KOP-FLEX®

High Performance Couplings for Turbomachinery

EMERSON™
Industrial Automation

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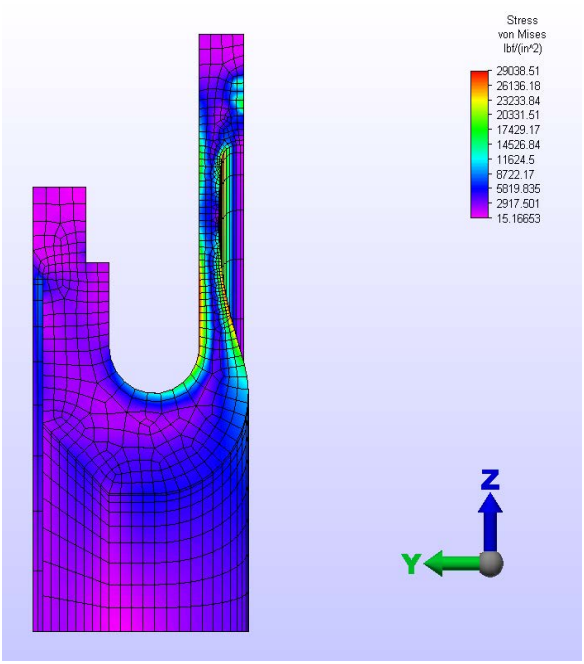


Kop-Flex History

- Invented First Gear Coupling in 1918 - Fast's®
- Started in 1920 as Bartlett-Hayward
- Koppers Co. purchased Bartlett-Hayward in 1926
- Division of Koppers Co. until 1986
- LBO created (by Management) Kop-Flex, Inc. In 1986
- Emerson Electric Co. purchased Kop-Flex in May 1996

Kop-Flex Today

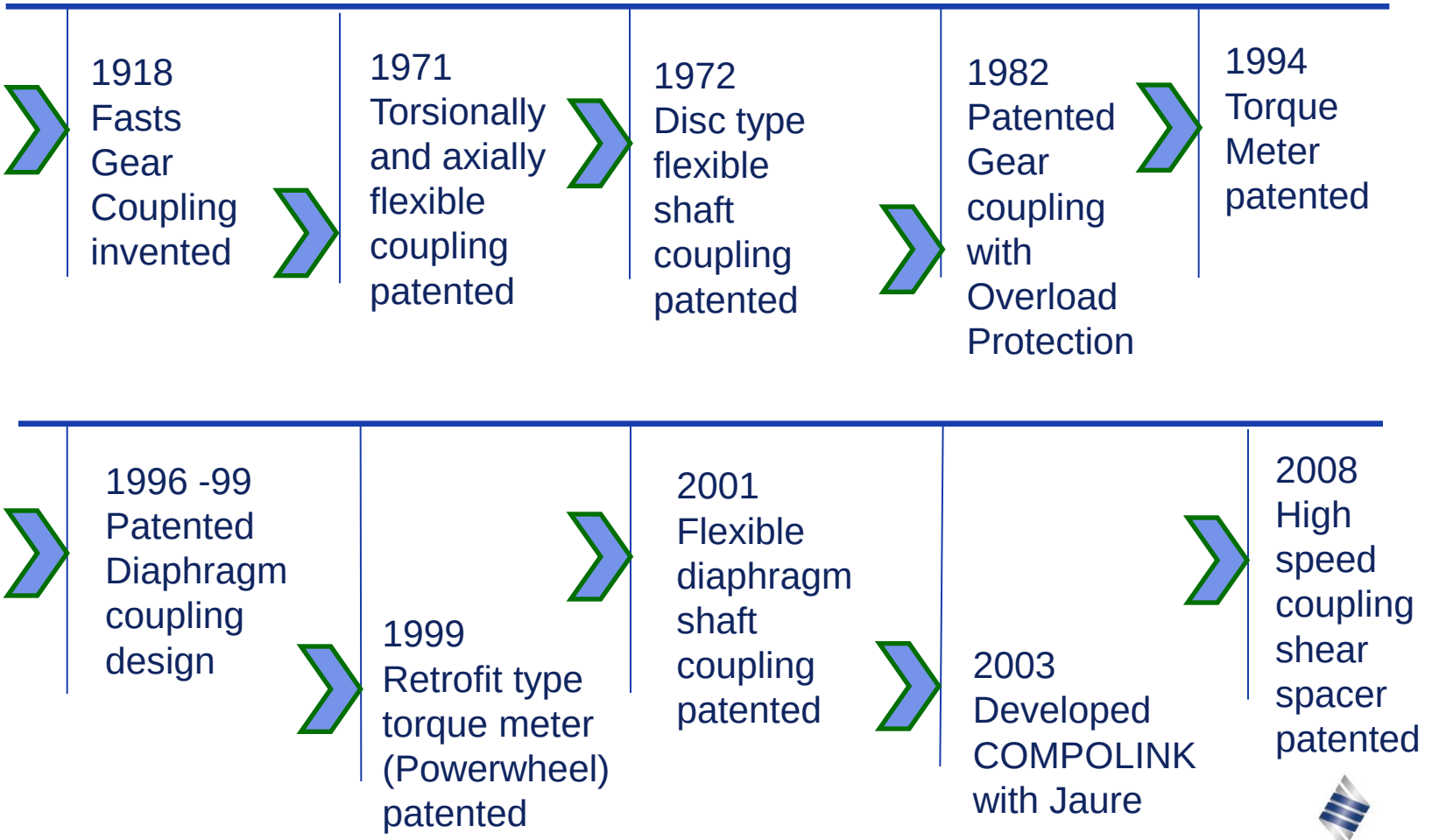
Represented in many locations across the globe.

Middle East - Dubai

KOP-FLEX®

EMERSON™
Industrial Automation

Kop-Flex Engineering Excellence



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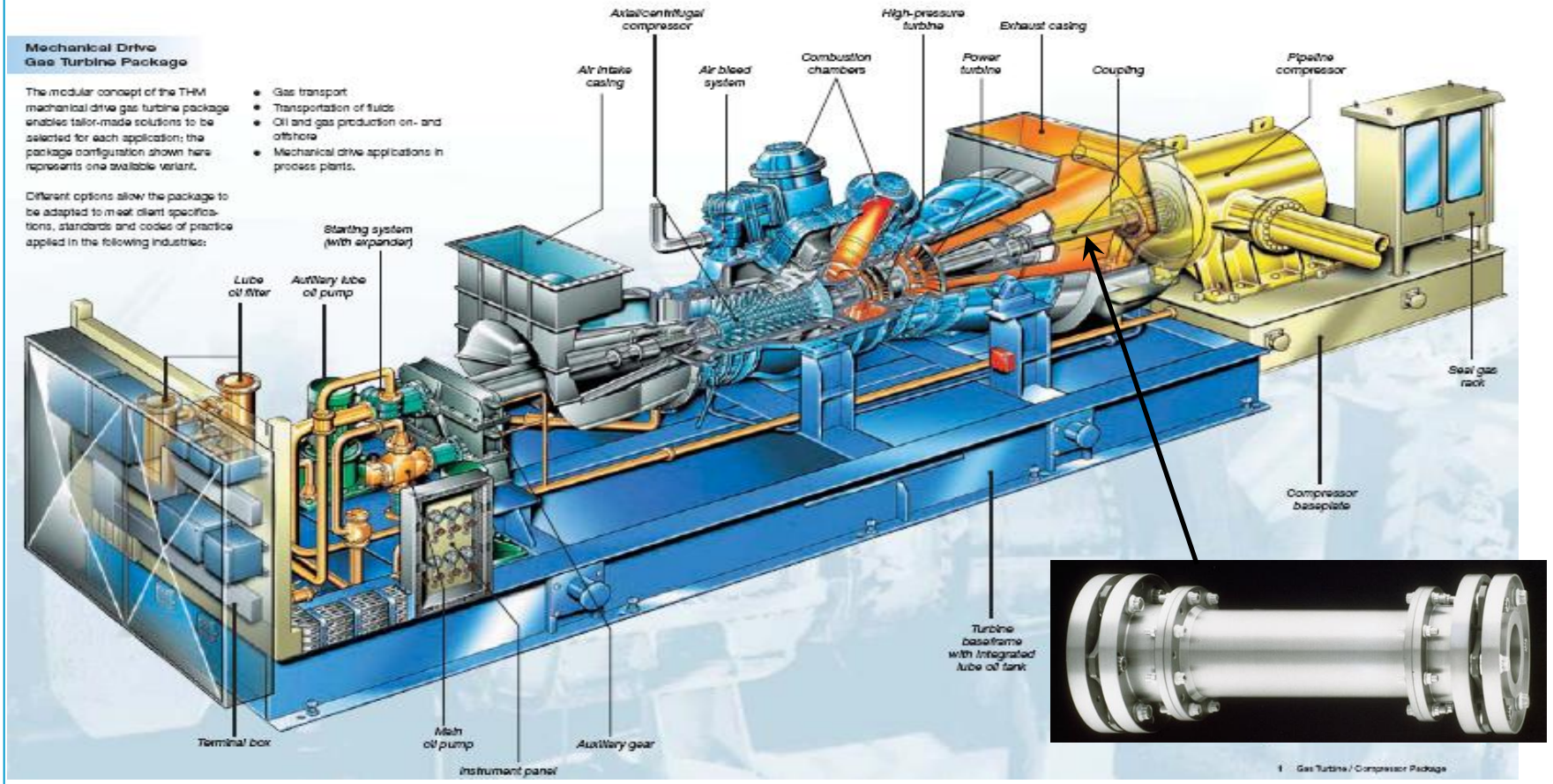
Importance of couplings



Importance of couplings

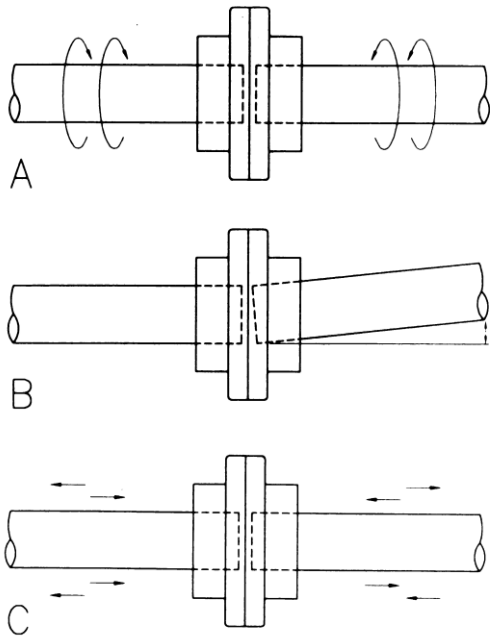
"Critical Equipment"

as defined by Shell International Petroleum

- *High performance / critical equipment or machines which generally are (but not limited to) 1000 horsepower and rotate 3000 rpm or greater.*
- *All rotating machines whose reliability is essential to plant operations.*
- *All rotating machines whose failure (or shut down for maintenance) cause a unit to shutdown resulting in production loss.*
- *Safety and environmental issues may qualify a machinery train under this criteria.*

Importance of couplings

- Demands on High Performance Couplings
  - Transmit massive torque of the prime movers
  - Rotate at High speeds
  - Accommodate the offsets of the shafts
  - Accommodate the angular misalignment
  - Accommodate axial movement of the shafts at operating temperatures of the prime movers and driven machines.

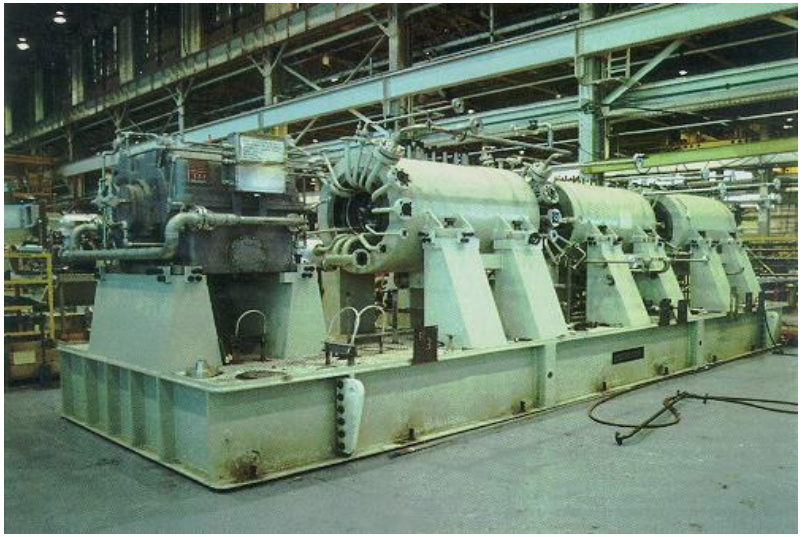


Importance of couplings

- Operate at high temperature and corrosive atmospheres
- Accommodate torsional vibrations
- Should perform safely in hazardous area
- May need to act as safety device
- Should have minimum maintenance
- Should perform reliably for years so as to avoid production loss and damages to very expensive turbomachines.

