Rotational Compressor Valve

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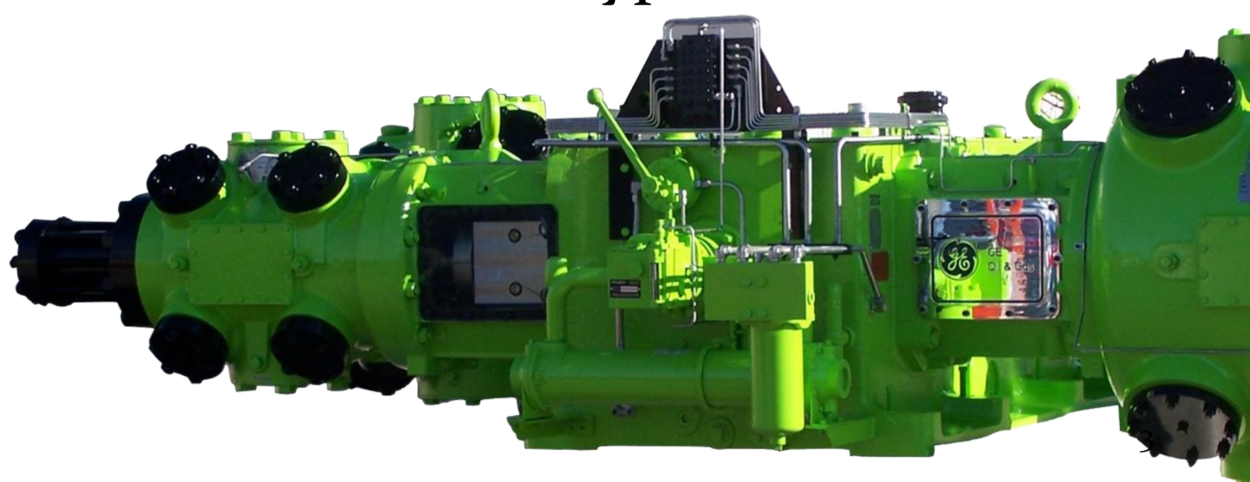
Overview

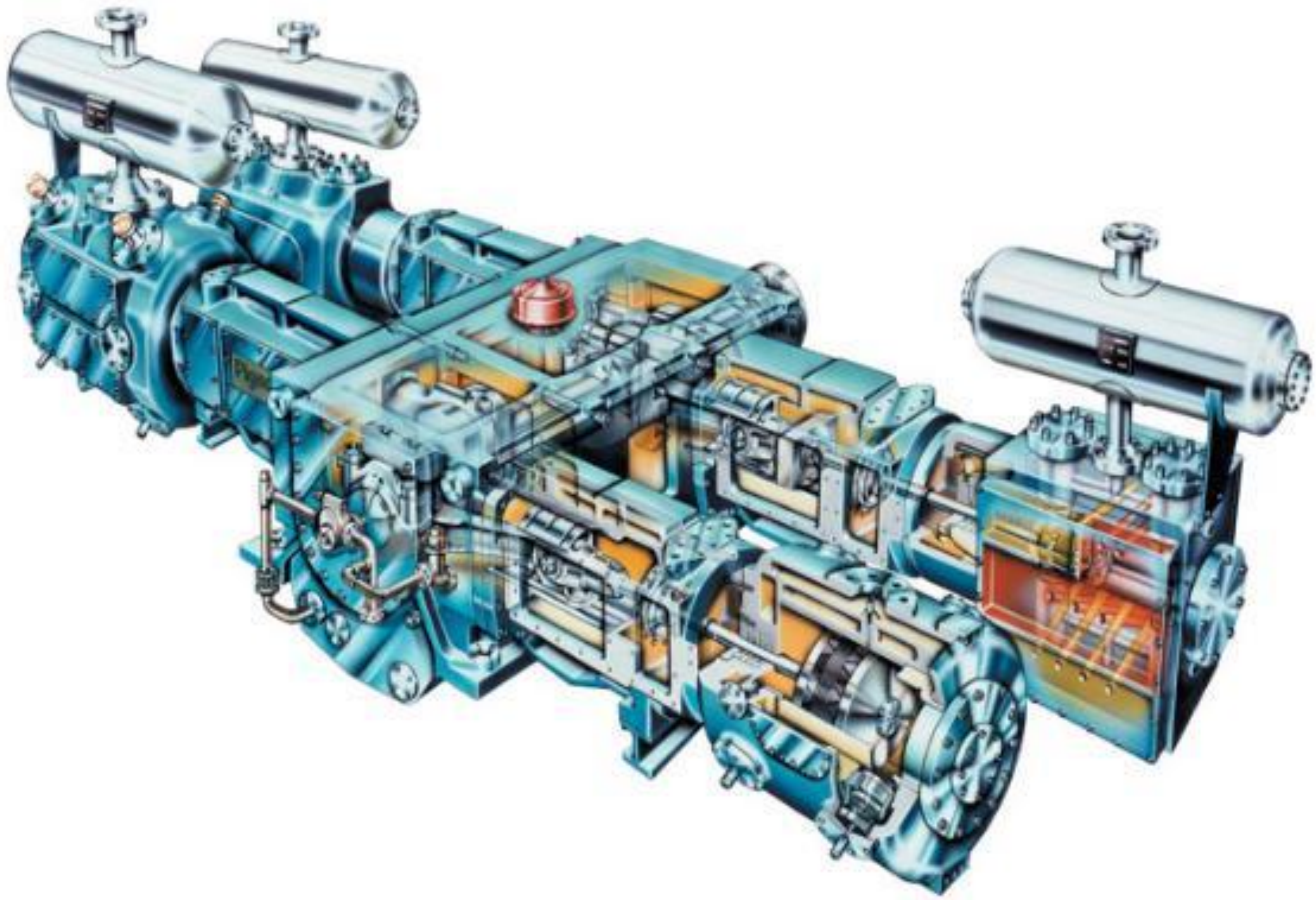
- Problem Statement
- Application
- Concept Selection
- Flow Calculations
- Concept Designs
- Force Calculations
- Material Selection
- Brief Cost Analysis
- Failure Mode Analysis
- Summary

