Tensor Visualization Guiding Component Design

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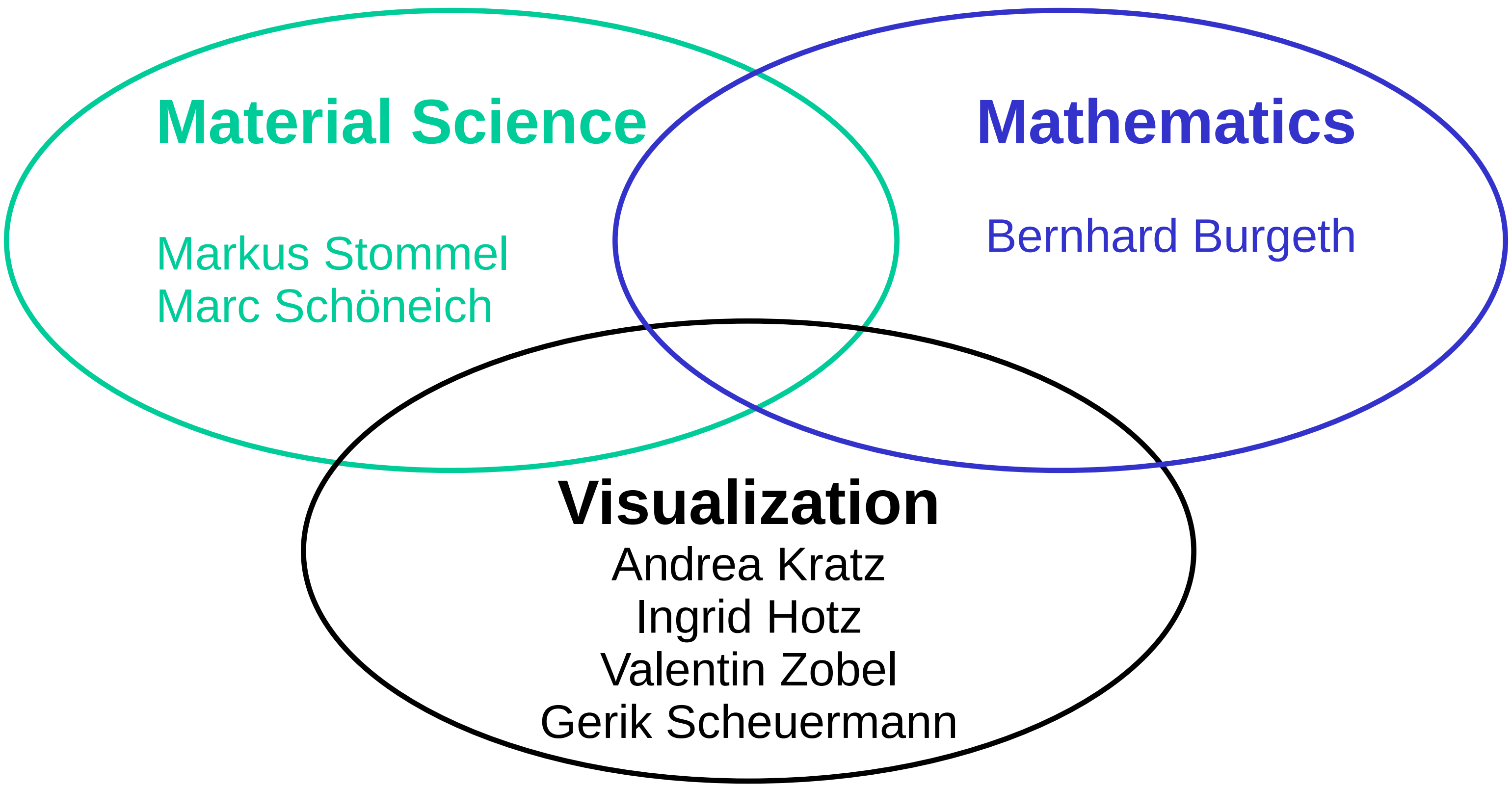
What do all these authors do?

- Applied problems require interdisciplinary teams:

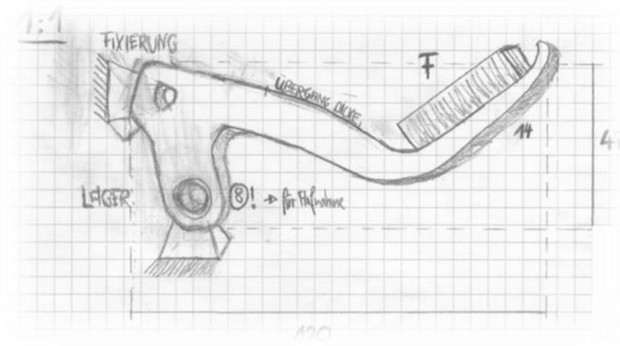


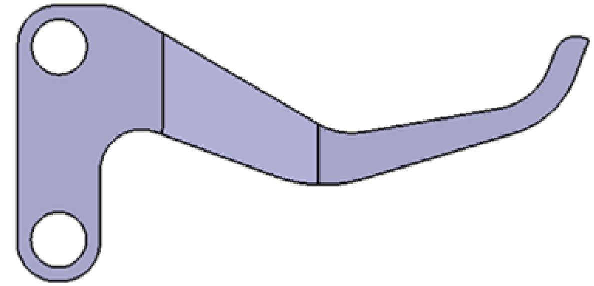
Engineering Problem

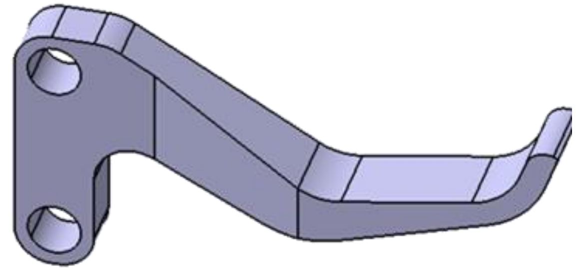
- Design of a brake lever (bike)
- Goal:
  - Replace metal by thermoplastic polymer
  - Reduce material, energy and production costs
  - Reduce weight

