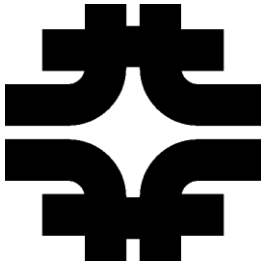

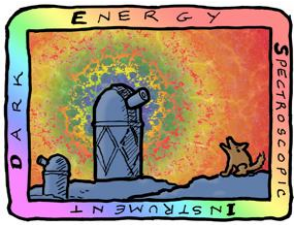

Development and optimization of conceptual design of ADCs Rotating Mechanism for DESI Project

Summer Student Program

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PPD, Fermilab

Introduction: DESI Project

The Dark Energy Spectroscopic Instrument (DESI) will measure the effect of dark energy on the expansion of the universe. The DESI consists of a spectrometer and an optical corrector.

DESI will be conducted on the Mayall 4-meter telescope at Kitt Peak National Observatory starting in 2018.

Fermilab is involved in the design of the optical support (Barrel) and the ADC Mechanism.

The entire optic system is characterized by weight of about 10 tons, diameter of more than 1 meter and length of 3 meters.

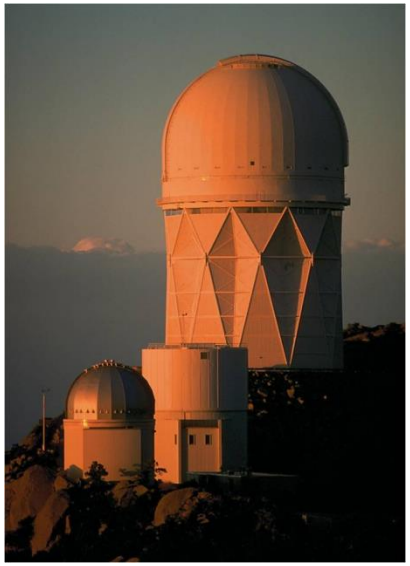


Figure 1 - Exterior of Kitt Peak Mayall 4-meter telescope (Image: NOAO/AURA/NSF)

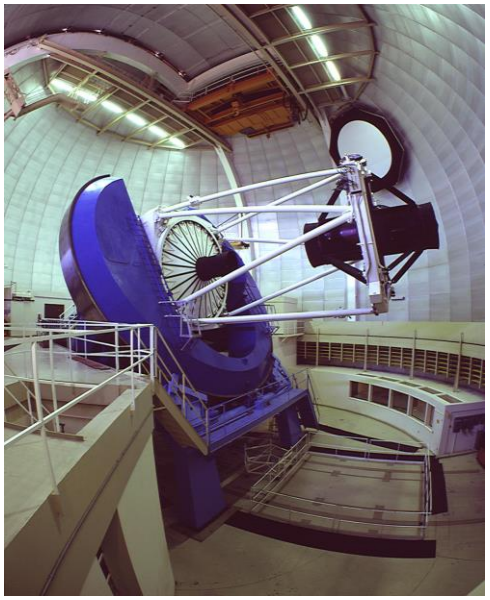


Figure 2 - The Kitt Peak National Observatory's Mayall 4-meter telescope

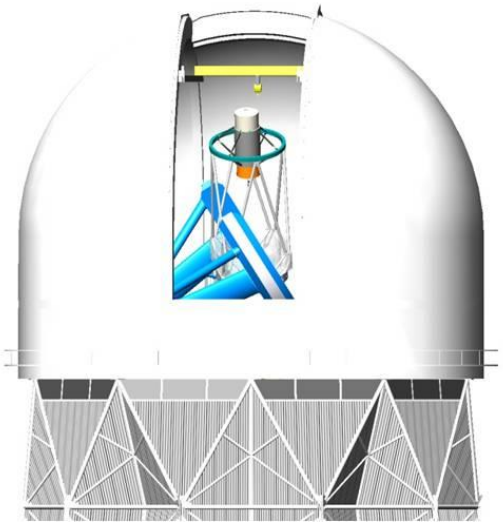


Figure 3 - A model of the Mayall telescope with a DESI Prime Focus Assembly

ADC Mechanism

ADC is an acronym for Atmospheric Dispersion Corrector.