Problem Statement

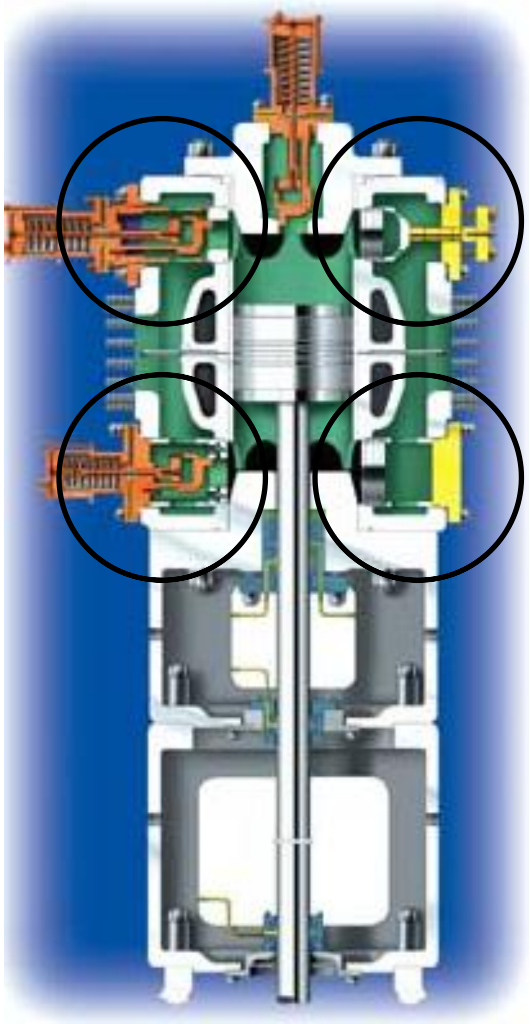
- Gas compressors are used to transport and store natural gas
- Current compressor valves are reliable but inefficient in flow
- A valve with a more direct flow is needed
- Obtain direct flow with a rotational type valve



Application



Application



Concept Selection

Impact Rating System
1 – Unsatisfactory
2 – Below average
3 – Satisfactory
4 – Good
5 – Excellent

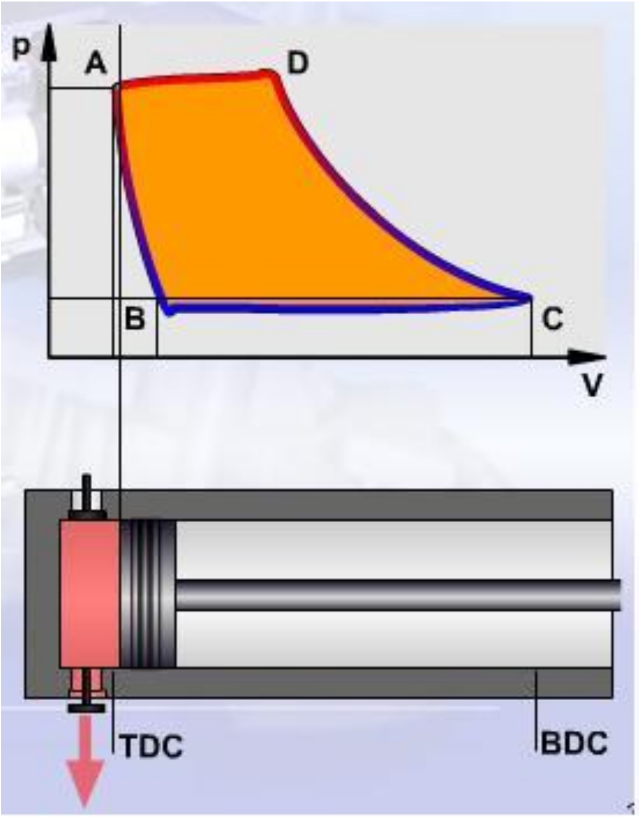
	Solenoid /Distributor	Microprocessor	Mechanical Linkage	Pressure(Partial Rotation)	Pressure(Full Rotation)
Reliability (20%)	4	3	3	3	5
Cost (20%)	3	3	2	5	5
Ease of Construction (10%)	3	4	2	3	3
Ease of installation (25%)	3	3	3	5	5
Flow Rate (25%)	5	5	5	4	4
Total (100%)	3.7	3.6	3.2	4.15	4.55

Flow Calculations(Time)

$$\omega = \frac{1200rot}{m} * \frac{1m}{60sec} = \frac{20rot}{s}$$

$$\frac{1}{\omega} = \frac{0.05s}{rot}\ \frac{1}{\omega} * (0.5) = 0.025 \text{ sec}$$

$$\therefore t \approx 0.025 \text{ sec}$$



*Calculations based on ideal gas properties and instantaneous opening of valve

Flow Calculation(Inlet)

$P_{intake} = 1247.\,kPa$ $\quad$ $P_{exhaust} = 2039kPa$

$T_{intake} = 322.04K$ $\quad$ $T_{exhaust} = 380.65K$

$Bore = 2.095m$ $\quad$ $Stroke = 0.1524m$

$\forall = 2\pi R^2 \cdot h = 0.8645m^2$

$$\dot{m}_{in} = \frac{\forall * \rho}{t} \quad \text{Where, } \rho = \left(\frac{P}{R*T}\right)$$

Once mass flow rate is known:

$$\dot{m}_{in} = \dot{m}_{out}$$

$\dot{m}_{in}$= Mass rate into cylinder

$\forall$= Volume of Cylinder

ρ= density of incoming fluid

t= Time of mass flow(Estimated)

P= Suction Pressure

R= Gas Constant

T= Inlet Temperature

*Calculations based on ideal gas properties and instantaneous opening of valve

Flow Calculation(Exhaust)

$P_{intake} = 1247.kPa$	$P_{exhaust} = 2039kPa$
$T_{intake} = 322.04K$	$T_{exhaust} = 380.65K$
$Bore = 2.095m$	$Stroke = 0.1524m$
$\forall = 2\pi R^2 \cdot h = 0.8645m^2$	

