

# Load sharing in wind turbine gearboxes. **Reinvented.**

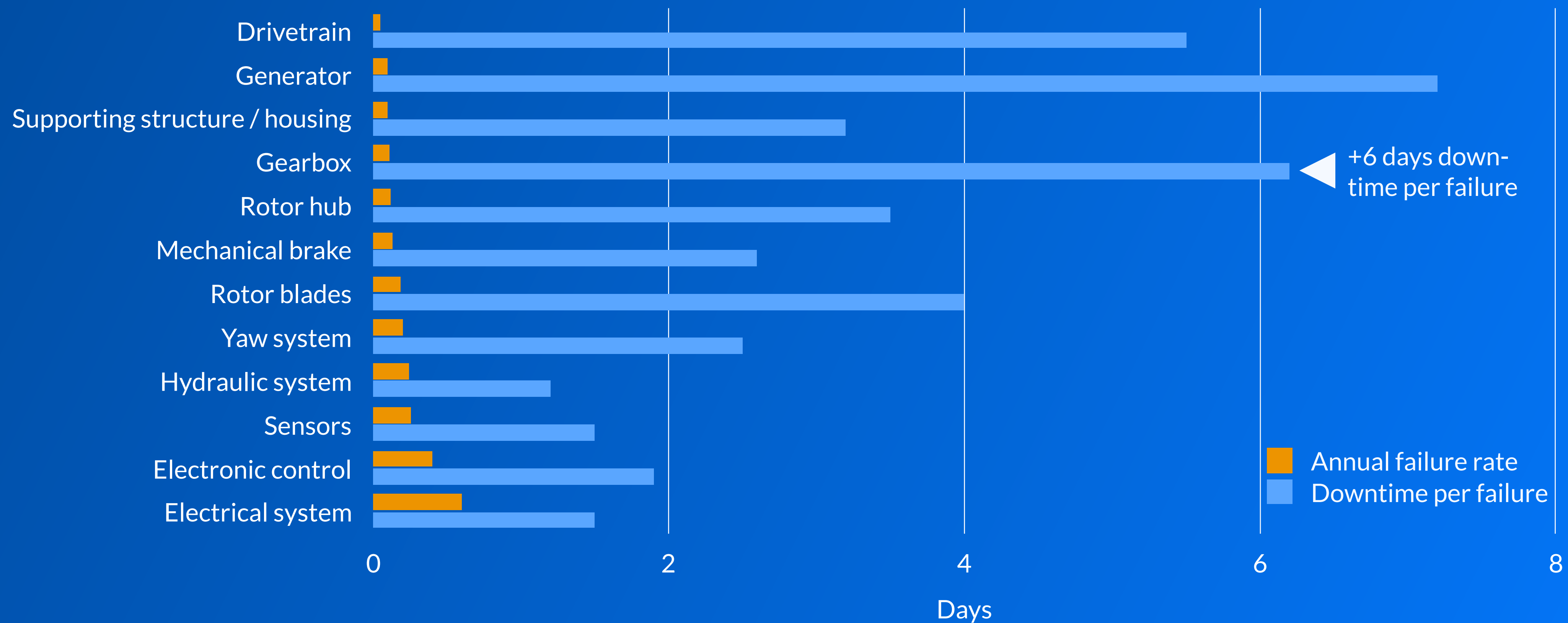
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MSc Mechanical Engineering  
Certified PMP





# Wind turbines | failure rate and downtime



# Gearbox exchange

€200K - €500K  
Up to 10% of total turbine cost

Component cost

6-7 days

Downtime

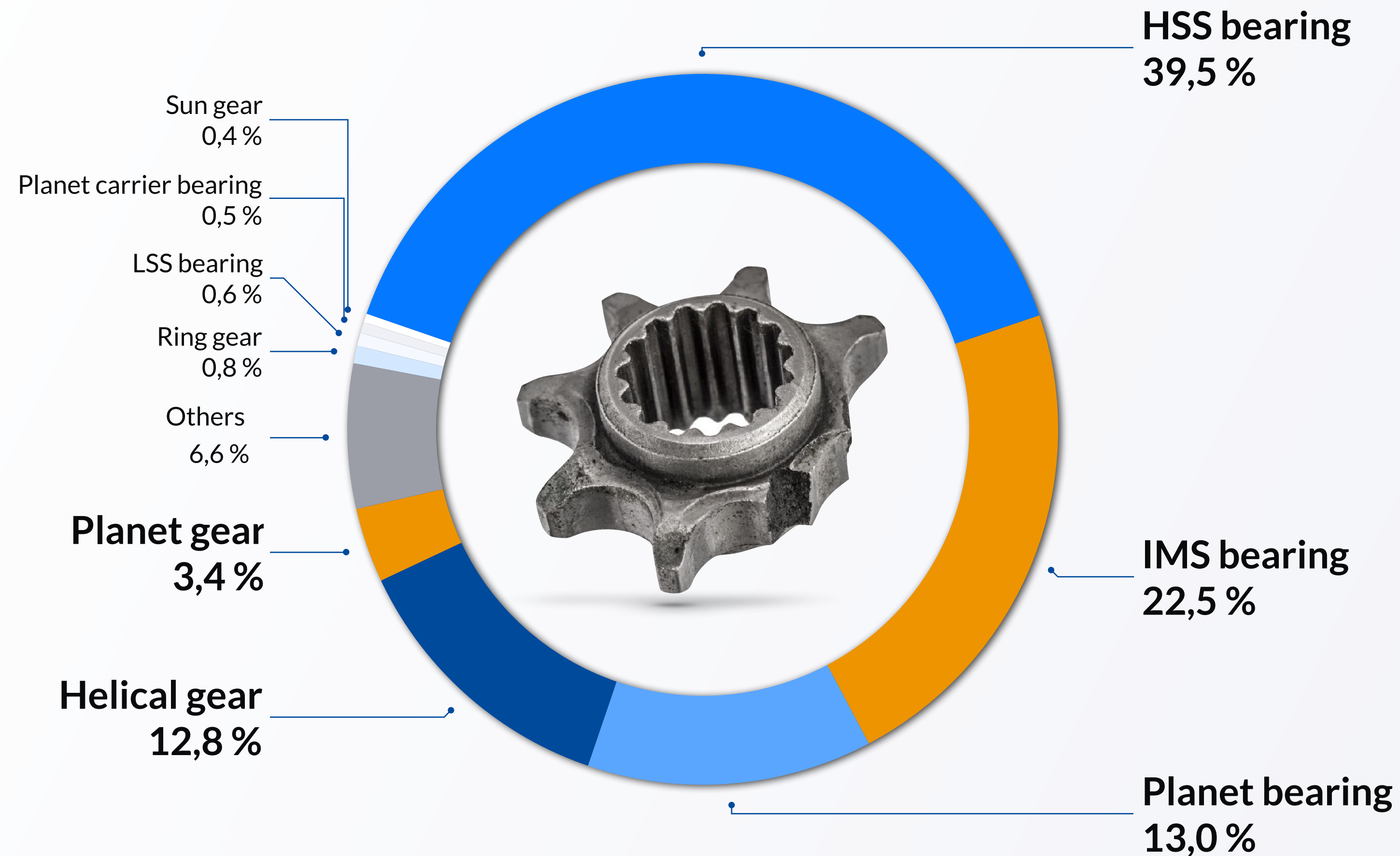
Site dependent

Replacement work





# Failure distribution





# Gearbox design challenges

## Engineering

- » Transient loads
- » Temperature range
- » Wear
- » Particles / oil contamination
- » Viscosity – LSS to HSS
- » Efficiency

