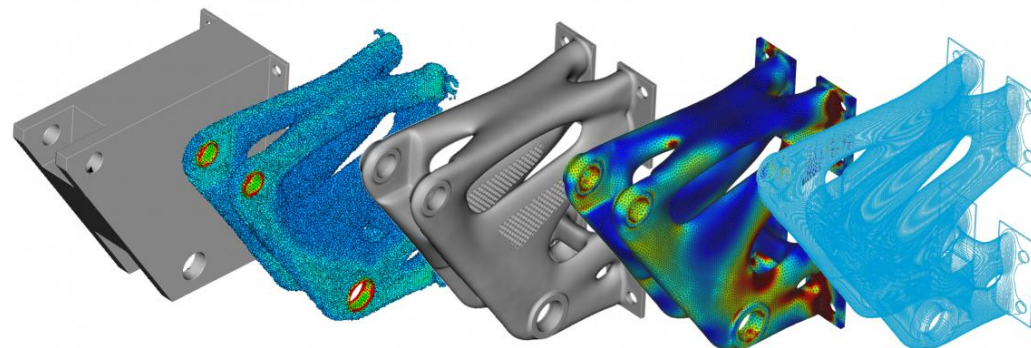




Význam topologické optimalizace pro aditivní technologie



Lukáš Pelikán

ČVUT v Praze, Fakulta strojní

Ústav obrábění, projektování a metrologie

Phu Ma Quoc

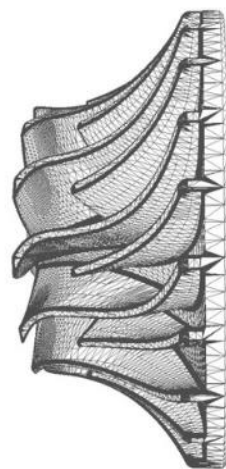
Fakulta strojní VŠB-Technická univerzita
Ostrava

Katedra obrábění, montáže a strojírenské
metrologie



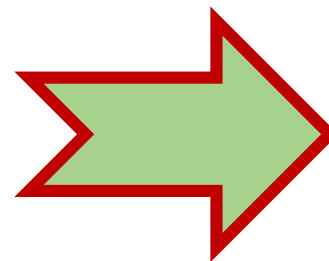
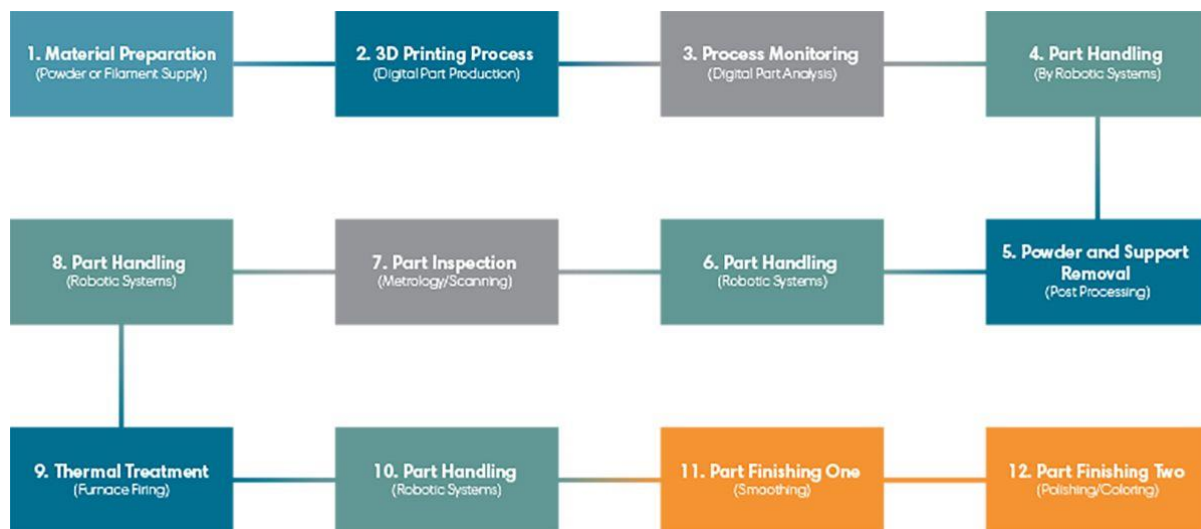
Skutečně tak jednoduché?

1 Design 2 Print 3 Use



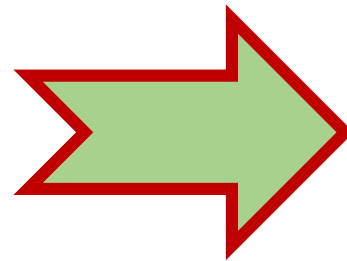


Náklady na metalický 3D tisk

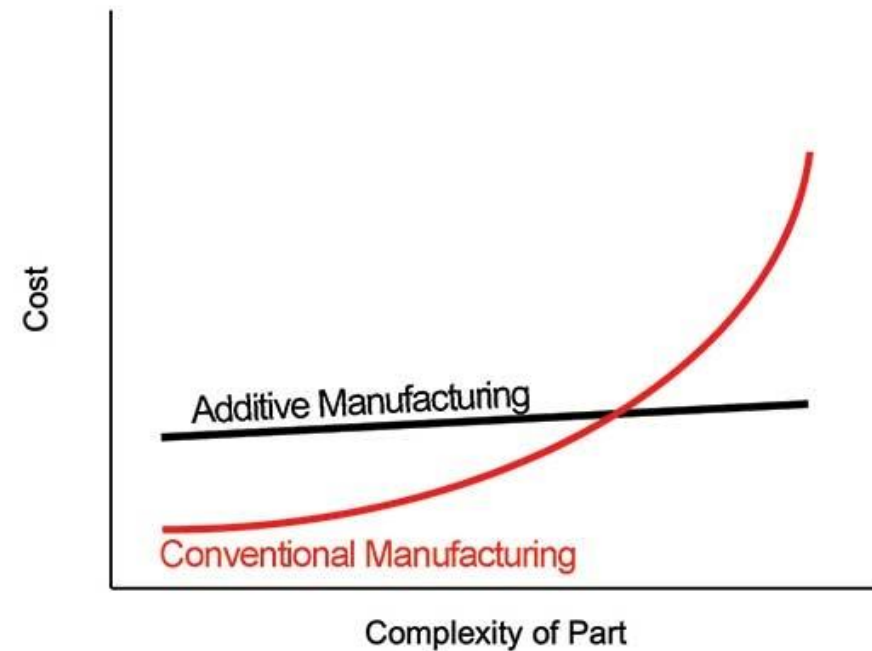




Co je ve výrobě priorita č. 1?



Kdy se stává 3D tisk zajímavý pro průmysl?



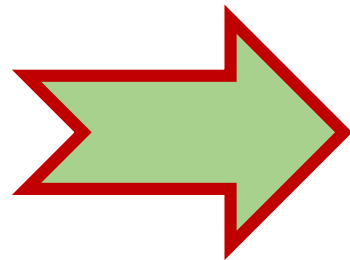


Proč budu navrhovat komplexní (složitý) díl?

