MANUFACTURING & DESIGN

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EPSRC Centre for Doctoral Training in Composites Science, Engineering and Manufacturing

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UKRI Engineering and Physical Sciences Research Council

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Accessible prosthetic sockets

Kevin Alarcón

BCI Doctoral Research Symposium

12th of April 2022

University of BRISTOL
EPSRC Centre for Doctoral Training in Composites Science, Engineering and Manufacturing

UKRI Engineering and Physical Sciences Research Council

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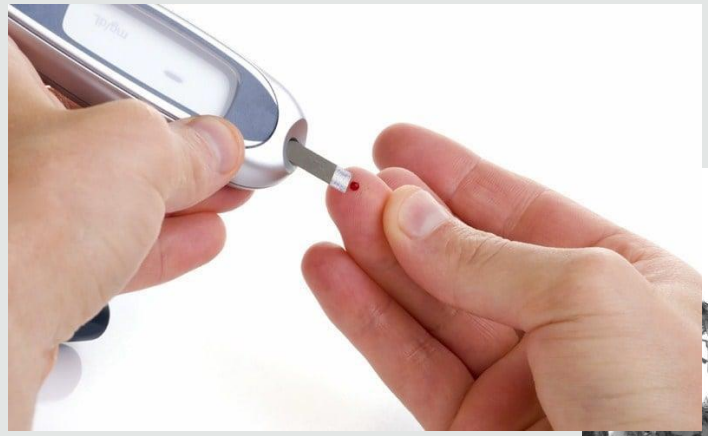
Background

- 1 million annual amputations globally

One amputation every **30** seconds

Background

- Main causes
  - Vascular disease (e.g. Diabetes)
  - Trauma

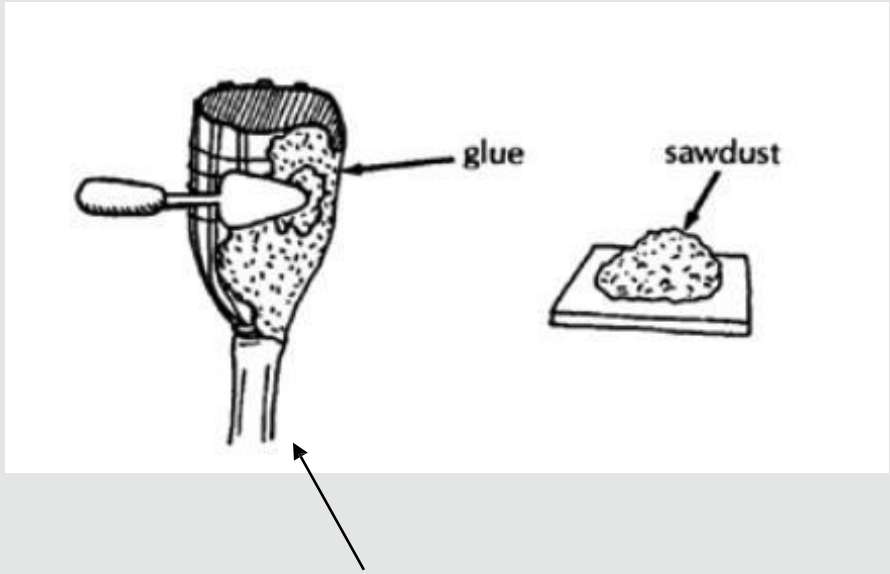


285 million to reach 435 million by 2030
(International Diabetes federation)

Lower limb prosthesis development

Wood & Leather

Plaster and bamboo



Bamboo pylon

CFRP

Current issues – Elkin's story

Elkin

Amputation → Six months → 1st prosthetic

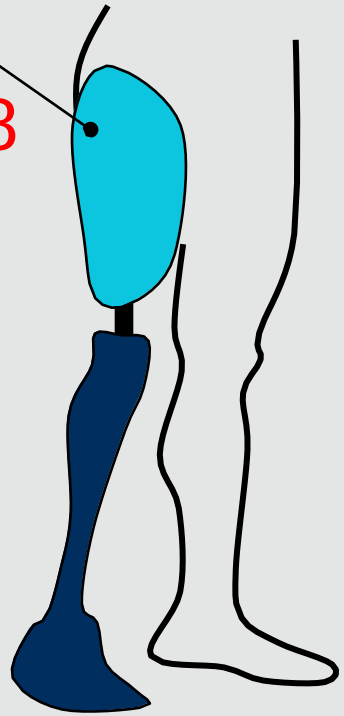
- Complex manufacturing
- Material unavailability
- Prosthetist unavailability
- High cost

