Applicability of CPR-based Thoracic Stiffness and Damping Properties to the Motor Vehicle Crash Environment

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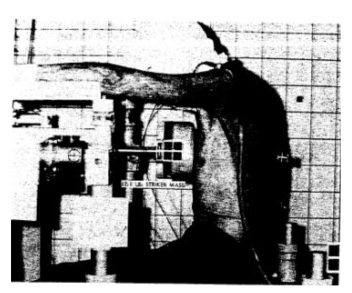
INTRODUCTION

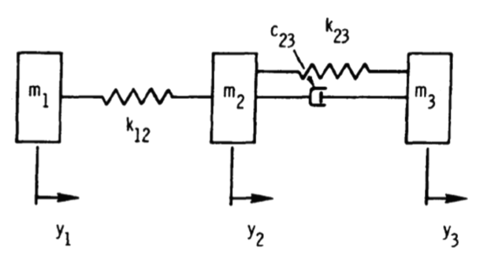
- •Motor vehicle crashes are the leading cause death and injury for children and adults between 3 to 36 years old in the United States (Centers for Disease Control, 2006)
- •A biofidelic anthropomorphic test device (ATD) or crash test dummy is essential for developing crash safety systems for occupants
- •Typically, post-mortem human subject (PMHS) experiments are conducted to obtain necessary data to design ATD
- •Limitations are associated with biomechanics data obtained by PMHS testing
  - •Differences between PMHS and living humans
  - •The age range of test subjects is small – typically elderly
- •Recently collected thoracic force-deflection data from cardio-pulmonary resuscitation (CPR) patients offer a large dataset of thoracic biomechanical data across a broad age range
- •The applicability of CPR data to inform ATD biofidelity requirements is unknown
- •The purpose of this study is to evaluate the use of CPR data-derived thoracic stiffness and damping properties in an impact model of the thorax

METHOD

PMHS Tests (Kroell 1974)



SMD Model



- •Blunt hub impact to PMHS thorax with varying impactor mass and initial velocity (Kroell et al. 1974)
- •Spring mass damper (SMD) model proposed by Neathery et al (1973) based on the PMHS experiment - this model gives force-deflection response of thorax
- •Data from PMHS experiment is used in the current design of crash test dummy or ATD

NEW METHOD

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Phillip Heartstart Monitor Defibrillator

Measure the force-deflection property of chest undergoing CPR

- •Force-deflection property of chest is measured when subject receives CPR
- •Force-deflection data from CPR are extrapolated to loading rates equivalent to Kroell PMHS experiments
- •Data is solved using Runge-kutta integration and extracted chest properties are then integrated into the SMD model
- •Compare the differences/similarities in response between PMHS and CPR derived models

REFERENCES

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- Kroell, C.K. "Impact Tolerance And Response Of The Human Thorax II." *SAE International Journals*. (1974): Print.
- Maltese, M.R. "Methods For Determining Pediatric Thoracic Force-Deflection Characteristics From Cardiopulmonary Resuscitation." *Stapp Car Crash Journal*. 52. (2008): 41. Print.
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RESULTS

The spring-mass-damper (SMD) model proposed by Neathery et al (1973) was reproduced (first model)

A second model, SMD-CPR, was created by replacing the thoracic spring (k_{12}) and damper (c_{23}) with parameters derived from CPR

A third model, SMD-CPR-C, was created by replacing only the thoracic damping constant in SMD model by the CPR derived model

A fourth model, SMD-CPR-K, was created by replacing only the thoracic spring constant in the SMD model by the CPR derived value

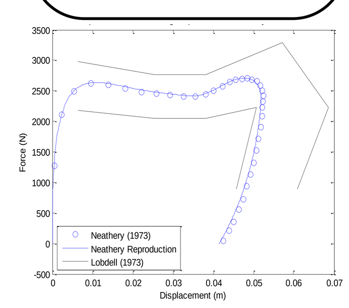
Parametric study of the SMD-CPR-K model was performed to quantify the effects of changes in mass, spring, and damping constants on the model force-deflection curve