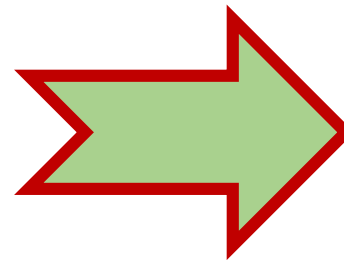
- Protože se konstruktér naučil používat pokročilé funkce CAD systému

- Líbivý design

- **Užité vlastnosti**

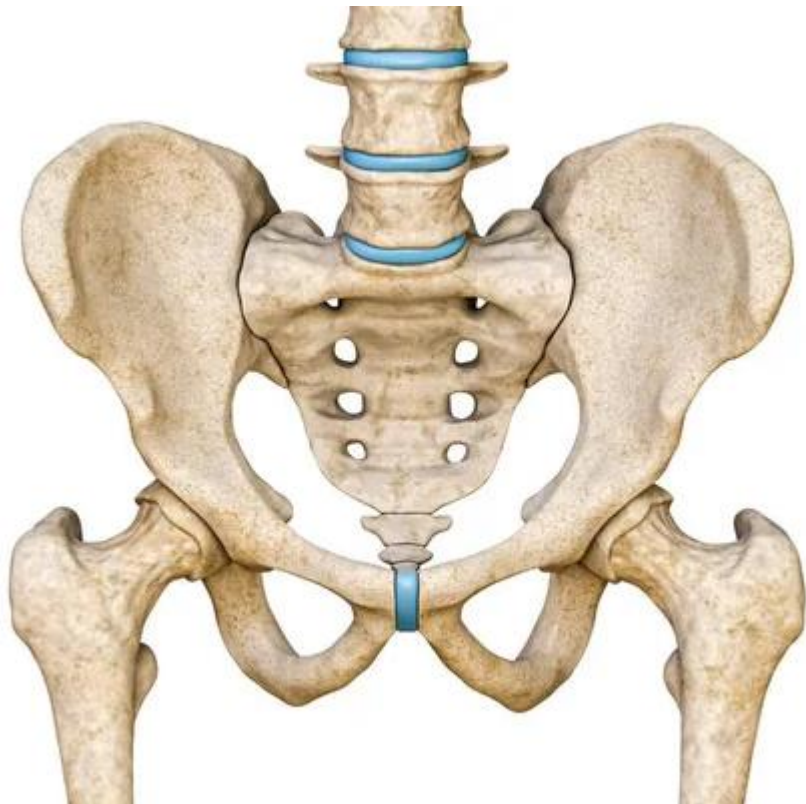


- Tuhost
- Hmotnost
- Termodynamická efektivita

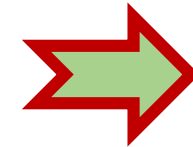


Teď už to jen
napočítat a
nakreslit...

Optimalizovaná sestava s pružnými elementy a kloubovými spoji Mnoho zátěžových stavů, statických i dynamických

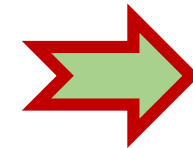


Návrh „optimálního“
designu vzhledem k
zátěžovým stavům



**Bez softwaru
nereálné**

Jak takto komplexní
díl vyrobit?



3D tisk



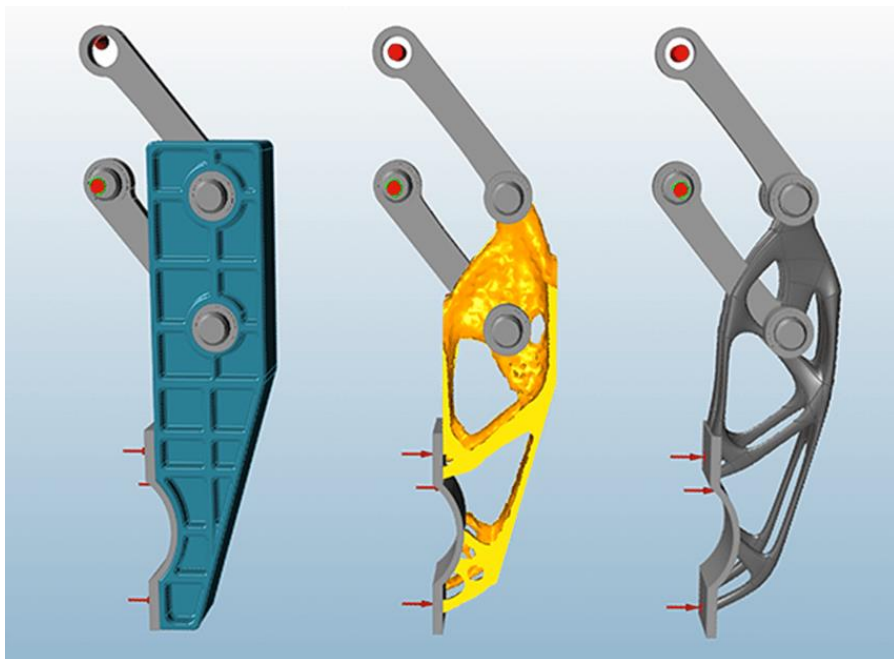
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\$

**Konvenční
výroba**

\$\$\$\$

**Konvenční
výroba**



3D tisk

\$\$\$

3D tisk

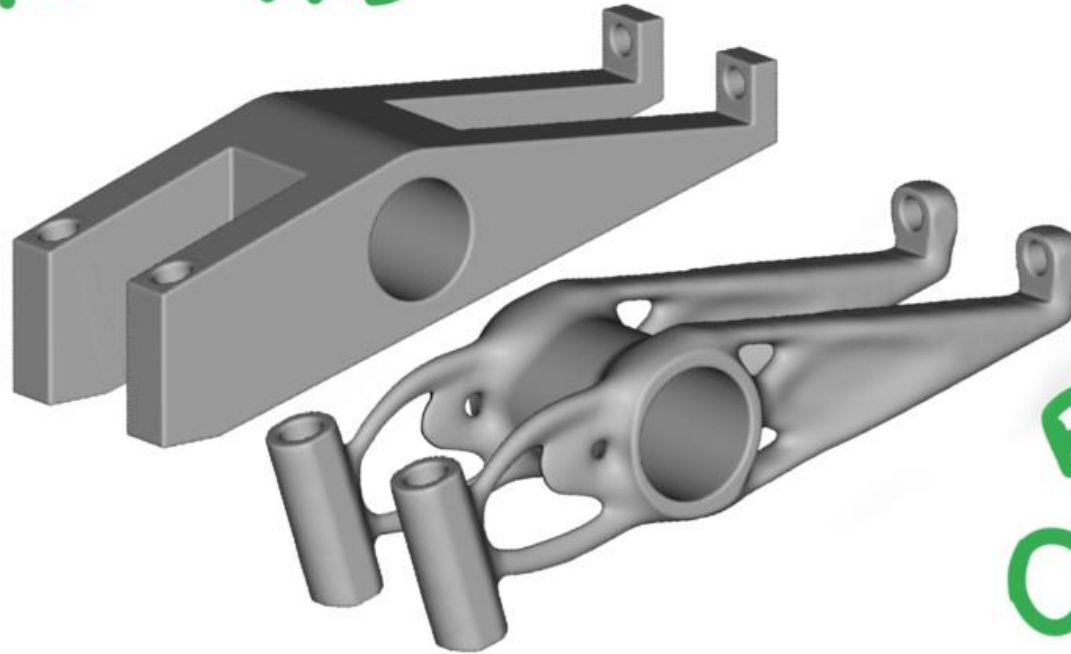
\$\$





Rizika topologické optimalizace

THE PAST



THE
AMAZING
FUTURE!
OMG.

