REDEN

Multi-level skin modelling for skin-product interaction

4a Technologietag 2020

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Specialists in
product development
& virtual testing

We
understand
innovation

About Reden

Engineering consultancy company

Specialisation in Modelling and Simulation
(physics based models in the Digital Twin)

SME: approx. 20 engineers

We understand innovation

Edwin Lamers

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Content

- Introduction
- Objective
- Usecase: Hybrid Plastic-Metal products
- Skin
- Skins physical phenomena
- Skin model validation by doming
- Application to VMAP usecase
- Summary

Introduction

Industries of the VMAP consortium

- Wide range of markets
- Very different products
- Large diversity in processes

Nonetheless:
We all use virtual engineering to do process design and enhance product quality

We need interoperability in the virtual domain

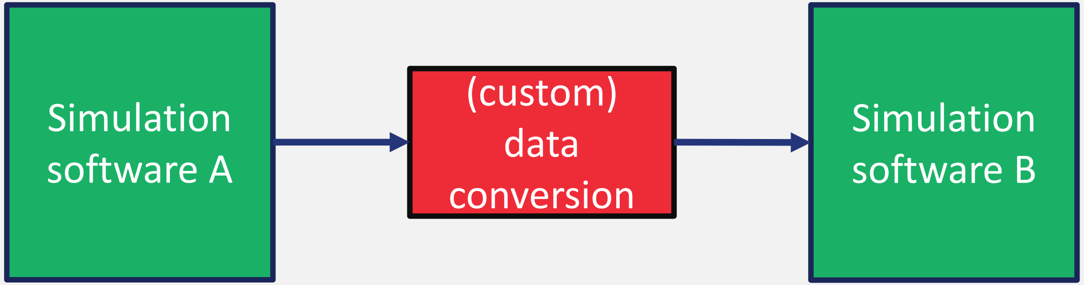
- ➢ Multi-vendor
- ➢ Multi-physics
- ➢

Introduction

Objective of VMAP

Interoperability → seamless transfer of information

Current state



Usually the creation of a custom data conversion is not done therefore chain simulation is not performed:

→ Time consuming

→ Requires specialists

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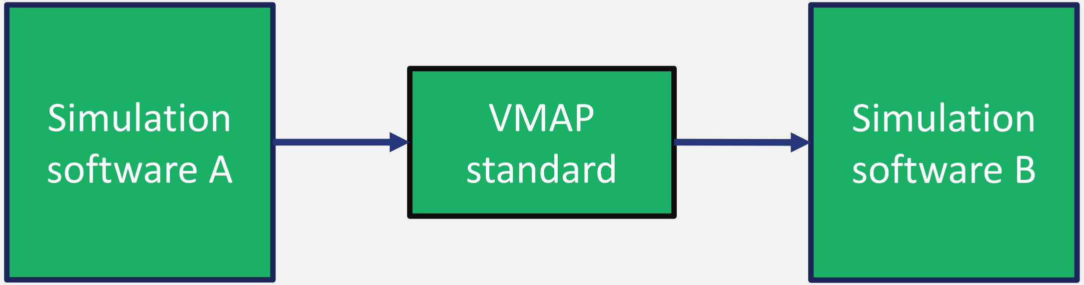
Introduction

Objective of VMAP

Interoperability → seamless transfer of information

Future state



Software A output is software B input:

→ no conversion needed

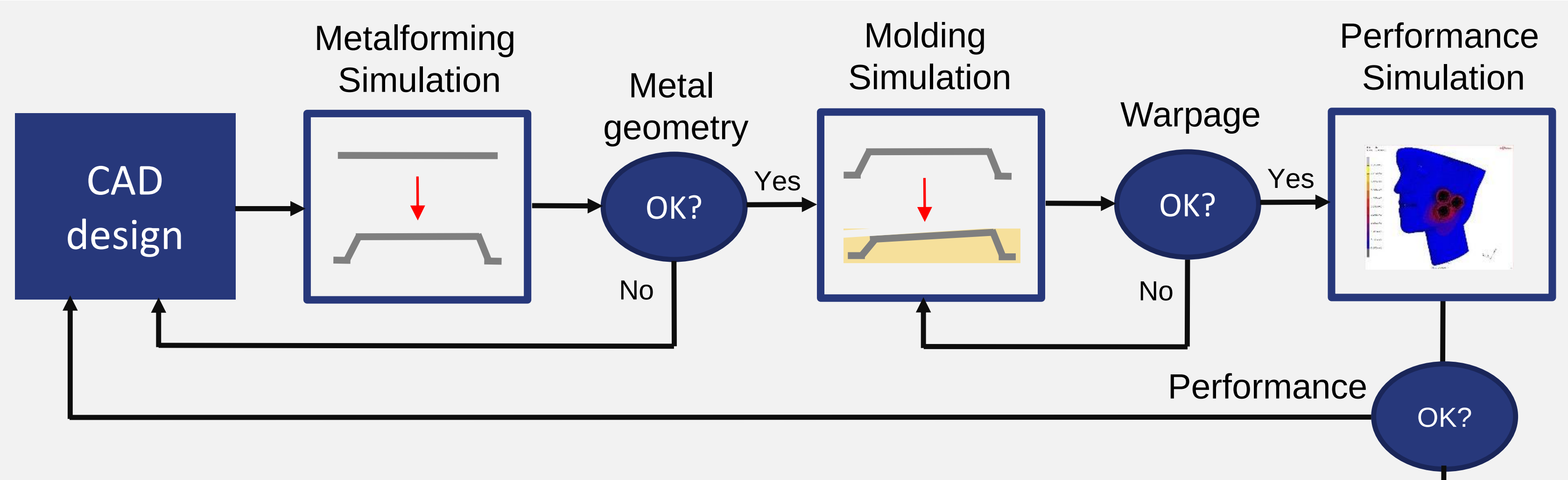
→ Software A and B interchangeable by C, D, E = **Flexibility**