## Manufacturing

- » Large components
- » Precision and tolerance
- » Uneven load sharing
- »  $L_{10}$  – Time when 10% of the bearing fails (probabilistic)

## Current status

- » Lifetime hard to reach

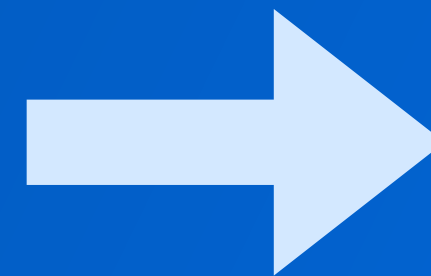




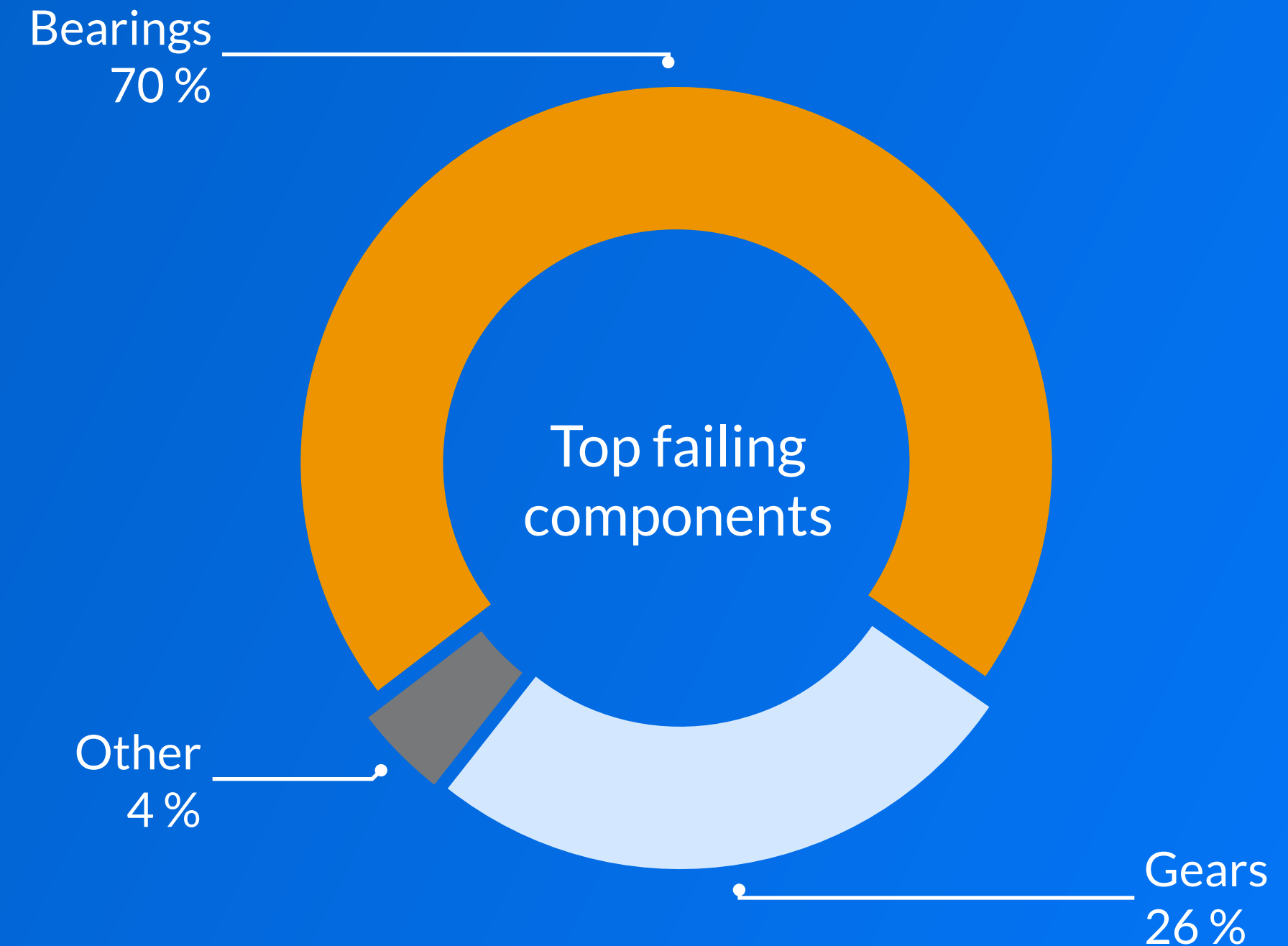
# Gearbox failures

## Load transients is one contributor

- » Gusts
- » Blade passing tower
- » Air density variation
- » Turbulence
- » Fault events



