Innovative Bicycle Drivetrain

UNIVERSITÉ DU LUXEMBOURG

Design of continuously variable bicycle transmission

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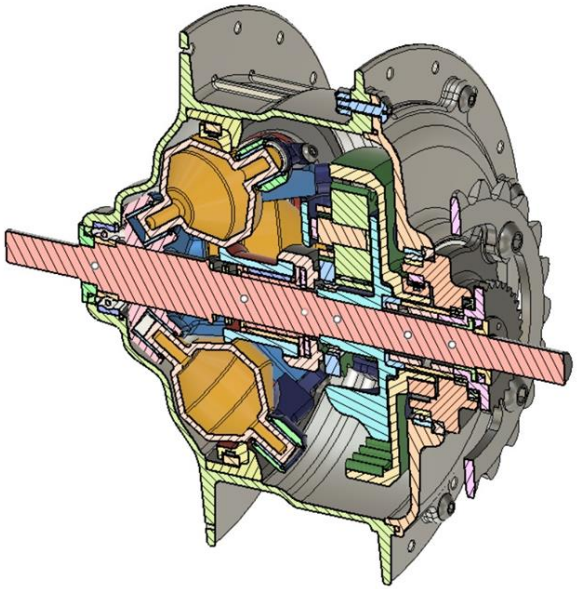
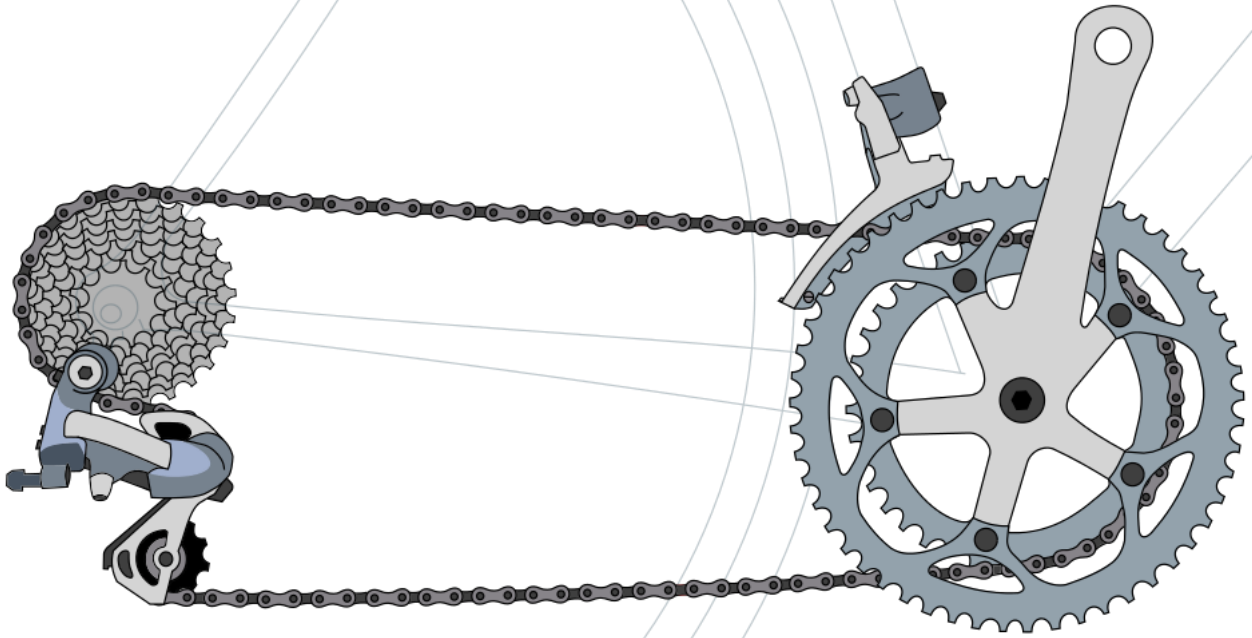
Supervisor: Dr Eng. Slawomir Kedziora

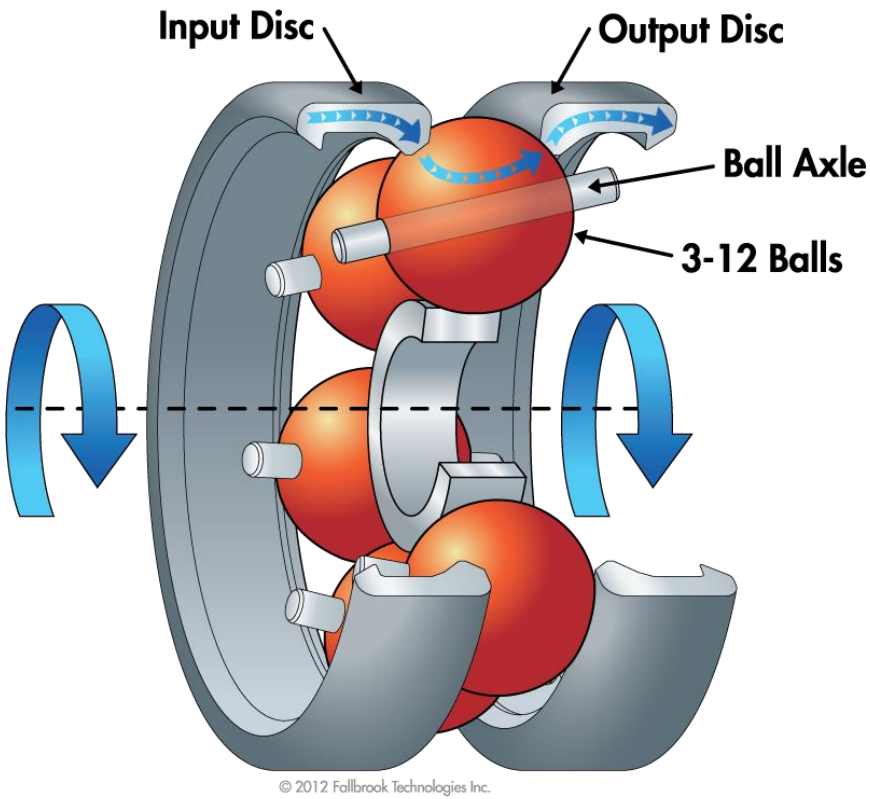


Chain drive with derailleur change mechanism

- 98.5% efficiency
- Relatively low weight
- The most common drivetrain
- Not innovative