There are two ADCs in the DESI optical corrector. Each ADC has one lens and an electric motor drive that rotates the lens about its optical centerline (z-axis).

During observations, both ADCs are independently adjusted for optimum optical performance. The lens in an ADC is supported on roller-type bearings.

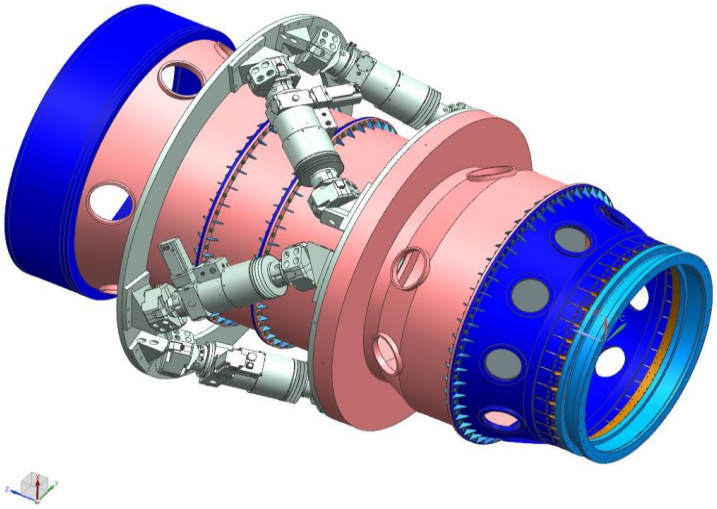


Figure 4 - 3D model of the barrel and hexapod system

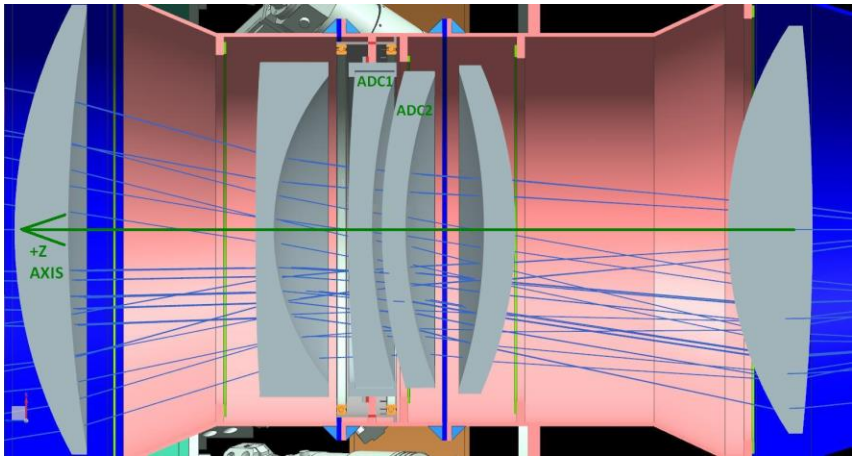


Figure 5 - Location of ADC Mechanism Inside the barrel

Summer Student Training Program

- Developing conceptual design of the bearing system assembly
  - Bearing solutions
  - Housing
  - Lubrication and sealing system
- Analyzing the possible solutions for the motion and positioning system

Bearing System

- The bearing system connects lens with barrel and allows rotary motion and positioning of the lens.
- High precision for the centering of the lens is required
- Connection with transmission system

