LS-DYNA Simulation of *in vivo* Surgical Robot Mobility

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Abstract

In vivo *surgical robot wheels were studied to develop a better wheel design using finite element analysis. A liver material model, derived from component testing, was implemented as a viscoelastic material. LS-DYNA simulation of this testing confirmed the accuracy of the liver material model. This material model was then used as the tissue model to study wheel performance. A helical wheel moving on the liver model was used to replicate laboratory experiments. Drawbar forces required to move the wheel across the liver for various slip ratios produced in simulation showed good agreement with the physical tests. The wheel design was then adjusted in the simulation to study how changes in the wheel diameter and the pitch of the helical tread affected the drawbar force. Results showed that an increased diameter and decreased pitch angle increased drawbar force. These results will be used in future surgical robot wheel designs.*

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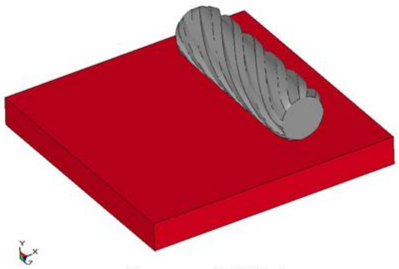

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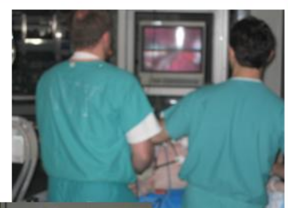
Introduction to Laparoscopy

- Laparoscopy
  - Minimally invasive surgery (MIS)
  - Small ports (5-20mm)
  - Insufflation
- MIS problems
  - Entry port constraint
  - Reduced dexterity
  - Limited perception
- da Vinci Surgical System
  - Scaled motion, reduced tremor
  - Large, expensive
  - Entry port constraint



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Introduction to *In Vivo* Robots

- Two wheels and tail
- Mobile platform for camera, biopsy, etc
- Need to increase drawbar force

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Problem

- *Goal: design a better wheel*
- Simulate liver using viscoelastic material
  - Compare to laboratory results
- Simulate wheel/liver interaction
  - Compare to laboratory results
- Modify wheel parameters
  - Identify a "best" wheel

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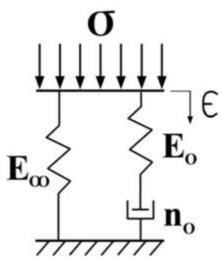
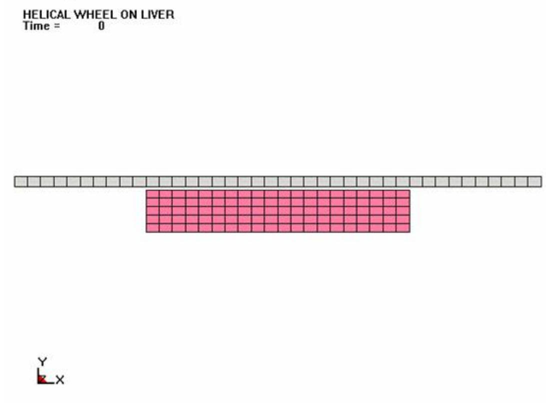
Material Model

- 3 element viscoelastic model from laboratory tests
- Implemented into LS-DYNA
- Simulated the lab creep test





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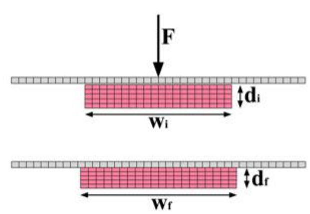
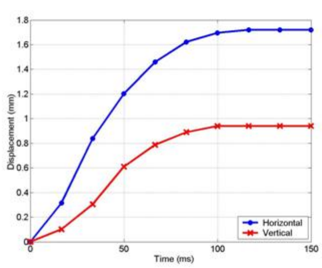
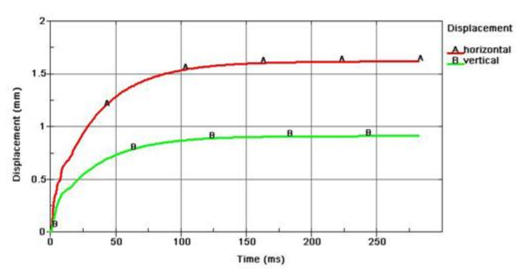
Material Model