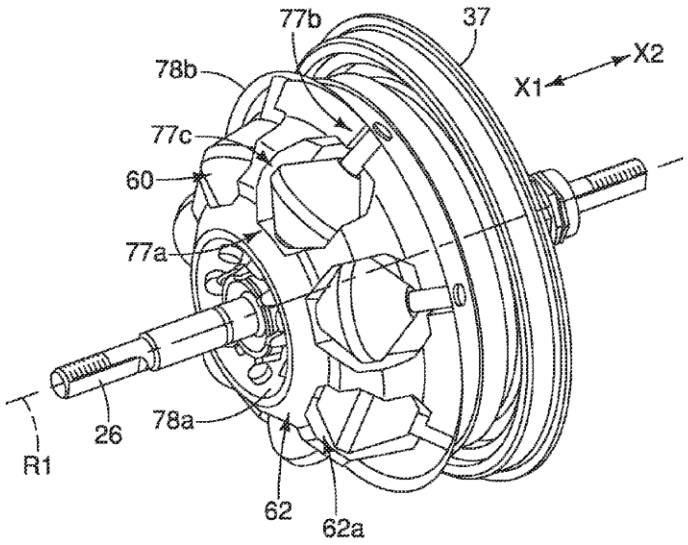
NuVinci CVT hub



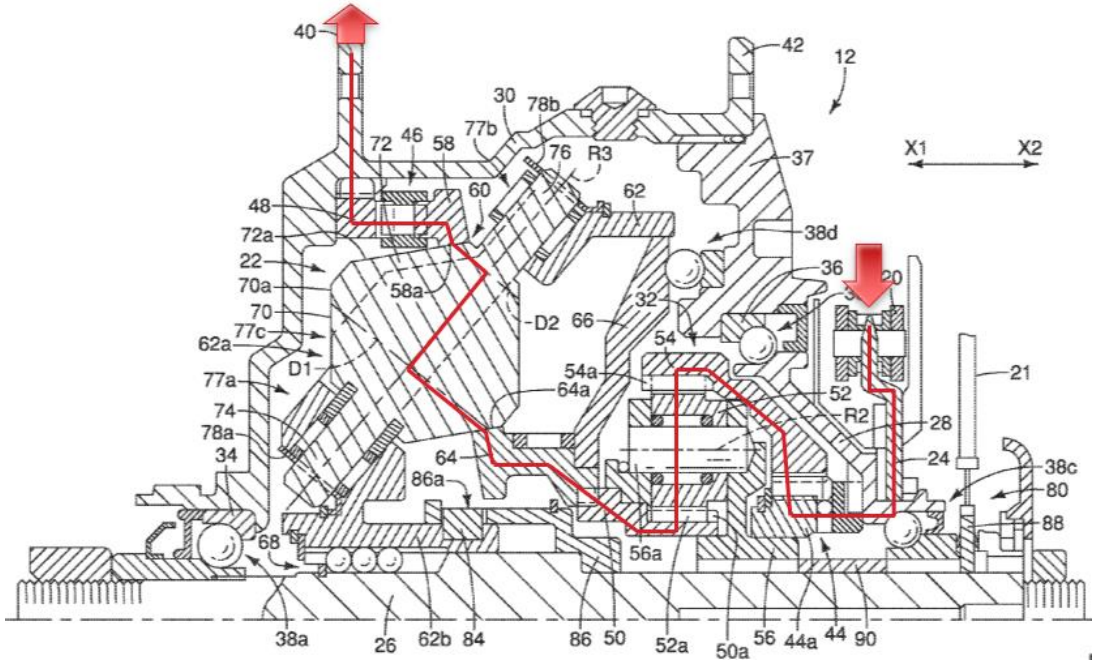
- Continuously variable ratio
- Torque transmitted by traction
- Ball planets change the contact angle

Source: https://www.fallbrooktech.com/nuvinci-technology

CVT hub by Hiroyuki Urabe



- **Used as reference for own design**
- Upstream planetary gear train and roller train
- Estimated efficiency of 90%
- Patented, but not developed



CVT hub by Hiroyuki Urabe

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Pros

- Different and innovative
- Continuously variable
- Enhanced e-bike engine efficiency
- Protected in hub enclosure
- Clean look

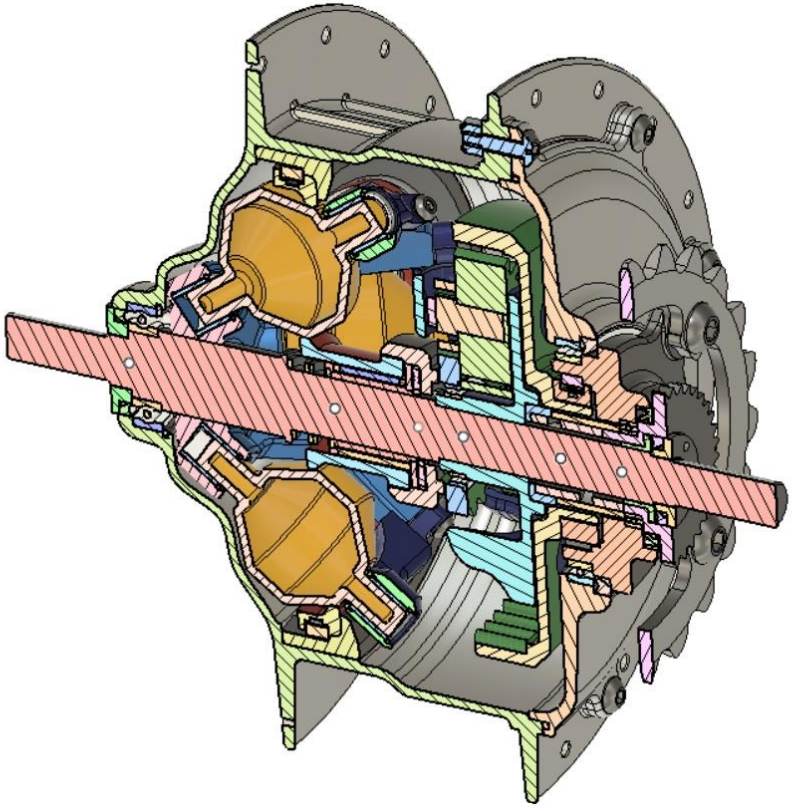
Cons

- Relatively heavy weight
- Lower transmission efficiency
- More complex than the comparable design from “NuVinci”