Current issues – Elkin's story

Socket

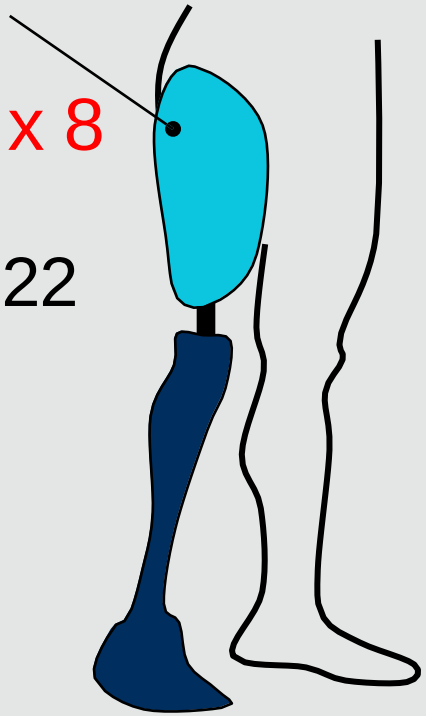
x 8

2005 - 2022



Current issues – Elkin's story

Socket

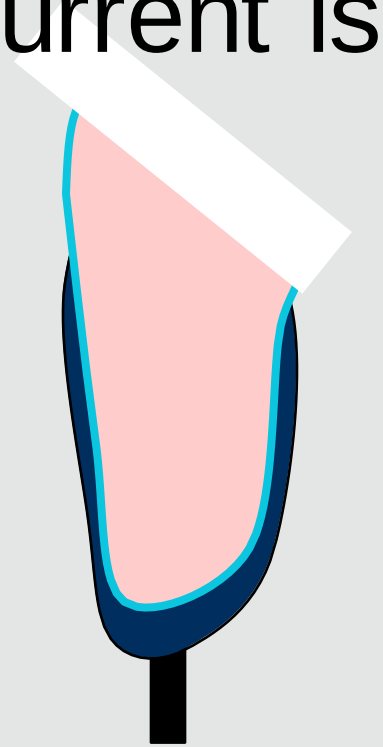


2005 - 2022

- Pain
- Blisters

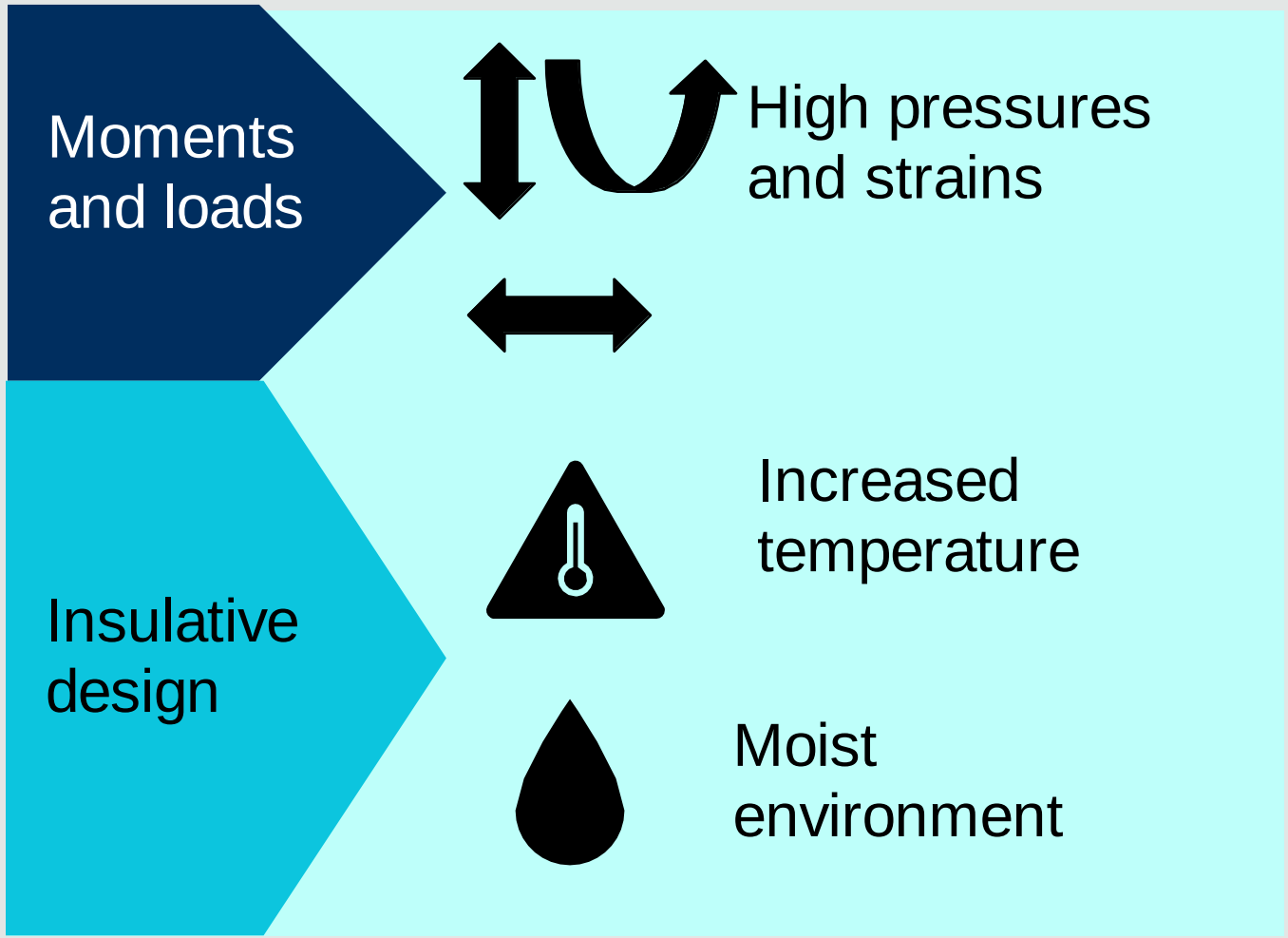
What are the implications?