1. Basic Design

- Draw a sketch
  - Obey design constraints (Fixations, other components, ergonomy)
- Create a 2D CAD Model
- Extend to 3D CAD Model





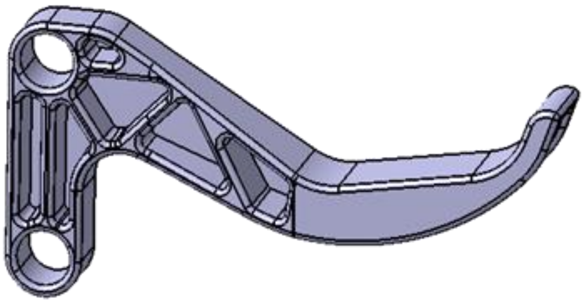


Design Improvement

- Production Constraints
  - Injection molding requires thin walls
    => Design space

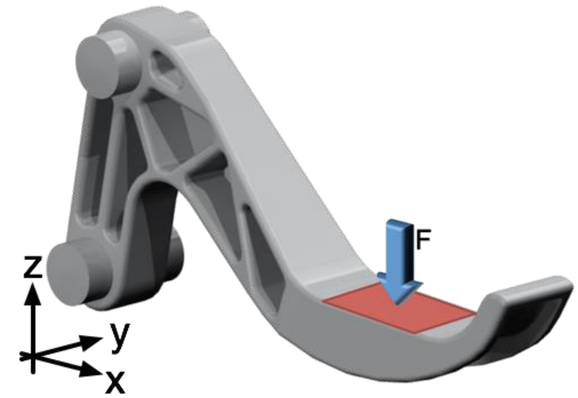
- Component Constraints
  - Loading requires certain stiffness

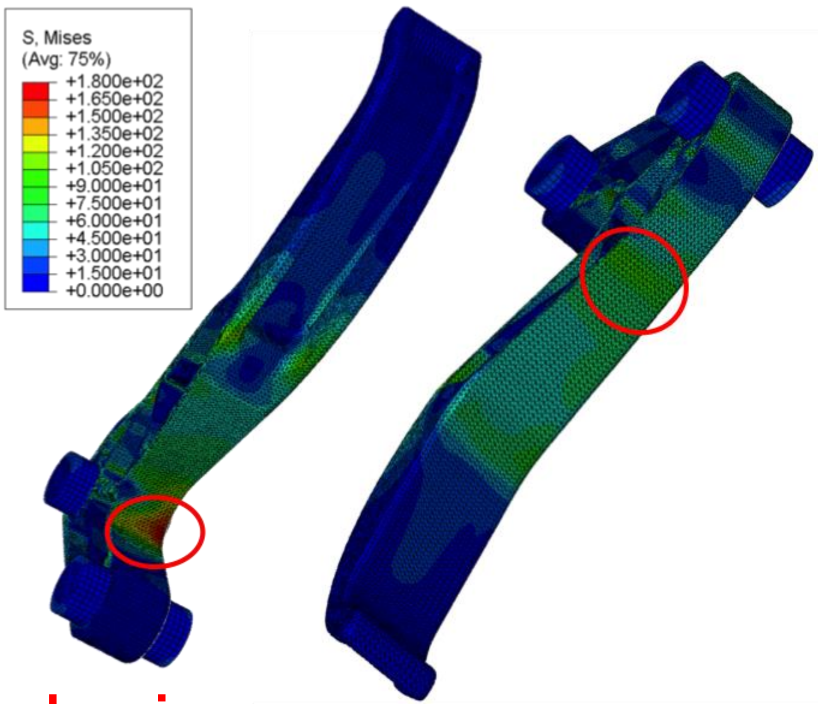
  => Design rib structures
  (following textbook rules)



2. Virtual Test

- Define load condition.
- Perform FE Simulation.
  - Define FE grid.
  - Setup FE model.
    (Material model, load)
  - Do FE simulation.
  - Visualize the results.

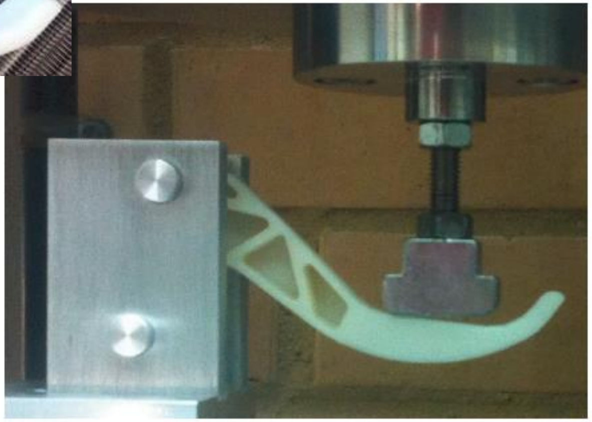




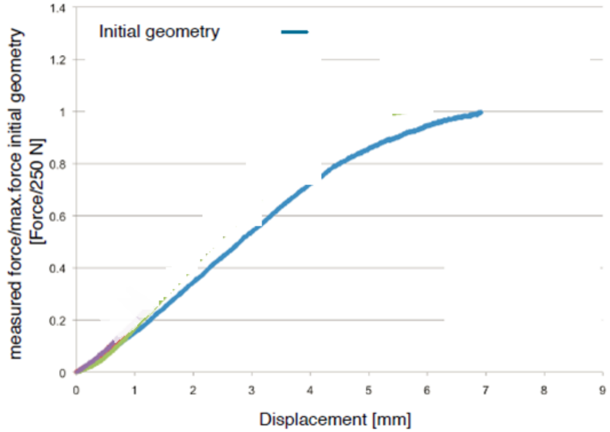
- If stress too high, change rib design.

