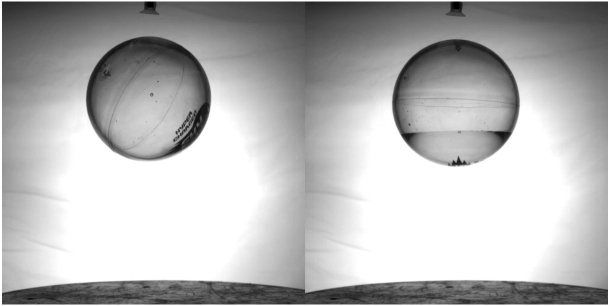
Harnessing Sloshing as a Passive Dampener



Taylor Killian Robert Klaus*,
with: Prof. Tadd Truscott*

Department of Mathematics, Department of Mechanical Engineering*
Brigham Young University

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Objectives

Focus Areas

- Determine the dynamics of rebound mitigation.
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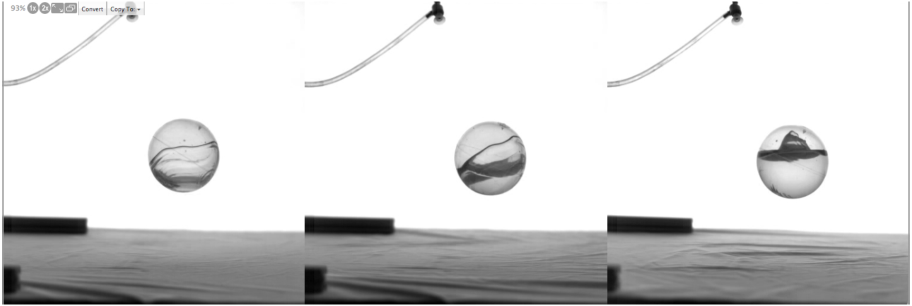
  - Quantify the motion of the sphere.
  - Discover the influence of varying physical parameters
- Determine the details of the internal energy exchange.
  - Investigate the interplay of cavity collapse and rebound mitigation.
    - Video analysis shows the formation of an internal jet at the same time as rebound mitigation.
  - Extract the dimensionless parameters that define the energy loss

Fill Volume Influence on Rebound Mitigation

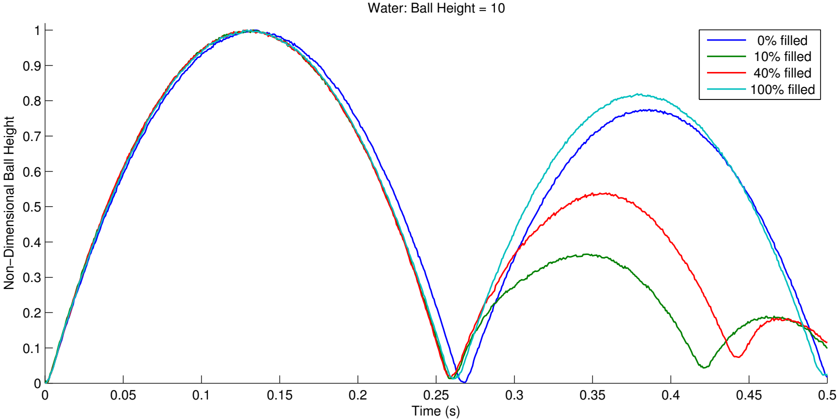
- Different fluid responses arose when varying the interior volume.



- Trials of (l-r) 10%, 30% and 70% of internal volume and are dropped from 20 cm

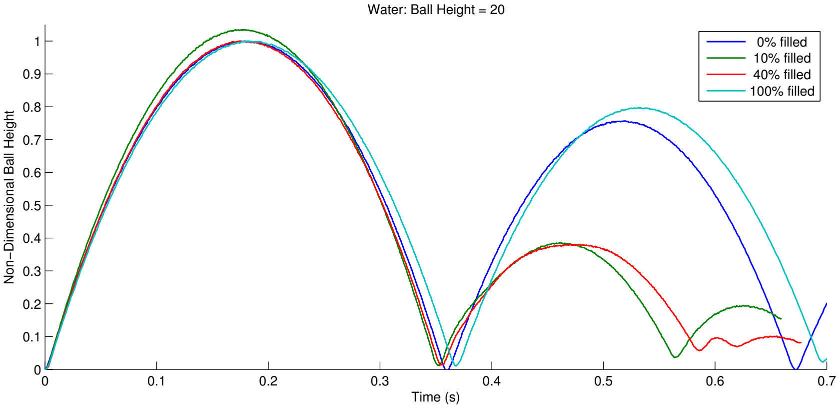
Effect of Drop Height

- The measured rebound heights of a 10cm drop: water filled.



