How much will the hail damage cost?

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Hail Impacts on Automobiles: A state-of-the-art review

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The Hail Problem

- Texas: The costliest storm claimed 560 million dollars in damages to automobiles(Hanna, 2016)
- Alberta: The costliest storm of 2015 claimed 230 million dollars in total damages (Adams, 2015)
- Automobile hail damage accounts for 34% of hail insurance claims in the United States.(Fennig, 2016)
- 700 000 claims were made between 2013 and 2015.(Fennig, 2016)

Problem Statement

- Products exist on the market that allegedly offer hail protection, but there is no standard testing method for evaluating performance.
- A standard testing method is needed to qualify hail protection products.

Project Scope

- This project is intended to act as a knowledge base for subsequent projects attempting to make advances into hail impact testing methods.
- This project provides one with:
  - A background literature review
  - Preliminary impact testing results on automobile parts
  - Recommendations for future projects

Overview

- Literature review
  - Impact Mechanics
  - Automobile hail damage repair
  - Hail protection products
  - Hail Properties
  - Hail Replication
- Impact testing
  - Calculations
  - Testing setup
  - Procedures and Results
- Recommendations

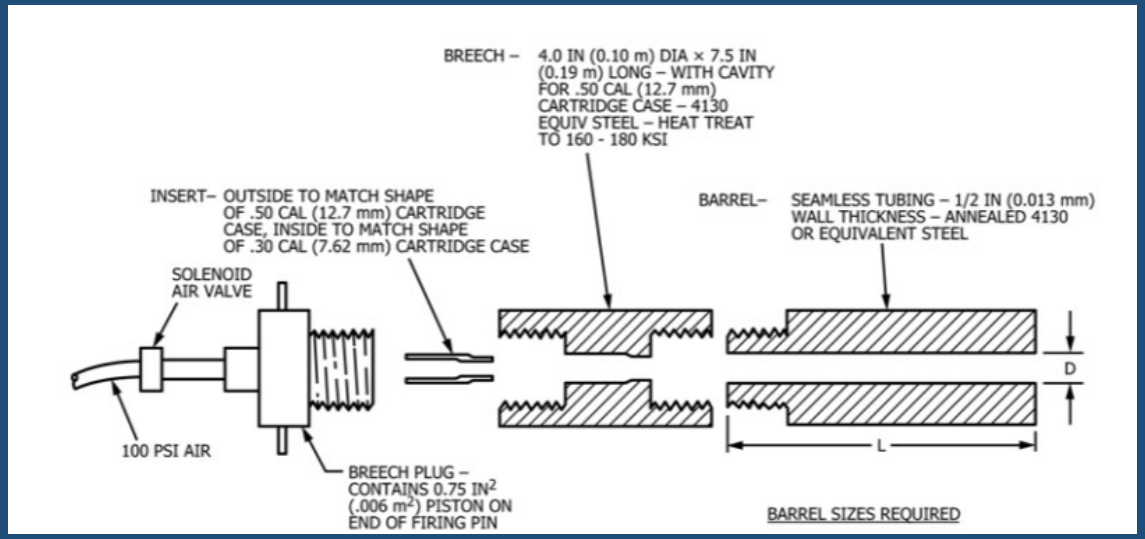
Literature Review: Impact Mechanics

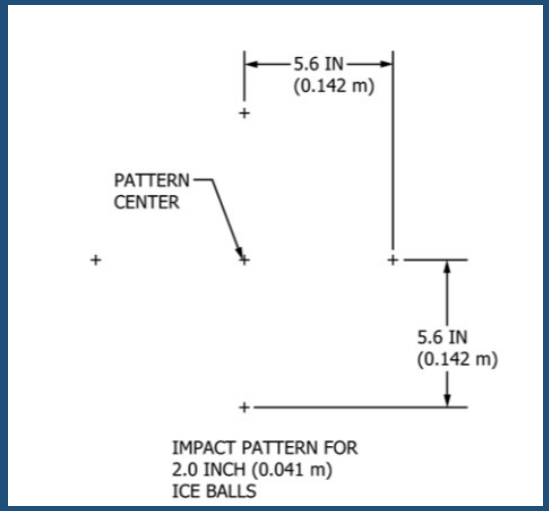
- Materials transfer impact energy into deformation.
- Different parts of the car deform differently.
  - Windshield vs. side/rear windows
  - Body Panels

- Modes of deformation: plastic, elastic, subsurface-plastic
- The mode of deformation can be predicted (Fischer, 2000).