$$L_{10} = \left( \frac{C}{\overline{P}} \right)^p$$





# Key challenges in gearbox design

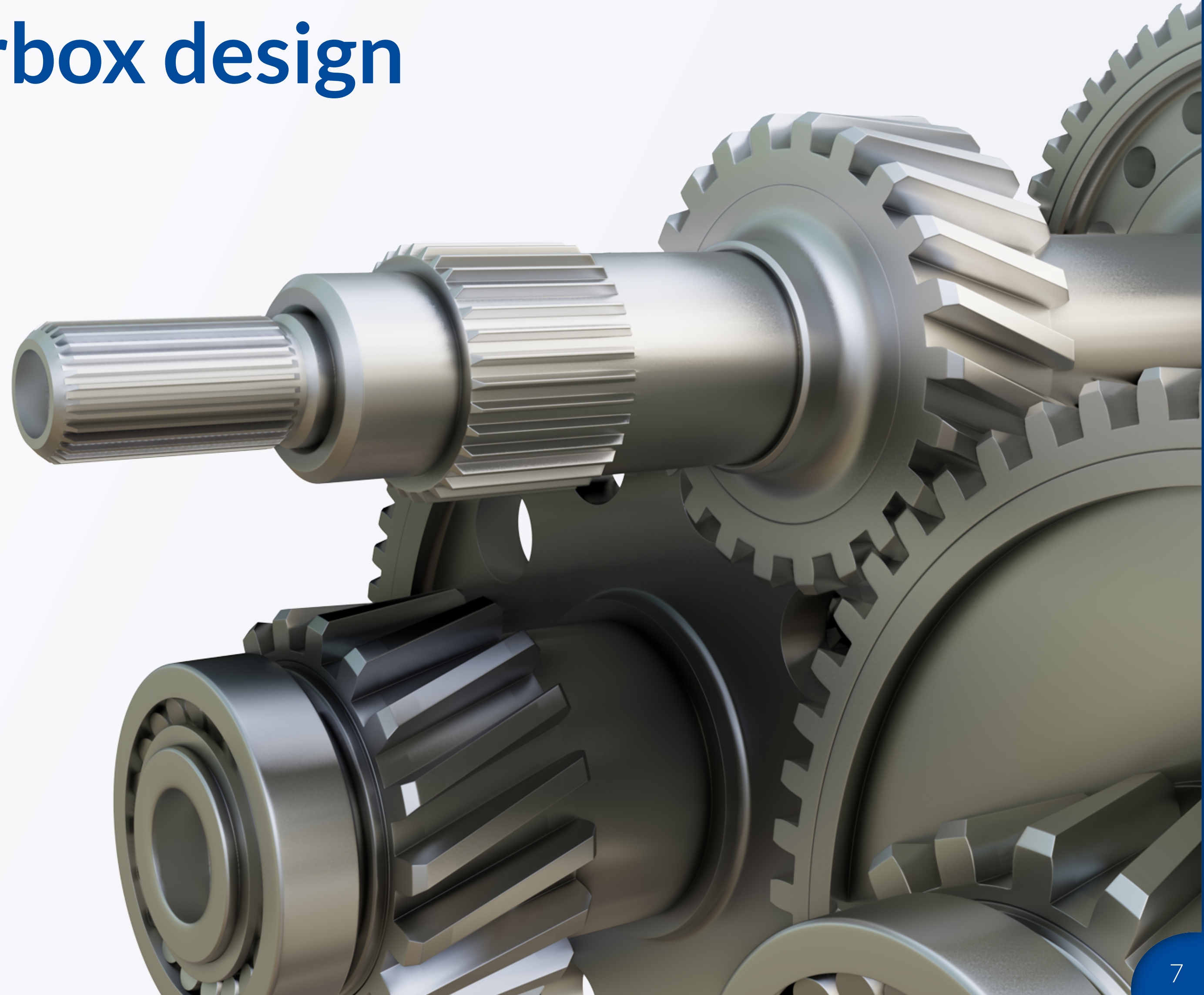
Efficiency

Load sharing

Load transients

Bearing life

Maintenance





# This is Cascade Drives

- » Founded in 2014
- » Six highly skilled employees
- » Unique patented solutions
- » Two core products with benefits in multiple application areas

## Our potential and track record

- » 7 customer-financed pilots in different application areas
- » 71 000 MSEK global addressable market growing at +5%
- » Enabler of transition to all-electrical industrial systems