Introduction

UseCase: Hybrid Plastic-Metal products

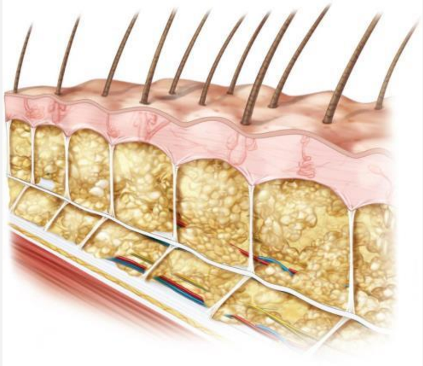
Philips OneBlade

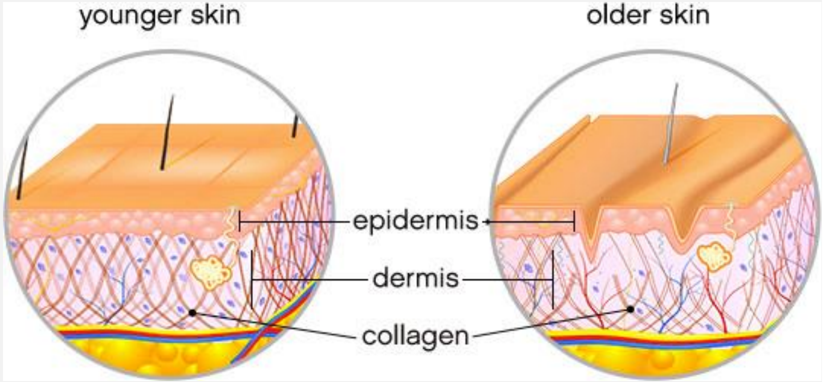
Introduction



Skin

- Multi-layer system to
  - project against outside world
  - regulate heat, moisture
  - sense
  -

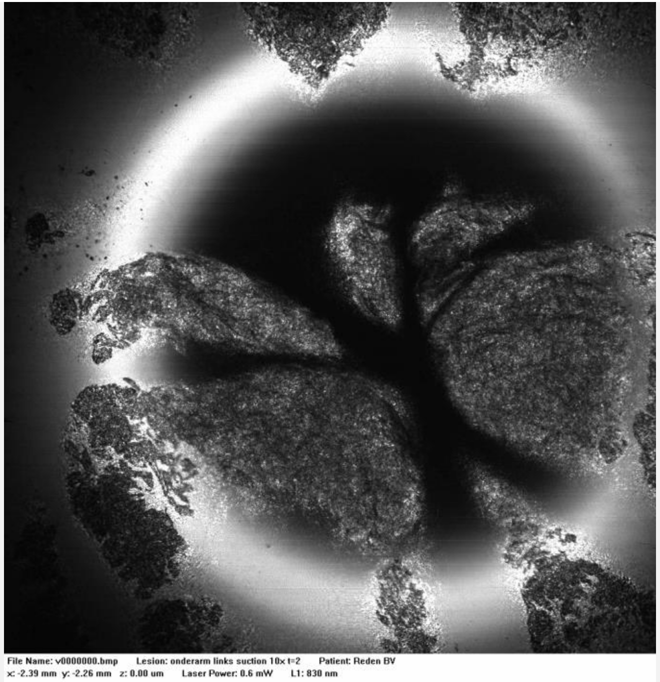




Skin

- Epidermis
  - Stratum corneum
  - Living epidermis

- Stratum corneum
  - “dead-cell” layer on top, contains furrows
  - 0.1-0.2 mm thickness
  - CONFOCAL IMAGING forearm (left)
- Living epidermis
  - contains nerve ends, hair, etc.
  - 0.2-1.0 mm thickness