Literature Review: Impact Mechanics

- ASTM F320: Standard Test Method for Hail Impact Resistance of Aerospace Transparent Enclosures.

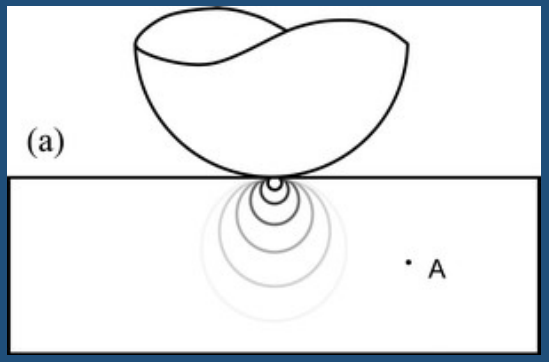




ASTM F320-16, Standard Test Method for Hail Impact Resistance of Aerospace Transparent Enclosures, ASTM International, West Conshohocken, PA, 2016, www.astm.org

Literature Review: Impact Mechanics

- Elastic deformations are defined with equations.
  - Hertzian Stress fields (Fischer, 2000)
  - Vertical displacement for various impactor shapes (Fischer, 2000)
- Plastic deformations are approximated through Finite Element Analysis.
  - Finite Element Analysis Software has been developed (Thomas, 2001).



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Literature Review: Automobile hail damage repair

- Paint-less Dent Removal(PDR) is used to repair body panels.
- In Canada, PDR specialists are certified by Vale Training Solutions.
- The PDR specialist estimates damage based on the Hail Pricing matrix, then repairs it.

DENTS UNLIMITED
Paintless Dent Removal Specialists

HAIL REPAIR PRICING MATRIX

JOHN (519) 871-1490 TODD (519) 851-4839
151 Tiner Ave., Dorchester, ON N0L 1G2
Serving London and Surrounding Area

Repair Location _____
Date _____
WO/RO# _____

SEVERITY / TOTAL DENTS	VERY LIGHT 1 TO 5 DENTS			LIGHT 6 TO 15 DENTS			MODERATE 16 TO 30 DENTS			MEDIUM 31 TO 50 DENTS			TOTAL
AVG. SIZE	DIME	NKL	QTR	DIME	NKL	QTR	DIME	NKL	QTR	DIME	NKL	QTR	
HOOD	130	180	210	195	245	310	260	310	400	400	505	600	
ROOF	145	195	250	245	295	325	340	425	490	470	620	680	
DECK LID	100	145	180	160	245	270	225	310	340	345	440	505	
L QUARTER	100	145	180	160	210	240	245	310	CVR	290	375	CVR	
L ROOF RAIL 25%	100	145	CVR	160	210	CVR	245	CVR	CVR	CVR	CVR	CVR	
LR DOOR	90	130	165	145	195	230	230	295	CVR	275	CVR	CVR	
LF DOOR	90	130	165	145	195	230	230	295	CVR	275	CVR	CVR	
L FENDER	100	145	180	160	210	245	245	310	CVR	290	CVR	CVR	
R FENDER	100	145	180	160	210	245	245	310	CVR	290	CVR	CVR	
RF DOOR	90	130	165	145	195	230	230	295	CVR	270	CVR	CVR	
RR DOOR	90	130	165	145	195	230	230	295	CVR	270	CVR	CVR	
R ROOF RAIL 25%	100	145	CVR	160	210	CVR	245	CVR	CVR	CVR	CVR	CVR	
R QUARTER	100	145	180	160	210	240	245	310	CVR	290	375	CVR	
METAL SUNROOF	90	130	160	145	195	230	CVR	CVR	CVR	CVR	CVR	CVR	
COWL, OTHER	90	130	165	145	195	230	CVR	CVR	CVR	CVR	CVR	CVR	

SEVERITY / TOTAL DENTS	HEAVY 51 TO 75 DENTS			SEVERE 76 TO 100 DENTS			EXTREME 101 TO 150 DENTS			LIMIT 151 TO 200 DENTS			TOTAL
AVG. SIZE	DIME	NKL	QTR	DIME	NKL	QTR	DIME	NKL	QTR	DIME	NKL	QTR	
HOOD	490	570	700	585	765	890	730	CVR	CVR	860	CVR	CVR	
ROOF	570	750	845	630	845	1105	790	1060	1360	945	1270	1620	
DECK LID	500	600	CVR	585	765	CVR	700	CVR	CVR	CVR	CVR	CVR	

