THE EVOLUTION OF OBLIQUE IMPACT FLOW FIELDS USING MAXWELL'S Z MODEL.

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Introduction: Oblique impacts are the norm rather than the exception for impact craters on planetary surfaces. This work focuses on the excavation of experimental oblique impact craters using the NASA Ames Vertical Gun Range (AVGR). Three-dimensional particle image velocimetry (3D PIV) [1, 2] is used to obtain quantitative data on ejection positions, three-dimensional velocities and angles. These data are then used to test the applicability and limitations of Maxwell's Z Model in representing the subsurface evolution of the excavation-stage flow-field center during vertical and oblique impacts.

Three-Dimensional Particle Image Velocimetry: A laser sheet is projected horizontally above the target surface during impacts at the AVGR. A ring of particles within the ejecta curtain are illuminated and imaged twice in rapid succession by two cameras above the target surface. Processing software tracks the movement of ejecta particles between time frames and combines the data from the two cameras to obtain three-dimensional velocities of ejecta particles within the laser plane. Entire ballistic trajectories are reconstructed for ejecta in all directions around the impact point, leading to ejection positions, vector velocities and angles. These quantitative data can be compared directly to numerical models and predictions from empirical models such as Maxwell's Z Model.

Maxwell's Z Model: Maxwell's Z Model [3, 4] is based on three main assumptions: (1) subsurface material flow is incompressible, (2) material moves along independent, ballistic trajectories after spallation at the surface plane and (3) the subsurface radial component of velocity is given by $u_R=\alpha(t)/R^Z$.

The Z Model, an empirical model based on explosion cratering data, places the flow-field center at the target surface. However, the flow-field centers of vertical impacts best match a moving source located at some depth below the target surface [5, 6, 7]. Croft [8] generalized the Z Model to include a term for the depth to the flow-field center.

Maxwell's Z Model predicts constant ejection angles at all ranges from the flow-field center. Croft's modified model predicts higher ejection angles than the Z Model at all ranges, but allows those ejection angles to vary with the radial distance to the flow-field center. 3D PIV measures the ejection position and ejection angle directly. With inverse modeling, it is possible to determine best-fit values for the Maxwell Z parameter and the depth to the flow-field center using Croft's modified Z Model as the forward model.

For oblique impacts, the ejection angle varies with azimuth (Figure 1) and so the value of Z will be allowed to vary as a linear function of the cosine of the azimuth in the forward models. In Figure 1, the uprange (0˚/360˚ azimuth) ejection angles for this 30˚ impact are very high, while the downrange (180˚ azimuth) ejection angles are low. The Z Model suggests that high ejection angles, such as those observed in the uprange curtain, imply a deeper flow-field center, while low ejection angles (such as those downrange) imply a shallower flow-field center. As time progresses, the ejection angles increase downrange and decrease uprange. This indicates that the depth to the flow-field center is changing. Conversely, if the flow-field center depth were held constant, the Z value would depend on azimuth and change with time. These data imply that a superposition of point sources may better represent the subsurface flow during oblique impacts.

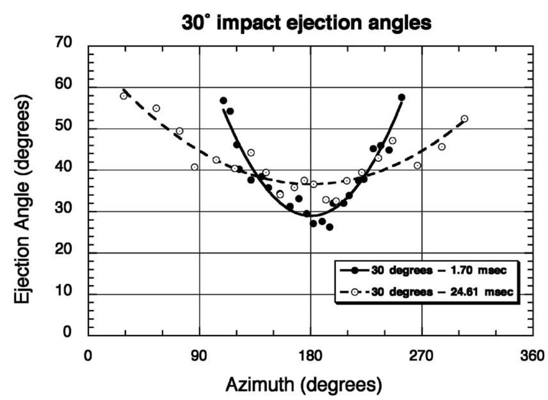

Figure 1. Ejection angles as a function of azimuth around the impact point for 30˚ impacts. Times represent the time after impact that the data was obtained.

Implications: Ejection angle data derived using 3D PIV is combined with Maxwell's Z Model, to determine Z values and the depth to the flow-field center for vertical and oblique impacts. The location of the flow-field center must evolve as the crater grows. A superposition of flow fields defined by the Z Model may be able to better model the excavation flow of oblique impacts.

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