Presentation and explanation of the developed design

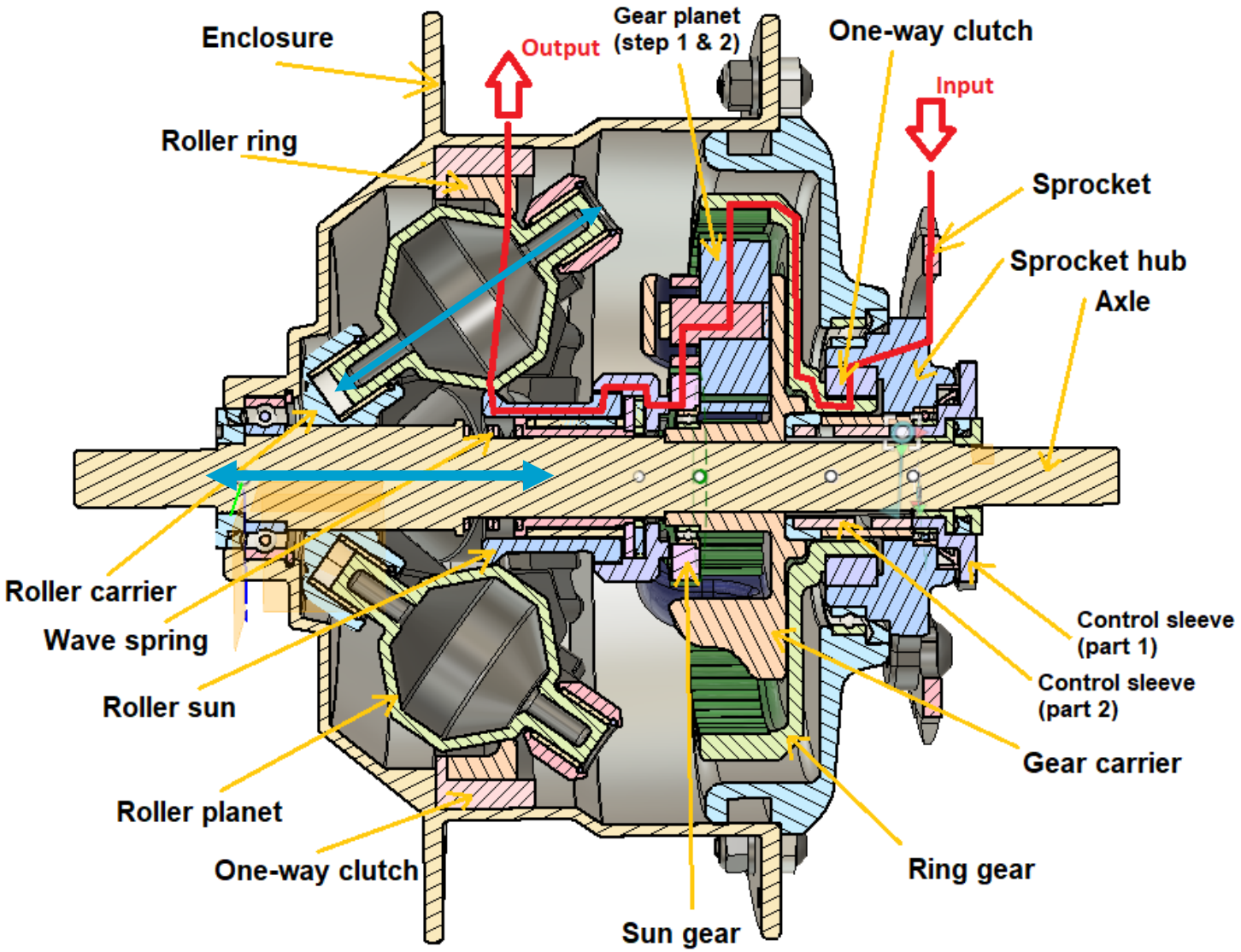
CVT hub

Developed CVT hub

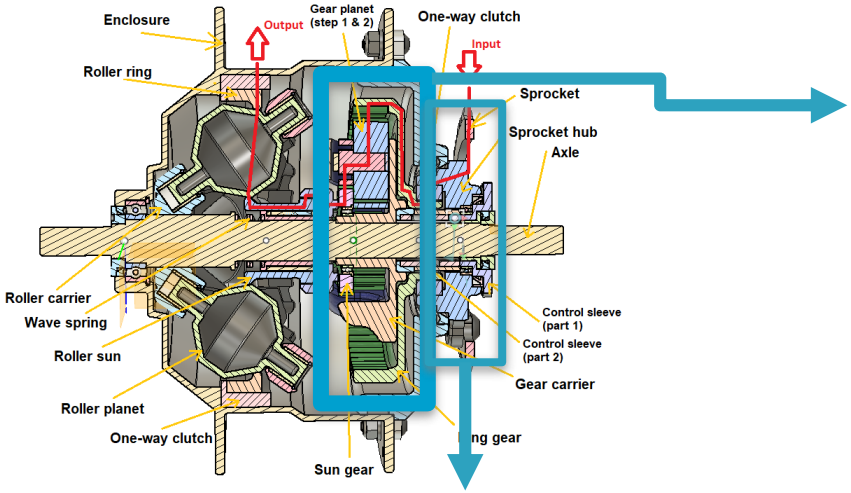


- Autodesk Fusion 360 unites every development step
- Cloud computing

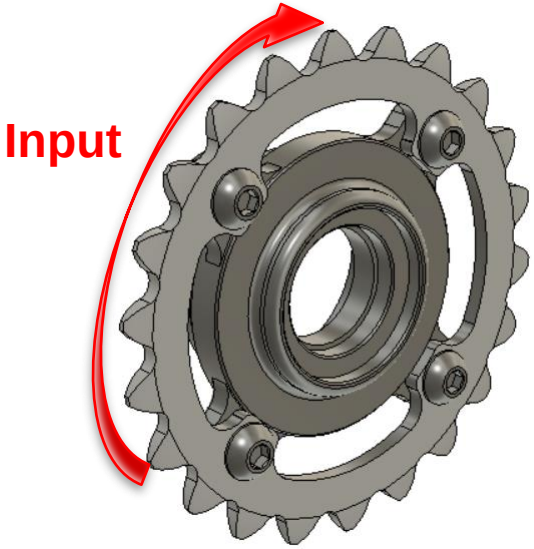