$\dot{m}_{out} = \rho * A * V_{out}$ Where, $\rho = (\frac{P}{R*T})$

ρ= density of outgoing fluid

P= Out going Pressure

R= Gas Constant

T= Outlet Temperature

A= Active Valve Area

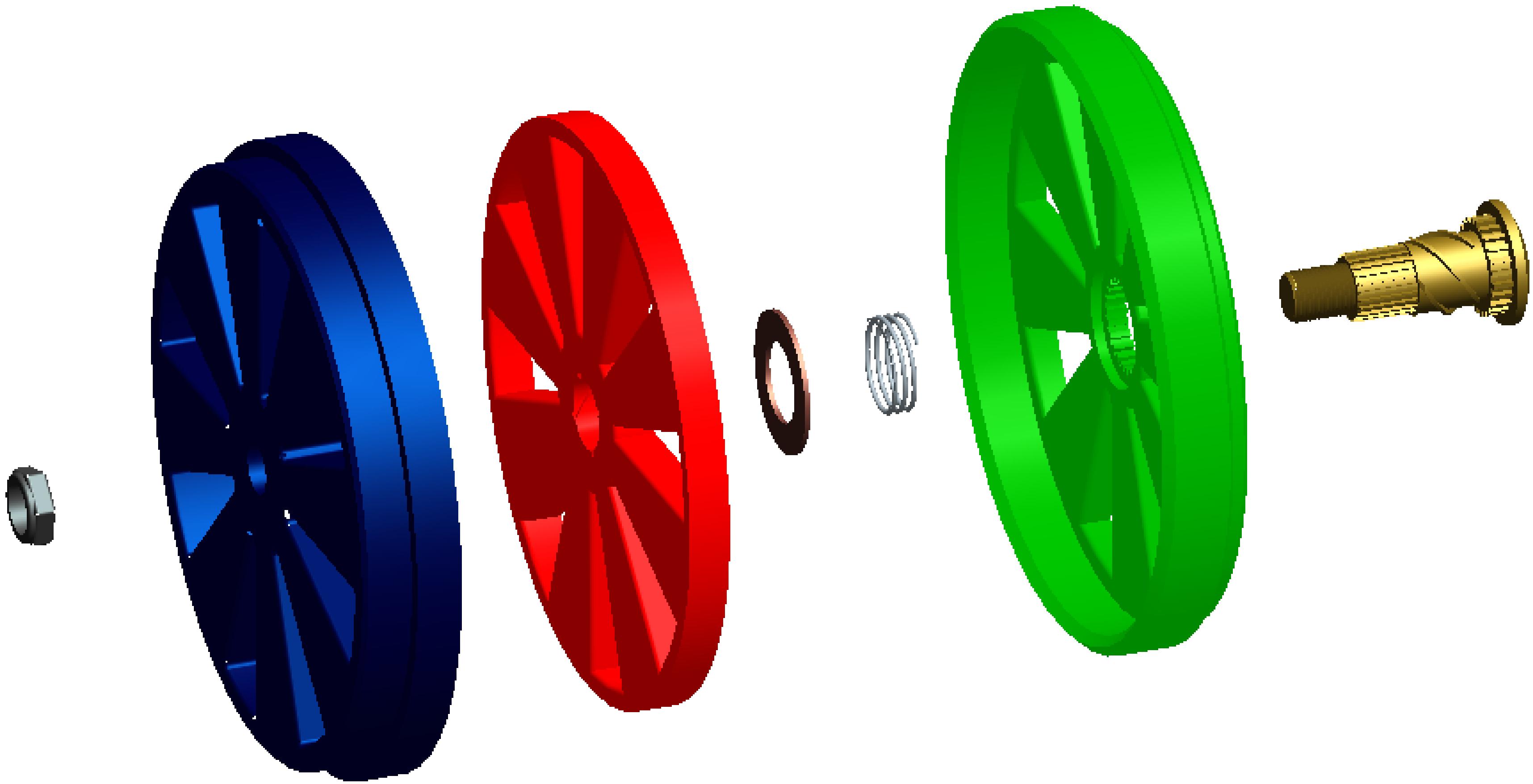
V_{out} = Velocity of exiting gas

With the above information, V_{out} can be found. Then:

$$\dot{\forall}_{out} = V_{out} * A$$

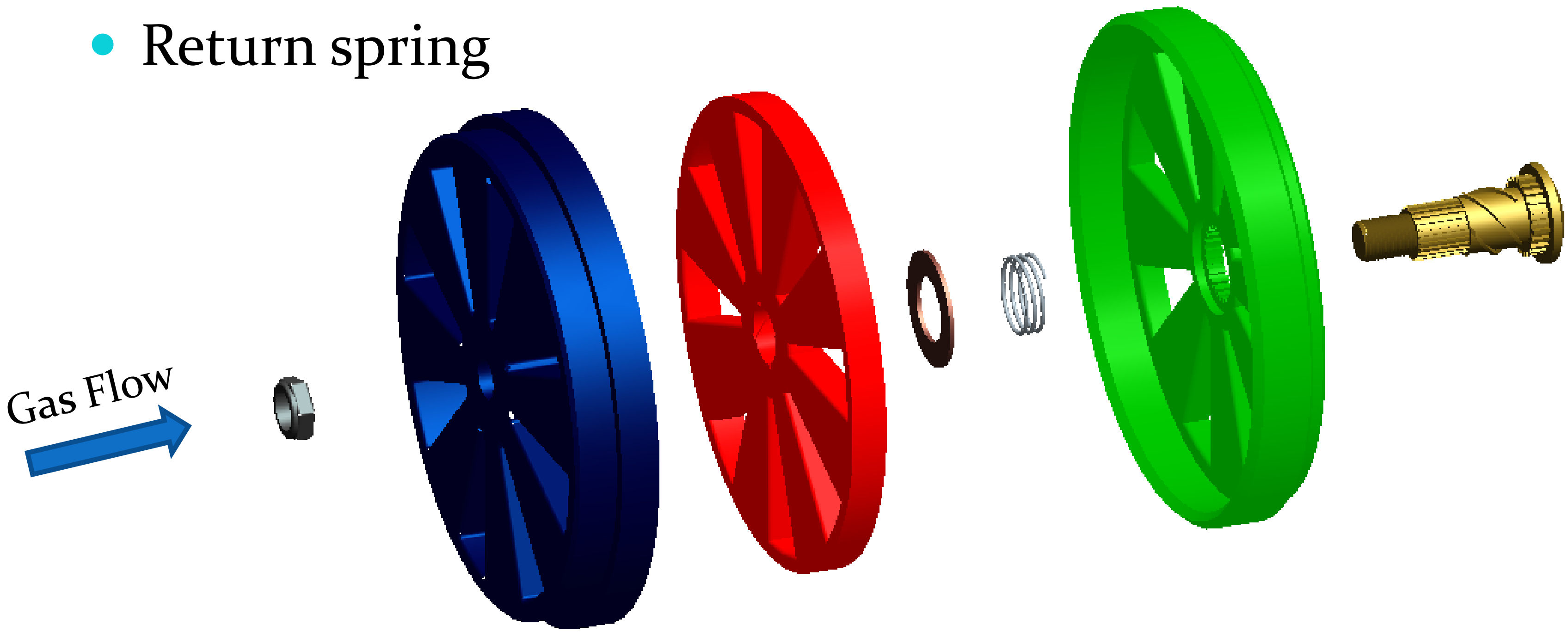
*Calculations based on ideal gas properties and instantaneous opening of valve