<https://www.puntozero3d.com/en/2-topology-optimization-is-the-best-choice-for-those-who-go-to-the-supermarket-by-blimp/>

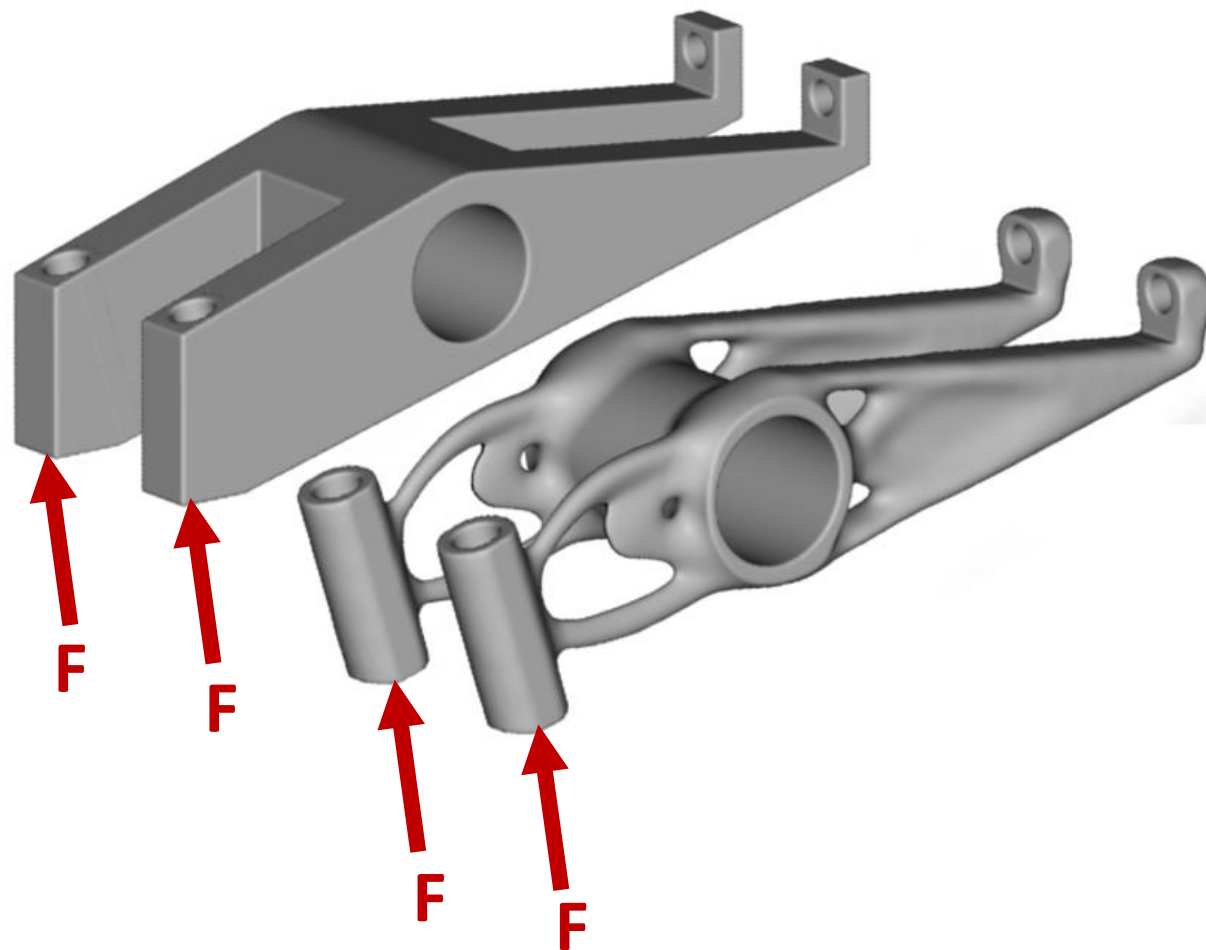


Rizika topologické optimalizace

Vytvářím optimalizaci pro zadané síly.



Ve skutečnosti opravdu působí jen
mnou uvažované síly.



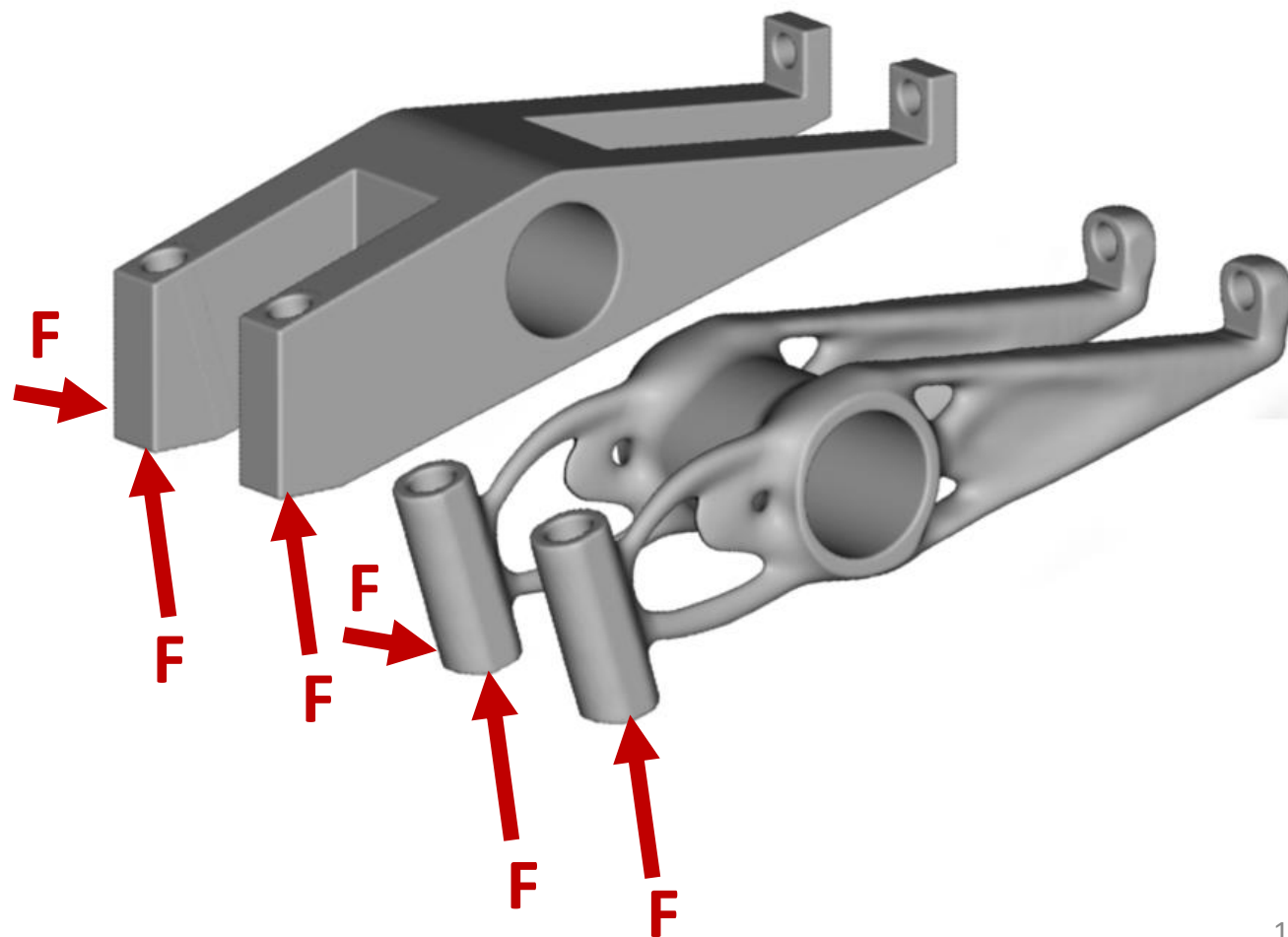


Rizika topologické optimalizace

Vytvářím optimalizaci pro zadané síly.



Ve skutečnosti ale působí i další síly, které jsem neuvažoval.





An application engineer's perspective on software design optimizations

- The need to carry out optimizations from the point of view of a technician (non-designer) - the ability to quickly respond to demand, propose and modify the design with regard to experience with the technological nature of the construction and respecting the limitations of the given production technology. Mindset: Design for Additive Manufacturing (DfAM)
- Most of the time, it is not within the capabilities of a manufacturing technology expert (and it is not an effort) to be an expert in meshing, setting up calculations, analyzing too large output data - the ability to use a simple SW is desirable. The designer may not get the best result, but he/she must not be drowned in the simulation errors. Creativity should not be limited and some realistic results are desired.