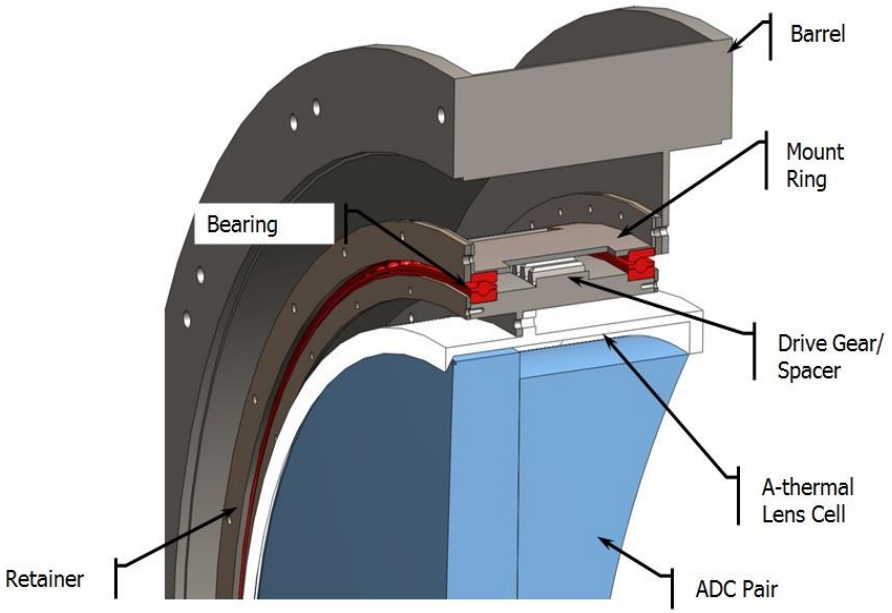


Figure 6 - First conceptual design of ADC Mechanism developed by LBNL

Requirements

- Small available space between cell lens and barrel
- High precision of position of lens axis
- Low weight
- Loads: lens weight
- High cleanliness
- Very low operating conditions

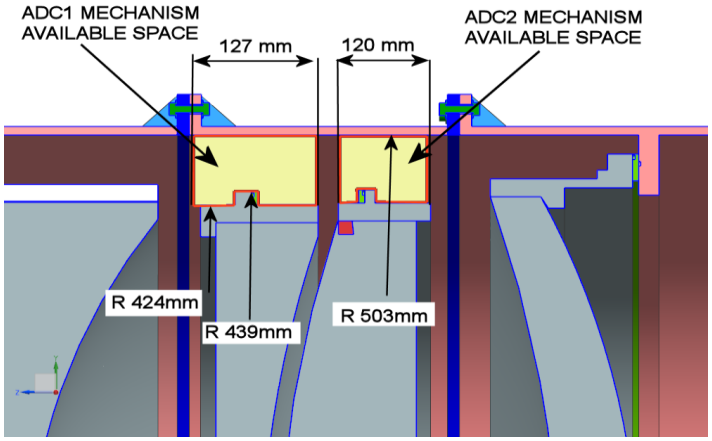


Figure 7 – Available space for ADC Mechanism

ADC Displacements Requirements for Bearing System		
Elements	Decenter	Tilt
	(± µm)	(± µrad)
ADC1	55	93
ADC2	55	43

Table 1 – Displacement requirements

Analysis Steps

- Space Analysis
- Load Analysis
- Bearing solutions: Type A vs Type X
- Deformation Analysis
- Clearance Analysis
- Kaydon Bearings Cooperation
- Final Concept Design of ADC Mechanism

Load Analysis

- Force applied in center of mass of the lens
- Bearing's reference system
- Telescope operating range of motion
- Axial, radial and moment
- Worst case scenario
- Lens weight: 200 kg