Design 1: Inner-thread Rotation

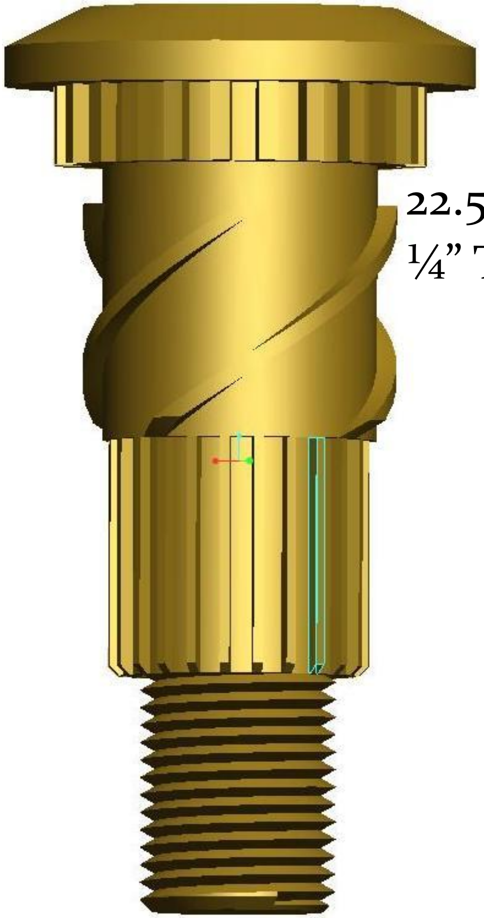


Design 1: Thread Rotation

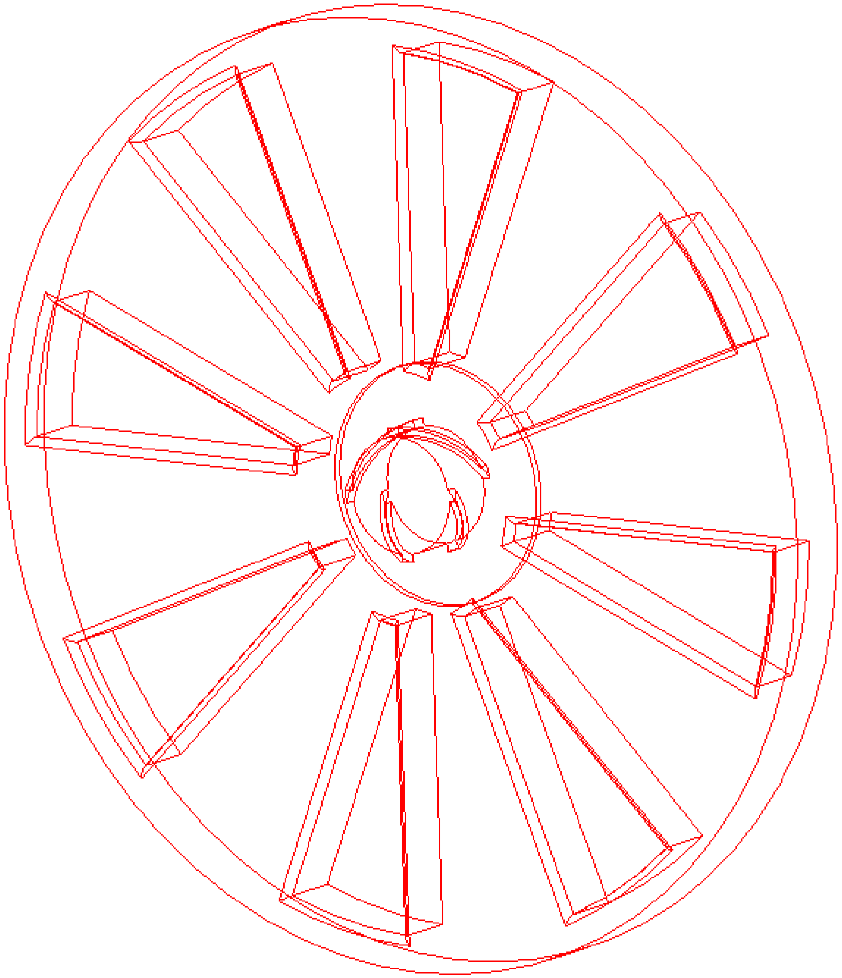
- Fixed outer casing
- Rotating/translating center plate
- Splined and threaded center bolt
- Return spring