REMOVE & INSTALL

- Hood & Liner ☐
- Trunk/Tailgate/Liner ☐
- Headliner ☐
- Sunroof ☐
- R Tail Light ☐
- L Tail Light ☐
- R Headlight ☐
- L Headlight ☐
- Door Panel ☐
- R Quarter Inner Trim ☐
- L Quarter Inner Trim ☐
- Cowl ☐

* Roof repairs on minivans, SUV's and extendicab trucks add 25%
* Double panels or aluminum panels add 25%
* Dent counts above 200 are estimated on a per case basis

Customer _____ NOTES _____
Insurance Co. _____
Claim # _____
Year _____ Colour _____
Make _____
Model _____
VIN# _____
Licence Place # _____

P.D.R.	
R & I	
TAX	
TOTAL	

* * CVR - Conventional Repair Recommended

How much will the hail damage cost?

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Literature Review: Automobile hail damage repair

- Resin Glass repair can be used to repair windshields.
- Chips and cracks must be less than the size of a dollar coin, and at least 5cm away from the glass edge.

Repair costs:

- 100$ for a chip or crack
- 400$ to replace a van sized windshield

Literature Review: Hail Protection Products

- Coverking Coverbond 4
  - $184.00 USD

https://www.coverking.com/moderate-weather-coverbond4.html

- Hail Protector
  - $399.99 USD

https://www.hailprotector.com/

Literature Review: Hail Properties

- Hailstones are formed in supercell thunderstorms, which precede tornadoes.
- Wet growth vs. dry growth
- 84% spheroidal, 10% conical, 6% irregular(Giammanco, 2014)

http://www.theweatherprediction.com/severe/gianthail/

Literature Review: Hail Replication

- ASTM F320: Standard Test Method for Hail Impact Resistance of Aerospace Transparent Enclosures
  - Injection molded ice balls

- Injection mold hailstones have a higher hardness than natural hailstones, for all sizes.(Giammanco, 2014)
- Theoretically, harder hailstones impart more damage on the specimen(Giammanco, 2014).

Impact testing: Calculations

- Hailstones impact at terminal velocity.
- Terminal velocity occurs when the drag force equals the gravitational force.
- In an 8m drop, only the 0.5cm hailstone would reach terminal velocity.

- Kinetic energy of hail can be matched by increasing the mass, but decreasing the impact velocity.

Impact testing: Calculations

Diameter (m)	Mass (kg)	Velocity Function $v = \sqrt{\frac{mg}{c}}\tanh\left(\sqrt{\frac{gc}{m}}t\right)$ $c = 0.5C_d\rho_{air}A$	Terminal Velocity (m/s)	Approx. Time to 90% of terminal velocity (s)	Distance Function $d_t = \frac{m}{c}\ln\lvert\cosh\left(\sqrt{\frac{gc}{m}}\,t_t\right)\rvert$ $c = 0.5C_d\rho_{air}A$	Approx. Distance to 90% of terminal velocity (m)	Terminal Kinetic Energy (j)
0.005	0.00006		9.9	1.5		8.3	0.0029
0.01	0.00048		14	2.1		17	0.047
...	...		...	...		...	...
0.08	0.25		40	5.9		130	190

Impact testing: Testing setup and procedures

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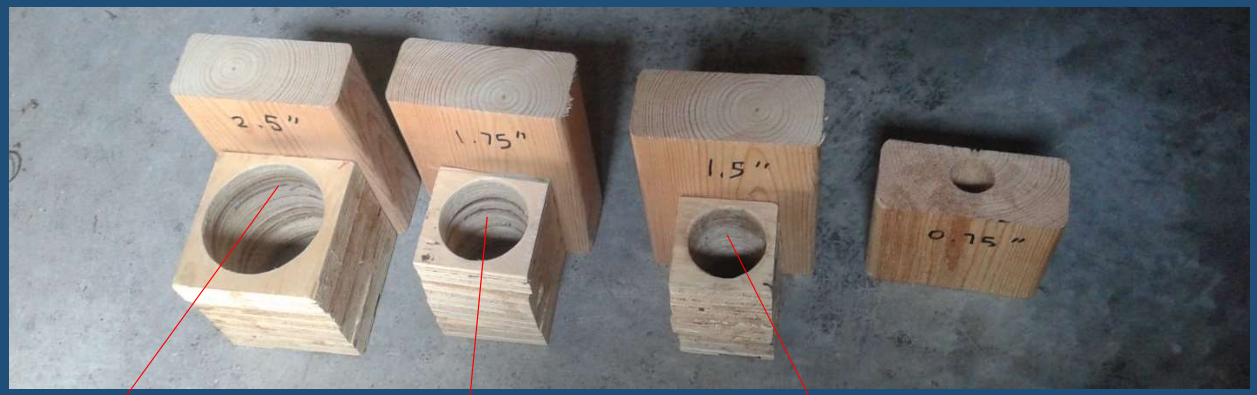