Current issues – Socket environment



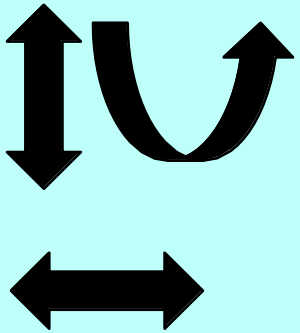
Soft Liner

Rigid socket



Current issues – Socket environment

Moments and loads



High pressures and strains

Insulative design

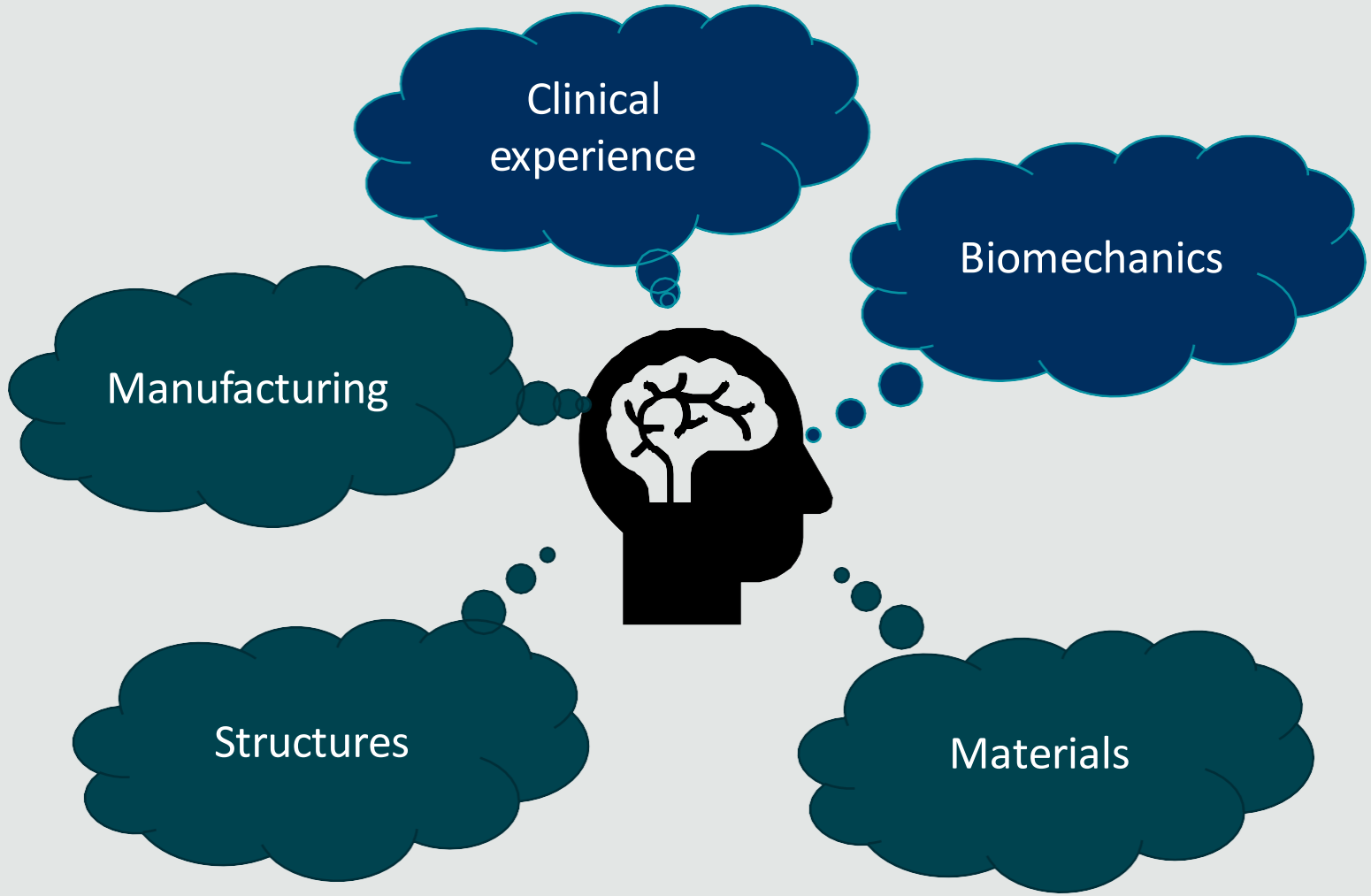
Increased temperature

Moist environment