3. Physical Test

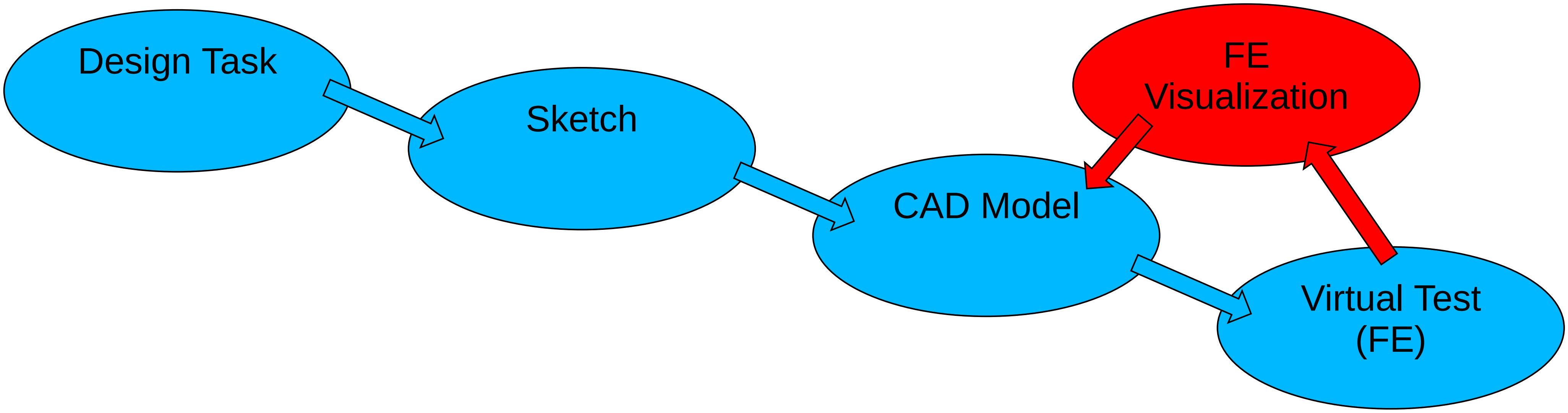
- Build a physical prototype.
  - Use rapid prototyping.



- Perform physical test.
- Visualize the result.
- If result differs seriously from FE,
  - Check test conditions
  - Check physical prototype
  - If checks ok, go back to virtual test: check FE model (esp. material law)



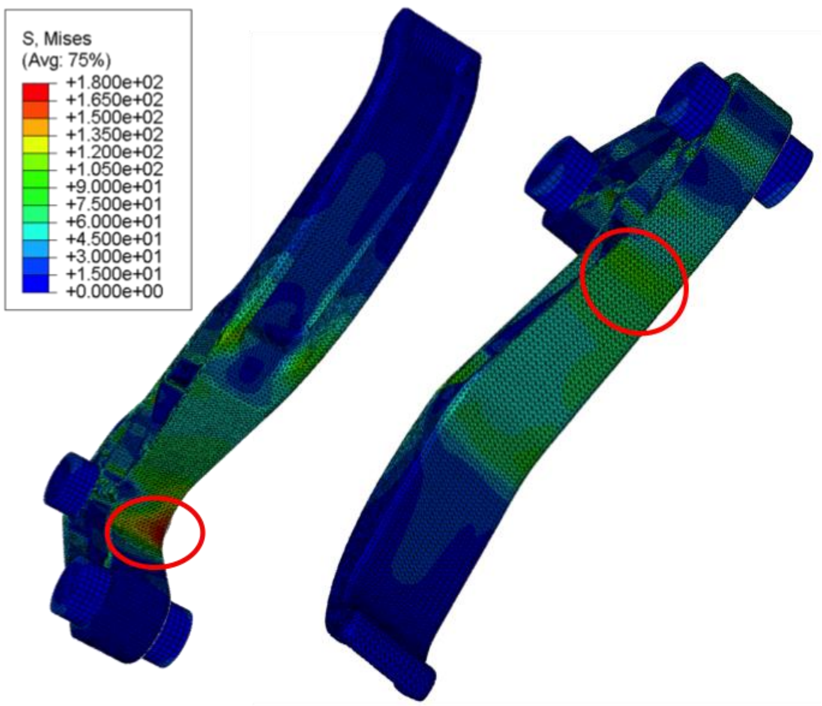
Engineer‘s Workflow



- FE-systems only use scalar visualization.
- Why?
- What is wrong with our tensor visualizations?