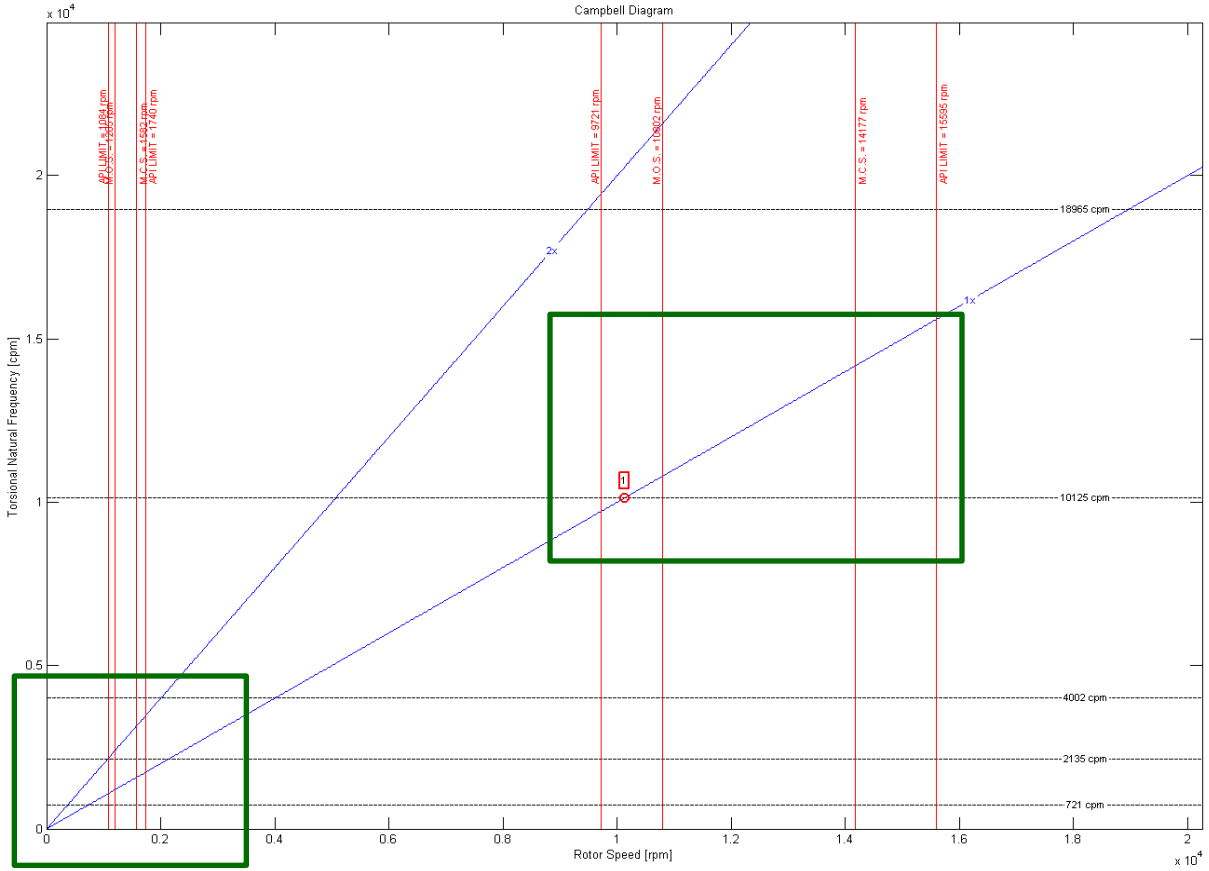
Importance of couplings

- For large trains coupling also need Stiffness tuning and shock torque refining
- API 671 compliant couplings



Importance of couplings

- Stiffness tuning using Campbell Diagram



5° TNF

4° TNF

3° TNF

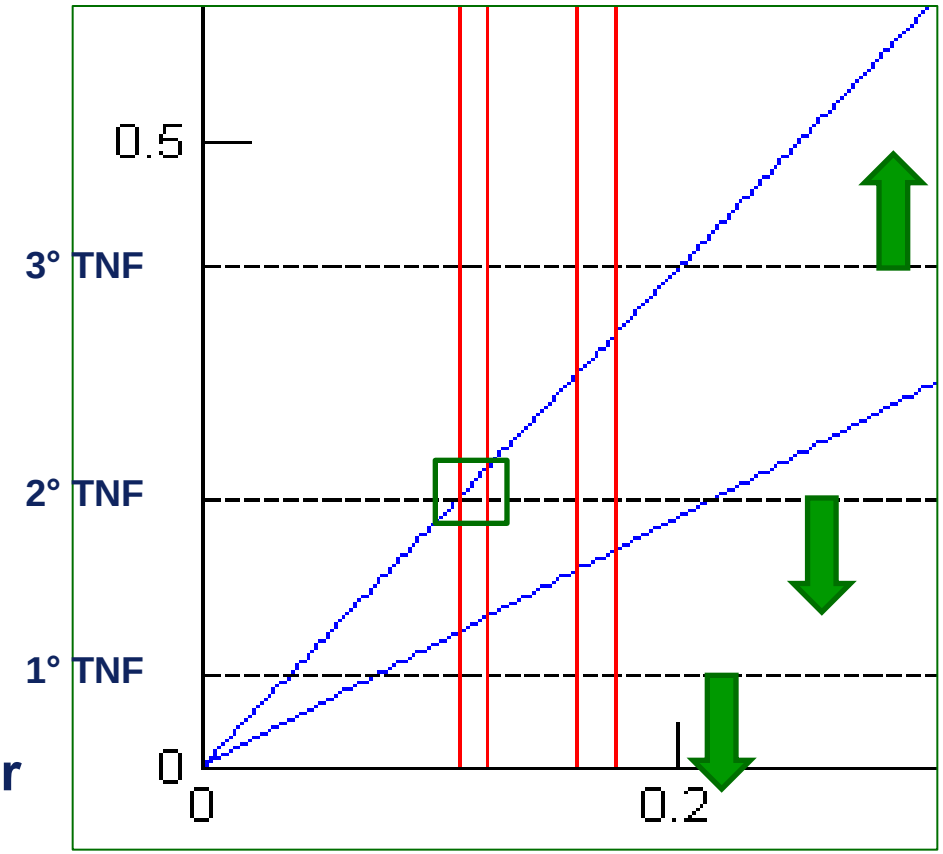
2° TNF

1° TNF

Importance of couplings

- Torsional Natural Frequencies need to change to avoid torsional vibrations

Therefore High Performance coupling is one of the most important parts of the Turbomachines and often need to "Custom Engineer" for a particular application.

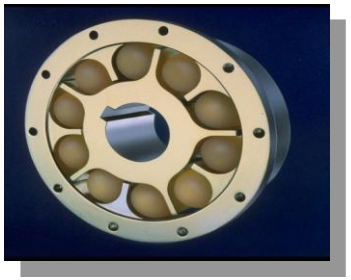


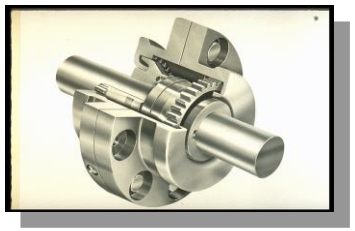
Kop-Flex Couplings

High Performance
- Disc
- Gear
- Diaphragm
- Torquemeter

Mill Products
- Large Gear Couplings
- Universal Joints
- Gear Spindles
- Large Max C

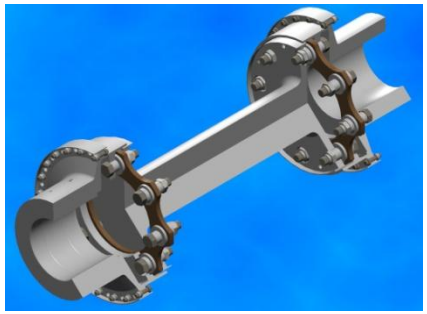
Standard Products
- Gear Couplings
- Grid Couplings
- Jaw Couplings
- Resilient Couplings (Max C)
- KD Disc Couplings
- Elastomeric Couplings



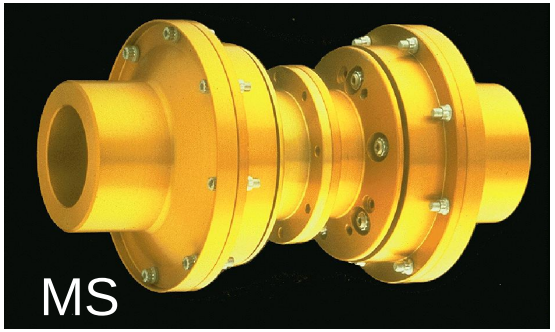
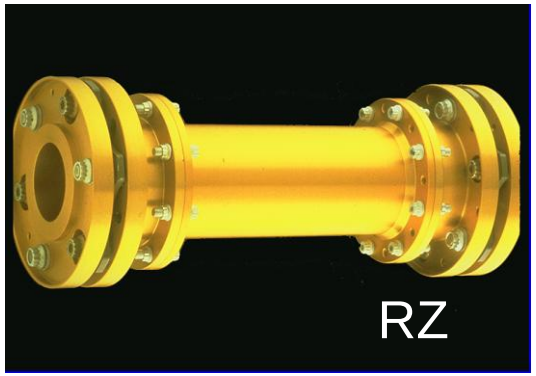
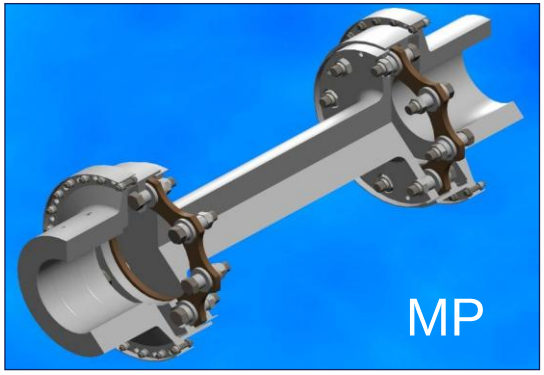


High Performance (HP) Couplings

- Lubricated –
  - Gear couplings.
    - Very reliable and very high torque transmission ability.
    - Maintenance prone.
- Non Lubricated
  - Disc
  - Diaphragm
  - Special executions
    - Very reliable and are maintenance free designs.

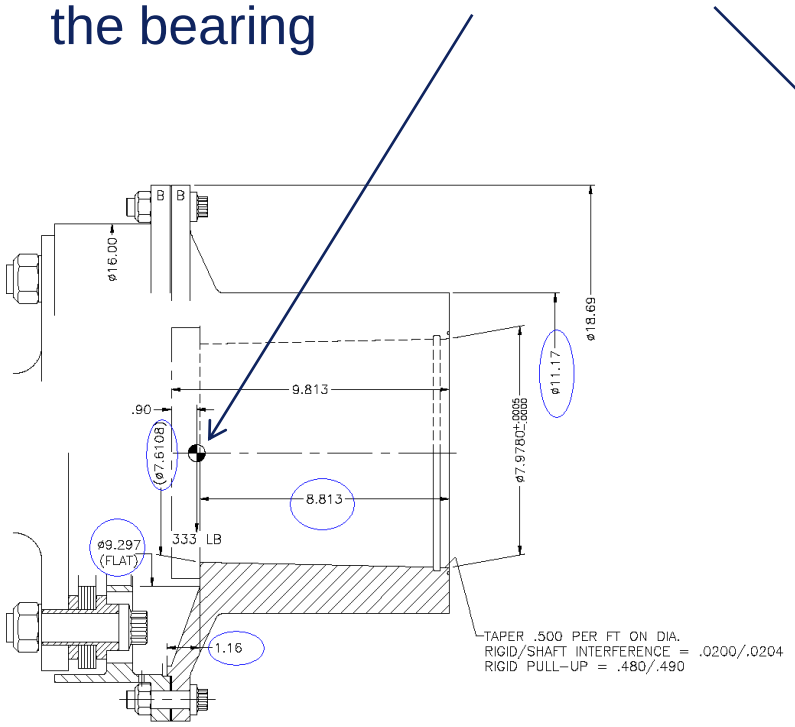


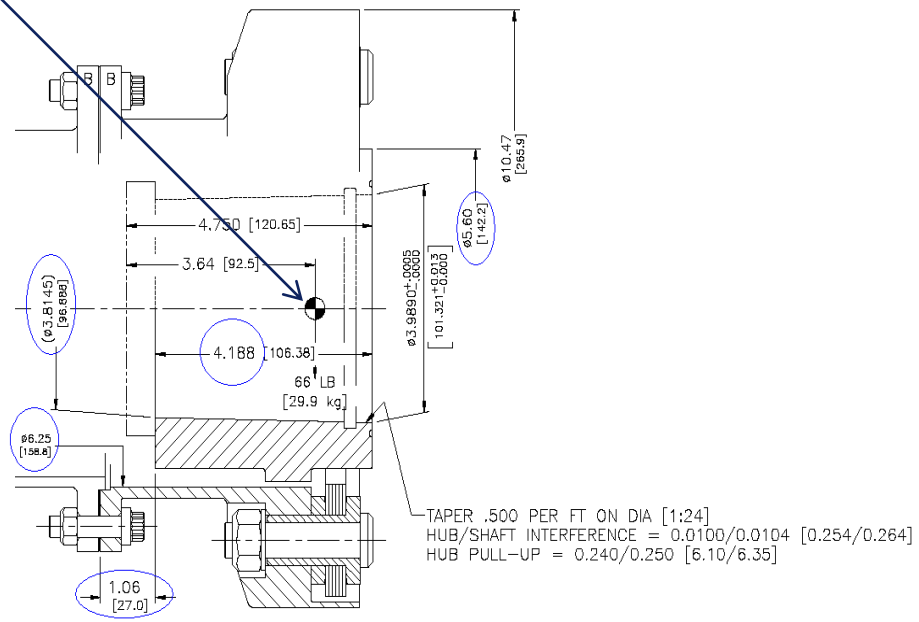
Kop-Flex HP Disc Couplings

	Reduced Moment	Marine Style
Interlocking Flange		
Standard Flange		

Reduced moment disc coupling

- Position of Center of Gravity for the half coupling is brought nearer to the bearing

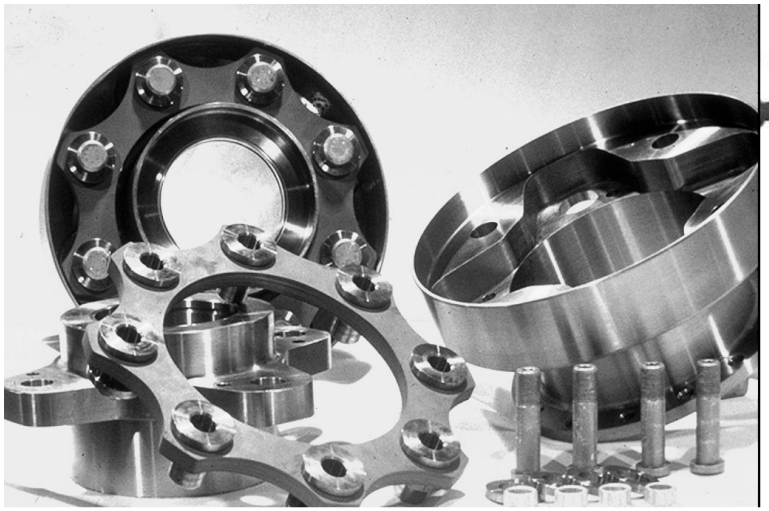




- Reduces the load on the shaft bearing

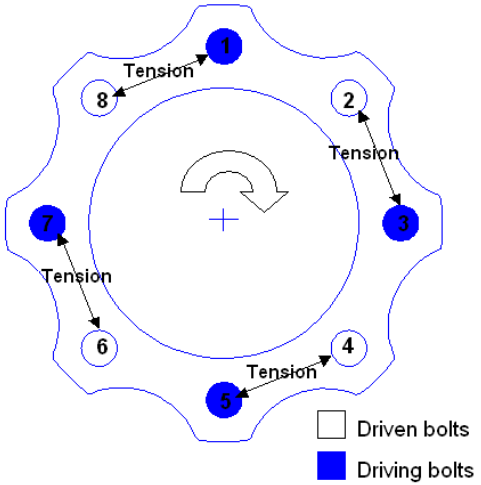
Interlocking flange

- Fail safe design



Disc Pack features

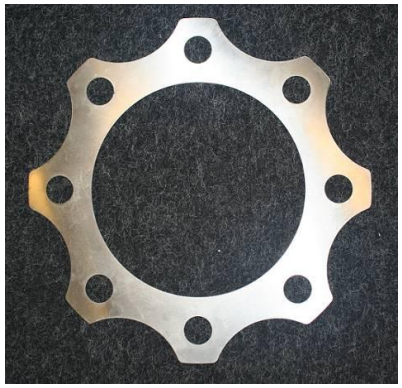
- Designed for infinite life.
- Higher lateral critical speeds compared to gear couplings.
- Low reaction load transmitted to machinery
- Flexible Disc Packs
  - Transmit Torque Circumferentially
  - Flexible Links
  - Disc Pack Multiplicity
  - Optimized stress distribution
  - Stainless Steel or Inconel