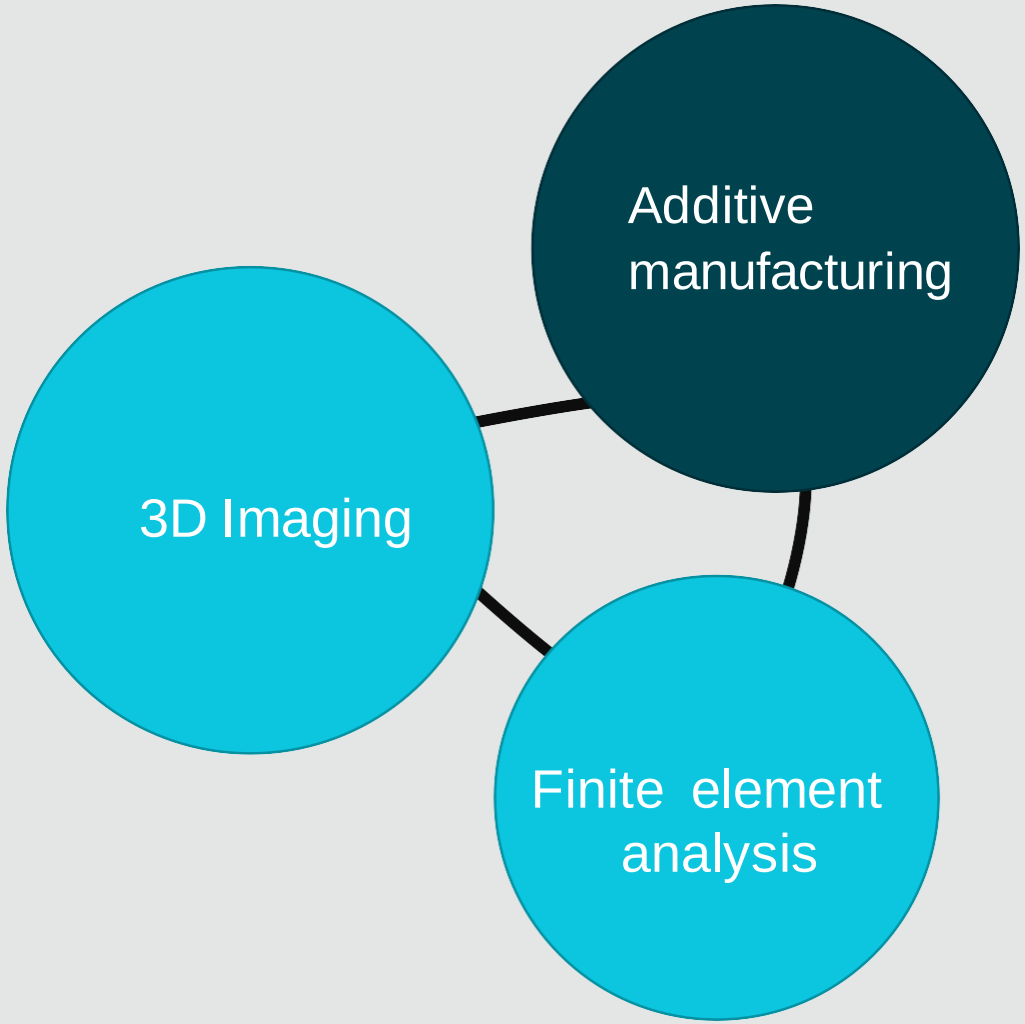
Current issues – tackling the issue

- Comfortable, easily adjustable design
- Fast manufacture
- Affordable

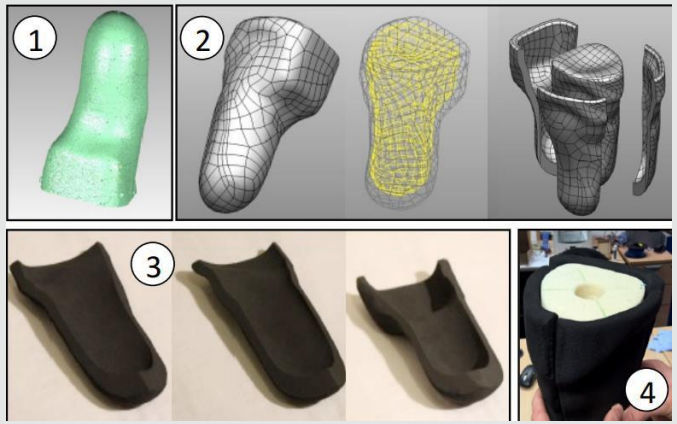
The remaining 85%



Research landscape



- 3D printing liners

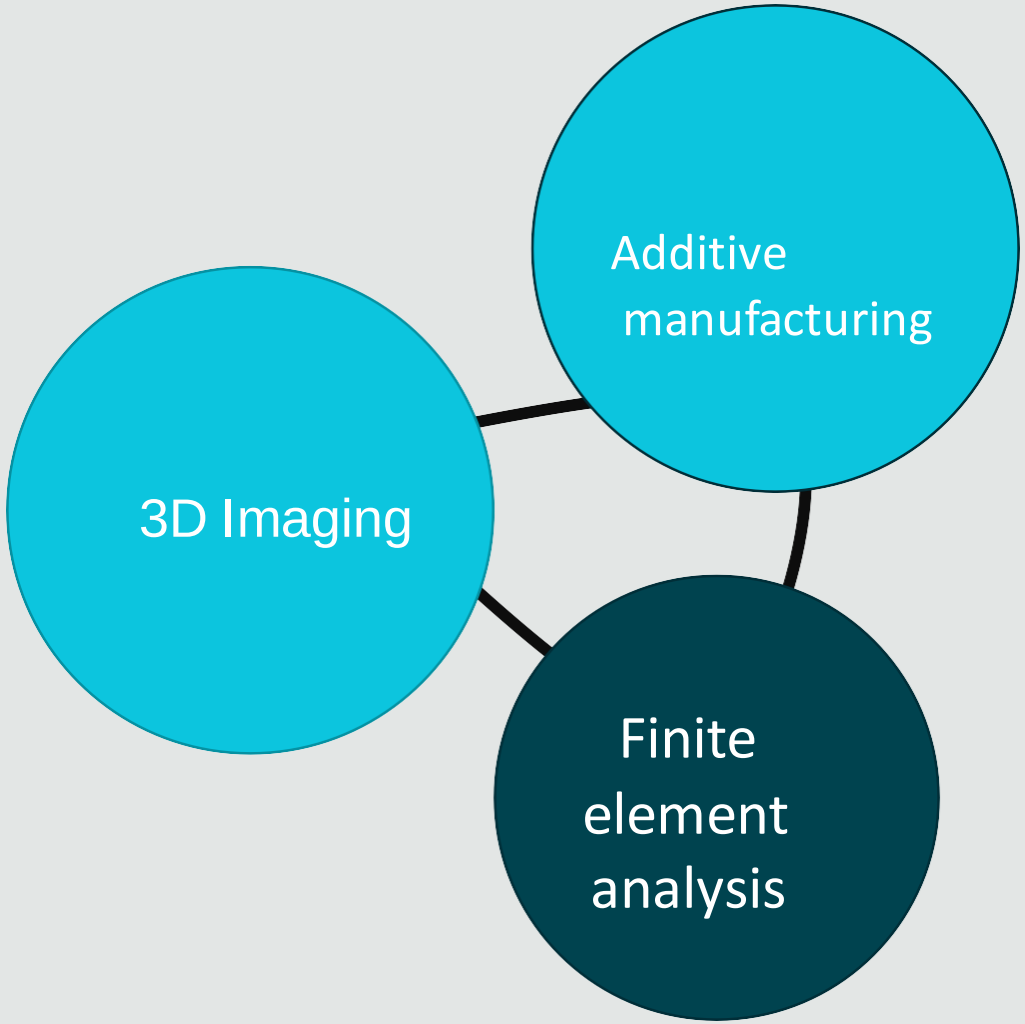


