Super Seal:
Development of a Robust 2nd Stage Oil Sealing Device for Heavy Duty Engines.

Midterm Presentation 2

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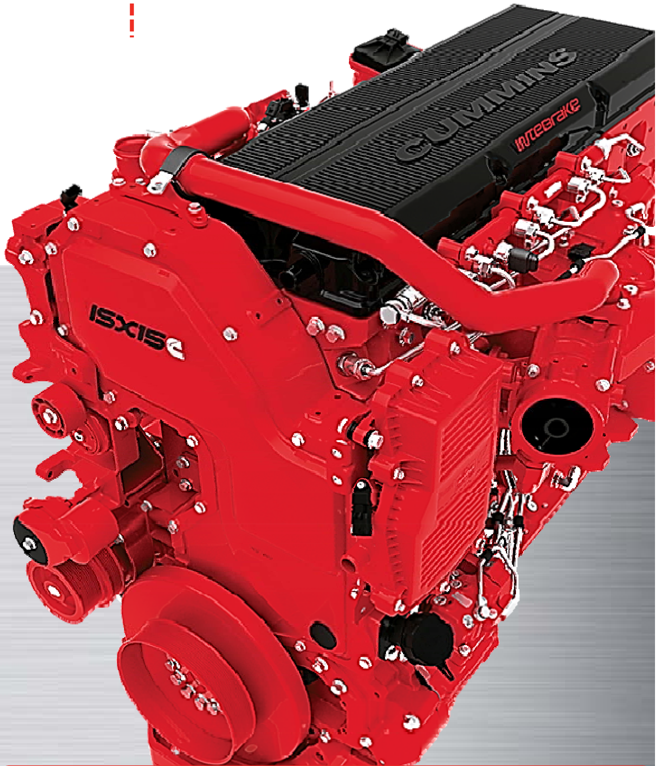


Cummins' Heavy Duty Truck engine, the ISX 15 @ 15 Liters, 600 HP

Presentation Overview

- **Project Review**
  - Background Information
  - Updates to Project Scope
- **Seal Design Selection**
  - Design Pro/Con Matrix
  - Foundation of Design
  - Seal Concept Selection & Basic Visualization
- **Relevant Formulas**
- **Challenges**
- **Project Schedule**
- **Conclusion**

Project Background

What's The Problem?

- Motor oil is repeatedly leaking past the rear crankshaft seal.
  - Failed seal[1]
  - Material fluctuations due to thermal transients

Figure 1: Depiction of rear crank seal leaking oil.[2]

Why Do We Care?

- Cost
- Evolution of Customer Perceptions

Figure 2: Cummins' newest engine,
the Hedgehog @ 95 Liters, 4500 HP
Cost for crank seal replacement: $21,000.[3]

Presenter: Olaniyi Ogunbanwo

Project Scope

Goal Statement

- Design a device to capture leaking oil from a rotating test crankshaft and deposit it into a reservoir so that it can be reintroduced to the crankcase. Additionally, a test rig must be fabricated in order to assess the functionality of the design.

Special Consideration

- More specifically:
  - **Scope of project is to primarily demonstrate functionality/performance of design solution.**
  - **NOT to demonstrate life capabilities of design solution.**

Concept Design Selection

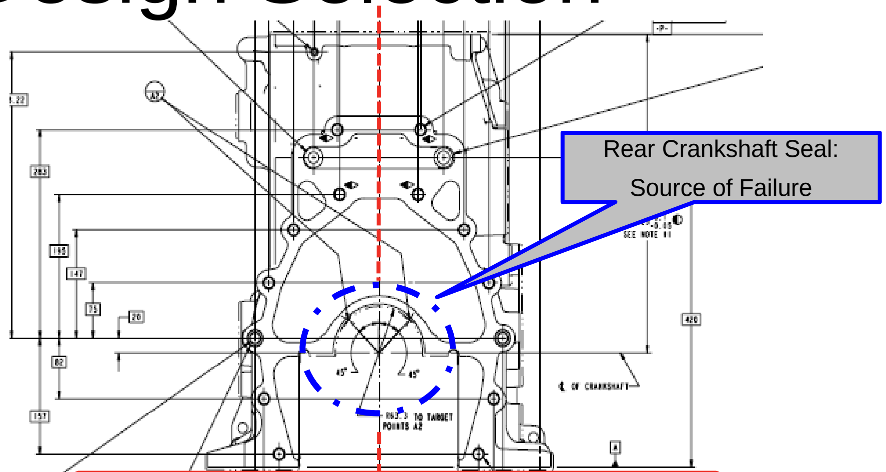


Figure 3: CAD drawing: rear face of engine block.[4]