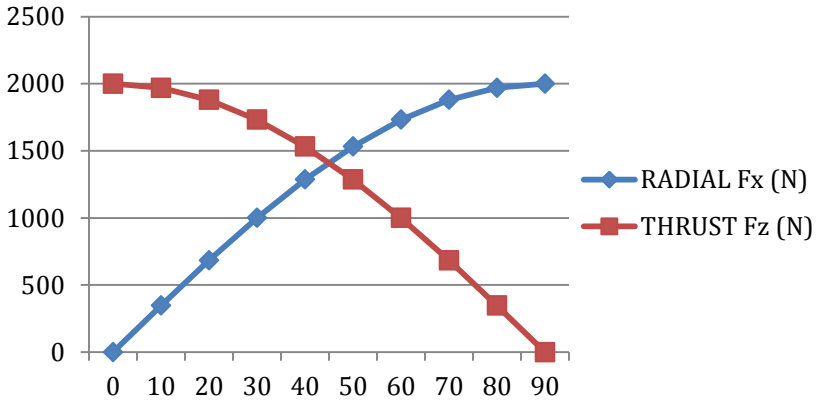


Diagram 1 – Axial and radial load vs zenith angle

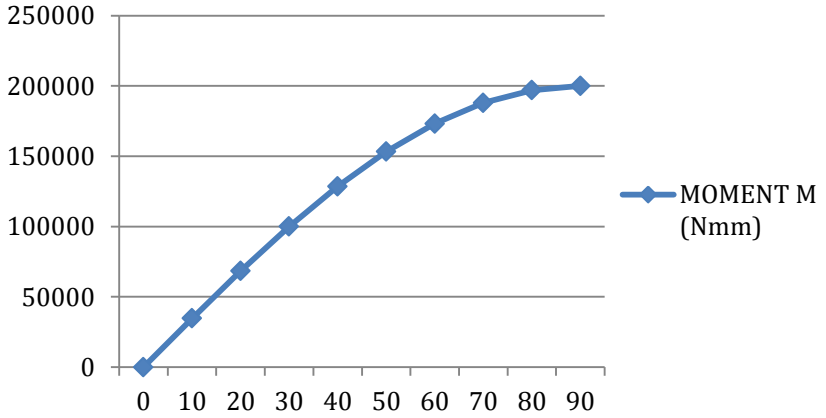
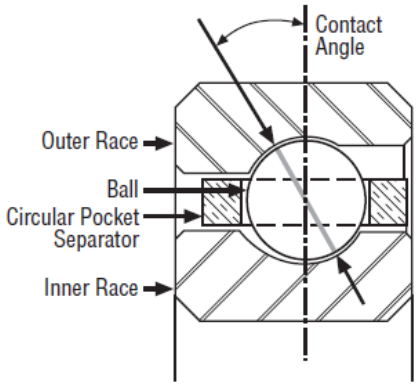


Diagram 2 – Moment vs zenith angle

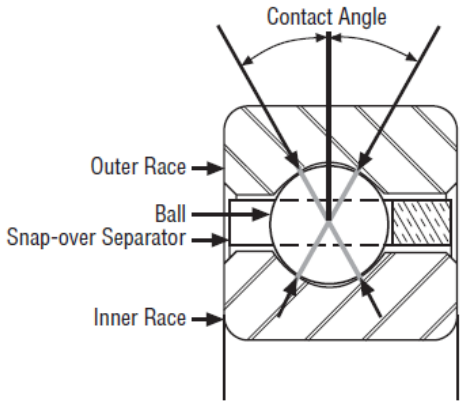
Bearing Solutions

Type A



- Two bearings required
- Complex design
- Preloading during mounting
- Control preload without high level of stress
- External lubrication system required

Type X



- One bearing required
- Simple design
- Save space and weight
- Internal preload with larger balls
- Possible high level of stress
- Already sealed solution available

Deformation Analysis

- FEA of whole assembly (type X)
- Fixed support on barrel flange
- Force and moment applied on cell lens flange
- Planar symmetry
- Frictionless contact between bearing and housing
- Bounded contact between housing and retainers