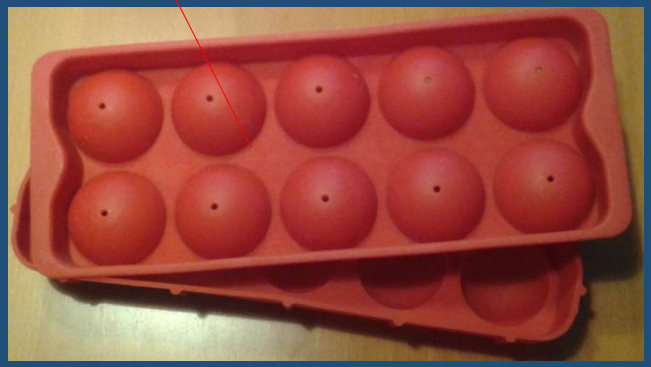

Impact testing: Procedures and results

Phase 1: Impacts with a 0.75” steel ball bearing

- With and without the hail cover
- On the hood and door
- Velocities were confirmed with a chronograph
- 7.9m and 3.3m drop heights
- Hood areas impacted: front, back, and support

Impact testing: Procedures and results

Phase 1 Conclusions

- The door was more resistant to damage.
- The door seemed stiffer than the hood.
- The hail cover failed to decrease the damage for financial savings.
- Impact damage did not vary between the areas of the hood.

Impact testing: Procedures and results

Phase 2: Impacts with a 1.75” ice ball

- With and without the hail cover
- Above and around a hood support
- 4.9m drop height

Impact testing: Procedures and results

Phase 2 Conclusions

- Ice balls hitting close to the hood support break apart on impact, and impart less damage.
- Ice balls hitting far from the hood support would bounce off, and impart more damage.

Impact testing: Procedures and results

Phase 3: Impacts with 2.5”,1.75”, and 1.5” ice balls

- With and without the hail cover
- On the hood and door
- Dropped from 1.7m, 3.3m and 7.9m

Impact testing: Procedures and results

Phase 3 Conclusions

- Steel ball with similar impact energy created a sharper dent, confirming the hardness effect.
- The ice balls created more oil canning surrounding the dent.
- Ice ball diameter did not seem to have an effect on damage for a similar impact energy.
- The cover did not decrease damage, but it tended to cause the 1.5” ice balls to bounce off.
- 2.5” ice ball masses were the most consistent.

Impact testing: Procedures and results

Figure 3: Equal Energy Impact Comparison

0.75” Steel	1.5” Ice	1.75” Ice	2.5” Ice
7.9m	7.9m	4.9m	1.7m

Impact testing: Procedures and results

3D printed ice cone mold

Figure 1: Bottom View

Figure 2: Top View

Conclusions

- The CoverKing Coverbond 4 Hail cover does not decrease damage for ice/steel ball impacts.
- Overlaid covers can cause ice balls to bounce off rather than explode.
- Harder steel balls impart sharper dents.
- Doors damage less due to stiffer construction.
- Hood supports cause ice balls to explode, therefore reducing damage.
- 3D printed molds are satisfactory for forming ice cones.
- Single ice balls molds are better than tray-style molds.

Recommendations

- Develop an ice-ball shooter.
- Develop a method to capture impact and measure impact depth.
- Perform impact tests on windshields installed on an actual automobile.
- Perform layered ice ball impacts.
- Compare lab dents to real life hail dents.

Final Remarks

- As communities continue to grow in the Canadian prairies and central United States, one can expect hail damage to automobiles to be an increasing problem(Roach, 2016).

- A testing method is needed in order to engineer solutions that can mitigate hail damage to automobiles.

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Questions?

http://www.nssl.noaa.gov/education/svrwx101/hail/img/IMG_0097.jpg

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