Additional Secondary Contact Seal (current one being used/size variant)		Recollection Through A Vacuum		Pressure Cavity Behind		Centrifugal Pressure Seal	
PRO	**CON**	**PRO**	**CON**	**PRO**	**CON**	**PRO**	**CON**
In production	Fail due to dry sliding	Optimal Re-Capture	No vacuum source	Prevents Leakage	No PSI source	Non-Contact	No Sealing Stopped
Easy to use	If lubed, fail w/ primary seal		Dry Sliding Seal Req'd	Favorable PSI Gradient	Dry Sliding Seal Req'd	Low Friction	Size Constraints?
	Envelope too big		Primary seal distortion		Primary Seal distortion	+ Eff vs. Labyrinth	+ Cost
	Copying failure				What if more oil gets out?		
Labyrinth		**Hybrid Labyrinth**		**Hybrid Labyrinth + Centrifugal Pressure Seal**		**New Primary Seal**	
PRO	**CON**	**PRO**	**CON**	**PRO**	**CON**	**PRO**	**CON**
Non-Contact	No Sealing Stopped	Non-Contact Running	Wear when Contact	HL Pushes Fluid IN	Space	Nano-Composites for Low Wear	
	Size Constraints?	Contact Slow/Stopped	Weep/Seep	Cntr Pushes Contamin. OUT	Oil Recapture	COE Advisor Wants This	
	+ Cost		Pushes Contaminants IN				

Figure 4: Matrix of potential solutions; all-in-one comparison.

Concept Design Selection

Foundation of Design

- Pressurize cavity behind rear main seal
  - Aids in a solution to the root cause of the problem = **Best** place to start

Drawbacks	Considerations
No Source of Pressure	All Cummins Engines Are Turbocharged
Potential Primary Seal Distortion	Regulate Air Pressure to Mitigate
Control Of Oil That Does Leak	Careful Placement of Pressure Introduction Point
Air Seal Needed To Maintain Pressure Gradient	***Do Not Need An Absolute Seal (e.g. House Heater)***

Idea(A) +
Idea(B) + …

Table 1: Considerations needed for a cavity pressurization approach.

Seal Design Selection

Previous Seal Considerations

Engineering Characteristics	Sealing Options			
	Labyrinth	Hybrid Labyrinth	Centrifugal Pressure Seal	Secondary Crankshaft Seal
Efficiency	1	2	2	1
Durability	1	2	2	0
Size	1	1	1	1
Total	3	5	5	2

Figure 5: Pugh Matrix of different sealing options for an oil capturing device.

- Important Note: both the hybrid labyrinth and centrifugal pressure seal failed previous selection process.
- *Scope has changed!*

Seal Design Selection

How to Maintain Pressurized Area Behind Main Seal?

- Implementation of a Hybrid Labyrinth Seal

Figure 6: Hybrid labyrinth visualization.[5]

Why?

- Non-Contact Element:
  - Grooves designed for a tortuous path for fluid
  - Provides a seal when the shaft is rotating
- Contact Element:
  - Provides a seal when the shaft is not rotating
  - Contact elements lifts due to centrifugal force during operation