Disc Pack features

- Koplon Coating
- Heat-treated Alloy Steel Hubs, Spacers, and Sleeves

3-Bolt



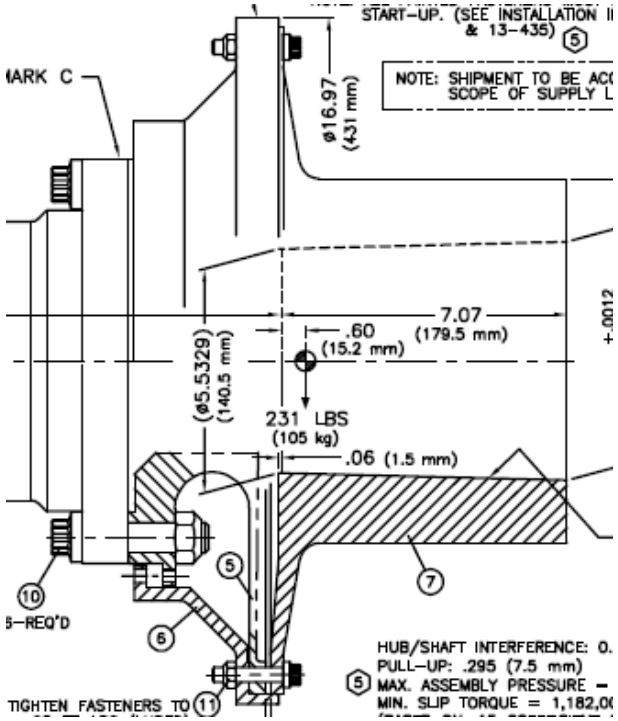
4-Bolt

5-Bolt

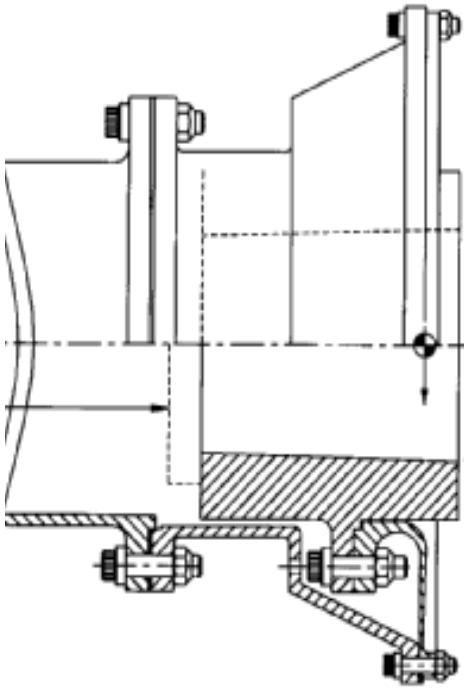
Torque vs. Misalignment

Kop-Flex HP Diaphragm Couplings

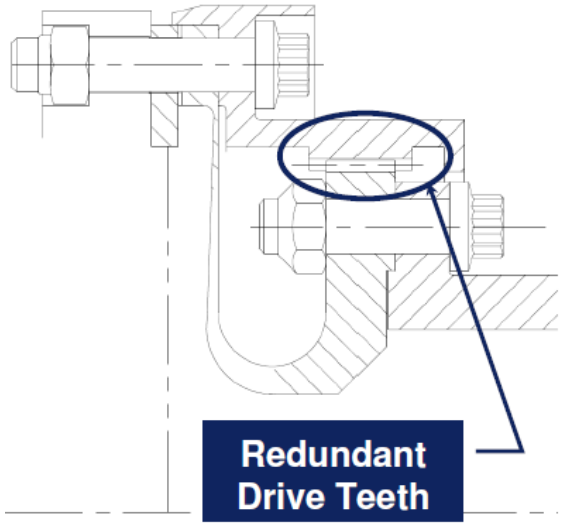
Marine style

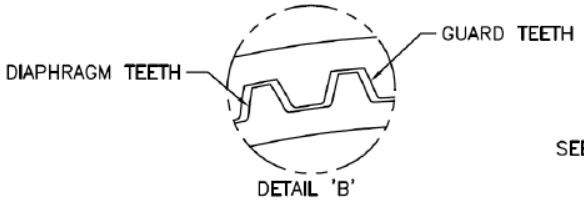


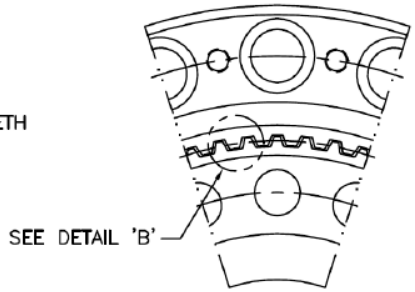
Reduced Moment style



Diaphragm coupling fail safe design







- Non-contacting during normal operation, engage only during the event of shock to protect the diaphragm from failure
- Engagement of teeth occurs above normal torque (Typically 1.5 X normal or more)
- After engagement torque load is shared between the guard and the diaphragm (Dual torque transmission paths)

Diaphragm coupling fail safe design

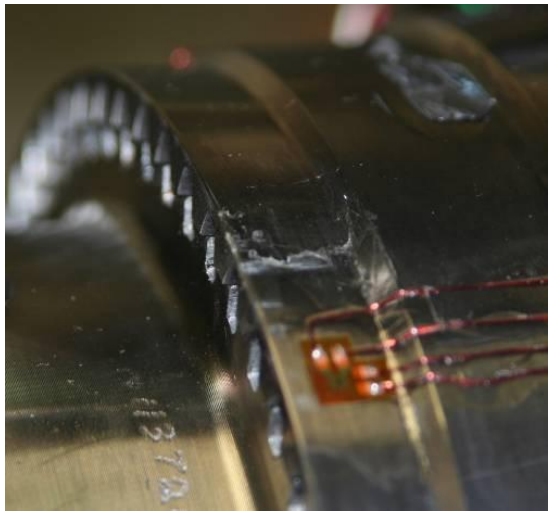
- Calculations based on classical spline analysis

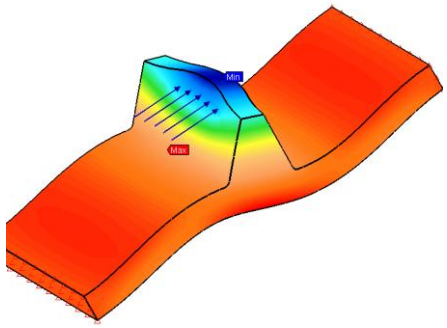
  – Includes bursting, bending, speed, and shear components

  – Enhanced and verified with empirical data and FEA

  – Based on our analysis classical calculations are conservative

- Patented design

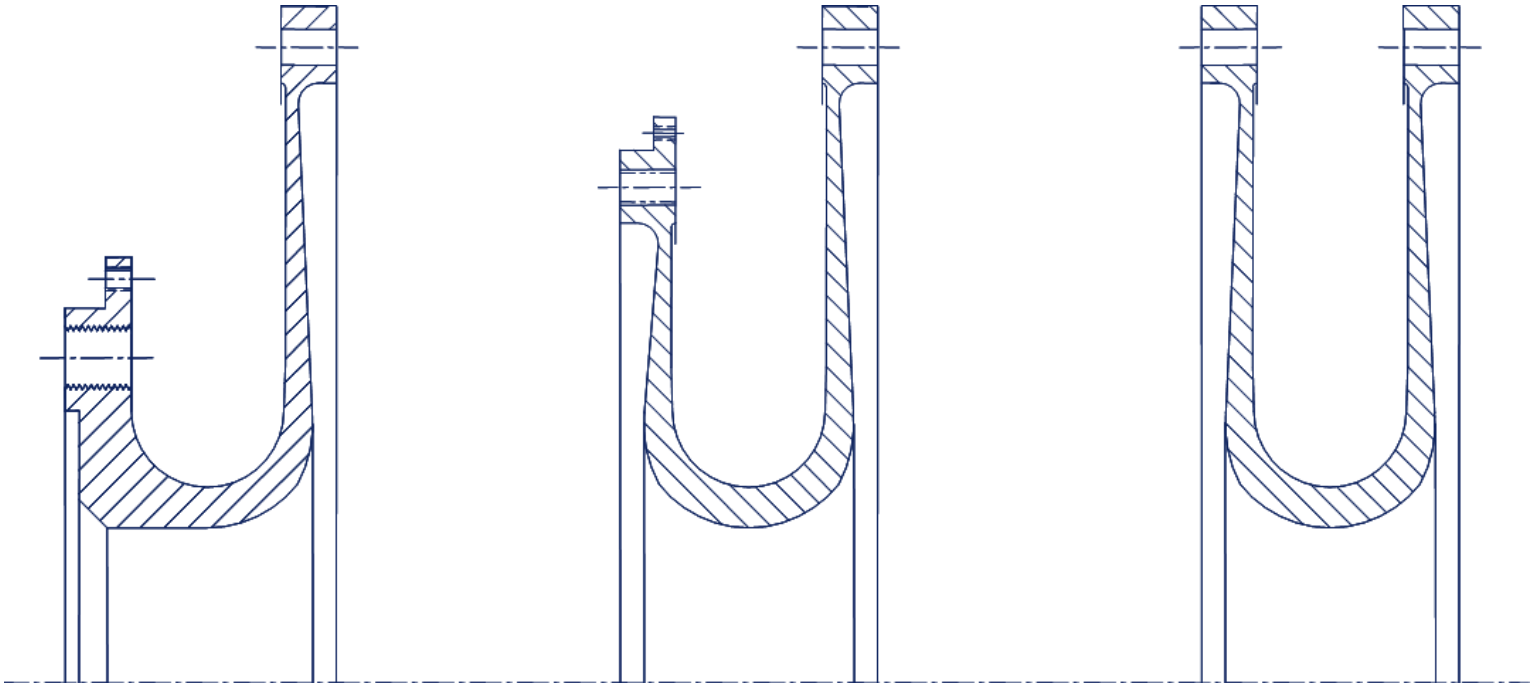




Diaphragm features

- Preferred where shaft axial travel is more (up to 25 mm).
- For larger sizes diaphragm is less expensive.
- Easier to install.
- Easier to balance.
- Less windage losses.
- Kop-Flex diaphragms are one piece (no joints).
- Polished and shot peened.
- Customized Profiles for Special Applications