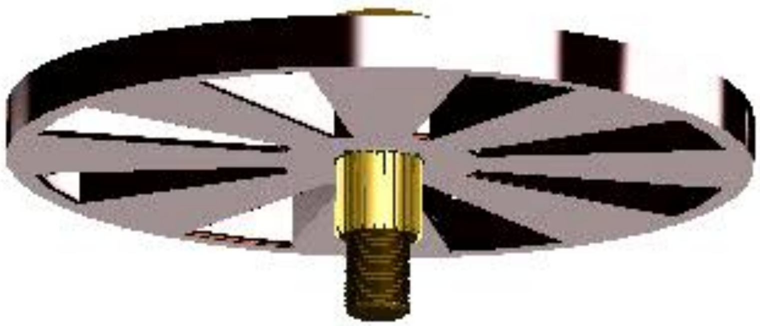
Design 1: Thread Rotation



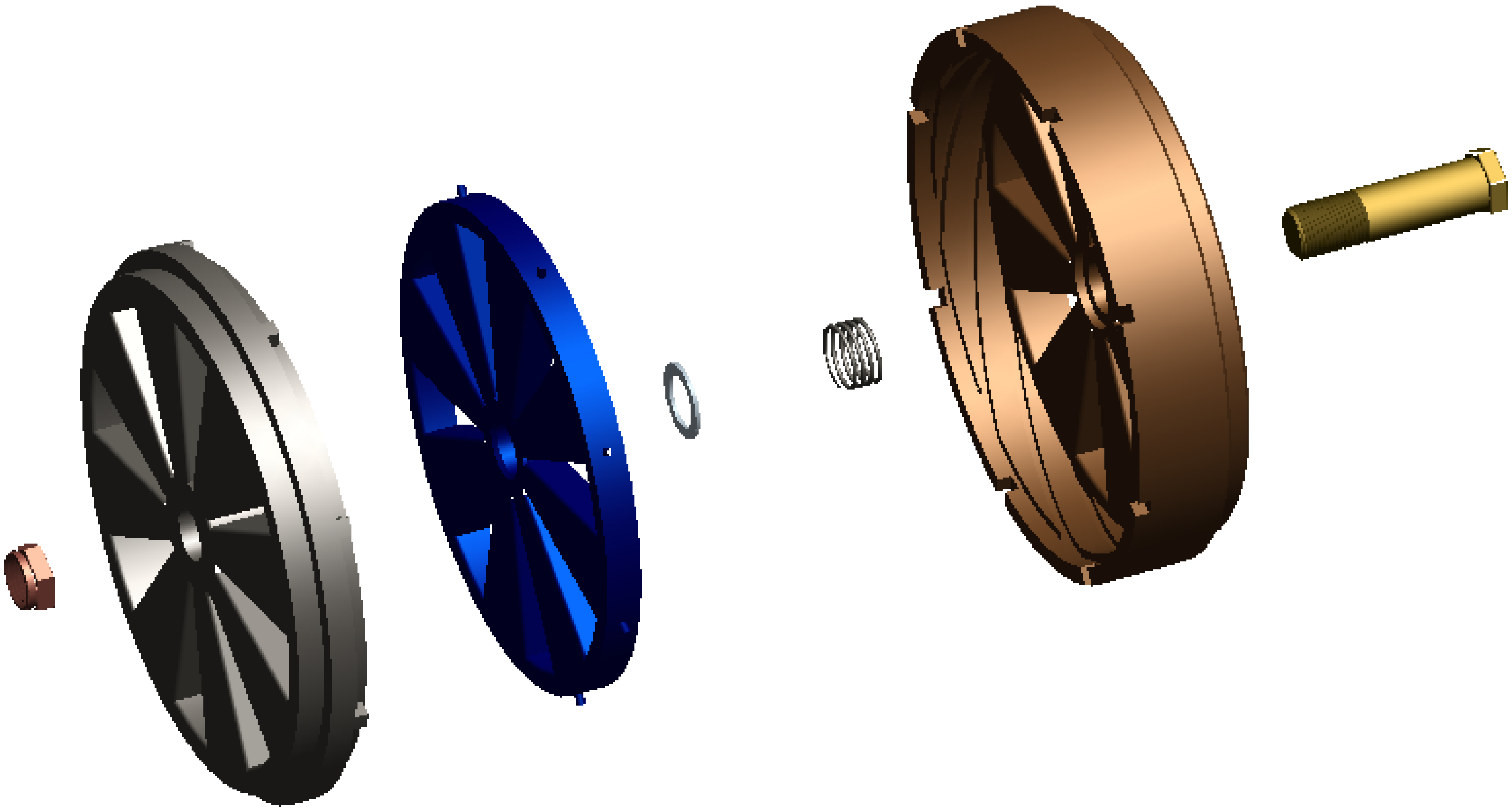
22.5° Rotation
¼" Translation



Concept 1: Valve Operation

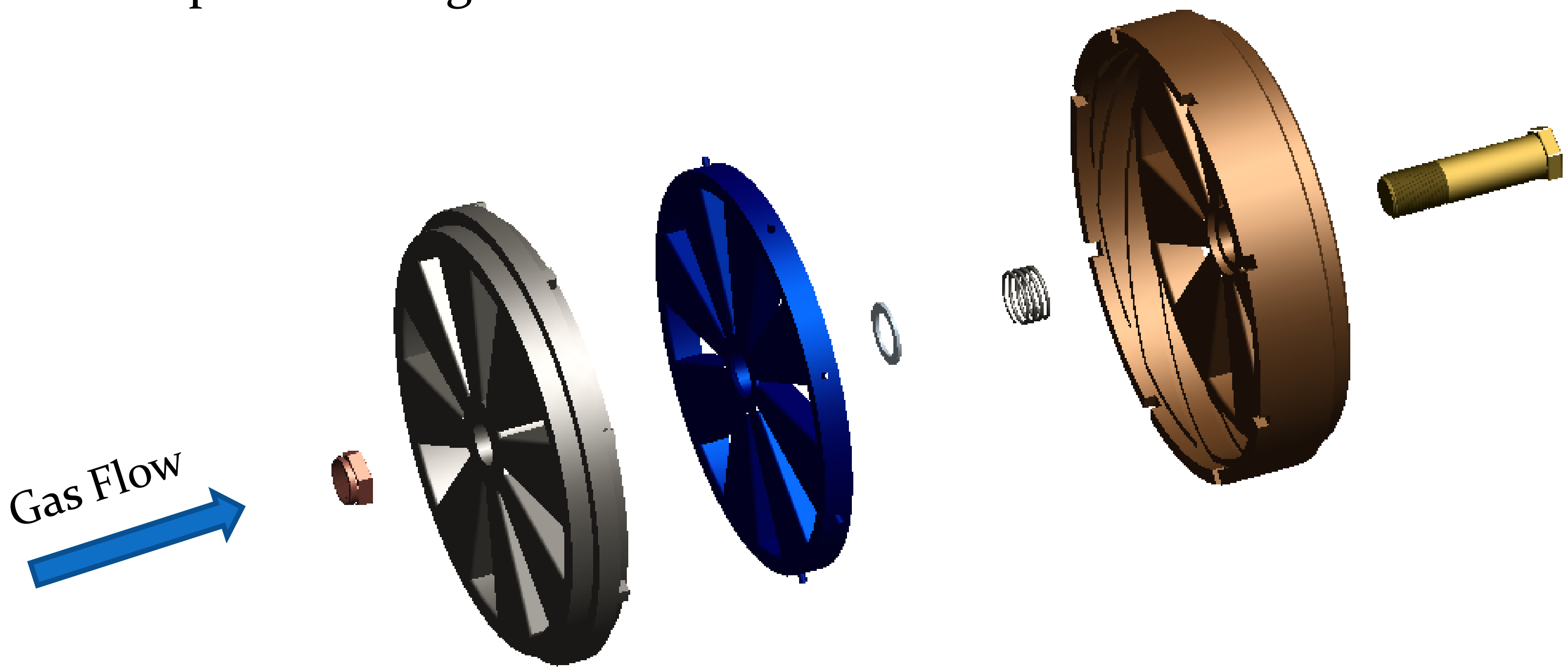


Design 2: Pitch Rotation



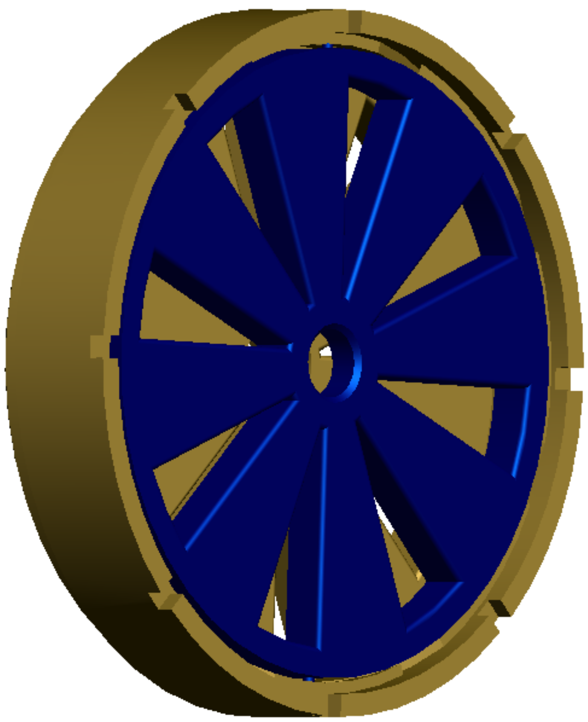
Design 2: Pitch Rotation

- Same basic concept as Design 1
- Threaded outside housing plate