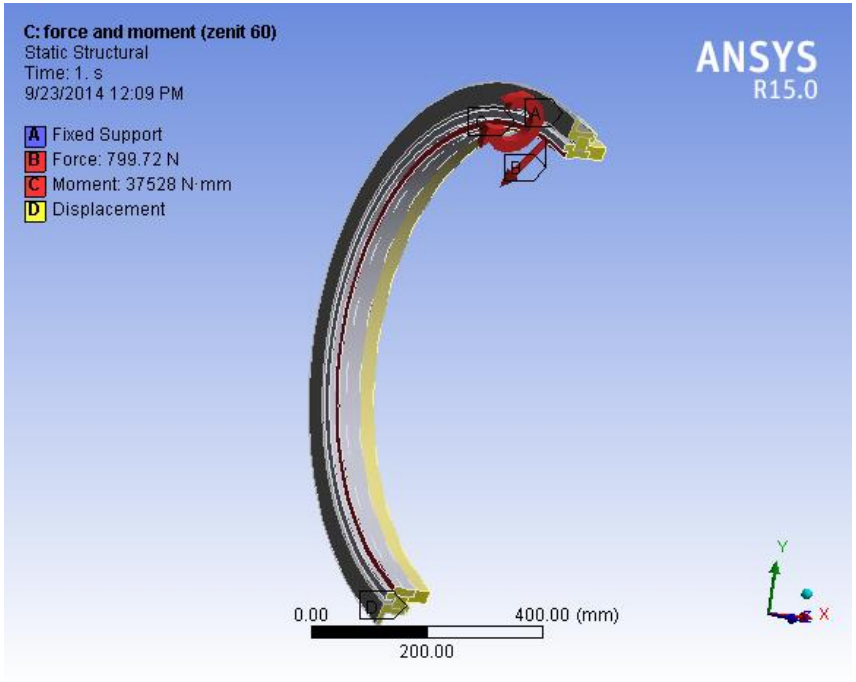


Figure 8 – Static Structural loads and constraints definition (zenith angle 60 degrees)

Deformation Analysis

- Radial deformation is the most important effect
- Small axial deformation
- Radial deformations satisfy the requirements
- Higher stiffness of Type X assembly

Type A		Type X		Requirements	
Decenter (± µm)	Tilt (± µrad)	Decenter (± µm)	Tilt (± µrad)	Decenter (± µm)	Tilt (± µrad)
7	<1	2.5	<1	55	43

Table 2 – Deformation Analysis Results (zenith angle 60 degrees)

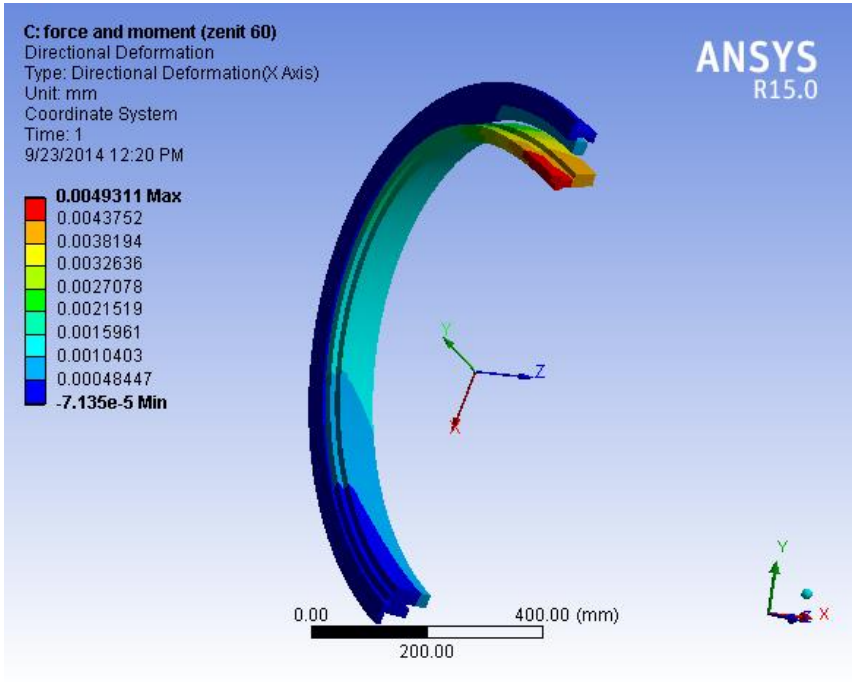


Figure 9 – Static Structural Results (type X): radial displacements (zenith angle 60 degrees)

Clearance Analysis

- Rotating shaft condition requires clearance fit on external housing
- Recommended clearance is very high
- This effect strongly influences the solution
- Worst case: decenter of 50 microns
- Custom mounting solution is required

