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Numerical Investigation of Nose Sharp Changes in Ice Projectile with Conical Shape

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***Abstract*- Hail impact is an actual threat for aircraft structures that to fly through a hailstorm region cannot be avoided. In this paper, numerically evaluates the effect of indenter geometry on metal target plate. The six hail projectile (the angles of $40°, 50°, 60°, 70°, 80°, 90°$) with conical nose shape performed. The effect of sharp nose of conical hail projectile investigated on metal target plate behaviors like impact force, kinetic energy and internal energy. The results showed that the sharpness nose of conical hail projectile reported the highest wasted energy. This projectile entered the less significantly energy on metal target plate. The conical hail projectile with angles of $60°, 80°$ showed the highest and less contact force in hail impact event.**

***Keywords* –** Hail impact, Ice conical projectile, Various hail projectile.

I. INTRODUCTION

Flying through a hailstorm is dangerous not only for the direct damage but also for the hidden damages which may concur to more serious accidents. The first studies about hail impact founded when Kim et al. [1] analyzed the effect of ice spheres of different diameters on composite panels. More recently, Anghileri et al. [2] surveyed three numerical models for ice impact; finite element (FE), arbitrary Lagrangian-Eulerian(ALE) and smooth particle hydrodynamics (SPH) model. They concluded that the smooth paricle hydrodynamics model is the most effective and the least CPU time for the analysis of the event. Carney et al. [3] performed a model for behavior of hail impact and compared calculations and experiments results. Sanchez et al. [4] studied the model based on the Drucker-Prager plasticity criteria. The validated analytical and experimental results and showed that the fracture energy is very small compared to the total kinetic energy. Also, they studied [5] the behavior of composite laminates subjected to ice spheres a wide ranges of velocities (50-250 m/s).

In fact that the hailstorm in the impact event has the different size, from the golf ball until tennis ball, and they have the wide ranges of velocities [6]. The few studies were performed on the effect of shape of ice projectile in impact loading. So, the shape ice conical projectile has been investigated in this study.

II. SIMULATION OF HAIL ICE IMPACT

1. Model validation

In order to validate the numerical model, experimental results obtained by Carney et al. [3] were chosen. In these tests, the size of ice cylinders was 17.5 mm and 42.2 mm diameter and length, respectively. The circular target plate has 63.5 mm of diameter.

TABLE 1. MECHANICAL PROPERTIES OF STEEL PLATE AND ICE PROJECTILE [3]

	Steel	Ice
$\rho\ (kg/m^3)$	7850	846
$E\ (GPa)$	210	-----
$\sigma_y\ (MPa)$	207	28000
ϑ	0.3	------
$G\ (GPa)$	-----	3.46
$E_H\ (GPa)$	-----	6.89
$P_{Cut-off}\ (MPa)$	-----	-4

In this paper, the numerical simulations are performed using the LS-DYNA software. For the steel plate, elastic material model (MAT-024) and a Lagrangian mesh is used. The SPH model and MAT-010 have been used to simulate the conical ice projectile. The mechanical properties have been shown in Table 1.

The automatic-nodes-to-surface contact is defined between target plate and ice projectile. The compared results of force-time curves in velocity of 91.5 m/s showed the appropriate agreement between numerical and experimental results (See Figure 1).

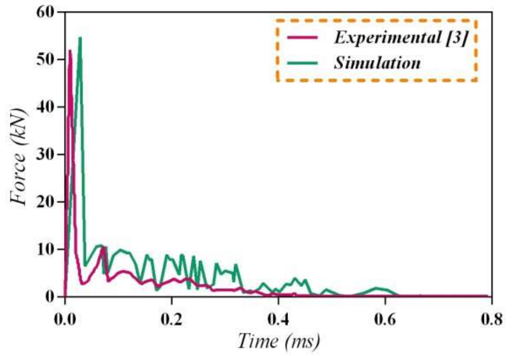

Fig. 1. Impact force vs. time curve; experimental and numerical results.

2. Numerical simulation of conical ice projectile with different geometry

In this paper, the conical ice projectile with different geometry of nose has been considered. The six angles of $40°, 50°, 60°, 70°, 80°, 90°$ have been surveyed for changing of conical ice projectile's nose (See Figure 2). The same diameter, mass and velocity (in before section) have been applied to simulate ice projectile.

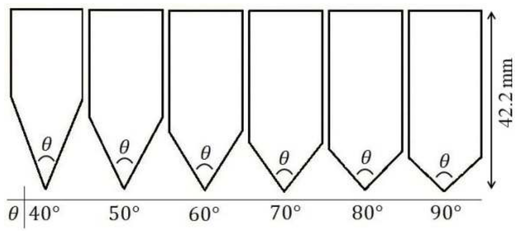

Fig. 2. The conical ice projectile with different angles of nose.