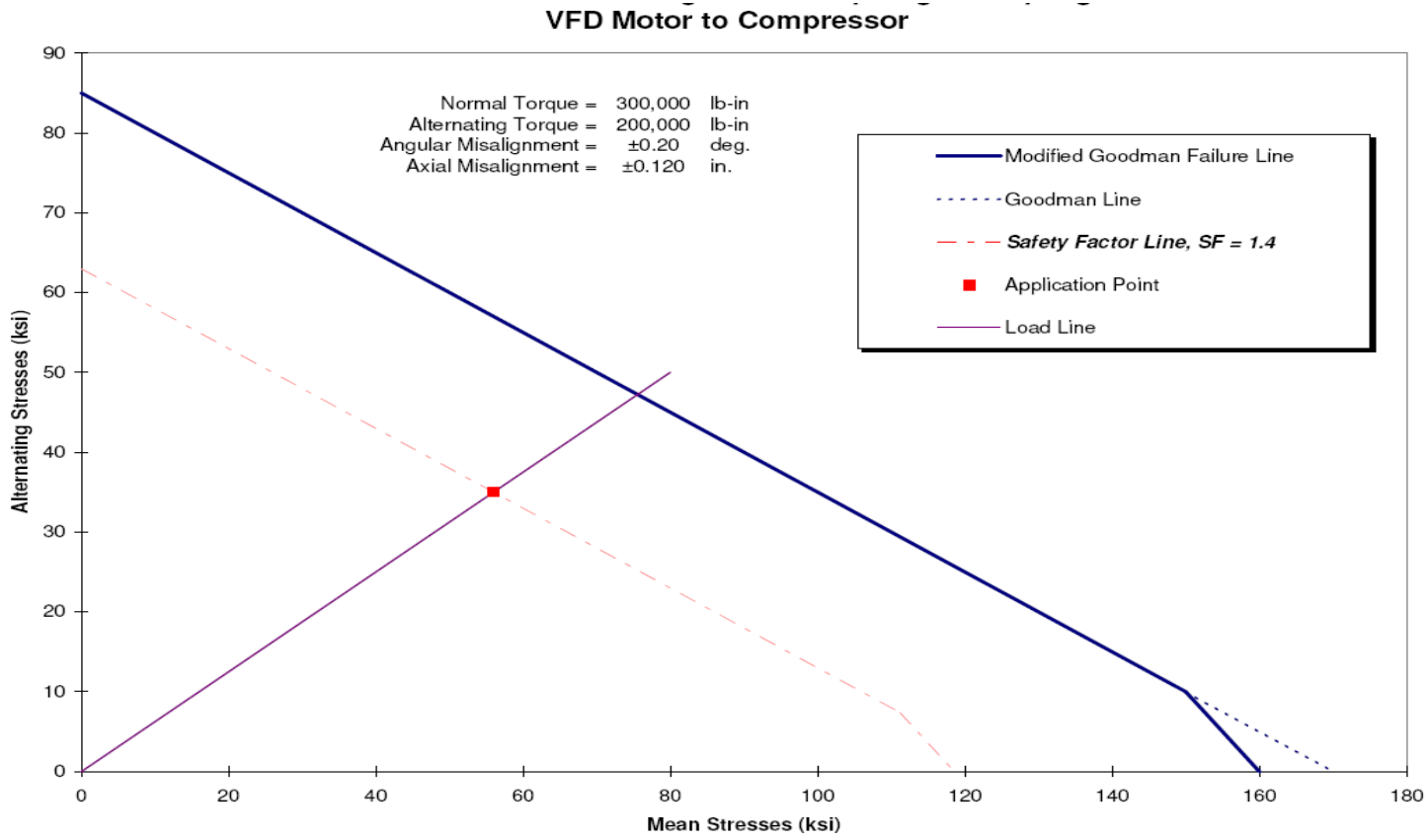
Diaphragm designs



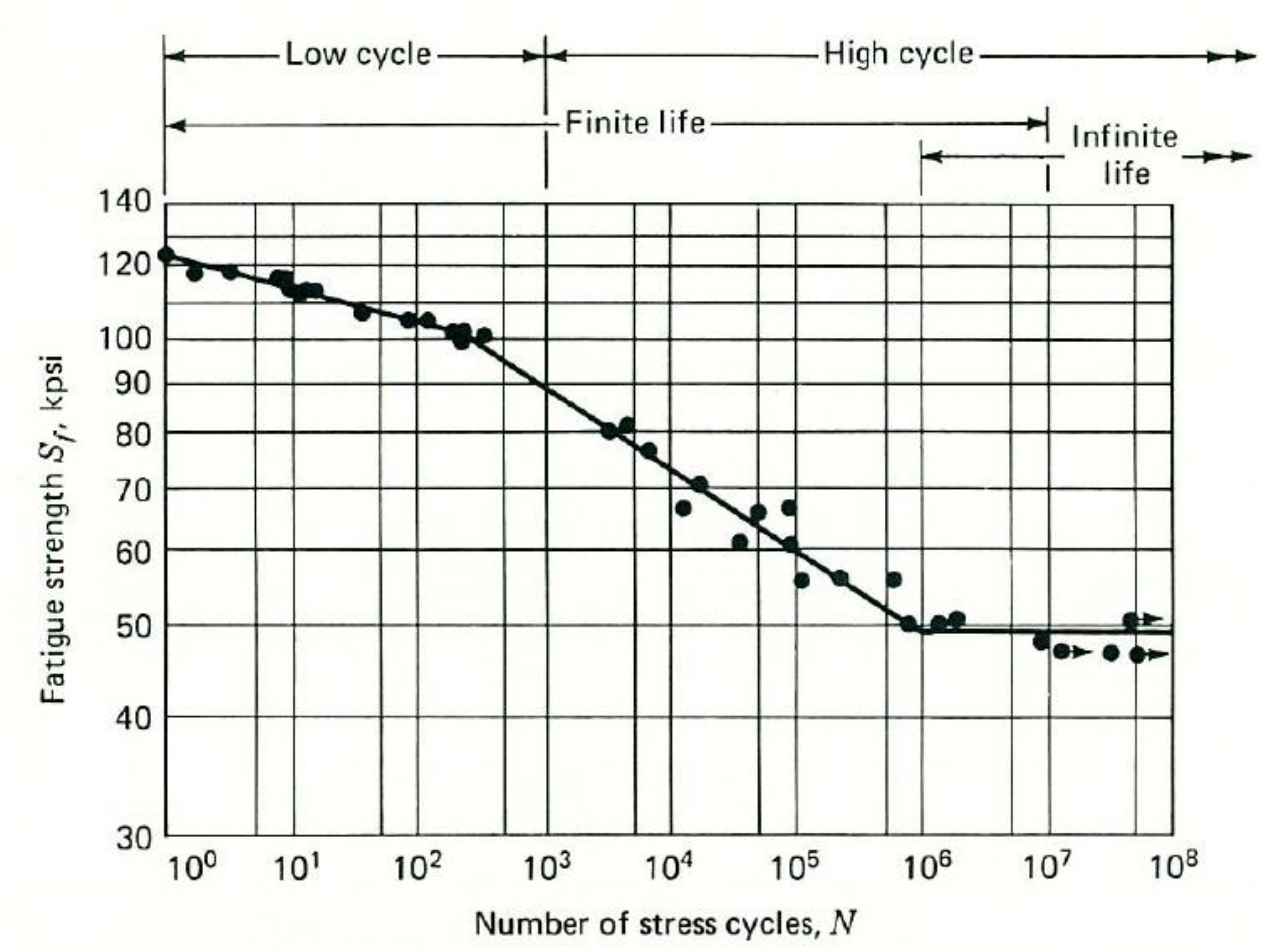
I-Shape J-Shape U-Shape

Goodman Diagram

Different vendors rate this differently, Kop-Flex rate the coupling at worst case – max speed, max misalignment and max torque.

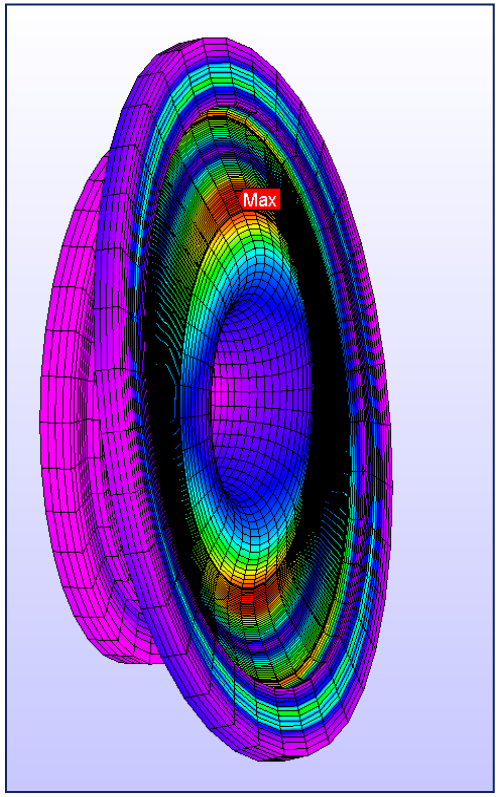


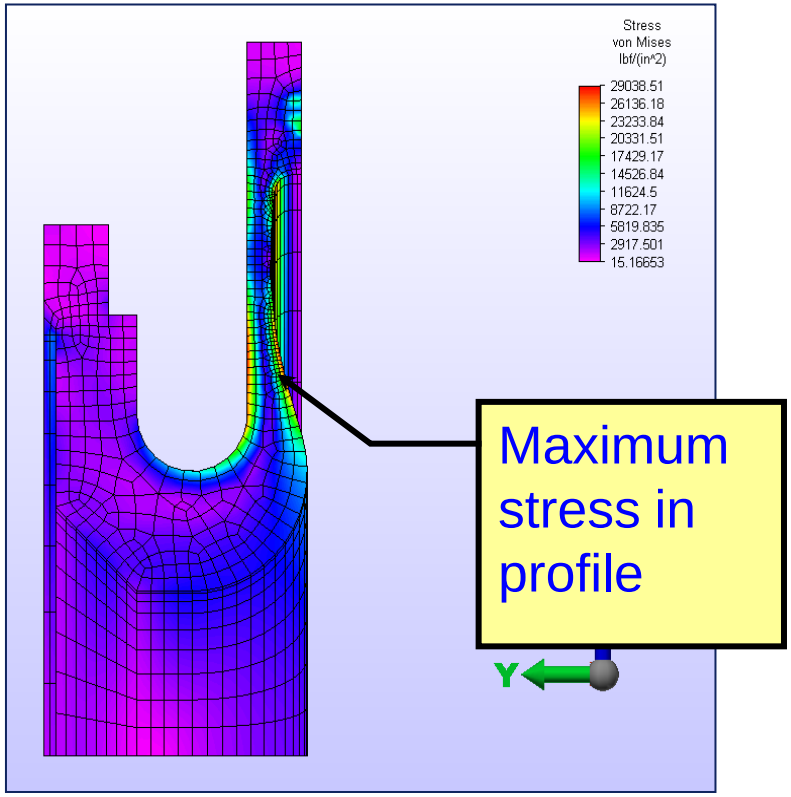
S-N Curve


Low cycle
High cycle
Finite life
Infinite life
140
120
100
90
80
70
60
50
40
30
Fatigue strength S_f, kpsi
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
Number of stress cycles, N

FEA Diaphragm

Angular = .20 deg

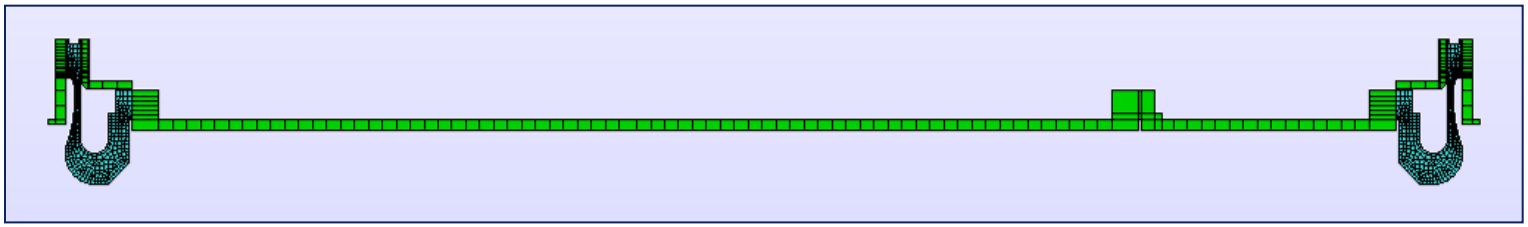




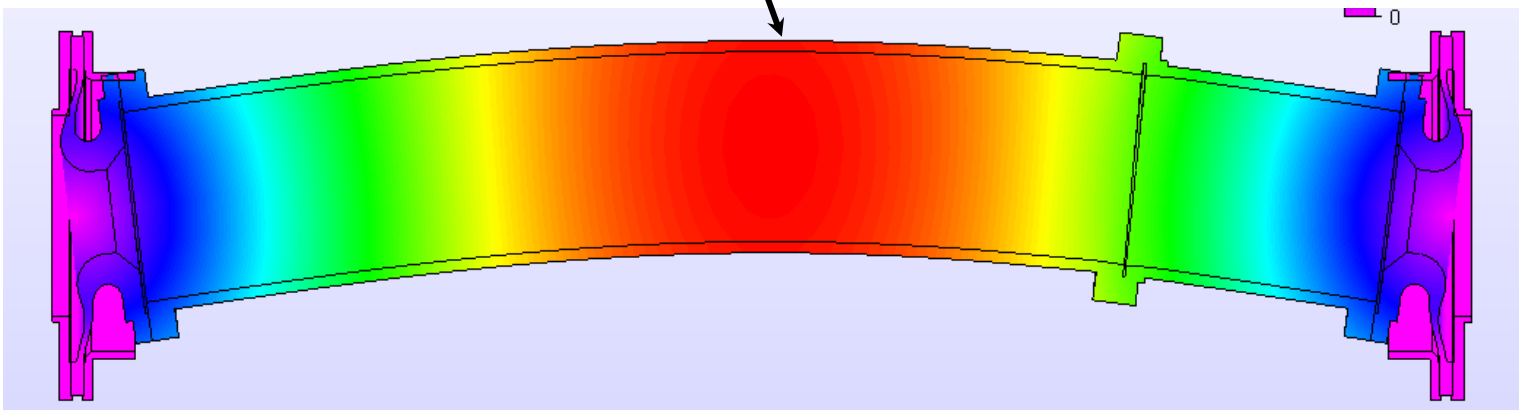
Long Shaft Separation

- Higher Speed Applications with Longer Shaft Separations.
  - Balance Lateral Critical Speed, Overhung Moment, and Cost