Incorporation of topological optimization into the teaching of technical subjects at VŠB

- The previously mentioned reasons are why a technologist needs to do design optimizations himself – That's why it is important to teach within technology subjects
- Connection with the teaching of additive technologies - understanding the importance of topology for 3D printing, understanding topology and that the results cannot be taken at 100% - we must respect the technological nature of the construction - students must understand the sequence of the process - the basic functions of the part, assembly and production space for the part
- Workflow: Design space -> topology -> modification with regard to the technological nature of the construction -> analysis of the results (it may be completely different from the original design) -> the workflow that the designer has to start all over again in case the whole thing doesn't work out
- Use of lattice structure - usually cannot be produced by other technology - again connection with teaching 3D printing, use for lightening, internal cooling - understanding of manufacturability, post-processing (remove the powder out of the printed part)



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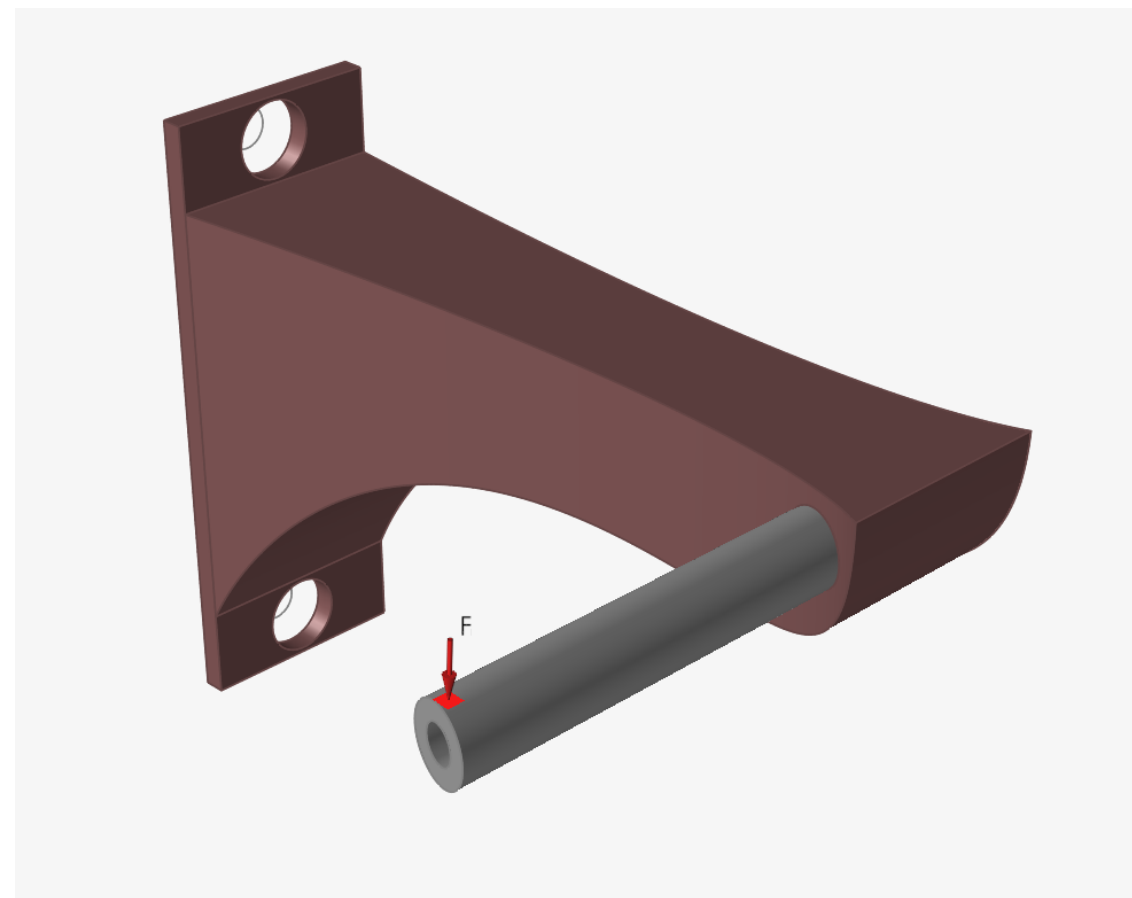
**ÚSTAV
TECHNOLOGIE OBRÁBĚNÍ,
PROJEKTOVÁNÍ A METROLOGIE**

Case studies ČVUT - FS



Základní díl

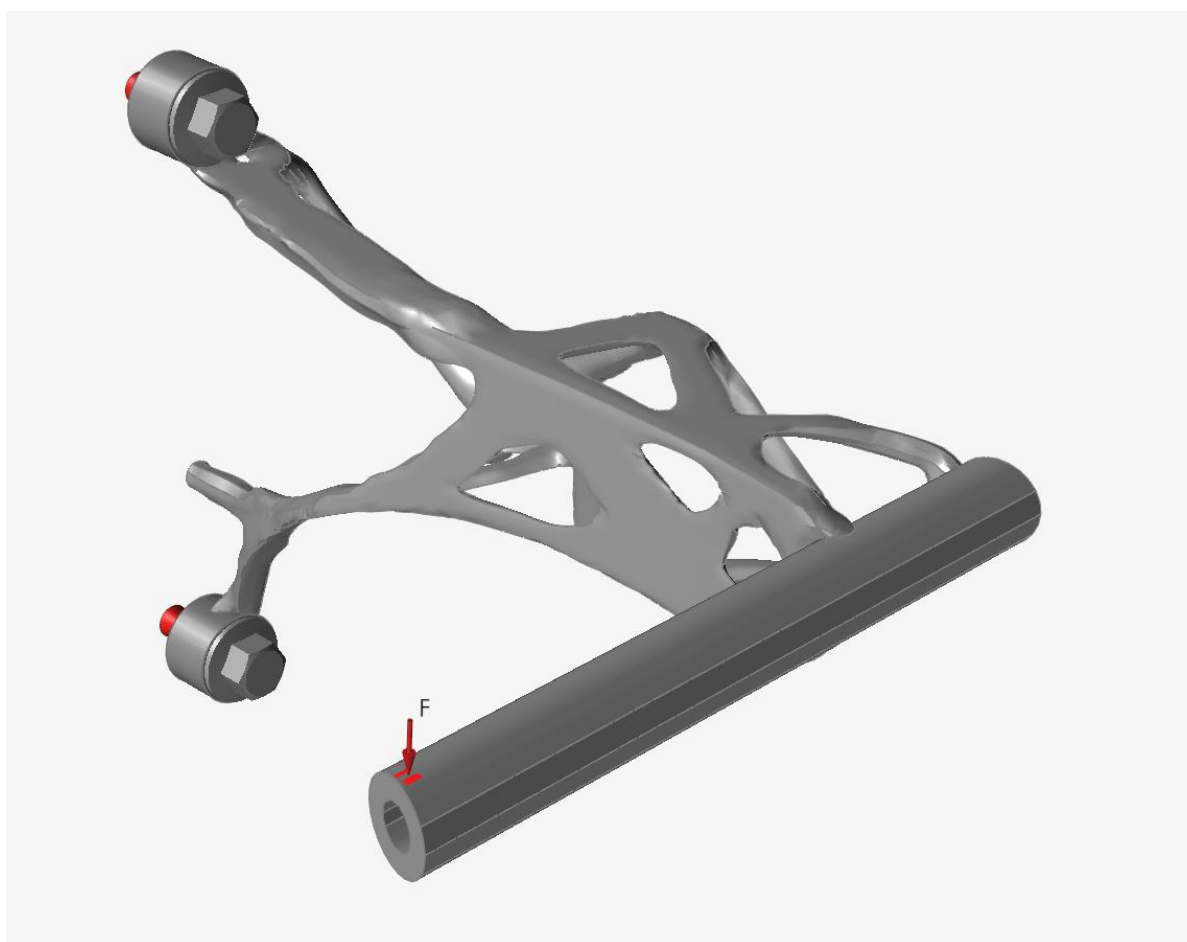
- Hmotnost DS 360g
- Síla 150 N
- Varianta topologicky optimalizovaný pro kovový 3D tisk a ve variantě pro konvenční třískové obrábění
- Oba finální díly mají stejnou hmotnost, ale výrazně odlišné vlastnosti v oblasti uvažovaného zatěžování
- Ale také výrazně jiné náklady na výrobu
- Je uplatněn jiný systém návrhu dílu