Developed CVT hub



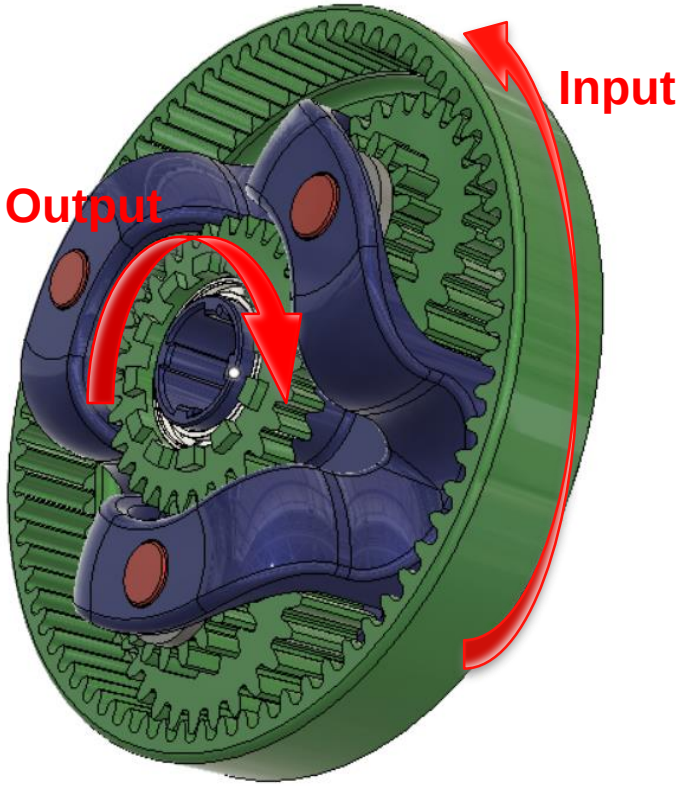
Developed CVT hub



Sprocket

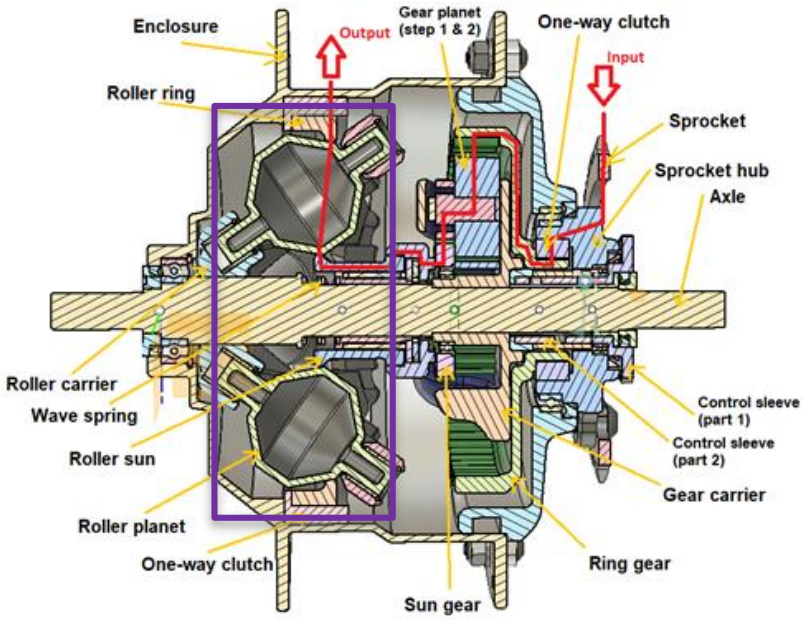


Upstream planetary gear train



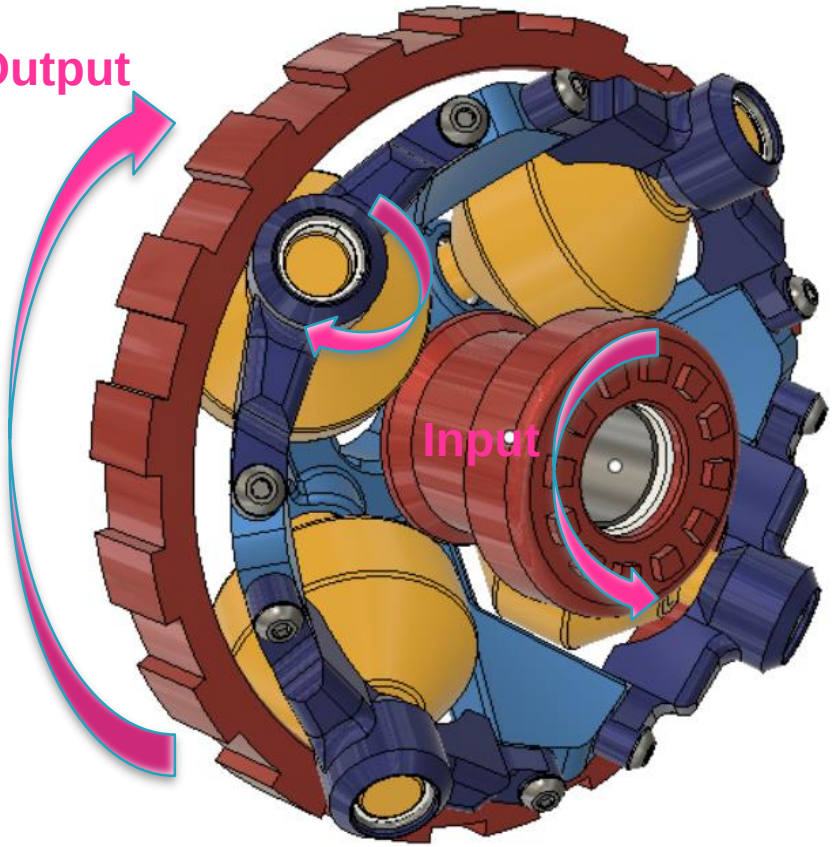
- Input torque on ring gear
- Fixed carrier