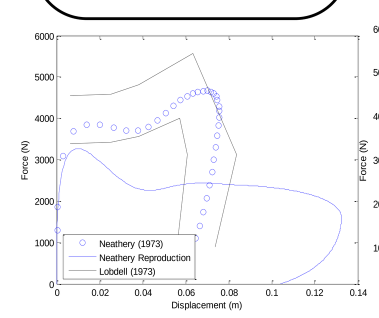
Increasing mass of the sternum increased the stiffness early in the event

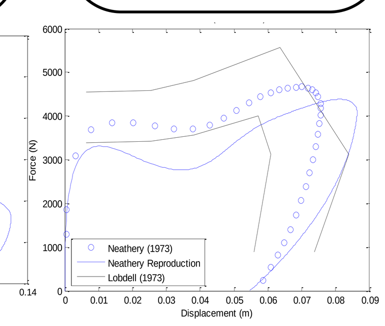
Increasing magnitude of the spring constant of the sternum increased the stiffness early in the event

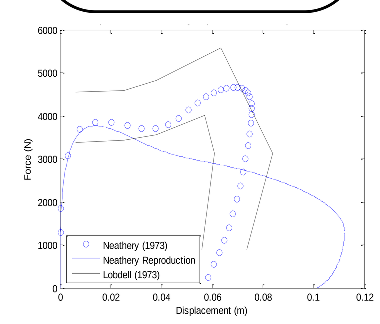
Increasing magnitude of the damping constant of the thorax increased the stiffness early in the event and lowered the deflection later in the event

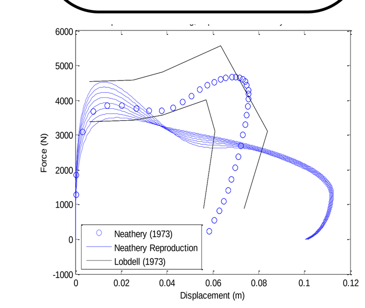
Increasing magnitude of the spring constant of the thorax lowered the deflection later in the event