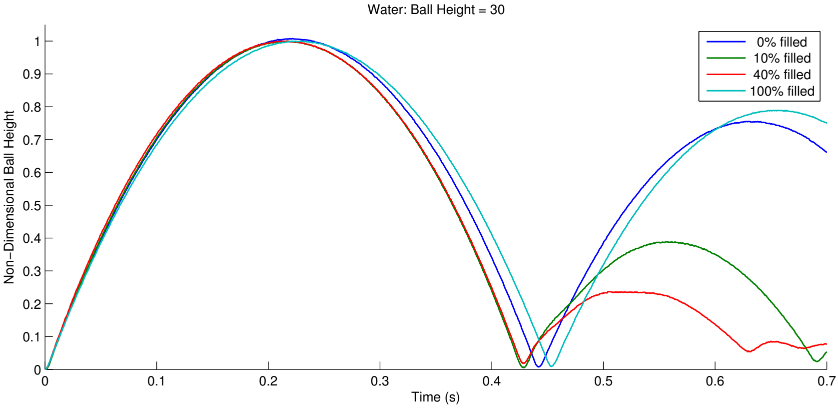
Effect of Drop Height

- The measured rebound heights of a 20cm drop: water filled.



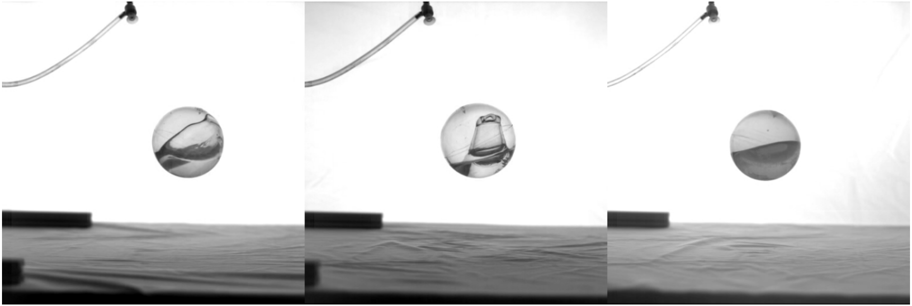
Effect of Drop Height

- The measured rebound heights of a 30cm drop: water filled.



Viscosity's Influence on Rebound Mitigation

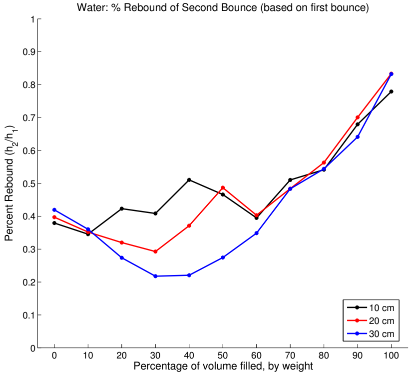
- Different viscosities were tested, varied fluid behavior was observed.

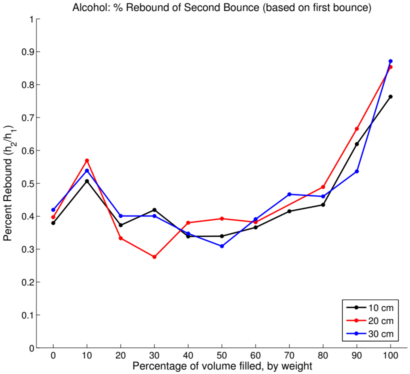


- All trials are filled to 30% of internal volume and are dropped from 20 cm
- Trials of (l-r): Water $\mu = 8.9 \times 10^{-4} \frac{N\ s}{m^2}$, Alcohol $\mu = 1.92 \times 10^{-3} \frac{N\ s}{m^2}$, Glycerin $\mu = 9.5 \times 10^{-1} \frac{N\ s}{m^2}$

Viscosity's Influence on Rebound Mitigation

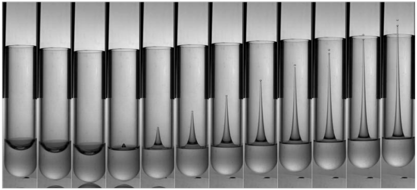
- Analysis of our data showed that the global effect of the sphere's motion is unchanged.