FEA Result for Assembly

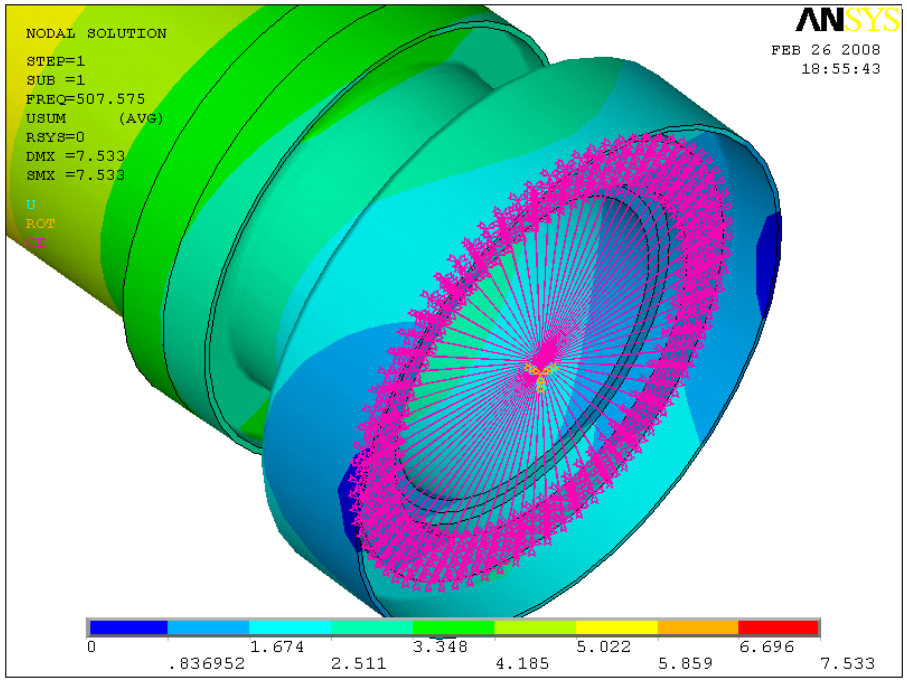


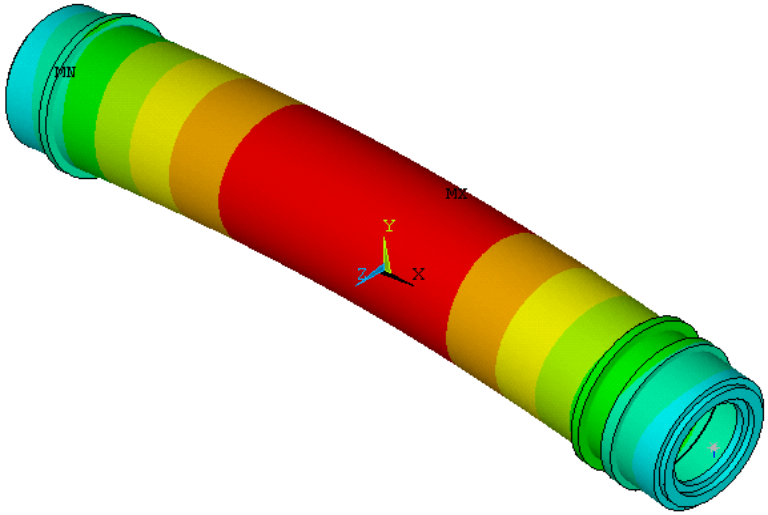
Lateral Critical Speed



Lateral Critical Speeds

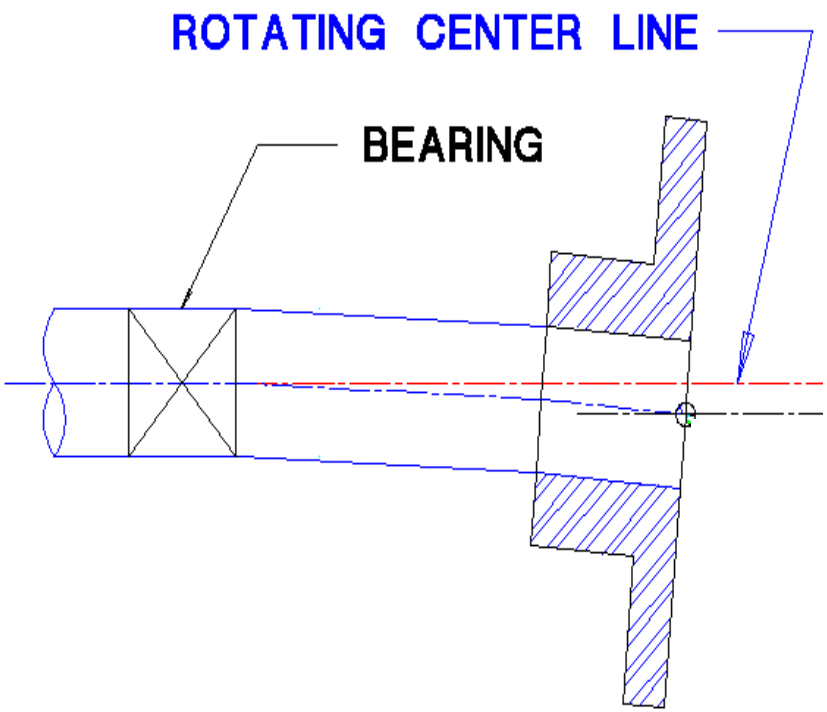
5.3 The ratio of the lateral critical speed of the coupling on rigid supports and maximum continuous operating speed (MCOS) shall be at least 2.0. If the ratio is 2.5 or greater, a simply supported tube equation may be used. If the ratio is less than 2.5, the coupling needs to be explicitly modeled on rigid supports either using a transfer matrix method or a finite element (2-D or 3-D) method.





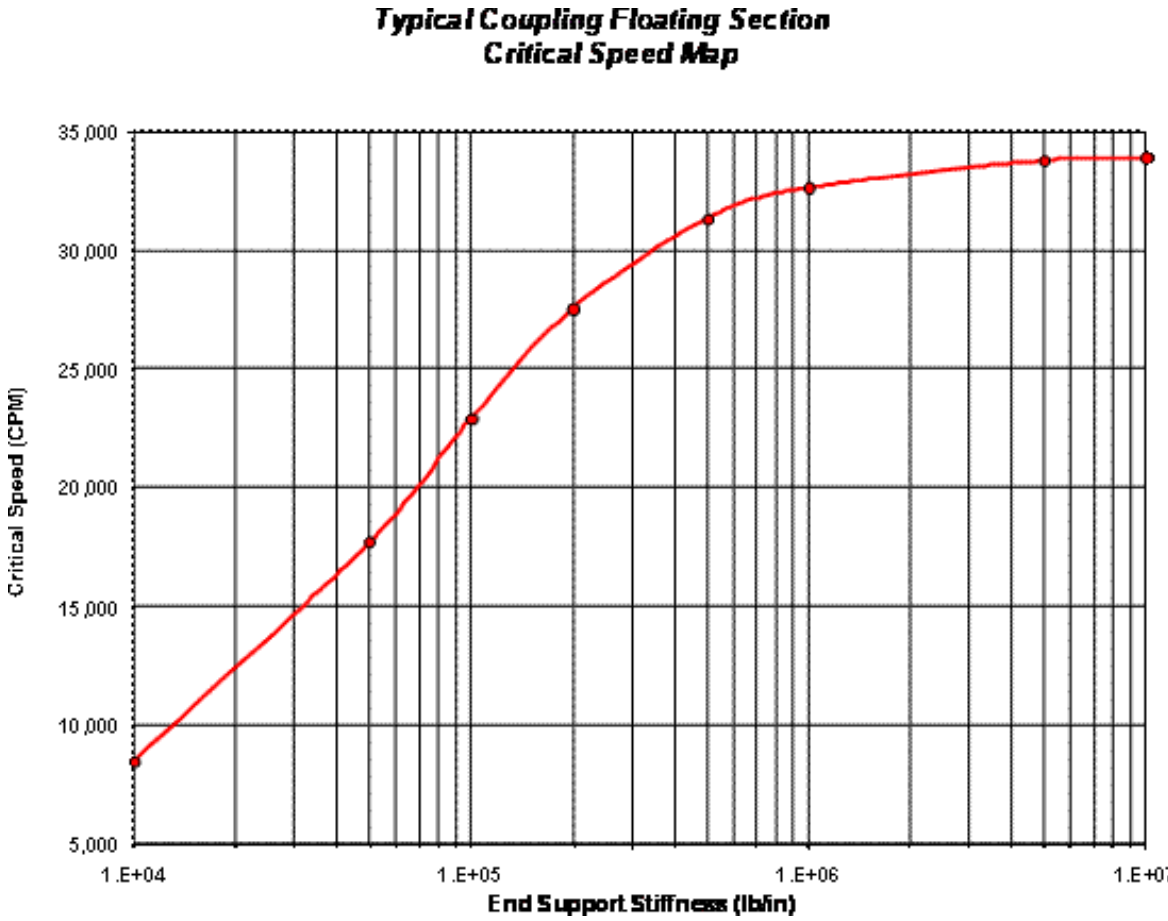
Lateral Critical Speeds

- Coupling End Support Stiffness
  - Bearing
  - Shaft
  - Coupling Flexible Element



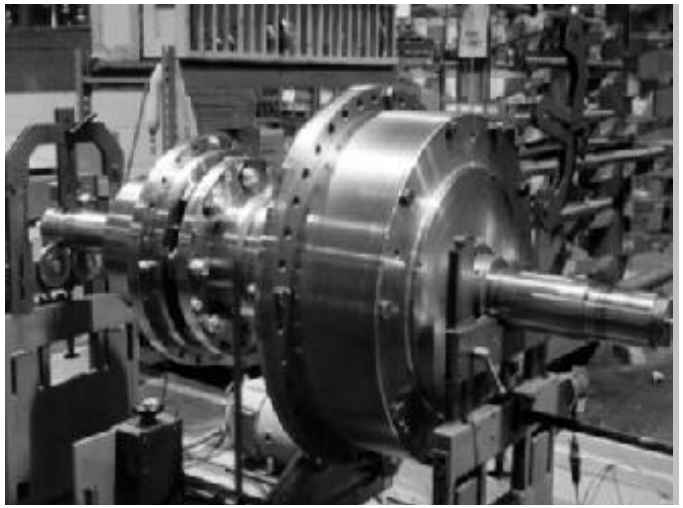
End Support Stiffness

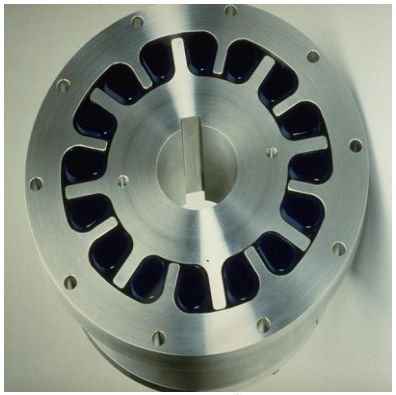
- Success in the Field With 1.25 Ratio to MCOS



Innovation- Hybrids

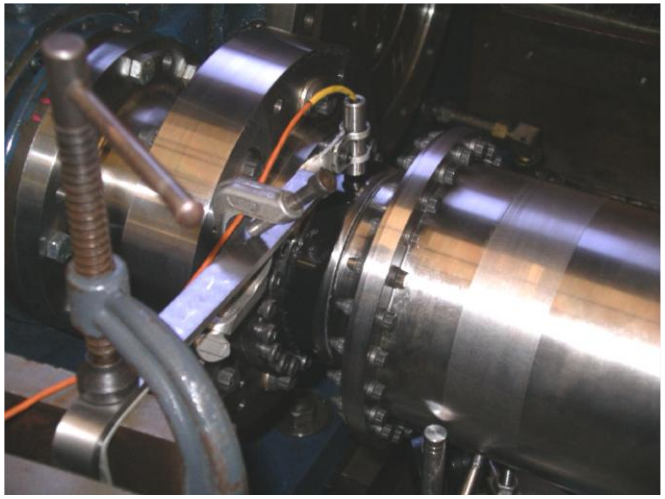
- **Max-C® Resilient**
- Used in trains with high vibratory torque loads
- Typical applications
  - Synchronous motor
  - Variable frequency motor
- Reduced torsional loads
- No lubrication
- SBR high dampening blocks
- High shock load capacity
- Coupled with disc, diaphragm, or gear
- Single source of supply.

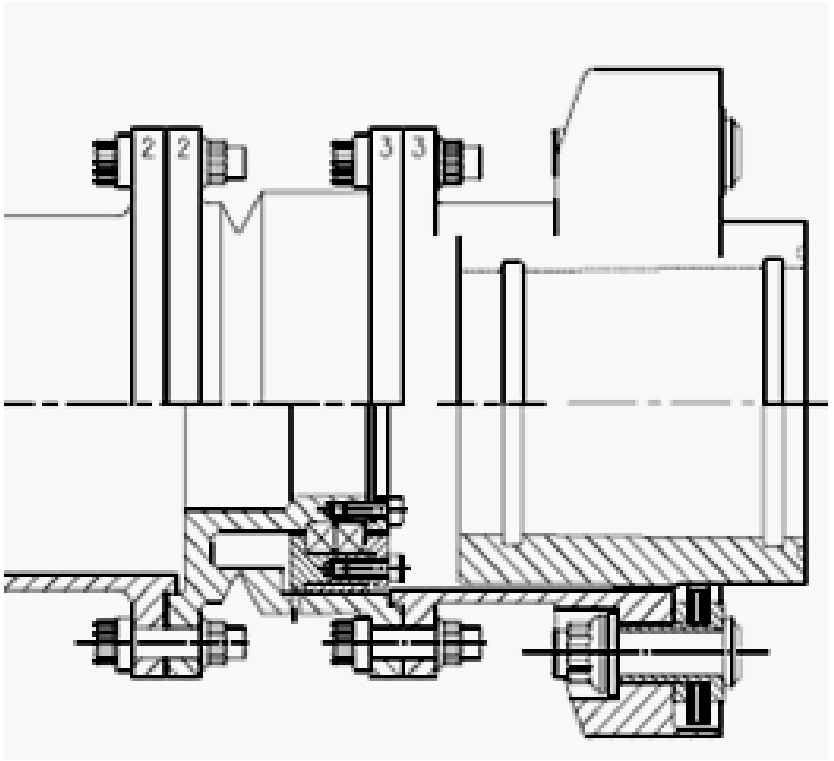


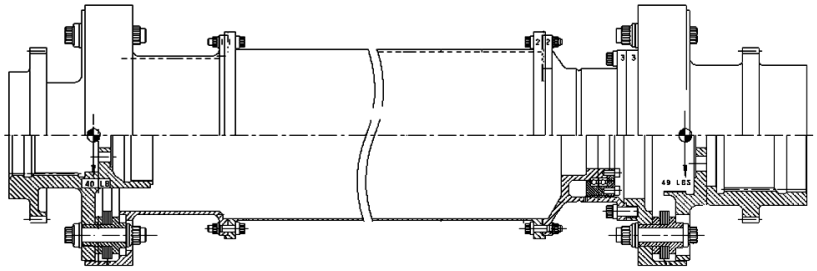


Innovation- High Speed Shear

- High Speed Shear Coupling







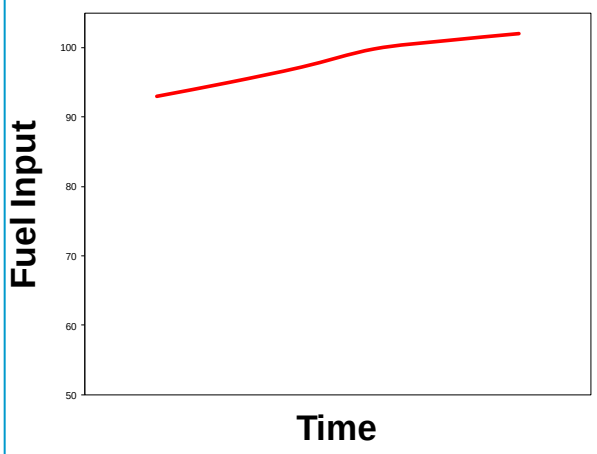
Innovation - Powerlign® Torquemeters

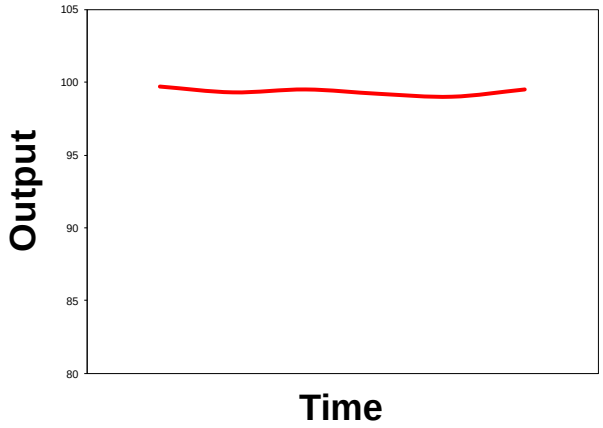
- Why use torque meters?
  - Identify machine train performance deterioration and improve overhaul schedules
  - Reduced emissions
  - Check fuel costs
  - Expanded system control integration; plant-wide