- Measured horizontal and vertical displacement
- Results compared favorably to laboratory data







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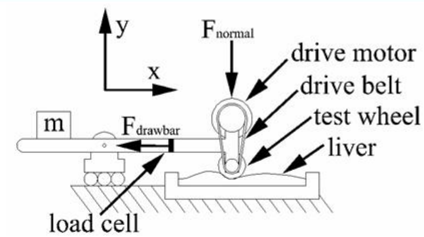
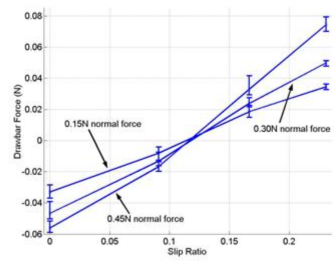
Wheel Performance

- Linear slide
- Induce slip
- Adjust normal force
- Measure drawbar force



$$SR = 1 - \frac{\dot{x}_{cm}}{r\dot{\theta}_{cm}}$$



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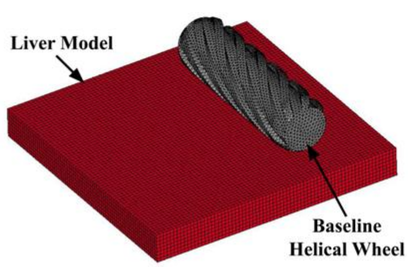
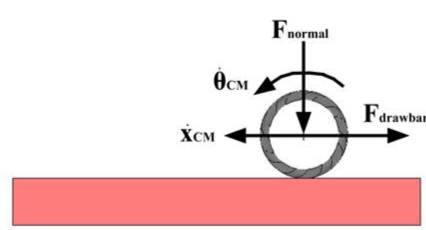
Simulation Development

- Loads – vary the normal forces (weight)
- Motions – translation and rotation
- Results – force transducers measure drawbar force
- Wheel is rigid
- Tissue is liver material model





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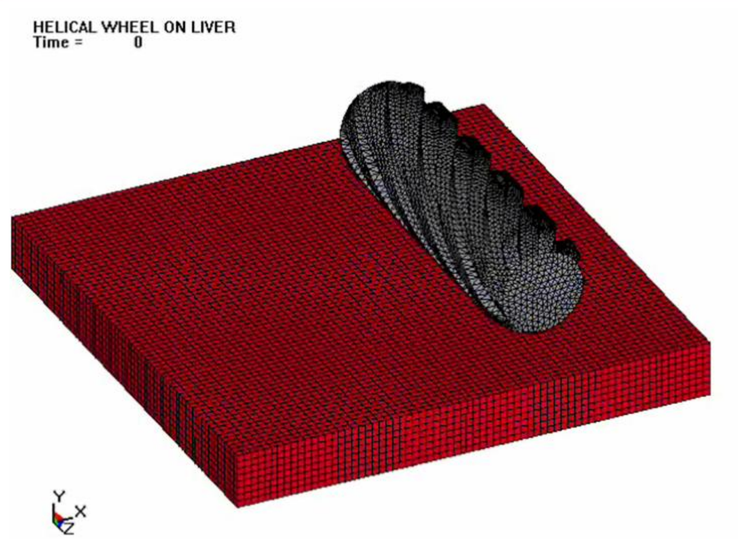
Simulation Results