Topologicky optimalizovaný díl

- Hmotnost 120 g
- Síla 150 N





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Obráběný díl

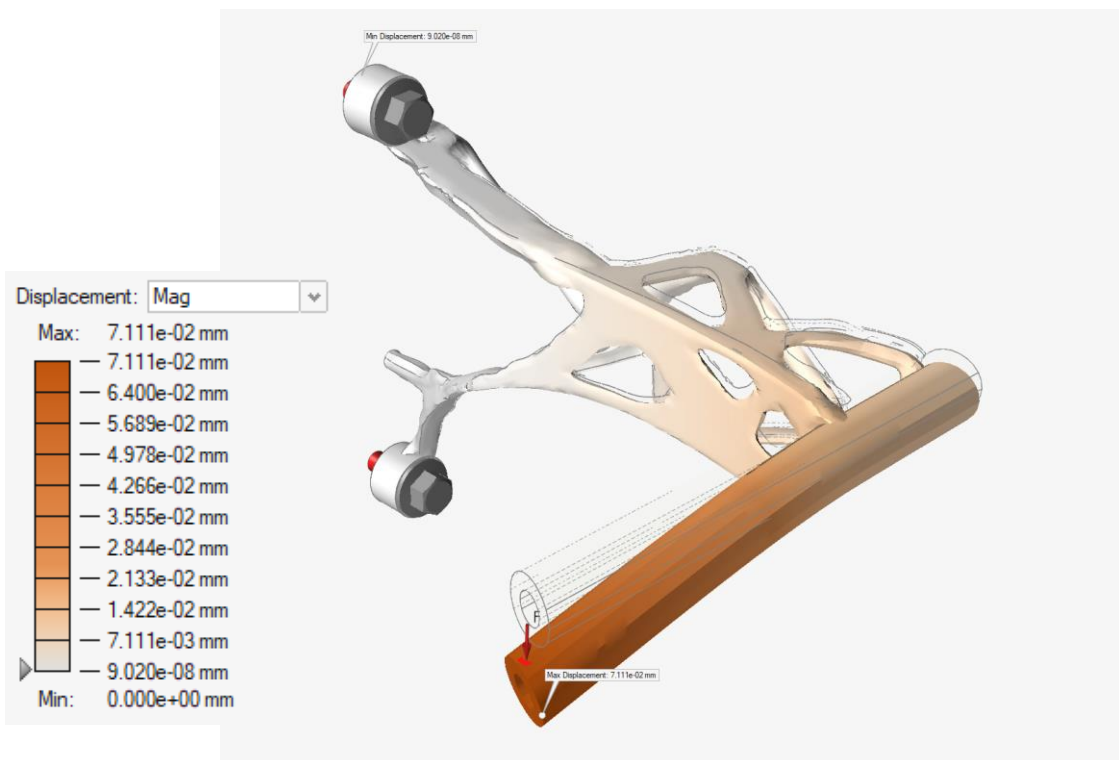
- Hmotnost 120 g
- Síla 150 N



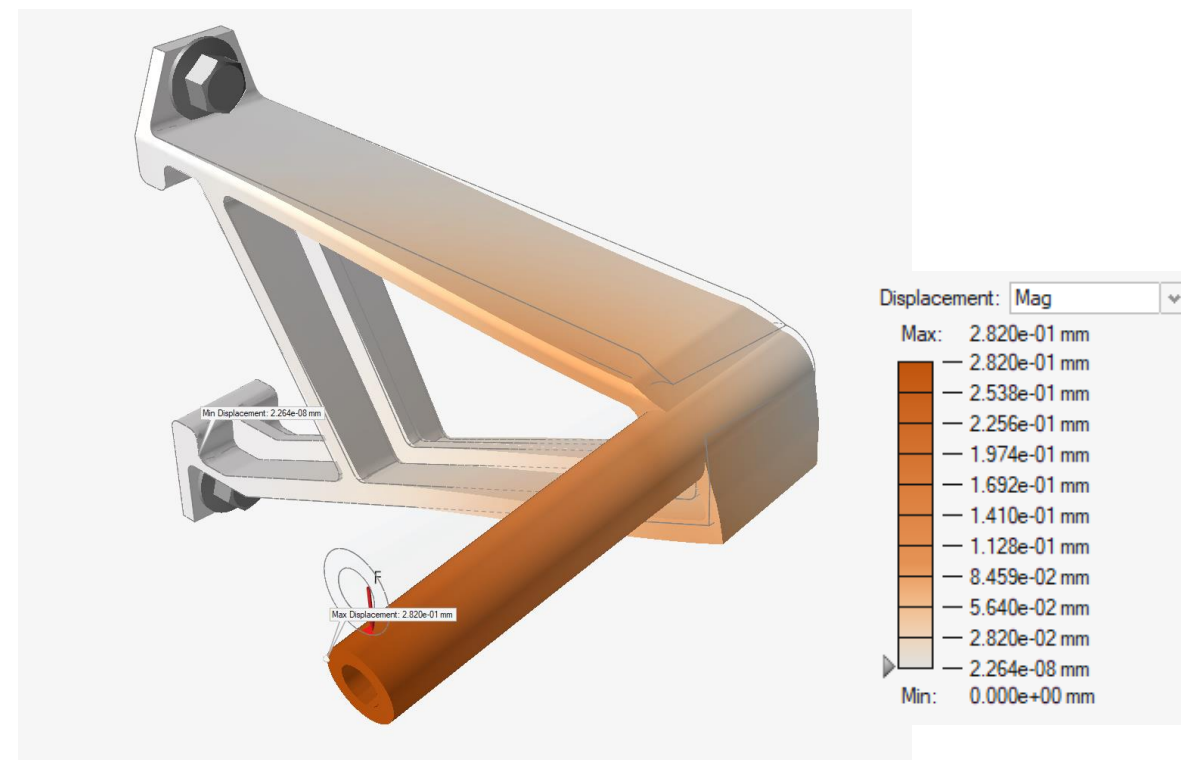


Porovnání deformace

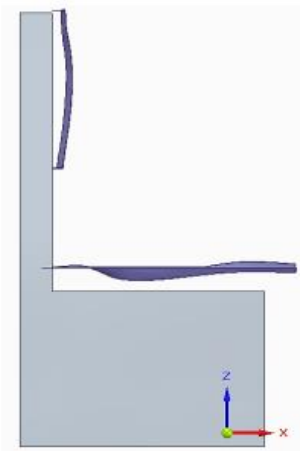
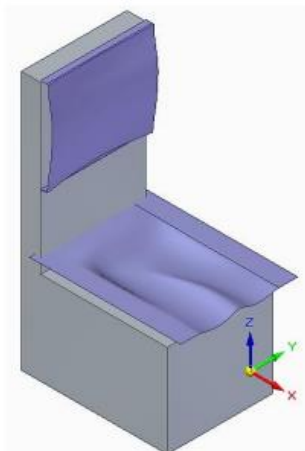
Maximální velikost průhybu 0,071 mm