Developed CVT hub

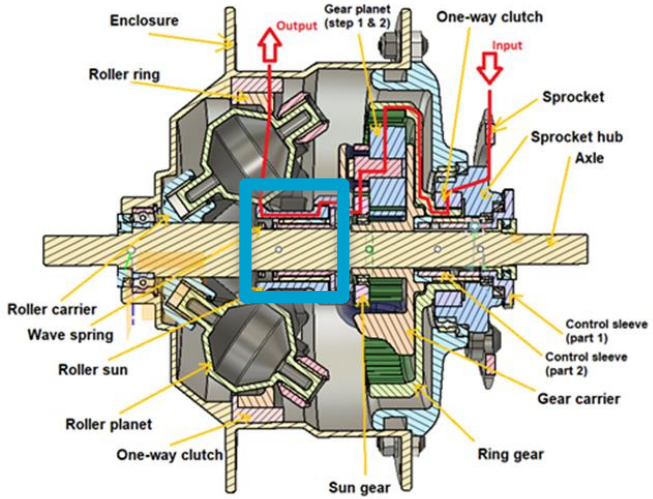


- Input torque on sun roller
- Non-rotatable but on axle displaceable carrier

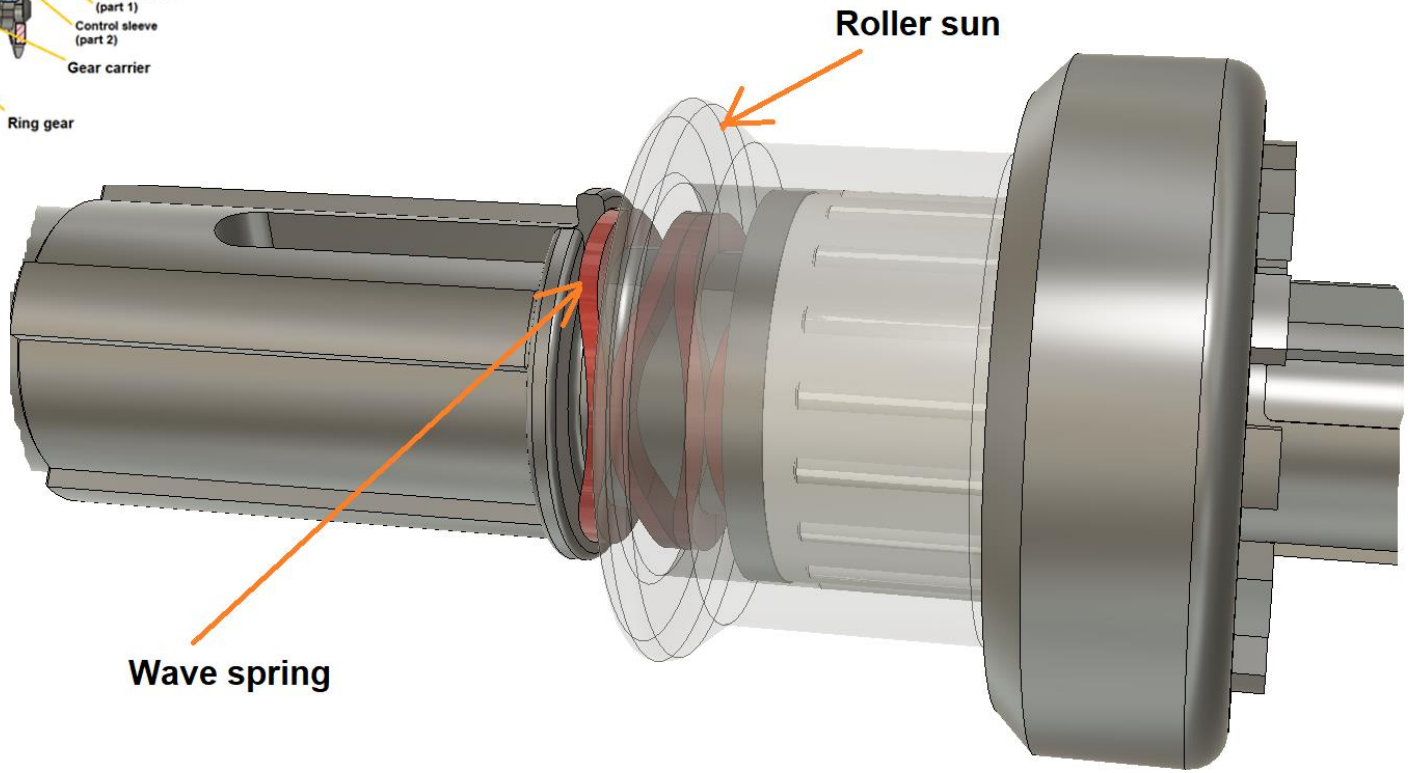
Planetary roller train



Preloaded spring

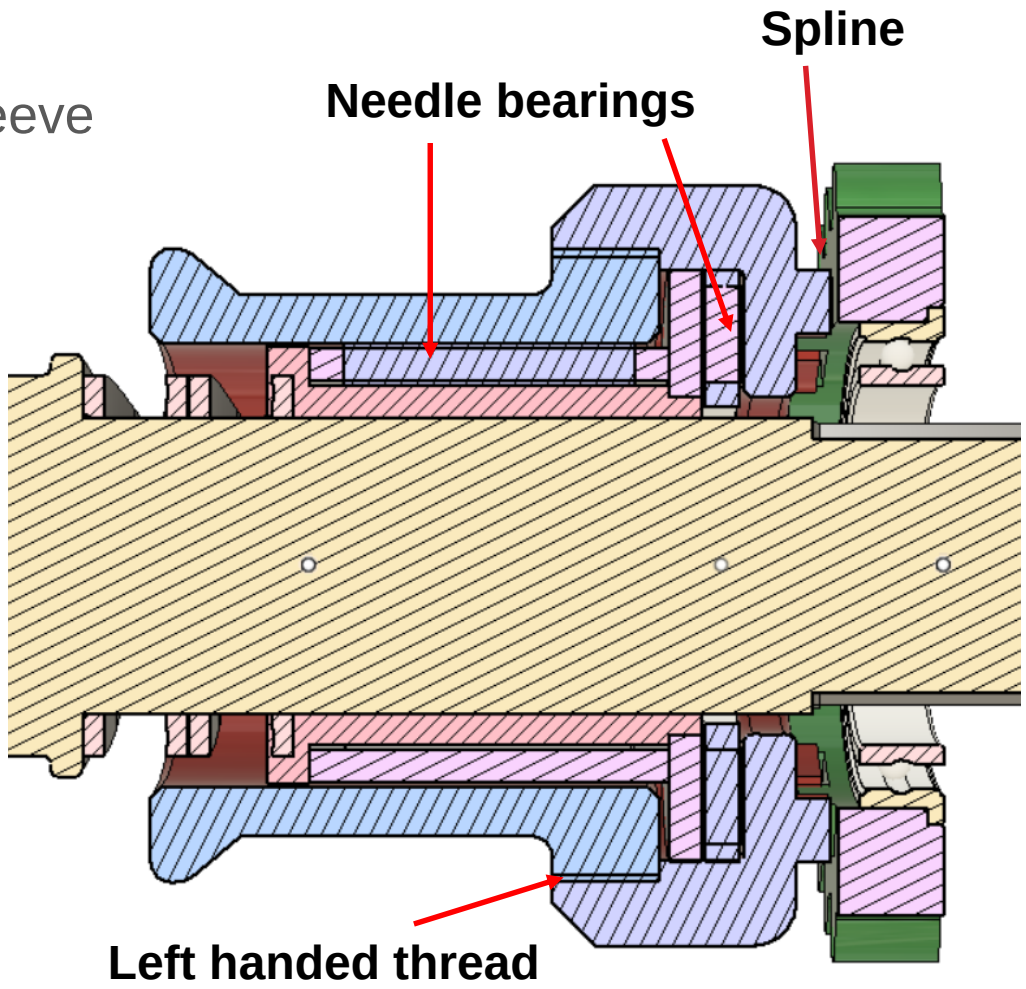


- Preloaded spring to guarantee enough traction
- Wave spring



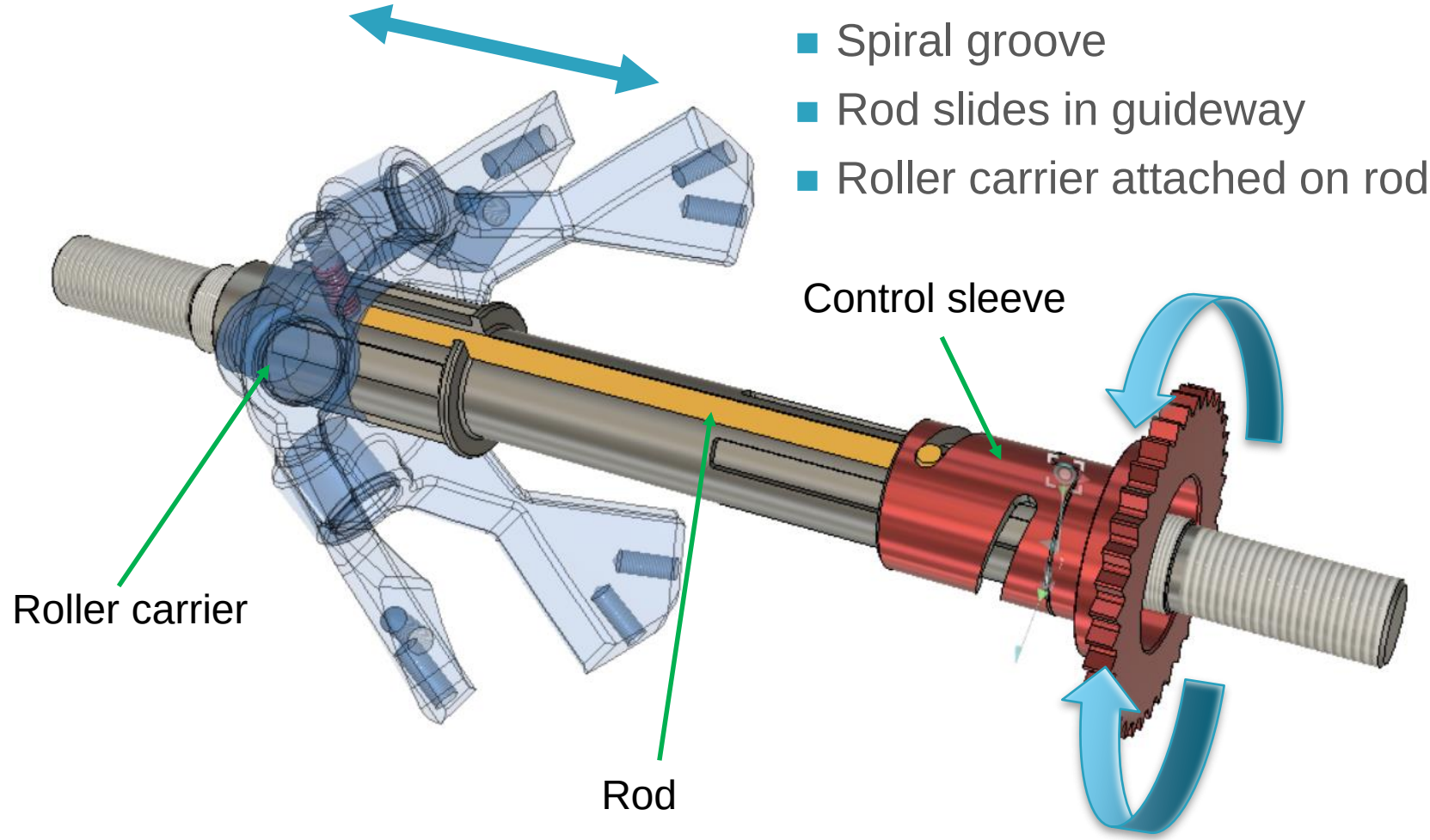
Preloaded spring

- Radial bearing on slidable sleeve
- Axial bearing gets pushed
- Left handed thread
- Gap between roller and sun