Basic Design Visualization

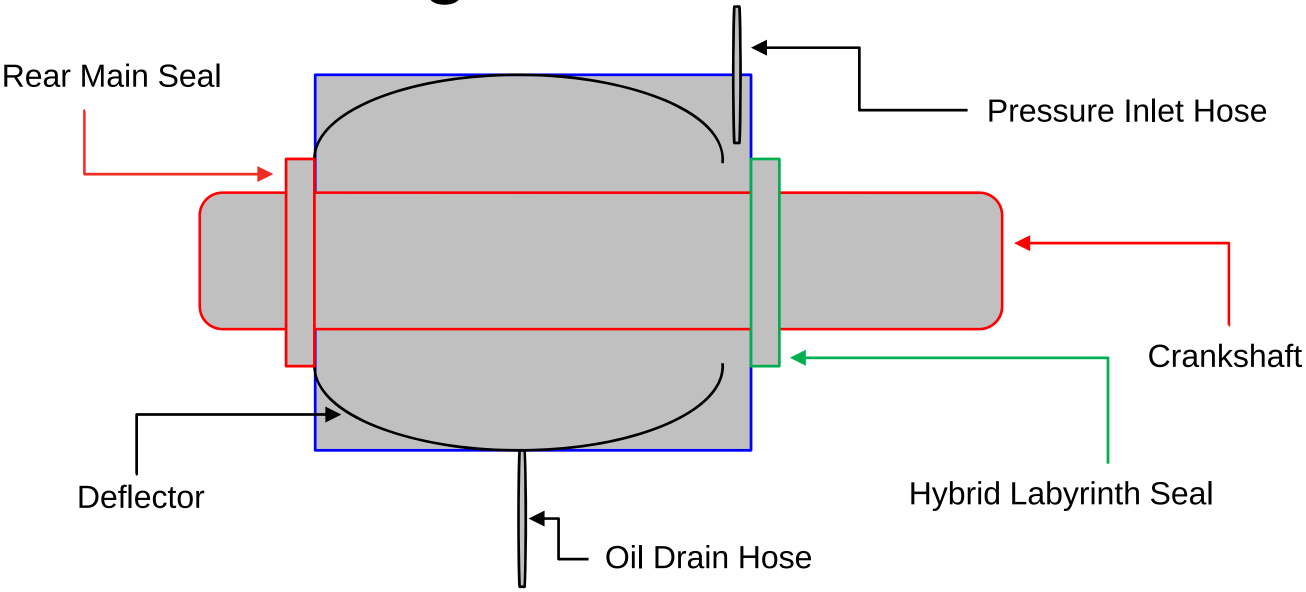


Figure 7: Basic visual of intended design of device.

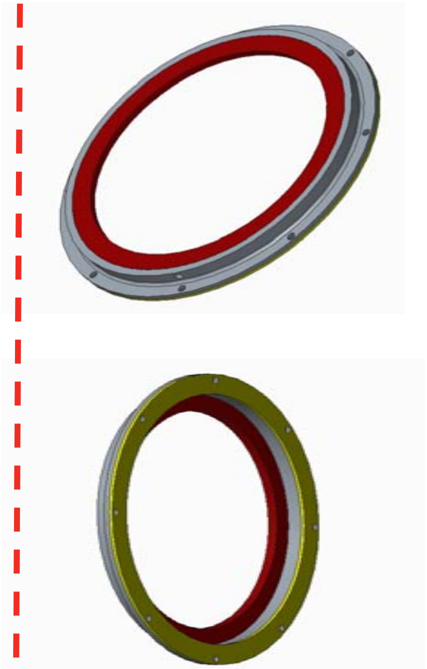


Figure 8: CAD rendering of device housing.

Things To Consider:

- Dynamic TIR: .35 mm, Static TIR: .50 mm
  - Ensure seal tolerances to prevent a crash; explore PTFE labyrinth seal for malleability to absorb.
    - » *KACO FRed Engine Seal*[6]

Formulas

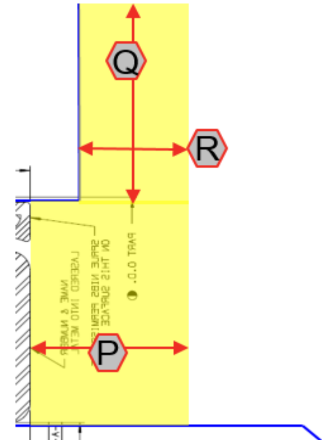


Figure 9: Spatial dimensions available.[3]