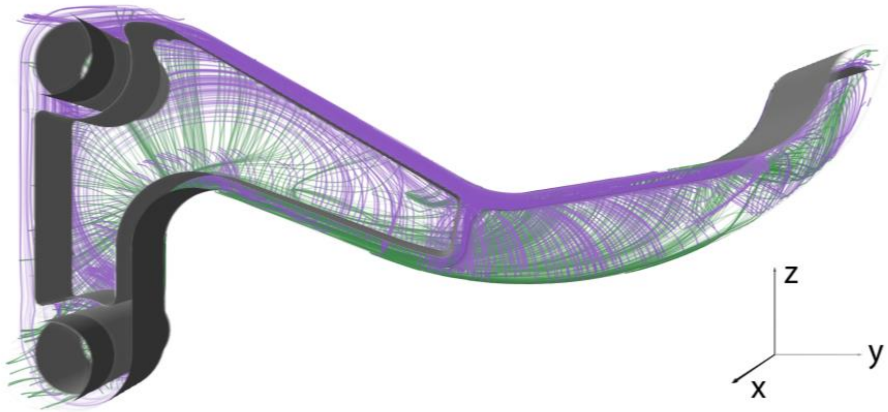
The insight problem

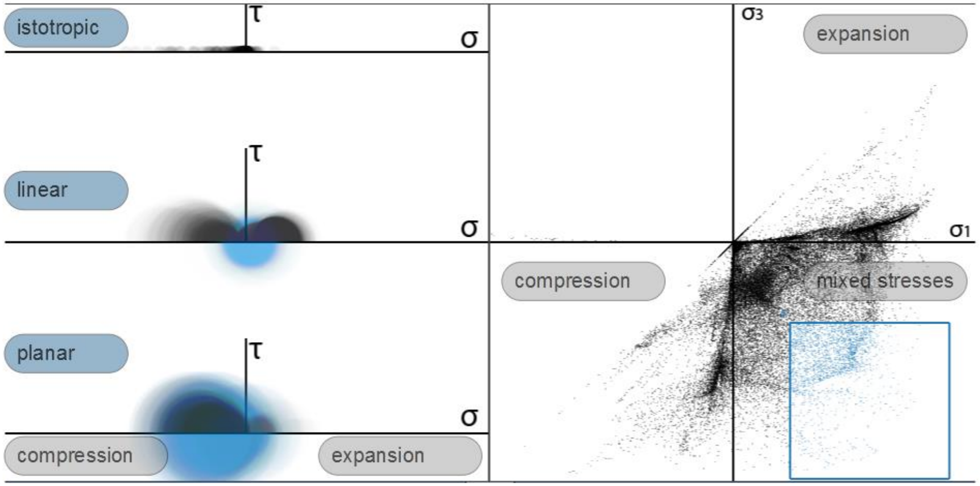
- Visualization aims at insight.
  - Insight leading to better design.
- Scalar Visualization
  - High value indicates problem and informs about its position.
  - Low values indicate good design.
  - **Insight!**



The insight problem

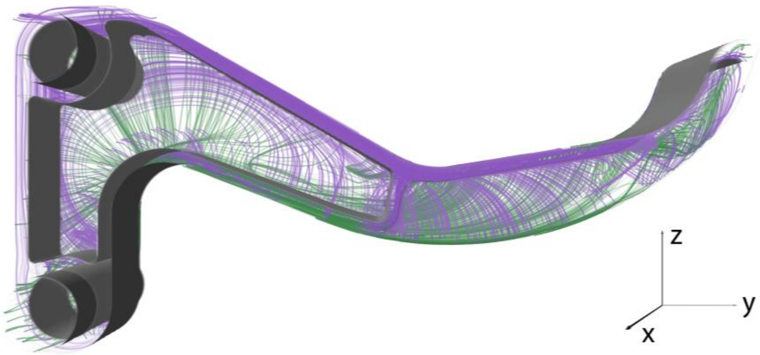
- Tensor Visualization
  - It gives more information.
  - Engineers miss this information.
  - Engineers have no clue what it means for design!
  - **No Insight!**

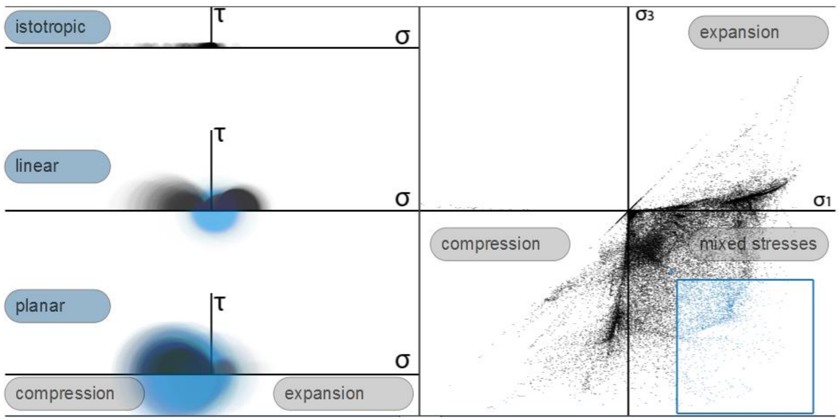


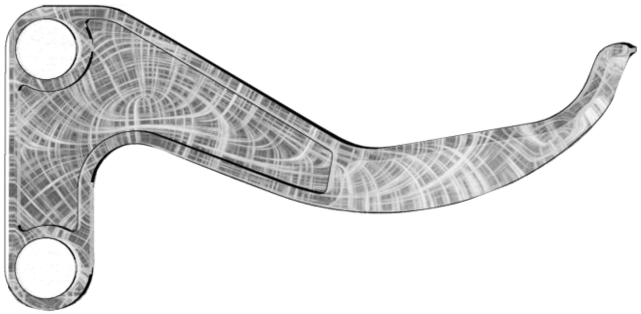


Our Approach

- Try many tensor visualization techniques.
  - Check which lead to insight concerning design!