Changing the ratio

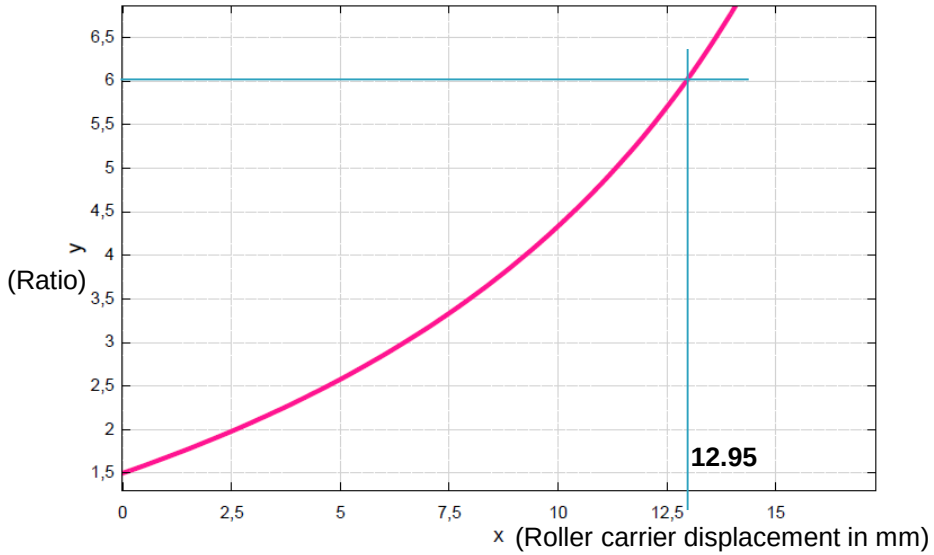
- Control sleeve gets rotated
- Spiral groove
- Rod slides in guideway
- Roller carrier attached on rod



Ratio range

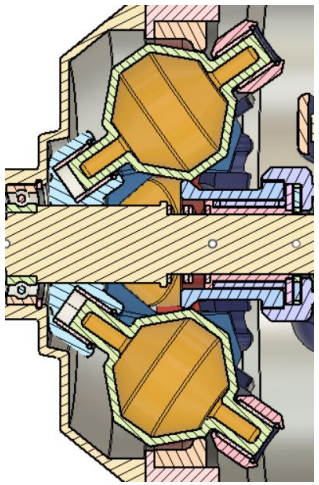
- Crank set to rear sprocket -> 0.5
- Planetary gear train (Step 1) -> 0.37
- Planetary gear train (Step 2) -> 1.82
- Planetary roller train -> 1.5 to 6

$$RatioDisp(x, r1, ro2, ro3, r4) := \frac{r4 \cdot (ro2 + x \cdot \cos(\alpha 1) \cdot \cos(\beta))}{r1 \cdot (ro3 - x \cdot \cos(\alpha 2) \cdot \cos(\beta))}$$



Low ratio

High ratio



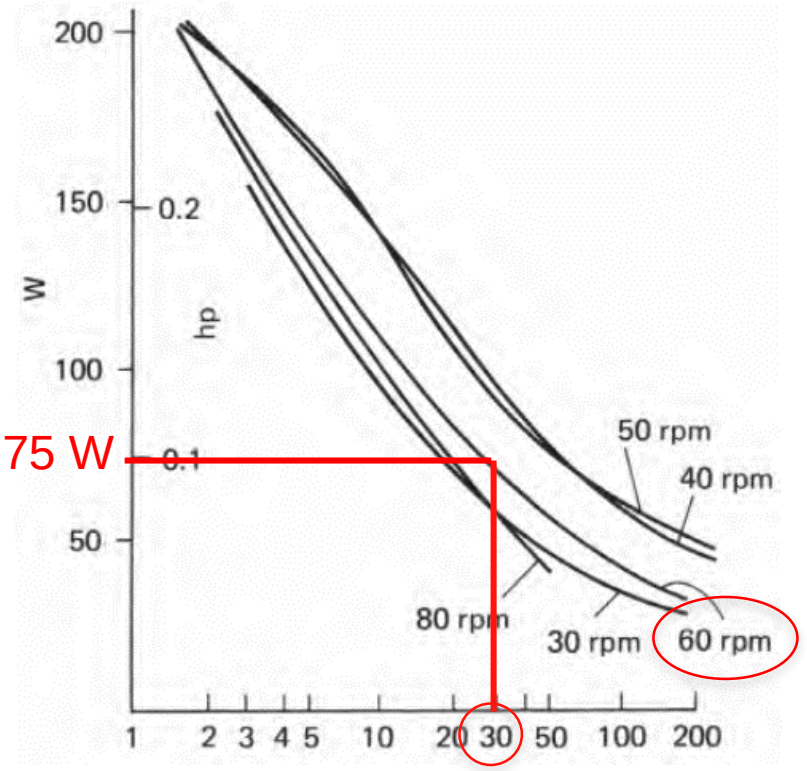
Lowest ratio = 0.5

Highest ratio = 2

400% ratio range

Input power and standard dimensions

- 75 W at 60 rpm for 30 minutes
- 12 Nm input torque
- Maximum peak 200 W



Source: Bicycling Science, Second Edition 2nd Edition, Frank Rowland Whitt, David Gordon Wilson, ISBN-10: 026273060X

Standard dimensions:

- Over-locknut-dimension : 135 mm
- Axle threads on both sides: M10 x 1
- Flange width : 3.2 mm
- Number of spoke holes : 36

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Finite Elements Analysis

FEA Examples

FEA

- Static linear analysis
- Reaction forces have been calculated
- Parabolic mesh – second order tetra element
- Fusion cloud computing