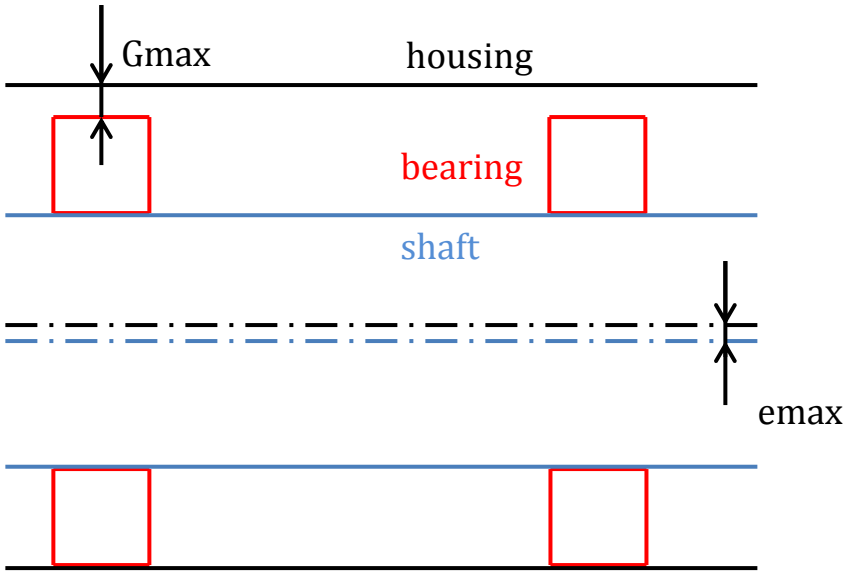


Figure 10 – Decenter effect created by clearance fit

Kaydon Bearings Co.

- Kaydon Bearings REALI-SLIM bearing
- Collaboration with Kaydon Product Engineers
- Custom mounting solution can satisfy requirements
- Type X bearing with press fit in both races and custom housing made by Kaydon
- Kaydon commissioned to design the bearing system
- Final concept design proposal
- Detailed Specification & Requirement Document