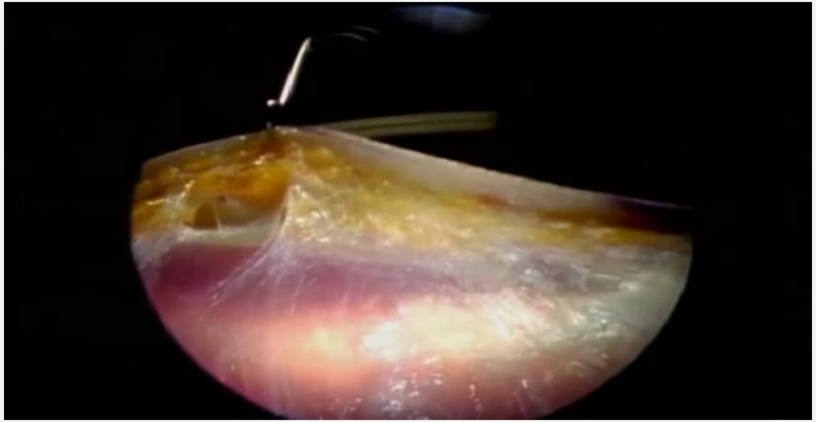


Skin

- Dermis
  - Ligaments of collagen and elastine
- Hypodermis
  - Fatty layer

Which slide on top of

- Muscles
  - Controls movement

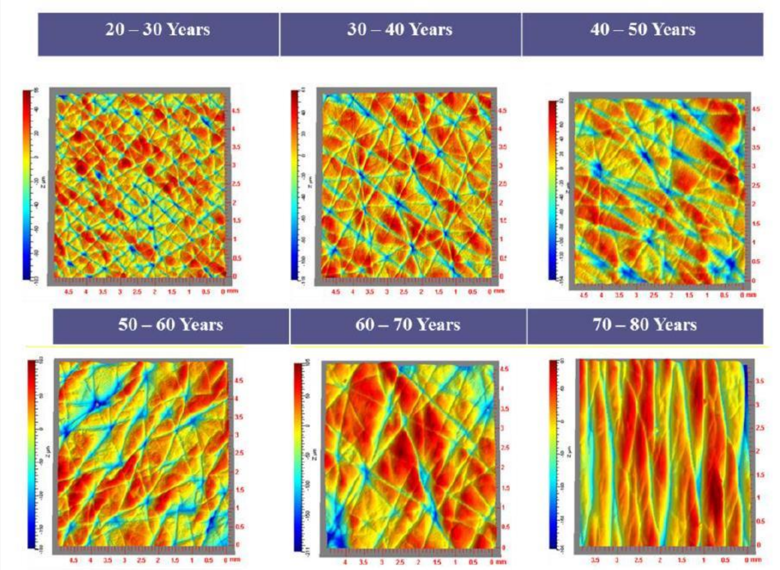


ADF Films-productions and Cerimes, **Promenades sous la peau**, https://www.youtube.com/watch?v=eW0lvOVKDxE

Skins relevant phenomena

- Properties vary widely between persons:
  - Age
  - Diseases

- With environment:
  - Humidity



Skins relevant phenomena

- In-plane properties vary in:
  - Direction
  - As a function of strain (non-linear)

- “roughness” reduces with strain increase

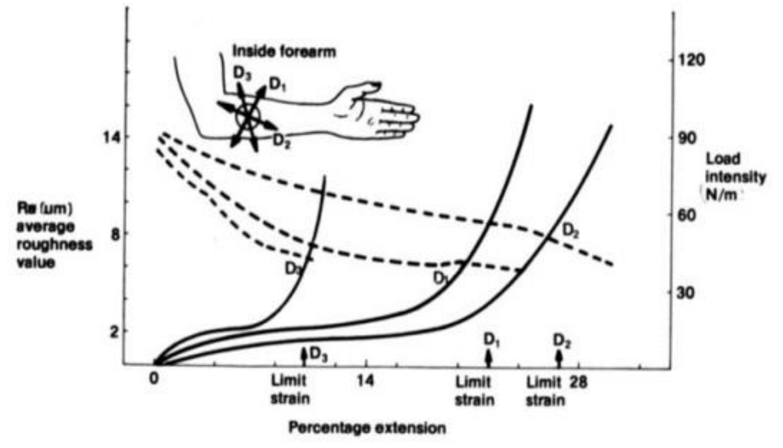
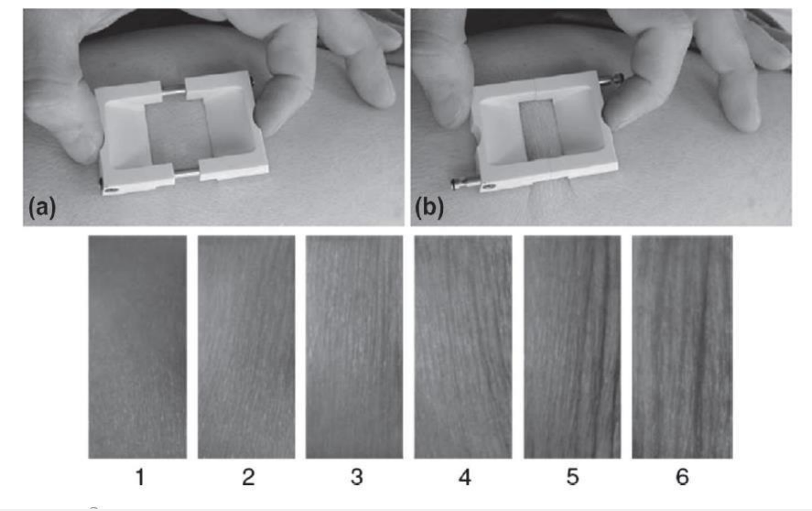