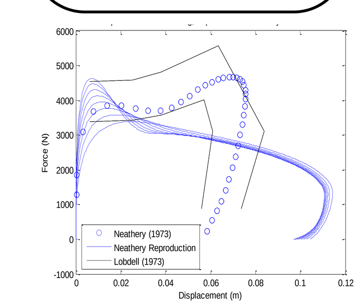


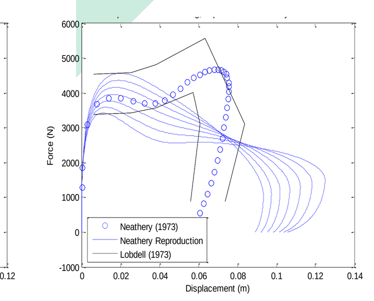


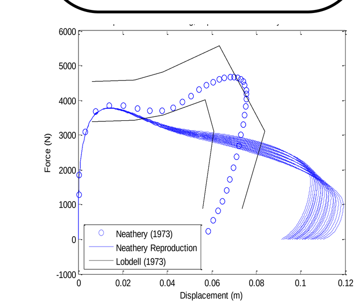


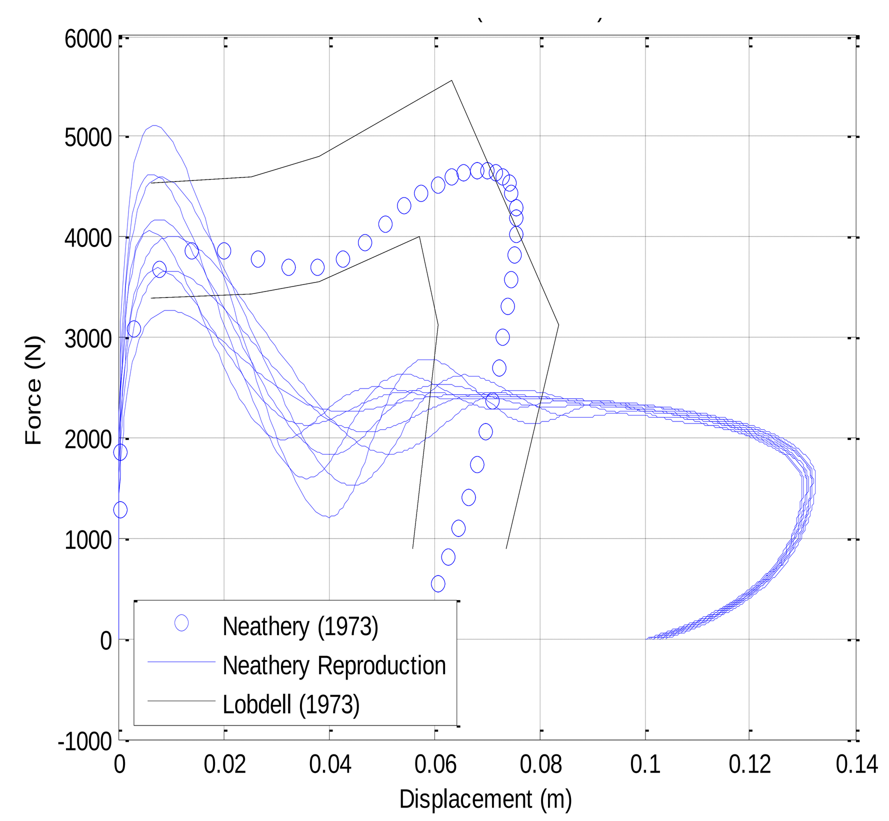




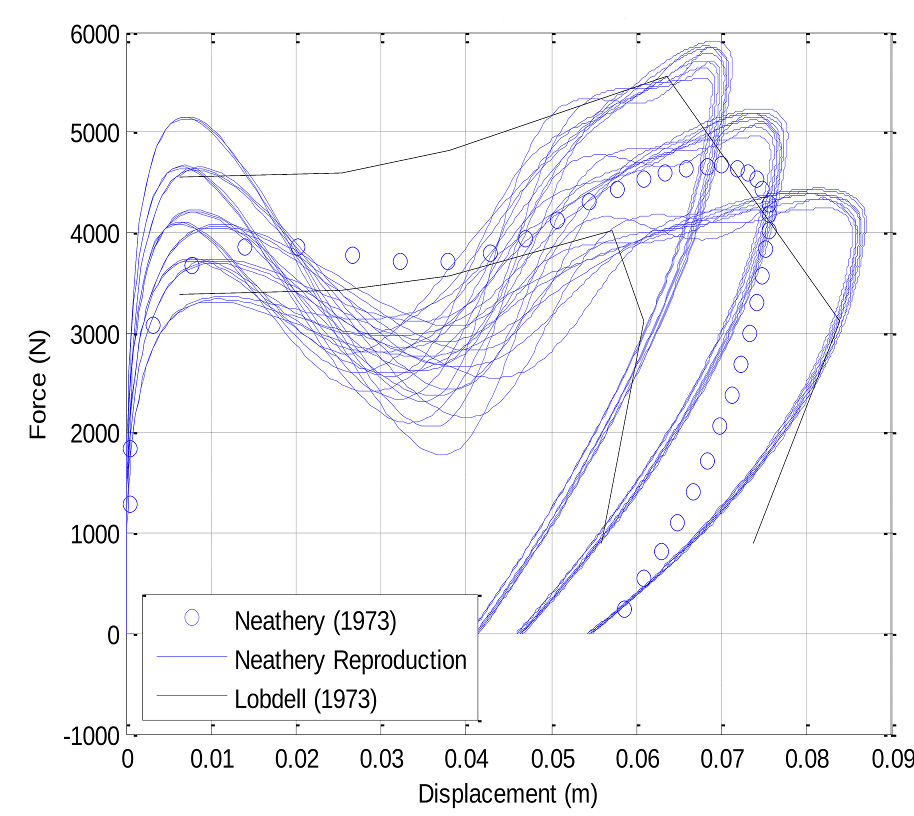




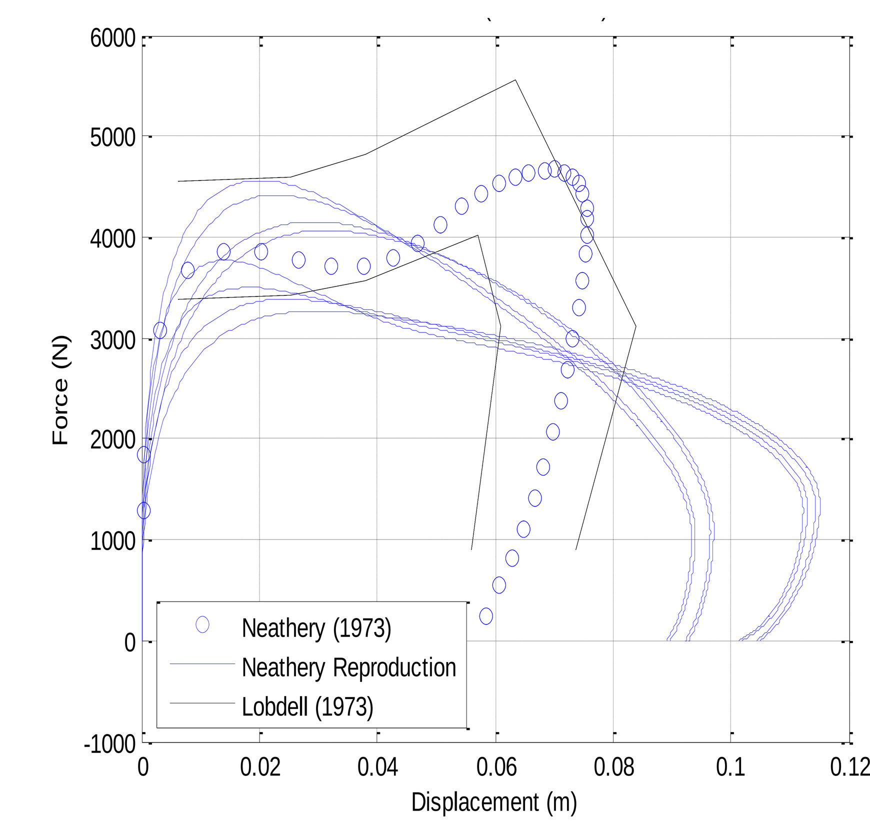




- •Combined parametric study of SMD-CPR model
- •Mass of sternum (m2)and spring constant of flesh (k12) were altered



- •Combined parametric study of SMD-CPR-C model
- •Mass of sternum (m2), spring constant of flesh (k12), and spring constant of thorax (k23) were altered



- •Combined parametric study of SMD-CPR-K model
- •Mass of sternum (m2), spring constant of flesh (k12), and damping constant of thorax (c23) were altered

DISCUSSION

- Incorporation of the CPR data yields results different from the original PMHS impact data
  - In general, lower force and greater deflection
- Differences may be due to
  - Variations in biomechanical characteristics between the PMHS and living subjects
  - The simplicity of SMD model
    - A more complex thorax model, with more masses, springs, and dampers may need to be introduced to yield higher accuracy
  - Difference in experimental procedures
    - PMHS experiment – apply blunt hub impact, with certain impactor mass and velocity, to the chest of test subjects
    - CPR experiment – extrapolate force-deflection data, which were obtained under low force condition, to loading rates equivalent to PMHS experiment.

CONCLUSION

- SMD-CPR, SMD-CPR-K, and SMD-CPR-C model indicates that when stiffness and/or damping of chest in SMD model is replaced with CPR derived values, resulting force-deflection response does not fit within the standard corridor
- Each segment of force-deflection curve is affected by different parameters or specific part of the chest

ACKNOWLEDGMENT

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