- Simple retaining bolt

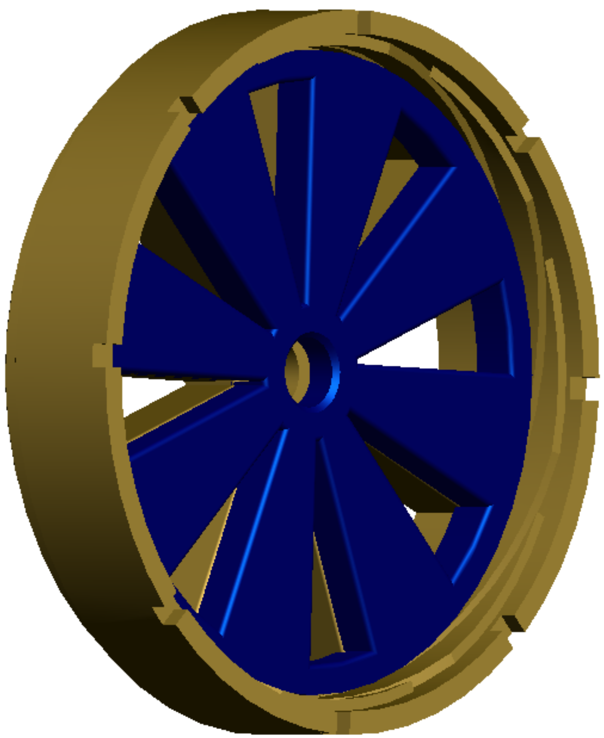


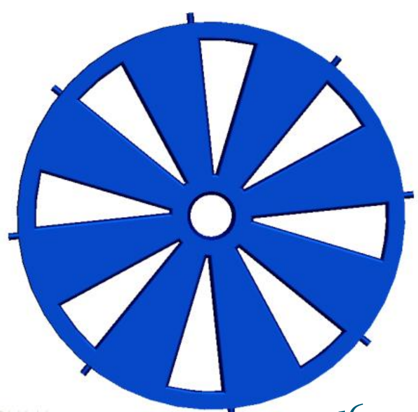
Design 2: Outer Pitch Rotation

Closed



Open





Concept Comparison

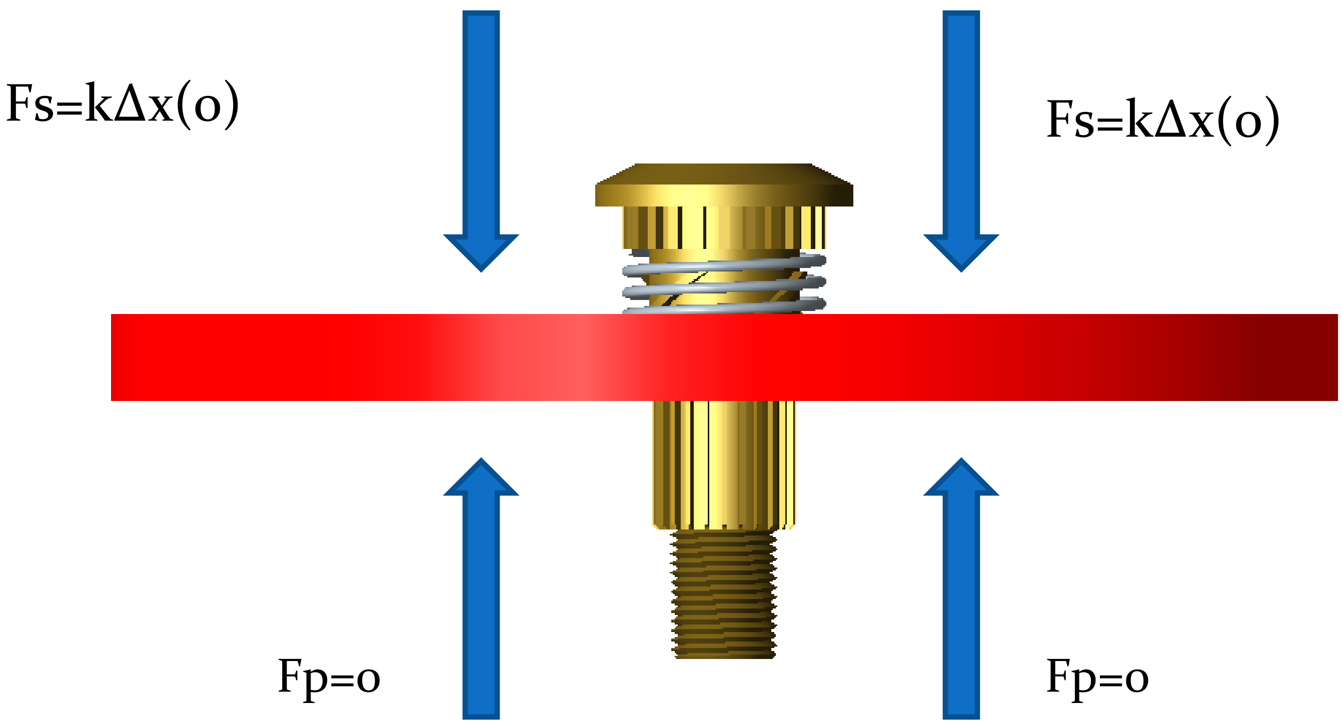
Threaded Bolt

- Higher pitch angle
- Higher chance for debris
- Bolt difficult for machine
- Pressure difference across valve face
- Tighter tolerances