Figure 10.1 Directional variation in load–extension response (——) and alterations of roughness values with extension (- - -)

Ferguson & Barbenel, 1981

Skins relevant phenomena

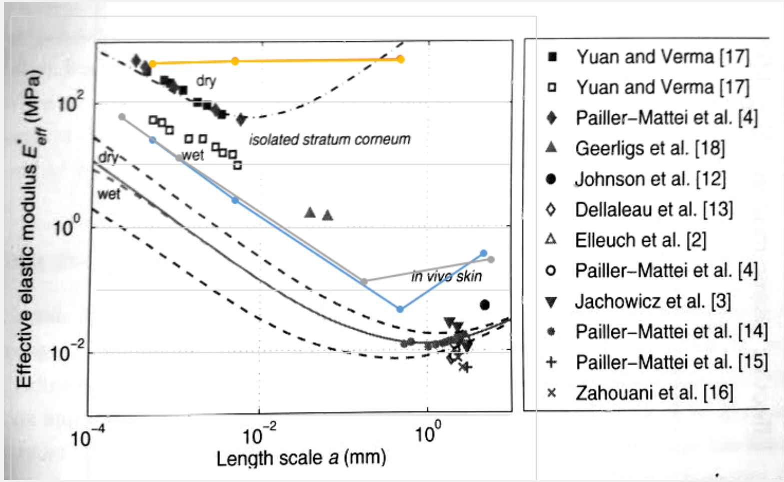
- In-plane compression tests show complex wrinkling behaviour
- At small in-plane compression strains small high frequency wrinkles occur
- Larger in-plane compression strain give larger wrinkles with smaller wrinkles superimposed



Skins relevant phenomena

- Out-of-plane measurements (compression) show indenter size dependent properties (spherical indenters)

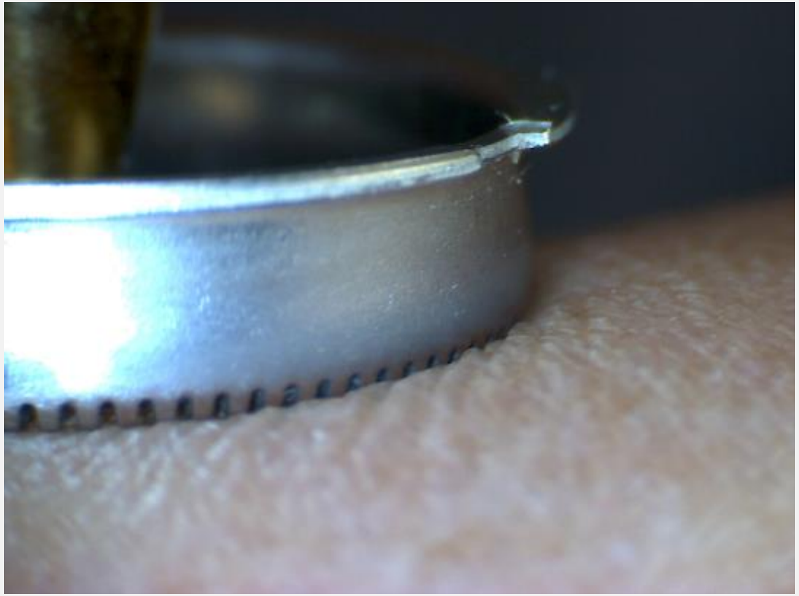
- Lower stiffness at larger indenter sizes



Skins relevant phenomena

- Relevant for usecase
  - detail during shaving
  - where is the skin supported, and how
  - pressure distribution of product on skin