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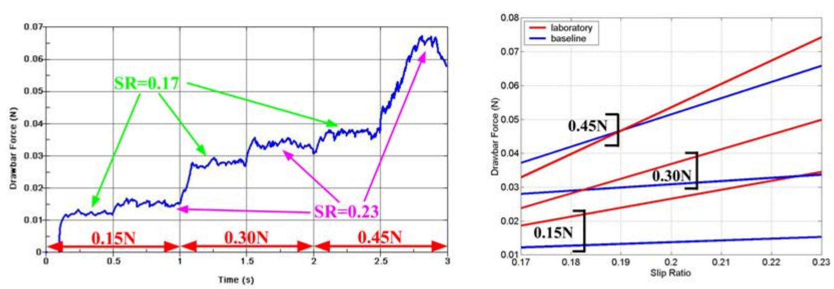
Simulation Results

- Two slip ratios, three weights
- Results compare favorably to lab data
  - Approximately same magnitudes
  - Same weight trend
  - Same slip ratio trend



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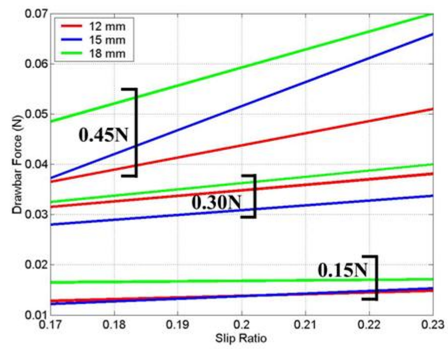
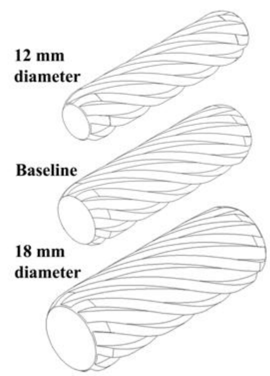
Diameter Size

- Simulated 3 diameters
- Larger diameter is better – less resistance





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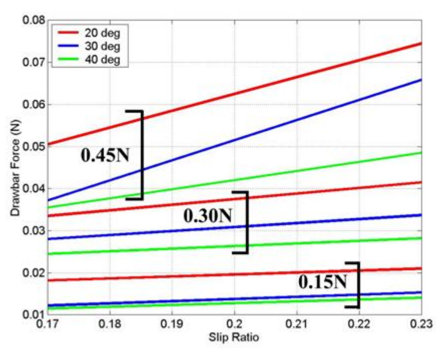
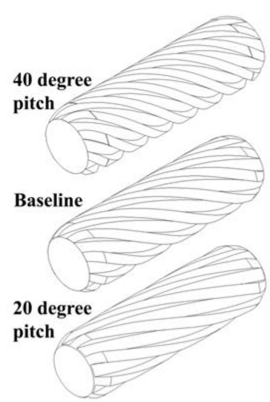
Tread Angle

- Simulated 3 tread pitch angles
- Lower angle is better – high stress concentrations