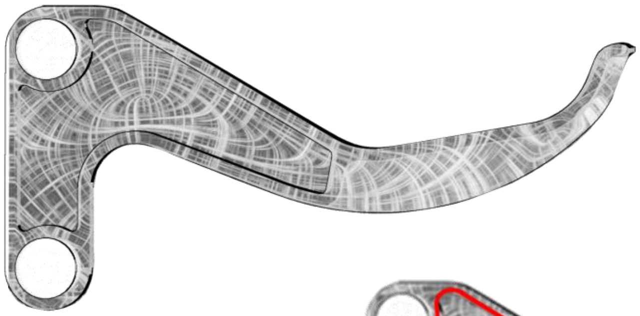




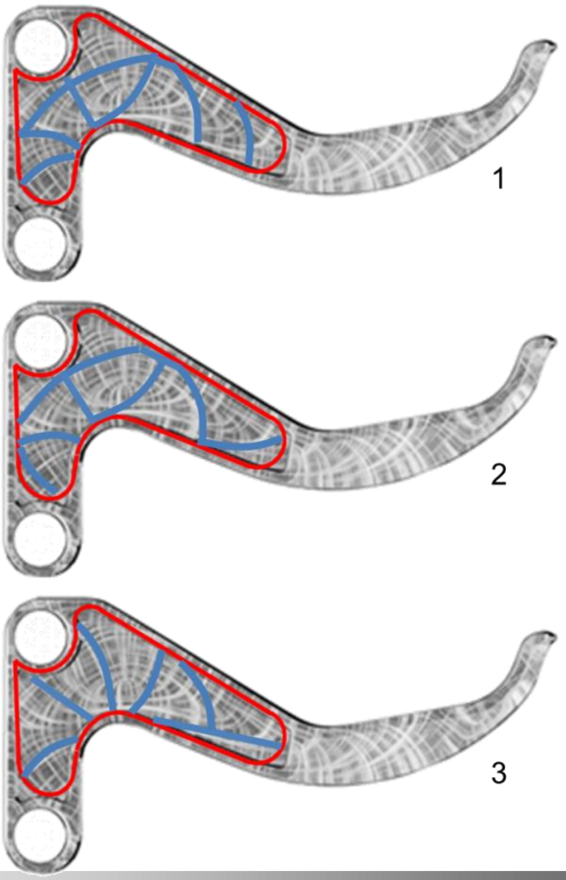


Our Successful Candidate

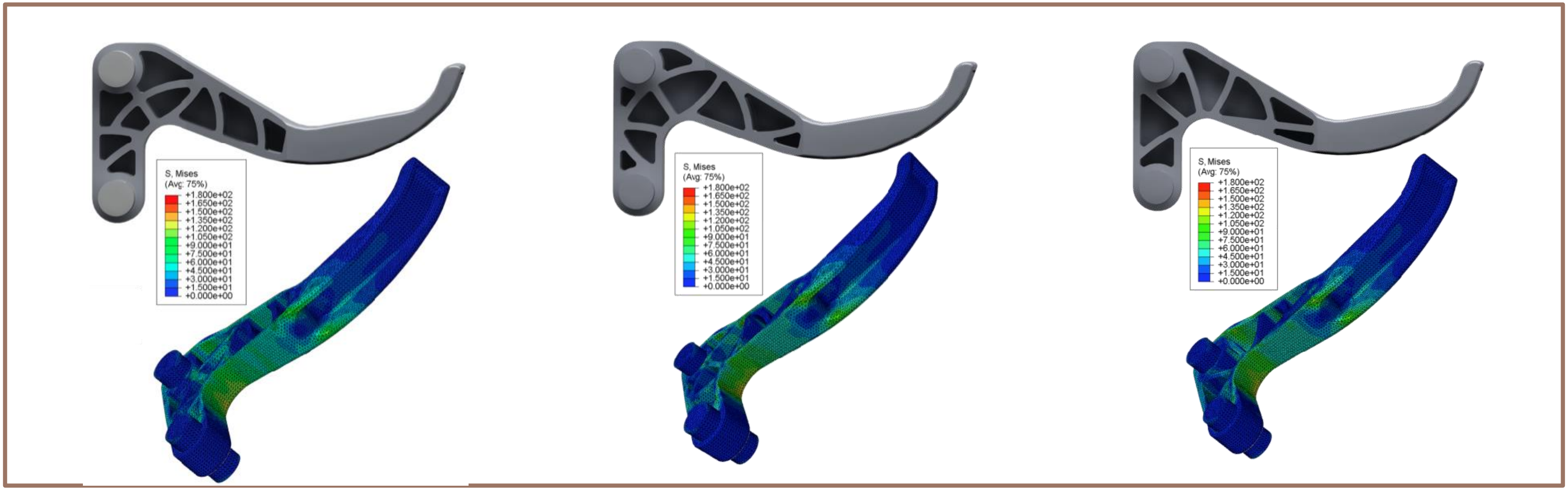
- Fabric-Like Texture [Hotz et al. 2009]



- Engineer can use this technique to change his rib design.
- Marc created three alternative rib designs without additional trys.