Torquemeter Benefits

- Identify machine train performance deterioration and improve overhaul schedules
- Reduced emissions
- Check fuel costs
- Expanded system control integration; plant-wide

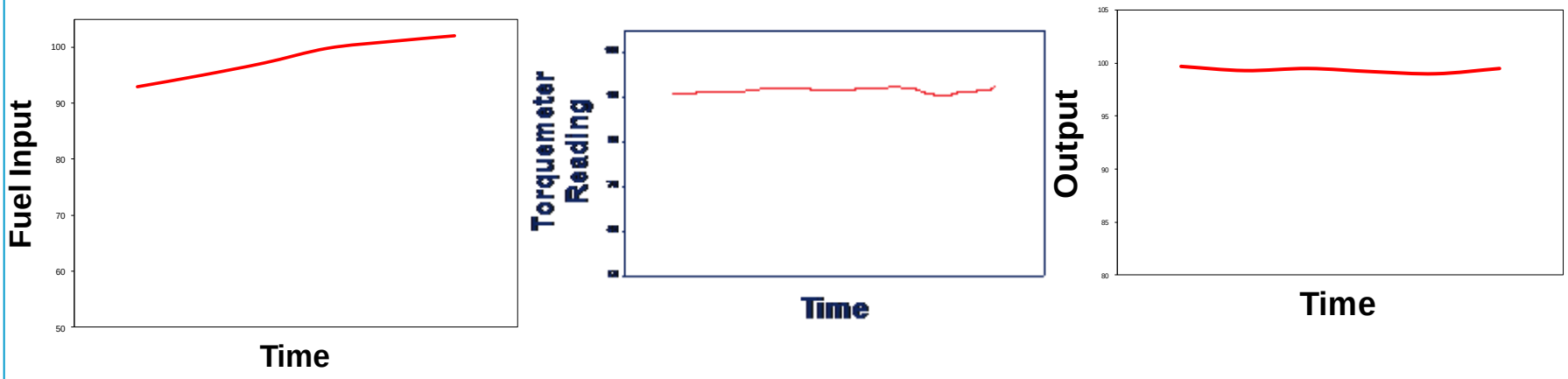
Simple Gas Compression Train

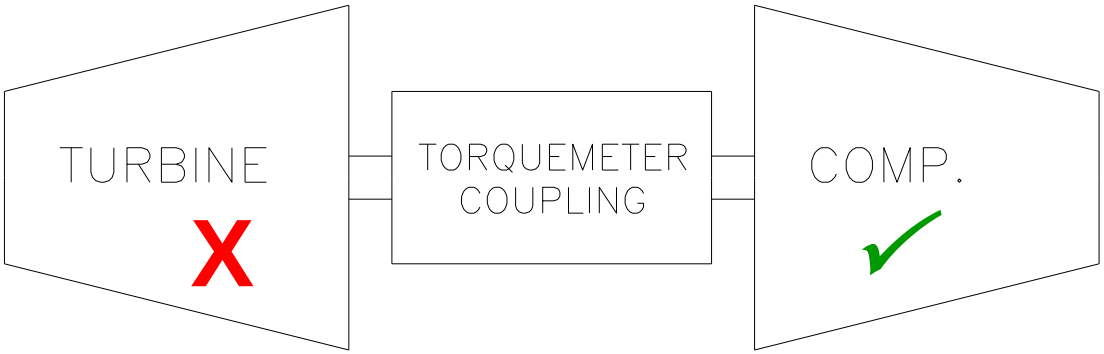




Loss of efficiency over time. Where is the problem?

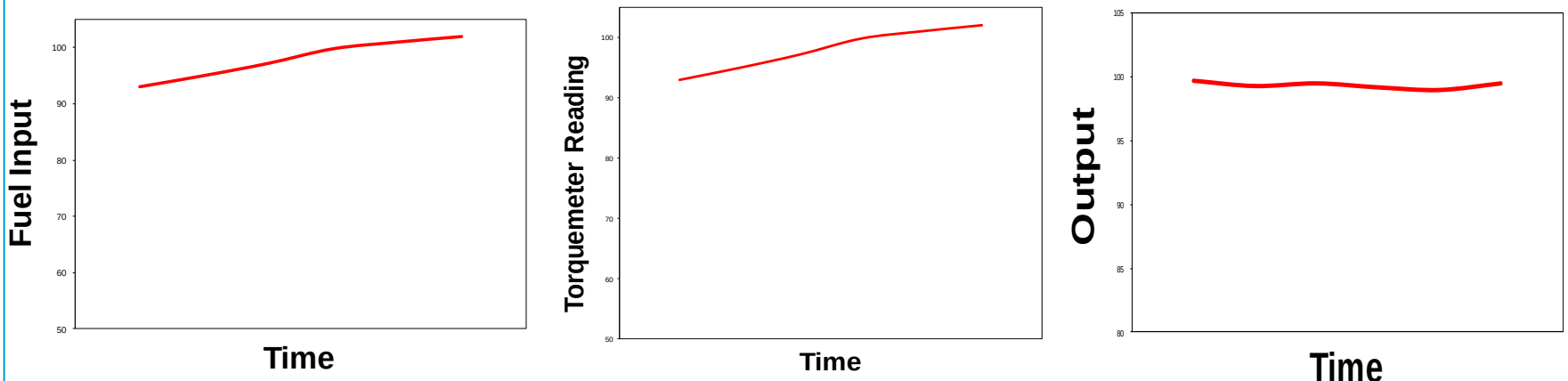
Gas Compression Train with Torquemeter

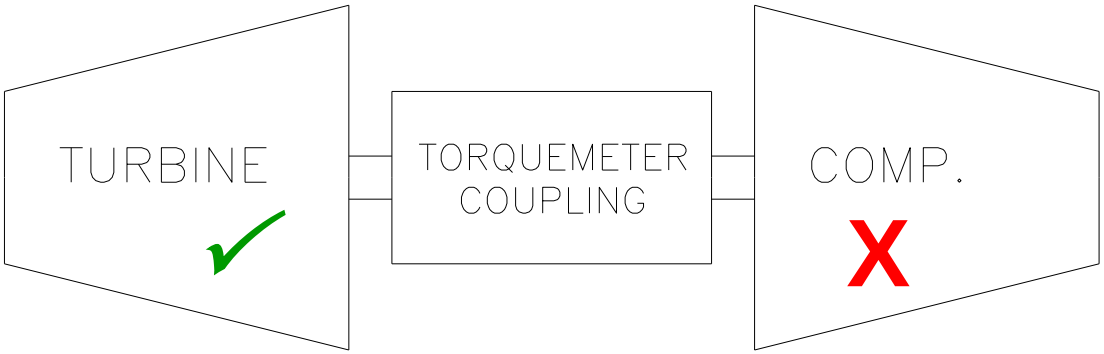




Problem in turbine.

Gas Compression Train with Torquemeter

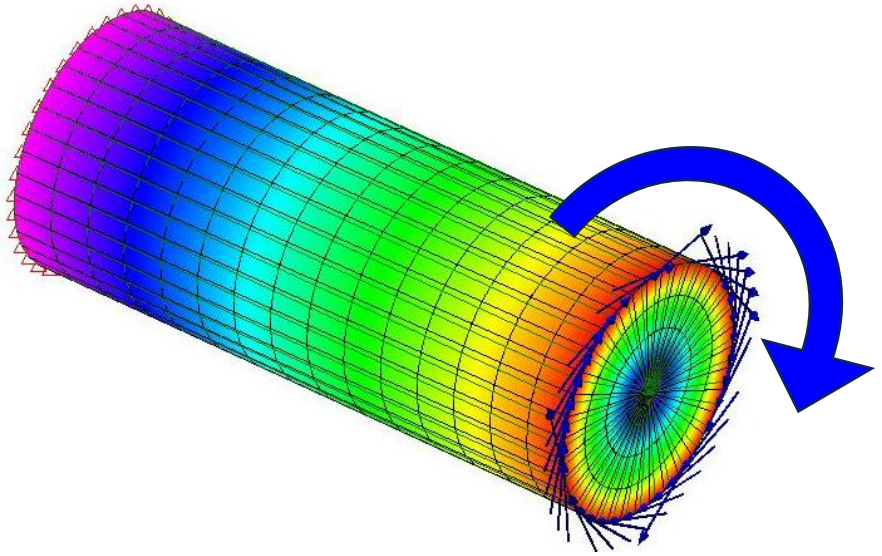




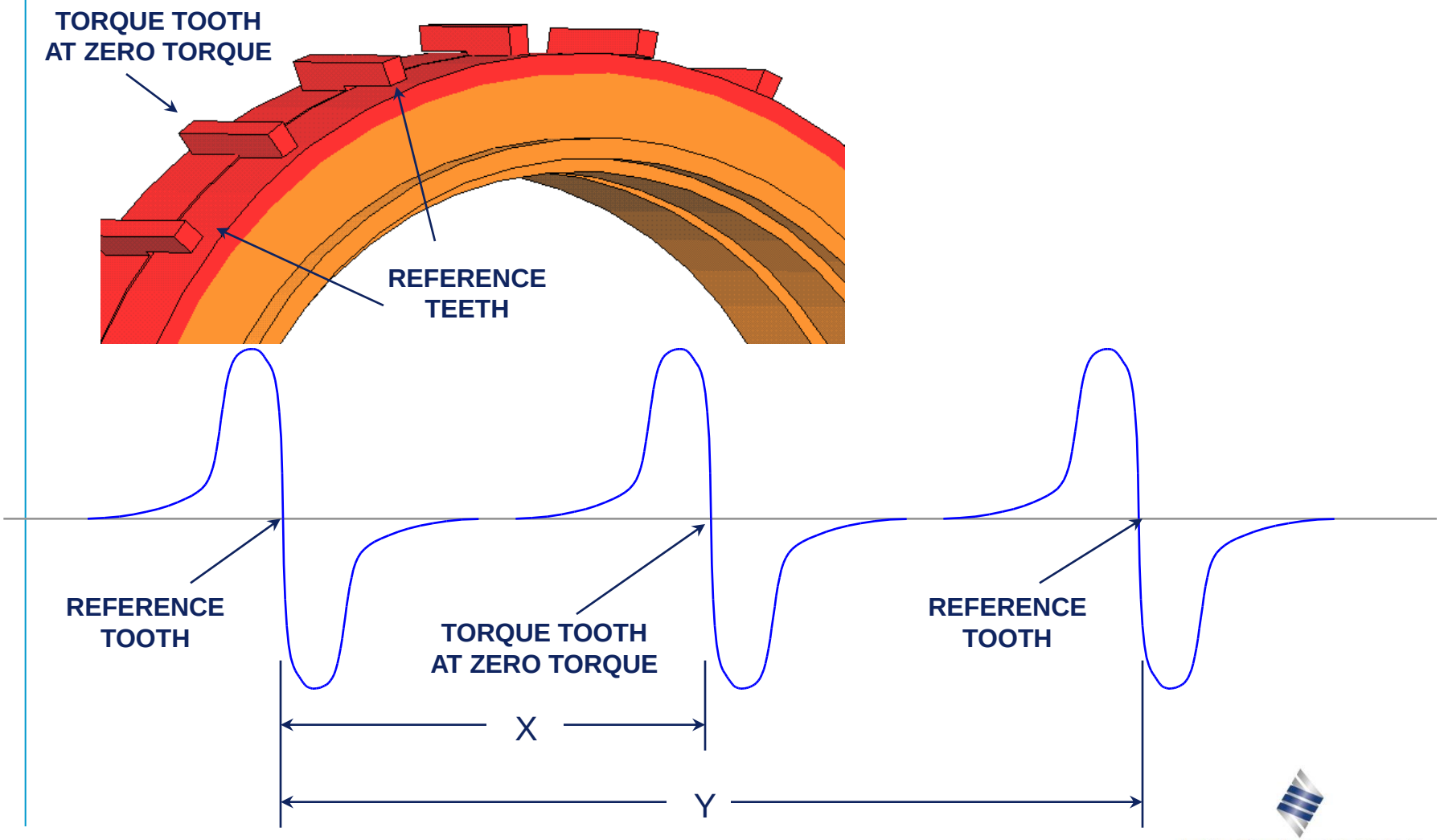
Problem in compressor.

