Validation of a Numerically Inflated Polyethylene Bag

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Aim

- Create numerical model to model stiffness and inflated shape of simple bag

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- Increase complexity of model

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- Create numerical model to model stiffness and inflated shape of simple bag
- Increase complexity of model
- Use model for shape optimisation for inflatable wing

Trailing_Edge_1.jpg

Inflatable Wings - Planes

Inflatoplane.jpg

Methodology

- Measure stiffness through 4 point bending tests

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- Capture physical model geometry with 3D scanner

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- Capture physical model geometry with 3D scanner
- Construct finite element models of single cavity bags
  - LS-DYNA's explicit solver

FE Model - 4 Point Bending

- Polyethylene - Linear elastic membrane

Tensile_Testing.pdf

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- Polyethylene - Linear elastic membrane
- Airbag model for inflation

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- Two boundary condition types used

Tensile_Testing.pdf

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- Polyethylene - Linear elastic membrane
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- Dynamic relaxation

Tensile_Testing.pdf

FE Model - 4 Point Bending

- Polyethylene - Linear elastic membrane
- Airbag model for inflation
- Two boundary condition types used
- Dynamic relaxation
- Mass scaling

Tensile_Testing.pdf

4 Point Bending Tests

- Measure force vs. displacement

4_Point.jpg

4 Point Bending Tests

- Measure force vs. displacement
- Diameter 50, 75 and 100 mm tubes

4_Point.jpg

4 Point Bending Tests

- Measure force vs. displacement
- Diameter 50, 75 and 100 mm tubes
- 3 different pressures tested per tube

4_Point.jpg

All_5_75.pdf

(a) Bag size comparison at 5.75 kPa.

50_All.pdf

(b) Pressure comparison for 50 mm bag.

4 Point Bending Tests

At displacement of 40 mm:

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4 Point Bending Tests

At displacement of 40 mm:

- At 5.75 kPa a 100% increase in bag size yields a 375% increase in stiffness
- For the 50 mm bag a 160% increase in pressure the stiffness increases by 46%
- Increase on bag size has a larger influence on the stiffness than the pressure

4 Point Bending Tests - 75 mm Bag

75_5_75.pdf

(a) 75 mm bag at 5.75 kPa.

75_6_75.pdf

(b) 75 mm bag at 6.75 kPa.

75_9.pdf

Shape Validation

- Point clouds of bags both under load and no load compared

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- Metamodel based optimisation used to minimize Hausdorff distance

$$\begin{aligned}&\text{Minimise } f(\mathbf{x})\\&\quad\text{where } f(\mathbf{x}) = \text{Hausdorff Distance}\\&\qquad\text{and } \mathbf{x} = [T_x, T_y, T_z, R_x, R_y, R_z]\end{aligned}$$

Shape Validation

- Point clouds of bags both under load and no load compared
- Metamodel based optimisation used to minimize Hausdorff distance
- Rigid body transformations used to rotate physical model

$$\begin{aligned} &\text{Minimise } f(\mathbf{x}) \\ &\quad \text{where } f(\mathbf{x}) = \text{Hausdorff Distance} \\ &\qquad \text{and } \mathbf{x} = [T_x, T_y, T_z, R_x, R_y, R_z] \end{aligned}$$

Hausdorff Distance

Shape Validation - 75 mm Bag Under No Load

Tube_75_xz.pdf

Tube_75_yz.pdf

Shape Validation - 75 mm Bag Under Load

4-point_75_xz.pdf

4-point_75_yz.pdf

- Larger displacement from physical bag
- Best fit on zy plane

Shape Optimisation

- Parametrise movement in the x and z directions

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- Minimise RMSE between NACA 0030 aerofoil

Shape Optimisation

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Shape Optimisation

Shape Optimisation - 3 Bag Aerofoil

Shape Optimisation - 8 Bag Aerofoil

Shape Optimisation - 15 Bag Aerofoil

Shape Optimisation - Bag Comparison

	3 Bag	8 Bag	15 Bag
RMSE	0.02606	0.00844	0.00453
R^2	0.557	0.961	0.990

Physical Model - 8 Bag Aerofoil

Physical Comparison - 8 Bag Aerofoil

Physical_Comparison_8.pdf

Concluding Remarks

- Able to achieve high R^2 fit from between physical profile and target profile.
- More accurate material model could help achieve better fit.

Questions?