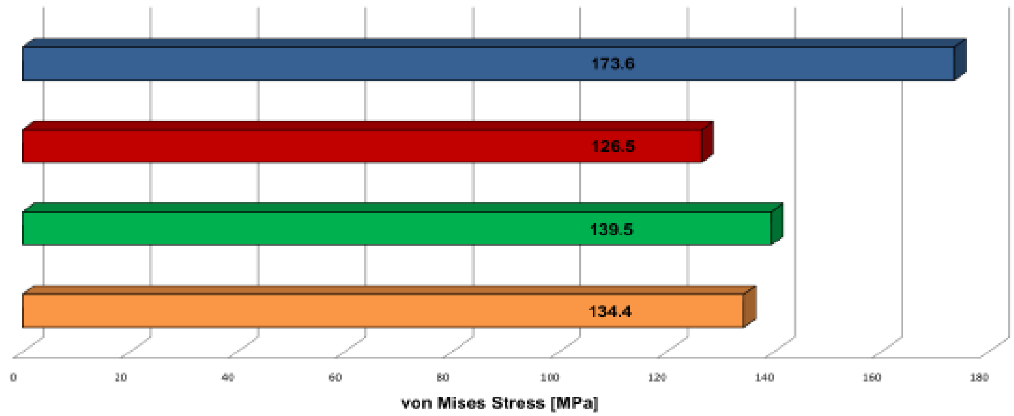
FEM Simulations

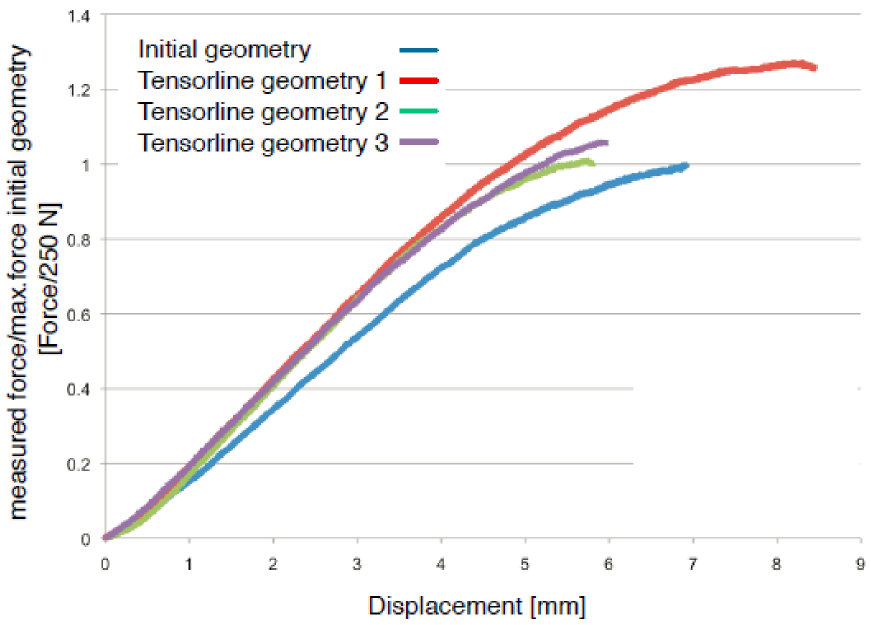


- Three CAD models were created.
- Volume equals old design.
- New models fulfill all design contraints.
- FE: equal load condition, same material law.

FE Result

- All three new designs:
  - Lower maximal stress
  - Higher stiffness





Are you excited?

- It is one of the most boring visualizations, Gerik ever showed…
- He says that the approach worked, so what?
- It would have been more interesting to hear that it did not work…

Well, you are not excited, because you are no mechanical engineers…

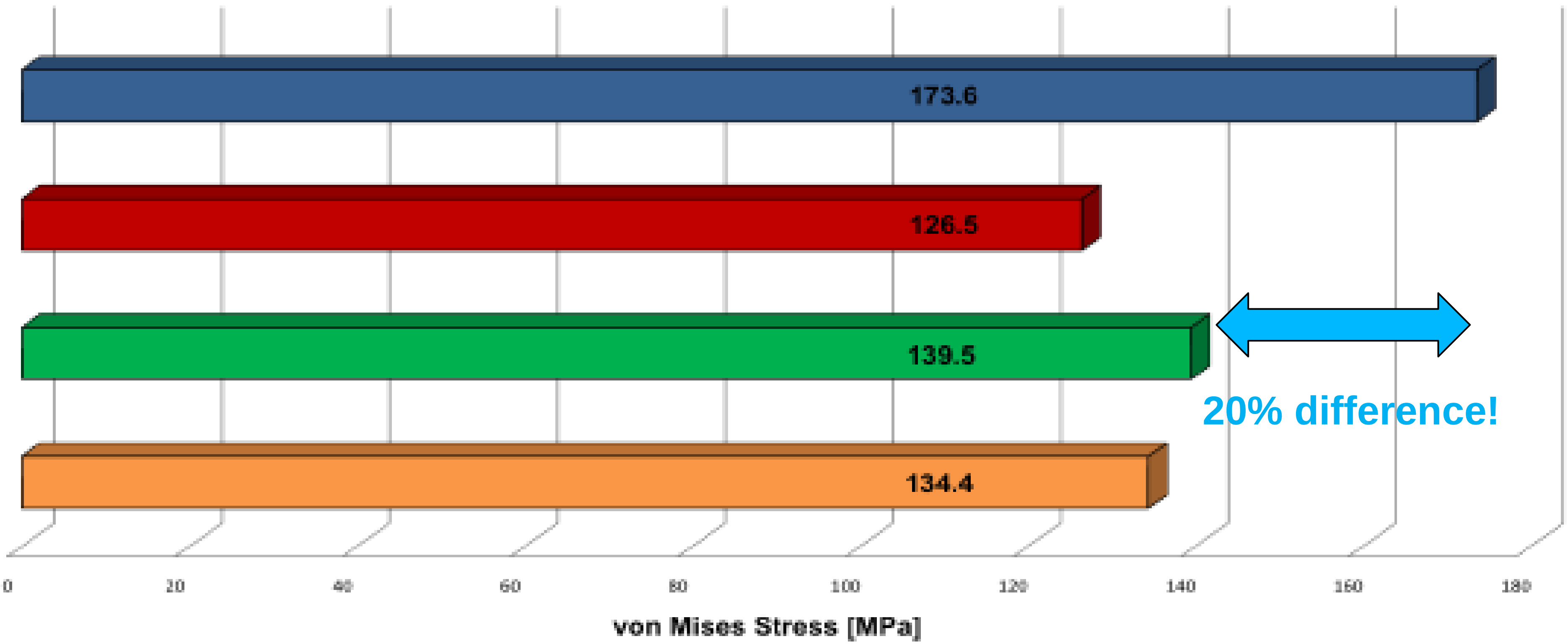
You do not really speak their language!

What would an engineer say?

