Correlation of Particle Volume and Velocity of Fragments of Different Types of Meteorites During Disruption Events.

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Introduction: Samples of meteorites have been studied to further understand how they break apart during disruption events. Through small-scale impact experiments, models have become increasingly more realistic, yet the current results on meteorite fragmentation are still relatively speculative [1,3]. These scaled down results are extrapolated to predict what large scale collisions would look like [3]. It has been suggested that hydrous and anhydrous bodies behave differently upon impact [2]. This study includes analysis of different types of meteorites through examining the volume-velocity relationship of disrupted particles. This is done in order to gain a systematic understanding of how different meteorites may behave during disruption events. Investigation into similar volume specific disruption patterns between several types of meteorites was done. Cameras at the NASA Ames Vertical Gun Range were used to obtain videos of numerous meteorites being disrupted. This study is looking at shots done in 2017 and 2018.

Experimental: Four to six cameras are used at the NASA Ames Vertical Gun Range to capture imagery from multiple angles for each meteorite being disrupted. These images are later converted into TIFF virtual stacks to be analyzed in ImageJ®. After impact, the particles are tracked as they disperse. A 1-inch grid board placed behind the suspended meteorite is used to set the scale in ImageJ. Along with the set scale, the ImageJ distance tool allows for the particle distance traveled to be measured (Figure 2). This is done by measuring the distance between the place of impact and the place where the particle has traveled in space. Particle travel time is determined by the camera's frame rate. Frame rate changed from year to year; in 2017 the frame rate was 71,000 frames per second while in 2018 it was 130,000 frames per second. Initially all shots were examined at 1,000 frames after impact, which is either .014 seconds or .008 seconds after impact. Ten particles were tracked for each shot. Along with the velocity of these ten particles being calculated, particle volume was also measured. This was found by using the length tool to measure the particles dimensions while in rotation as it traveled.

Results and Discussion: Three different types of meteorites were examined in this preliminary study: Ordinary Chondrite (Saratov), Carbonaceous Chondrite analog (Hydrated Northwest Africa 869), and CI Carbonaceous Chondrite analog (Hydrated Northwest Africa 4502). For each meteorite type, videos from two separate shots were analyzed, either from an overhead or as side view. All meteorites had particles that varied in volume, ranging from 8.19 x 10^{-4} cm^3 to 1.49 x 10^1 cm^3. While some of the fastest particles were out of the cameras range by frame 1000, there were still a large collection of differently sized particles present at the measured time.

From the data currently collected, there seems to be a trend. In all three types of meteorites, velocity seems to be a consequence of the disrupted particles volume. Besides a few outliers, small particles tend to travel at higher velocities than large particles, as expected. There is a wide range of particle velocities, from the minimum of 207.39 cm/sec to the maximum velocity observed of 2,105.36 cm/sec. The particle with the maximum velocity of 2,105.36 cm/sec was the smallest particle tracked. Generally, particles with the largest volumes were the particles with the lowest velocities. In all the shots, there is a noticeable correlation between volume and velocity (Figure 1). This corresponds with observations that the first particles to leave the frame are very small in size, sometimes being too small to distinguish a reliable size. Small particles of all the meteorites, which were less than 1.64 x 10^{-2} cm^3, had velocities 1.6X to 2.6X the velocities of the larger particles, which were greater than 1.64 x 10^{-2} cm^3. When looking at velocity of particles alone, the three types of meteorites all disrupt in a similar pattern.

The next step in comparing different meteorites disruptions would be to do more volume-velocity measurements using consistent time rather than a consistent frame. A consistent time will make differing velocities easier to compare and more accurate. Still, with the data from the six shots examined, it can be seen that volume is a major factor in particle velocity. In the future, more volume-velocity measurements should be done on the rest of the shots from 2017 and 2018 as well as from years prior. These results can be added to the results of previous studies to further improve meteorite disruption models and our understanding of how meteorites will behave upon impact [1, 2, 3].

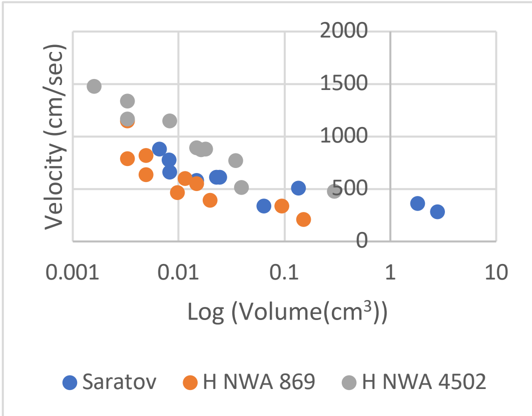

Figure 1: The volume-velocity relationship of particles from each type of meteorite. This graph shows one shot (ten particles) for the three types of meteorites studied. A correlation between volume and velocity can be seen; large particles travel at lower velocities and small particles travel higher velocities.

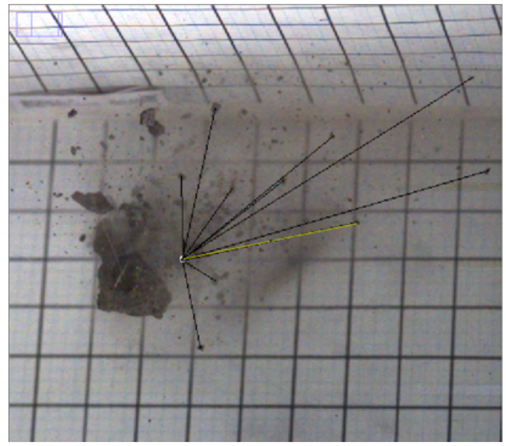

Figure 2: The disruption of a Saratov meteorite sample after impact. This image shows the process done in ImageJ to calculate velocity using the distance particles travel. The black and yellow lines show the distance tool measuring from particle to impact point. All ten particles chosen for this shot are traced.

References: [1] Holsapple K. A. and Housen K. R. (2005) *BAAS, 37,* 623 (1990) *Icarus*, *84*, 226-253. [2] Flynn G. J. et al. (2020) *Planetary and Space Science*, vol. 187. [3] Elmer W. C. and Strait M. M. (2017) Lunar and Planetary Science XLVIIII, Abstract 2931.