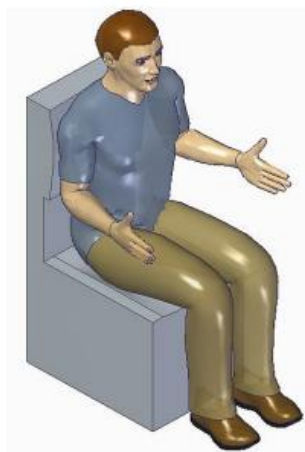
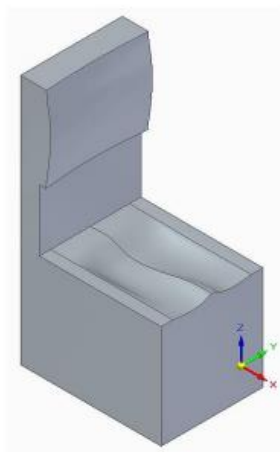
Maximální velikost průhybu 0,282 mm



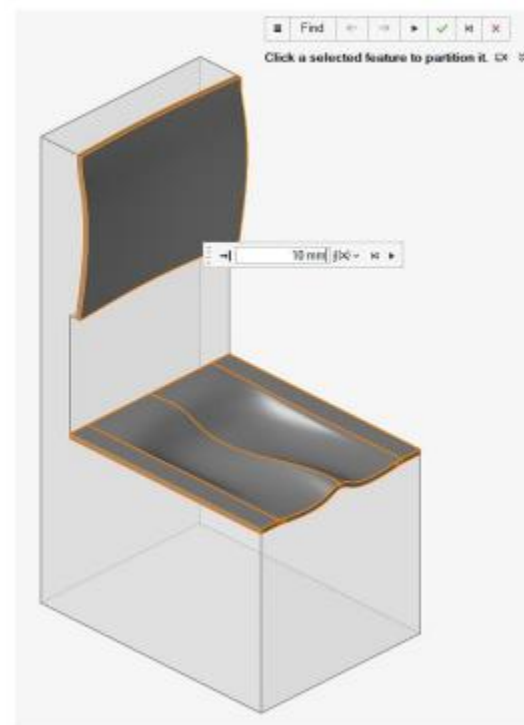
Návrh židle



Obrázek 41 Tvorba tvarových ploch pro lepší ergonomii



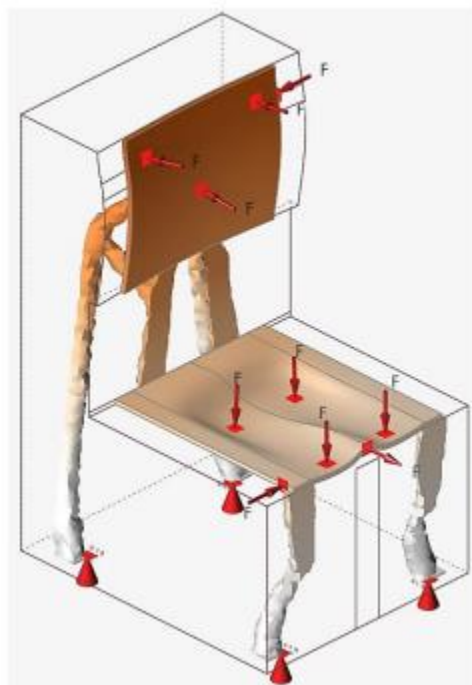
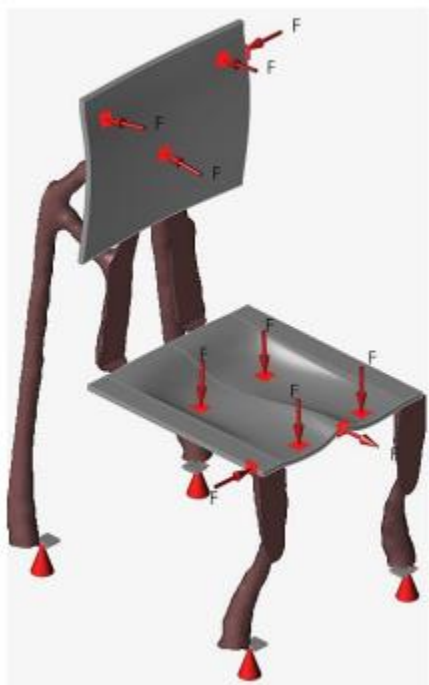
Obrázek 42 Finální podoba modelu před TO



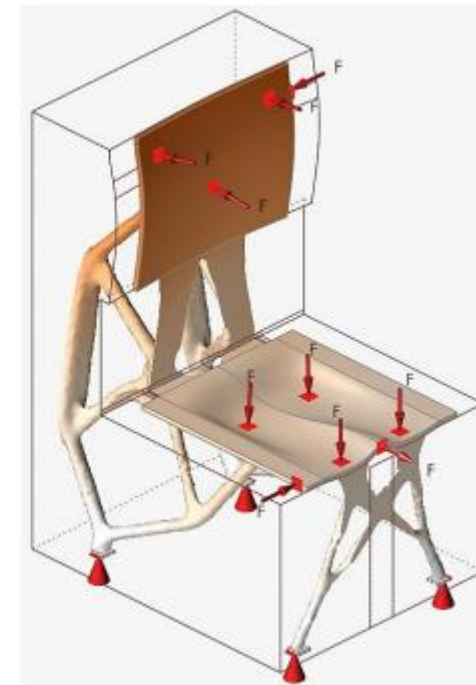
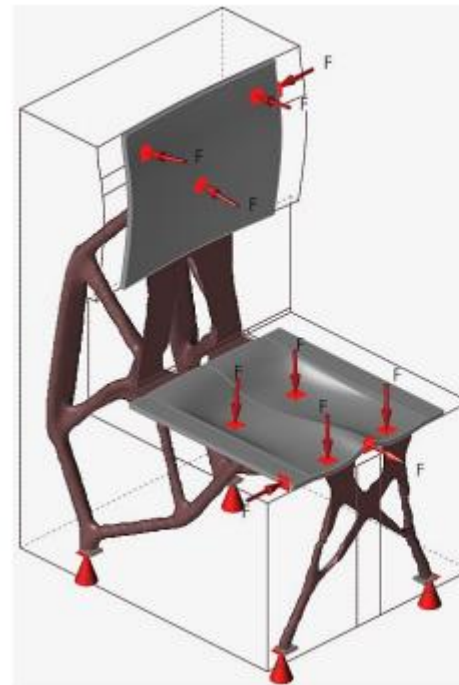