- Air Leak Rate[7]:
  - Ideal Gas Law $P * V = n * R * T$
    - n, R and T are constant → $P_1 * V_1 = P_2 * V_2$
    - Solving for △V / time = *Leak Rate*
- Volume of Chamber: Volume of yellow area extruded around shaft
  - *V = 753.6* cm^3
- Pressurized Air Flow Rate = Area * Velocity
- Power[7]: $P = \frac{\gamma * Q * P_1}{\gamma - 1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$

Test Rig

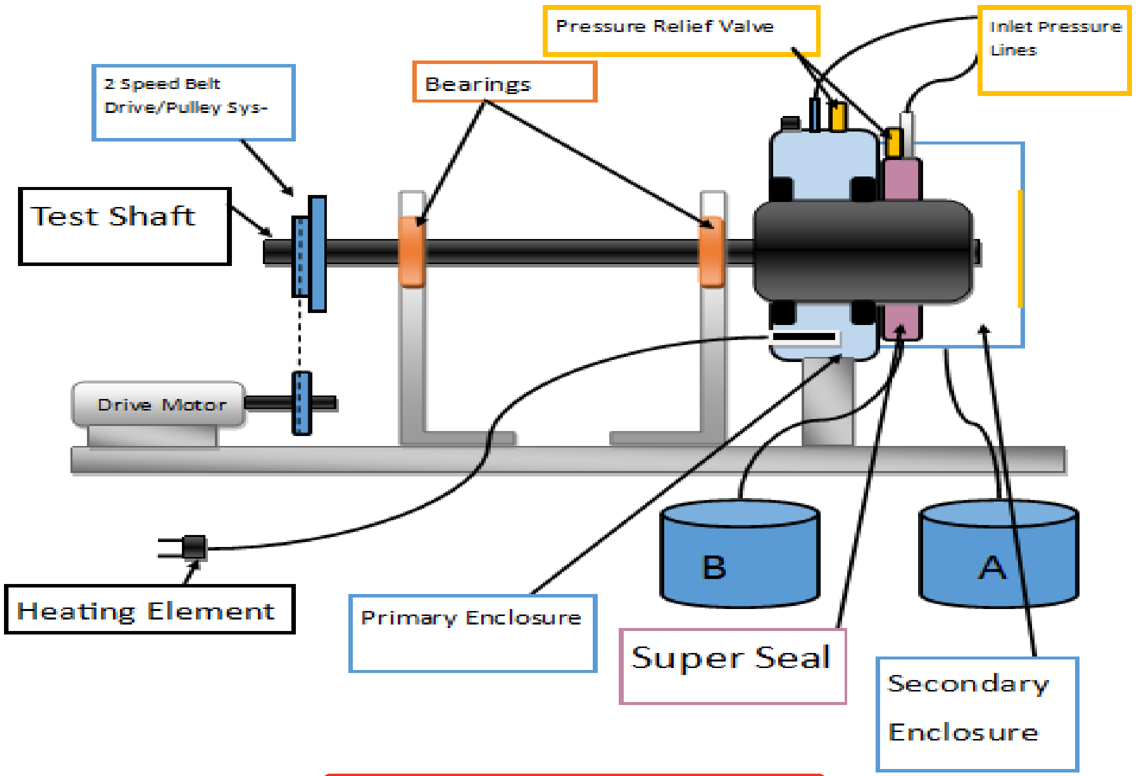


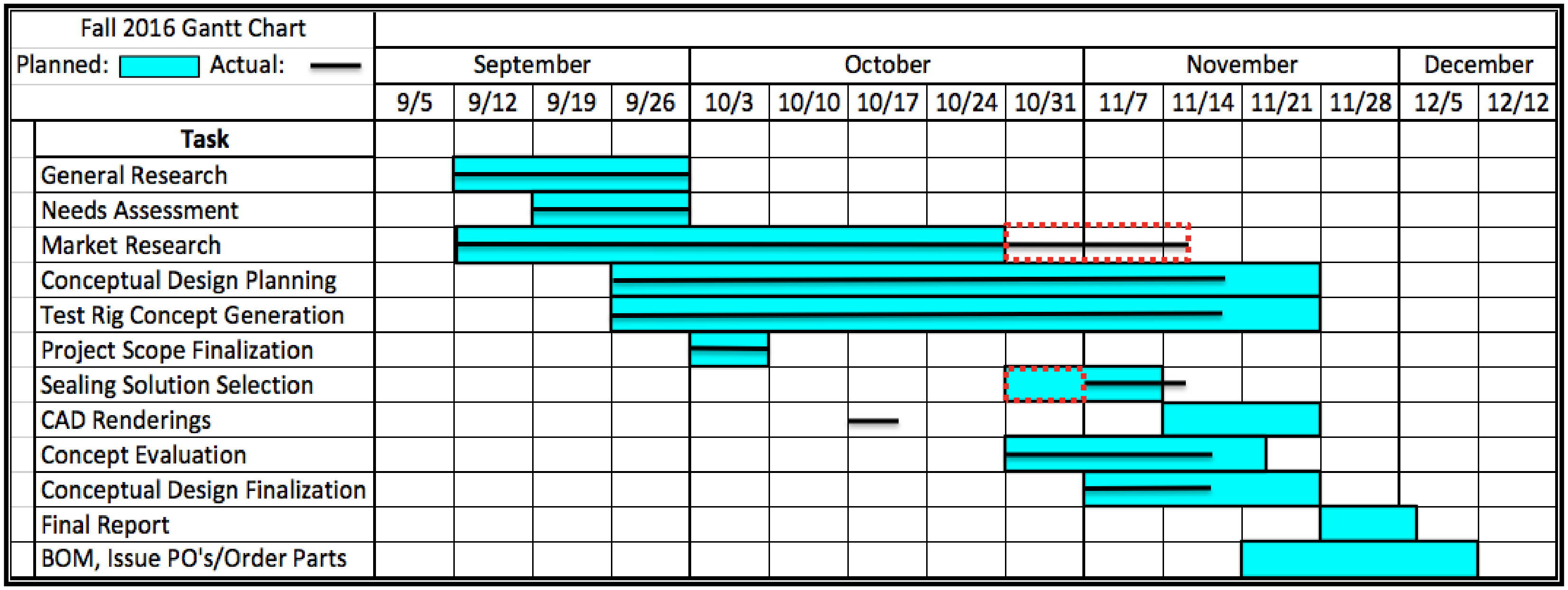
Figure 10: Test rig design visualization.

- Variable Speed Elec. Motor
  - Linked to 2-Speed Belt Pulley System
- Test Shaft (4140 Steel)
  - 165mm Only In Enclosure
- Air Relief Valve
- Shaft Bearings
- Oil Heater
- Air Regulator For psi Feed
- Feed/Drain Lines
- Stand/Base Plate

Challenges

- **Sealing**
  - Volume of air entering chamber exceeds volume of air exiting through seal
    - Otherwise, entire concept fails
  - Acquisition of a malleable and resistant hybrid labyrinth seal
    - Aid in the prevention of crash
- **Space**
  - Tight tolerances on spatial availability for device.
    - Dynamic TIR = 0.35mm, Static TIR = .50mm
- **Test Rig**
  - Ensure design and BOM is finalized on schedule considering setbacks experienced.
- **Time**
  - Make up lost time due to unanticipated obstacles concerning a sealing solution

Project Schedule



Conclusion

- **Project Goal:**
  - Develop a device to capture oil and increase overall robustness of crankshaft seal. Prove effectiveness of concept through a fabricated test rig operated at sponsor designated parameters.
- **Current Obstacles Hindering Progress:**
  - Limited space, such tight tolerances
  - Yet to find a malleable hybrid labyrinth seal
    - Without one, possibility of a system crash due to tight tolerances
- ***<u>What's Next?</u>***
  - Identify and select which hybrid labyrinth seal to be implemented
  - Finish test rig design; calculations and component selection
  - Create a Bill of Materials to begin ordering parts

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Questions?