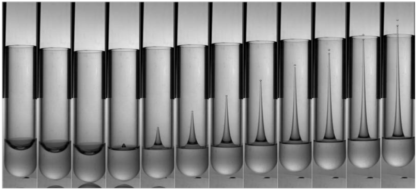


Previous Work

- **Antkowiak et. al. 2006**, *Short-term dynamics of a density interface following an impact*



- **Antkowiak et. al. 2006**, *Short-term dynamics of a density interface following an impact*



  - "The interface curvature reverses violently, forming a concentrated jet thanks to a purely inertial mechanism..."

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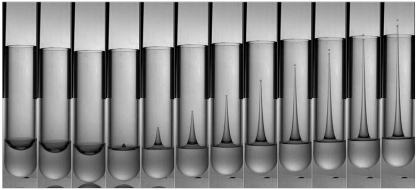
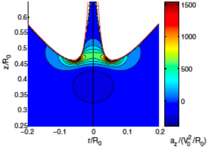
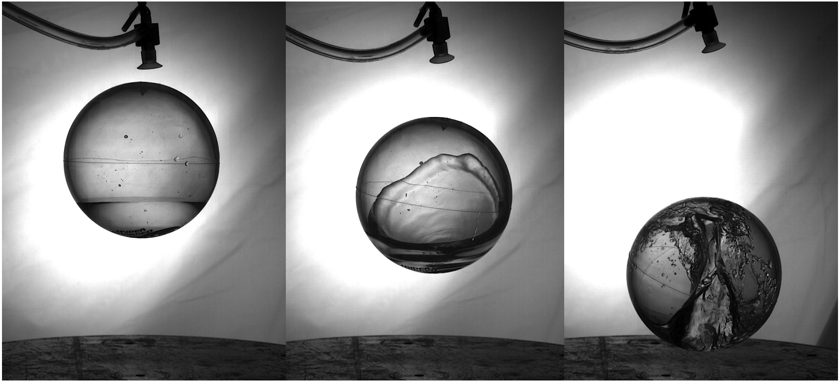


  - "The interface curvature reverses violently, forming a concentrated jet thanks to a purely inertial mechanism..."

- **Gekle et. al. 2009**, *High-Speed Jet Formation after Solid Object Impact*
  - "Jet formation...depends crucially on the kinetic energy contained in the entire collapsing wall of the cavity..."

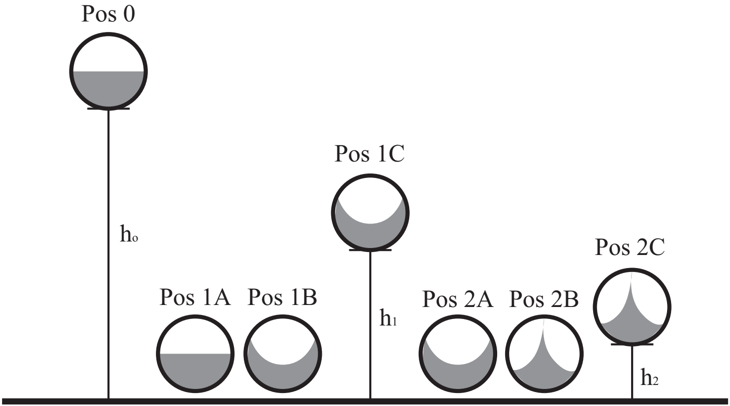


- This conceptual approach validates our direction and focus.



- Sequence above: fill volume of 20%, dropped from 20cm.

- We investigate the mechanism of cavity collapse in kinematic terms.