- Large scale differences
  - Micro near head
  - Macro to “fix” the skin

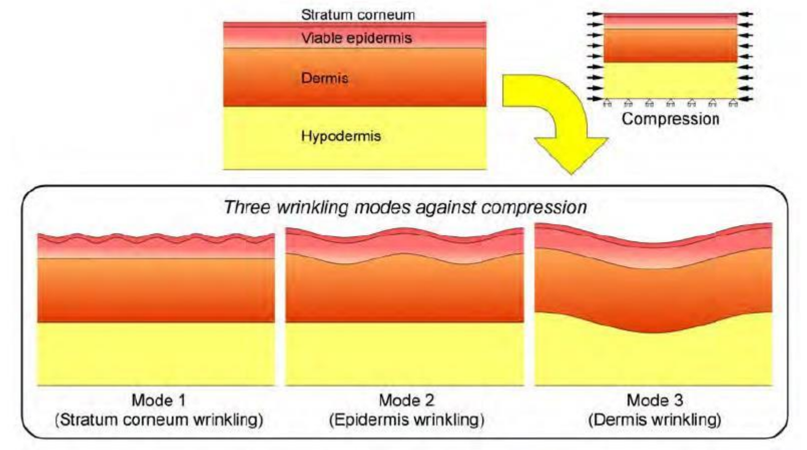


Skin model

- Skin is modelled as a multi-layered (5) solid with varying material properties for each layer.

Material properties fitted from in-plane tensile tests and out-of-plane compression tests:

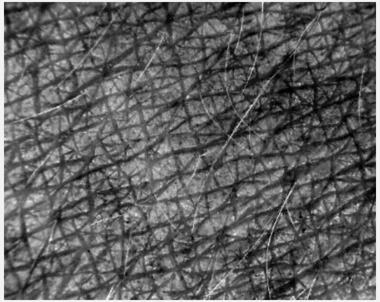
- While maintaining correct wrinkling behaviour
- incorporation size effects on stiffness
- Stiff on top, less stiff below