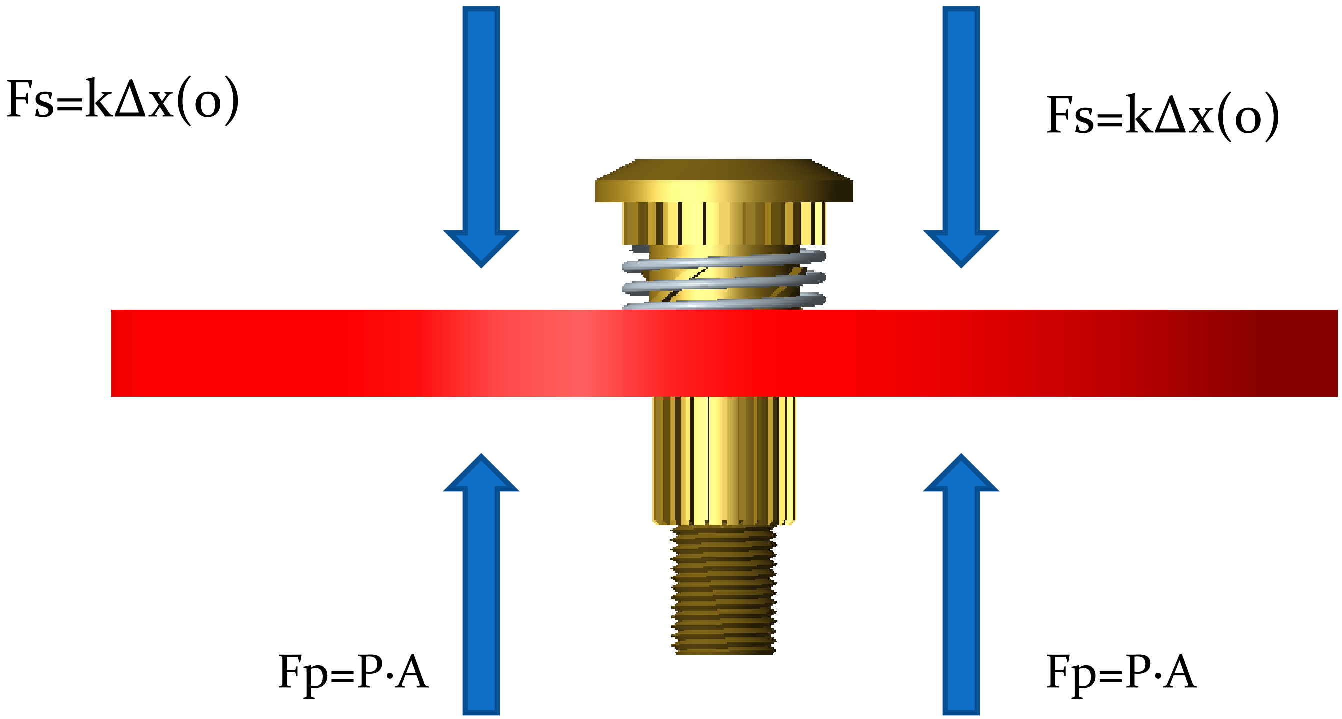
Threaded Housing

- Uniform force distribution
- Less force on threads
- Less chance for debris
- Ease of machining
- Pins may not be durable
- Low pitch angle

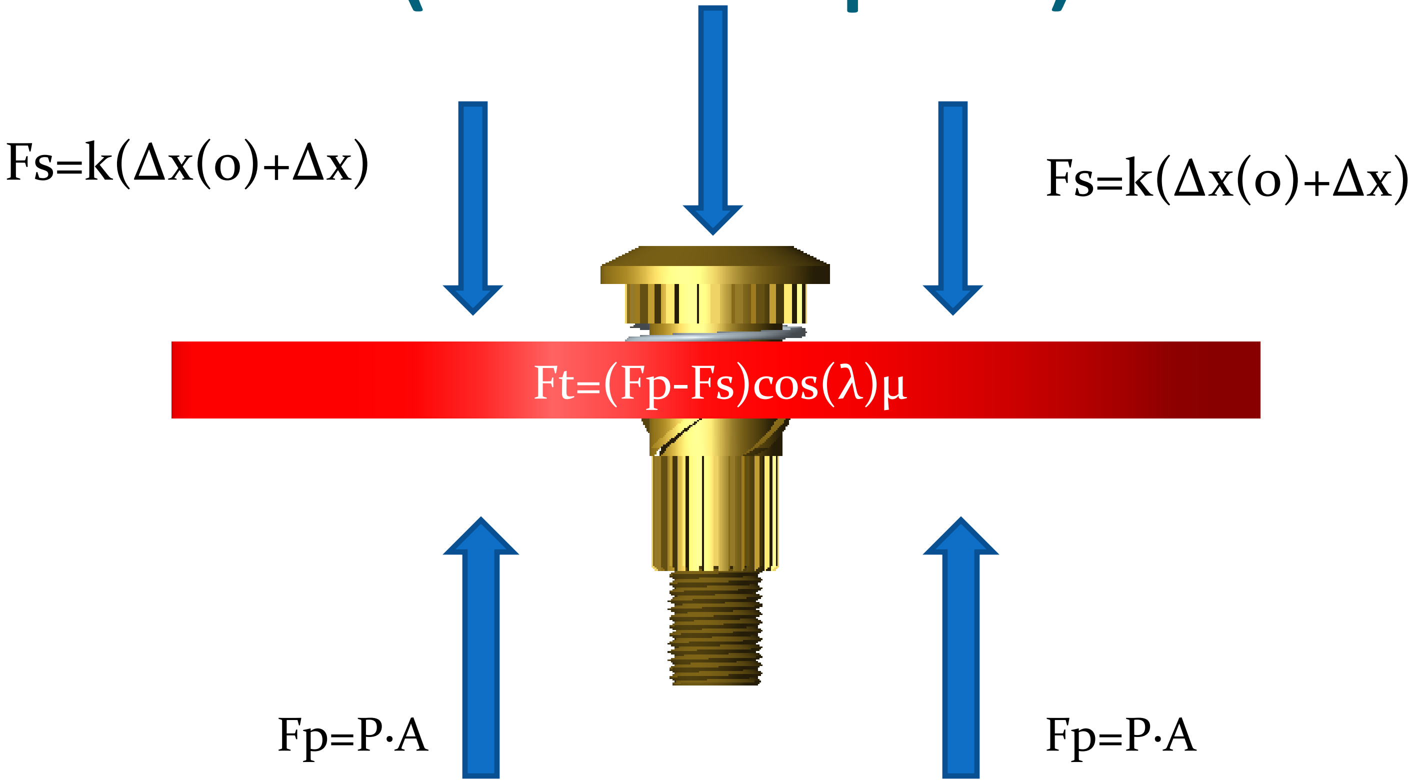
Force Calculation
(Bottom Dead Center)