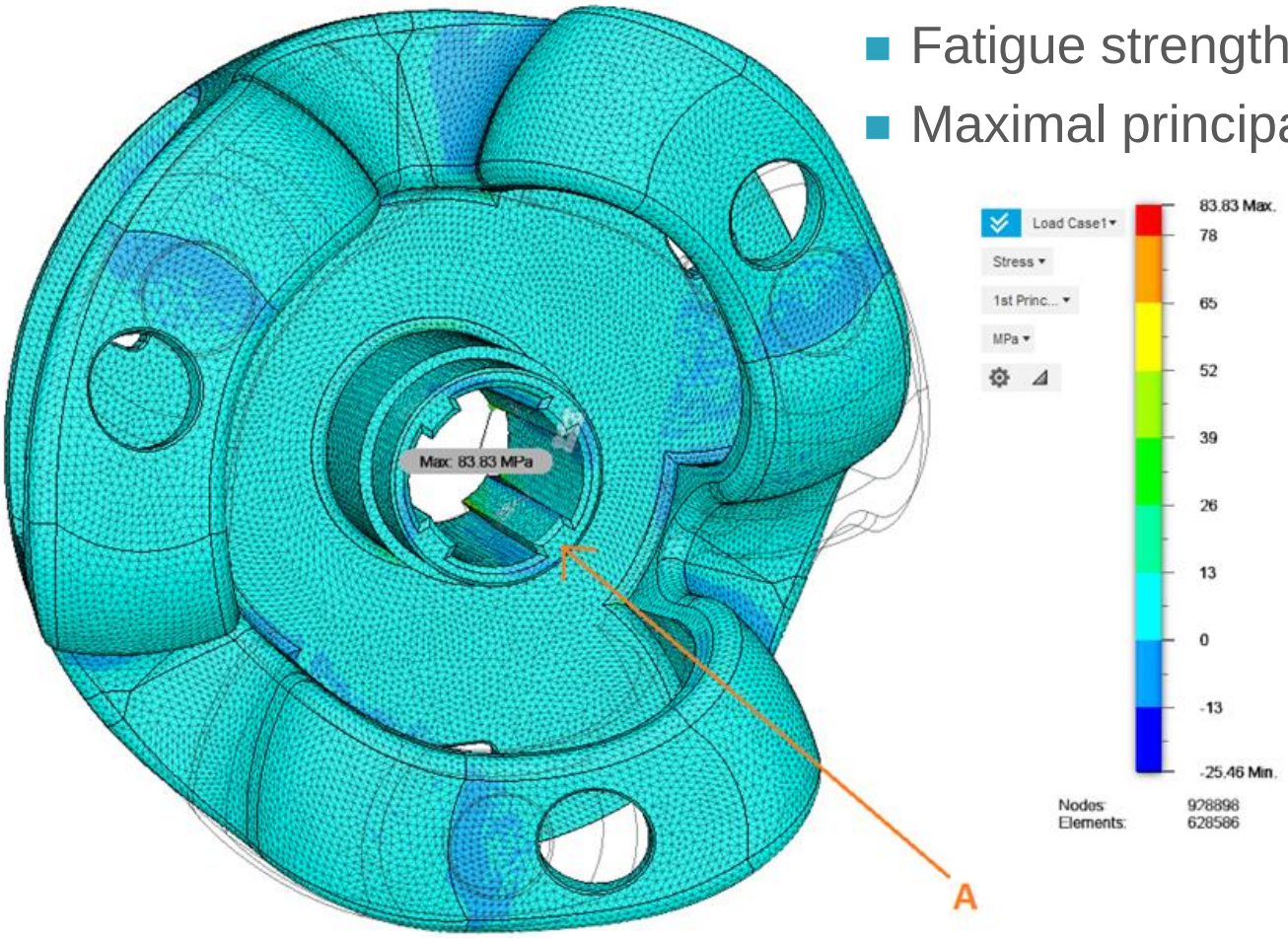
AUTODESK® FUSION 360™

Analysed components:

- Roller planet
- Axle
- Control sleeve (part 1)
- Control sleeve (part 2)
- Gear carrier
- Roller ring
- Sprocket-ring gear assembly
- Roller sun
- Roller carrier
- Enclosure

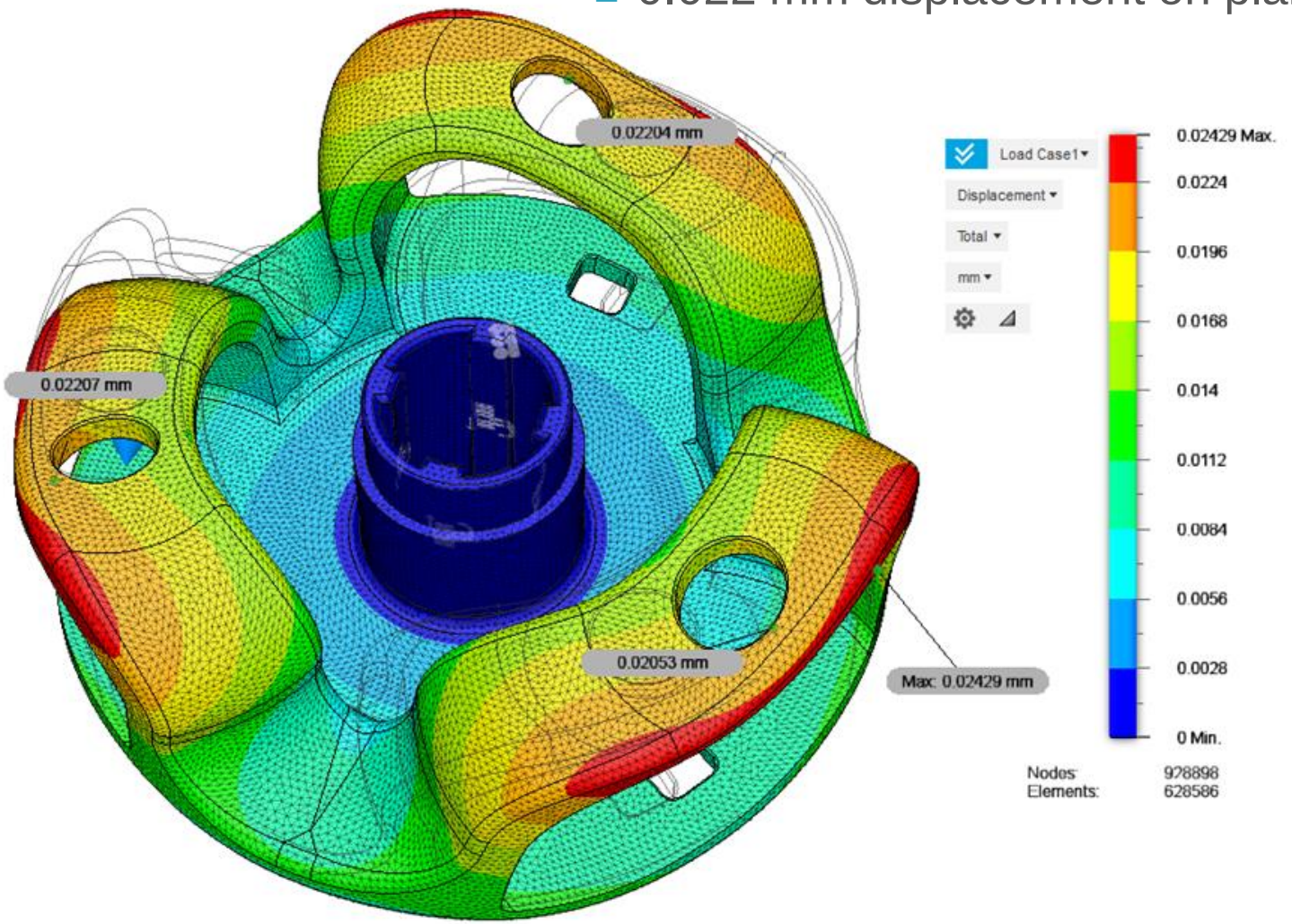
FEA example: Gear carrier

- Aluminium 201.0-T6 Casting Alloy
- Yield strength : 435 MPa
- Fatigue strength : 135 MPa
- Maximal principal stress : 83.8 MPa