Phase Displacement Systems

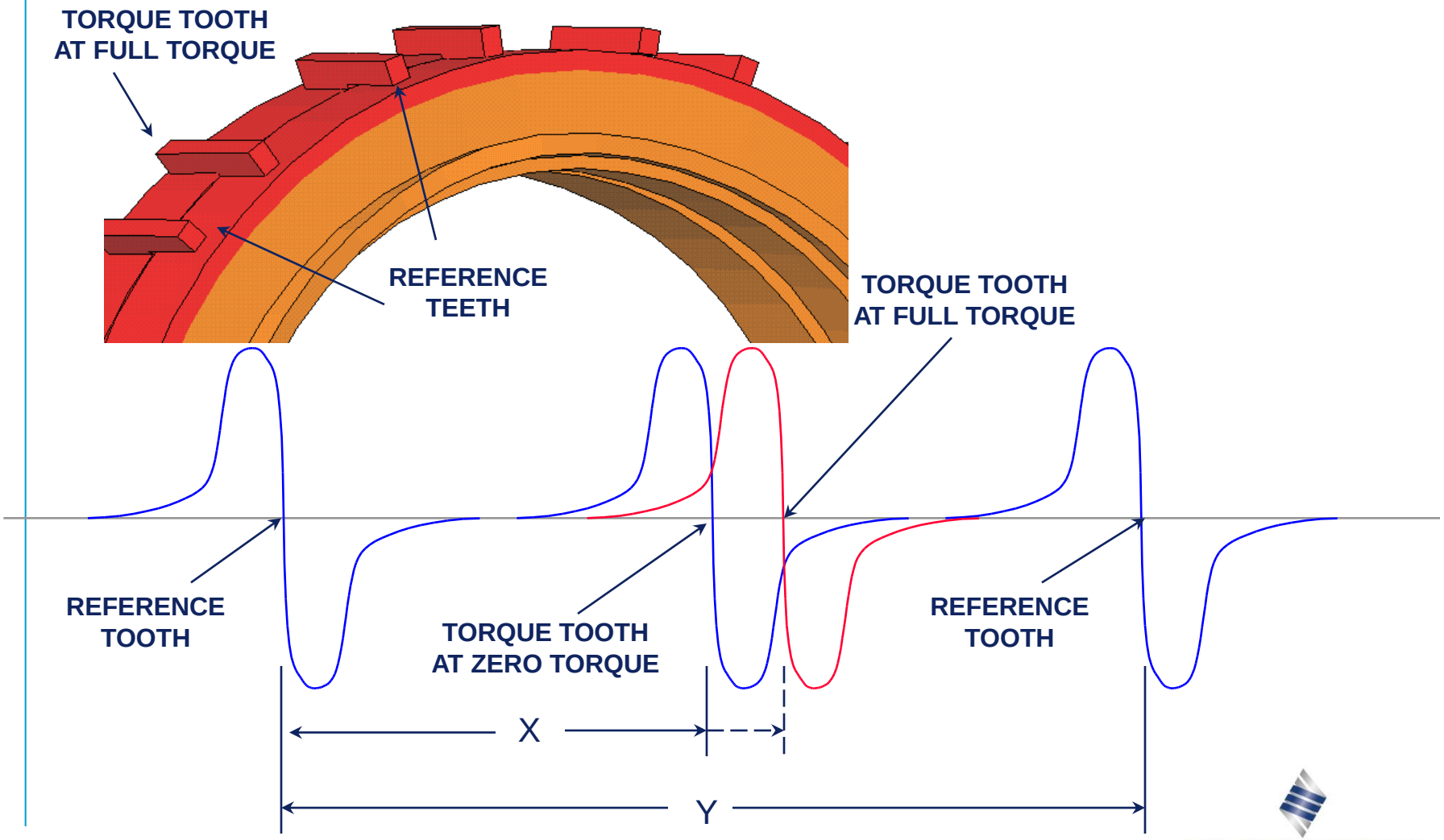
- Torque / twist: phase displacement
- Sensors pick up teeth associated with each end. Electronics time the pulses relative to each other.
- Several types:
  - 2-channel
  - 1-channel



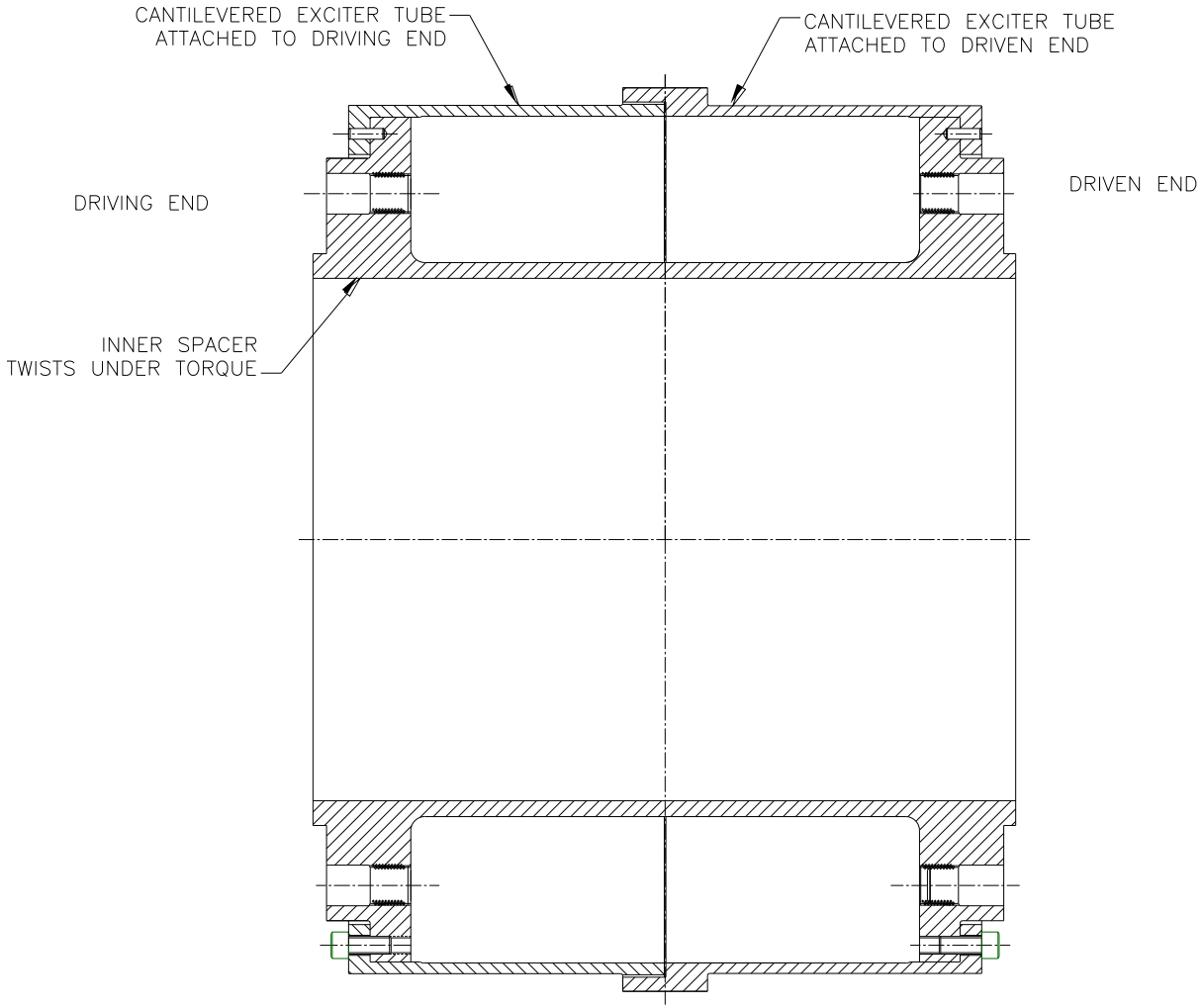
Sensor Phase Displacement Changes



Sensor Phase Displacement Changes

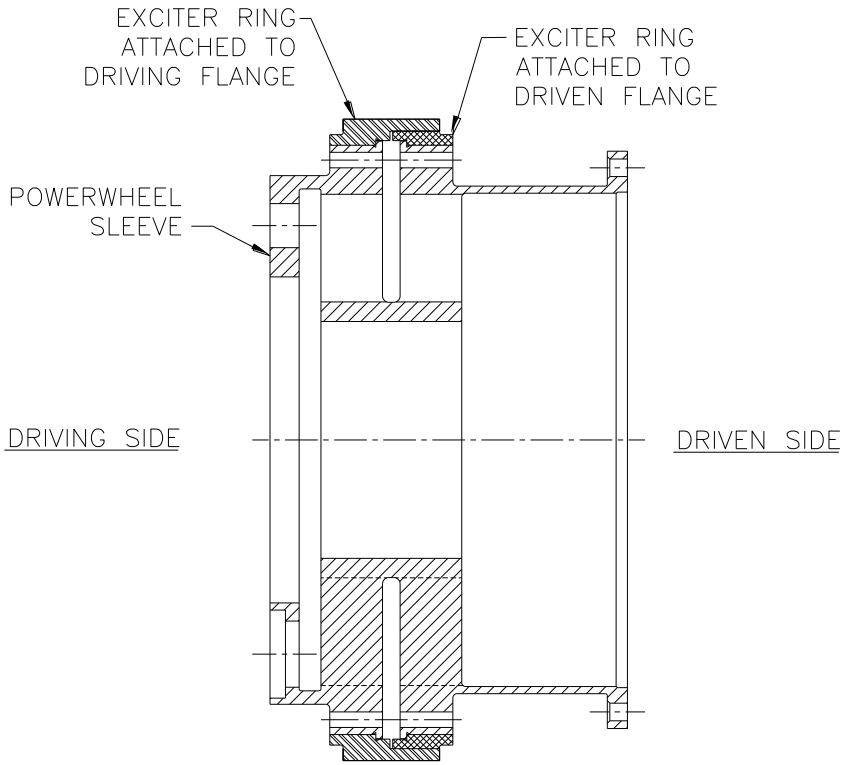


Powerlign: Single-Channel System



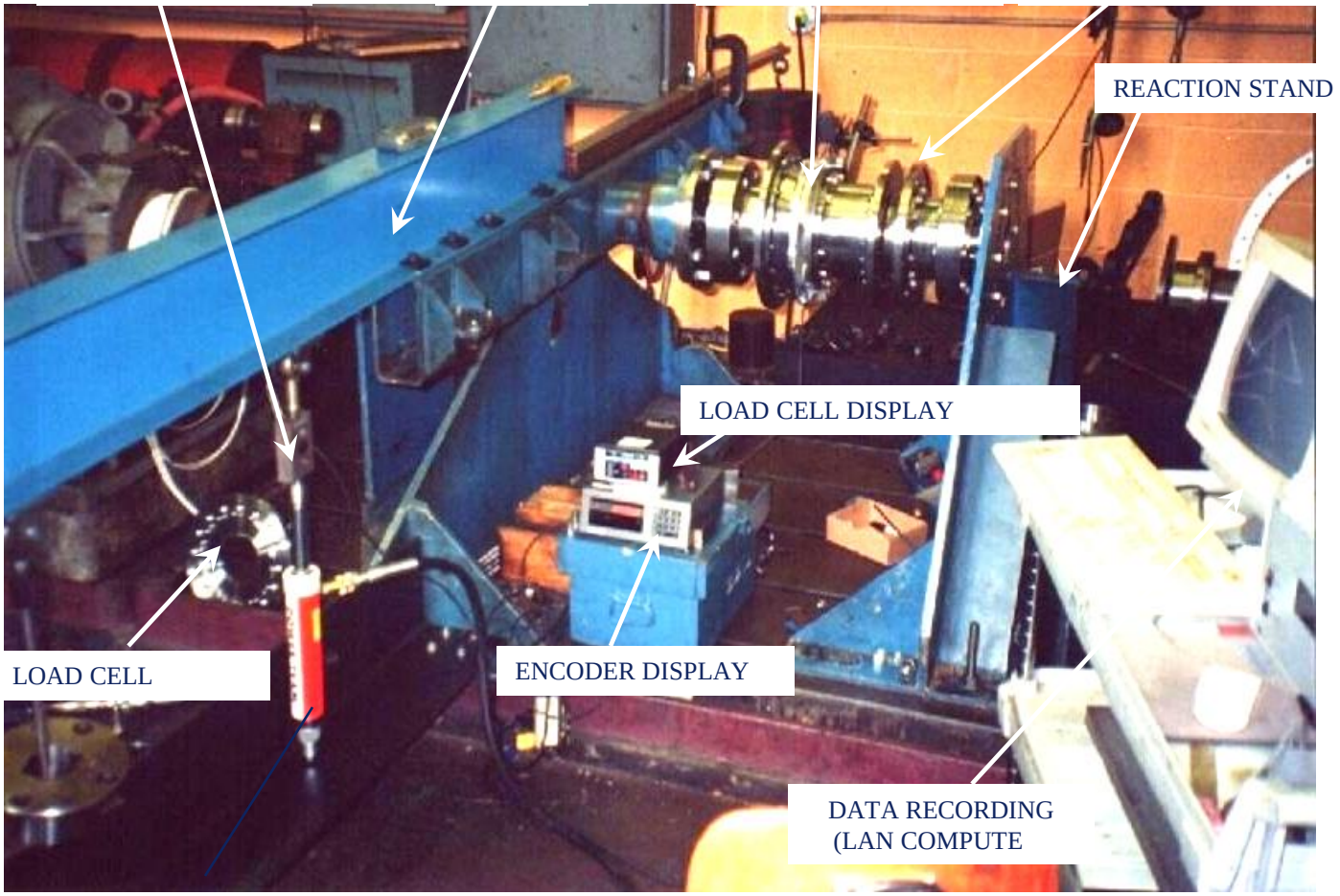
Powerlign: Powerwheel

Retrofit product



US Patent:
5,969,269

Powerlign Torsional Stiffness Calibration



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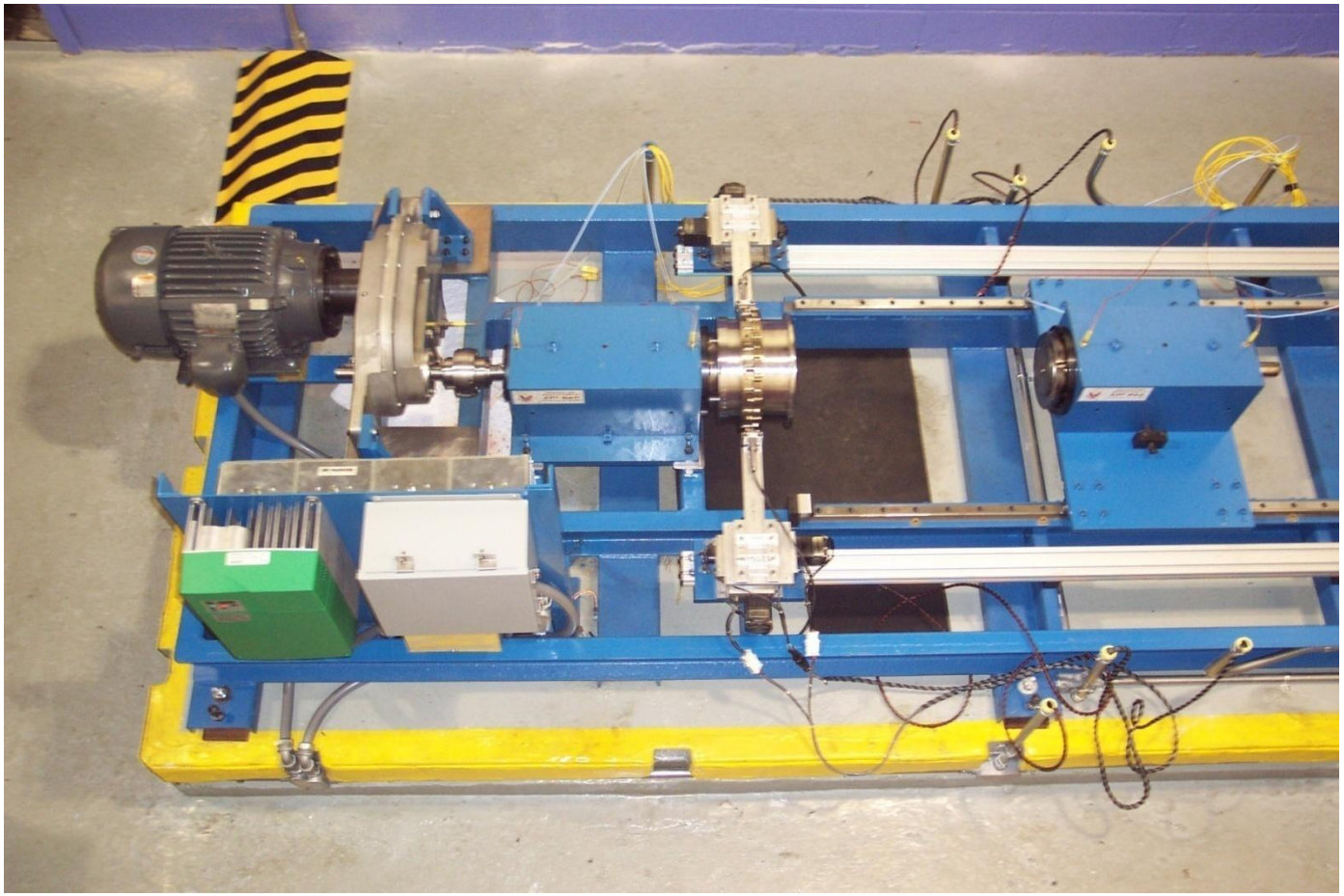
Powerlign Dynamic Calibration