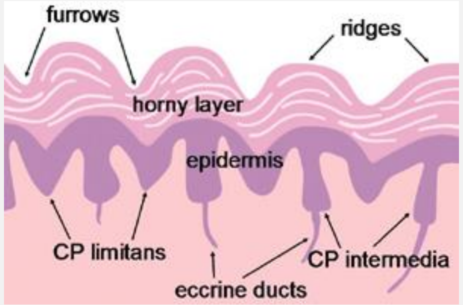
Skin model

Surface texture in model

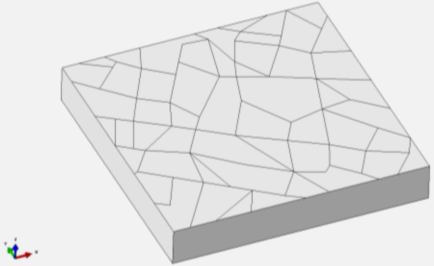
Unit cell based approach



Picture of skin texture



Furrows and ridges



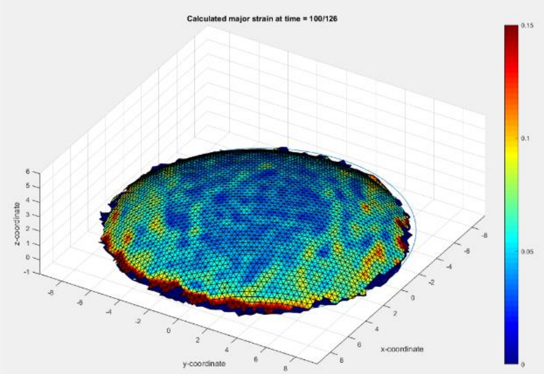
5x5 mm unit cell based on picture

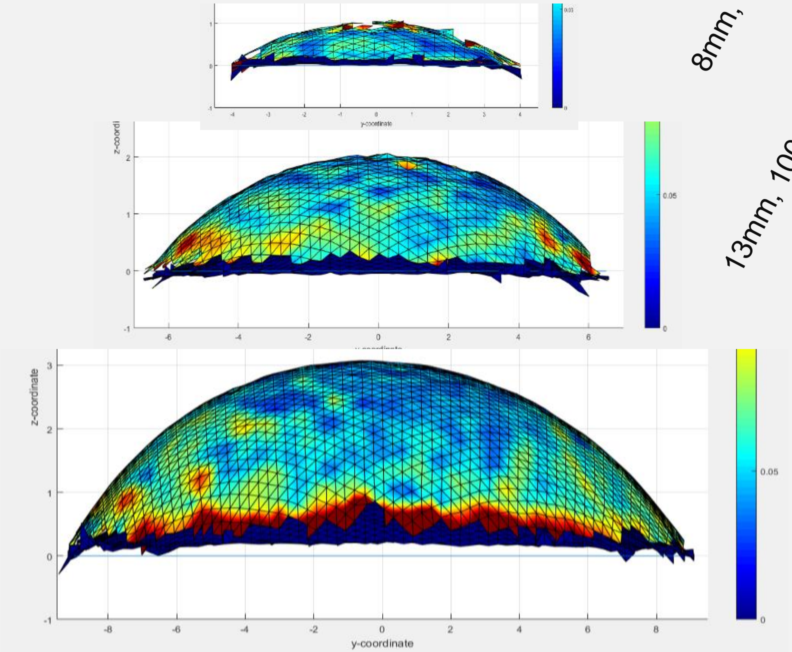
Skin doming

- Validation of skin doming
  - Suction test on skin (forearm)
- Varying
  - Cup size (D = 8 – 18 mm)
  - Pressure (0 – 100 mbar suction)
- Aramis system used to measure strain distribution at surface resulting in 3D strain field. Measured @Philips

Skin doming

- Validation measurements skin doming
  - Principal strain upto approximately 10%
  - Height approximately 3-4 mm





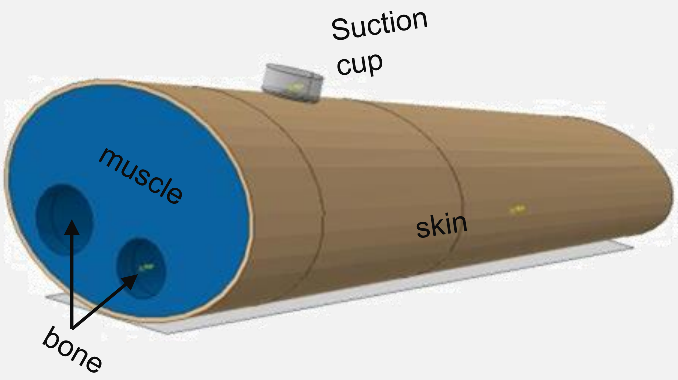
8mm, 100 mbar

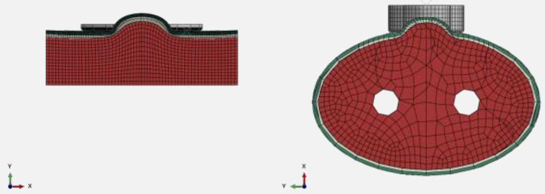
13mm, 100 mbar

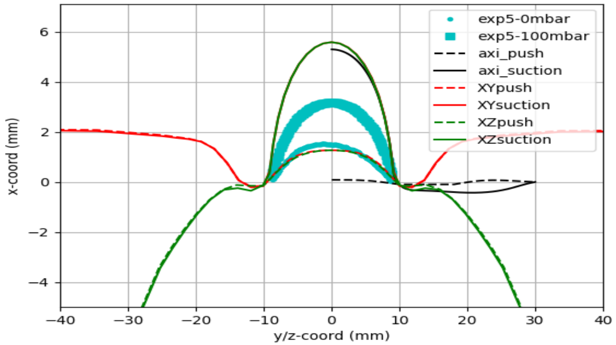
18mm, 100 mbar

Model setup skin doming

- Forearm model







Application example VMAP

The problem that we try to solve in VMAP is the problem of scale:

Detailed geometry should be taken into account to get correct mechanical skin behaviour.

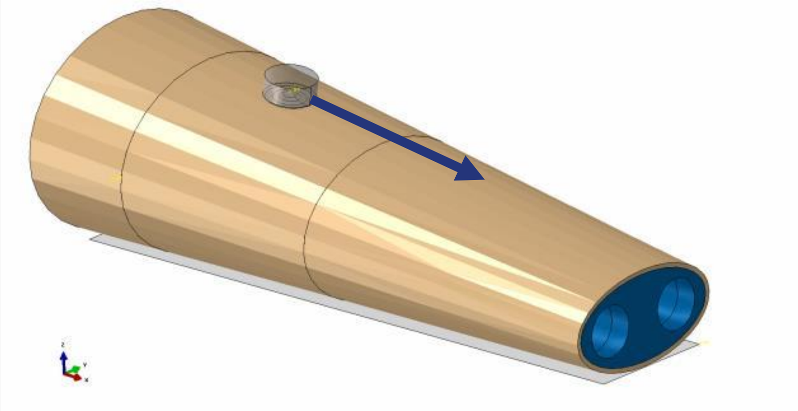
A large part of the geometry should be taken into account to get correct boundary conditions.

This leads to prohibitively large simulations and long run times.