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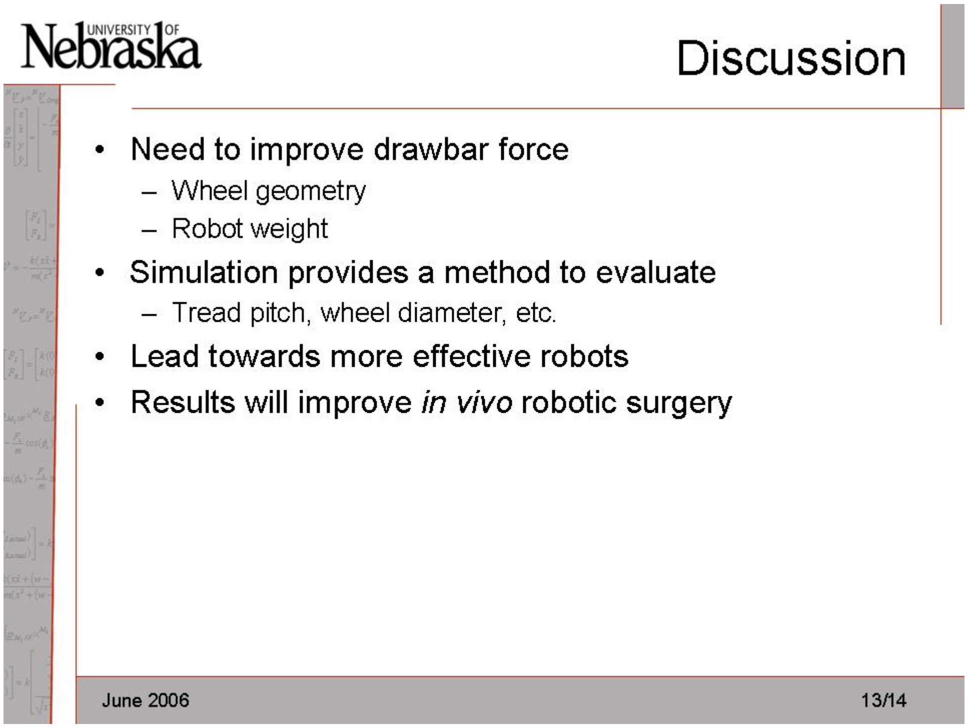
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Discussion
• Need to improve drawbar force
– Wheel geometry
– Robot weight
• Simulation provides a method to evaluate
– Tread pitch, wheel diameter, etc.
• Lead towards more effective robots
• Results will improve *in vivo* robotic surgery
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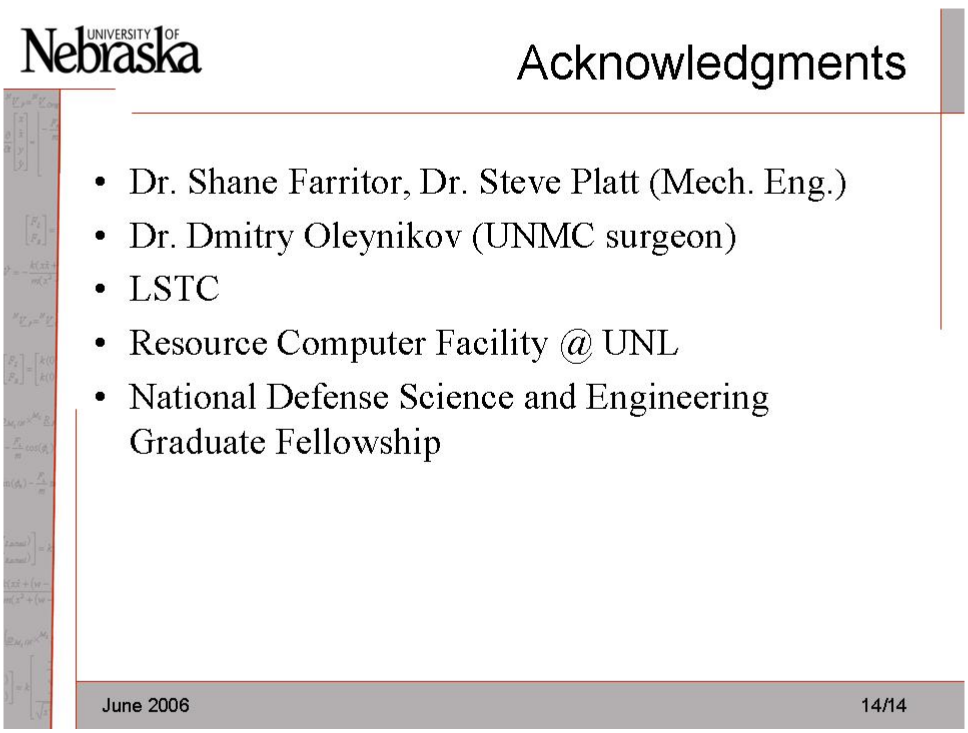
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Acknowledgments
• Dr. Shane Farritor, Dr. Steve Platt (Mech. Eng.)
• Dr. Dmitry Oleynikov (UNMC surgeon)
• LSTC
• Resource Computer Facility @ UNL
• National Defense Science and Engineering Graduate Fellowship
June 2006
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