E. Seminati et al., BAPO Conference (2017)

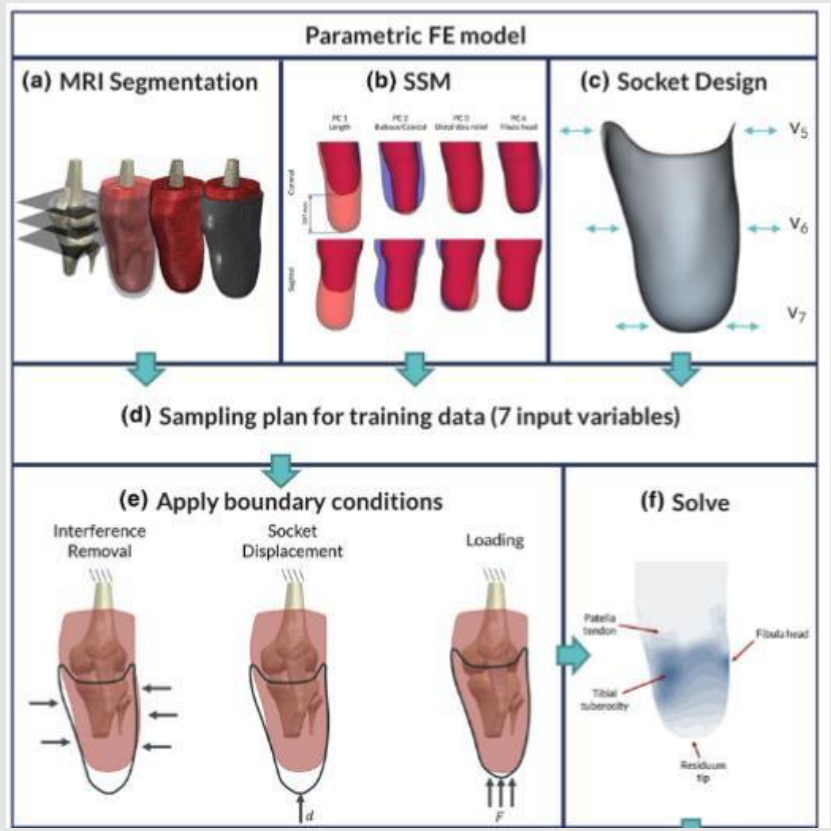
- 3D printing sockets

M. van der Stelt et al., EClinicalMedicine 35 (2021)

Research landscape

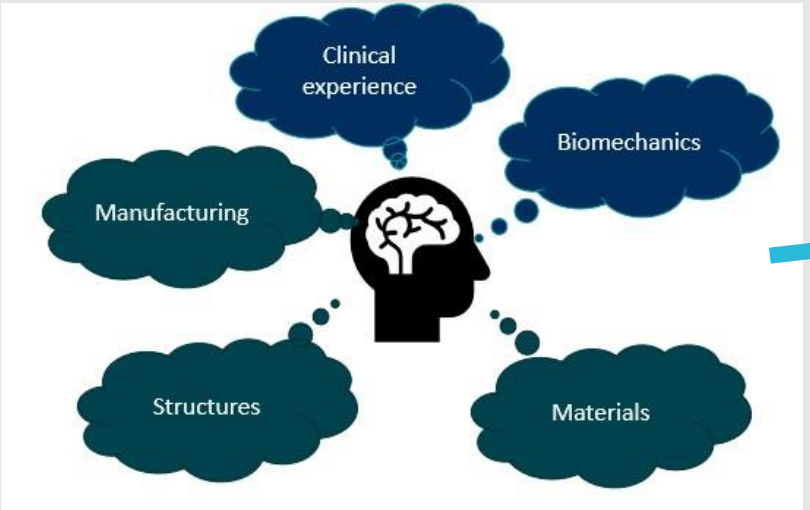


- Comparing socket designs



J. Steer et al., Biomechanics and Modelling in Mechanobiology (2020)

Project snapshot



System design methodology

Strategy generation

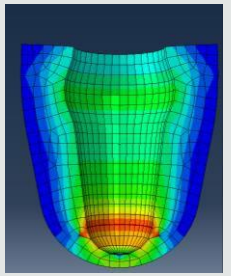
Axiomatic design thinking

Systems thinking

Strategy validation

CAE

Experiment



Significant improvement over base performance?