Solution:

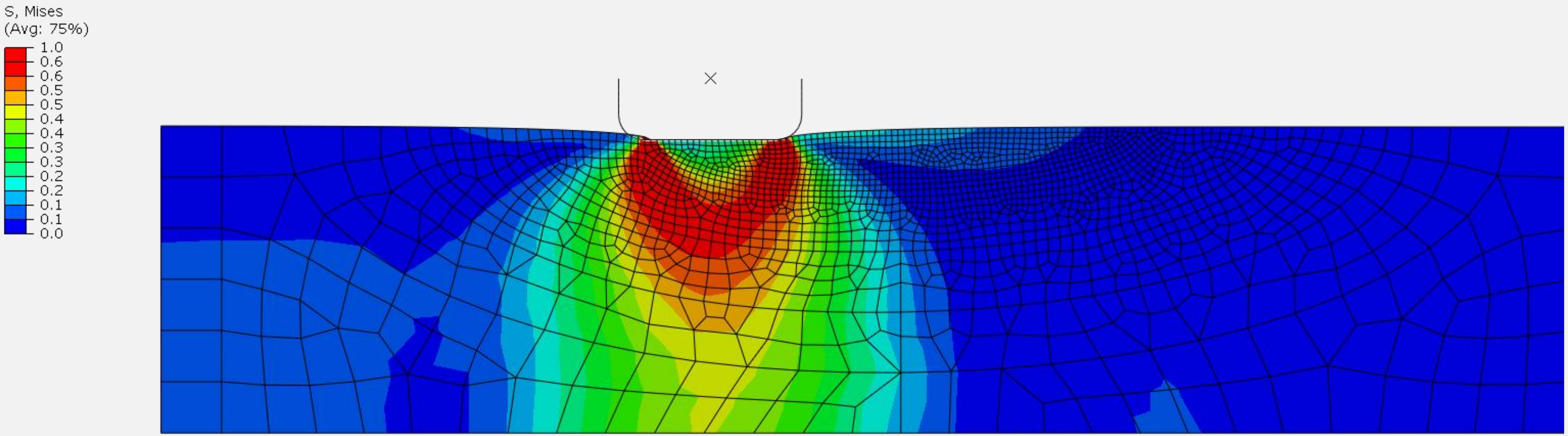
Start with a coarse (locally refined) model

Apply coarsening/refinement during the simulation where applicable



Application example VMAP

- The model problem is shown below in 2D plane strain: a rigid indenter is pressed into a block of elastic material and moved towards the left. Only the region below the indenter is meshed fine.



Application example VMAP

Strategy:
Moving local refined mesh with shaver head

Application example VMAP

Strategy:
Moving local refined mesh with shaver head

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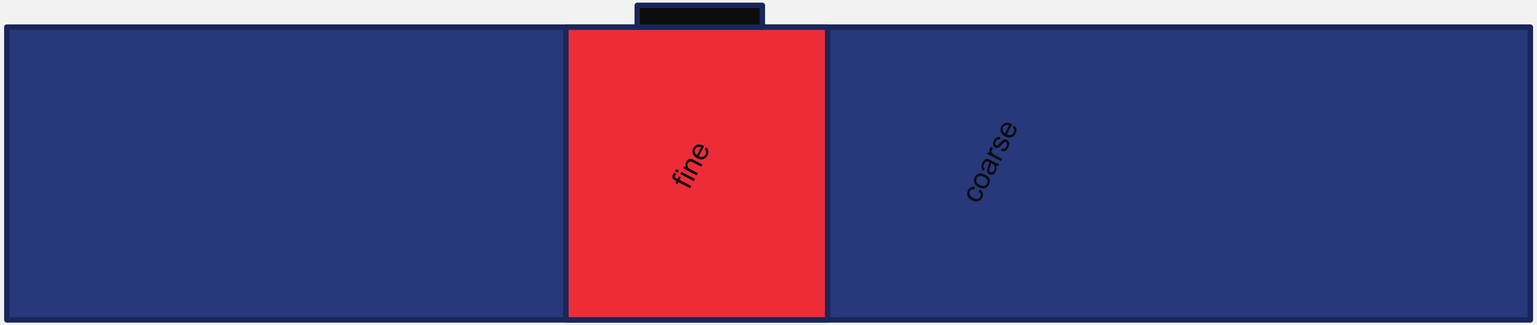
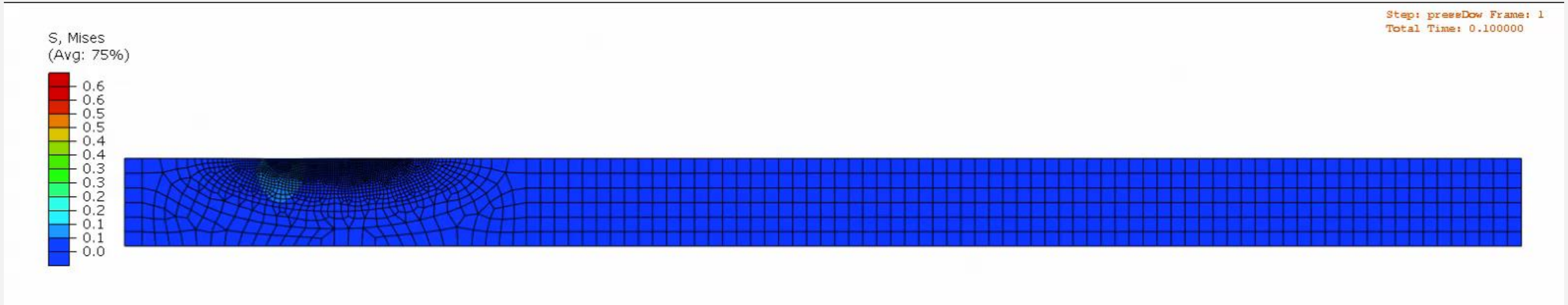
Moving local refined mesh with shaver head