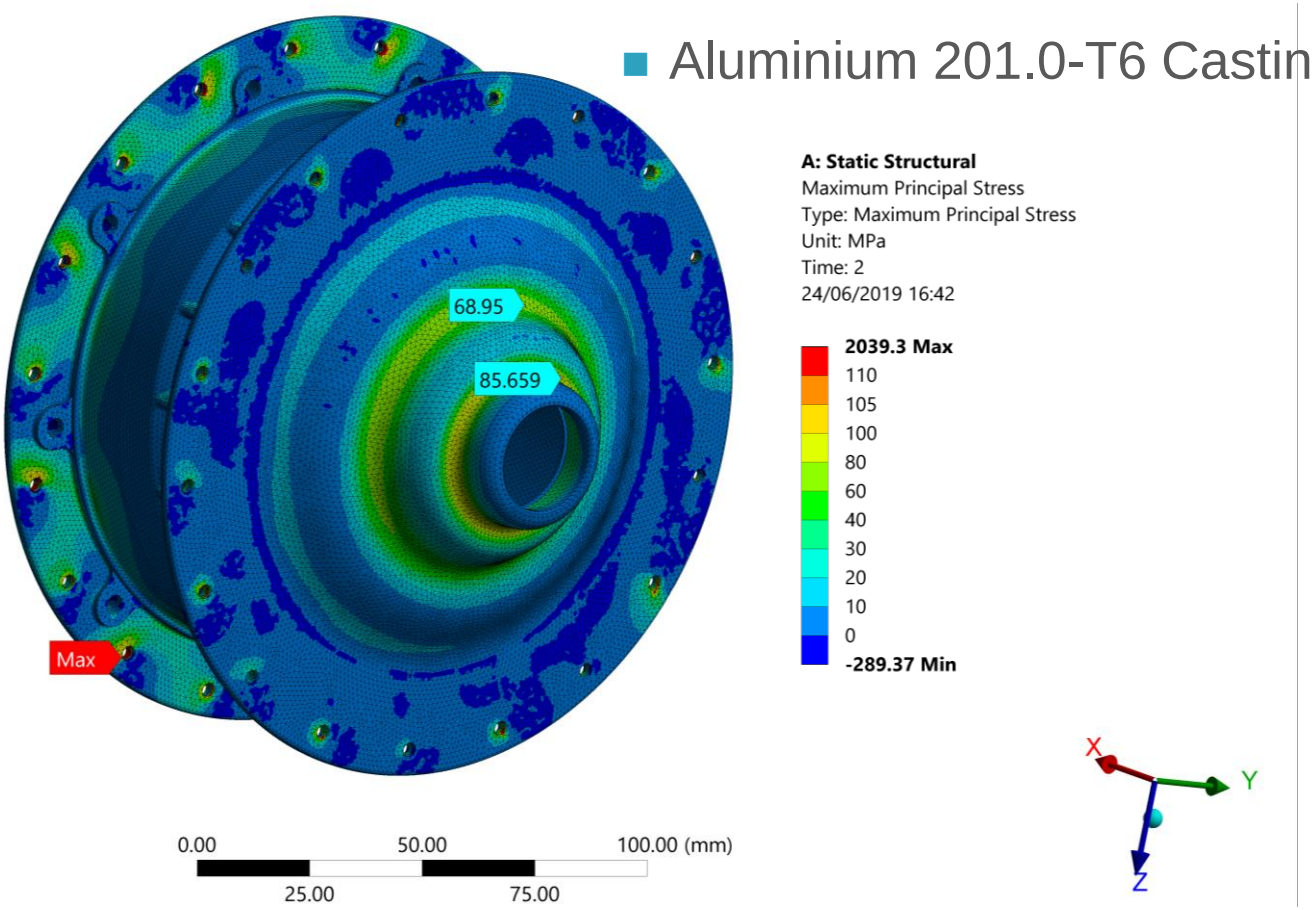
FEA example: Gear carrier

- 0.022 mm displacement on planet gear location



FEA example: Enclosure

- Analysed with ANSYS software
- Wheel assembly with pretension spokes, rim and tire
- Aluminium 201.0-T6 Casting Alloy



FEA example: Enclosure

A: Static Structural
Static Structural
Time: 2. s
Items: 10 of 43 indicated
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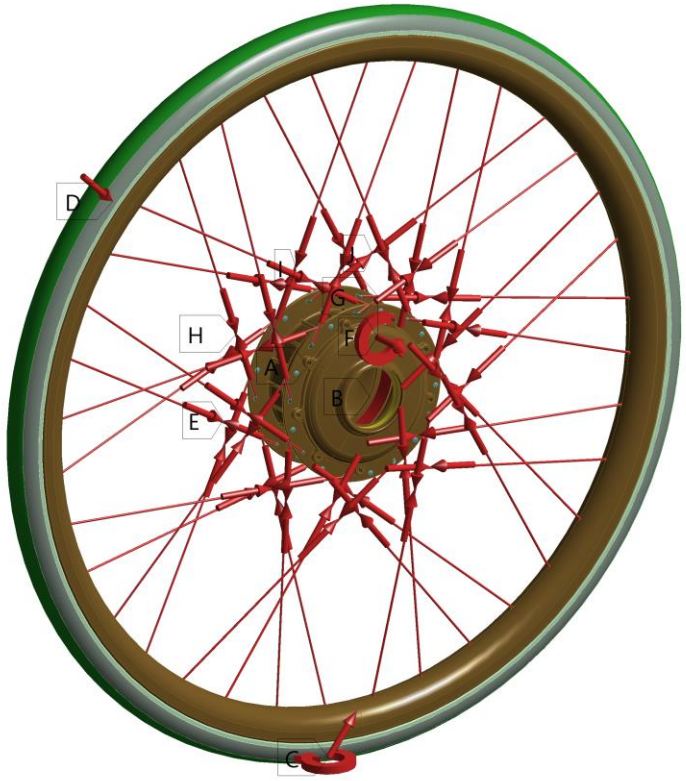
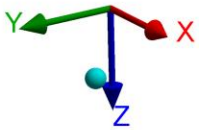
- **A** RP1
- **B** RP2
- **C** GroundForce: 1064.7 N
- **D** Pressure: 0.8 MPa
- **E** Pretension 1: 1000. N
- **F** Moment: 24000 N·mm
- **G** Force: 420. N
- **H** Pretension 2: 1000. N
- **I** Pretension 3: 1000. N
- **J** Pretension 4: 1000. N





Conclusion

- 400% ratio range ↑ N360: 360% (NuVinci CVT)
- 2.7 kg weight ↓ N360: 2.45 kg

Difficulties:

- Limited space for the design

Further work:

- Selection of the right lubrication
- Simplification of certain components
- Weight reduction
- Fatigue analysis