

NUMERICAL MODELLING FOR STRENGTH ESTIMATION OF FRAGMENTING METEORIODS. K. Nazarova and P. A. Bland. Impacts and Astromaterials Research Centre (IARC), Department of Earth Science and Engineering, Imperial College London, South Kensington Campus, SW7 2AZ, London, UK, e-mail: katsiaryna.nazarava@imperial.ac.uk.

Introduction: It has been estimated that the total number of meteoroids entering the Earth's atmosphere with masses above 1 kg is about 37000 per year [1]. And approximately 4400 events with mass more than 1 kg strike the Earth every year [1]. Among these impactors, those in the mass range $\sim 10^4$ - $3 \cdot 10^6$ kg fragment and form crater fields, with the largest crater resulting from impact of the largest fragment [2]. Fragmented impactors in the mass range over 10^6 – 10^8 kg strike together to form single craters [2]. According to previous estimates [2], eleven 10^5 kg events every 100 years will impact and form a crater field. It is possible to numerically model the formation of many terrestrial crater fields. The solutions, however, are not necessarily unique. A large uncertainty in numerical modelling is in the altitude of breakup, which is related to the yield strength of the meteoroid. Since the cross-range width of a given crater field depends primarily upon the breakup altitude and the down-range length is related to the angle of entry, it is possible to approximately derive these parameters from the terrestrial crater fields.

Modelling: Fragmentation of meteoroids by aerodynamic forces is closely connected with their strength – improving models of meteoroid strength is fundamental to understanding of meteoroid fragmentation and to improving our understanding of impact rates at planetary surfaces [2, 3, 4, 5].

Meteorite strength. The comparison of the measured and estimated values of material strength of meteoroids was performed. We estimated the strength of the main body (1 kg sample) for meteorites Lost City, Pribram, Innisfree, Sikhote-Alin, Benesov, Moravka, and Sumava according to Weibull distribution [6] and using the criterion of the meteoroid breakup [7]. Our estimates are in the same range as the measured values of strength for stony and iron impactors. Maximum strength of the fragmenting body was $4.4 \cdot 10^7$ H/m² for iron and $1.5 \cdot 10^7$ H/m² for stony bolides. However, some of the bodies have strength as low as $0.13 \cdot 10^6$ H/m². There is a great uncertainty and scatter in the measured strength: even for different samples of a common meteorite, values of ultimate strength may differ by a factor of three [8]. Moreover, although irons usually have higher ultimate strength than stones, it is not the case for every meteorite. However, by ignoring the extreme values, the ultimate tensile

strength of meteorites can be narrowed to a range from $2 \cdot 10^7$ to $5 \cdot 10^7$ H/m² (the average value is about $3.5 \cdot 10^7$ H/m²). It should be emphasized that the ultimate strength of a large specimen can be much lower than that of its constituents (Weibull law). The ultimate tensile strength for polycrystalline specimens of Sikhote-Alin meteorite was about $4.4 \cdot 10^7$ H/m², whereas for their constituent monocrystals it was 10 times higher [9].

Modelling terrestrial crater fields. Here we used the model of separate fragments (SF [4, 5, 10, 11]) to model the size distribution of craters and the size of the Morasko crater field. We performed 30 sets of SF model simulations. The initial flight parameters for the modelling were pre-entry mass, 100 t; initial velocity, 13 km/s; trajectory angle, 40°; drag coefficient, 0.8 [12] for spherical shape of the impactor; heat transfer coefficient, 0.1; strength coefficient, 0.09, and strength of the impactor material, $4.4 \cdot 10^7$ H/m². In our runs the mass of the main fragment varied from 50 to 200 t. The best results are obtained for the mass range 100 – 200 t, the velocity range 13 – 14 km/s, and the trajectory angle range 30 – 35°. The density of the body is assumed to be 7700 kg/m³.

Figure 1 demonstrates the schematic crater field of the Morasko meteoroid, where the radii of the circles correspond to the size of the craters, and an example of the modelled field. The size of the crater field agrees with the observations; however the positions of the individual fragments may vary as they were defined by the random procedure. The final velocities of the fragments are in the range from 3 to 7 km/s.

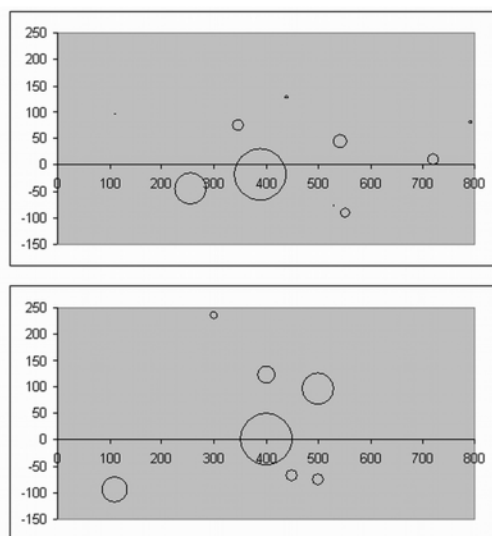


Figure 1. Modelled (above) and real (below) schematic map of the Morasko crater field (all distances are in meters).

The results obtained in different runs with the same initial data do not coincide because of the use of random procedures in the process of calculations. The impactors having the same density, velocity, and shape would fragment in a different way, because of the difference in their structure (defect distribution). Moreover, the real strength of the impactor and its fragments is a unique value and can deviate from the strength defined by statistical strength theory [5, 6]. These deviations can result from the features of fragment shape (drag coefficient, aerodynamical loading), flow conditions, etc. To model this idea, the strength of the fragments can be described with the normal statistical distribution, where the mean value is defined from Weibull law and dispersion $\delta=1-2$ [5].

Unlike the Sikhote-Alin iron meteorite shower, most of the craters at Morasko probably have been destroyed by agriculture, and the meteorites buried. That is why on the real map (Figure 1) there are no small craters. It has become impossible to recognize the ploughed craters at Morasko. Therefore, it is impossible to collect the meteorites in a systematic manner such as at Sikhote-Alin.

An important outcome of the SF model simulations is the constraint they place on the crater field formation and impact rate. The simulated values of mass, velocity and angle for small terrestrial craters allow us to understand the processes of fragmentation and formation of strewn fields. Also, extending the model to other solid planets with atmospheres, it is expected that crater fields on Mars are at least an order of magnitude smaller than terrestrial crater fields

(assuming that the present Martian atmospheric conditions have persisted throughout the period of meteorite bombardment [4, 5]). For Venus, one would expect to find crater fields that are approximately an order of magnitude larger than crater fields on Earth [4, 10].

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