III. RESULT AND DISCUSSION

In order to assess shape of hail impact on metal plate, conical ice projectile with different of nose sharp has been considered. Figure 3 shows the increasing angle of conical ice projectile is spread the most hail projectile around, at the same time. In other words, to increase angle of nose is caused the further length of cylindrical part of conical ice projectile so the most of hail projectile is crushed.

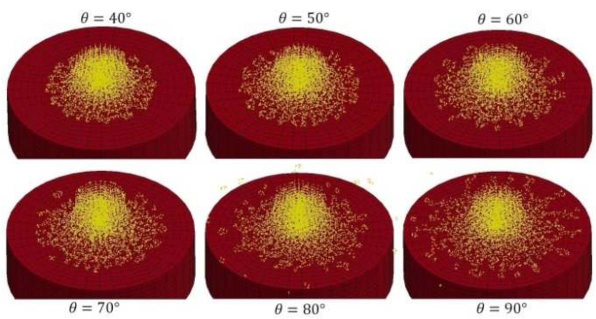

Fig. 3. The hail ice impact with different geometry at time=0.3 ms.

Force and energy vs. time curves confirm in Figure 4. To increase the angle from $40°$ to $90°$ is caused that the less energy is wasted. The significant differences can be seen between the angles of $40° - 70°$ and $80°, 90°$. In fact that in these angles less energy is needed to crush hail projectile. Furthermore, the force-time curve shows that the decreasing angle of conical ice projectile is motivated to increase the time of peak force because of the length of conical part of hail projectile is increased so the higher time is required to reach the peak force. Maximum and minimum contact forces are occurred in angles of $60°, 80°$, respectively. There are a lot of oscillations in force curves due to the nose sharp of conical hail projectile and the crushing hail projectile in impact event.

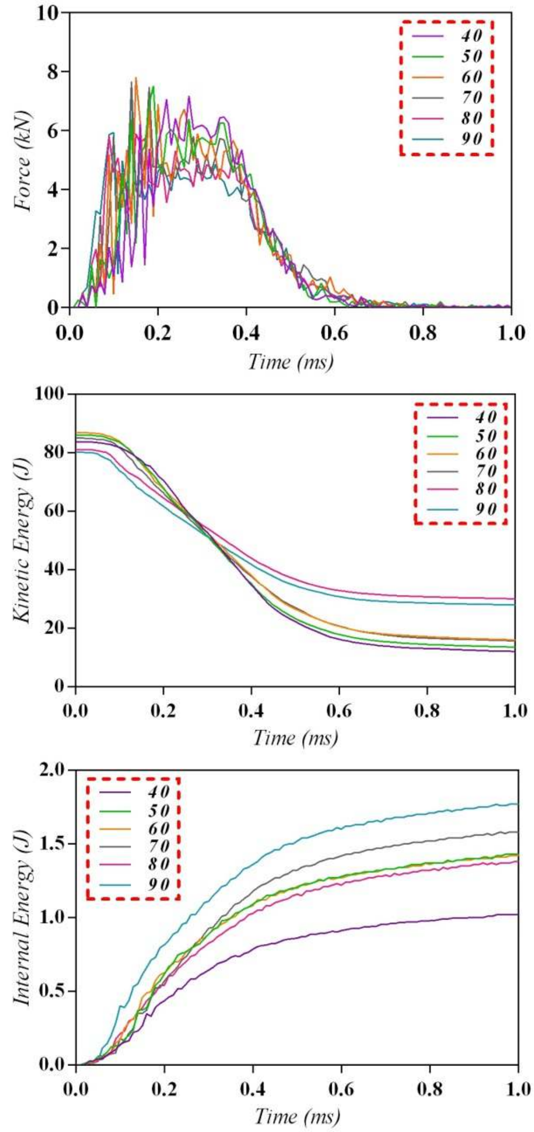

Fig. 4. (a) Impact force vs. time (b) Kinetic energy vs. time (c) Internal energy vs. time for different nose sharp of conical ice projectile.

The results show that at the angle of $40°$ is applied the less energy to the metal plate due to the sharpness nose of conical ice projectile. Maximum energy is presented at the $90°$.

IV. CONCLUSION

In this paper, the effect of sharp nose in conical ice projectile is investigated on the high velocity impact response of metal target plate. Based on the numerical results, conical ice projectile with the sharpness nose is crushed after other projectiles. The dissipated energy between the angles of $40° - 70°$ and the angles of $80°, 90°$ almost 55% is reported. The process of increasing angle of conical ice projectile is caused to decrease the dissipated energy and to increase the entered energy to metal plate.

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