Application example VMAP

This simulation includes the relevant steps:
Creating a new mesh where the appropriate region is coarsened/refined
Mapping the solution from the old mesh to the new
Continuation of the simulation



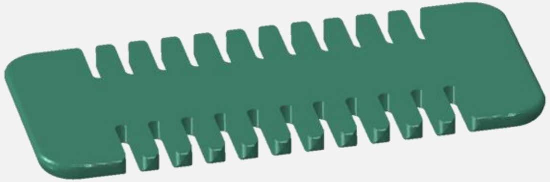
Application example VMAP

Philips ***Oneblade***

Teeth locally slide over skin

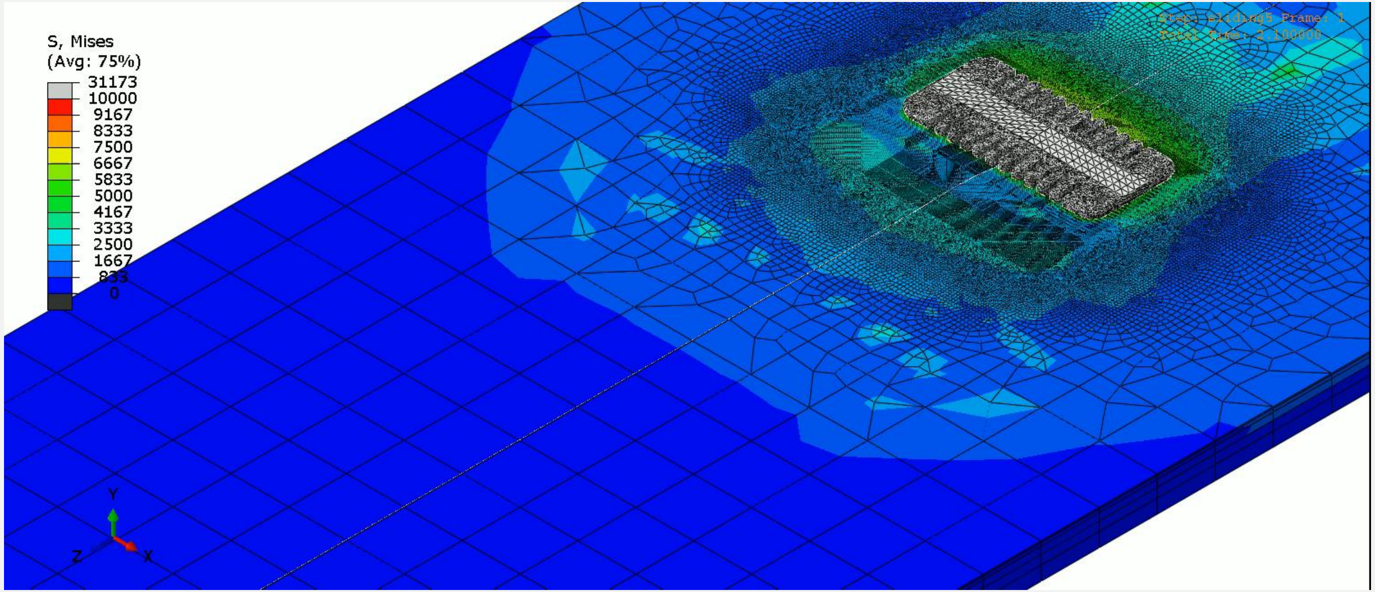
Distance between teeth small compared to size of human head (or arm)

Use of dummy blade teeth in this presentation to show the concept of the simulation strategy



Application example VMAP

Local refinement and coarsening for Oneblade example



Summary

Modelling skin:

- Multi-layer approach is required
- Large property differences between layers
- Since so many parameters are involved, several different test are required to create sensible material fits
- Still dedicated models for specific applications are required

Benefits:

- Communication with different software packages possible through VMAP standard
- Reduced simulation throughput time for problems where multi-scale moving phenomena play an important role

Outlook

Strategy works

Next step: apply strategy to forearm, and validate for demonstrator case

Feedback results for Philips optimisation case and close loop

Acknowledgements

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Thank you for your attention
Questions?