- This is a mistake – your measurements are incorrect.
- This is a fake.
- Your "standard" is a bad design.
- What were the exact test conditions?
- …

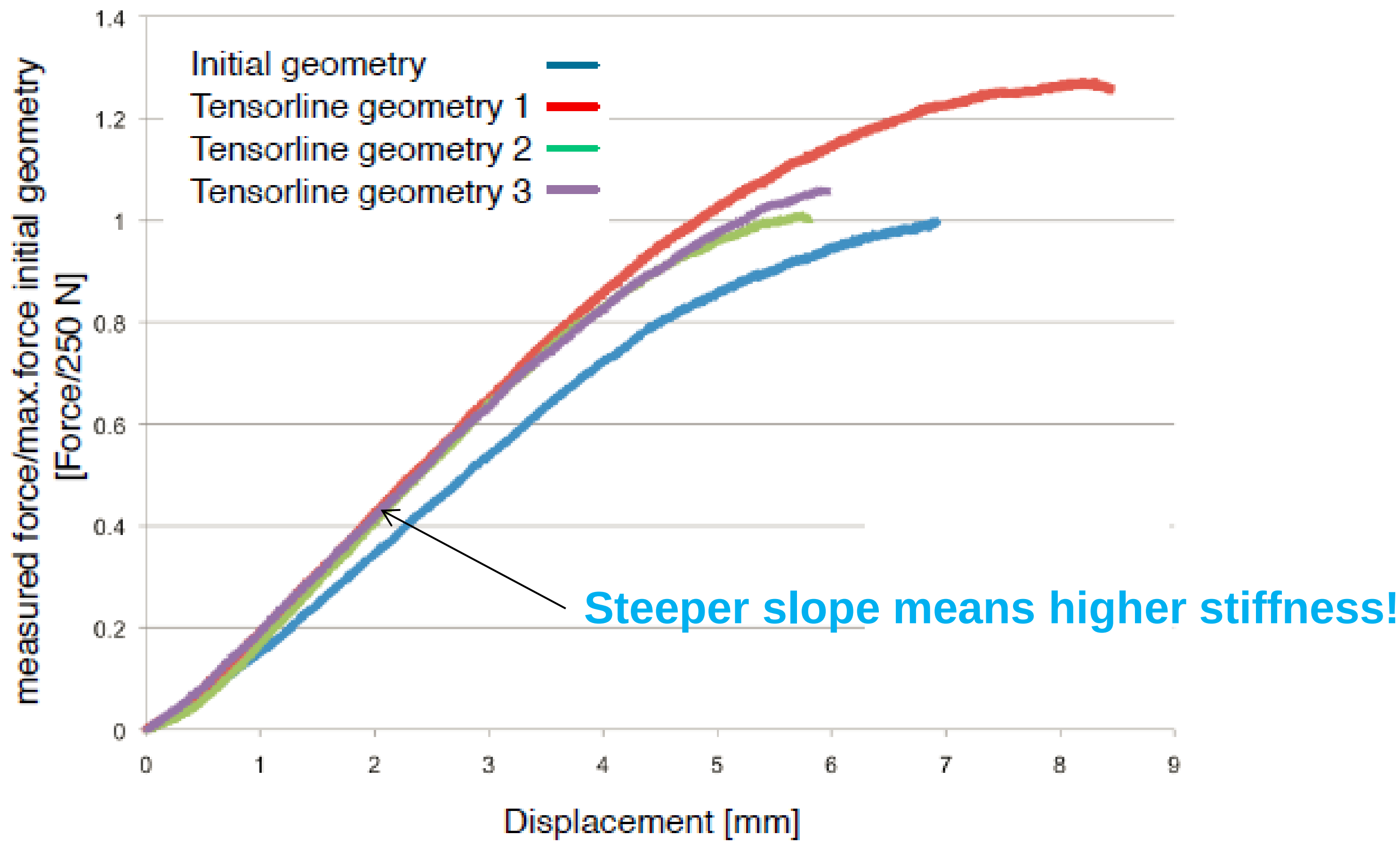
Once we have proved that it is not wrong, they will be excited!

Success in Engineer‘s Terms



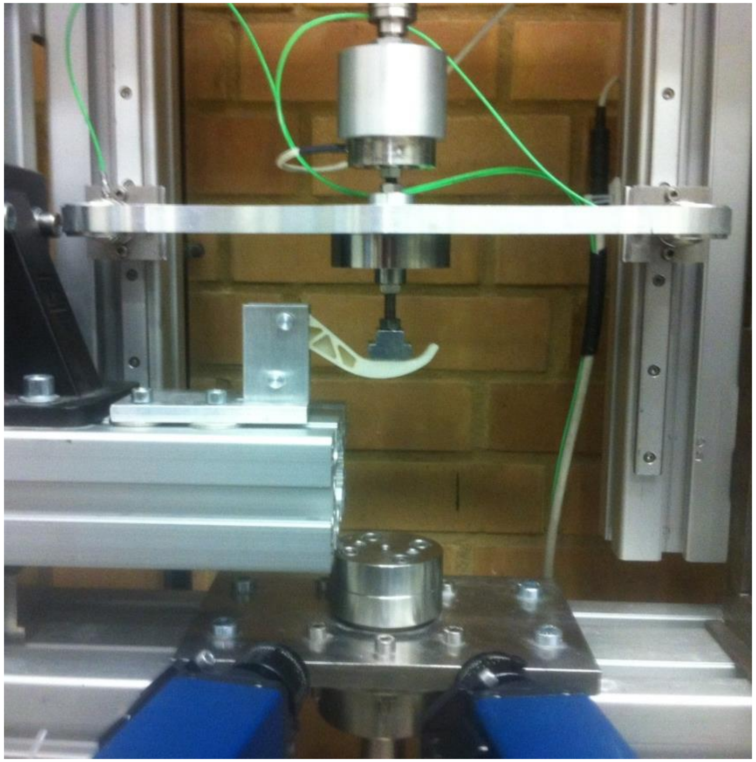
New designs have 20-28% less maximal stress!
But same amount of material (98-99%)!
Substantially better than standard design!