***We enable the transition to all-electrical systems and contribute to global sustainable growth.***





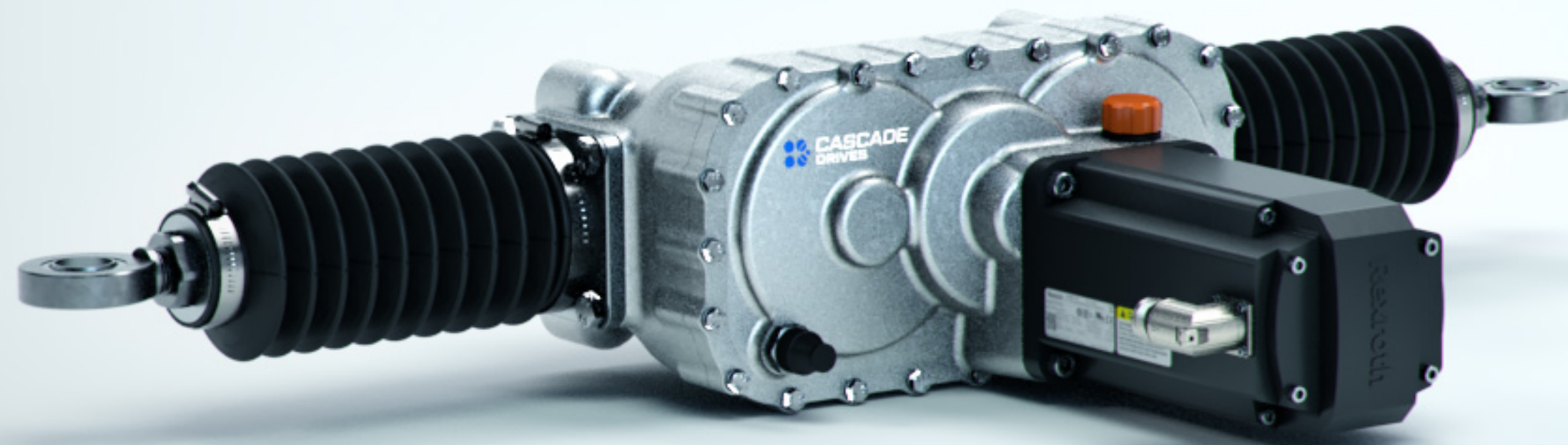
## Linear actuators

Heavy mobile equipment

» lifting, steering, tipping

Servo presses

Pressure boosters



## Planetary gears

Electric vehicle power trains

Wind-power turbines



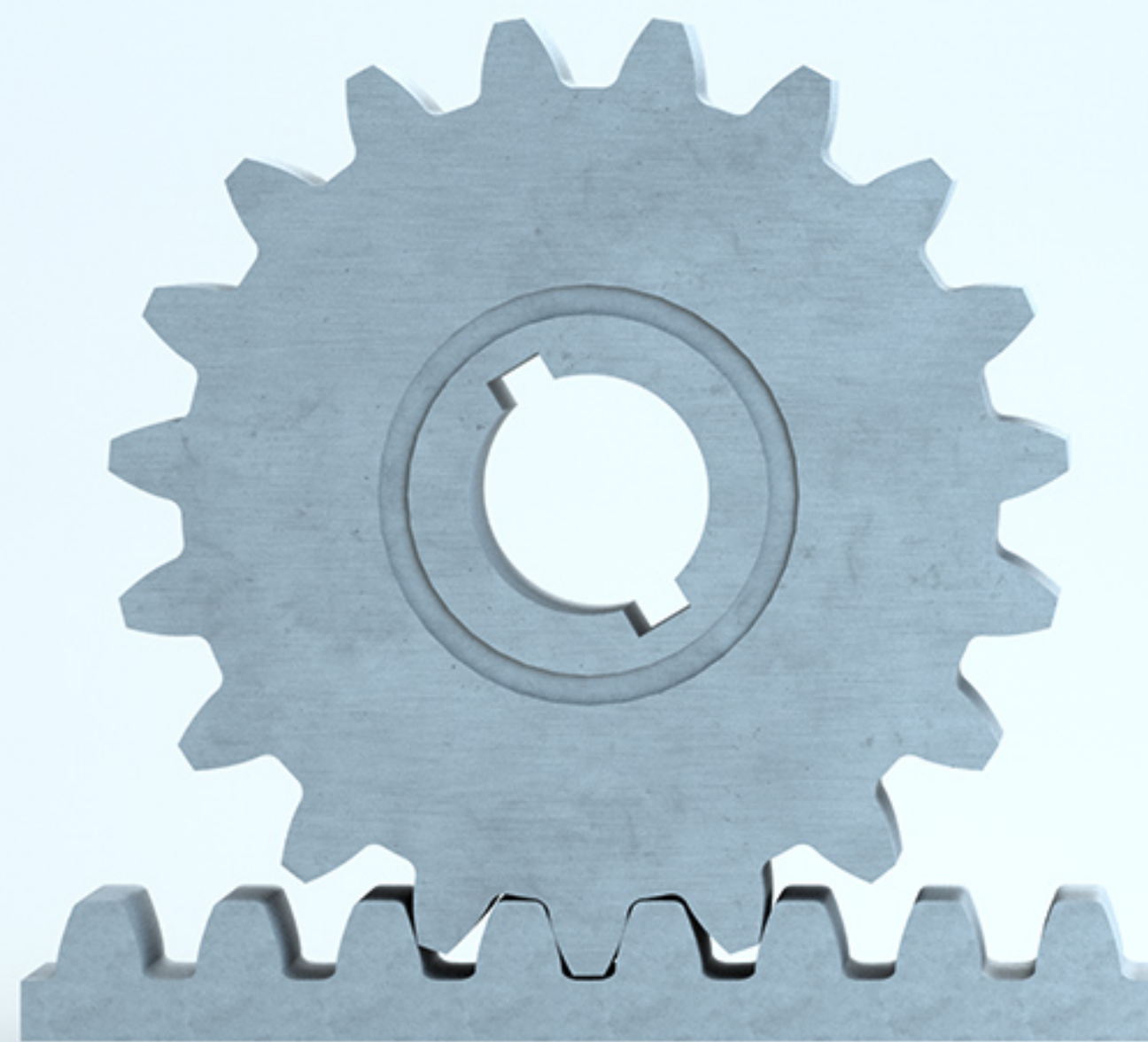


**2x**

max load

**1x**

max load



**cdGear**

**4x**

max load



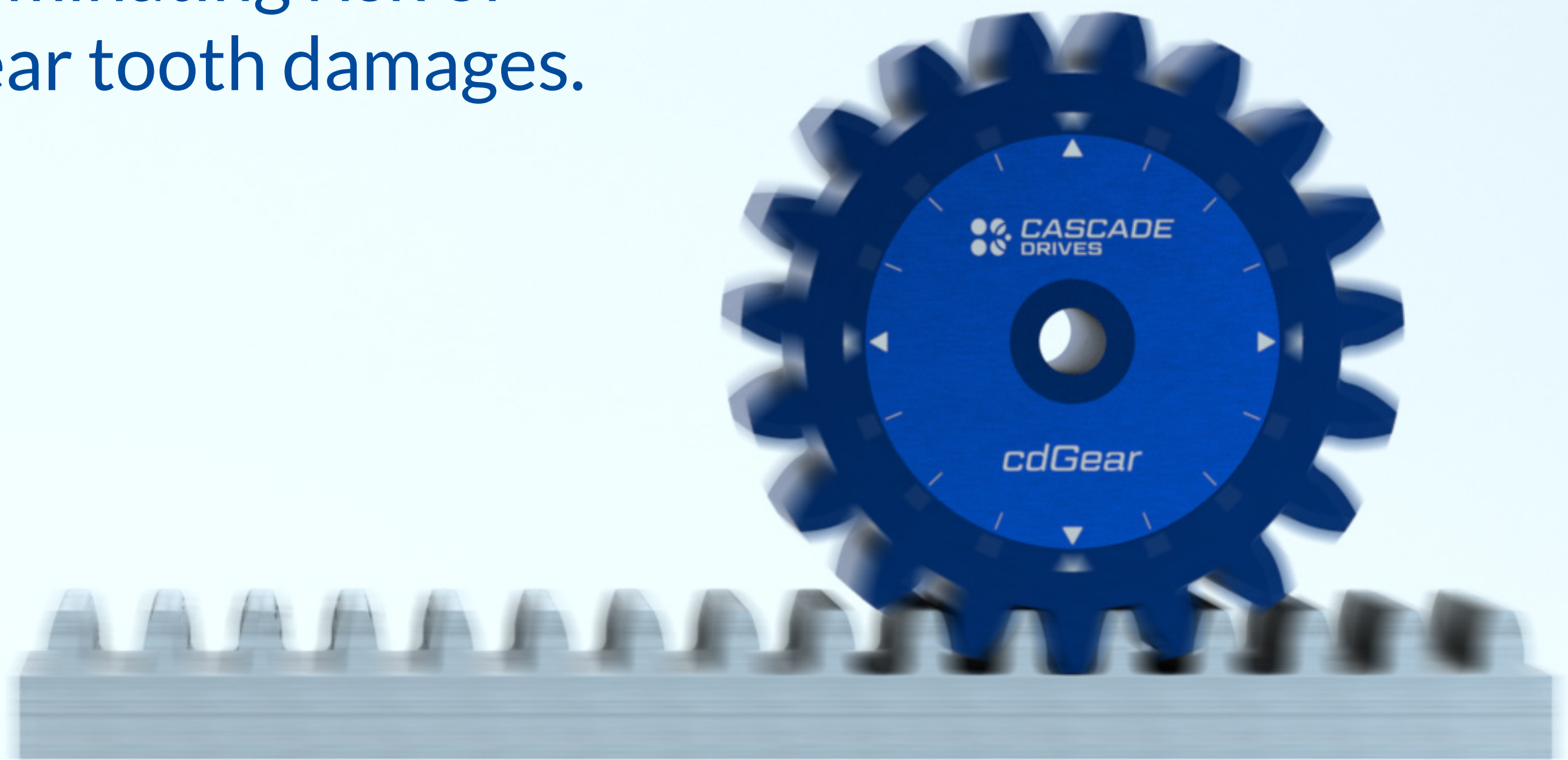
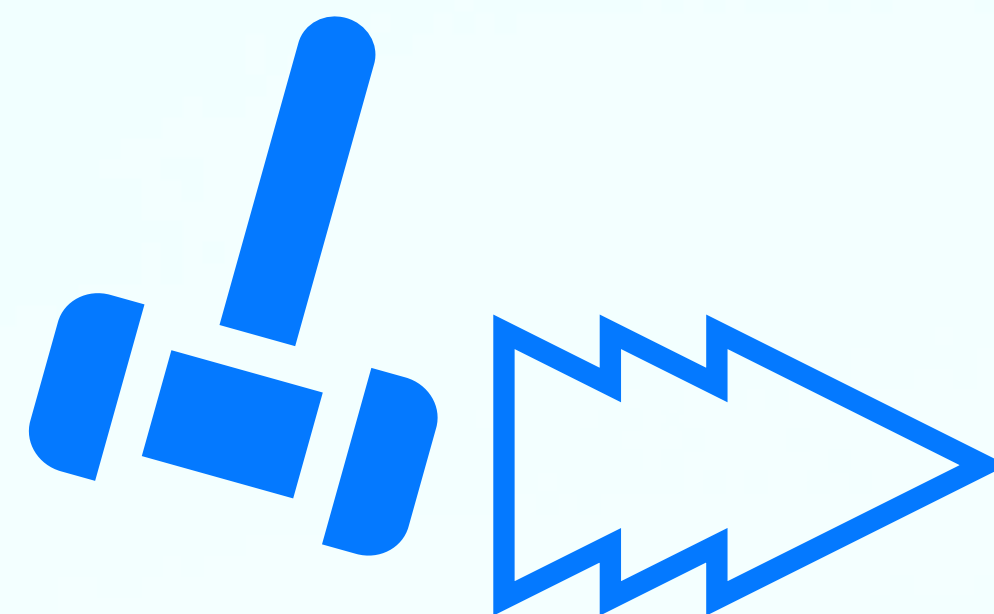


# Shock load resistance

The built-in pinion flex, makes cdGear resistant to impulse shock loads.

- » Longer life
- » Lower TLC
- » Increased reliability
- » Less maintenance

Shock loads are effectively absorbed, eliminating risk of gear tooth damages.