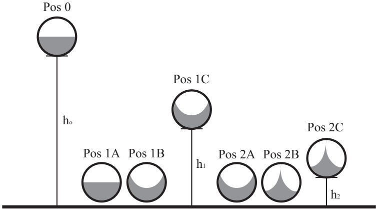


Energy Exchange: Formulation

Investigating the energy exchange

- $PE_0 = Mgh_0$
- $KE_{1A} = PE_0$
- $KE_{1B} = KE_{1A} - fl_{loss} - dyn_{loss}$
- $PE_{1C} = KE_{1B}$

  ...



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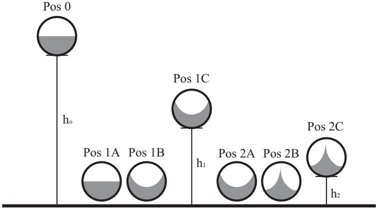


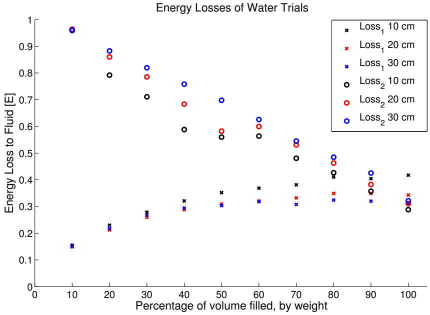
Determining the losses to fluid fill

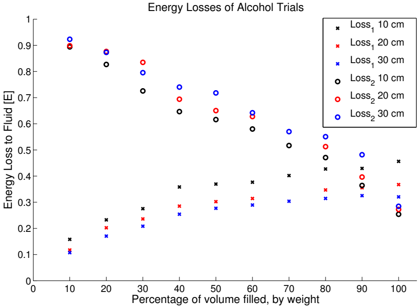
$fl_{loss,1} = Mg(h_0 - h_1) + m_b g(h_{1,empty} - h_0)$

$fl_{loss,2} = Mg(h_0 - h_2) + m_b g h_{2,empty} - fl_{loss,1}$

Energy losses to the fluid

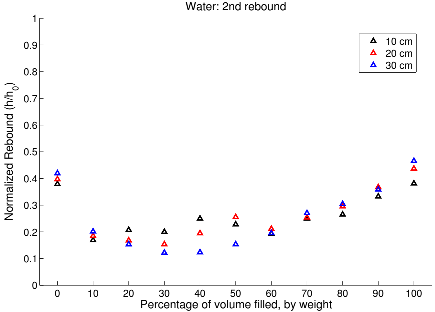
- $fl_{loss,1} = Mg(h_0 - h_1) + m_b g(h_{1,empty} - h_0)$
- $fl_{loss,2} = Mg(h_0 - h_2) + m_b g h_{2,empty} - fl_{loss,1}$
- From these relations we establish the non-dimensional parameter E.
  - $\mathrm{E} = \frac{fl_{loss}}{Mgh_0}$

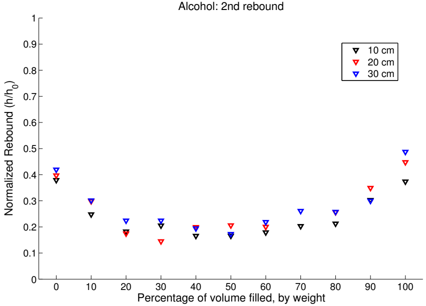




Normalizing the second rebound

- Second rebound data is normalized to extract global information.





- Serves as an analog/description for Roller Hockey Ball dynamics.

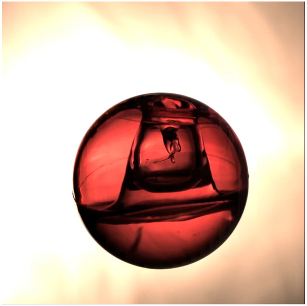
Conclusions

- Sloshing within a partially fluid filled sphere acts as a passive dampener.
- Rebound suppression depends on drop height and fill volume.
- There is an exchange of energy from the sphere to the fluid.
- This exchange of energy occurs at cavity collapse and jet formation.

Future/Continued Work

- Build and verify numerical model using ADINA.
- Analyze experiments performed with different sphere elasticity and greater drop height.
  - Determine convergence of data.
- Refine energy method to replicate observed data.

Acknowledements



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Brigham Young University

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