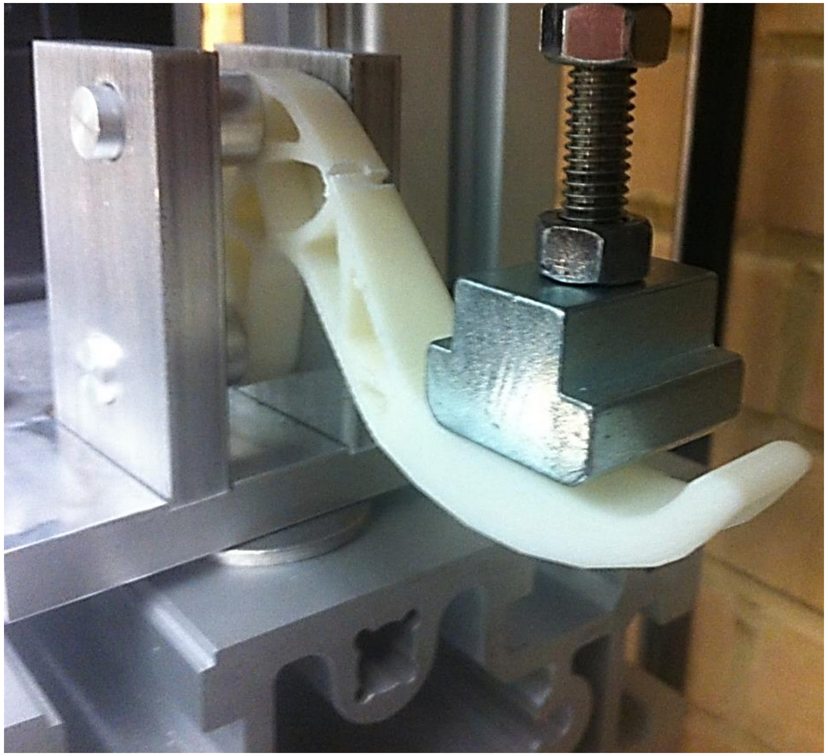
Success in Engineer‘s Terms



New designs have ~20% higher stiffness!
But same amount of material (98-99%)!
Substantially better than standard design!

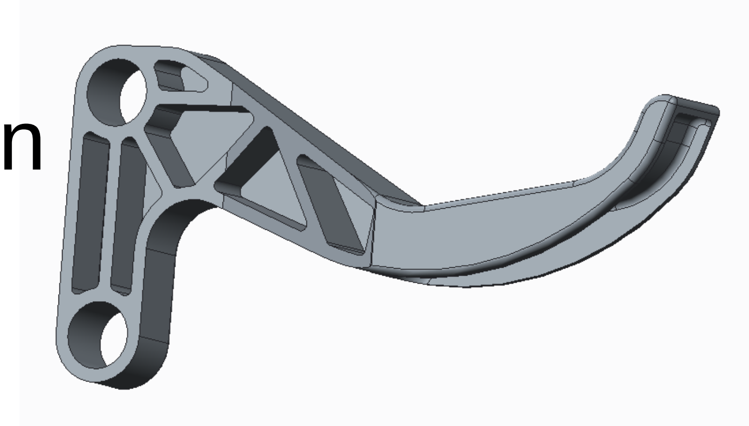
Success in Engineer‘s Terms





- Physical tests with rapid prototypes show 20% higher maximal load for our three new designs!
- This confirms our FE results.

Excitement!



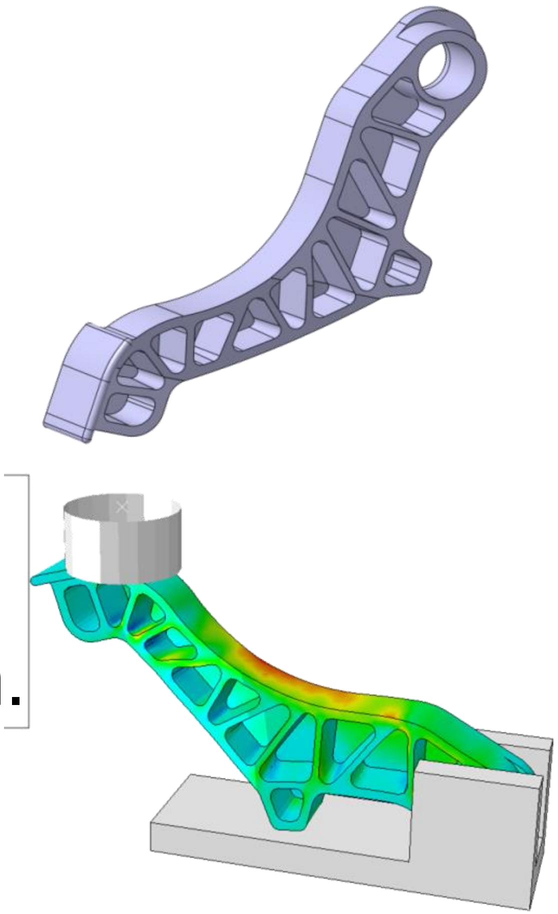
- We started with standard design according to textbook rules!
  - It was used in industry project.
  - Marc discussed design with his colleagues.
- Thousands of engineers do it that way – around the globe!
- But: Tensor vis leads to better design!
  - 20% better! In all (three) cases that we tried!
  - Marc & Markus hoped for equal stiffness!

Excitement!

- This result may indicate that you can save several percent of material in the design space!
  - Less material, but same stiffness!
- Injection molding is used for mass production!
  - Less material => less energy, less time
- This can save a lot of money even for just a single component.

Excitement!

- Rib design is a central theme in engineering.
  - E.g. automotive industry
- There are several components similar to our test case.
  - Some might profit from our approach.



Accelerator pedal of a car

Conclusion

- Tensor visualizations can have impact.
- We have a lot of methods, potentially good methods.
- We need to work on the insights!
- Regarding engineers, we have to look at their workflows, and to relate visualization and task.
- This requires close cooperation.

General Comments

- Many visualization methods can not be judged immediately.
  - We should not reject methods too early, e.g. without convincing application.
  - We need to collect them for future use.
- If a method is not (yet) used, it may be “just” the currently unknown relation to a user’s task.
  - We need more case studies to explicitly look for insight, i.e. relation between visualization and task.
- It can work surprisingly well!

THANK YOU!