# Track record

Prototypes applications delivered

- » Lifting
- » Steering
- » Pressing

Verified load sharing capabilities

Endurance test rigs



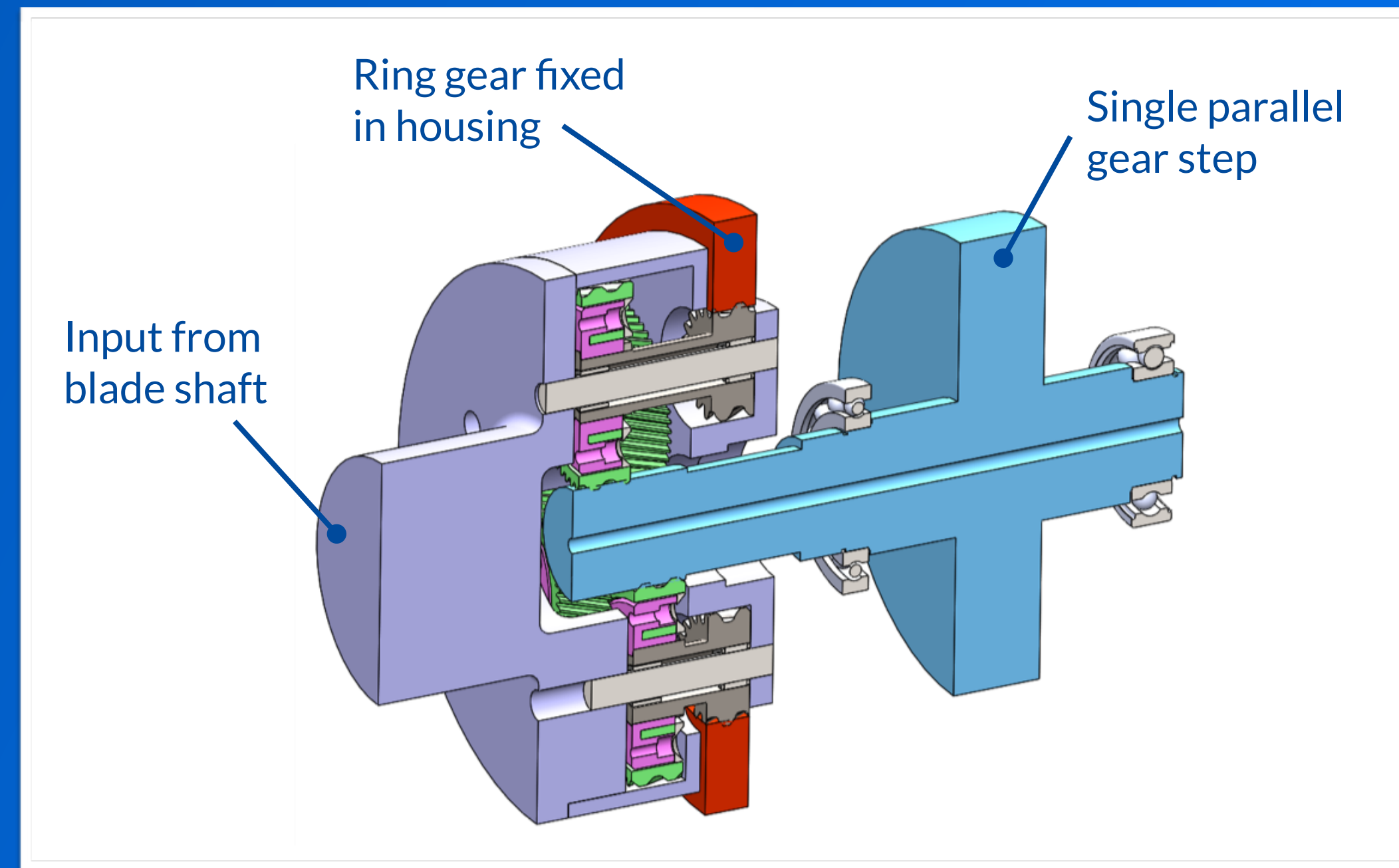


# Benchmark | 2 MW



## Traditional layout

- » One planetary step
- » Two parallel steps



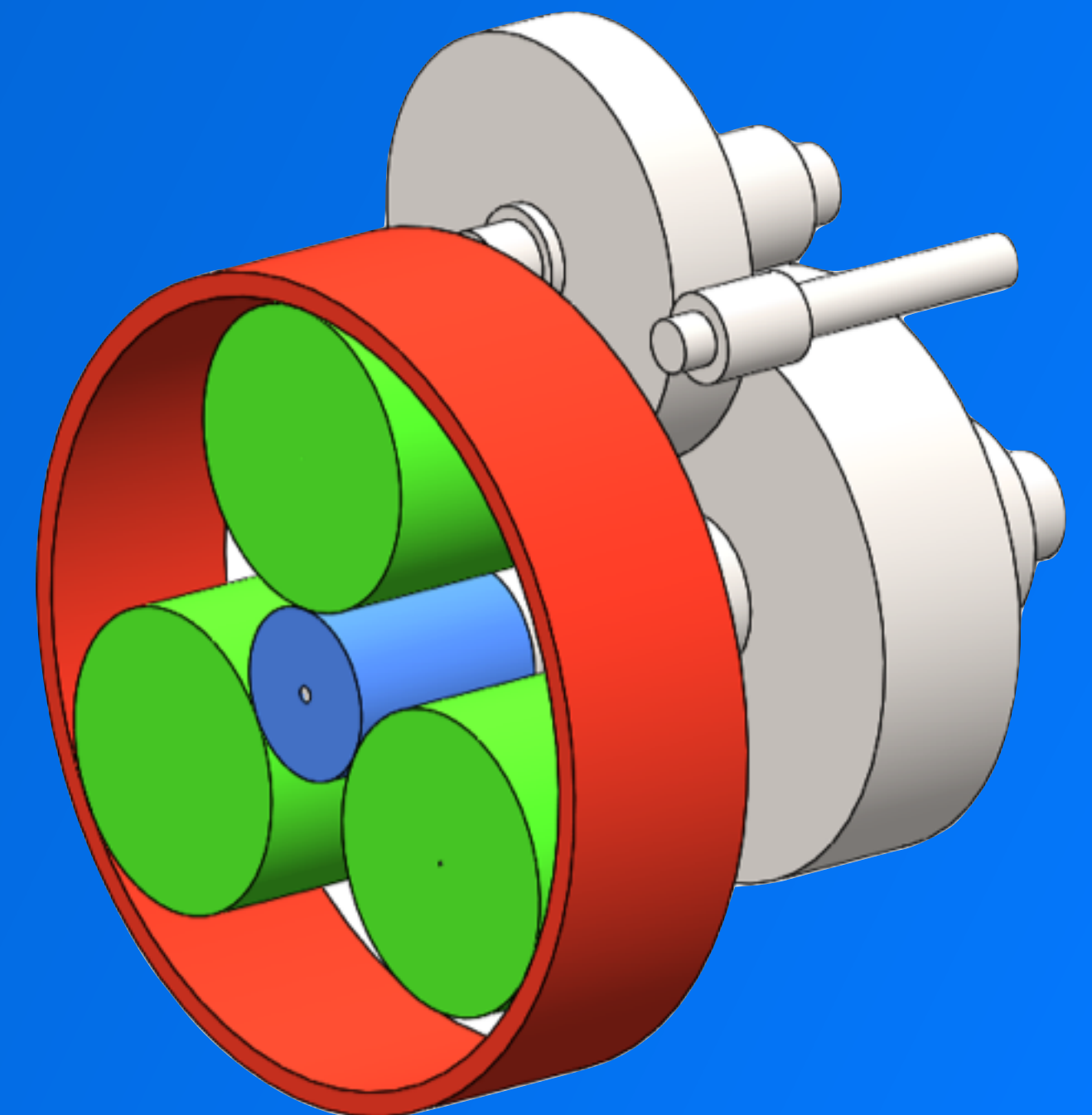
## Concept layout

- » One compound planetary step
- » One parallel step



# Benchmark | 2 MW (cont'd)

Stage	Gear	Number of teeth	Module [mm]	Helical angle [deg]	Pressure angle [deg]	Ratio	Tooth width [mm]