NO

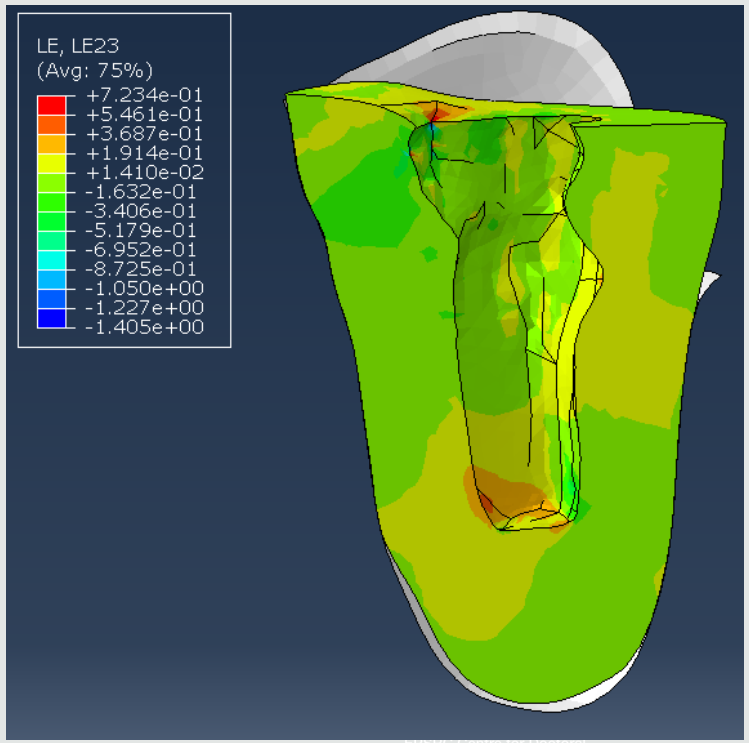
YES

Project snapshot – Design comparison model development

CT-Scan

FEA assembly

Preliminary analysis



Courtesy of Alex Dickinson, Southampton University, RAEng code RF/130 and EU code E19396

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Any input welcome

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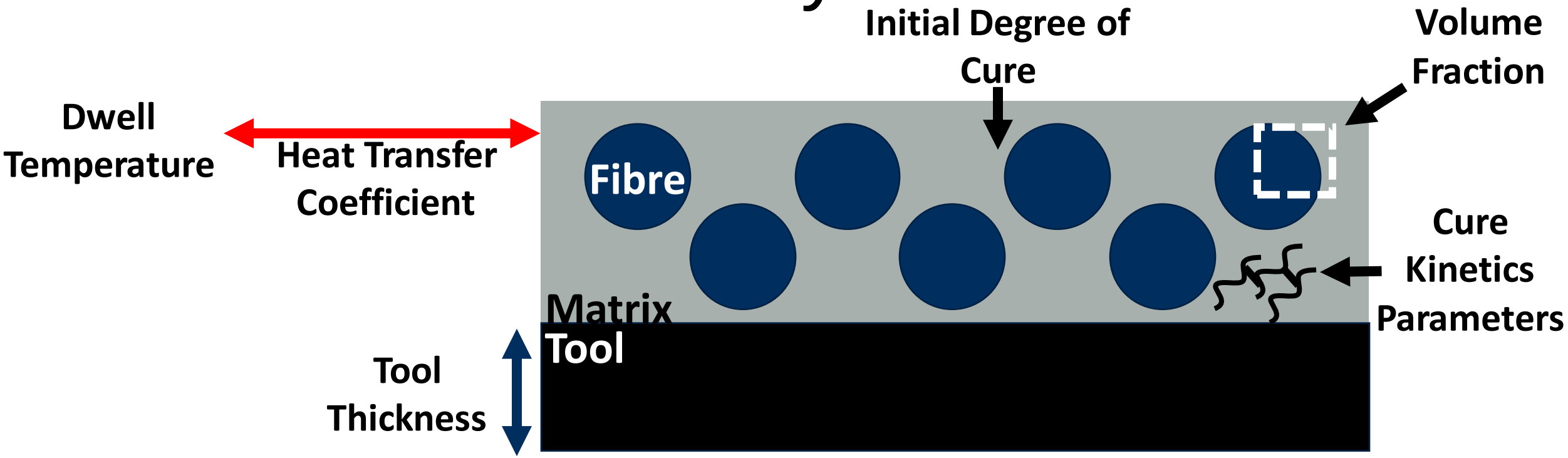
The most influential uncertainties in thermoset curing

Adam Fisher
PhD candidate
University of Bristol, Nantes Université

bristol.ac.uk/composites

Sources of Uncertainty



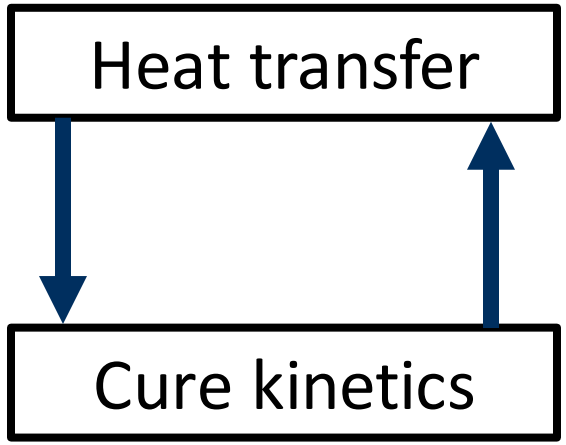
- What can and cannot be treated as deterministic?
- Influence of uncertainty?
- How misleading are deterministic assumptions?