Force Calculation (Up Stroke)

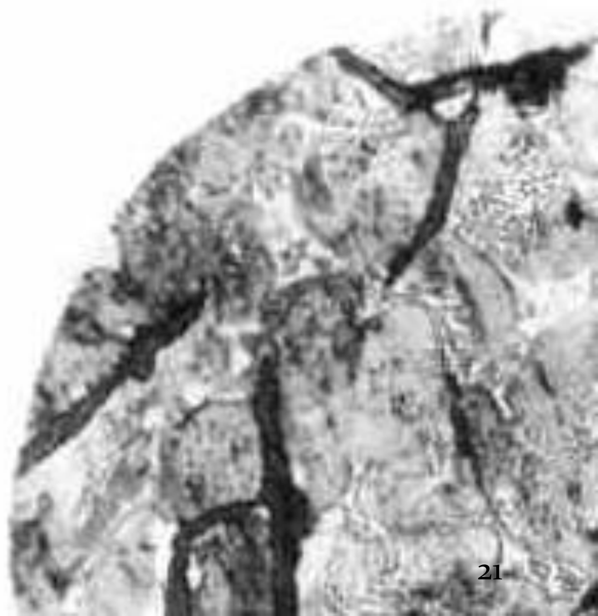


Force Calculation (Valve Open)



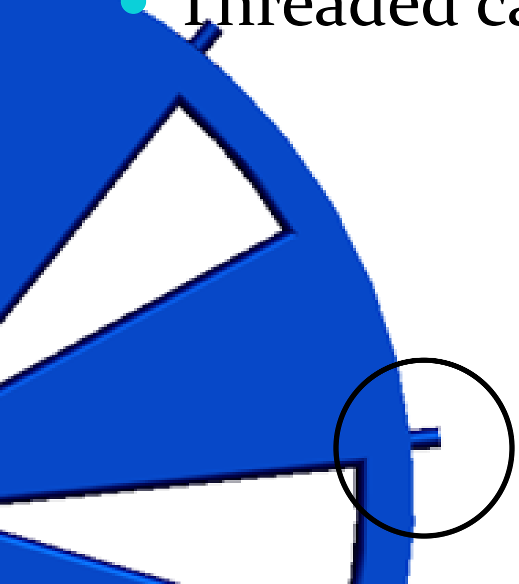
Material Selection

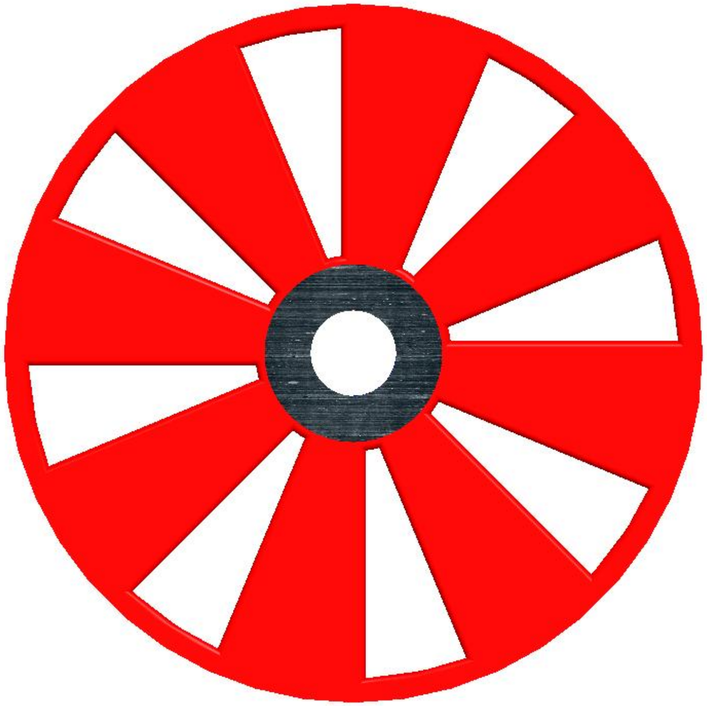
- All materials must be resistant to temperatures of up to 350oF
- Translating materials must be wear resistant due to required lifetime (6.3x10^{8} cycles)
- Sliding surfaces must also be low in friction ($\mu < 0.15$)
- Valve is to be sealed to prevent leakage



Translating Material

- No lubrication
- Graphite in cast iron creates a natural lubrication
- Hardness
- Surface roughness
- Threaded cast iron insert





Gasket Material

- Perfluoroelastomer (FFKM)
  - Rubber form of PTFE
  - High temperature stability up to 327°C (620°F)
  - Almost universal chemical resistance
  - Outstanding mechanical and chemical properties

Cost Analysis

- Raw cast iron(cylinder): $5
- Raw cast iron (plate): $120
- Spare parts: $10
- Machining (College of Engineering): $0
- Total: $135

Failure Mode and Effects Analysis

- Procedure in product development to detect possible failures and score them on severity, occurrence, problem detection

Item/Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Sev	Potential Cause(s)/Mechanism(s) of Failure	Occ	Current Design Controls	Det	RPN	Recommended Action(s)
Center bolt material, Gasket	Debris in shaft	Poor gas flow	6	Improper material selection, valve exceeding lifetime	5	Material extensively researched	7	210	Screen the valve, more research on proper gaskets and center bolt
Valve Plates/Spring/ Gaskets	Corrosion of Parts due to gas type	Gas leakage, excessive wear, valve failure	8	Incorrect material choice, excessive temperatures	4	None	6	192	Research all material choices
Center bolt and housing	Overall height of valve incorrect, Piston interference	scar piston, bend rod, valve damage	9	improper dimensions	2	following design parameters closely, check valve clearance with piston	2	36	Run clearance test prior to installation

Summary

- Concerns of complete open operation
  - Vary pitch angle
  - Adjust spring constant
  - Alter valve passage geometry
- Wear and Debris
  - Adjust tolerances
  - Material selection
- Operation Speed/Spring flutter
  - Avoid resonance

References

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QUESTIONS