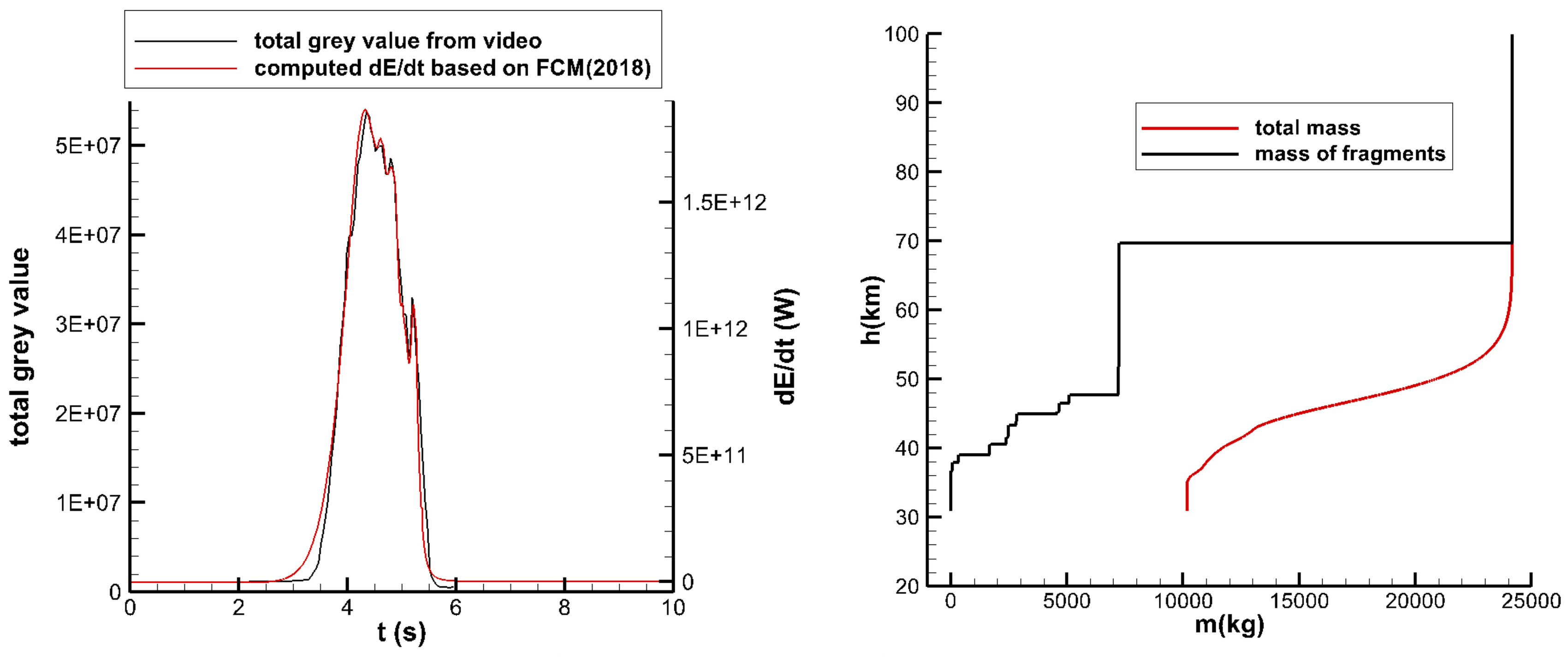

Fig.1 Computational results of entry process. Left: time versus energy deposition. The black curve was total grey value from a video on internet, proportional to energy deposition dE/dt, While the red curve was computational energy deposition. Right: mass versus altitude.

Computational results of ground damage:

- Maximum overpressure was only 76Pa, less than value for glass breakup 500Pa [3](Popova, 2013).
- The actual airburst altitude was 47.3km, higher than that for 1^{st} degree burn.