Rozdílný cíl, rozdílný výsledek

Minimalizace hmotnosti



Maximalizace tuhosti





Výsledný model

Varianta 1

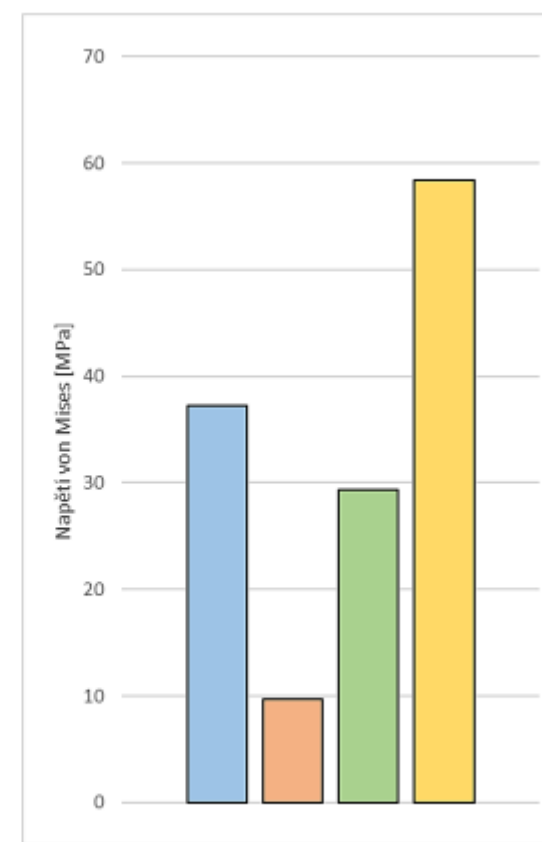
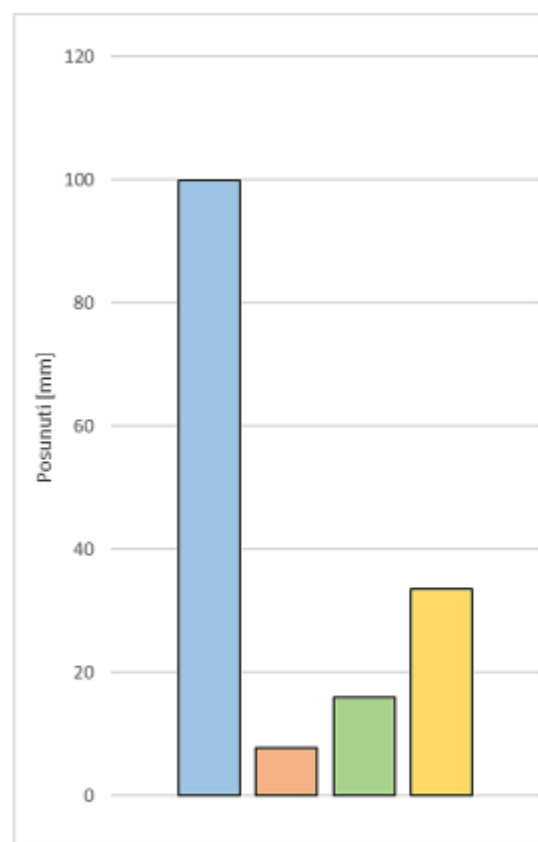
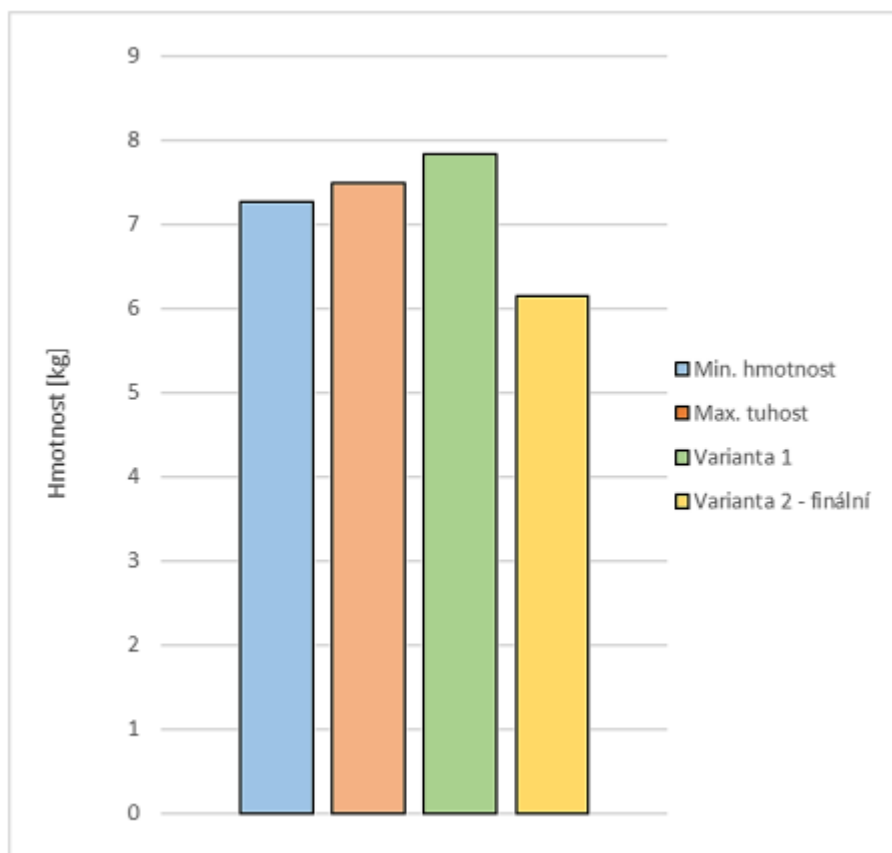


Varianta 2





Výsledky analýz



Min. hmotnost Max. tuhost Varianta 1 Varianta 2 - finální



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Case studies in VŠB

Three case studies

1. Frame Design for Skating Shoes
2. Clutch Lever in Formula Student Car
3. RC Car Frame



Frame Design for Skating Shoes

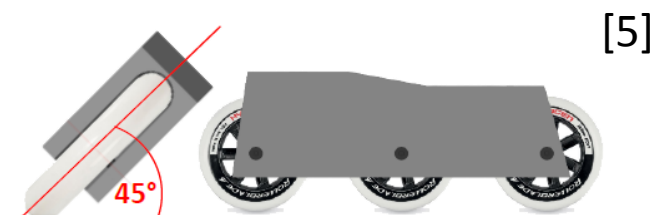
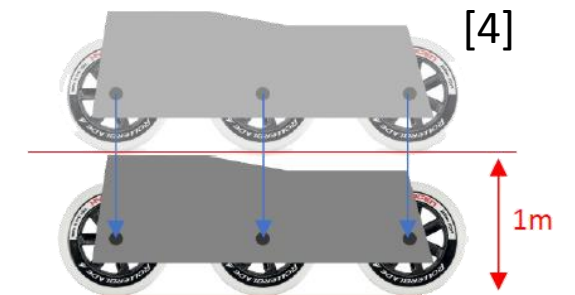
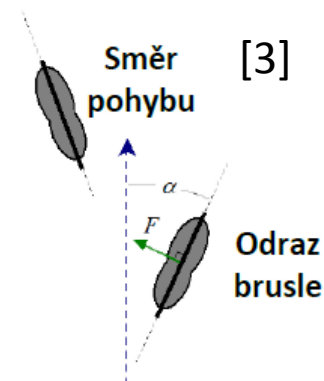
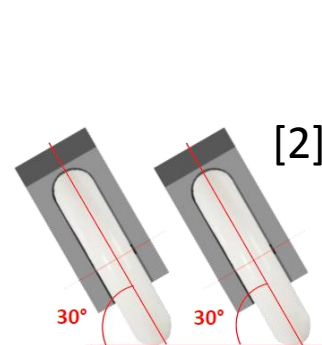
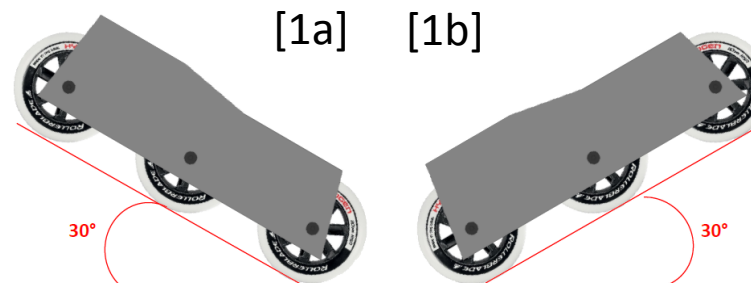
- Maximum weight of user - 85 kg
- Production by SLM (3D printing)
- Material: AlSi10Mg