Numerical simulations

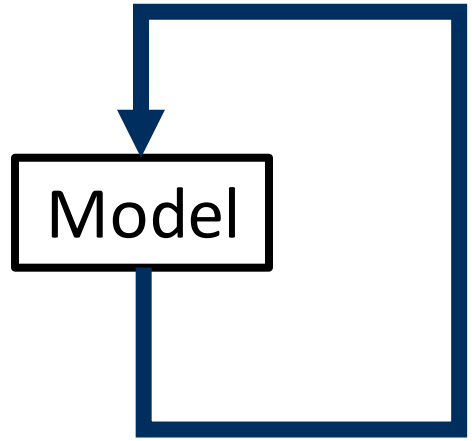
1D

Finite Elements

Model Coupling



Monte-Carlo



Conditions

Tool materials

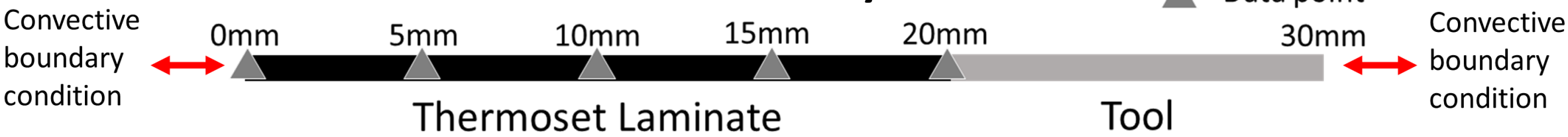
Invar | **Composite**

Heat transfer coefficients

$50 Wm^{-1}K^{-1}$

$120 Wm^{-1}K^{-1}$

Geometry

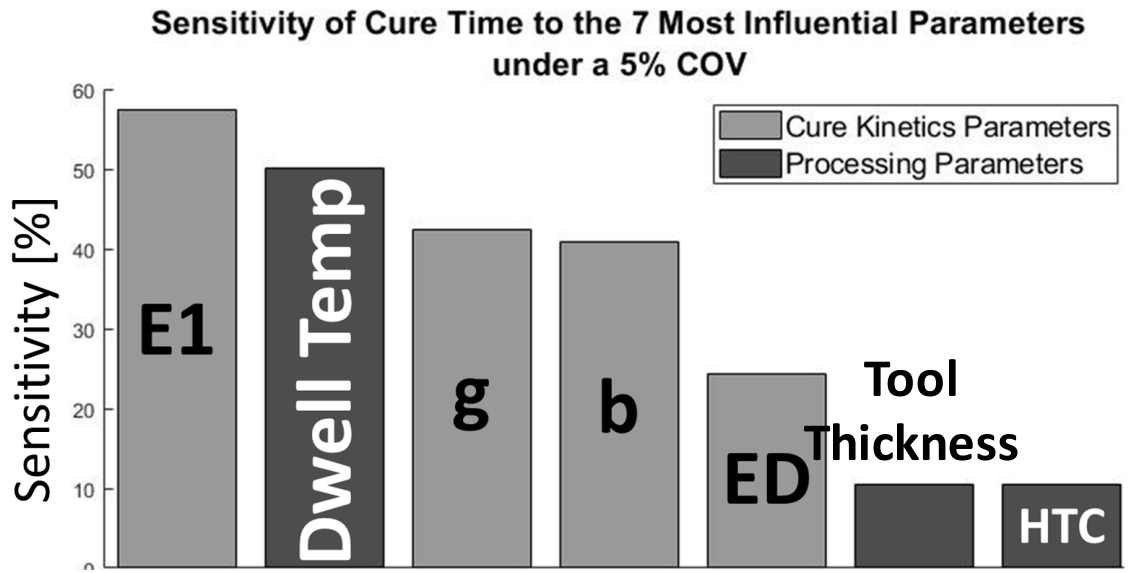


▲ - Data point

Relative Influence

Results of sensitivity analysis

- Influence on cure time dominated by parameters shown
- Influence on temperature overshoot dominated by activation energy E1 and dwell temperature
- Robust to tool material & HTC



Cure Kinetics Equation

$$\frac{d\alpha}{dt} = k_1(1-\alpha)^{n_1} + k_2\alpha^m(1-\alpha)^{n_2}$$

$$\frac{1}{k_i} = \frac{1}{k_{iC}} + \frac{1}{k_D}$$

$$k_{iC} = A_i exp\left(\frac{-E_i}{RT}\right) \quad i = 1,2$$

$$k_D = A_D exp\left(\frac{-E_D}{RT}\right) exp\left(\frac{-b}{f}\right)$$

$$f = w(T_g - T) + g$$

Most influential parameters

Influence of input uncertainties

Monte-Carlo results summary

- Normally distributed inputs resulted in skewed output distributions
- Cure time distributions were shifted the right
- Temperature overshoot distributions were shifted to the left
- Deterministic predictions: excessive cure times and optimistic temperature overshoots