Final Concept Design

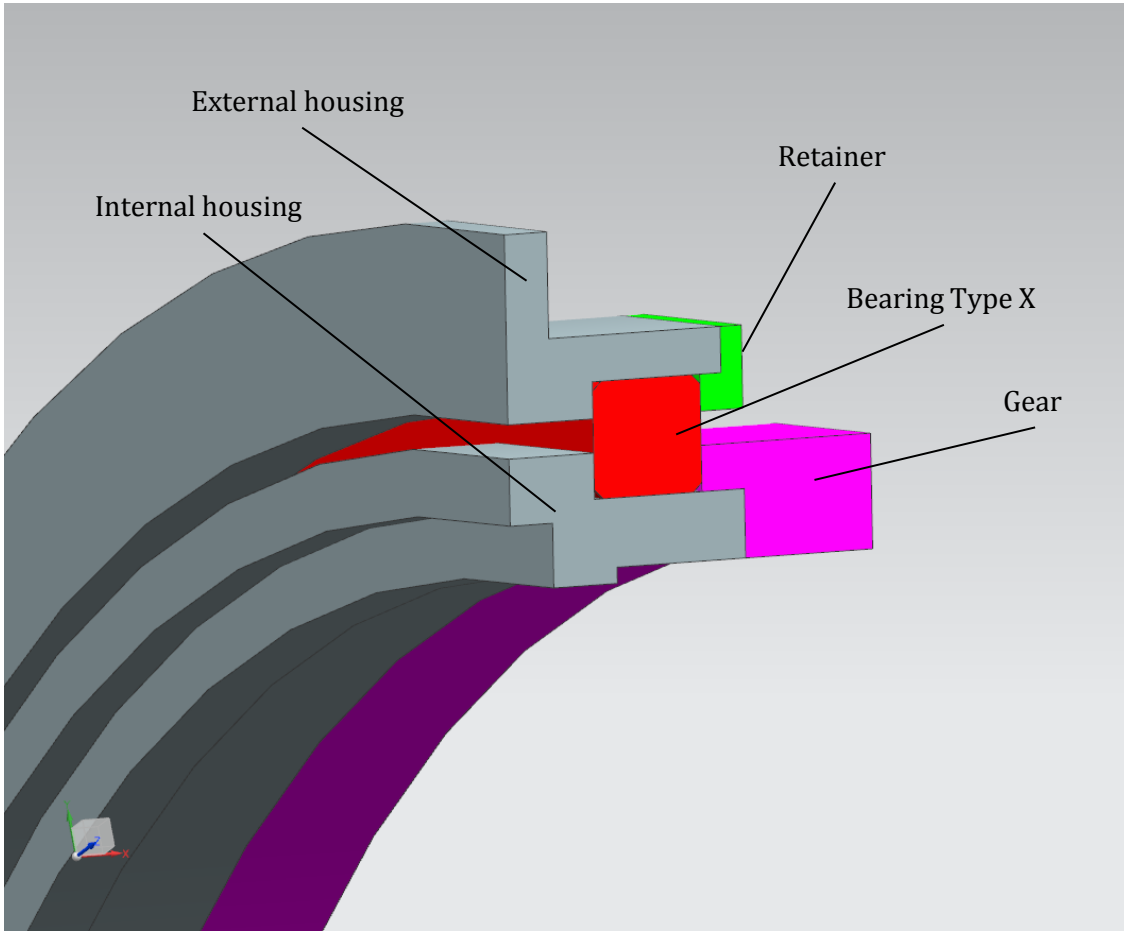


Figure 10 – Final Concept Design section

Motion and Positioning System

- ADC lenses shall be capable of commanded, continuous rotation with no end of travel stops
- Low level of velocity and acceleration
- Low rotation lifetime
- High precision of positioning system
- High cleanliness
- Two main possible solutions
  - Gears
  - Timing Belts

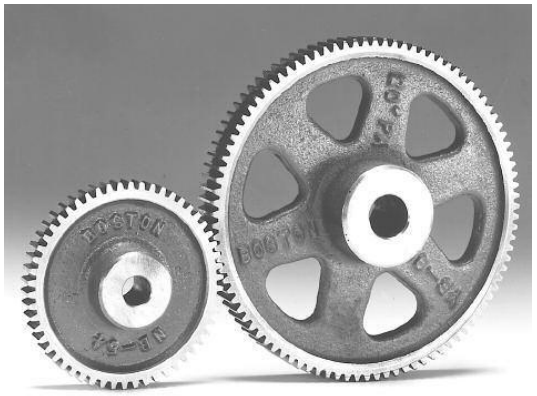


Figure 11 – Gears

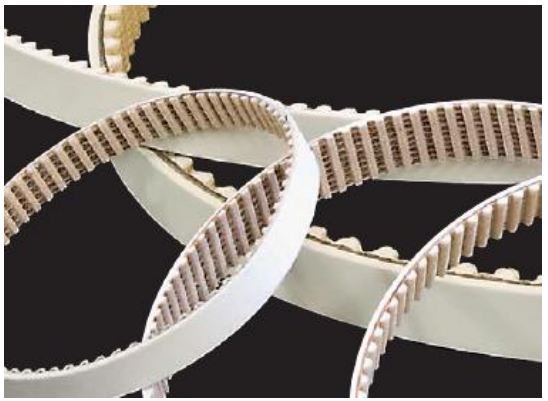


Figure 10 – Timing Belts

Transmission Solutions Comparison

Gears

- High precision
- No lubrication if high cleanliness required
- Plastic gear
- Wearing problem
- Simple mounting solution
- Simple replacement
- Small hole on barrel

Timing Belts

- Good precision
- High cleanliness system
- No wearing problem
- Complex replacement
- Larger hole on barrel

Conclusions

- Design of final concept for ADC Bearing system
- Bearing choice: Type X
- Future collaboration with Kaydon Bearings for the design of the bearing system
- Next steps of ADC Mechanism design:
  - Spec&Req Document of bearing system for Kaydon
  - Transmission system choice
  - Development of first conceptual design of transmission system