1	Sun	21	15	8	25		395
	Planet (x 3)	37	15	8	25	5,57	390
	Ring	96	15	8	25		395
2	Gear	97	11	10	20		310
	Wheel	23	11	10	20	4,22	320
3	Gear	103	8	10	20		180
	Wheel	21	8	10	20	4,90	190
Total						~115	





# Design constraints and load case

## » Safety factors according to IEC

- Pitting 1,25
- Root fatigue 1,53

## » Design life

- 20 years

## » Constant speed

- 15 rpm

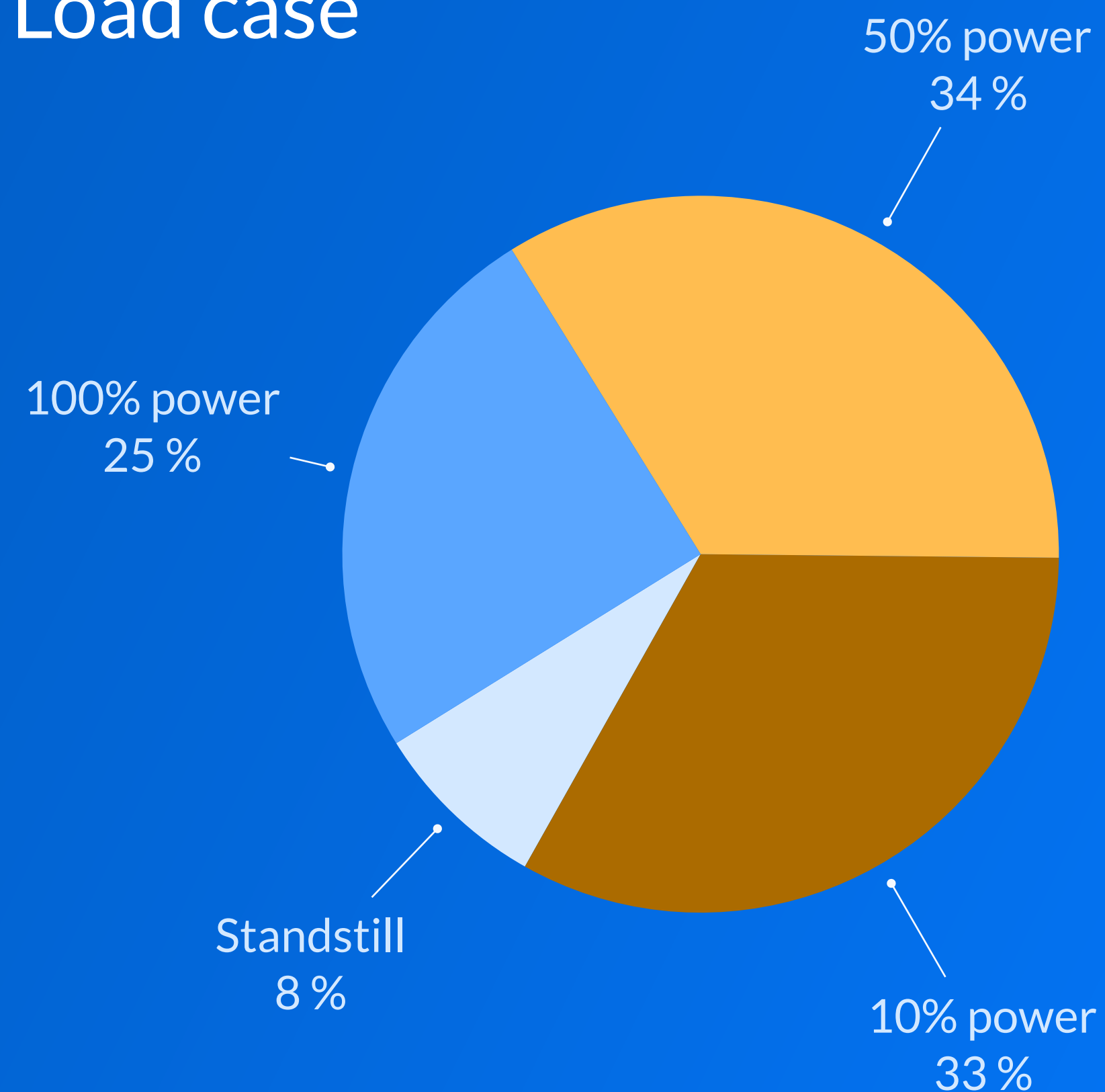
## » Wind class

- III (Low wind)