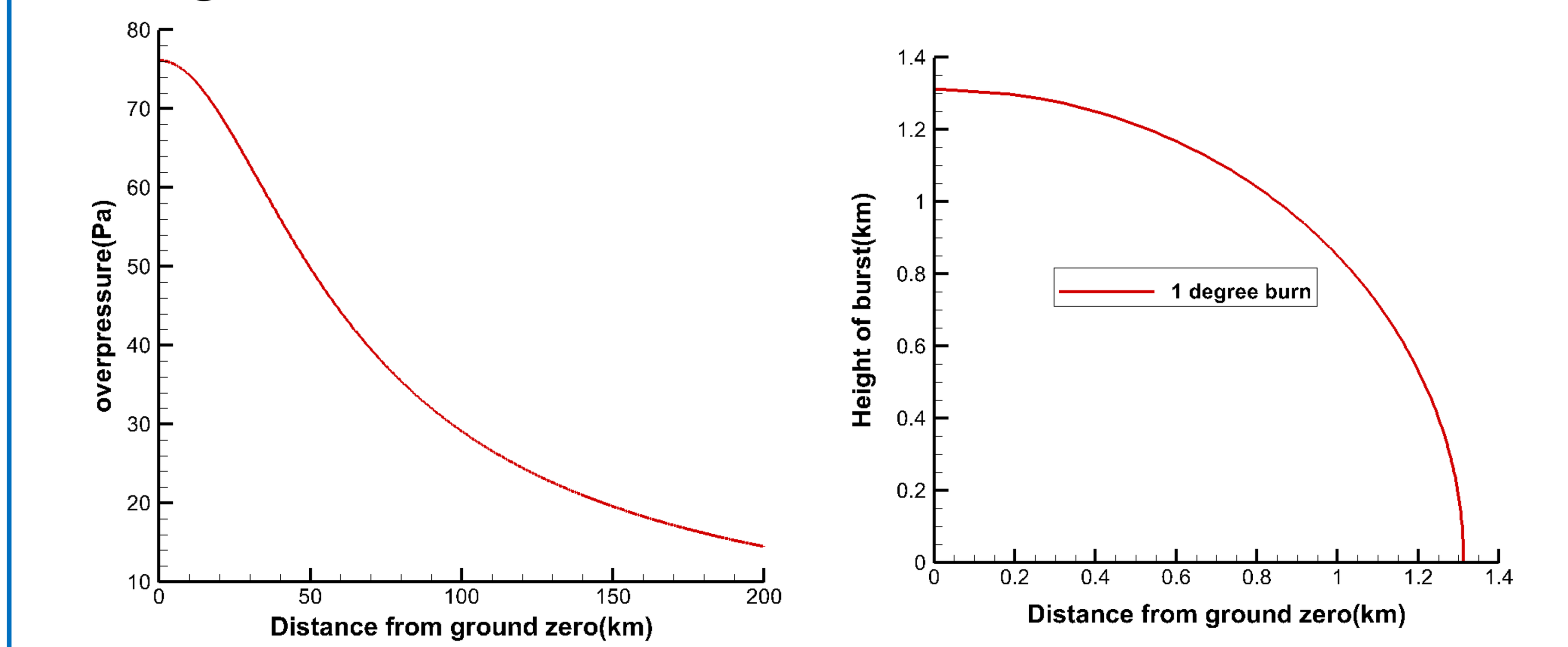

Fig.2 Computational results of ground damage. Left: distance from ground zero versus overpressure. Right: distance from ground zero versus height of burst, for 1^{st} degree burn and entry energy of Songyuan meteoroid.

Conclusion

- Songyuan meteoroid before entry was probably a rubble pile, maybe composed by regolith and several groups of monoliths.
- Songyuan meteoroid firstly breakup at an altitude of 69.8km, continued to disintegrate during subsequent flying process, achieving maximum energy deposition at an altitude of 47.3km. All large fragments were completely ablated above altitude of 30km, with no meteorites falling to ground.
- Maximum overpressure due to this impact was 76Pa, less than the value for glass damage. The actual airburst altitude was 47.3km, higher than that for 1^{st} degree burn. Therefore, this meteoroid caused no damage to ground.

Reference

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