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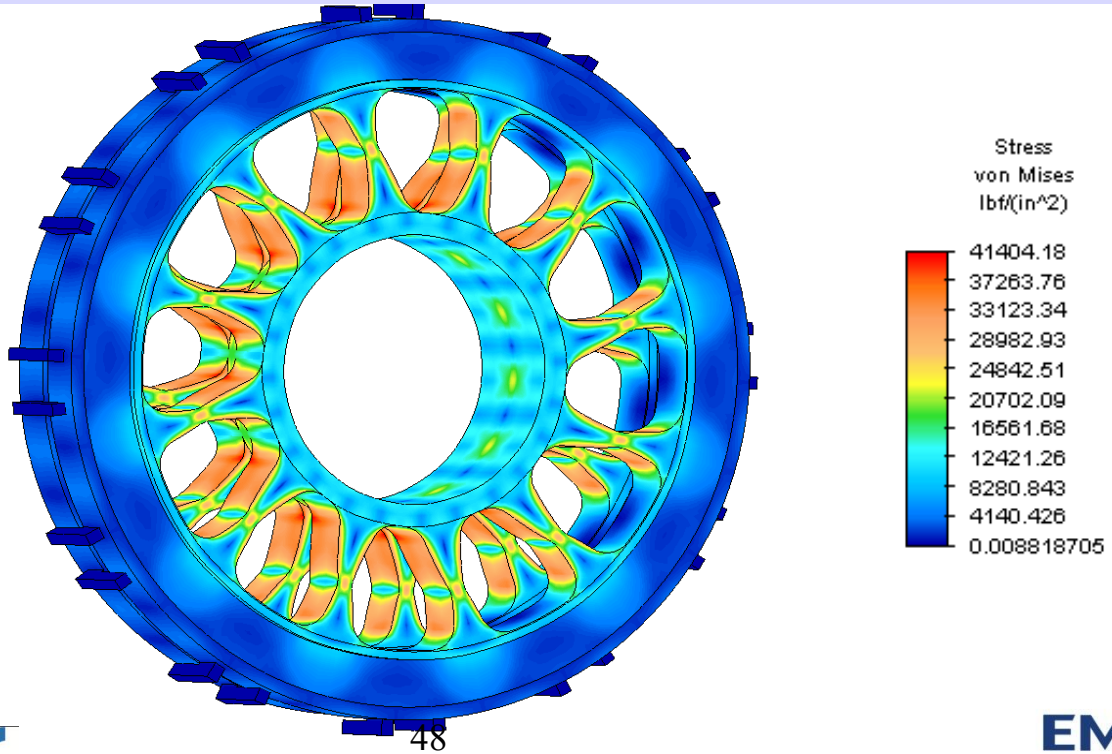
Industrial Automation

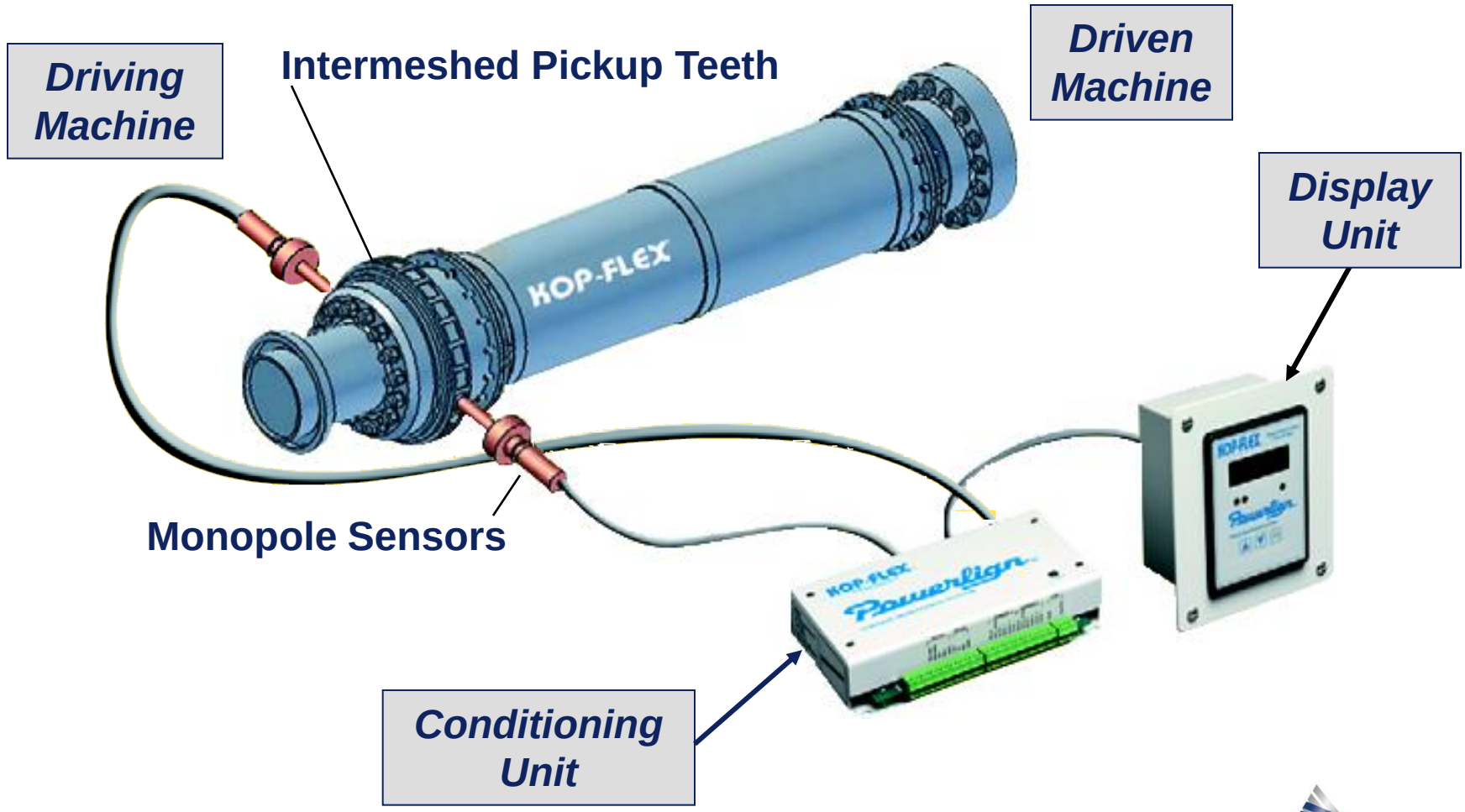
Powerwheel Torquemeter Analysis
LNF, Deflections, and Stresses



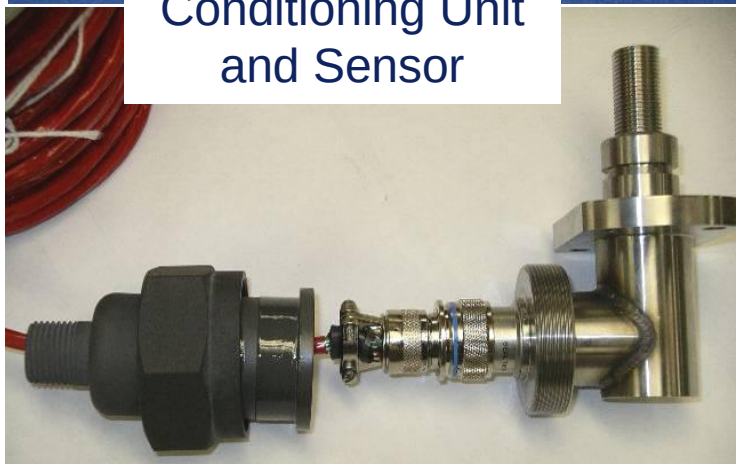
KOP-FLEX®

EMERSON™
Industrial Automation

Powerwheel System



Powerlign Electronic



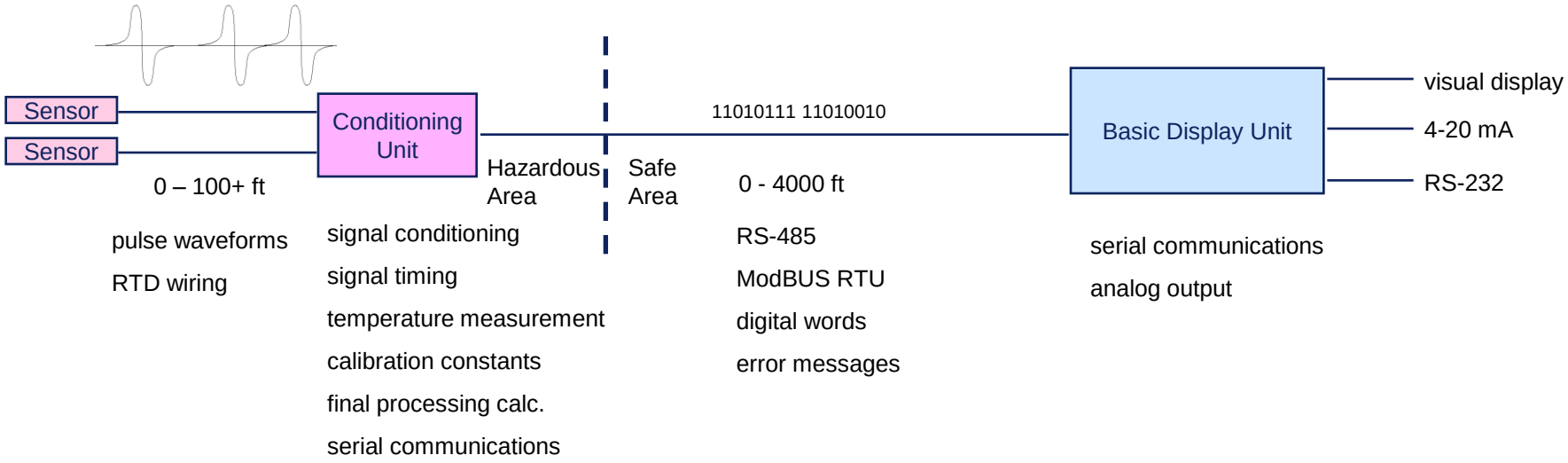
Conditioning Unit and Sensor

Display Unit

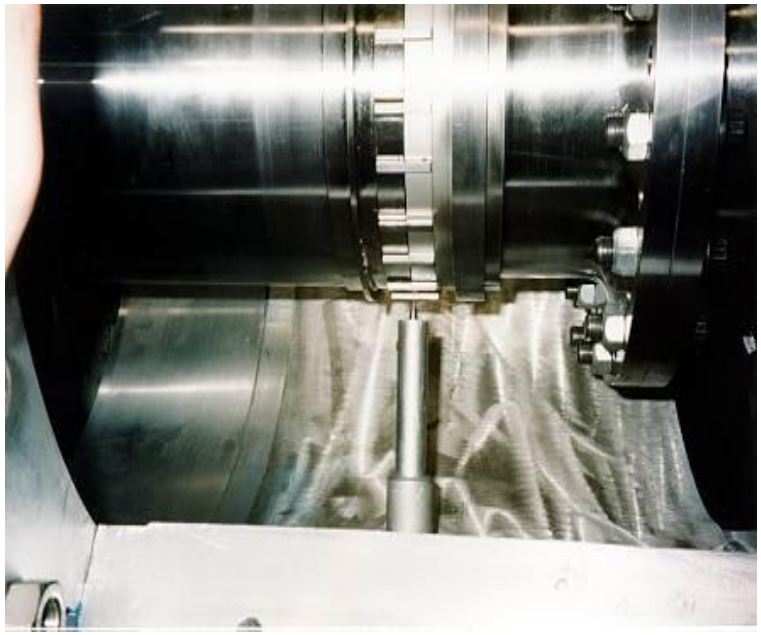
Powerlign configuration

Meets international requirements for intrinsic safety / ATEX

Digital Transmission (complete intelligence near sensors) – New System



Kop-Flex Powerlign Torque Monitoring



Powerlign / Powerwheel

- Torquemeters provide a tool to measure and improve the efficiency and reduce emissions of rotating machinery
- Reliable single channel phase displacement systems have repeatable accuracy to within 1%
- Single source supplier, only supplier that manufactures the coupling and electronics
- Recently sold 300th Powerlign system

Coupling today

- Turbo machinery couplings are high tech products
- These are engineered solutions
- Help the major machines run reliably
- Turbo train is as reliable as its weakest link
- Torque meters will help in running the machinery at its optimum efficiency
- Always go for engineered couplings with phase shift type torque meters

Thank you for your time

Any questions?

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