## » Capacity

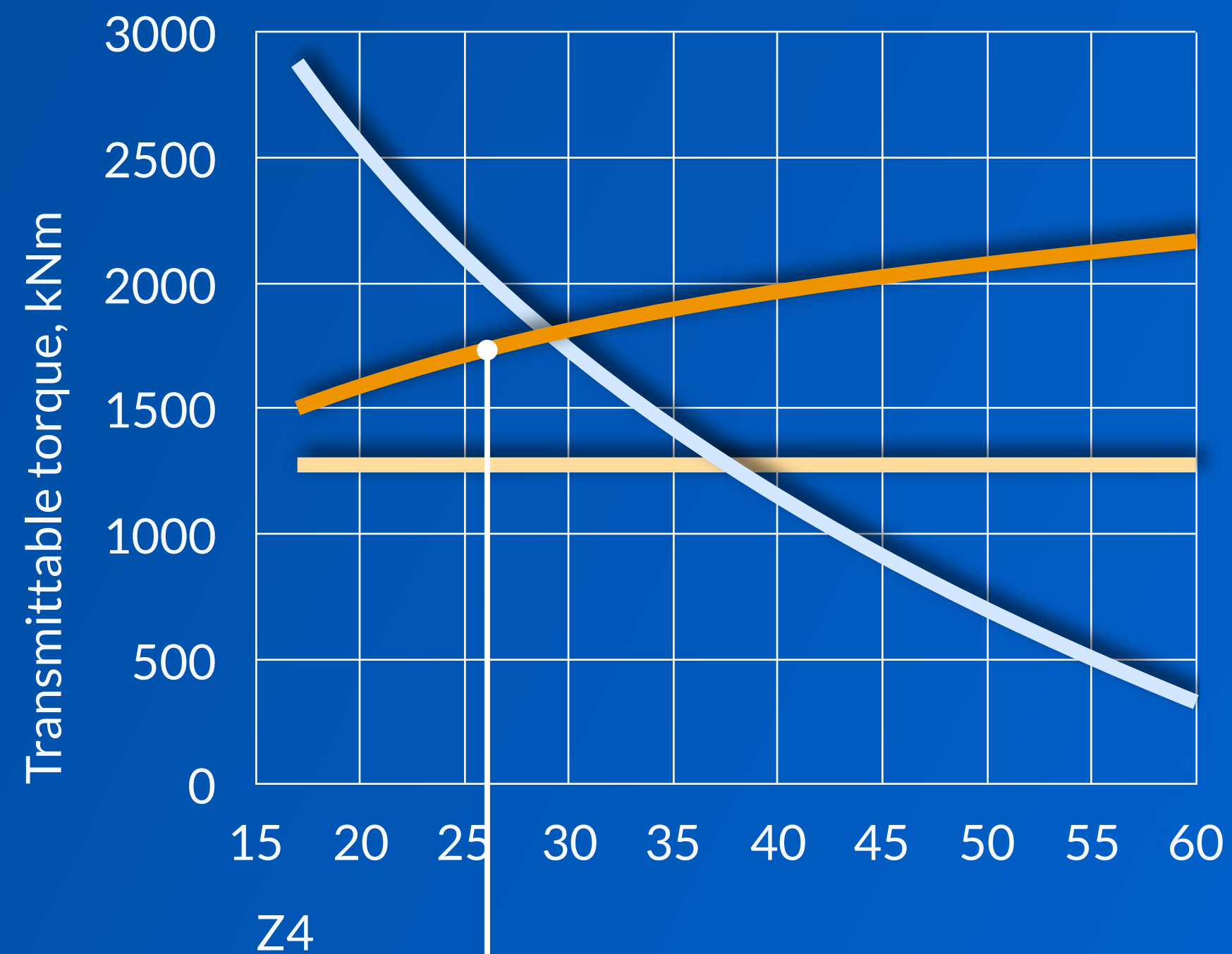
- 2000 kW

## Load case



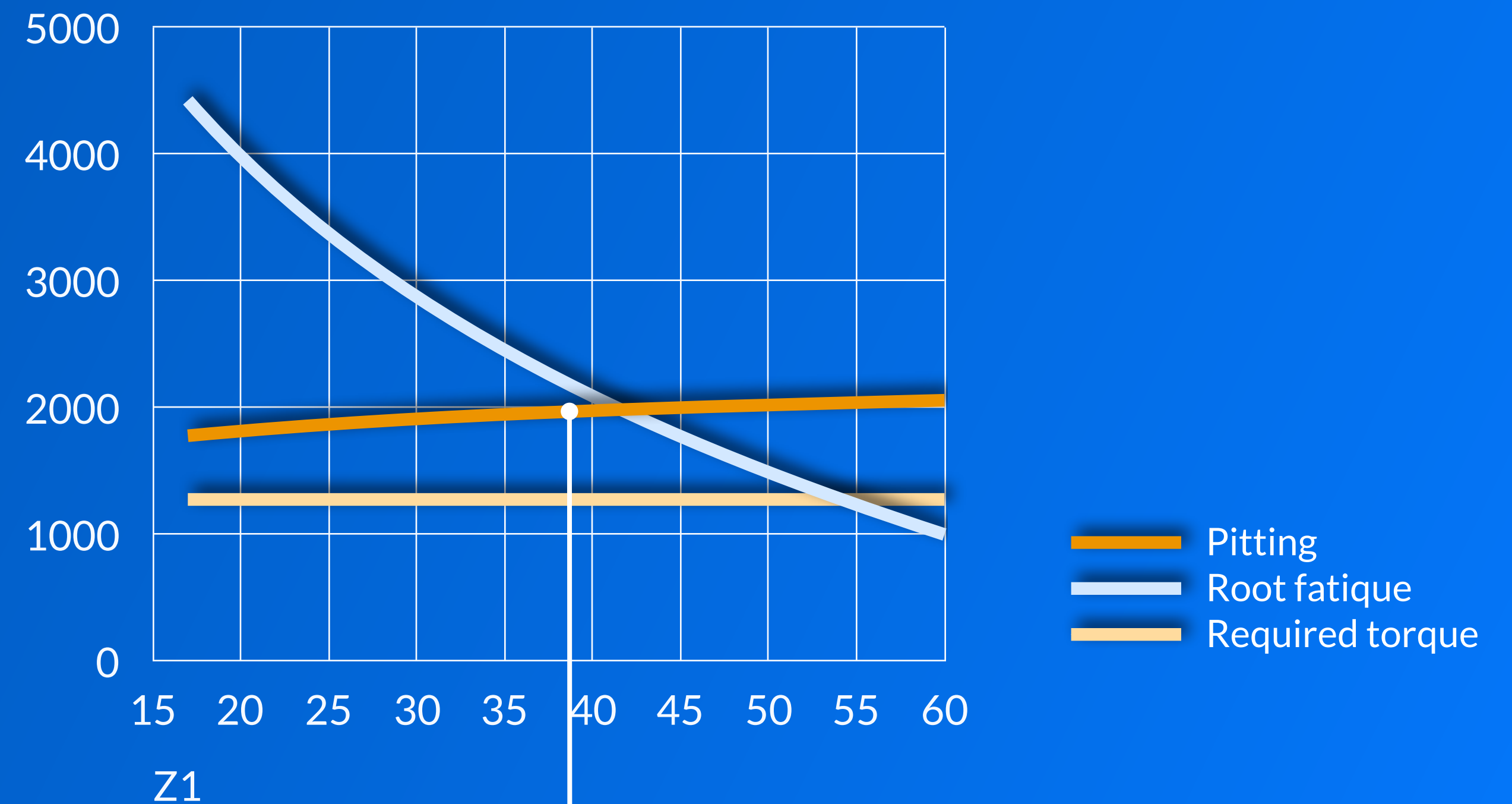


# Results | Compound 2MW gearbox



**Z= 26**

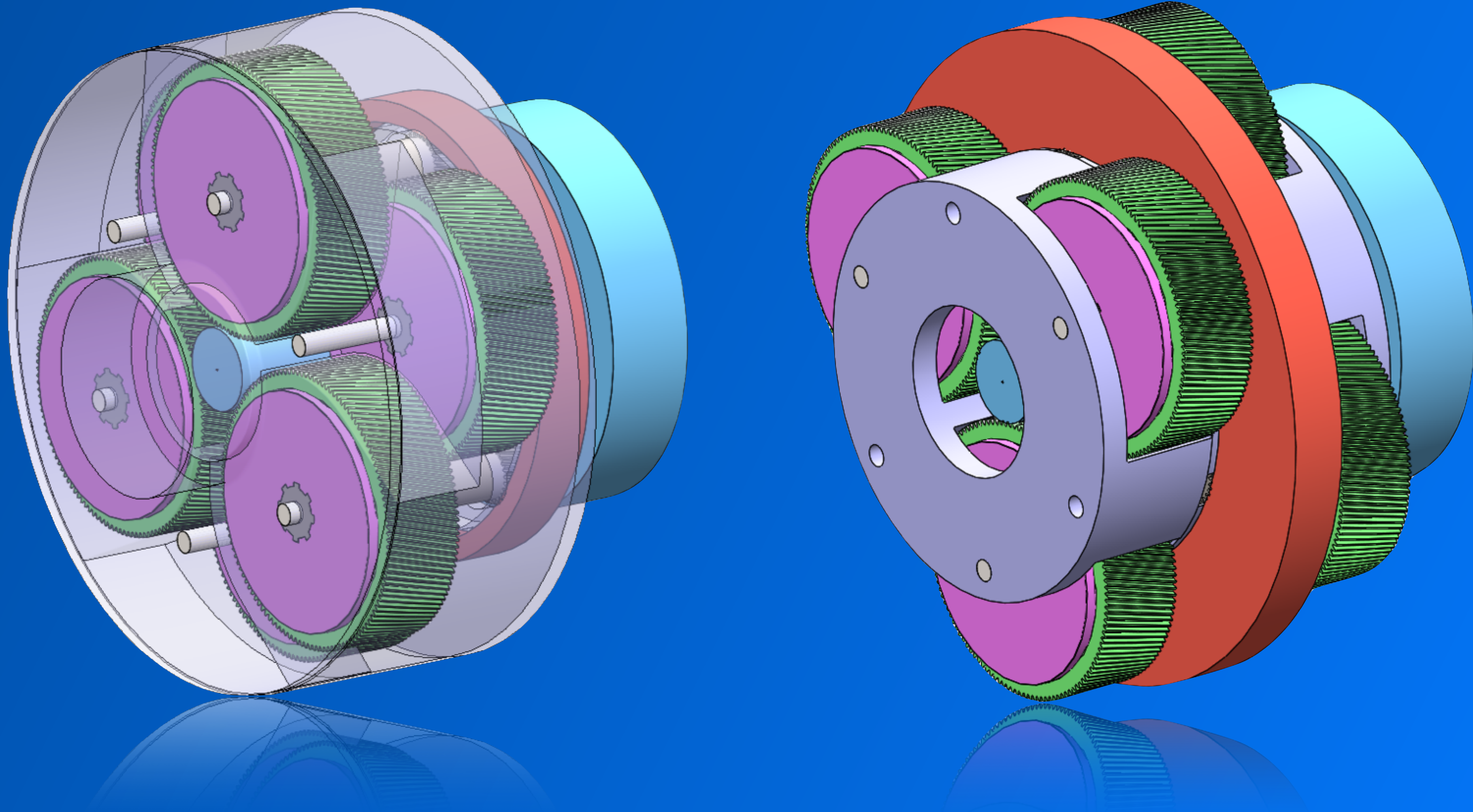
Margin to pitting / root fatigue > 1.30



**Z= 38**

Margin to pitting / root fatigue > 1.50

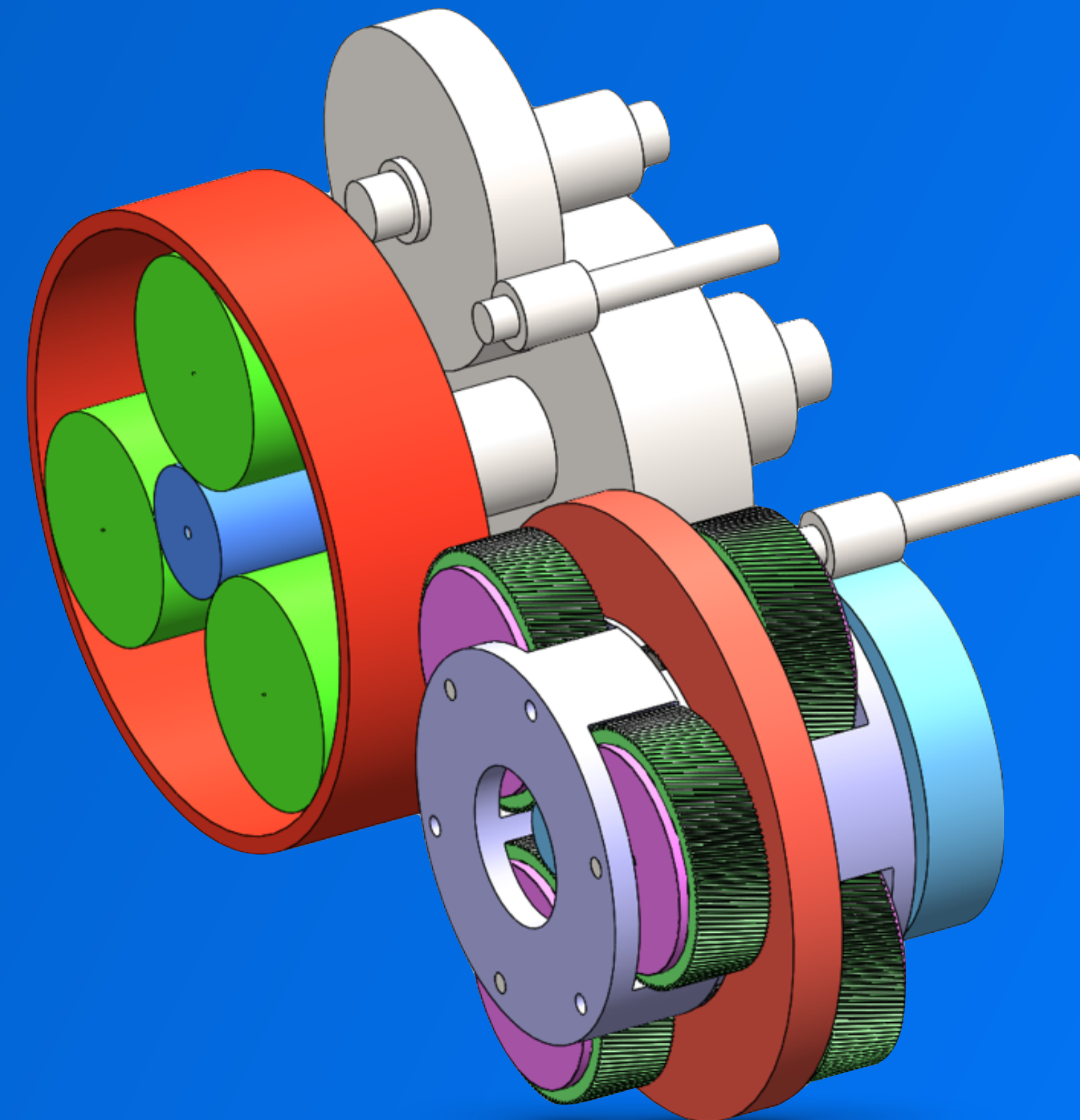






# Compound vs traditional

- » Input / output shafts in identical position
- » Fits within given geometry
  - Margin to increase torque or
  - Reduce face width
- » Planet wheel load reduced
  - Distributed between more axles
  - Less transients and lower load per axle means bearing situation is improved
- » Load transients from rotor to HSS significantly reduced
  - Improves bearing dynamics
- » ISS removed – no bearing issues
- » Planet wheels – full load sharing between shafts





# Wind turbine applications

## » Superior performance

- High torque density
- Reduces load transients to HSS
- Full load sharing between planet gears
- Utilizes more planet gears, less load per gear

## » Energy efficient

- Increased ratio
- Gear step reduced

## » Compact design

- High torque density
- Reduced weight/space requirement

## » Lower TCO

- Increased bearing life due to lower bearing load
- Less corrective maintenance

## » Retrofit

**CASCADE**  
**TORQUE**





# Q&A

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