Frame Design for Skating Shoes

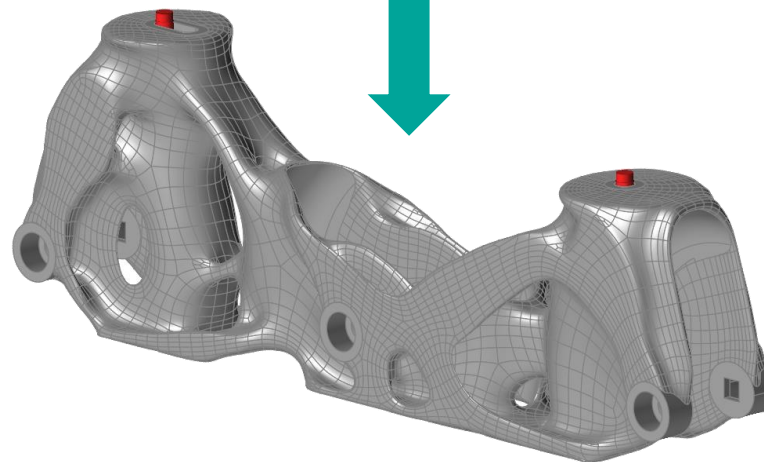
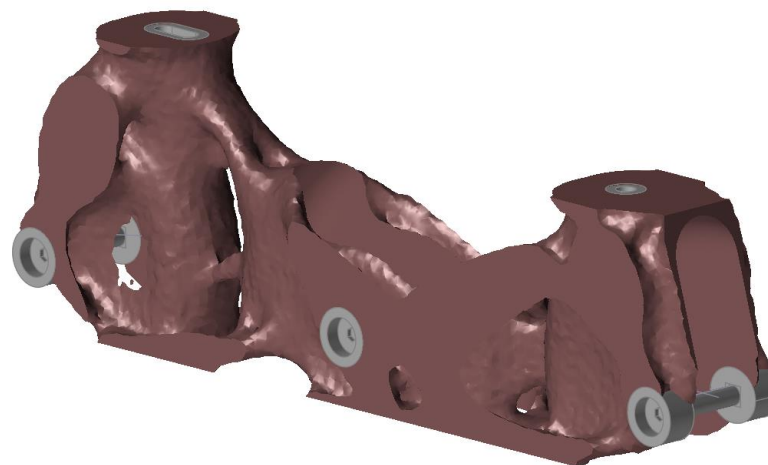
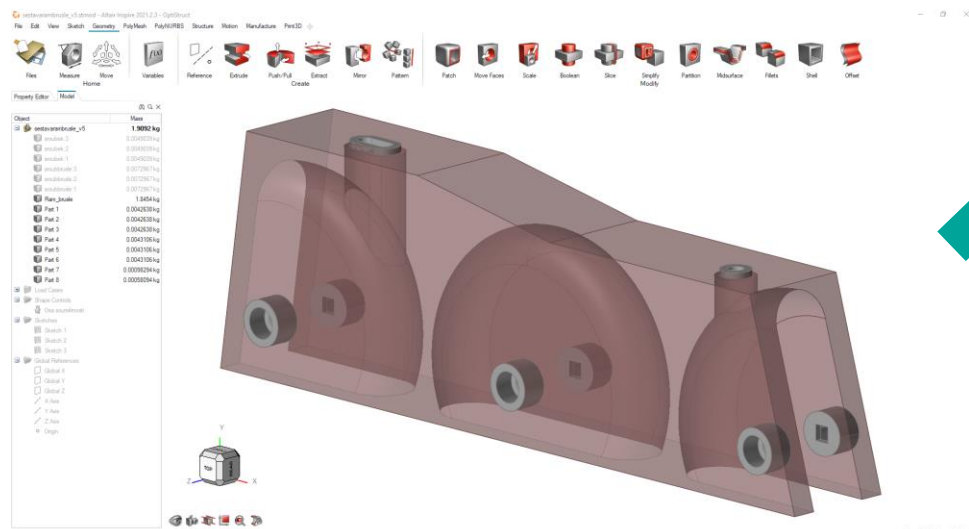
Considered loadcases:

- [1a] Standing still (front wheel)
- [1b] Standing still (back wheel)
- [2] Cornering
- [3] Skating
- [4] Impact from 1m high
- [5] Braking





Frame Design for Skating Shoes





Frame Design for Skating Shoes





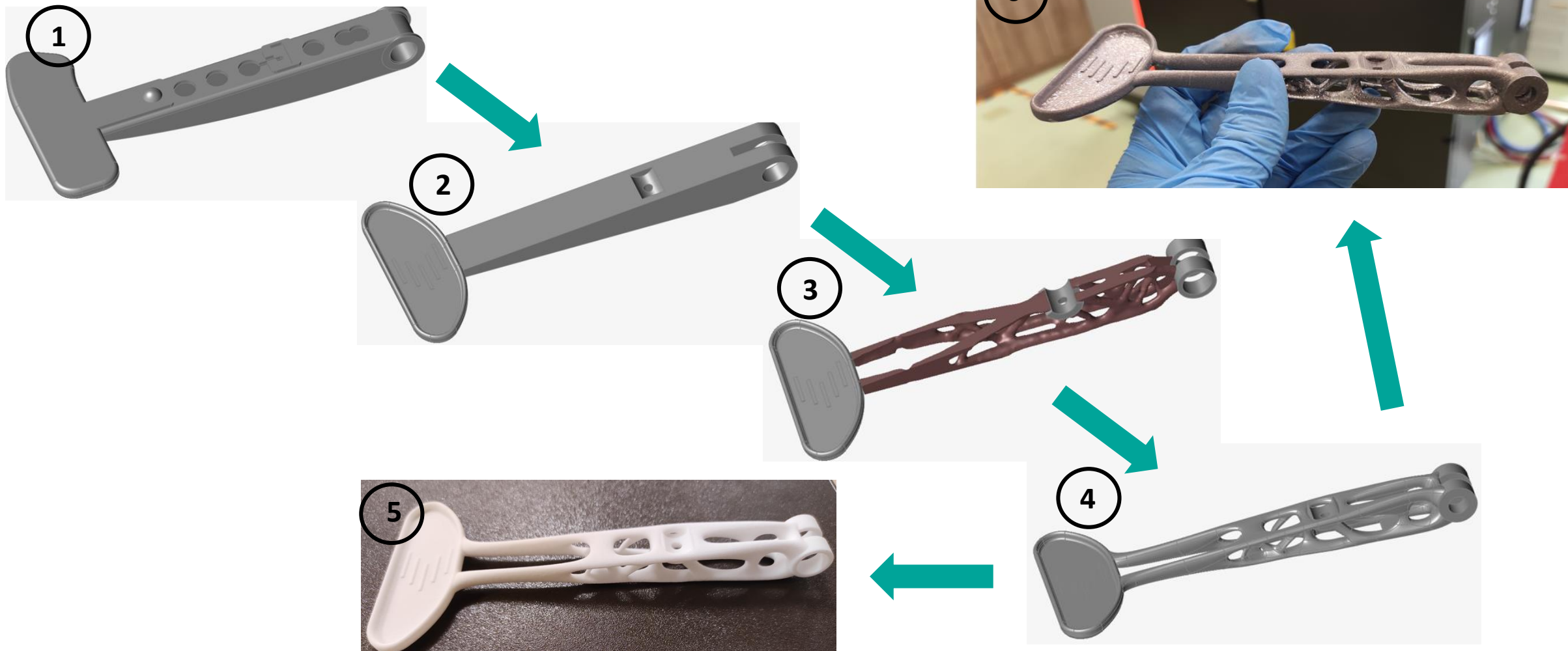
Clutch Lever in Formula Student Car

- Weight reduced from 52g
- Production by SLM (3D printing)
- Material: AlSi10Mg





Clutch Lever in Formula Student Car





Clutch Lever in Formula Student Car

	Origin	TO
Weight [g]	52	47
Max stress VMS [MPa]	42	66
Factor of Safety (2.0 – 2.2)	6	3.3
N.o of components	6	1



Hour	0	6
E (GPa)	60 ± 0.7	76 ± 1.2
S _y (MPa)	279 ± 4	310 ± 1
S _u (MPa)	409 ± 8	448 ± 3
ε _{max} (%)	3.2 ± 0.2	3.0 ± 0.1
BHN (HB)	127 ± 1	143 ± 1
β (°)	1.1 ± 0.3	0.6 ± 0.2



RC Car Frame

- Material: PA12

